AIC 2007

Color Science for Industry

Midterm Meeting of the International Color Association

12-14 July 2007，Zhejiang University，Hangzhou，China

PROCEEDINGS

Color Association of China

AIC

International Color Association

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Guanrong YE and **Haisong XU**

Editors

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Zhejiang Association for Science & Technology

Zhejiang University

Hangzhou, China, 2007

PREFACE

Dear Participants at the AIC 2007 Midterm Meeting,

The Chairman of the AIC 2007 Midterm Meeting appreciates all of you making a great effort for the Meeting, and also wants to thank AIC Board supporting the organization of the Meeting. The members of the international scientific committee helped to review the abstracts and contributed with comments and criticism. All of your supports make the possibility of the Meeting to be held in Hangzhou.

Hangzhou has been known as a “Paradise on Earth” in China for thousand years, she has a history of more than 2000 years since the Qing Dynasty set up the municipality. Now she is one of the 7 ancient capitals and the most beautiful tourism city of china, Marco Polo praised her as “The most gorgeous city in the world”.

It is the first time of AIC Meeting in 40 year history of the International Color Association to be held in Hangzhou China. The theme “Color science for industry” covers a wide range of topics related to the application of color technology in manufacturing and product research.

The meeting will bring together leading researchers from all over the world to exchange the latest information on the developments in the application of color science and technology.

Finally we will also thank the sponsorships to support the AIC 2007 Midterm Meeting in Hangzhou China.

The organizing committee hopes that you will enjoy the city Hangzhou.

General Chair of the AIC 2007 Midterm Meeting

Hangzhou China

FOREWORD

The picturesque city of Hangzhou, known as a "paradise in Earth" and acknowledged by Marco Polo at the end of the 13th century as "the most elegant and beautiful city in the world", hosts in 2007 the Midterm Meeting of the AIC. Hangzhou, the capital of Zhejiang province, has a millenary history and is one of the famous historical and cultural cities of China, having served as one of its ancient seven capitals. More than 4,700 years ago, during the Neolithic Age, human beings already lived in this place and gave origin to the Liangzhu culture. Just one of the many attractions of Hangzhou is the set of three pagodas on the West Lake, the three pools mirroring the moonlight.

These stone pagodas were taken to form the logo of the AIC Meeting 2007, representing the three primary colors of trichromatic theory, which is in turn at the basis of the development of the science of color measurement and reproduction. Precisely, the theme of this AIC Midterm Meeting is "Color science for industry", and it has promoted the submission of papers from various different fields of color research: communication, image technology, textiles, printing, paints, displays, measurement and instrumentation, architecture, and others, which you will find in these Proceedings. One of the highlights of this meeting is the lecture delivered by the recipient of the Judd Award. As it happens every two years since 1975, this meeting is the opportunity to present the Judd Award, which this year goes to Dr. Alan R. Robertson, after a process of evaluation of antecedents of six very distinguished candidates made by the members of the Judd Award Committee.

For the second time in its history, the AIC holds a general assembly during a midterm meeting (the first time was in 2003, in Bangkok). This resulted from an initiative of former president Mitsuo Ikeda, handled over by former president Paula Alessi and incorporated as a regular meeting of delegates in the proposed modifications to the AIC statutes, to be voted precisely during this assembly. This possibility of having an assembly in years other than during full congresses existed before, but it was an exceptional situation, to be requested by the executive committee or by the majority of the regular members.

Coinciding with the beginning of summer in the Northern hemisphere and winter in the Southern hemisphere, the AIC celebrates its 40th anniversary in 2007. The AIC foundation occurred the 21st of June of 1967, during the 16th Session of the Commission Internationale de l'Éclairage held in Washington DC. The year 2007 is also commemorative of the 10th anniversary of William D. Wright's death [1906-1997], and the 20th anniversary of C. James Bartleson's death [1929-1987]. Wright was the 1st president of the AIC, while Bartleson was the 4th one. The 100th anniversary of Wilhelm von Bezold's death [1837-1907] and Sven Hesselgren's birth [1907-1993] also occur in 2007. They were two important contributors to color theory who, among other aspects, have developed color order systems.

I want to thank especially Prof. Guanrong Ye and all the members of the Color Association of China that have made the organization of this meeting possible, as well as the members of the international scientific committee who reviewed the extended abstracts and contributed with comments and criticism. I congratulate all the authors for the quality of their work, and I am sure that you will enjoy reading these texts.

José Luis Caivano, AIC President

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Posters: ***Color in Architecture***

Citation for the 2007 Judd Award Presented to Alan R. Robertson

Roy S. Berns*

Munsell Color Science Laboratory, Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology, 54 Lomb Memorial Dr., Rochester, NY 14623 (USA)

ABSTRACT

The AIC Deane B. Judd Award was established in 1973 to honor the memory of Deane B. Judd; it is the highest honor that can be bestowed by the international color community. The Award recognizes work of international importance in the fields of color perception, color measurement, and/or color technology. The Award is presented every two years, at AIC Congresses and Mid-term meetings. The 2007 recipient is Dr. Alan R. Robertson. This award was based on "his seminal work in accurate colour measurement and colour difference evaluation, his contributions to a wide variety of other fields of colour science and metrology, and his commitment to disseminate his knowledge to others," Colour Group (GB).

Keywords: Judd award, Alan R. Robertson

1. INTRODUCTION

The AIC Deane B. Judd Award was established in 1973 to honor the memory of Deane B. Judd; it is the highest honor that can be bestowed by the international color community. The Award recognizes work of international importance in the fields of color perception, color measurement, and/or color technology. The Award is presented every two years, at AIC Congresses and Mid-term meetings. The 2007 recipient is Dr. Alan R. Robertson.

2. CONTRIBUTIONS

The following paragraphs were written by the Colour Group (GB).

"Alan R. Robertson was educated at King Edward's School, Birmingham, England. He received his B.Sc. in 1962 and his Ph.D. in 1965, both from Imperial College of the University of London, England. His Ph.D. was under the supervision of Professor W. David Wright and resulted in a thesis entitled "Errors in spectrophotometry with particular reference to near-white and near-black surfaces." After leaving Imperial College, he went to the National Research Council of Canada (NRC) to work as a Post-Doctoral Fellow under Dr. Günter Wyszecki. He joined the continuing staff of NRC in 1966 and by 1984 had risen to the position of Senior Research Officer and Group Leader of the Photometry and Radiometry Group. He retired from NRC in 2000 after serving as Director of the Chemical and Mechanical Standards Section and Strategic Advisor to the Director General of the Institute for National Measurement Standards. In retirement, he has continued to work part-time at NRC as a Visiting Worker.

One of his first projects at NRC was the development of digital methods for calculating correlated colour temperature and distribution temperature. The method for correlated colour temperature has been used by many lamp manufacturers and spectroradiometer manufacturers who built it into their computer programs and for many years it was the de facto standard method for these calculations, superseded only recent by more modern optimization techniques.

His Ph.D. thesis led to a paper on the propagation of uncertainties in colour measurement that was ahead of its time and has formed the basis of several recent papers on the subject responding to the current interest in determining and specifying the uncertainties of measurement. His interest and expertise in spectrophotometry continued at NRC and he developed NRC's spectrophotometric facilities to a position of world leadership. He performed pioneering work on the characterization and use of stable working standards for reflection spectrophotometry and, in 1987, published a seminal paper on the use of diagnostic standards to improve the performance of spectrophotometers. This work forms the basis for the modern technique of "profiling" which is used

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by spectrophotometer and colorimeter manufacturers to improve the performance of their instruments in the field.

During the late 1960s and early 1970s, Dr. Robertson participated in a major experimental program at NRC to measure new colour-matching ellipses. This led to a life-long interest in colour-difference evaluation. He has been a leader in the development of color difference formulae and played an active role in the establishment of the 1976 CIELAB and CIELUV color difference formulae, chairing the working group that did the final development of the formulae and fixed the constants. From 1976 to 1987, he chaired an international committee organizing collaborative research aimed at developing new standard colour-difference formulae to improve on the 1976 formulae. He remained as an advisor to subsequent committees and played a role in the development of the CIE94 and CIEDE2000 formulae.

His contributions to colour science have not been limited to spectrophotometry and colour-difference evaluation. He studied colour order systems, writing several papers on the subject and playing a prominent role in CIE and ISO committees that attempted to resolve differences in philosophy between the Munsell and NCS systems. He has served as a consultant to CIE committees that developed chromatic adaptation transforms and color appearance spaces. His 1983 paper on metamerism was instrumental in resolving misunderstandings concerning the definition of metamerism that were prevalent at that time.

In retirement, he is pursuing another area of interest – that of the validity of Grassmann's Laws of colour matching. Spurred by his experience in making colour matches on the Wright Colorimeter and the NRC Trichromator and by William Thornton's results and his controversial explanations of them, Alan has been working with students at the University of Leeds to study the uncertainty and additivity of colour matching.

Throughout his career, Alan has demonstrated excellent leadership. He was head of the Photometry and Radiometry Group and the Chemical and Mechanical Standards Section of NRC. He has been a leader within the CIE and the AIC, serving as Associate Director of CIE Division 1 from 1989 to1991, as CIE Vice President from 1995 to 1999, and as AIC President from 1990 to1993. He is the longest-serving member of the Canadian National Committee of the CIE, having served continuously as a member since 1967 and as President from 1985 to 1992. He has been a Director of the Inter-Society Color Council and President of the Canadian Society for Color. He has also served in a broader capacity in the field of metrology, particularly in the North American Cooperation in Metrology (NORAMET), and the Inter-American Metrology System (SIM). He had a key role and influence in the drafting and implementation of an historic document (the CIPM MRA), signed in Paris in 1999 by the Directors of 38 National Measurement Institutes.

Alan has always been actively involved in standardizing color. He has a commitment to teaching the world how to do color science the correct way and that is why the push for standards that would be available to organizations outside the CIE has been so important to him. He played a role in the establishment of the first CIE standards, S001 on Standard Illuminants for Colorimetry, and S002 on Standard Colorimetric Observers. In the late 1990s, aware of the diversity of colour standards in the field of imaging and of the need for the CIE to take on a leadership role, he formed and chaired an ad hoc working group that was responsible for the creation of CIE Division 8 on Image Technology to look into the optical, visual and metrological aspects of the communication, processing and reproduction of images. This initiative was widely praised in the community. Alan is currently the chair of CIE TC1-57 on Standards for Colorimetry and of TC2-57 on standard illuminants.

He is the author of over 60 published papers, many of them still widely quoted, and is the author or co-author of one book and three book chapters. In 1992 he was honoured to be invited to write an article on colour perception for a special issue of Physics Today. He is an excellent speaker and has given numerous invited talks throughout the world.

In 2005, the ISCC honoured Dr. Robertson with the presentation of its Godlove Award. Founded in 1931, the ISCC is an organization of societies and creative individuals that work to propagate the understanding of color in art, science and industry. The Godlove Award was named for Dr. I. H. Godlove and is the highest honour bestowed by the ISCC. It is given in recognition of a lifetime of distinguished service to the color community. Dr. Robertson received the Canadian Society for Color Merit Award in 1981 and is an Honorary Member of the Grupo Argentino del Color. He was also privileged to be the Grum Memorial Speaker of the Council for Optical Radiation Measurements in 1991."

3. SIGNIFICANT PUBLICATIONS

Dr. Robertson published in a variety of topical areas, displaying his wide range of expertise and interests. Several of these have had a profound impact on my development as a color scientist and educator. Below is a list of papers I define as seminal. I have divided them topically. This is not comprehensive, but representative of Alan's outstanding contributions to color science.

3A. Spectrophotometry

A. R. Robertson. "Colorimetric Significance of Spectrophotometric Errors", J. Opt. Soc. Am. **51**, 691-698 (1967).

A. R. Robertson. "Diagnostic Performance Evaluation of Spectrophotometers," Advances in Standards and Methodology in Spectrophotometry", C. Burgess and K.D. Mielenz, Eds., Elsevier, Amsterdam, 277-286, (1987).

Dr. Robertson defined common spectrophotometric errors as a series of linear equations: photometric, wavelength, and bandwidth. These equations could be exercised to determine the colorimetric significance of typical errors. He later combined these equations and used them to develop a statistical method that estimated spectrophotometric errors from a series of measurements of standard color tiles. Alan served on the M.S. thesis committee of Kelvin Petersen at RIT where this technique was further refined. Today, several commercial products that use software to improve inter-instrument agreement are based on this approach, so-called "profiling."

3B. Correlated Color Temperature

A. R. Robertson. "Computation of Correlated Color Temperature and Distribution Temperature", J. Opt. Soc. Am. **58**(11), 1528-1535 (1968).

A number of methods exist to calculate correlated color temperature and distribution temperature. This is the most cited and used method.

3C. Color Differences

A. R. Robertson. "Comparison of the Two Uniform Colour Spaces Proposed by CIE TC-1.3 for Study". Proc. 18th Session CIE, 174-179 (1975).

A. R. Robertson. "The CIE 1976 Color-Difference Formulae", Col. Res. Appl. **2**, 7-11 (1977).

A. R. Robertson. "CIE Guidelines for Coordinated Research on Color-Difference Evaluation", Col. Res. Appl. **3**, 149-151 (1978).

A. R. Robertson. "Colour Differences", Die Farbe **29**(4/6), 273-296 (1981).

A. R. Robertson. "Historical Development of CIE Recommended Color Difference Equations", Col. Res. Appl. **15**, 167-170 (1990).

Dr. Robertson participated in the development of CIELAB and CIELUV. He derived the final constants for CIELAB and evaluated the two spaces for statistical significance using independent visual discrimination data. Below is a photograph from the 1973 CIE meeting at the City University, London where CIELAB and CIELUV were first written.

Figure 1 Birth of CIELAB (Left to right: Ganz, MacAdam, Robertson, Wyszecki); photographed by F.W. Billmeyer.

He remained active in this area, both as a research advisor and historian. He also was a member of both CIE technical committees that developed CIE94 and its successor, CIEDE2000.

3D. Color Education

A. R. Robertson. "Colour Differences", Die Farbe **29**(4/6), 273-296 (1981).

A. R. Robertson. "Critical Review of Definitions of Metamerism", Col. Res. Appl. **8**, 189-191 (1983).

A. R. Robertson· "Colour Spaces and Models", Colour Report No. F28, 62-75, Scandinavian Colour Institute, Stockholm (1983).

A. R. Robertson. "Colour Order Systems - an Introductory Review", Col. Res. Appl. **9**(4), 234-240 (1984).

A. R. Robertson. "Color Perception", Physics Today **45** (12), 24-29 (1992).

N. Ohta and A. R. Robertson. "Colorimetry: Fundamentals and Applications", Wiley (2005).

Dr. Robertson has been very generous with his time in writing review and historical articles. Co-authoring the colorimetry text with Noboru Ohta is a clear demonstration of his commitment to education; much of his role was insuring that the book communicated clearly Dr. Ohta's intentions.

4. PERSONAL THOUGHTS

I met Alan Robertson as a graduate student. Since that time, he has been a valued mentor, colleague, and friend. He has been unselfish of his time and expertise. He has been active in the AIC since its beginnings and was president from 1990-1993 and I have always appreciated his interpersonal style and elegance.

One of my favorite articles written by Alan is "The Future of Color Science", Col. Res. Appl. **7**(1), 16-18 (1982). He envisioned a visual apparatus where one could control stimuli using perceptual controls, for example, L*, C^*_{ab}, and h_{ab}:

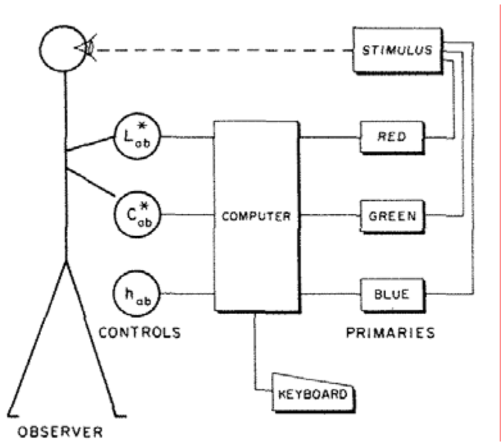

Figure 2 Schematic of the future visual colorimeter from Robertson, 1982.

This has come to pass. Today, we have amazing imaging tools to perform visual experiments. In 1982, Alan predicted progress concerning chromatic adaptation, color appearance, color-difference formulae, heterchromatic-brightness, color constancy, color rendering, and colorant strength. This article became a roadmap for research within the international color science community. Significant progress has been made in each topical area, many due to Alan's contributions. I am honored to present Dr. Alan Robertson with the 2007 AIC Judd Medal.

Uncertainty, Simplicity and Reasonableness – Three Golden Rules of Modelling

Alan R. Robertson

Ottawa, Canada

ABSTRACT

Three "golden rules" are presented for modelling in colour science. These are to take account of the uncertainty of the data being modelled, to keep the model as simple as possible, and to make the model physiologically reasonable as far as is practical. Examples are given of models that have followed these rules and some that have not.

Keywords: Colour science, colour differences, additivity, adaptation

1 INTRODUCTION

I would like first of all to express my gratitude to the AIC for the great honour that they have bestowed on me today and to thank Roy Berns for his kind words in the citation. I have met and admired all the previous recipients of the Judd Award and it is difficult to believe that my name is now included among them.

In my presentation today, I would like to discuss what I consider to be three "golden rules" for model building in colour science. These rules are (i) to take account of the uncertainty of the data being modelled, (ii) to keep the model as simple as possible, and (iii) to make the model physiologically reasonable as far as is practical. I will give examples where these rules have been followed and others where they have not. I will conclude with a very rough outline of a model that has the potential to account for one of the most perplexing problems of basic colorimetry, namely the apparent breakdown of Grassmann's laws of additive colour mixture.

2 UNCERTAINTY

Suppose that one tosses a coin 100 times and it comes down "heads" 55 times. It would be easy to conclude that the coin was biased but, in fact, a result of 55 or more "heads" will occur by chance more than 30% of the time. The same principle applies to measurements. Every measurement has an uncertainty and one should never conclude anything about a measurement without knowing its uncertainty. To quote the ISO Guide to the Expression of Uncertainty in Measurement[1], "when reporting the result of a measurement of a physical quantity, it is obligatory that some quantitative indication of the quality of the result be given so that those who use it can assess its reliability. Without such an indication, measurement results cannot be compared, either among themselves or with reference values given in a specification or standard." Unfortunately, the complex nature of colour measurements, particularly their three-dimensional nature and the fact that there are correlations between the three dimensions makes this rule difficult to apply rigorously in colour science.

2.1 Colour Differences Ellipses

The well-known MacAdam ellipses[2] were used for decades as the basis for the evaluation of the perceptibility of small colour differences and for the development of colour difference formulae. They are an invaluable resource and there is no doubt that they represent the main features of chromaticity discrimination. Nevertheless, they are the results of only one observer and there has always been a reservation that other observers (or even the same observer repeating the observations) might give slightly different results. In other words there is an unknown uncertainty built into the results and it can never be known for sure whether fine details of the variations are real or not. In a follow-up to MacAdam's work, Brown[3] measured colour difference ellipses for 12 observers and found general agreement with the previous experiments although some differences appeared to be significant. An example of Brown's results for one colour centre is shown in Fig. 1, giving a clear indication that the inter-observer uncertainty is considerable.

In addition to the inter-observer uncertainty, there is also an inherent uncertainty in the results of a single observer due to the random nature of the matches. Wyszecki and Fielder[4] derived formulae for the standard deviations of ellipse parameters and found that, for ellipses based on 30 observations, the standard deviations (nowadays we would call them standard uncertainties) of the length of the ellipse axes were 13%. Thus the 95% confidence limits are

±26%. In later work, using ellipses derived from judgements of surface colours, Luo and Rigg[5] took a more pragmatic approach. They applied simulated errors in a Monte Carlo fashion and showed that, when the distribution of samples around a standard was unsatisfactory, the ellipses obtained were unreliable.

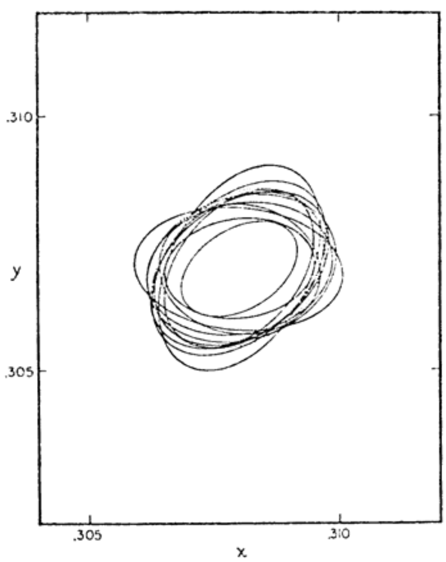

Figure 1 Colour difference ellipses of twelve observers[3].

The issue of uncertainty does not mean that the published results are wrong but only that it is wasteful to try to find a model that fits them exactly. A model that fits within the uncertainty is all that can be justified.

2.2 Colour Matching Functions

The uncertainty of colour matching functions is well known and is easier to quantify. For example, the main basis of the CIE 1964 Standard Observer is the set of 10° colour matching functions of 49 observers measured by Stiles and Burch[6]. Figure 2 is a plot of these and it is clear that the uncertainty is very substantial.

This uncertainty is important in applications such as the assessment of metamerism and in certain types of modelling. However, it does not mean that the publication of standard colour matching functions with six significant figures[8] is unjustified. Standards ideally have a precision that is one or two digits better than the most demanding application and there is no doubt that there are applications where accurate and reproducible colour specification demands four-digit precision. An analogy can be found in the field of length measurement. The foot is a unit of length in the Imperial System and, despite the fact that real human feet vary in length by 10 or 20%, the unit is defined very precisely[9] as 0.3048 metres, where a metre is the length of the path travelled by light in a vacuum during a time interval of 1/299 792 458 of a second, and a second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom. Satellite navigation systems that determine a location anywhere in the world within a few feet or better would not be possible without such a precise definition.

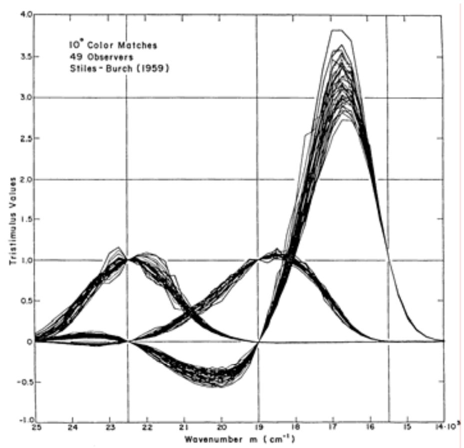

Figure 2 10° colour-matching functions of 49 observers[7].

2.3 Additivity Failures

Basic colour theory and the calculation of tristimulus values depend on the validity of Grassmann's Laws[7], particularly the law of additivity. It has been known for some time that this law fails in certain circumstances[7, 11-17] but the significance of these failures relative to the uncertainties of their measurement and to the uncertainties of practical colorimetry has been difficult to confirm.

In a series of papers about 15 years ago, Thornton[18-20] showed more evidence of additivity failures, this time in the form of inconsistencies in the transformation between different sets of primaries in an additive colour matching experiment. Unfortunately, no uncertainties were attached to Thornton's results and this led some critics to suggest that they might be within the range of variability of normal observers. Consequently, Oicherman et al[21] repeated some of Thornton's experiments with a rigorous analysis of the uncertainty. They concluded that some of the failures of additivity in their experimental setup were indeed statistically significant. In a later experiment, Oicherman et al[22] showed that failures of additivity could also be significant in a practical industrial situation (soft proofing).

3 SIMPLICITY

The second "golden rule" is based on two quotations[23], one by Confucius: "Life is really simple, but we insist on making it complicated" and another by Albert Einstein: "Everything should be made as simple as possible, but not simpler." There are examples in colour science where Einstein's rule has been followed but also many where it has not.

The Munsell value function given by

$$Y=1.2219V-0.2311V^2+0.23951V^3$$
$$-0.021009V^4-0.0008404V^5 \qquad (1)$$

has been used very extensively and successfully but it is difficult to see how such a complicated formula, with five significant figures in the coefficients, can be justified by the inherent uncertainty of the visual data on which it is based. The CIELAB L^* function given by

$$L^*=116(Y/Y_n)^{1/3}-16 \qquad (2)$$

fits the Munsell function very well and is much simpler. Who knows how colour science might have developed if Eq. (2) had been adopted from the very beginning instead of Eq. (1)?

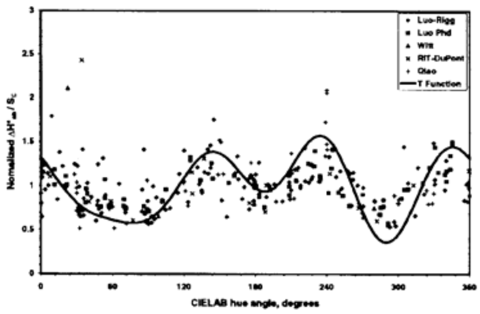

Figure 3 Normalized hue data plotted against CIELAB hue angle. The curved line represents the CIEDE2000 *T* function[25].

The CMC formula[24] and its successor the CIEDE2000 formula[25, 26] are complex procedures for calculating the relative perceived magnitudes of colour differences. The *T* function of the CIELAB formula is shown in Fig. 3 together with the data that it is intended to fit. The complicated nature of the function:

$$\begin{aligned} T &= 1 - 0.17\cos(\overline{h'} - 30°) + 0.24\cos(2\overline{h'}) \\ &+ 0.32\cos(3\overline{h'} + 6°) - 0.20\cos(4\overline{h'} - 63°) \end{aligned} \qquad (3)$$

contrasts with the horizontal straight line that was used in the earlier CIEDE94 formula[27]. While it is clear that a horizontal straight line does not account for some of the features of the data, one wonders whether a simpler function than Eq. (3) would perform equally well. However, the CMC and CIEDE2000 formulae both work very well so the complexity is clearly not harmful but computer programmers might have been grateful for a simpler version!

4 REASONABLENESS

I believe it is important that a model of a colour vision phenomenon should be as reasonable as possible from the physiological point of view. Of course, an exact physiological model is impossible because not enough is known about the details of how the human colour vision system works. However, building a model that mimics real physiological processes, at least in outline, makes the model more amenable to later improvements. If too many purely empirical corrections and improvements are added to a model it is possible that one will be merely correcting for the deficiencies of another.

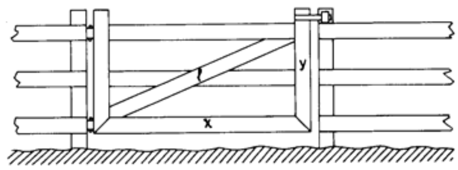

Figure 4 Schematic diagram of a farm gate with strut of length *l*, rails of length *x*, and stiles of length *y*[7].

An example of the problems that can occur is illustrated by the *Farm-Gate Contraction* described by Wyszecki and Stiles[7]. A farmer wants to construct diagonal struts to strengthen farm gates with rails of length *x* and stiles of length *y* as illustrated in Fig. 4. His first model for the length *l* of the strut is

$$l=x+y, \qquad (4)$$

but he soon realizes that this model requires a correction to account for discrepancies between the model's predictions and the experimental results. Unaware of the Pythagoras formula, he decides that the correction should be in the form of a factor *e* in a new model:

$$l=e(x+y). \qquad (5)$$

The farmer performs experiments to measure *e*, plots the results as shown in Fig. 5, and works out a complicated function, the farm-gate contraction, to fit them. The authors speculate that the farmer may have had a previous career in colour science.

The various colour difference formulae, such as CMC and CIEDE2000, developed from CIELAB, are examples of adding empirical corrections to a formula that was over-simplified in the first place. While CIELAB does contain elements of signal compression and opponency that are physiologically reasonable, it suffers from too rigorous an application of the simplicity rule.

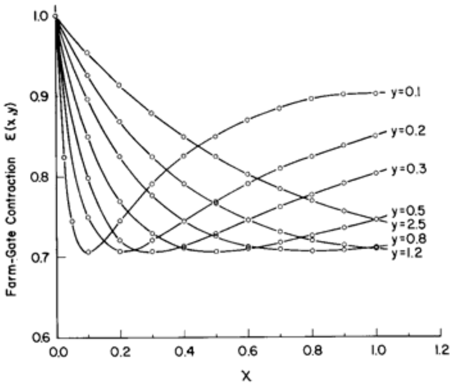

Figure 5 The farm-gate contraction *e* plotted as a function of *x* and *y*[7].

The basic parameters of the CIELAB formula are CIE tristimulus values, which have no direct physiological significance. Perhaps if the CIE values had first been transformed into cone responses, some of the later empirical corrections would have been simpler. In this case, too rigorous an application of the first two golden rules caused a violation of the third.

The possibility that CMC and CIEDE2000 would have been less complicated if CIELAB had been based on cone responses is pure speculation, however. Without doubt, the formulae have been very successful but it does seem likely that we have reached the limit of what can be achieved by empirical "farm-gate" corrections. Further progress is likely to come only from a more physiologically based formula. In a recent report[28], the CIE has provided a good basis for this with the publication of a standard set of cone fundamentals.

5 ADDITIVITY FAILURES

As an example of a model that follows the three rules, let us consider the case of the colorimetric additivity failures discussed in Sect. 2.3. In a careful analysis of his own experimental results, Zaidi[16] concluded that the failures he found were not due to computational imprecision, not due to pre-receptoral filtering, not due to rod intrusion, not due to variation of cone absorption spectra and not due to two pigments feeding into one channel. He suggested that the cause lay in some kind of post-receptoral feedback whereby the short-wavelength cone signal is modified by the medium- and long-wavelength cone signals.

Building on Zaidi's suggestion, Oicherman et al[22] have recently developed a very simple model that fits their results on additivity failures when paint samples and computer monitors are compared. They work in the MacLeod-Boynton chromaticity diagram[29] because this is believed to be representative of post-receptoral processes. One of the co-ordinates of the MacLeod Boynton diagram is the ratio of the short-wavelength cone signal to the sum of the other two cone signals:

$$s=S/(M+L) \qquad (6)$$

The authors suggest a simple non-linear adaptation of this coordinate:

$$s'=-0.11s^{-0.32}+0.68 \qquad (7)$$

that explains their results very well. Whether the model can also fit other results remains to be seen but the authors point out that most reports of additivity failures have the same general feature, namely that when narrow-band stimuli are mixed to colour-match broad-band stimuli, the narrow-band mixture always looks relatively more yellow than the CIE standard observer predicts. They also point out that many adaptation phenomena have a similar feature. This leads to the speculation that adaptation of the short-wavelength signal could occur in a similar fashion to Eq. (7) when the adaptation is caused by previously viewed or surrounding stimuli instead of by the test stimulus itself as in Eq. (7).

The model has the advantage that it follows all three of the "golden rules". It also has the advantage that it does not abandon traditional CIE colour-matching functions and tristimulus values. One of the problems in dealing with additivity failures has been the fear that they could not be handled without abandoning traditional CIE colorimetry which has worked exceedingly well in most situations for over 75 years. The Oicherman model retains tristimulus values and additivity as a measure of the quantum catch in each type of cone but suggest that a small non-linear adaptation occurs in at least one channel before the human visual system makes its judgement of a match.

6 CONCLUSION

For the best results in model building in colour science, three rules should be followed:

1. Do not fit to a greater precision than is justified by the uncertainty of the data being fitted;
2. Keep the model as simple as possible (but not too simple); and
3. Make the model physiologically reasonable as far as is practical.

ACKNOWLEDGMENTS

I would like to acknowledge the contribution of Boris Oicherman in developing the model outlined in Sect. 5.

I would also like to acknowledge my two major mentors, David Wright (1906-1997) and

Gunter Wyszecki (1925-1985), both previous recipients of this Award. Without their friendly guidance, I would not be here today.

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Colour measurement of LEDs, problems and corrections

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ABSTRACT

The general belief is that tristimulus colorimeters are less accurate, because the spectral shaping of the detector has to be done using filters precisely ground and polished to the required thickness. As the number of filter glasses that can be used is finite, the accuracy of the filter adjustment is also limited. Two methods have been developed to decrease the measurement uncertainty of tristimulus colorimeters: Firstly adding a fifth filter to the stack of X_{short}, X_{long}, Y and Z filters and using matrix transformation of the output signals the measuring accuracy could be increased considerably. As a second step – for the *Y* tristimulus value, i.e. for the Average LED Intensity (ALI) or luminous flux component of the tristimulus values, colour dependent individual correction factors were introduced. By the help of this technique the determination of the *Y* tristimulus value could be increased by a factor of 2 to 3. In case of spectrometric measurement the wavelength inaccuracy and the stray light of the instrument cause the most important errors. Our investigations have shown that in case of a modern spectrometer with CCD detector the uncertainty of LED measurements is in the same order of magnitude as that of tristimulus colorimeters.

Keywords: LED colorimetry, tristimulus colorimetry, spectroradiometery, LED standards.

1 INTRODUCTION

Colour measurement can be done using a tristimulus colorimeter or measuring first the spectrum of the source and then calculating the tristimulus values by numeric integration. Both methods have their advantages and disadvantages.

The general belief is that tristimulus colorimeters are less accurate, because the spectral shaping of the detector has to done using filters precisely ground and polished to the required thickness. But, e.g. to get in a reasonable time colorimetric information of an entire image one has to use filter based colorimeters in image taking colorimeters. As the number of filter glasses that can be used is finite, the accuracy of the filter adjustment is also limited.

The goodness of fit of the colorimetric filters is usually done by a somewhat simplified version of the CIE f_1' index: an equienergetic spectrum is assumed as irradiator[1]:

$$f_{1,i}' = \frac{\int_0^\infty \left| s_{\mathrm{rel},i}*(\lambda) - \bar{t}_i(\lambda) \right| \cdot \mathrm{d}\lambda}{\int_0^\infty \bar{t}_i(\lambda) \cdot \mathrm{d}\lambda} \cdot 100\% \qquad (1)$$

where $\bar{t}_i(\lambda)$ is one of the colour matching functions ($\bar{t}_1(\lambda) = \bar{x}_s(\lambda)$, $\bar{t}_2(\lambda) = \bar{x}_l(\lambda)$ (index “s” describes the short-, “l” the long wave peak of the $\bar{x}(\lambda)$ function), $\bar{t}_3(\lambda) = \bar{y}(\lambda)$, and $\bar{t}_4(\lambda) = \bar{z}(\lambda)$); *i* has similar meaning in the following equations. $s_{\mathrm{rel},i}*(\lambda)$ is the normalized relative spectral responsivity

$$s_{\mathrm{rel},i}*(\lambda) = \frac{\int_0^\infty \bar{t}_i(\lambda) \cdot \mathrm{d}\lambda}{\int_0^\infty s_{\mathrm{rel},i}(\lambda) \cdot \mathrm{d}\lambda} \cdot s_{\mathrm{rel}}(\lambda) \qquad (2)$$

$f_{1,3}'$ values of the $\bar{y}(\lambda)$-function approximation can be better than 1,5 %, for the $\bar{x}(\lambda)$ and $\bar{z}(\lambda)$ functions the approximations are usually poorer, depending to a large extent on the permissible total absorption. This can lead in the measurement of LEDs to photometric errors in the range of 5 to 10 per cent, and in colorimetric errors in the second decimal of the *x*, *y* chromaticity co-ordinates.

In spectrometric measurements the range of available instruments is very large, from small CCD array single grating instruments to highly sophisticated double grating and prism + grating scanning monochromator instruments. Several companies advertise for LED measurement the smaller instruments, without stating measuring uncertainties for LED measurements.

Several years ago we performed a comparison of different spectrometers. Our investigations have shown that even in standard one-grating instruments the stray light can be so high that a calibration with a tungsten lamp might produce an erroneous colorimetric measurement for LEDs. Figure 1 shows the chromaticity determined from measurements with five spectroradiometers of different sophistication[2]: Reference was the NIST LED measuring double monochromator instrument, when using 1 nm step-size and bandwidth. As seen a different double monochromator (prism plus grating instrument) and the 5 nm integration at NIST gave deviations from the 1 nm value of the same order of magnitude. But both (low end and high end) CCD array + single grating instruments and a standard one-grating spectroradiometer showed much larger deviations.

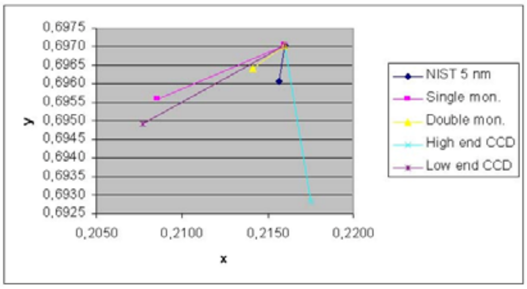

Figure 1 Chromaticity of a green LED measured with five spectroradiometers.

2 POSSIBILITY TO IMPROVE TRISTIMULUS COLORIMETRY

Two methods have been developed to decrease the measurement uncertainty of tristimulus colorimeters: Firstly adding a fifth filter to the stack of X_{short}, X_{long}, Y and Z filters and using matrix transformation of the output signals the measuring accuracy could be increased considerably, as shown on the example of the LED spectra seen in Figure 2. Figure 3 shows the CIE 2° colour matching functions (CMFs) and the spectral responsivity curves of a five filter colorimeter. For the above stack of LEDs the chromaticity determination could be increased using this technique, as seen in Table 1 by almost an order of magnitude.

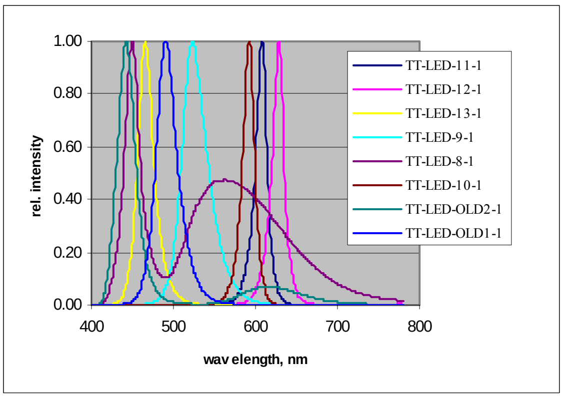

Figure 2 LED spectra used in the optimization.

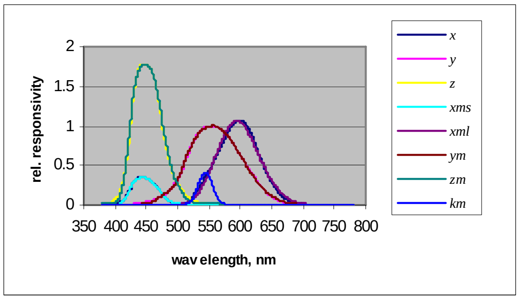

Figure 3 CIE-CMFs and filtered detector responsivities.

In the first raw we see the average colorimetric error when the eight LEDs are measured using the four filters and just adding the signals of the x_{long} and x_{short} channels. The second raw shows the average colorimetric error if the signal of the four filters is matrixed to give the smallest average ΔE_{ab}* value, while the third line show the effect of an optimally selected fifths filter. Compared to the traditional non-matrix colorimetry a dramatic increase in accuracy can be achieved.

Table 1 Average colorimetric errors

Matrix type	Colorimetric error, ΔE_{ab}*
Without matrixing	9,67
4 filter matrix	3,76
5 filter matrix	1,09

As a second step – for the *Y* tristimulus value, i.e. for the Average LED Intensity (ALI) or luminous flux component of the tristimulus values, independent colour correction factors were introduced for the red, yellow, green, and blue emitting LEDs, for spectral correction compared to the white LED measurement.

The problem here is that it is most difficult to reproduce the $y(\lambda)$ function in the deep blue and red parts of the spectrum.

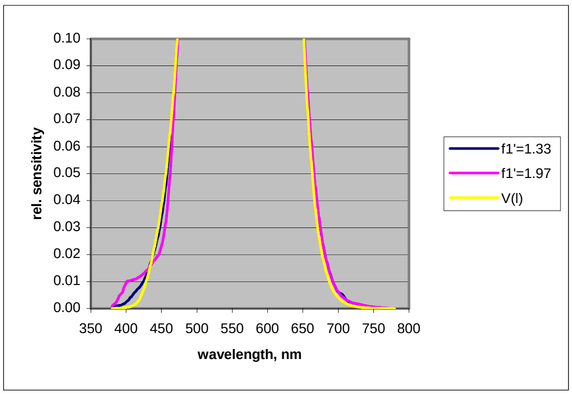

Figure 4 Parts of the spectral responsivity of two good $y(\lambda)$ filters and the $\bar{y}(\lambda)$ function.

As can be seen in Figure 4 even for filter corrections below f_1'=2% the deviation between the CMF and the filtered detector is considerable, leading to big measurement errors for the red and blue LEDs. If, however the LEDs to be measured are not compared to an incandescent lamp standard, but to an LED standard with similar spectral distribution this mismatch error can be decreased considerably.

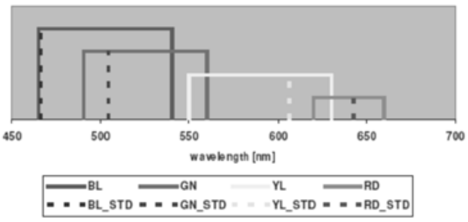

Figure 5 Recommended wavelengths ranges (continuous lines) and optimum dominant wavelengths of standard LEDs (broken lines)

By the help of this technique the uncertainty of the determination of the Y tristimulus value could be decreased by a factor of 2 to 3.

3 REFERENCE STANDARDS

To make use of the above techniques LED secondary standards are needed. LEDs are, however, temperature sensitive: both their absolute emission as their relative spectral power distribution (SPD) changes with temperature, and time. Figure 6 shows the SPD of a red LED at different temperatures.

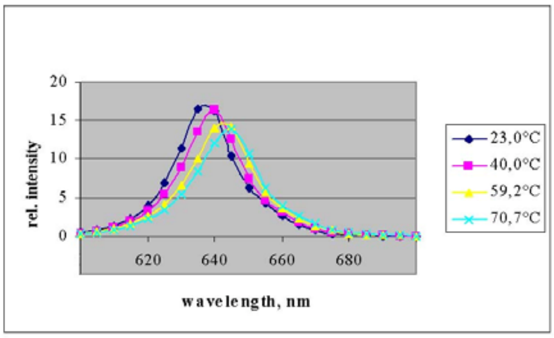

Figure 6 Temperature dependence of a LED SPD.

It is usually assumed that LEDs have 50.000 to 100.000 hours long lifetimes, although recent publications report already shorter values and big differences between individual LEDs too[3].

Thus to achieve high stability it is not enough to feed the LEDs with constant current, but for standards purposes the LEDs have to be selected for stability and used at constant temperature. As the emission of the LEDs is usually also highly directional one has to use fixtures that provide good repeatability. Figure 7 shows a temperature stabilized LED, and Figure 8 shows the clamp by the help of which such a standard LED can be inserted in an ALI measuring system* with a very high repeatability.

Figure 7 Temperature stabilized LED with built in current stabilizer.

Figure 8 Clamp on an ALI-B tube for accepting an LED.

We have developed such LED standards both for traditional 20 mA LEDs and high power LEDs, where, however, to secure highest stability instead of the nominal 350 mA the LEDs are driven only at 100 mA.

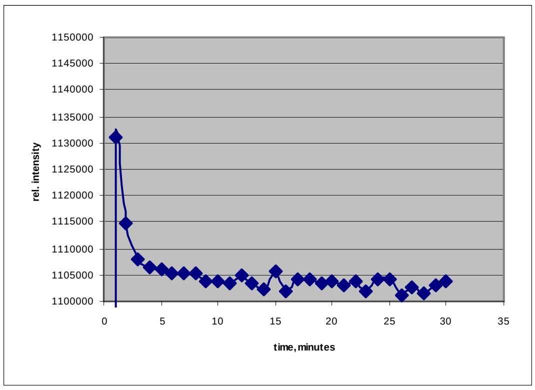

Figure 9 Stabilization curve of a white LED standard.

* CIE prescribes for LEDs two Average LED Intensity (ALI) measuring geometries: ALI-A and ALI-B.

As can be seen from Figure 9, after a stabilization time of about 20 minutes the stability is in the order of ±0,2 %, this is at least by a factor of 5 smaller than the uncertainty budget of the master standard got from the calibrating laboratory.

The LEDs to be calibrated using these standard LEDs can be clamped in special (non-temperature stabilized) holders, as seen e.g. in Figure 10.

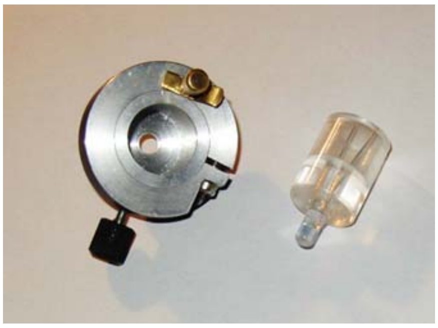

Figure 10 Clamp for a 5 mm test LED.

4 APPLICATION

Such standard LEDs can be used to calibrate luminance or illuminance measuring equipment that are used to measure LED sources (e.g. LED traffic lights). Figure 11 shows a test box with a standard LED to produce a given illuminance on the PTFE standard at the bottom of the box, for testing luminance meters.

Figure 11 Test box with standard LED.

Figure 12 shows another application: To develop high power LEDs and LED fixtures their photometric, colorimetric and thermal characteristics have to be known. The instrument developed in collaboration with an other university department enables to determine in one step the optical and thermal characteristics[4]. This is needed, because only part of the input power is emitted as light and the dissipated power heats up the LED. Properties of the final product are highly influenced how well this dissipated power is extracted from the system, i.e. how good the thermal management is.

Figure 12 TERALED complex thermal - colorimetric measuring system.

5 CONCLUSION

In the paper we showed that using standard LEDs for calibrating the measuring system, and by properly developing a tristimulus colorimeter, measuring uncertainties of tristimulus colorimetry can be comparable to that of much more elaborate and expensive spectroradiometric systems.

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Visual colour control - are we standardized?

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ABSTRACT

The authors have collected information on commercially available colour matching booths and other light sources for visual colour control and evaluated their performance according to the different standards. It was concluded that for visual colour control practical daylight simulators exist with characteristics satisfying the major national and international standards, but most of the commercially available booths do not, in many cases in spite of the manufacturer's claims that they do.

Keywords: colour matching booth, daylight simulators, illumination, light sources, visual colour control

1 INTRODUCTION

In spite of the ubiquity of colour measuring instruments, visual colour control still has a place in industrial practice. One of the major problems is the standardization of daylight simulators. CIE has defined daylight illuminants but there are no corresponding standard sources.

There are national and international standards specifying the requirements of colour matching booths for visual colour control. Most of these standards require that the spectral power distribution (SPD) of the daylight simulator in the booth be Category BC or better according to the CIE Publication 51, or describe the limits (in the case of the BS 950) in tolerances for different bands along the spectrum. Table 1 summarizes the illumination requirements according to different standards.

Lam et al.[1] published data for a SpectraLight-II (MI_{vis} = 0.24) and a VeriVide (MI_{vis} = 0.34) booth and found that they conform (at least in the visible range) to the most stringest standards (CIE Category A or B).

Xu et al.[2] evaluated 15 D_{65} and 58 D_{50} daylight simulators (only in the visible range) and found that the two booths using filtered tungsten lamps (like the SpectraLight) have excellent rating (MI_{vis} = 0.18 resp. 0.23, CIE Category A) the rating for the fluorescent lamps varied from MI_{vis} = 0.25 (Category B) to 2.31 (E). For the D_{50} simulators the situation was not quite as good, only a dichroic lamp had Category B (MI_{vis} = 0.28) rating, while the 57 fluorescent tube based simulators varied between 0.91 (C) and 2.74 (E).

Table 1 Standard requirements for illumination level and SPD of daylight simulator for colour matching booths.

Standard	Illumination (lx)	SPD
AS/NZS 1580 AS 4004	1000 to 5000+ (1500 to 2500 preferred)	**D_{65} -** BC (exact or critical match) **D_{65} -** DD (close match)
ASTM D1729	810 to 1880++ (general) 1080 to 1340++ (critical) Min. 540 (light samples) Max. 2150 (dark samples)	**D_{50}; D_{65}; D_{75}** BC
BS950 Part I: **D_{65}** Part II: **D_{50}**	750-3200	Band tolerances ±15% (visible) ±30% (UV)
DIN 6173/2	1000 to 5000+	**D_{65}**
ISO 3664	2000 ± 500 (± 250 in the centre)	CRI ≥ 90 **D_{50}** MIvis B/C **D_{50}** MIuv ≤ 4
ISO 3668	1000 to 4000	**D_{65}** BC
JIS Z 8723	1000 to 4000+	**D_{65}** or **D_{50}** BD

+Difference between maximum and minimum ≤ 25 %
++Tolerance ± 20%

Some of the standards also specify the colour of the base and the walls of the booth as summarized in Table 2.

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Table 2 Standard requirements for the colour of the base and the walls of colour matching booths.

Standard	Lightness	Chroma
AS/NZS 1580 AS 4004	$50 \leq L^* \leq 75$ Munsell N5–N7	$C^*_{ab} \leq 4$ Munsell C ≤ 0.5
ASTM D1729	Base: N5-N7[+] Walls: N6-N7	Munsell C ≤ 0.3[++]
BS950	n/a	n/a
DIN 6173/2	n/a	n/a
ISO 3664	$10 \leq Y \leq 60$	$C^*_{ab} \leq 2$
ISO 3668	$45 \leq L^* \leq 55$[+++]	$a^* \leq 1$; $b^* \leq 1$
JIS Z 8723	$45 \leq L^* \leq 55$[+++]	n/a

[+]For critical evaluation: similar to standard
[++] For critical evaluation: Munsell C ≤ 0.2
[+++]For mainly light colours L*=65 or higher; for mainly dark colours L*=25 or lower

2 EXPERIMENTAL

The colour of the interior, the level and the uniformity of illumination and the SPD in two new and five 4 to 13 years old booths and the SPD of six lamps were measured in the SENAI/CETIQT Colour Institute. Data on other booths and lamps were provided by members and advisors of the CIE TC1-44[†].

2.1 Booths and lamps tested at SENAI/CETIQT

The following booths were tested:

- ColorVue: Tailored Lighting – 10 years
- Judge II: GretagMacbeth[‡] – 6 years
- Mathis LBM – new
- SpectraLight II: GretagMacbeth – 13 years
- SpectraLight III: GretagMacbeth – new
- TrueVue: ACS – 12 years
- VeriVide CAC DC – 4 years

Other lamps (i.e. not installed in booths) tested:

- GretagMacbeth F40T12/65
- GretagMacbeth F40T12/75
- Osram Biolux L18W/72-965
- Philips TL-D / 950 -36W
- Philips TL-D / 965 -36W
- Sylvania Daylight Plus

2.1.1 Colour of booth walls and base

The booth walls and base were measured using a MINOLTA CM-2600d portable spectrophotometer. The photometric scale adjustments were performed with a white standard traceable to the National Physical Laboratory (NPL), Teddington, UK.

On each part of the cabin (left and right side, back and base) 8-8 points (total of 32) were measured and the averages and the uniformity calculated.

2.1.2 Level and uniformity of illumination

The level of illumination was measured using a Minolta T-1 light meter, calibrated by INMETRO (Rio de Janeiro, Brazil) and several of the measurements verified using an Optronic OL750 photometer system consisting of an OL 730-9Q telescope with V(λ) filter, an OL 750-HSD-301C high-sensitivity detector and an OL 83A programmable DC source.

The illuminance (lx) was measured at nine points uniformly distributed within the central area (15 cm distance from the edge in each direction) of the base. The uniformity of the illumination is given as twice the standard deviation (in % of the average value).

2.1.3 Spectral power distribution

The SPD of the illumination inside the booths was measured using an Optronic OL750D spectroradiometer system consisting of an OL 730-9Q telescope, an OL750D double monochromator, an OL 750-HSD-301C high-sensitivity detector and an OL 83A programmable DC source.

The measurements were performed with the telescope looking at a $BaSO_4$ plate positioned at the centre of the base; in 5 nm intervals with 5 nm bandwidth between 300 nm and 800 nm. The complete setup was calibrated to an OL 200C high-accuracy irradiance standard traceable to the National Research Council (NRC), Ottawa, Canada.

The irradiance of lamps not installed in cabins was measured with the same OL750D system, but instead of the telescope an 8” OL IS-670 integrating sphere was used.

3 RESULTS AND DISCUSSION

3.1 Colour of booth walls and base

Table 3 shows the colour of the interior of the seven booths measured at SENAI/CETIQT.

[†] CIE Technical Committee TC1-44 Practical Daylight Sources for Colorimetry.
[‡] Now X-Rite

Table 3 Colour of the interior (3 sides, base and average) of seven booths. Average of 32 measurement points of each booth.

	CIE		Munsell	
	Y	L*	V	C
ColorVue	51	76	7.5	0.3
Judge II	45	73	7.1	0.1
Mathis	43	72	7.0	0.1
SpectraLight II	39	69	6.7	0.6
SpectraLight III	40	70	6.8	0.3
TruVue	40	70	6.8	0.3
VeriVide	20	52	5.0	0.2

As the requirements of the different standards are contradictory there is no booth satisfying all of them. (It should, of course, be remembered that many of these standards have been developed to be used for different products in different industrial sectors). Most of the booths satisfy the lightness requirements for all of the standards except for the ISO 3668 and JIS Z 8723, which require a very dark surface (only met by the Verivide), while the ColorView is somewhat too light according to all of the standards except for the very lenient ISO 3664. The Chroma of the SpectraLight II booth is too high for any of the standards, the ColorView, SpectraLight III and TrueView satisfy the general requirements while the Judge, Mathis and VeriVide booths satisfy even the most stringent requirements.

3.2 Level and uniformity of illumination

Table 4 shows the level and uniformity of the illumination in the seven booths measured at SENAI/CETIQT.

Table 4 Level and uniformity of the illumination of D_{65} simulators in colour matching booths.

Booth	Size (cm)	lx	2σ
ColorView	61x44.5	387	±32%
Judge II	61x51	1060	±19%
Mathis	70x50	1390	±8%
SpectraLight II	92x60.5	1633	±22%
SpectraLight III (new)	94x65	1319	±16%
TrueView	61x42	1140	±20%
VeriVide	68x57.5	1054	±20%

The level of the illumination inside the booths was found to fulfil the general requirements for all but the ColorView booth, and most of them satisfied (or nearly) even the critical requirements of the ASTM D1729. The uniformity of illumination was within (or nearly) the required 20% for all booths but the ColorView.

3.3 Spectral power distribution

The SPD of four of the seven booths and that of the six lamps listed in 2.1 was determined as described in 2.1.3. Additional data on two booths and three lamps were received from members and advisers of CIE TC1-44 snd for one lamp from a Japanese Industrial Standard:

- Fluorescent lamp JIS Z 8716
- GTI Color Matcher booths and lamps
- SpectraLight II booth

The spectral data were used to calculate the MI_{vis} and MI_{uv} values according to CIE Publication 51.2, and the following results were obtained:

Table 5 CIE 51 classification of the D_{65} simulators installed in booths.

Booth	Data source	MI_{vis}	MI_{uv}	CIE Class
GTI	GTI[3]	0.48	0.80	BC
Judge II	CETIQT	0.61	3.88	BE
Mathis	CETIQT	0.63	0.97	CC
SpectraLight II	CETIQT	0.35	2.57	BE
SpectraLight II+	GM[4]	0.27	0.69	BC
VeriVide	CETIQT	0.50	3.57	BE

+with special UV lamp

Table 6 CIE 51 classification of D_{65} simulator lamps.

Lamp	Data source	MI_{vis}	MI_{uv}	CIE Class
GM F40T12/65	CETIQT	0.98	4.39	CE
GM F40T12/75	CETIQT	0.64	5.09	BE
GTI CM 50	GTI[3]	1.13	1.53	DD
GTI CM 75	GTI[3]	0.67	1.58	CD
JIS Z 8716	JIS[5]	0.29	0.44	DE
Osram 965	CETIQT	1.90	5.18	DE
Phillips TLD 50	CETIQT	0.61	4.48	CE
Phillips TLD 65	CETIQT	0.72	4.45	CE
Sylvania DP	CETIQT	1.96	5.20	DE

Some of the best D_{65} simulators were also evaluated according to the widely used BS 950. Based on a large number of visual experiments Xu et al.[6] concluded that The BS 950 and the CIE 51 methods are equally reliable for evaluating the quality of daylight simulators [in the visible range].

Our comparisons of the two methods, however, showed significant differences in the UV range. Two types of simulators were analysed: the SpectraLight II booth (filtered tungsten filament lamp with additional UV lamp) and two fluorescent lamps: the JIS Z 8716 and the VeriVide.

The SpectraLight is an excellent D_{65} simulator in the visible range, it complies with the requirements of all major standards. In the UV range, however, the SPD of the filtered tungsten + UV lamp combination provides more than sufficient UV in the 360 to 400 nm region but lacks significantly in the 300 to 350 range. This has probably been balanced to give acceptable CIE 51 rating (which it does, MI_{uv}=0.69, Category C) but does not comply with BS950 (outside the ± 30% limit in the 300 to 340 band).

There is not enough information available to decide whether this conformance to CIE 51 but non-conformance to BSI make it an acceptable or an unacceptable daylight simulator for the visual evaluation of fluorescent samples, particularly fluorescent whites excited in the UV region. This problem needs to be further investigated.

The detailed analysis of the BS 950 bands for the JIS Z 8716 lamp shows that it also has too much energy in the 340n to 400 nm range: 64.4 mW, nearly 50% above the nominal value. This, once again, raises the question whether a lamp acceptable by the very strict ASTM D 1729 but outside the tolerance for BS 950 is "good enough" or not. A similar question may be raised for the VeriVide lamps (acceptable according to BS 950 and also to ISO 3664 but not to ASTM D1729).

4 CONCLUSIONS

D_{50} simulators (dichroic lamps and fluorescent lamps) are available conforming –in the visible range - to the principal national and international standards according to spectral data provided by the manufacturers and measurements on fluorescent D_{50} lamps. We could not find any lamp or source satisfying the standard requirements in the UV range.

Some of the D_{65} simulators (filtered tungsten and fluorescent lamps) fully comply with the requirements of the principal national and international standards.

Some of the manufacturers claim that their D_{75} simulators conform to the principal national and international standards, but no spectral data were made available to the authors substantiating these claims. The lamps measured by the authors show reasonable simulation in the visible range but very poor in the UV.

It is concluded that for visual colour control practical daylight simulators exist with characteristics satisfying the major national and international standards, but most of the commercially available "daylight"lamps and booths do not, in many cases in spite of the manufacturer's claims that they do.

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The Color and Image Processing Technology Trends of Future Digital TV

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ABSTRACT

Since the debut of the black and white television in 1932, the current television is developing into a new media device driven by advancements in digital and display technologies. The current digital television is the dominant device for leading the digital revolution era through the convergence of various digital technologies such as broadcasting, communication, computing, etc. The television is poised to become a platform for all digital information at home and especially, through the convergence of broadcast and communication technologies, developing into a next generation intelligent device that can deliver various high-quality digital content without being bounded by time and space while catering to diverse user interests and preferences. This paper will look into color technology, which is important for the direction of development and technology trend of the next generation television.

Keywords: Digital TV, Digital Convergence, Intelligent TV, Ultra Realistic

1. INTRODUCTION

The television, which some may tout as the most important invention of the twentieth century, plays an important role in the life of modern people. The advent of television marks the beginning of popular culture that can be enjoyed by people of all classes. Especially, since the advent of the color television, it has played an important role in setting cultural trends through, for example, fashions of actors and actresses and commercials.

In recent times, with the development of digital technology, digital television has appeared as well as mobile broadcasting services, such as DMB, that enable television viewing experience to be carried anywhere. Furthermore, the union of internet technology and HDTV opens the door to, aside from digital broadcasting services, interactive services with bidirectional data communication.

This paper, following a brief history of the television that offers important insights into digital television development, will discuss digital television and image quality enhancement technologies, which constitute the core of present HDTV systems, and the direction of development for the next generation television.

2. A BRIEF HISTORY OF TELEVISION

Following the 1932 introduction of the black and white television in Great Britain, the NTSC color television standard was devised in the United States in 1953, with market introduction a year later in 1954. Motivated by developments in digital signal processing and VLSI technologies, the first satellite digital broadcasting was launched in the United States in 1994. Presently, digital broadcasting is poised to become widespread due to developments in broadcasting and signal processing technologies.

In this paper, for convenience, the developmental stages of television are broken down into four stages characterized by changing issues in image quality. The first generation signifies the era of black and white television, the second is the era of color television, the third is the era of digital television, and finally, the fourth is the era of post-HDTV (Fig. 1).

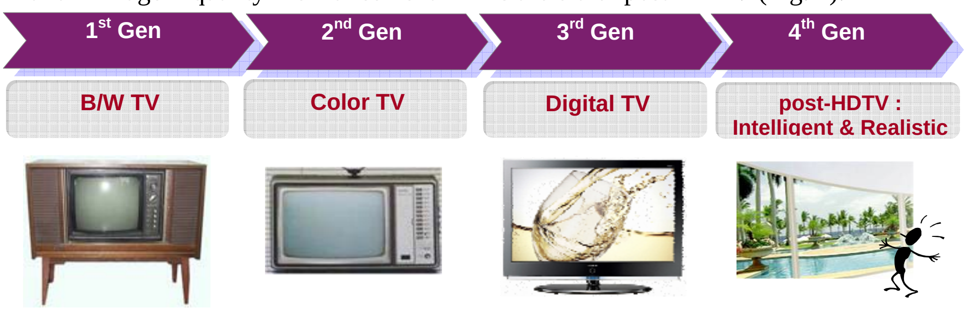

Figure 1 Developmental stages of television.

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The image quality issue of television can be said to have officially started with the advent of color television in the second generation. During the period when CRT was the predominant display technology for television, image quality control was carried out by compensating analog input signals through contrast, brightness, and tint control units.

By the third generation, which corresponds to the present era, big strides in television image quality are beginning to be made with the development of flat-panel displays and digital signal processing technologies. The television display market is becoming inundated with flat-panel displays, such as LCDs and PDPs, gradually displacing traditional CRTs that cannot adequately meet consumer demand for large displays. The rapid development of flat-panel displays has become a catalyst in the development of image quality improvement technologies that strive to meet consumer demand for better image quality. The larger color gamut of flat-panel displays allow more vivid image reproduction than that defined by the broadcast standard, which is based on the color gamut of CRTs.

At the same time, advancements in digital technology have enabled the emergence of preferred image reproduction technologies that work by digitally manipulating each pixel in an image. Such digital image processing techniques are used as key image quality differentiators by various television manufacturers in the form of image processor chips.

As described, the development of flat-panel display technologies and an explosion in the supply of high-quality content have fueled consumer demand for high-quality image reproduction, which in turn brought forth rapid developments in high-quality image processing technologies. Recently, with the advent of mobile television broadcasting services, such as DMB, One-seg, and DVB-H, that enable television viewing experience anywhere, the need for environment-adaptive image processing technology is rising.

The author will describe image quality aspect of the forthcoming post-HDTV era with the keywords "intelligent" and "ultra-realistic." Due to rapid development of internet technologies, the television market and general technology trends are undergoing fast change. Presently, rudimentary interactive television services are being provided under these circumstances. This change in the service model is expected to be followed by the development of user-optimized television that optimizes image quality to each individual. Finally, the era of ultra-realistic television will commence under the premise that high-quality content, exceeding high-definition (HD) in image quality, will be in large supply in the not-too-distant future.

3. CURRENT DEVELOPMENT OF DIGITAL TELEVISION

Image quality in the digital television era, the third generation of television development, can be considered from two points of view: the display panel and the video processor[1]. Better image quality can be sought by improving various attributes of the display panel, such as brightness, contrast, viewing angle, response time, and color gamut; on the other hand, the video processor seeks to minimize visual artifacts, such as motion blur and noise, while attempting to achieve optimal image reproduction with respect to viewer preference through image processing. This section will discuss developmental direction for image quality improvements on the digital television and mobile television, which is becoming a hot issue, and look into color technologies required by each type of service.

3.1 Development of Digital Television Image Quality

Since the latter half of the 90's display panels have developed from the traditional CRT to PDP, LCD, DMD projector, etc. In recent times LCD and PDP flat-panel displays are beginning to dominate the digital television market, gradually supplanting the CRT. These flat-panel displays occupy less volume than traditional CRT displays, a great advantage for realizing large-display television.

Today, digital television manufacturers are actively developing televisions with higher luminance and larger color gamut in order to achieve bright and vivid image reproduction. In the case of LCD, advancements are made by improving the backlight unit and color filter. Samsung LCD televisions currently on the market exhibit average luminance of approximately 500 cd/m^2, while color gamuts with respect to NTSC in the xy-space are approximately 95% and over 100% for panels with CCFL (Cold Cathode Fluorescent Lamp) and LED backlight, respectively.

Therefore, when developing a display with high luminance and large color gamut, there is a need to perform research on optimal luminance and appropriate color coordinates in order to achieve optimal image quality. Regarding research on luminance, discussions should be carried out on whether greater luminance is necessary and what the optimal luminance is for minimizing visual stress for large displays that exceed 60 to 70-inches. Considering that currently color gamut is measured triangularly in the xy-space with respect to NTSC, actual perceptible image quality and visual gamut are greatly influenced by the primaries used even if the gamut sizes are identical. Due to the loss in the meaning of standard color space in view of the fact that primaries used in televisions already reproduce larger gamut than the broadcast standard, each television manufacturer should be concerned about the selection of color primaries with regard to image quality in order to appeal to consumers. The research on choosing optimal color primaries[2,3] is still in preliminary stages and requires further examination.

Aside from increasing brightness and color gamut via conventional RGB primaries, new proposals are being made that seek to achieve the same objectives by introducing additional primary colors. Introducing white to RGB primaries is an effective method to increase brightness without requiring additional power consumption. Consequently, many display manufacturers are incorporating this RGBW technology into their DMD projectors or OLED displays. In the case of Samsung, RGBW LCD was exhibited at 2003 SID, and 5-primary DLP and 6-primary LCD were exhibited at 2004 SID. Figure 2 compares the conventional RGB stripe structure with various multi-primary pixel structures. Development of displays utilizing these new structures requires color gamut mapping and RGB-to-multi primary color decomposition technologies[4,5,6] as well as sub-pixel rendering technology suited to each structure for natural image reproduction without visual artifacts.

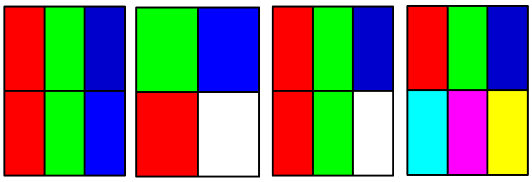

Figure 2 Conventional RGB stripe structure vs. multi-primary pixel structure.

Reproduced image quality is largely dependent on how the image is processed even when identical panels are used. For this reason, major digital television manufacturers procure their own unique image processor chip for image quality differentiation, and the representative examples are Samsung's DNIe (Digital Natural Image engine), Sony's WEGA, and Matsushita's New PEAKS.

While early image processors incorporated basic image processing techniques such as contrast or sharpness enhancement and sRGB color matching, recent processors include more advanced image quality enhancement technologies such as reduction of noise and motion blur[7] inherent in the input image or caused by limitations of the display panel, sub-pixel basis image processing[8] to reproduce visual resolution that exceeds the physical resolution of the display, and preferred color reproduction[9,10,11,12] including individual control of three important memory colors, skin tone, sky, and grass.

This development of the image processor has been largely based on basic research on visual perception and user color preference, and further basic research on image quality is necessary in order to develop more advanced television image quality enhancement algorithms.

Most importantly, image quality quantification is essential for image quality algorithm development. Although it is not difficult to ascertain whether image quality is good or bad in daily life, exact definition and quantification of image quality has not been satisfactorily developed despite numerous attempts by color scientists. Research results on quantification of various aspects of image quality, such as naturalness of color, sharpness of edge, brightness and darkness of image, do partially exist; however, analyzing the correlation of these attributes to derive a method for assessing general image quality has yet to produce promising results. In order to attain ideal image quality on television, the answer to "what is ideal image quality?" should precede.

3.2 Mobile Television

Apart from telecommunication capability, due to the inclusion of multimedia capabilities with the recent introduction of camera phones and mobile television broadcasting services, image quality on the mobile phone is becoming an important issue. Since mobile television can display the same content as home television and uses the same display panel technology, the same image quality issues described in Section 3.1 apply. However, due to differences in usage environment and display size, new factors should be considered that are not important for the home television. Primarily, the complexity of image quality enhancement algorithms must be less than those intended for the home television due to lower power consumption requirements and miniature size of the device. Power consumption reduction and outdoor visibility enhancement are representative examples of newly demanded technologies due to the mobility of the device.

Power consumption reduction of the mobile display can be achieved by adaptively reducing the backlight of the LCD, the predominant form of mobile displays, depending on the content of the input image such that there is no significant loss in image quality.[13] In addition, technology is being developed that achieves lower power consumption than traditional RGB panels by the addition of white alongside RGB such that the same level of brightness can be attained while using less power.

In contrast to home television that is typically used indoors under fixed environmental conditions, mobile display is used under various ambient light conditions ranging from bright sunny outdoors to dark indoors. Therefore, it is important to secure technology that extends the visibility of mobile displays under strong outdoor light. A good example of mobile image quality enhancement, as conceptually illustrated in Figure 3, is processing the image adaptive to outdoor brightness to improve visibility by predicting the change in color perception due to outdoor lighting. In the case of Samsung, mobile phones with low-power and outdoor visibility enhancement technologies were introduced to the market in 2006.[14]

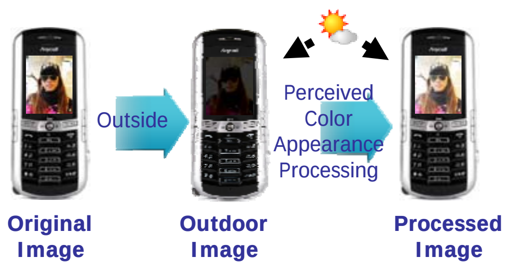

Figure 3 Visibility improvement under highly illuminated outdoor environment.

The currently used mobile displays are mostly LCDs while devices with OLEDs are cropping up every now and then. The LCDs and OLEDs both have limitations in coping with outdoor light environments due to limited panel brightness. It is expected that in the future, development of new types of mobile displays will be made possible through reflective-type displays, such as E-ink, with more effective color reproduction at outdoor condition. In preparation of widespread deployment of reflective-type displays, research is needed regarding quantification of color perception difference between self-luminance and reflective-type displays and its application for optimal image quality reproduction.

4. POST-HDTV ERA

Widespread deployment of terrestrial HDTV broadcasting and the imminent termination of analog television broadcasting will accelerate the market share of HDTVs. Future development trends in the post-HDTV era are discussed in this section.

4.1 Intelligent Television

In addition to conventional cable television, IPTV services will broaden the amount of content available on television far greater than imagined. Since the digital television can retrieve and manipulate information on the internet, besides receiving television broadcast signal many interactive services become possible such as internet browsing, home shopping, home banking, and online games.

IPTV standardization efforts are actively pursued at organizations such as DVB (Digital Video Broadcasting), ATIS[15] (Alliance for Telecommunications Industry Solutions), and ITU-T[16], where service, consumer demand, and service architecture are being defined and used as a basis for devising specifications for specific technologies, such as quality of service, content protection, middleware, and compatibility.

According to IPTV service provider reports[17], as of February of 2006 there are approximately 370 medium-sized operators servicing at regional levels. European and Asian service providers are utilizing DSL (Digital Subscriber Line) or Ethernet-based communication medium to provide traditional channel service and video-on-demand content on non-standard platforms. Although IPTV has yet to achieve general market presence, IPTV subscriber base is predicted to grow at 92.1% CAGR (Compound Annual Growth Rate) between 2005 and 2010[18]; hence, IPTV is poised to become common in the not-too-distant future.

As television users acquire more choices on what and when to watch, due to the development of IPTV, the television will become more and more personalized compared to the times when only a handful of channels were received. Therefore, image quality on the television needs to be optimized to each viewer's preference. More research is required on discerning the relationship between images, human emotion, and image color characteristics.

4.2 Ultra-Realistic Television

Fast popularization of high-resolution images along with fast adoption of HDTV foreshadows the start of the next-generation image format generally known as ultra-high definition (UD) with more than 2000 scan lines. UD video format will have greater impact on multimedia experience than HD has over analog television. High-quality multimedia on large UD displays will impress viewers with never-before-achieved sense of immersion and realism.

NHK Science & Technical Research Laboratories exhibited Super Hi-Vision[19] (Ultra High Definition widescreen system with over 4000 scan lines at 7680×4320 pixels) to the public at Expo 2005 Aichi. DCI[20] (Digital Cinema Initiatives, LLC), a joint venture of seven major movie studios in the United States, adopted 4096×2160 (4K×2K) as the standard image format for digital cinema. Table 1 compares HDTV and DCI specifications including resolution, color space encoding, bit-depth, and others.

Table 1 HDTV and digital cinema specifications.

Item	ATSC	DCI
	Full HD	Digital Cinema
Resolution	1920×1080	4096×2160
Frame Rate	60i/30p/24p	24p
Aspect Ratio	16:9 (1.78:1)	1.896:1
Bit/Channel	8 bits	12 bits
Color Space	sRGB (22%*)	XYZ (100%*)
Video Coding	MPEG-2	JPEG-2000
Audio	5.1 Channel	16 Channel

* Compared to unit triangular area in the xy color space

UD displays will demand advanced image processing techniques. First, successful commercialization of the UD display requires effective image resolution and frame rate conversion techniques in order to accommodate HD as well as SD contents. Conversion of SD, HD, or digital cinema content to UDTV format requires much higher performance algorithms than before. Second, it should be considered that the size of UD displays at home will be smaller than that for digital cinema. It is well known that larger the screen size stronger the sense of presence[21,22,23]. Reduced sense of presence and reality on home television will be regarded as image quality deterioration. Viewers might be able to enjoy greater level of presence at home if there are other visual factors affecting presence apart from the display size, and those factors can be digitally enhanced. Also, enhanced presence can be achieved not only on existing flat-panel displays but also on new types of displays, such as curved-surface displays, and with mass deployment of flexible displays in the near future, research on optimal display form for immersive viewing experience is in need.

Image quality factors such as ultra realism or presence are new concepts compared to naturalness or viewer preference, which are image quality keywords for HDTV. More research is needed to understand the mechanism of realism and presence perception for the development of future image quality enhancement algorithms.

5. DISCUSSION

In this paper, the developmental history of the television and image quality enhancement techniques as well as future direction have been reviewed.

Image processing techniques, starting with analog control on the CRT television, have made tremendous progress in producing more vivid and natural images with color gamut exceeding that of the broadcast signal due to the development of flat-panel display and digital processing technologies.

Future television can be characterized by the keywords “intelligent” and “ultra-realistic” with IPTV and UDTV as examples. In coming years, people will experience more realistic and immersive images and receive more personalized services on the television. Such technical developments set the stage for pursuing ultimate realism and individually-tailored image quality on the television.

In coming years, with the arrival of larger displays, the ultimate goal for television quality will be to deliver a sense of presence, a sense of really being at the scene. More research should be carried out on “presence” since it is not yet a well-defined technical terminology in the field of image quality. In addition, in order to design the optimal display, basic research is needed on such topics as the relationship between display size and sense of presence, optimal display resolution with respect to contrast sensitivity function of the human eye, and impact of frame rate on human visual perception through flicker and judder.

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Optimizing Color-Difference Equations and Uniform Color Spaces for Industrial Tolerancing

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ABSTRACT

Euclidean distances calculated for CIE recommended color spaces such as CIELAB and CIECAM02 have limited correlation with visual color-tolerance datasets. The RIT-DuPont and Qiao datasets were used to demonstrate such limitations. A weighted color-difference equation was optimized to improve the performance of CIECAM02. This equation was used to derive a Euclidized CIECAM02 by integrating line elements. The coordinates of CIECAM02 were also rotated to improve visual uniformity about mid-gray stimuli. PF/3, maximum disagreement, and an F-test were used to evaluate performance. All of these distance measures had equivalent performance to CIEDE2000, indicating future opportunities for color spaces with improved performance

Keywords: Color difference equations, Euclidized color spaces, CIECAM02, CIEDE2000

1. INTRODUCTION

In 1931, colorimetry was defined by the CIE, providing a common method of determining whether two stimuli matched under a set of viewing conditions for an average observer.[1] Beginning in 1932,[2] publications appeared that evaluated the visual uniformity of the CIE system for setting industrial tolerances. As it became clear that a nominal-scale system did not yield an interval or ratio scale, efforts have been ongoing to develop metrics that predict visual responses of discrimination. Three approaches are taken, commonly. The first is to derive a three-dimensional "color space" in which Euclidean distances are assumed to correlate with perceived differences in color. Tristimulus values are transformed nonlinearly to a new coordinate system and a simple color difference calculated:

$$\Delta E = \left[(\Delta X_1)^2 + (\Delta X_2)^2 + (\Delta X_3)^2 \right]^{1/2}, \quad (1)$$

where X_1, X_2, and X_3 represent the three coordinates. CIELAB is an example.

The second approach is to derive a distance metric that is a function of three-space location and viewing parameters based on the assumed uniform color space, often referred to as a weighted-color difference equation:

$$\Delta E = \left[\left(\frac{\Delta X_1}{k_{x_1} S_{x_1}} \right)^2 + \left(\frac{\Delta X_2}{k_{x_2} S_{x_2}} \right)^2 + \left(\frac{\Delta X_3}{k_{x_3} S_{x_3}} \right)^2 \right]^{1/2}, \quad (2)$$

where k is a parametric factor (scalar) and S is a function of location. CIE94 and CMC are examples.

The third approach is to integrate line elements resulting from the weighted color-difference equation:

$$X_1^E = \int_0^{X_1} \frac{1}{k_{x_1} S_{x_1}} dX_1 \quad X_2^E = \int_0^{X_2} \frac{1}{k_{x_2} S_{x_2}} dX_2 \quad X_3^E = \int_0^{X_3} \frac{1}{k_{x_3} S_{x_3}} dX_3, \quad (3)$$

where the superscript E represents the new Euclidized three-space. A color difference would be calculated as in Eq. (1) using the new coordinate system of X_1^E, X_2^E, X_3^E. DIN99 is an example. It is clear that as the weighted color-difference equation becomes complex, integration becomes very difficult or impossible. Efforts to Euclidize CIEDE2000 demonstrate this difficulty.[3]

Suppose one takes a system's approach. That is, if we know *a priori* that the third approach will be used, greater care can be taken in defining the approximately visually-uniform color space and the weighted-color difference equation such that integration is possible. This is demonstrated in this paper using CIECAM02.

2. VISUAL DATA

Two visual datasets were used. The first was the RIT-DuPont dataset, consisting of 156 visual

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tolerances about 19 color centers.[4] Glossy automotive paints formed color-difference pairs and Probit analysis was used to transform binary visual perceptibility decisions compared with a near-neutral anchor pair stimulus to interval scale data. The second was the Qiao, et al. dataset,[5] consisting of 44 visual tolerances varying in hue at two lightness and chroma levels. Glossy photographic papers formed the color-difference pairs. Probit analysis was also used. One important feature of these experiments was that 50 observers were used and for each tolerance, confidence limits were calculated. Because the same anchor pair was used in both experiments, the two datasets could be combined. Thus there were 200 color tolerances, all with the same visual difference. The RIT-DuPont and Qiao and Berns data are plotted in Figures 1 and 2.

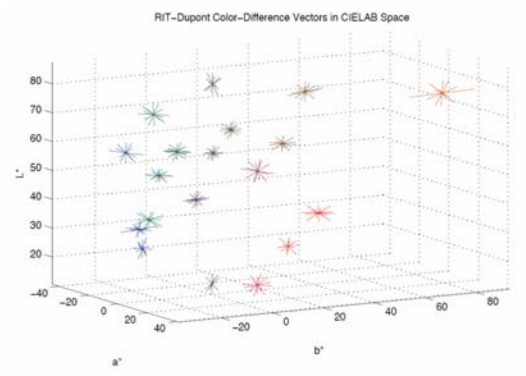

Figure 1 RIT-DuPont color-tolerance vectors plotted in CIELAB.

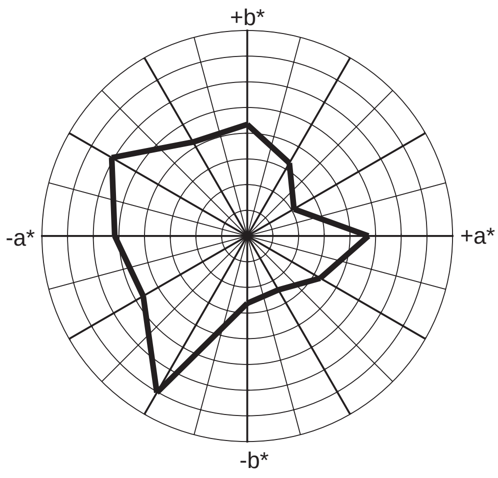

Figure 2 Qiao and Berns hue data CIELAB color differences for L* = 40 and C^*_{ab} = 35 (color-difference range 1.05 - 3.52).

Each tolerance has three CIELAB coordinates: *+T50*, $\bar{x}$, and *-T50*. CIECAM02 *J* (lightness) *C* (chroma) and *h* (hue angle) coordinates were calculated for for an adapting illuminance of 1500 lx, a .2Y/Y_n background, and average surround. With the exception of the light-gray color center, the ±T50 positions were symmetrical about each average.

3. EQUATION MODELING

CIECAM02 was selected as the approximately visually-uniform color space because of its growing usage in color technology, for example, in Microsoft Window's new color management embedded in Vista. Furthermore, as a color-appearance space, it seemed possible that an equation could be derived that could be integrated with similar performance to CIEDE2000. CIE94 was used as the form for S_C and S_H. The RIT-DuPont dataset has a lightness position dependency, similar to achromatic induction. An exponential model was used to account for this effect. Constrained nonlinear optimization was used to derive constants for the model shown in Eq. (4):

$$\Delta E_{optimized} = \beta_e \left[\left(\frac{\Delta J}{\beta_{L,0} + \beta_{L,1} \left(\bar{J}/100 \right)^{\beta_{L,2}}} \right)^2 + \left(\frac{\Delta C}{1 + \beta_{C,1} \bar{C}_{pt}} \right)^2 + \left(\frac{\Delta H}{1 + \beta_{H,1} \bar{C}_{pt}} \right)^2 \right]^{1/2} . \quad (4)$$

The objective function minimized a coefficient of variation (CV) subject to the constraint that the average color difference was unity. Because of the exploratory nature of this research, only the $\bar{x}$ and *+T50* coordinates were used and the visual uncertainties were not included as weightings.

One of the noted deficiencies of CIELAB was that neutral tolerances were not spherical.[6] In CIEDE2000, the a* axis was stretched nonlinearly. Following optimization, the mid-gray tolerances were evaluated for equal size (length) and compared with other equations, shown in Table I where the magnitudes are normalized to have an average of unity. Although CIECAM02 resulted in an improvement, it was of interest to optimize the tolerances for equal magnitude where the three axes could be rotated relative to each other. The independence between lightness and chromaticness is an assumption in CIELAB and CIECAM02. Tilted tolerance ellipsoids indicate interdependence. Using color tolerances as a criterion, this can be evaluated and possibly improved. A rotation matrix was optimized where the objective function was minimizing the mid-gray coefficient of variation. The rotation matrix and final optimized equation are given in Eqs. (5) and (6). The rotation matrix did not change the positional functions.

$$\begin{pmatrix} J' \\ a' \\ b' \end{pmatrix} = \begin{pmatrix} 1.000 & 0.015 & -0.032 \\ -0.166 & 0.934 & -0.086 \\ -0.060 & -0.088 & 0.892 \end{pmatrix} \begin{pmatrix} J \\ a \\ b \end{pmatrix} \quad (5)$$

$$\Delta E_{CAM,OPT}=\left[\left(\frac{\Delta J'}{k_J S_J}\right)^2+\left(\frac{\Delta C'}{k_C S_C}\right)^2+\left(\frac{\Delta H'}{k_H S_H}\right)^2\right]^{1/2}$$
$$S_J=0.5+1.25\left(\bar{J}'/100\right)^2 \qquad (6)$$
$$S_C=1+0.02\bar{C}' \quad S_H=1+0.01\bar{C}'$$

Table I Mid-gray tolerance vector color-differences for each listed equation.

Vec	LAB	CIE94	DE 2000	Opt	Opt + Rot
A	0.92	0.95	0.75	0.99	1.04
B	0.85	0.85	1.14	0.95	1.00
C	1.30	1.26	1.13	1.12	1.01
D	0.91	0.92	1.07	1.09	1.01
E	1.25	1.20	1.27	0.96	1.01
F	1.01	1.03	0.97	1.13	0.98
G	0.99	1.00	0.94	0.92	0.98
H	0.85	0.86	0.85	0.90	0.98
I	0.91	0.92	0.88	0.93	0.98
CV	0.16	0.14	0.17	0.09	0.02

4. LINE ELEMENT INTEGRATION

For a visually-uniform color space, a line (distance) element, *ds*, calculated as a Euclidean distance, e.g., Eq. (1), predicts perceived color differences. The need for a weighted color-difference equation, e.g., Eq. (2), means that the line element cannot be calculated as a Euclidean distance; rather, it must be calculated along a path defined by the positional weightings. Transforming the color space appropriately, the new space results in Euclidean distances predicting perceived color differences. The transformation is accomplished by integration along the path.[7] Equation (6) is rewritten as:

$$ds^2=\left(\Delta E_{opt}\right)^2=\left(\frac{dJ}{k_J S_J}\right)^2+\left(\frac{dC}{k_C S_C}\right)^2+\left(\frac{Cd\hat{h}}{k_H S_H}\right)^2, \qquad (7)$$

where $dH=Cd\hat{h}$ and $d\hat{h}=h\pi/180$. Solving the partial differential equations:

$$J^E=\int_0^J \frac{1}{k_J S_J}dJ=\int_0^J \frac{1}{0.5+1.25(\frac{t}{100})^2}dt$$
$$=\frac{100\times 2}{\sqrt{2.5}}\int_0^J \frac{1}{1+(\frac{\sqrt{2.5}t}{100})^2}d(\frac{\sqrt{2.5}}{100}t), \qquad (8)$$
$$=\frac{200}{\sqrt{2.5}}\arctan\frac{\sqrt{2.5}}{100}J$$

$$C^E=\int_0^c \frac{1}{k_c S_c}dC=\int_0^c \frac{1}{1+0.02t}dt, \qquad (9)$$
$$=50\ln(1+0.02C)$$

$$C^E d\hat{h}^E=C^E\left(\frac{\partial h^E}{\partial C}dC+\frac{\partial h^E}{\partial h}dh\right)=\frac{C}{S_H}d\hat{h}. \qquad (10)$$

From Eq. (10):

$$h^E=\frac{C}{C^E(1+0.01C)}h. \qquad (11)$$

We see that the new hue angle would be rotated as a scaling, resulting in a highly asymmetric rotation as a function of both angle and chroma. The convention is to assume that $S_H=S_C$, resulting in the new Euclidean space and color-difference equation, Eq. (12). (The scalars of 0.99 and 0.94 are described below.) Note that the same equations result using Jab or the rotated coordinates, J'a'b'.

$$J^E=0.99\times\frac{200}{\sqrt{2.5}}\arctan\frac{\sqrt{2.5}}{100}J$$
$$C^E=0.94\times 50\ln(1+0.02C)$$
$$h^E=h \qquad (12)$$
$$a^E=C^E\cos(h^E) \quad b^E=C^E\sin(h^E)$$
$$\Delta E_{Euclidean}=\left[(\Delta J^E)^2+(\Delta a^E)^2+(\Delta b^E)^2\right]^{1/2}$$

The new Euclidean space, Eq. (12), was compared with the weighted color-difference equation, Eq. (6), in similar fashion to Thomsen,[8] shown in Figure 3.

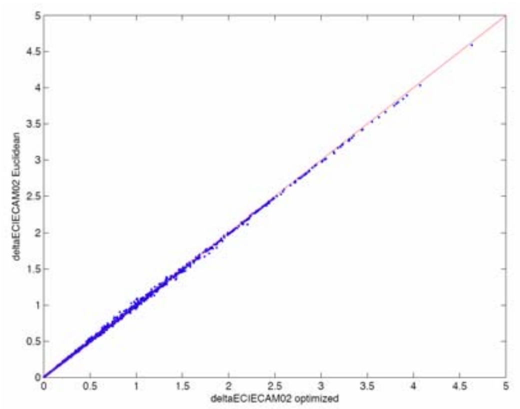

Figure 3 Scatter plot comparing Eq. (6) with Eq. (12) for 100,000 color-difference pairs randomly sampled within CIECAM02.

100,000 positions in CIECAM02 were randomly selected ("standards"). For each position, a random direction and random distance scaled between 0 and 5 CIECAM02 Euclidean distances were used to define 100,000 "batches." Color differences were calculated using the weighted and Euclidized equations. PF/3 and the average maximum disagreement (MD) were used as performance metrics. An additional optimization was performed to improve the correlation over this range of color differences, resulting in a slight compression of lightness and chroma, hence the scalars of 0.99 and 0.94, respectively. The performance metrics were 2.0

(PF/3) and 1.02% (MD) indicating that the Euclidean space well approximated the weighted color-difference equation.

5. DATA VISUALIZATION

The RIT-DuPont vectors are plotted in the new Euclidean space, Figure 4. The vectors are more similar in length compared with their representation in CIELAB, Figure 1. The Qiao hue tolerances are more equal is size compared with CIELAB: Figure 5 compared with Figure 2. This is more of a feature of CIECAM02 since these data have constant chroma and lightness.

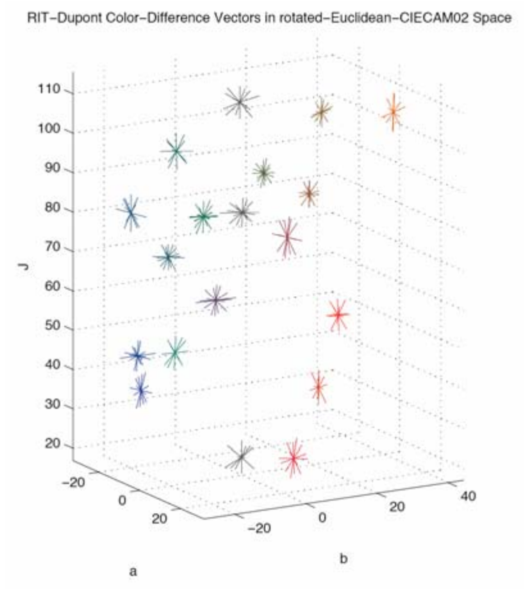

Figure 4 RIT-DuPont color-tolerance vectors plotted in rotated-Euclidean-CIECAM02: Eqs. (5) and (12).

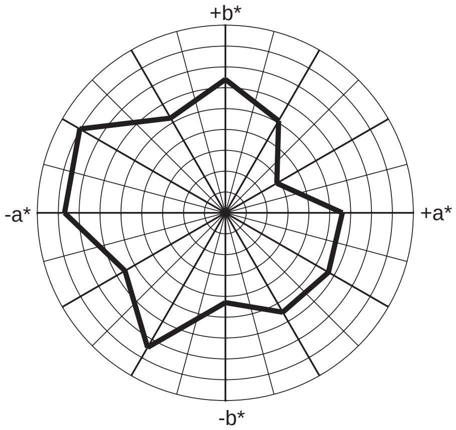

Figure 5 Qiao hue data rotated-Euclidean color differences for L* = 40 and C^*_{ab} = 35 (color-difference range 0.57 - 1.61).

6. QUANTITATIVE EVALUATION

The performance of these various equations and spaces were evaluated using the RIT-Dupont and Qiao datasets. The results are shown in Tables II and III. There are two important results. First, CIE94 and CIEDE2000 have equivalent performance, suggesting that CIEDE2000 may be over-fitting typical visual data. Second, simple weighted color-difference equations and Euclidized spaces have equivalent performance to CIEDE2000.

Table II PF/3 and maximum-disagreement (MD) statistics.

	PF/3	Mean MD	Max MD	S.D. MD
CIE-DE2000	22.88	1.19	1.91	0.17
CIE94	25.72	1.22	2.23	0.21
Optimized	22.65	1.31	2.30	0.24
Optimized rotated	21.63	1.33	2.16	0.25
Euclidean	22.84	1.29	2.22	0.22
Euclidean, rotated	21.83	1.30	2.05	0.23

Table III The *F* test results. Note: the critical values, F_c and 1/ F_c, were 0.757 and 1.321, respectively. Values exceeding this range indicate statistically significant differences.

	DE2000	CIE94	Optimized	Opt+Rot	Euclidean	Euc+Rot
CIEDE2000		0.808	1.169	1.216	1.158	1.229
CIE94	1.238		1.447	1.521	1.433	1.504
Optimized	0.855	0.691		1.051	0.991	1.04
Optimized,rotated	0.822	0.657	0.951		0.943	0.989
Euclidean	0.864	0.693	1.009	1.06		1.049
Euclidean,rotated	0.814	0.665	0.962	1.011	0.953	

7. CONCLUSIONS

CIECAM02 is a promising color space for setting industrial tolerances. Weighted color-difference equations can be derived with equivalent performance to CIEDE2000 without complicated positional functions. The advantage of such a simple equation is that line elements can be readily integrated, resulting in a Euclidized color-appearance space. Similar findings have been found by Luo, et al.[9]

These results should be considered exploratory rather than definitive. Because the RIT-DuPont vectors are not symmetric in CIECAM02, the optimization should be repeated included both positive and negative T50 positions, as well as including the visual uncertainties as weights. A more thorough error analysis is required to evaluate systematic limitations in predicting the visual data. Other criteria require evaluation such as hue linearity. It is of interest to repeat this approach using other color spaces such as IPT. Finally, any weighted-color difference equations or Euclidized color spaces require testing using independent verification visual data.

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Use and application of the PAD scale in the study of colour emotion

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ABSTRACT

This study concerns the affective impact of the colour and appearance of materials in the self reported emotional responses of groups of observers. A comparison will be made between the use of the Pleasure Arousal Dominance (PAD) Scale and the more commonly used Colour Emotion Scale (Nobbs, 1997 and 2004 and Ou, 2004). This paper reports on the development and use of the PAD Scale for assessing observer response to single colours in controlled conditions. An aim of the study reported here is the assessment of the usefulness of the PAD Scale in studies of Colour Emotion.

Keywords: Colour, Colour Emotion, PAD Scale, Pleasure Arousal Dominance Scale.

1 INTRODUCTION

The effective use of colour in materials, objects, and products enhances reflectivity, visibility, contrast, and legibility. Colour can also be used to entice people, enhance an idea, twist a message, or express a feeling or emotion relating to anything from a product to an environment, an individual, a website or advertising (Triedman and Cullen, 2002, and Lee and Qian, 2005). Much human behaviour is controlled by responses to the five senses, either singly or in combination. To the consumer, the appearance, the feel, the smell, the sound, and the taste of a product or an environment are used to assess quality, both consciously and subconsciously, and so affect product choice (Pointer, 2004-2005). Colour and appearance is the first point of contact for the consumer, this will imply a level of quality, which will or will not then lead them to try a product. It is the affective use of colour in this way that this project will study. This is an important subject area as the results are relevant in many areas of life; colour is used in practically everything we come into contact with. The combination of colour, shape, perception, and psychology is a very powerful one (Guthrie, 2005), so when the influence of these factors is understood, it will enable use of this effect to its fullest extent.

The primary aim of this study is a comparison between the PAD Scale and the Colour Emotion Scale. The secondary aims are to investigate the effects that the following factors (underlined) have on the emotional reaction perceived by an observer: <u>Knowledge background</u> – using observers with and without a background in Colour Science; <u>Culture</u> – Using a group of observers from the UK and also a group from outside the UK; <u>Situation</u> – Approaching real life versus controlled laboratory viewing.

The PAD Scale was originally developed by Mehrabian and Russell (1974) and is designed for use in the study of environmental psychology. The scale takes its name from the three factors that Mehrabian and Russell suggest underlie all emotions. These being Pleasure, Arousal and Dominance:

Pleasure – how much happiness a person feels;

Arousal – the amount of stimulation that is generated in a person by the surroundings;

Dominance – how 'in control' a person feels in relation to the surroundings.

The following examples show PAD Scale definitions of various emotion terms (underlined), where scores on each PAD Scale range from -1 to +1: <u>angry</u> (-0.51, 0.59, 0.25 = highly unPleasant, highly Aroused, and moderately Dominant); <u>bored</u> (-0.65, -0.62, -0.33 = highly unPleasant, highly unAroused, and moderately submissive (the inverse of Dominant) (Mehrabian 1995-2005).

The PAD Scale has been widely used in consumer research. There are several advantages to using the PAD Scale. It is well researched, so the word pairs that are used should be well chosen, and (as much as is possible) the opposites of each other. PAD Scale word pairs should cover all emotions, so will give a wider understanding of the affect of colour on emotions without having to select one word pair (or more) for each emotion that would be studied (as would have to happen with the Colour Emotional Scale). Also, there are many different emotional scales in use (Nobbs, 1997 and 2004, Ou, 2004 and Sato, 2004 amongst others), and only one PAD Scale, so this aspect will be useful for continuity and will also make it easier to compare results from one study to another. This is not easily possible with emotional scales, even if only slightly different words are used. As well as the above given advantages, perhaps the main advantage that the PAD Scale offers over the Colour Emotion Scales is that there is a strong likelihood that some Colour Emotion Scales measure word association instead of emotion (for example: warm/cool, elegant/inelegant and healthy/unhealthy), whereas the PAD Scale is more likely to measure true emotion, which is after all, the aim of studies within Colour Emotion.

Although there is debate regarding the suggestion that the three factors that underlie all emotions are Pleasure, Arousal and Dominance; there is a large body of research regarding the different uses to which the PAD questionnaire has been put and critique regarding this. Even if it is an oversimplification to consider just three basic factors, it does at least make it possible to test, and makes the situation approachable for experimental investigation.

Many of the studies considering the use of the PAD Scale have shown that the pleasure, arousal and dominance constructs are sufficient to define all emotions (Holbrook and Batra, 1987 and Mehrabian, 1995). An important consideration, however, is that the PAD Scale is only sufficient to describe other emotions from the basic pleasure, arousal and dominance set when the stimuli selected for the study cover the area to be studied fully. Mehrabian acknowledges the difficulty in doing this.

"*The difficulty to develop broad based and emotionally balanced samples of stimuli may explain the temptation for other investigators to delete the dominance factor and to rely only on the pleasure and arousal factors, or rotations thereof, to describe emotions*"(Mehrabian, 1974).

The PAD Scale has been extensively used in consumer research, including studies that have looked at the affect of colour on consumer behaviour. A recent study in this area (M. Brengman and M. Geuens, 2003), considered the affect of colour and found that for the sample group in question, the main factors were pleasure, tension, excitement and dominance. It was also found that the PAD scores had adequate reliability and validity, although the dominance factor was weak. This observation was a result of factor analysis, and found that the dominance factor had low validity and reliability compared with the results generated for the pleasure and arousal factors. The study (M. Brengman and M. Geuens, 2003) suggested that the dominance factor might be ignored completely as some previous researchers have done (Van Kenhove and Desrumaux, 1997). This supports the suggestion (Russell and Pratt, 1980) that the dominance factor is not applicable in environments that are being assessed for their affective response. There is also evidence that suggests that the applicability of the dominance factor depends on the type of environment setting used (Foxall, 1997). This may explain why the studies in question, and others, have found that the information concerning the dominance factor is less reliable than that concerning the pleasure and arousal factors. It is not unlikely that the reason that these studies have found the dominance construct to be weak is because the sample set used did not sufficiently cover the area under study, as Mehrabian and Russell noted (see the quotation in the previous paragraph). Therefore, as Mehrabian and Russell intended, to ensure that a study of all three emotion factors (pleasure, arousal and dominance) is relevant and useful, it is a matter of applying them as a tool in the correct way to the appropriate design of experiment.

In the study by Brengman et al (2003), the PAD Scale was validated for capturing the emotional responses of observers to store interior colours. Unlike previous studies in this subject area, the study used a range of colour stimuli that attempted to cover a large region of colour space including a range of luminance and chroma, which many other studies have either not covered or have covered insufficiently.

2 METHOD

2.1 Colour Selection

The colours used for the test material have (as much as is practical) a good and even coverage of colour space with as little as possible correlation between the lightness, intensity of colour sensations, and hue. The initial steps for selecting the colours to be used involved downloading the co-ordinates of a list of real colours from the Munsell Colour Order System and converting these values into L* a* b* and L* C* hº values.

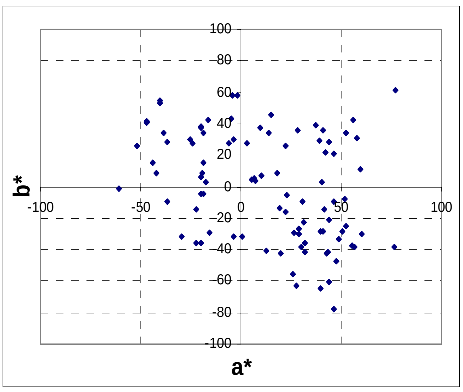

Figure 1: a* versus b* of colour set

Using the L* C* hº values, the boundaries for the x, y gamut and the luminance range of the method of reproducing the colours were identified. Colours outside of these boundaries were then removed from the colour list. The reproducible set of colours was then split into sections. Five colours were then selected randomly from each section in order to give a reduced set of ninety colour samples (see Figure 1: a* versus b* of colour set).

Table 1 reports the correlation between the colour parameters for the reproducible colour set, showing that the objective of negligible correlation was achieved.

Table 1: Correlation of reproducible set of colours

	L*	a*	b*
L*	1.000	-0.237	0.093
a*	-0.237	1.000	-0.356
b*	0.093	-0.356	1.000

2.2 Sample preparation

The co-ordinates of the chosen colours were converted into sRGB values and the test panels printed using a Hewlett Packard inkjet printer. The printed samples created were measured, and the values (target and actual) were entered into a simple printer characterisation model to start characterising the printer. The model was based on the amount of light reflected in three wavelength bands and included factors for dot-gain. Several cycles of this were necessary in order to generate prints of the required colours.

2.3 Focus groups and questionairre design

Several focus groups (with colour knowledgeable, colour naïve, British, and non-British observers) were run in order to generate words that observers would use to describe a range of different colours and surface finishes so that these might be considered for inclusion into the PAD questionnaire. It was decided however, not to include any of the words generated from the focus groups as the emotional content of the words used was limited, making them unsuitable for inclusion into the questionnaire.

2.4 Observer tests

The observers consisted of two groups, those from inside (colour experienced) and outside (colour naive) of the department. There was also a non-british group as it has been shown that culture affects the perceived emotion. All observers have normal colour vision (as assessed by the Ishihara Test). The order of presentation of samples and emotion scales was randomised for each observer.

The semantic difference method of self-reporting was used to obtain sensory data describing the emotional response of observers to coloured panels. During an experiment, an observer looked at a coloured panel under controlled conditions and selected a point on a seven point bipolar scale between the word pairs, stated by the PAD Scale, that they felt best describes their impressions of that colour. See Table 2 for the PAD Scale word pairs. Like and dislike were also added in order to judge the observer preference for each colour.

Table 2: PAD Scale word pairs

Dominant	Submissive	Frenzied	Sluggish
Satisfying	Unsatisfying	Exiting	Calming
Stimulating	Relaxing	Controlling	Controlled
Jittery	Dull	Autonomous	Guided
Hopeful	Despairing	Influential	Influenced
Happy	Unhappy	Arousing	Un-arousing
Pleased	Annoyed	Important	Awed
In control	Cared for	Contented	Melancholic
Wide awake	Sleepy	Relaxing	Boring

As described in the previous paragraph, each word pair used was on a 7 point scale. This is a bipolar scale. However, when designing a questionnaire it is usually considered to be better to use a unipolar scale as a bipolar scale necessitates finding opposites to the words being used, and it is often difficult to do this successfully (Chambers and Baker-Wolf, 1996). In this case, however, a well researched and widely used scale is used so in this instance a bipolar scale is considered to be suitable.

It is generally suggested that ratings scales should not usually have less than 5 categories. The discrimination and reliability of the results is often assumed to increase with an increased number of segments. However, beyond 9 segments this increase is only slight and the noise that is generated is not sufficient to make up for the increase in discrimination (Chambers and Baker-Wolf, 1996). For these reasons, a 7 point scale was considered to be the most appropriate for giving a good level of discrimination, without generating noise that would detract from the results.

Affect of viewing conditions on the observer reported emotion was also investigated. Judgements on coloured cards were made in the following three settings; i) Using a viewing cabinet with neutral grey background and D65 light, viewers requested not to touch the samples. The viewing cabinet will be placed in a darkened room; ii) In a room illuminated with D65 lamps (replacing the usual light sources), samples placed an a table covered by a neutral grey piece of card, viewers requested not to touch the samples; iii) In a room illuminated with D65 lamps (replacing the usual light sources), samples placed on a natural wood surface table and viewers allowed to touch and move the samples.

2.5 Analysis of results

After defining the emotions from the word pair answers, the results will be analysed in order to create predictive equations. These may then be used to predict the most likely emotional response to the appearance of coloured materials. Factor analysis will also be used to understand which variables have the greatest effect on the emotional response to the colour and in what way this is affected.

2.6 Current status of work

The colour selection and initial sample creation steps have been completed. The printer characterisation is progressing and is expected to be completed shortly. The observer tests will start as soon as the printer characterisation is completed.

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Colour Emotion and Area Proportion

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ABSTRACT

This study investigates the effects of area proportion on colour emotion using psychophysical methods. The results suggest that the effect was significant only for colour combinations having great difference in colour emotion values between the constituent colours, especially for the "heavy-light" scale.

Keywords: Colour emotion, colour semantics, colour meaning, area proportion

1 INTRODUCTION

Colour emotion has been used in recent years for an intensively studied research area which uses quantitative approaches to investigate the relationship between colour and semantic words (while some of the words were in fact real emotion terms, such as "exciting" and "calming"). A number of studies in this area have been carried out for single colours [1-3] and for two-colour combinations [4-6]. For the latter, the results were based on stimuli with equal-sized colours, and have been thought to be insufficient for practical use in design work. Therefore, the present study used a number of colour combinations as the stimuli, each consisting of three colour chips with different sizes, in order to see whether different proportion lead to different colour emotion scores for the same constituent colours.

2 METHODS

The aim of the study is to investigate any influences of area proportion on colour emotion. To achieve this, visual assessments of three colour emotion scales, i.e. "warm-cool", "heavy-light" and "active-passive", were conducted using the method of categorical judgement [7].

2.1 Colour Stimuli

Thirty colour combinations (each containing three constituent colours), generated randomly by 35 colours, were used as the stimuli in the experiment. As shown in Table 1, these 35 colours were selected to cover a large gamut in CIELAB space. For each of the 30 colour schemes, 7 area ratios were set up in determining sizes of each constituent colour, including (4:1:4), (3:1:3), (2:1:2), (1:1:1), (1:2:1), (1:3:1) and (1:4:1). An illustration of these area ratios is shown in Figure 1. This resulted in 30 x 7 = 210 stimuli for each participant to view in the experiment.

Table 1 CIELAB specifications of the colour samples

	L^*	C^*_{ab}	h_{ab}
1	35.2	52.2	53
2	57.7	58.8	24
3	80.2	62.4	357
4	35.4	35.5	320
5	35.4	21.6	330
6	35.4	32.0	358
7	35.2	46.3	49
8	80.4	22.7	13
9	80.3	25.7	5
10	80.2	30.5	342
11	80.2	21.9	357
12	80.3	19.5	12
13	57.7	22.5	18
14	57.7	27.5	356
15	57.7	17.1	344
16	35.2	24.6	15
17	35.5	26.8	327
18	35.4	22.3	357
19	80.3	16.0	357
20	80.3	10.6	353
21	80.6	6.9	4
22	57.6	11.1	8
23	57.6	13.0	3
24	57.7	16.4	346
25	57.6	10.2	357
26	57.8	8.3	7
27	35.3	10.9	13
28	35.3	14.0	357
29	35.2	8.2	347
30	35.3	9.6	14
31	11.8	1.6	0
32	35.5	3.3	356
33	57.7	4.2	357
34	80.3	5.0	357
35	100.7	1.0	359

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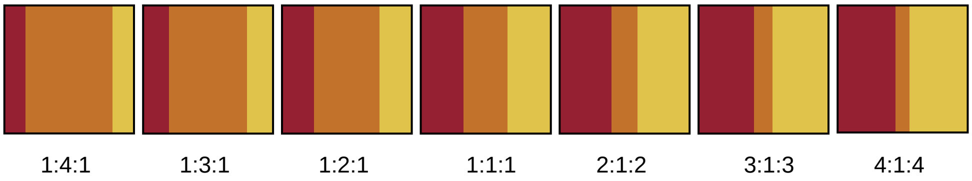


Figure 1 Seven area ratios were used in the experiment

2.2 Experimental Set-up

The experiment was conducted using a calibrated cathode ray tube (CRT) display in a darkened room. Fifteen participants, all Chinese students at the University of Leeds, including 7 males and 8 females, took part in the experiment.

Figure 2 shows the experimental layout, indicating that a medium grey with a lightness value of 50 was used as the background. Three word pairs, "warm-cool", "heavy-light" and "active-passive", were used in the experiment as these have been found to be the main underlying factors of colour emotion [1-2, 8]. Each word pair was presented on a seven-category scale, e.g. "very warm", "warm", "a little warm", "uncertain", "a little cool", "cool" and "very cool".

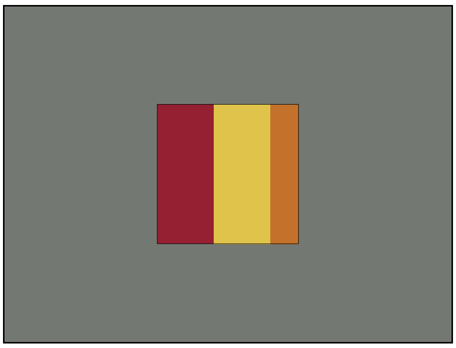


Figure 2 Experimental layout

2.3 Research Hypotheses

The present study hypothesises that the psychophysical models for single-colour emotion [2] and for colour-pair emotion [4] developed recently by the co-authors can well predict visual results obtained from the current experiment, with consideration of area proportion. The single-colour models under test included "warm-cool" (WC), "heavy-light" (HL) and "active-passive" (AP), as shown in the following:

$$\mathrm{WC} = -0.5 + 0.02\,(C^*_{ab})^{1.07}\cos(h_{ab} - 50°) \quad (1)$$

$$\mathrm{HL} = -2.1 + 0.05\,(100 - L^*) \quad (2)$$

$$\mathrm{AP} = -1.1 + 0.03\,[(C^*_{ab})^2 + (L^* - 50)^2]^{1/2} \quad (3)$$

where L^*, C^*_{ab} and h_{ab} are the three colour-appearance attributes lightness, chroma and hue angle, respectively, in CIELAB system [9].

The colour-pair model under test is shown in the following:

$$E = (E_1 + E_2)/2 \quad (4)$$

where E represents the colour emotion value for an entire colour pair; E_1 and E_2 represent colour emotion values for the two constituent colours in that pair, and can be determined using Equations (1) to (3).

Note that the present study uses three-colour combinations as the stimuli. It was thus assumed that Equation (4) can be extended to the following, given that the three constituent colours share the same size:

$$E = (E_1 + E_2 + E_3)/3 \quad (5)$$

The study further assumes that in a colour combination, the contribution of each constituent colour to the emotion value of an entire combination is proportional to the size of that colour area. Accordingly, Equation (5) was modified into:

$$E = (a_1E_1 + a_2E_2 + a_3E_3)/(a_1 + a_2 + a_3) \quad (6)$$

where E represents the colour emotion value for an entire colour combination; E_1, E_2 and E_3 represent colour emotion values for the three constituent colours in that combination, and can be determined using Equations (1) to (3); a_1, a_2 and a_3 represent the area for each of the three colours.

3 RESULTS

To see whether the hypotheses described above really worked for the present study, the colour emotion values predicted by Equations (5) and (6) were calculated using the experimental data, in which the colour emotion value for each constituent colour was determined by Equations (1) to (3). Predictive performance of each equation was measured using the Pearson product-moment correlation coefficient (r) between the visual results and the values predicted using the equation in question.

The results are shown in Tables 2(a) and (b) for Equations (5) and (6), respectively, indicating good predictive performance for both equations, with a mean correlation coefficient of 0.86 for Equation (5) and 0.87 for Equation (6). Note that Equation (5) is a simple "average" model and that Equation (6) considers area proportion by adding proportion values into the model as the weighting. Therefore, the two figures (i.e. 0.86 and 0.87) suggest that area proportion had little impact on colour emotion.

In addition, Table 2(a) shows that the correlation coefficients for each area ratio are virtually equal (e.g. 0.86 for 1:4:1, 0.87 for 1:3:1, etc). This also suggests that there the effect of area proportion was insignificant.

To find out why there was little impact of area proportion, we looked into every single colour combination used in the experiment, with an assumption that the significance of area proportion was perhaps related to colour emotion difference between constituent colours within each colour scheme.

First, a measure of colour emotion difference (ΔCE) for each colour scheme was established, as shown in the following:

$$\Delta CE = \left| E_2 - \left(E_1 + E_3 \right)/2 \right| \quad (7)$$

where E_2 represents the colour emotion value for the colour at the middle of a colour combination; E_1 and E_3 are colour emotion values for those on the two sides within that combination.

Figures 3(a) to (c) show colour emotion difference values plotted against the predictive performance of Equation (6), in terms of correlation coefficients (r) between the predicted values and the visual results for various area ratios within each colour scheme. Since Equation (6) was based on area proportion, the r values shown here can represent the effects of area proportion; the higher the r value, the more significant the effects of area proportion.

The diagrams show that colour combinations with high ΔCE values tend to have high r values, thus having great influence of area proportion. This tendency was found to be significant especially for the "heavy-light" scale, indicating that the impact of area proportion was most significant for this word pair.

Table 2 Predictive performance (in correlation coefficient) of (a) Equation 5 and (b) Equation 6

(a)

	1:4:1	1:3:1	1:2:1	1:1:1	2:1:2	3:1:3	4:1:4	All
WC	0.84	0.85	0.85	0.87	0.87	0.88	0.87	**0.86**
HL	0.91	0.94	0.93	0.95	0.94	0.93	0.95	**0.93**
AP	0.82	0.83	0.83	0.81	0.77	0.76	0.76	**0.80**
Mean	0.86	0.87	0.87	0.88	0.86	0.86	0.86	**0.86**

(b)

	1:4:1	1:3:1	1:2:1	1:1:1	2:1:2	3:1:3	4:1:4	All
WC	0.89	0.88	0.88	0.87	0.85	0.85	0.83	**0.87**
HL	0.92	0.93	0.92	0.95	0.96	0.96	0.97	**0.95**
AP	0.81	0.82	0.82	0.81	0.79	0.79	0.79	**0.80**
Mean	0.88	0.88	0.87	0.88	0.86	0.87	0.86	**0.87**

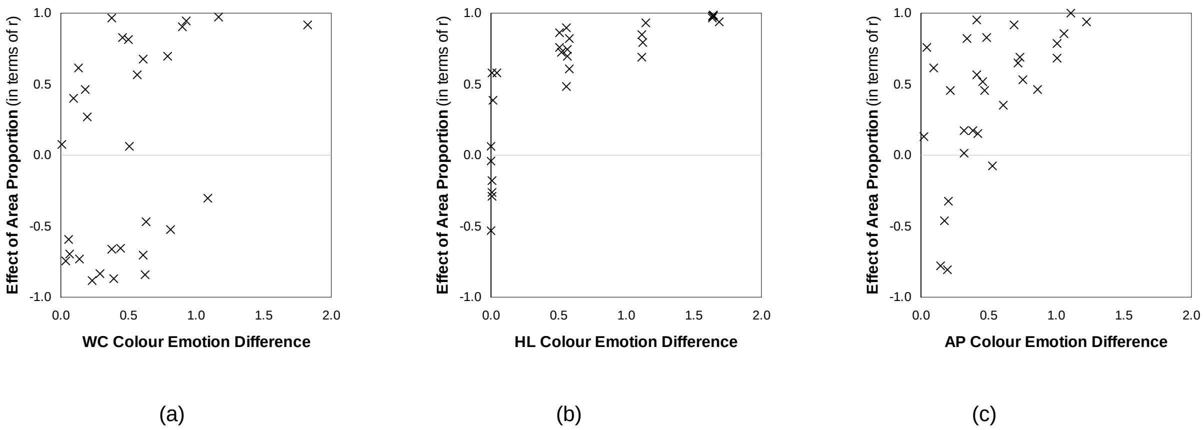
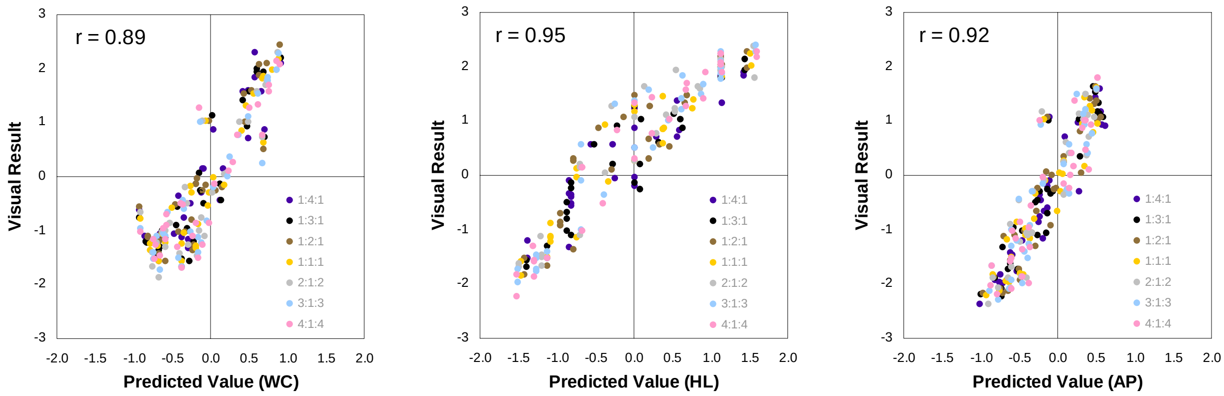


Figure 3 The effects of area proportion (in terms of Pearson r) plotted against colour emotion difference between constituent colours in each colour combination for scales (a) warm-cool, (b) heavy-light and (c) active-passive.



(a) (b) (c)

Figure 4 Predictive performance of Equations 8, 2 and 9, based on Equation 6, for scales (a) warm-cool, (b) heavy-light and (c) active-passive, respectively.

As shown in Tables 2(a) and (b), the predictive performance of psychophysical models "warm-cool" and "active-passive" was not as good as that of "heavy-light". Modified models of these two scales were then developed, as shown in the following:

$$WC' = -0.22 + 0.15\,(C^*_{ab})^{0.6}\cos(h_{ab} - 20°) \quad (8)$$

$$AP' = -1.43+0.03\{(C^*_{ab})^2+[(L^*-40)/0.85]^2\}^{1/2} \quad (9)$$

where L^*, C^*_{ab} and h_{ab} are the three colour-appearance attributes lightness, chroma and hue angle, respectively, in CIELAB system.

Predictive performance of the models (based on Equation 6) are shown in Figures 4(a) to (c), with a correlation coefficient of 0.89 for "warm-cool", 0.95 for "heavy-light" and 0.92 for "active-passive".

4 CONCLUSIONS

The study investigates the effect of area proportion on three-colour emotions for scales "warm-cool", "heavy-light" and "active-passive". The results show that such effect was perhaps only significant for colour combinations with a high ΔCE value, in particular for the "heavy-light" scale. To verify these findings, it is necessary to carry out further research with a wider range of colour samples and perhaps a wider range of area ratios for each colour combination to be studied.

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The role of the colour training into the development of the industrial offer

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KEYWORDS: colour training for industry, colour knowledge, industrial world, creation process

ABSTRACT

Within several institutions such as big industrial groups and universities, colour knowledge and know-how training exist but are not teach the same way. Actually, several stakes have to be considered as far as the teachings of what is the colour material and how to use it is concerned.

1. INTRODUCTION

In the first time, we will try to understand how the colour design notion could be considered as a know-how isolated from every notion of productivity and mass broadcast, as a very artistic practice which theories open mind to new creation possibilities.
Then, we will consider the colour trainings in professional areas where colour classes are given and we will try to identify their main stakes.
At the end, we will focus on the understanding of political stakes of the colour training in industrial areas, questioning ourselves permanently.

2. COLOUR TEACHING : TOWARDS A PROJECT ISSUE

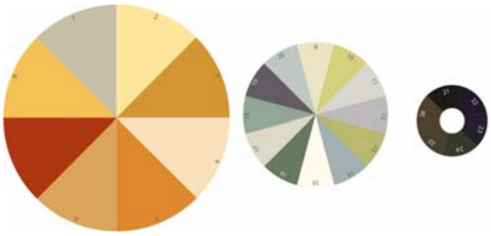
A colour training, in a design school opens the mind towards another way to apprehend the material itself as well as the creation process. The shape leaves its place to colour and the using notion leaves the place to the pure percept.
Colour feeds by its plurality the formal and technical research as colour is a multiple material, a material which can wear the object, protect it and give it an existence in the world.

2.1 From the percept to the concept

The student who has to carry out a project with a colour issue will have to interrogate the notions of materials and colour and make **modelization**s.

By this way, the colour modelization makes it possible to reuse tangible information coming from its perception (for example colours of stones from traditional buildings) in order to put it in a new context and create a new product.
The colour, once isolated from its former function, will begin a material for creation.

1 et 2 : Students work, Piquecos' chromatic chart, France, Preliminary studies.



3 : Students work, Piquecos' chromatic chart, France, Modelization of colours for frontages

This creation coming from a thinking based on colour and material will then integrated into a conception process linked to the designer's requests.
The very fact of having interrogated the material and having carried out a specific analysis and then a modelization will provide credibility to the creation act.
Thanks to this process, a designer trained to colour achieves much more easily to consider the "decoration" issue (of which colour is one of the key components) not like a pejorative aspect of design, but like a necessary condition for the very existence of the object.

For Alessandro Mendini, the « modern designer » is different from the one of the industrial period, he is more female, he thinks space as a cosy and warm cloth, and he prefers the word "live" (abitare) to the word "project" (projettare). [1]
This contemporaneous designer he describes is the designer who thinks colour and for him, colour is "clothing" or "makeup", it has a decorative value.
"We come back to the idea of colour as a language, an alphabet: it becomes a signs system which takes part of the three main components of an object, that is to say the shape, the colour and the decoration".[2]
Those quotes coming from a book written for the Sikkens brand testify of a successful collaboration between an artist and an painting manufacturer, in order to promote products but also to create new range of products, enriched and created by the designer.

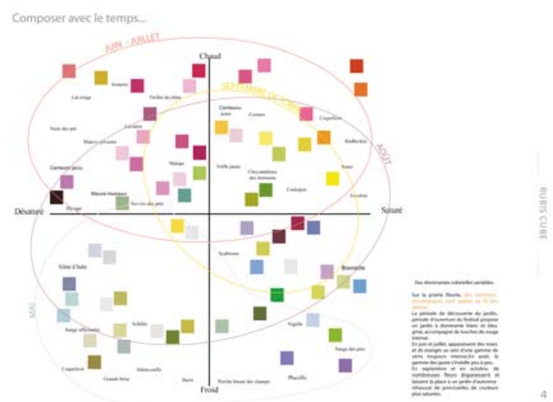
2.2 Colour modelization

Taking into account the industrial reality, the notion of range of products which is at the very heart of colour conception is also an important notion to teach as no industrial object works like a unique object. They form part of a « collection ».

At the Professional University Institute of Applied Arts in Montauban, where classes about colour theories are given as well as classes about project practices, the colour is teach as a mean to have access to the expertise of the project based on colour and material.
The industrial sector as well as the colour jobs are of course present in order to make it possible for the students to be both in a poïetical position (they question the knowledge and the know-how at the same time) and in the position of future professionals of colour, from the perception to the conception and from the conception to the realization.

So students learn to talk about colour but also to communicate about and with the colour : that is why they use colour codification systems created by industrials (ACC, NCS, RAL…) and create project communication tools.

Then, the colour map, a tool as many others, makes it possible to wonder about the colour systems issue.
From Newton to Chevreul, experts created colour systems to make it express itself. From JP Lenclos to Kobayashi, colour, thanks to the colour systems, offers new readings of socio-cultural spaces, of their codes and symbols.



5 : Colour map, hue classification by chromatic areas.

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3. THE SENSIBILISATION OF INDUSTRIAL WORLD TO COLOUR ISSUES

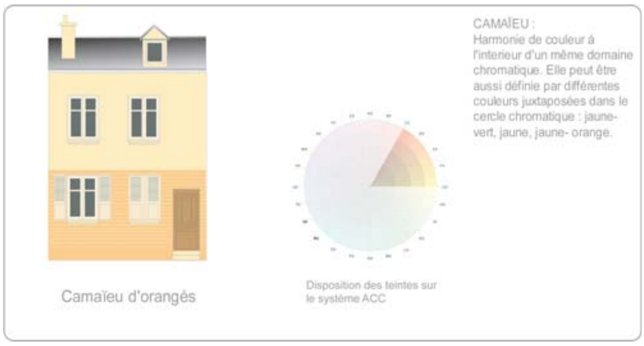
In the industrial world, the colour training has more commercial objectives: it has to promote products, but it is not the unique objective.

3.1 To promote the knowledge in order to promote the product « colour »

The benefits that result from a colour training are necessary in every area of the industrial creation and the building sector.
Nevertheless, step by step, numerous stakes appear as colour training makes it possible to question, on a regular basis, the creation process as well as the production one and gives the opportunity to discover constant innovation in this area.
If a painting manufacturer wishes to train the painters who use its products it is, of course, to value the qualities of their products, but also to provide him with the keys of more thought and more qualitative harmony creations.
And when it deals with internal training, persons in charge of the industrial product promotion will be able to sell, thanks to the colour training, a product which aesthetical features are known and are communicable.
Usually, the colour training should also sensitize industrial professionals to a sensible and an artistic knowledge, a knowledge which is often far from their day-to-day preoccupations.
The colour training has also to give sense to an harmony, to the space transformation through colour use and to every percept linked to the colour material.
Last but not least, colour training should entail perpetual interrogations about creation process set up for economic and marketing reasons.

Tools that make it possible to set up a reflection about colour in industrial sectors are first, tools of experimentation of the colour phenomenon (experiments of the coloured prism, of colours mix), but also tools to put projects in situation, tools for coloured spaces simulations which make the trainees compose with colours in fake spaces.
Obviously, their creations will have to be described and explained, which make it possible to theorize a phenomenon that is difficult to link to an objective knowledge.
Every parameter in relation with colour could be used (physiological, physical, psychological, sensitive, aesthetical…) in order to produce objective arguments to justify the use of the chosen colour and its aspect.

6 : Farer, closer : analyse of the impact of distance on the hue perception.



7 : Compose with colour : example of an harmony in camaïeu

3.2 Ethic and political involvment

Colour is a phenomenon so linked to our perceptions that it is sometimes difficult to consider it objectively and to make distinction between our tastes and objective knowledge.
And when a creative, a colourist, enters into an industry it is of course to bring its knowledge and its trainers skills but not only :

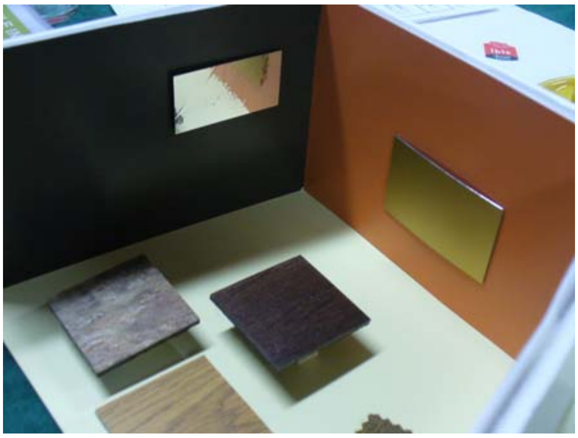
The commercial and the prescriptor, waited by their superiors on competitive results, want always to sell a product without wondering themselves about the validity of this product from an aesthetical point of view as well as from a technological, ecological and durability points of view. So they will suggest very often a “broken white” to hide a lack of expertise by a neutral chromatic answer.
This consensual response, which aims at preventing visual aggressions, will lead to the development of a urban space completely asepticized.

Then, thousands of litters of setting coats sold every year by industrials will have an impact, not only on the urban landscape but also on traditional practices and, sometimes, on the environment.
Think about the impact of what we produce on the visible world it is also think about our role in the society.
The theorical approach of colour which gives a sense to our culture an its specificities, as well as the practical approach, which will confront ourselves to our sensibility but also to our culture of colour, can and should entail interrogations.
Colour is a material with infinite features and the industrial, after a colour training, could question the stakes in relation with this material.

So, a company that wonders about its products and their political validity is a company that positions itself towards research and development: the search for a better living, to take into account, beyond the market, the people's expectations, motor of change.
Thus, the research in human sciences and in the arts and urban and architectural innovation has an important role to play in enterprises.

Its first role is to file information about traditional material and colour, in artisanal and local practices, in order to restore them in the coming future.
Then, it should position itself in relation with the new technologies without forgetting that every material is a material that we see, that we touch, a material that contributes to build our daily environment.

8 : Colour training for industrials



9 Exercice of interior space simulation with industrials (colour and materials samples).

CONCLUSION

To be sensible to the material, to the object itself which is at the very heart of the industry, is to be sensible to the reality of what is manufactured. But to be sensible to the material is also to see beyond the matter, in another light, the colour material, a transitory material.

Though, to offer colour training to many manufacturers, is to offer them the possibility to question perpetually their raw materials.
As far as the pedagogy itself is concerned, it is, obviously, the basis of the relation with trained people: once again, colour creates links and set up a relation to the others, a relation to the world which is specific to the colour itself .

As Giacomo Balla means, « today we would like to abolish (…) every neutral, pleasant, faked, fantasist, half-dark or humiliating hue. (…) Thus, future clothes will be… happy. Coloured fabrics and iridescent filling with enthusiasm. Use muscular coloured, very violet, very turquoise, very green, very yellow, orange, vermilion.
If the government does not decide to wear out its passeist clothes of fear and indecision, we will double, multiplicate by hundred the red of our flag"[3]

We should inspire ourselves from this futuristic utopia in order to make the key players of our time to innovate and question the past, for a future leading to renewal.

---

[3] Giacomo Balla, *the unneutral wearing*, futuristic manifest, Milan 1914.

Warm and cold colours

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ABSTRACT

A group of 12 observers evaluated the perceived warm and cold appearance of 130 colours, chosen to represent the NSC colour solid, in independent trials. Results show that subjective colour temperature changes abruptly passing from hues below to hues above 120°, and the same brusque change appears around 330° in the CIELAB colour system; saturated colours are warmer; very dark and very light colours are cold. These results and the mathematical model then derived agree well with previous studies and supply detailed data on the boundaries in the colour solid separating the cold from the warm colours.

Keywords: subjective colour temperature; warm and cold colours; cross-sensorial perception.

1 INTRODUCTION

The distinction between warm and cold colours is very old, rooted in the colour language itself[1] and of great perceptual importance. Although largely used, a precise definition of which are the warm and the cold colours is seldom given, the reported reason being that the distinction is evident to all people. The reference to the experience of thermal sensations with warm and cold objects of specific colours seems irrelevant to explain the distinction. The characterisation of colours according to their perceived temperature is always found in research using the semantic differential[2,3], and it almost always appears as an independent factor in factorial analysis[4].

This research is directed to experimentally specify, in a standard colour system and in a controlled situation, which colours are perceived as warm and which as cold.

2 METHOD

An accurate choice of 130 colours (Figure 1) has been made by splitting the whole set of colours listed in the NCS Colour Atlas[5] and described inside the CIELAB system, in eight horizontal layers as a function of their lightness (from L* = 20 to L* = 99).

The whole colours solid was moreover vertically divided in 10 equispaced sectors roughly corresponding to the five main hues (Y, R, P, B, G) and their intermediates.

Ten colours were taken from the first (20 < L* < 30), the second (30 < L* < 40) and the last layer (90 < L* < 99), one for each hue sector, at a short distance from the achromatic axis. From the other five layers ten colours were taken at a relatively short distance from the achromatic axis (Figure 1a) and more ten at a larger distance (Figure 1b).

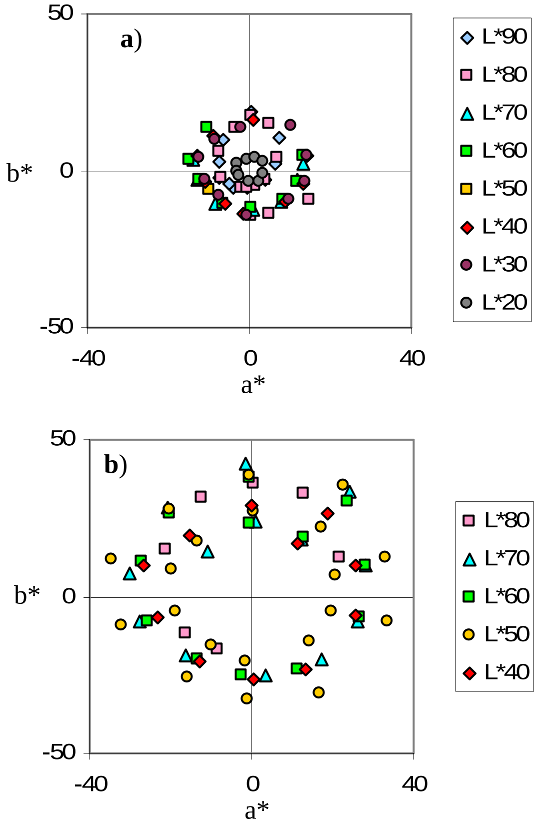

Figure 1. The less chromatic colours used in the experiment are plotted in **a)**, while the more chromatic colours are plotted in **b)**.

The coloured area (21° x 17° at a viewing distance of 70 cm) was displayed at the centre of a 39.5 × 29.5 cm screen of a CRT 19' monitor (Barco Reference Calibrator V); the left and upper sides were surrounded by black and the other two lower and right sides by white background (0.1 and 80 cd/m^2 respectively). To mask possible after images, a 1-sec full screen chessboard with 1 × 1 cm light and dark grey squares (54.9 and 7.0 cd/m^2, respectively) was presented before each stimulus, with the offset of the mask coinciding with the onset of the stimulus.

3 PROCEDURE

Twelve observers volunteered in the experiment, the two authors who made a series of 5 complete trials, and a group of ten university students who went only once through the whole procedure. In a first run the task consisted in evaluating in a Likert scale (from 1 to 7) how much warm was the observed colour. In a second run the observers had to evaluate the cold instead of the warm appearance. The evaluation order was inverted for half observers. There was no time limit. Given the length of the task, observers were allowed a rest any time they liked.

3 RESULTS

The separate assessments of the cold and warm colour appearance were highly consistent (Pearson correlation $r = 0.96$, $p < 0.0001$).

Therefore the two evaluations were transformed into a unique value between 100 and -100, with positive numbers for the warm colours and negative for the cold ones. Results are shown in Figure 2.

Results show that the warm-cold dimension characterizes two well distinct groups of colours as a function of their hue: there is a well clear-cut change in the evaluations around 120° and 330° hue angles. The interval between these two angles contains the cold colours while all the other colours appear mostly warm.

More chromatic colours appear significantly warmer, and less chromatic colours appears significantly cooler (this effect can make cold the colours belonging to 'warm' hues).

Saturated greens are the least cold in the group of the cold colours (Figure 3), but still they appear cold, while some desaturated reddish colours (from magenta to yellow-green) appear not only less warm but also positively cold (Figure 4).

There is no statistical difference in the perceived temperature as a function of the lightness (L*), as it appears in Figure 5. Nevertheless very dark colours, under L* = 35, are always cold, and this is true also for the very light ones; only in the range 35 < L* < 85 colours can appear warm.

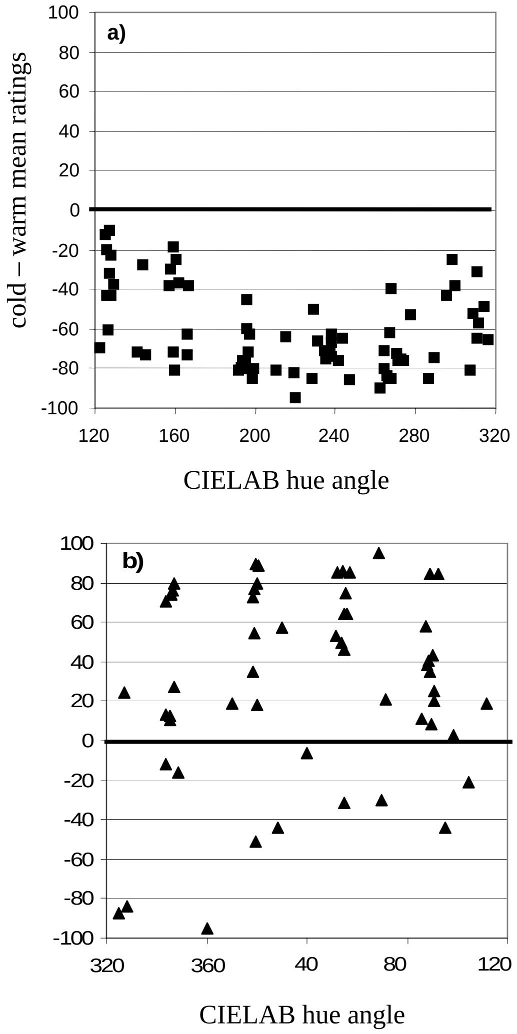

Figure 2. Mean ratings of the cold (negative, **a)** – warm (positive, **b)** appearance of the various colours as a function of their hue angle in CIELAB.

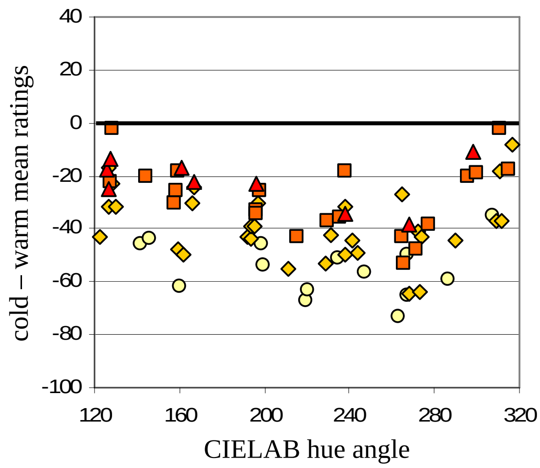

Figure 3. Mean ratings of the cold colours as a function of their chroma (circle = C* < 10; diamond = 10 < C* < 20; square = 20 < C* < 30; triangle = C* > 30) and hue angle in CIELAB.

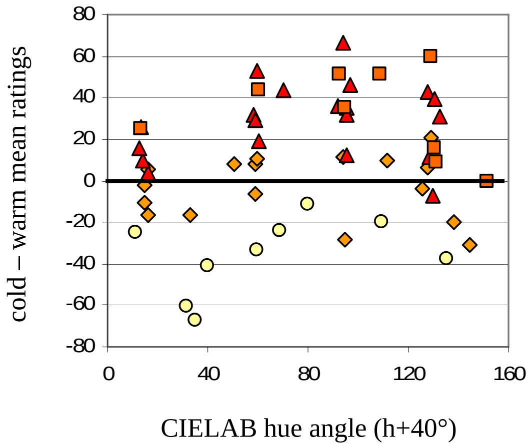

Figure 4. Mean ratings of the warm colours as a function of their chroma (circle = C* < 10; diamond = 10 < C* < 20; square = 20 < C* < 30; triangle = C* > 30) and hue angle in CIELAB.

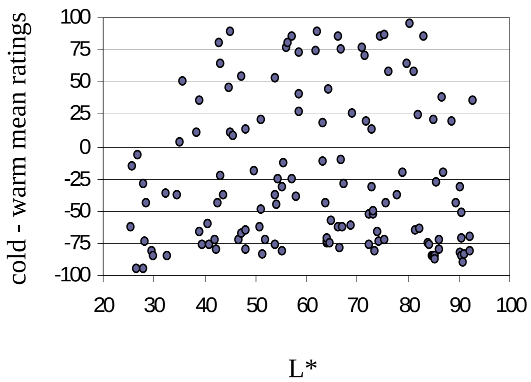

Figure 5. Mean ratings of the warm and cold colours as a function of their lightness.

5 TOWARDS A MODEL

This study was focused on the determination of the regions of the colour solid which characterise the warm and the cold colours, respectively. Factorial analysis in previous research[3,6,7] showed that one factor in judging colour appearance is always the warm / cold dimension, almost always saturated by the semantic scale 'warm-cold', and for this reason we limited our inquiry to his dimension. The observers' task was to give, in two separate runs, a direct measure of each colour aspects, i.e. the warm and the cold appearance of the selected colours. In other recent works the study was extended to a number of semantic scales, and the colour dimensions derived by a factorial analysis were colour activity, colour weight, and colour heat in one research[6], and colour activity, potency and warm-cold in another research[9]. Another recent work[8] compared the performance of three groups of observers as regard to a dozen of semantic scales, one of which was warm – cold, where the task consisted in choosing one appropriate adjective for each observed colour.

In general all results seem to agree quite well as regard to the role played by hue, lightness, and saturation in determining the perceived temperature of the colours, and often a mathematical model has been proposed.

Some limitations in the comparisons are due to the different number of examined colours (20[6], 218[8], 130 here), the different size of colour patches (7.5 x 7.5 cm^2[6], 1.0 cm x 1.5 cm^2[8], 30 x 20 cm here), and the different procedures (pair comparison[6], direct estimation here). Nevertheless the resulting models not only fit well their own data (R^2 = 0.74[6], R^2 = 0.862[8], R^2 = 0.898[here)], but also correlate well one each other.

Colour heat[6]:

$$= -0.5 + 0.02\,(C^*)^{1.07} \cos(h - 50°) \qquad (1)$$

$WC^{8}_{0° \le h \le 180°}$: (2a)

$$= 0.154\,L^* + 39.378\,C^{*\,(0..372)} - 0.303\,h - 113.855$$

$WC^{8}_{180° \le h \le 360°}$: (2b)

$$= 0.355\,L^* + 23.476\,C^{*\,(0.429)} - 0.159(360° - h) - 105.71$$

Our model for the $W_{arm}C_{old}$ dimension:

$$= -40 + 20/a \log(C^*) \cos(h - 40°) \qquad (3)$$

where $a_{0° \le (h+40°) \le 160°} = 2$; $a_{160° \le (h+40°) \le 360°} = 0.3$

First of all lightness does not appear in equations (1) and (3), as it results nearly irrelevant in affecting the warm-cold dimension of colour, while it is linearly included in (2a) and (2b), although its influence is not relevant in that work too[7]. Secondly, al the equations (1), (2a) and (2b) perform relatively well (R^2 = -0.83) in predicting the present data, but the last equations do still better (R^2 = -0.855) if the parameters for the Thailand observers are used instead of those for the Hong Kong subjects (L*, x_1 = -0.331, x_2 = -0.315; C*, y_1 = 11.2, y_2 = 0.016; h, z_1 = -0.389, z_2 = -0.321; C* index, a = 0.621, b=2.05; constant, c_1 = -44.7, c_2 = -12.1). Moreover equations (2a) and (2b) with a set of specific parameters for the Italian observers (L*, x_1 = 0.19, x_2 = 0.19; C*, y_1 = 34, y_2 = 30; h, z_1 = 0.29, z_2 = 0.29; C* index, a = 0.36, b = 0.35; constant, c_1 = 111, c_2 = -99) fits our data still better (R^2 = 0.883).

4 CONCLUSIONS

This research shows that there is a high correspondence between the warm and the cold evaluations, which were given independently, and that warm hues are clearly distinct from the cold ones. Moreover, in agreement with previous findings[2,3,6,8] chromaticness (or chroma, or still saturation) is another relevant dimension affecting the warm-cold aspect of colours, being the more saturated colours warmer (or less cool). Lightness plays a minor role: at both extremities of the lightness interval colours appear cold, and this effect is more pronounced in the dark region,most probably because colours in these regions are also little chromatic.

In this research all colours were singularly presented in random sequences and therefore neither spatial nor temporal effects were considered. The mathematical model expressed by equation (3), in comparison with similar models, seems to be quite accurate in predicting our data.

Further research is needed to study how spatial and temporal interactions can modify the warm-cold attributes of colours, with the hypothesis that contrast effects will accentuate the differences in apparent temperature here determined in decontextualized colours.

Acknowledgments

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Color preference affected by mode of color appearance

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ABSTRACT

Most of color preference works focus on colors in surface color mode. However, there are several modes in our daily life. To explore the relationship between color preference and mode of color appearance, the experiment I was examined. Thirty-three color chips were chosen from the Munsell notation varying in hues and chromas. The color chips were presented in different color appearance modes. The results showed the brighter and more chromatic colors were more preferred. The subject preferred color in light source color mode to color in the other modes. In experiment II, we investigated the relationship between color preference and the perceived color attributes. The results showed that the preference score increase with increasing perceived chromaticness and decrease with increasing perceived whiteness or blackness. We found that both perceived whiteness and blackness play a role as underlying mechanism on the determination of the color preference on different color appearance modes. Consequently, we suggest that the color preference is dominated not only by physical color attributes, but also by mode of color appearance.

Keywords: Color preference, Color appearance mode, Color appearance mode preference, Color appearance mode index

1 INTRODUCTION

Color preference is a powerful tool to attract a subject's attention and to arouse the desire to consume. Color preference may be influenced by differences in age, gender, geographical region[1] or cognition.[2] Studies on color preference for single color have long focused on the hue effect. Previous studies showed what hues were generally preferred and what hues were not.[2-3] Most of these work have been done with surface color mode samples of moderate size and relatively high color purity. In our daily life, however, colors appear not only as surface color mode, but also as fluorent and luminous color modes.

The color of the object can be perceived in various modes of color appearance depending on the situation. The color appearance mode can be classified into three different modes: object color mode (OB-mode), unnatural object color mode (UN-mode), and light source color mode (LS-mode). According to the Recognized Visual Space of Illumination theory (RVSI), the color appearance modes are related to the recognized illuminance of an environment in which the object is placed.[4] The color appearance mode can be changed by adjusting the intensity of environmental illumination and the luminance of objects.

It would be important to know whether color preference remained static or not when the mode of color appearance had been changed while x-y chromaticity coordinates of the color kept unchanged. Two experiments were conducted for this study. In experiment I, we investigated the relationship between color preference and color appearance mode. Because of the change in amount of chromaticness, blackness, and whiteness for luminance increase of color chips,[4-5] in experiment II we investigated how the perceived color attributes relate to color preference.

2 EXPERIMENT I

2.1 Method

The apparatus was composed of subject's room and test chart's room separated by a wall having a 1^o square aperture. Subject's room was $1.3 \times 2 \times 2\ m^3$ (W x L x H) which was decorated with wallpaper of about N9 and illuminated by fluorescent lamps. The intensity of the lamps was adjusted by a light controller and the room illuminance was measured by an illuminometer placed on a shelf below the test stimulus at a distance of 44 cm. Many objects such as artificial flowers, dolls, books were put into this room. Color chips to serve as the test stimuli were attached to a rotating wheel placed in test chart's

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room. They were illuminated by fluorescent lamps. The subject sat in subject's room and looked at the aperture from a distance of 1.3 m.

Thirty-three color chips selected from the Munsell Color notation were used as the test stimuli (Table 1). Five subjects participated in this experiment. There were two sections for each subject. First, subjects were asked to answer the degree of color preference for each color by using the scale which was divided into 7 levels, as -3 (dislike) to +3 (like). Second, subjects were asked to judge the color appearance mode. Subjects were instructed to look around and not stare at the color chip. Within each session, 16 or 17 color chips were randomly presented at six experimental conditions to make 96 or 102 determinations. Each subject has done five sessions per condition. The experimental conditions were composed of the combination of 2 subject's room illuminance levels (I_S:50, 500 lx) and 3 test chart's room illuminance levels (I_T:300, 500, 700 lx).

Table 1 Color samples in Munsell Color Notation used in this study.

Hue	5R	5YR	5Y	5GY	5G	10BG	10B	5P	N
Value/ Chroma	5/2	5/2	5/2	5/2	5/2	5/2	5/2	5/2	5
	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	
	5/8	5/8	5/8	5/8	5/8	5/8	5/8	5/8	
	4/14	6/14	8/14	6/10	3/10	4/9	4/10	4/10	

2.2 Results and Discussions

For each color chip, the preference scores for the five subjects were averaged. The scores of 5YR and 10BG are plotted against different chromas in figure 1. Results showed the higher the chroma, the higher the preference score. The same tendency occurred in all conditions. Our result agrees well with previous works. Guilfore,[6] Smets,[7] and Guilford and Smith[8] all stated that subjects preferred vivid colors to grayish colors. However, it was noted that the score of 5G, 10BG, and 5P are lower at fully saturated chromatic color. It is possible that the Munsell value of fully saturated chroma color among these color chips are less than that of chroma 8.

To see the environmental illumination effect and the luminance effect figure 2 was prepared, where the average preference scores are taken along the ordinate and the luminance of color chips along the abscissa. As environmental illumination effect, the scores of I_S50 conditions were higher than that of I_S500 conditions at low luminance, but the scores become close to each other when the luminance was increased. As luminance effect, the subjects preferred the color chip which was brighter. It was noted, however, the score were quite constant in the I_S50 conditions. It is possible to have color preference constancy at low environmental illumination.

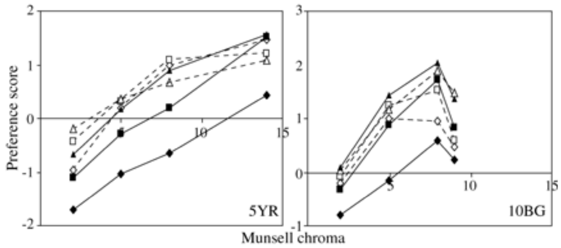

Figure 1 The preference score from average result across all subjects by plotting against chroma for different I_T; 300 (◇), 500 (□), and 700 (△). Filled symbols and solid lines represent data for I_S 500 conditions, whereas open symbols and dashed lines represent data for I_S50 conditions.

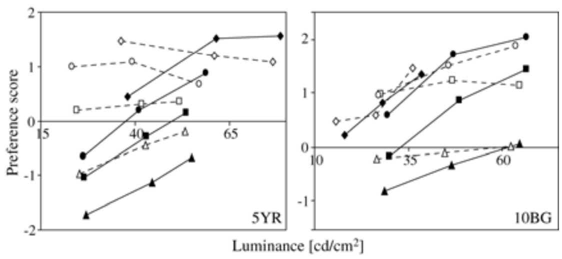

Figure 2 The preference score from average result across all subjects by plotting against chroma for different chromas; 2 (△), 5 (□), 8 (○), and fully saturated chroma (◇). Filled symbols and solid lines represent data for I_S 500 conditions, whereas open symbols and dashed lines represent data for I_S50 conditions.

Next we considered color appearance mode. The raw data accumulated from all subjects were calculated in term of the color appearance mode index (i_{mode}) by following equation:

$$i_{mode} = \frac{a(-1) + b(0) + c(1)}{a + b + c} , \quad (1)$$

where *a*, *b*, and *c* are the number of response in OB-mode, UN-mode, and LS-mode, respectively. If $i_{mode} > +0.5$, the color chip was classified in LS-mode, whereas if $i_{mode} < -0.5$, the color chip was classified in OB-mode. If the i_{mode} between -0.5 and +0.5, the color chip was classified in UN-mode.

In figure 3, i_{mode} of all color chips in all conditions were plotted against the preference score. Within each color appearance mode, the preference score increased when the i_{mode} increased. The range of preference score in OB-mode was wider than the other modes; -2.08 to 2.56 in OB-mode, -0.96 to 2.24 in UN-mode, and -0.56 to 2.4 in LS-mode. All color chips in LS-mode and almost in UN-mode dropped in positive side of preference score. This showed the color chips tended to be preferred if they appeared in LS- and UN-mode. It was noted, nevertheless, that the highest and lowest preference scores within each color chip fell in OB-mode (except 5YR, 5Y, and 5GY the highest score fell in the other modes).

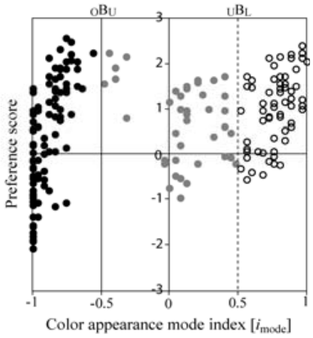

Figure 3 The relationship between preference score and i_{mode} in all color chips. Modes of color appearance are defined by solid dots (OB-mode), gray dots (UN-mode), and open dots (LS-mode). A horizontal solid line in each figure represents the border between OB-mode and UN-mode, whereas a horizontal dashed line represents the border between UN-mode and LS-mode.

3 EXPERIMENT II

Because of the change of color attributes when the color appearance mode had been change,[4-5] in this experiment we investigated the relationship between the perceived color attributes and color preference. The elementary color naming method was used to assess the color attributes of color chips based on the Natural Color System (NCS).

3.1 Method

The apparatus and experimental conditions were the same as the previous experiment. To do elementary color naming four subjects who participated in experiment I were asked to estimate the amount of chromaticness, whiteness, and blackness in the color chip by allocating one hundred points to them.

3.2 Results and Discussions

In figure 4 the preference scores were plotted against perceived chromaticness, whiteness, blackness and saturation. The color appearance modes were drawn with different symbols: OB-mode (solid dot), UN-mode (gray dot) and LS-mode (open dot). The amounts of perceive expressed as average value across all subjects for each color chip in each condition. The preference score and i_{mode} value came from average across same subject in the experiment I. Table 2 showed the correlation coefficient, *r*, of color appearance modes and perceived color attributes. The correlations of perceived chromaticness for OB-mode, UN-mode, and LS-mode were 0.730, 0.798, and 0.812 respectively. As shown in figure 4 (a), the preference score increased with increasing perceived chromaticness, regardless of the color chips. This result corresponded with the results of physical chromaticness from experiment I. This showed that both physical chromaticness and perceived chromaticness have an influence over the color preference. Moreover, the intersection of perceived chromaticness in LS-mode held the higher position than that in other modes. This indicated that the subjects preferred color in light source color mode to the other modes. This result emphasized the influence of color appearance mode effect on color preference.

In addition, it was found that perceived whiteness related to preference score as negative correlation in UN-mode and LS-mode (-0.768 and

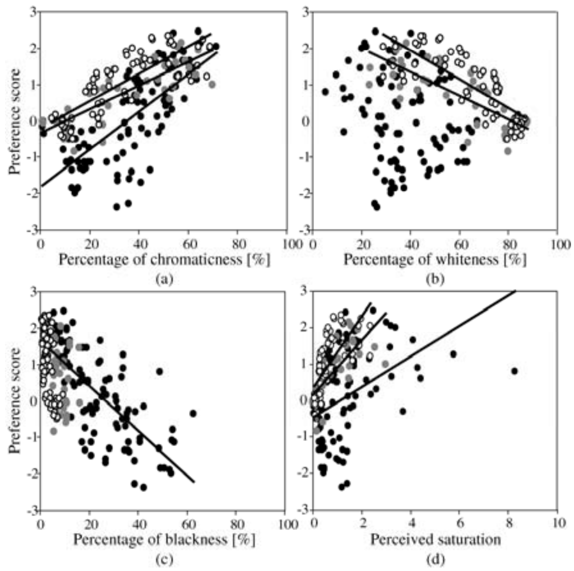

Figure 4 Scatter plot of preference score and color perception attributes; (a) chromaticness, (b) whiteness, (c) blackness, and (d) saturation. Modes of color appearance are defined by solid dots (OB-mode), gray dots (UN-mode), and open dots (LS-mode).

Table 2 The correlation coefficient, *r*, of color appearance modes.

Color appearance mode	Correlation coefficient, *r*			
	Perceived chromaticness	Perceived whiteness	Perceived blackness	Perceived saturation
OB-mode	0.730	-0.194	-0.704	0.441
UN-mode	0.798	-0.768	-0.360	0.664
LS-mode	0.812	-0.793	-0.596	0.676

-0.793) and perceived blackness in OB-mode (-0.704) as shown in Table 2 and figure 4 (b) and (c). This result showed the scores decreased when the perceived whiteness and blackness increased. The reason is that the large amount of chromaticness was replaced with whiteness at LS-mode and with blackness at OB-mode. Thus, the score decreased because percentage of chromaticness decreased. This decrease in chromaticness, when the color chip appeared in LS-mode, corresponded with pervious study by Ikeda *et al*.[4]

Finally, we consider the relationship between color appearance mode and perceived saturation. The perceived saturations were calculated in terms of a ranging from 0 to 10, as given in equation 2:

$$\text{Perceived saturation} = \frac{\text{chromaticness}}{\text{whiteness}} \qquad (2)$$

The correlations of perceived saturation for OB-mode, UN-mode, and LS-mode were 0.441, 0.664, and 0.676 respectively as shown in figure 4 (d) and Table 2. The result showed that the preference score increased when the perceived saturation increased within each color appearance mode. This result corresponded with the perceived chromaticness. Even though the color chip loses saturation in light source color mode, the degree of color preference is still high. A possible reason is that the loss of saturation in light source color mode was compensated by the bright or luminous color chip.

4 CONCLUSIONS

In this study, thirty-three color chips varying in hues and chromas were assessed on six conditions covered three color appearance modes. Findings showed that the color chips having maximum saturation were found to give high score. Both of environmental illumination and luminance of the color chip have an influence over the color preference.

In the present study, we assigned the different environment illumination and different luminance of color chips for simulating the situations of color appearance mode. The degree of i_{mode} increased when the luminance of color chip increased. Furthermore, we found that the color preference related to color appearance mode. The color chips which were high degree of i_{mode} dropped in positive side of preference score. This revealed that subject preferred color appeared in light source color mode to the other modes.

Although dominant wavelength plays a leading role in the determination of color preferences, perceived color attributes and mode of color appearance are also significant. We conclude that the degree of color preference was dominated not only by color attributes (hue, chroma, and lightness), but also by mode of color appearance. We found two components play a role as underlying mechanism on the determination of color preference. One is the perceived whiteness and another one is perceived blackness. Thus, it may be possible to use these components as a scale for predicting color preference on the different color appearance modes.

Colors in our daily life are never viewed in object color mode only. To attract one's attention, some item should be appeared in light source color mode or unnatural object color mode such as advertising board, mobile phone display, show window display, etc. This study attempts to contribute to the preference response for colors in different color appearance mode. The results of the study may be used in design applications like window lighting set-up, product designs, etc.

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The principles of Dynamic Colour Model development

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ABSTRACT

Background. The sunlight is the only source of light on the macroscopic level, which defines natural cycles. The framework of continuously changing light conditions was defined in daily- and yearly-cycles.
Aim. To explain the main features of daily-, yearly-cycles and, the geometric series of Major- and Minor-angled colour circles, which presents an input for Dynamic Colour Model (DCM) to expose changing positions of colour dominance.
Methods. The daily- and yearly-cycle systems base on different palettes typology, resulting in two different geometric series, which have certain influences on the colour-dominance selection process.
Results. We present the example of two basic palette extensions of Major- and Minor-angled colour circles, showing us the specific features of each system and their ability to function as input in DCM.
Conclusion. The potentials of DCM, as a complex analytical and prognostic tool, are lying in its systematic and further development abilities.

Key words: Macro-Cycle System, Daily-, Yearly-Cycle, Major-, Minor-Angled Circles, Mini-Colour System, Four-, Twelve-Period Seasonal Colour Model, Dynamic-Colour-Model (DCM);

1 INTRODUCTION

The Sunlight is the only source of light, which defines the natural cycles. Constantly changing light conditions in the natural environment has been defined as “the basis of colour perception experience”, which significantly influences the evolution of the eye and, simultaneously, the evolution of its visual perception.

2 AIMS

AIM is to explain the main features of daily-, yearly-cycles and, the geometric series of Major- and Minor-angled colour circles, which presents an input for Dynamic Colour Model (DCM) to expose changing positions of colour dominance.

3 EXPERIMENTAL

3.1 Macro level

Constantly changing light conditions in nature are the basis for a general colour perception experience. The colour systematization is based on two main principles: a Twelve-level grey-scale in Daily-cycle and a Seven-level colour circle in Yearly-cycle.

3.1.1 Daily-cycle

Daily-cycle encompasses 24-hour-time (3), when the Earth rotates 360° along its axis in its helix continuum. The brightest and lightest point is around noon and the darkest around midnight. The simplest division results in two extremes: White-Black (W-K), but more advanced on 12 levels grey scale (Figure 1).

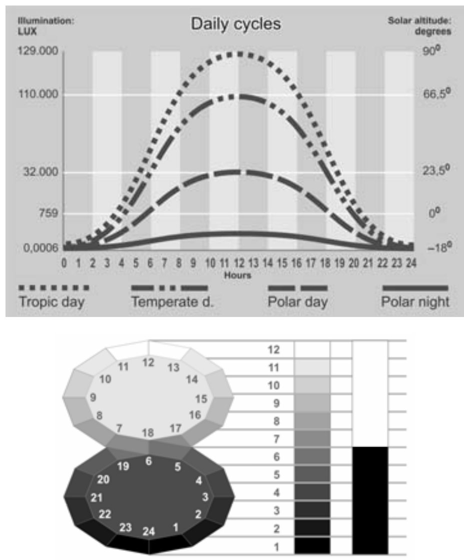


Figure 1: Daily-cycle encompasses 24-hour-time and result in a twelve-level grey-scale.

3.1.2 Yearly-cycle

Yearly-cycle presents one of the dominant cycles in human life. The Earth revolves around the Sun within a year and creates five symmetrically equal, horizontal levels and one antagonistic pair on ecliptic rail. The simplified division results in minimally two general oppositions, which are the basis for Four-seasonal-model (3, 4).

In more advanced interpretation, the distributed illumination symbolically correlates with relative values of the 7 achromatic scale steps, what is typical for each half-year period from one observing point of the globe (Figure 2) and, at the same time it is just opposite on the other side.

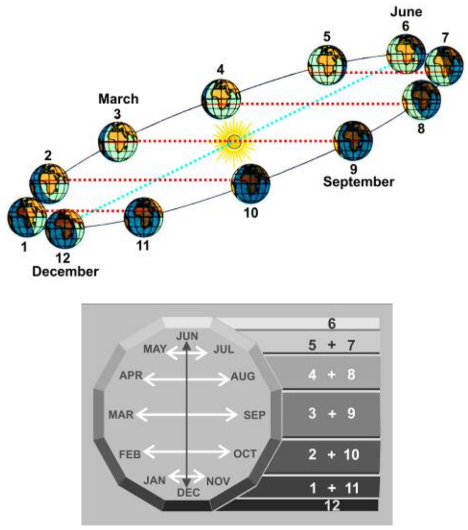


Figure 2: yearly-cycle is divided on the 5 equal horizontal levels and one vertical opposition.

The simplified version is divided on Yellow-Blue (Y-B), Red-Green (R-G) and White-Black (W-K) relation and that is also the smallest possible version of a complete colour universe, presented in a Mini-Colour System. More advanced model has been developed through transition from 7-level achromatic-scale to 12-part chromatic-colour circle. A certain level of achromatic scale corresponds with a certain lightness-level on the chromatic scale, allowing the colours to appear in two different qualities: warm and cold (1, 3, 4). That unique characteristic of colours in connection to wavelength is the background for colour-circles (Figure 3).

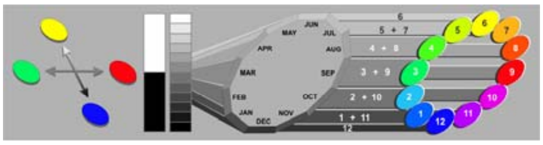


Figure 3: Integration of Yearly- and Daily-cycles: from the Mini-colour-system to the maximal extended one, in sense of the natural cycles.

3.2 Typology of colour circles

The circles rely on two different geometrical series of Major- and Minor-angled circle line. Major-angled circle consists of two pairs of opponent colours and one achromatic pair, with an angle of $\alpha=90^0$ in all directions. Minor-angled circle consists of three pairs of opponent colours and one achromatic pair, with an angle of $\alpha=60^0$ in horizontal plane only. All further palette extensions rely on differentiation of this two basic angle lines.

3.2.1 Major-angled circles

Major-angled circles (Figure 4) rely on following geometrical series:

$4x2^0 \rightarrow 4x2^1 \rightarrow 4x2^2 \rightarrow 4x2^3 \rightarrow 4x2^{n-1}$, resulting in corresponding number of angle-parts in circles: 4-, 8-, 16-, 32-, 64-parts, etc.

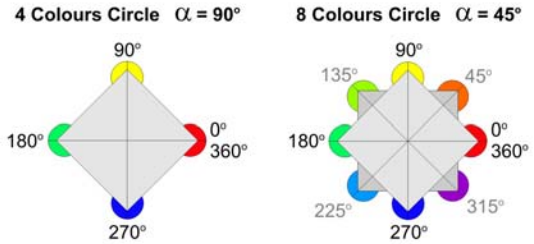


Figure 4: The sample of 4- and 8-part geometrical series of Major-angled circles line.

3.2.2 Minor-angled circles

Minor-angled circles (Figure 5) rely on following geometrical series:

$6x2^0 \rightarrow 6x2^1 \rightarrow 6x2^2 \rightarrow 6x2^3 \rightarrow 6x2^{n-1}$, resulting in corresponding number of angle-parts in circles: 6-, 12-, 24-, 48-parts, etc.

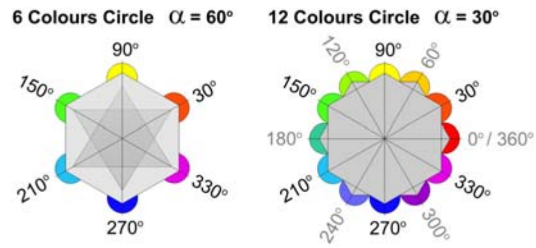


Figure 5: The sample of 6- and 12-part geometrical series of Minor-angled circles line.

Comparing Major- and Minor-angled circle-series, we observe, that each selection of opposed colours has different angle in circles, what results in different harmonious selection of opposed pairs, triples, quadrilles, quintuplets, etc.

3.3.1 Major-angled Mini-Colour-System

The Major-angled Mini-Colour-System (Figure 6a) is based on three discriminating oppositions: R–G on x– plane, Y–B on y–plane and W–K on z–plane, colour-related angle is $\alpha = 90^0$.

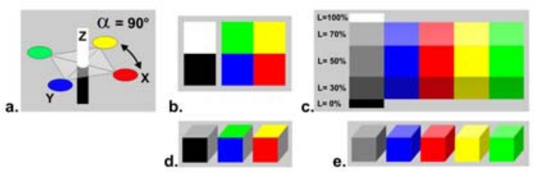


Figure 6: **a.** R–G on x–plane and Y–B on y–plane and W–K on z–plane, **b.** Cold-warm and light-dark oppositions, **c.** Nuances related to grey scale, **d.** Three cubes formed of 3 opposed pairs, **e.** Five cubes formed of minimally (3 steps) extended nuances.

The Mini-palette (Figure 6b) of the cold-warm and light-dark colours forms the smallest possible colour system.

A Mini-palette (Figure 6c), based on 4 colours, is vertically mono-angularly widened for one tone towards highlights (L=70%) and for one tone towards shadows (L=30%). Each colour-nuance is on relatively equal level with achromatic tones. Generally, the W–K opposition shows us already basic principle: White represents highlighted colours and Black shadowed ones. Therefore, Yellow is perceived as highlighted towards Red as shadowed or, as Green towards Blue, etc.

The palette sample (Figure 6d) consists of 3 Cubes, where opposed colour pairs describe 3D solid and presents the ability of a spatial construction of 4 colours and of White-Black.

The palette sample (Figure 6e) consists of 5 Cubes. Each is composed of the three nuances of palette 8c. Colours perform their proper logic of differentiation by each side of the Cube or 3D solid. Such principles of colour modulation were already developed in medieval heraldry, fine arts, illumination, known as local colouring principle.

3.3.2 Minor-angled Mini-colour-system

Minor-angled Mini-colour-system (Figure 7) is based on three discriminating oppositions: empty x–plane, Y–B on y–plane and, W–K on z–plane, horizontally colour-related angle is $\alpha = 60^0$ and, evidently differs from a previous one (3.3.1).

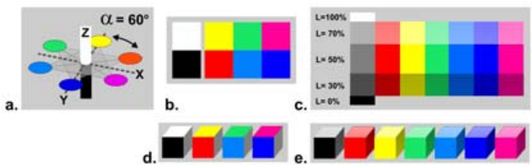
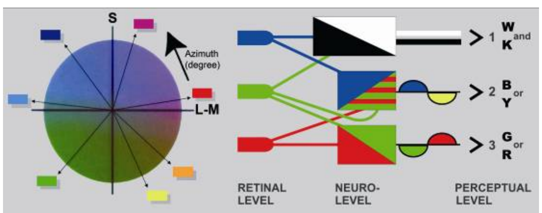


Figure 7: **a.** empty x–plane, Y–B on y–plane and, W–K on z–plane **b.** Cold-warm and light-dark oppositions, **c.** Nuances related to grey scale, **d.** Four cubes formed of 4 opposed pairs, **e.** Seven cubes formed of minimally (3 steps) extended nuances of palette 7c.

3.4 Micro level - Phenomenon "Urfarben"

Ewald Hering defined natural colour system by six "Urfarben" (2) in three antagonistic, non-simultaneous pairs that are visually always different (W-K, Y-B, R-G) (Figure 8).



a. b.

Figure 8: "Urfarben" with opposed colours (a) and the transmission of the receipted signal (b).

The "Urfarben" are defined by human visual perception ability to transform the electromagnetic signal from cone receptors over neurological to perceptual level.

Many colour systems base on this oppositions: from CIELAB, NCS to all ancient: Chinese Yin-Yang, Heraldry, Seal of Solomon, 6 colours in cardinal oppositions, Yantras of India, Tibetan Chortens, Japanese Stupas, all signifying Roles of the four elements, as well as Colour Cycle System-CCS and, Dynamic Colour Model-DCM.

3.5 Test of the colour differentiation

To analyse the plausibility of unambiguous colour differentiation, we made a simple test with 4 and 12 colours on different backgrounds. In 4- colour test, the colour differentiation was kept all the way in all samples. Uncertainty evidently grows by complexity and by the number of colours, as shown in test with 12 displaced colours. Some colours are from one to another background not anymore receipted as the same (Figure 9). Test convinced us that it would be necessary to examine limitations of all basic palettes.

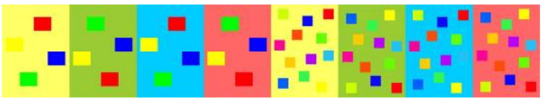


Figure 9: in test are 4 colours always unambiguous different on all backgrounds, but in 12 colours test uncertainty of unambiguous differentiation is growing.

3.6 The limitations of colours' systems

A *Major-* and *Minor-angled Mini Colour System* performs the smallest possible complete systems, which are already able to create harmonious combinations. Next enlargement of both systems results in 8- and 12-colour system, which present the reasonable peak of natural logic for human perceptive ability to differentiate colours unambiguously. A palette of 8 or 12 colours is giving much wider spectrum of colour combinations, but unambiguous differentiation is slowly vanishing by each added colour. Moreover, the psychological phenomenon of brain contrast enhancement and constantly changing visual conditions additionally cut down the number of possible colour differentiations! In that frame the functional abilities and values of each palette should be observed.

4 RESULTS

4. The Seasonal-Colour-Model

This model presents a kind of completed colour circle, correlated with already described natural time cycles and all psychological data related to colours. As an example, only the smallest Four-Seasonal Colour Model (4S-CM) will be presented (Figure 10), which is the base for more complex Twelve-Period Seasonal Colour Model (12PS-CM). Actually, both are 3D-models, interpreted in two dimensional schemes, applied as input in Dynamic-Colour-Model (DCM).

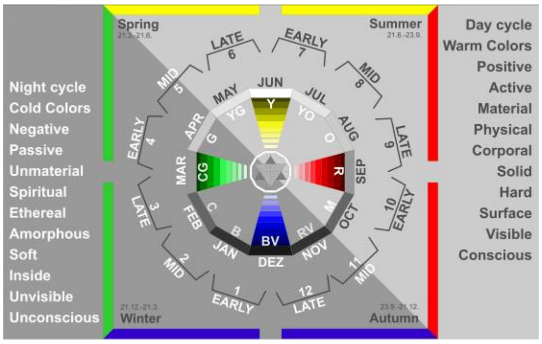


Figure 10: Version of Four-Seasonal-Colour-Model with all basic relations among different time cycles, periods, lightness levels, colours and terms.

5. Dynamic Colour Model - DCM

DCM presents 4-dimensional (4D) geometric colour model related to time and any type of cycles, with ability to process different data. For example we present as input Four-Seasonal-Colour-Model (4S-CM), which is rotating along the longitudinal axis from 0^0 to 360^0 (Figure 11).

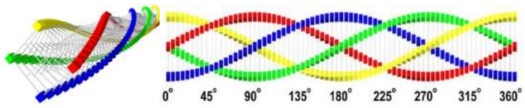


Figure 11: The simplified scheme of DCM with changing sequences of colour dominance.

Presented scheme of DCM is simplified and may produce too simple conclusions, but at the same time it would be more advanced and more accurate version, too complex to give the whole picture, what is all about.

5.1 DCM Formula

The example of the DCM formula, based on input of Four-Seasonal-Colour-Model (4S-CM):

t: 0,…,360

Y: (cos t, sin t)

R: (cos (t - 90^0), sin (t - 90^0)) = (sin t, - cos t)

B: (cos (t - 180^0), sin (t - 180^0)) = (- cos t, - sin t)

G: (cos (t - 270^0), sin (t - 270^0)) = (- sin t, cos t)

6. Sequences of colour dominance

In DCM we may observe changing sequences of colour dominance such as all values of terms related to colours, lightness levels, cycles, periods, colour angles and so forth - incorporated in 4S-CM, are constantly changing their positions, their ranking and their correlative meaning as well.

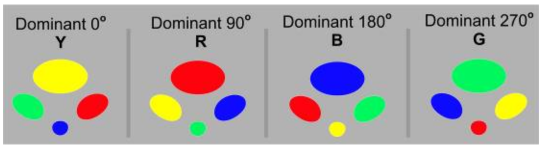


Figure 12: The sequences of colour dominance.

5 DISCUSSION & CONCLUSIONS

Results of this study lead us to conclusion that colours are in relation to the natural cycle system. We assume that cycles have notable impact on philosophy of colour perception, as well as on the colour appearance model development. In future we should define the functions of DCM in four dimensional space-time geometry, what involves some new legislations of existing colour models. The relation between colours and time-cycles postulate some new logic in achromatic scale and chromatic circle, for instance the question of the colour cycles spin, etc.

DCM allows us some new conclusions in translation of basic meanings in common cultural and visual communications. It could have irrepressible impact on colour systematic as its grammatical background. All the relations between lightness, colours and time-cycles, observed in DCM, could mean prospective background for systematic analyses and prognoses in the field of colours or in its psychological correlations. It could mean a new way of colour instrumentation and new tool for processing colours as composing elements of visual communication systems.

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Affective judgment of color in relation to visual stimuli

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ABSTRACT

Two empirical studies were carried out in order to investigate the affective judgment of color in two stimulus contexts. In the first experiment (N=46) 36 color stimuli were assessed in terms of valence, arousal, and dominance using the Self-Assessment-Manikin (SAM) scale. In the second experiment (N=45) subjects were shown to not only 17 colors, but also other types of visual stimulus modality, such as 8 pictures, 9 film-clips, and 9 adjectives. Consequently, the emotional profiles of visual stimuli were characterized by dimensions of emotion, and the SAM ratings of the 17 identical colors from the both experiments were compared. Empirical results showed that the reference field of emotional responses to colors was significantly shifted to be less arousing ($p<.05$, two-tailed).

Keywords: Color, Emotion, Affective Judgment, SAM, Context Effect

1 INTRODUCTION

Much concern has derived on research on color affectivity in various disciplines. Recent studies on color affectivity characterize emotional profiles of color in terms of emotional dimensions, thus approaching the issue of emotional influence of color attributes[1].

On the other side, the stimulus context has always been dedicated to color, which seems rather far from reality. Such limitations may weaken the relevance of the results of empirical studies on the impact of color on emotional reaction. Thus, it is necessary to investigate color affectivity not only within colors, but also in relation to other modalities of visual stimulus.

2 GOALS AND STUDY PLAN

2.1 Goals and Hypotheses

The purposes of this study are to describe emotional responses to colors in terms of three dimensions of emotion and to investigate a judgmental shift of color affectivity in a multi-stimulus-modality-context, in which other visual stimuli with higher semantic intensity are presented. Therefore, the following two hypotheses were formulated:

[H.1] Emotional response to color can be profiled in terms of three dimensions of emotion, valence, arousal, and dominance.

[H.2] The magnitude of affectivity is relative, and thus, the emotional response to color in a multi-stimulus-modality context may appear in a weaker pattern.

2.2 Plans of the Experiments

The affective judgment of color in the first experiment would provide the relative affectivity in valence, arousal, and dominance dimensions among color stimuli. Thus, the empirical results of the Experiment I provide a baseline that would be compared with those of the Experiment II. Between the two experiments a preliminary study had been carried out to select film stimuli for Experiment II.

3 MEASURING EMOTION

In comparison with discrete approach the dimensional approach to conceptualize emotion has the advantage of generality and potential versatility as a descriptive system for emotion. It characterizes an emotional profile of the stimulus and it provides a base for geometric construction, in order to explain the relationship among stimuli. However, it has been taken into consideration by only few researchers and the selection of color stimuli has not yet been systemically approached. Rather, the majority of the studies on color and emotion have focused on the synesthesia between basic categories of color and primary emotional terms. Valdez et al.[1] characterized this categorical approach as insufficient to produce reliable, valid, or comprehensive measures of emotional responses to color stimuli.

In this study, the emotional responses to colors were conceptualized with three dimensions of emotion and the Self-Assessment-Manikins

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(SAM) was employed to assess the affectivity in each dimension.

3.1 Self-Assessment-Manikins(SAM)

Developed by Lang[2], SAM is a nonverbal, culture-fair rating system based on a three-dimensional system of emotion consisting of valence, arousal, and dominance. The SAM rating scale is comprised of three sets of graphic figures, respectively representing the three dimensions (see Figure 1).

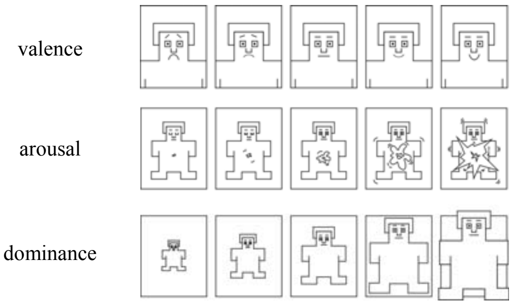


Figure 1 SAM figures.

Those graphic figures, which depict values along each of the three dimensions on a continuously varying scale, are used to indicate emotional reactions. As shown in Figure 1, SAM ranges from a frowning, unhappy figure to a smiling happy figure, when representing the valence dimension. For the arousal dimension, SAM ranges from a relaxed, sleepy figure to an excited, wide-eyed figure. For the dominance dimension, SAM ranges from a small figure (dominated) to a large figure (in control). The subject can elect any of the five figures comprising each scale.

In the following experiments, SAM will be used to assess emotional response to a stimulus implemented through PXLab© (www.pxlab.de) software in computer based experiments.

4 EXPERIMENT I

4.1 Method

4.1.1 Subjects

Forty-six people including 19 men and 27 women served as subject and were recruited through advertisements in the University of Mannheim (age: M=24.43, SD= 8.99). As reward, € 4.00 were offered for the approximately 20-minute experiment.

4.1.2 Stimuli

Five hue categories were fixed and the hue degrees of categories in CIELab Lch system are h=30° (red), h=80° (yellow), h=160° (green), h=260° (blue), and h=320° (violet). From each of them, representative colors of the following five tone segments were chosen: 'dark', 'deep', 'vivid', 'brilliant', and 'light'.

It was intended to let subjects recognize the same quality of tone (combination of Chroma and lightness) across hue categories. In fact, the segmentation of tone categories varies with hue, especially in case of yellow, a slight change of lightness results into a color of olive. Thus, it was necessary to consider different segments of Chroma and lightness that would be representative for the specific tone category of each hue.

In addition, cool gray (h=260°), warm gray(h=80°), and gray colors with lightness levels of 30, 50, and 70 were included, and black and white were added to the color stimuli.

4.1.3 Procedure

At the beginning of the experiment, a gray stimulus (L=30) was shown, in order to get acquainted with the SAM interface. Color stimuli were displayed centered on CRT monitors, in a size of 25.1 cm width × 15.2cm height.

Below every stimulus, a row of SAM pictograms was presented and subjects could select any of five by mouse click. Pressing a space bar, the next row of SAM appeared in an order of valence, arousal, and dominance. Once a stimulus was assessed by all three dimensions, the next stimulus was provided. All subjects were exposed to all stimuli.

4.2 Result

Based on SAM ratings of 46 subjects, reliability of internal consistency was tested. Cronbach's alpha yielded significant values to support [H.1] and thus, valence(α=0.793), arousal(α=0.880), and dominance(α=0.904) are adequate to describe emotional responses to digital colors.

The empirical results of the Experiment I provided a baseline that those of the Experiment II would be compared with.

4.3 Discussion

Although hypotheses, [H.1] was statistically supported, it does not seem safe to say whether color would induce emotion in a similar way in the context of other categories of visual stimuli, in particular, when other modalities of stimuli exhibit a higher intensity of semantic content. In reality, people may perceive colored surface as a sequence, while they are experiencing pictures or moving images (e.g. reading a magazine or watching TV).

This issue converges into stimulus context effects and their influences on target stimuli. The judgment of the target stimulus is affected by the given context. Thus, by viewing color in a multi-stimulus-modality-context, the affectivity of color as target stimulus, may be influenced by other stimulus modalities (e.g. film-clips, pictures, words).

In Experiment II, the context effect will be investigated focusing on judgmental shifts of color affectivity.

5 PRELIMINARY TEST

The Preliminary Test intended to select film-clips to be employed later in Experiment II. The film-clips could be seen as 'background stimuli' or 'anchor stimuli'[3] and may modify the affective impact of focal or target stimuli, i.e. the colors.

Moreover, in this test, the main concern was to express moving images by film-clips, which distinguishes film-clips from static pictures (still images) during the experiment. Hence, the role of film-clips differs from story-telling.

5.1 Method

5.1.1 Subjects

Twenty-four students including 11 men and 13 women volunteered and served as subjects for Preliminary test (age: M=26.38, SD=3.05).

5.1.2 Stimuli

19 Film-clips were collected from commercial films and the length of the film-clips for this Preliminary Test was edited to be 13 to 14 seconds in length in order to increase the homogeneity of semantic contents of film-clips.

5.1.3 Procedure

The 19 film-clips were played repeatedly without break, and the sound was switched off to focus on the effect of visual contents. The film-clips were presented in random order and subjects assessed emotional responses with SAM ratings by pencil-and-paper method.

5.2 Result

From the Preliminary Test, nine were selected (see Table 1), representing certain patterns of emotions. For instance, the film clip 'gangsters' and 'fighter' induced similar emotional responses. Thus, the 'gangster' clip was chosen, on behalf of semantic contents related to 'violence'.

However, the reliability coefficients were not satisfactory. It is thus still unclear whether the movie clips were robust enough to induce certain type of emotion (α=0.537: valence; α=0.683: arousal; α=0.380: dominance). Through a larger number of subjects, future research is expected to yield better internal consistency.

Table 1 The selected 9 film-clips for the Experiment II

film	t(sec)	scene description
A Clockwork Orange, S. Kubrick (1971)	14	viewing some buildings from flying vehicle
	13	Jesus Christ walking with the cross, tortured
	14	a man surrounded by three semi naked women
	14	four men assaulting on a homeless old man
Le Papillon, P. Muyl (2003)	14	big tree on the hill. Leaves fanning in the breeze
	14	a young girl calmly opens a door to butterfly garden
Amélie, J.P. Jeunet (2001)	13	a little girl photographing bunny-shaped clouds
Unfaithful, A. Lyne (2002)	14	husband and wife caressing each other
Legally blond, R. Luketic (2001)	14	many girls celebrating

6 EXPERIMENT II

6.1 Method

6.1.1 Subjects

The experiment was announced with flyers at the University of Mannheim and 45 subjects, including 24 men and 21 women, participated. They were either paid € 6.00 or given course credit for their participation (age; M=26.76, SD=10.58).

6.1.2 Stimuli

Target Stimuli: 17 colors

17 color stimuli were taken from those used in Experiment I: Each of the hue-categories 'red', 'yellow', 'green', and 'blue' possessed the three tone categories—dark, vivid, and light—and vivid violet was also included. In addition, dark gray, light gray, light warm gray, and light cool gray were used for Experiment II.

Background Stimuli: film-clips, pictures, words

The nine film-clips, 8 pictures—4 chromatic and 4 achromatic—from IAPS[4](see Figure 2), a standardized affective picture database, and 9 adjectives—'laut'(*loud*), 'langwilig'(*boring*), 'hektisch'(*hectic*), 'leicht'(*light*), 'aktiv'(*active*), 'dynamisch'(*dynamic*), 'gesund'(*healthy*), urban, and modern—were shown. The background stimuli were supposed to cover various emotional profiles in terms of valence, arousal, and dominance.

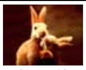
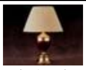
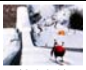
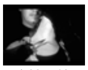
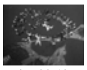
chromatic	 (1750)	 (6230)	 (7175)	 (8030)
achromatic	 (2070)	 (6350)	 (7010)	 (5621)

Figure 2 The 8 pictures selected from IAPS (IAPS nr.)

6.1.3 Procedure

Since film-clips were in different formats, PXLab© software adjusted them either to size of 19.0 cm width ·14.9 cm height or to that of 22.1 cm width · 14.9 cm height. Therefore, all film-clips were presented in the same height as colors and pictures (22.1 cm width × 14.9 cm height).

Taken together, a set of 43 stimuli and SAM figures were implemented by PXLab© software in Experiment II. All the stimuli were displayed identically like in the Experiment I and presented in a random order. Each subject was exposed to all stimuli and no missing data occurred.

6.2 Result

Cronbach's alpha was calculated and provided satisfactory level of reliable internal consistency of the measurements on valence(α=0.729), arousal(α=0.919), and dominance(α=0.842).

6.2.1 Judgmental Shift of Target Stimuli

Mean values of valence, arousal, and dominance of the 17 colors from Experiment I and II were observed as figure 3 illustrates; the arrows explain the direction and magnitude of judgmental shifts. Emotional responses to the 17 colors in Experiment II tended to shift towards negative ('–' valence) and calm ('–' arousal).

Figure 3 The displacements of 17 colors from Experiment I to Experiment II, illustrated with vectors in emotion space defined by valence × arousal.

The judgmental shift was statistically compared by running two-way ANOVA with repeated measurement on one factor, colors. The difference between Experiments I and II is significant in the arousal dimension [$F_{(1, 89)}=5.002$, p=0.028], whereas judgmental shifts in the other dimensions were not significant at α level of 0.05. Thus, the result partially supports the [H. 2].

7 GENERAL DISCUSSION

In Experiment I, the measurement with the 5-scale SAM system provided evidence for explaining the relationship between color and emotion, confirming the [H.1]. However, the measured values represent the affective relativity within colored surfaces only. Therefore, in Experiment II, it was examined whether visual stimuli with higher semantic intensity (than color) would anchor emotional reference in a multi-stimulus-modality-context. Hence, it was hypothesized that emotional responses to color would appear in a weaker pattern due to film-clips, which contain a higher degree of semantic intensity [H.2]. From statistical test, the judgmental shift of 17 colors from Experiment I to Experiment II was significant (p=0.028) in arousal dimension, partially confirming the [H.2]. Based on the empirical results, it is assumed that by increasing/decreasing the semantic contrast among stimulus modalities, more/less significant shifts of affective judgment of color would be found.

ACKNOWLEDGMENTS

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Absolut Industrial Art

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ABSTRACT

This paper looks into the conceptual transference of Duchamp's bottle rack from article of everyday use to art object and back again. Analysis is made of the contribution by Swedish artist Dan Wolgers to the *Absolut Art* advertising campaign of the *Absolut* spirits brand with the aid of philosopher Nelson Goodman's semiotically influenced discussion on original and copy, and autographic and allographic art. Differences in the mode of exposure and use of colour between Duchamp and Dan Wolgers are addressed. The paper notes that Wolgers' working method is metaphorical in Goodman's sense through utilization of the copying technique initiated by the twentieth century writer Pierre Menard, who according to Borges enriches reading through the use of deliberate anachronisms and erroneous attributions.

Keywords: Colour philosophy, conceptual art, industrial art, semiotics, visual semiotics, Jorge Luis Borges, Marcel Duchamp, Nelson Goodman

INTRODUCTION

Using a semiotic approach mainly derived from Nelson Goodman this paper discusses an everyday industrial product. Originally this product was created as a work of art, and eighty years later it has been taken back again from the realm of art to the world of industrial production.

Absolut Vodka, the Swedish registered trademark, is the third largest international premium spirit in the world, and the number two brand of premium vodka worldwide. Since its launch in 1979 it has achieved significant sales growth, from 90 000 litres to 83 millions of litres in 2005. Some 500 000 bottles are produced every day in the small city of Åhus in southern Sweden. The explanation of this worldwide success is, of course, an excellent product quality, but not least important is a determined and organized marketing strategy. Choosing the brand name of *Absolut Vodka* was deliberate and well thought out in every respect.

Sweden has more than 400 years of vodka-making tradition, namely of spirit made of potatoes or grain. But never before has the liquid been poured into such a unique and conspicuous bottle. This famous bottle is inspired by an eigtheenth century Swedish medicine bottle, and is made with special low-iron sand to ensure crystal clear glass. Before they are filled, every bottle is rinsed with *Absolut Vodka*.

And never before has a bottle been depicted in such glamorous ways, so to say detached from its everyday context. Closely related to the bottle is the award-winning advertising and marketing campaign. Skilfully made advertisements are published principally in exclusive life-style magazines all over the world. These ads are created successively by well-known artists using the bottle in an imaginative and unexpected way. The artistic pictures are finally signed with the name of the artist together with the word ABSOLUT in capital letters and the typeface of the trademark, e.g. ABSOLUT WARHOL (the very first involvment, in 1985, of Absolut Vodka with the arts) [fig. 1] or ABSOLUT CLEMENTE (a more recent example from the Italian artist Francesco Clemente, made in 1999) [fig. 2].

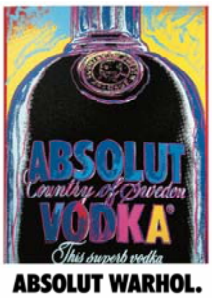

Fig. 1

Fig. 2

WOLGERS' CONTRIBUTION

In spite of *Absolut Vodka* being a genuine Swedish brand, only a few Swedish artists have been invited to create an advertisement. Among them is Dan Wolgers [fig. 3].

As depicted in the figure, the advertisement by Wolgers consists of a sharply focused photo of a bottle rack in galvanised iron, clearly illuminated in frontal portrait so observers are able to reach a conclusion regarding both character of material and function. We also soon see that an empty bottle of *Absolut Vodka* hangs from one of the upper spikes. Something of the bottle rack's light spills over onto the vodka bottle and illuminates its distinctive form and label. At the bottom of the ad are the words ABSOLUT WOLGERS in capitals and grotesque type, thus concurring with the typography of the *Absolut Art* series.

In chapter I of his *Languages of Art* the American philosopher Nelson Goodman states, "application and classification of a label are relative to a system" [p. 40]. It is likely that many readers of the lifestyle magazines in which the spirits advertisement is printed on full gloss paper know that bottle dryers of this type have long since been used in French cafés and restaurants. Drunk from and rinsed out, the bottles hang to dry from their spikes on the rack before once again being filled with the house *vin de table* for serving at the next lunch.

In the terminology of Goodman we can establish that the vodka bottle is an observable *sample* of how the bottle rack might be used, but it is also – quite literally – a *label* denoting a specific drink, a particular brand. The distinguishing of the label transforms the anonymous, interchangeable standard bottle.

At the same time, the Absolut bottle connotes to a longing to once again taste the refilled contents, or rather the choice liquid that is permitted to fill the labelled bottle. (I use the verb connote in accordance with Chandler's definition of *connotation:* "The socio-culture and 'personal' associations produced as a reader decodes a text." [p. 225]. The connotative reference is lacking in Goodman's symbol system, something I will soon take up.)

DUCHAMP'S READY-MADE

The bottle dryer in the vodka ad is likely to be recognised by many potential consumers leafing through the lifestyle magazine. In fact, Wolgers took great pains to portray his *objet trouvé* in perfect accord with the original work of art by Duchamp – if such an expression is valid in this respect. For comprehensible reasons the rounded bottle rack of Duchamp is usually depicted *en face*, and so to speak workaday or artlessly. And this is how observers encounter the bottle dryer at the museum of modern art in Stockholm (Moderna museet), where one of many replicas produced on the basis of Duchamp's *ready-made* is to be found on a simple plinth.

As is well known, in 1914 the French artist Marcel Duchamp bought an ordinary bottle rack in a Parisian department store. A few years later Duchamp exhibited his ready-made or *objet trouvé*, and thereby transferred it into an *objet d'art*, which has been regarded as a milestone in 20th century Western art [fig. 4]. Placed on a plinth, the bottle rack was seen by the public as a sculpture. It was the observers rather than Duchamp who made art of it. "It is the *viewers* who make the paintings", said Duchamp himself. His exploit (or that of the viewing public) meant that the hegemony of realism in western art came to be replaced by other modes of expression during the rest of the twentieth century, not least conceptual modes. And here we can recall Goodman's rather famous assertion in *Languages of Art* that "Realism is relative, determined by the system of representation standard for a given culture or person at a given time" [p. 37].

Fig. 3

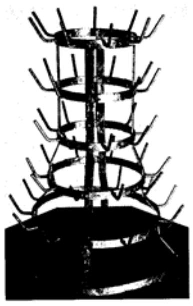

Fig. 4

AUTOGRAPHIC OR ALLOGRAPHIC?

In his approach to a theory of symbols Goodman makes use of the terms *autographic* and *allographic* art. The first term is applicable to art where the relationship between original and forgery has significance. In its turn, allographic art is determined with the help of a notation system such as a music score or text edition. "Thus painting is autographic, music nonautographic or *allographic*" [p. 113]. In systematic manner the philosopher works his way towards further designations: "Among other arts, sculpture is autographic; cast sculpture is comparable to printmaking while carved sculpture is comparable to painting" [p. 120]. The specifications of Goodman end in the following conclusion: "A forgery of a work of art is an object falsely purporting to have the history of production requisite for the (or an) original of the work." [p. 122].

With regard to the vodka advertisement we are able to instantly establish that this "history of production" is what Wolgers works with. The Swedish artist borrows and re-uses the production history of the Duchamp work openly and unabashed.

PIERRE MENARD'S DON QUIXOTE

Such a procedure is discussed in detail in another of Goodman's books: *Reconceptions in Philosophy and Other Arts and Sciences* (with Catherine Z. Elgin as co-author). The reasoning is based on an allographic example, the famous short story by Borges: *Pierre Menard, Author of the Quixote.* In the tale Borges has Pierre Menard, a French twentieth century *novelista*, write down *Don Quixote* with scrupulous care and precision in full concordance with the novel text of Cervantes 300 years previous.

Menard's work remains unfinished, with only chapters IX and XXXVIII and a fragment of chapter XXII in the first section of *Don Quixote* being realised. But according to Borges, the aim of Menard was clear: "His admirable intention was to produce a few pages which would coincide – word for word and line for line – with those of Miguel de Cervantes" [p. 6].

For Goodman Menard's work is "simply another inscription" of Cervantes' original. Goodman claims that by random effort a monkey could achieve the same results [p. 62]. Various interpretations of the allographic work may appear, but as long as the text or notation is identical then the work is once and for all "settled syntactically and semantically" [p. 65].

Thus as mentioned, according to the symbol theory of Goodman the connotative reference is lacking, the reference that points away from the denotational root meaning or the literal example. It appears to me that through his disregard of the further implications of connotation – the singling out of the historical, societal and reflexive functions of art – Goodman closes his eyes to the true contents and importance of *Pierre Menard, Author of the Quixote.* Goodman writes:

> Who wrote *Don Quixote* or when simply does not matter to the identity of the work. In both autographic and allographic arts the identity of particular works is independent of work-attribution. Although the identity of an autographic work depends on its history, that identity is not affected by our knowledge or ignorance of its history. [p. 65]

The latter sentence appears still more remarkable when read in the light of Duchamp's work. Without any attention paid to the production history of the bottle dryer, the copy by Wolgers would be far less luminous, both as artistic picture and advertising picture.

Despite being hidden in the shadows of fiction, the understanding of Borges appears contrary to that of Goodman: "Cervantes' text and Menard's are verbally identical, but the second is almost infinitely richer" [Borges, p. 11]. And Pierre Menard writes in a reflection on his work: "It is not in vain that three hundred years have gone by, filled with exceedingly complex events. Amongst them, to mention only one, is the *Quixote* itself." [p. 10]

THE WOLGERS VARIATION

But we are faced with a further issue. By hanging an empty bottle on one of the spikes, Wolgers made an addition to the naked bottle dryer of Duchamp.

In *Languages of Art* (chap. II) Goodman gave considerable space to the role of metaphor in a theory of symbols that he is in the process of developing. "Yet", he asks, "what distinguishes metaphorical truth from literal truth on the one hand and falsity on the other?" [p. 51]. The attention of Goodman is drawn equally towards the use of metaphors in language and pictorially. "A picture literally possesses a gray color, really belongs to the class of gray things; but only metaphorically does it possess sadness or belong to the class of things that feel sad" [p. 50f]. According to Goodman [p. 79f] metaphors work best when they combine the idiosyncratic with the obvious, newness with the habitual. That is to say when the result is changed organisation of our knowledge rather than the fastening of the new label of control on top of the old. In a chapter on *reference* in *Of Minds and Other Matters* Goodman summarises what he terms in the book "Fictive and Figurative Denotation" as opposed to literal reference. He writes that a symbol may denote metaphorically what it does not denote literally:

> Metaphor arises by transferring a schema of labels for sorting a given realm to the sorting of another realm (or the same realm in a different way) under the guidance or influence or suggestion of the earlier sorting. The new sorting echoes the old

> and is genuine, as 'factual', but is different. [p. 61]

Now we are able to see how Wolgers' empty bottle renders – or better recycles – the original function of the bottle dryer as a day-to-day, workaday object. That is to say the function it had, and still has in many cases, independent of Duchamp's conceptual metamorphosis of the rack into sculpture. But at the same time the metaphorical transfer transports the bottle from recycling bin to museum exhibition case. It is endowed with the aura of a cultural object and the mythology of art history. And as a guarantee of its authentic content, the label of its production history is ultimately attached to the bottle: ABSOLUT DUCHAMP.

Wolgers has at last done what the Swedish Duchamp expert Ulf Linde reflected on (and perhaps called for) from the exhibition public attending the opening back in 1914: "If the public had dispassionately hung up their bottles of wine to dry on Duchamp's 'sculpture' they would have offered him resistance" [Linde 1960, p. 44, my transl.].

Let us now consider how Wolgers packaged the bottle dryer, after eight decades of relative tranquillity in the art museums of the West, in its transference to the unshielded production conditions of industry and the world market.

He endeavoured to achieve a clear and illuminated exposure of the bottle rack, which emerges against a deep black background. We first become aware of the vodka bottle after attentive study of the picture. The blue upper case lettering of the label (PMS 286C+BLACK) is what initially extracts itself from the black. The seal of the bottle appears to melt into the rack. The sophisticated presentation is reminiscent of the use of light in a different picture with meta-motif – that is to say a work of art depicting a work of art – that of Velázquez' *Las Meninas*. The top lighting is the same, as is the dark background, the illuminated bottle corresponding to the inlet of light provided by the door ajar, and the form of the bottle rack correlating with the stiff crinoline of princess Margarita Maria.

On the other hand, Wolgers' picture hardly corresponds to Duchamp's own presentation of the bottle dryer. In his dialogues with Cabanne, Duchamp spoke of his practically random choice of ready-mades based on seeming indifference, with no aesthetic feeling. Which indeed was how the bottle dryer was exhibited at the *Exposition Surréaliste d'Objets* in Paris 1936; squeezed in among a score or so other objects in a poorly lit display case.

Duchamp's use of colour differs altogether from that of the industrial and utmost conscious use of colour of today. Companies now protect their choice of colours with patents, and assure correct reproduction via codes and numbers from various colour systems and models such as Munsell, Pantone, CMYK or NCS.

Occasionally even Duchamp however had to touch up his works [fig. 5]. In this rectified ready-made he changed a small enamel sign advertising the *Sapolin* brand of paint into the painted enamel sign *Apolinère Enameled*, the act enabled by the little girl's careful painting. Note the lettering in the lower right of the image. *Any act red*, it says, pointing out the colour of passion.

CONSEQUENCES

Wolgers, the well-read disciple of Duchamp, makes belated use of the knowledge at hand in *Pierre Menard, Author of the Quixote*, which according to Borges accommodates infinite applications:

> Menard (perhaps without wanting to) has enriched, by means of a new technique, the halting and rudimentary art of reading: this new technique is that of the deliberate anachronism and the erroneous attribution. [Borges, p. 14]

Transferring such insights from a conceptual world to what on a day-to-day basis is frequently termed tangible reality is of course not without risk. The demurral of Goodman has been noted. Wolgers himself appears to have suffered an adverse fate, like one taken from a dark tale by Borges.

How are we otherwise to interpret the image of Dan Wolgers, accomplished by his protégée the young artist Linn Fernström in a new contribution to the *Absolut Art* series of advertisements [fig. 6]? Should anyone by chance wonder, the blonde lady siren of the woods is Miss Fernström herself embracing her worldly goods, the vodka bottle to the left, and to the right Mr Wolgers.

Fig. 5

Fig. 6

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ILLUSTRATIONS

Fig. 1, Andy WARHOL – *Absolut Warhol*. © 1985 The Andy Warhol Foundation for the Visual Arts

Fig. 2, Francesco CLEMENTE – *Absolut Clemente*. 1999. © Francesco Clemente

Fig. 3, Dan WOLGERS – *Absolut Wolgers*. 1999. © Dan Wolgers

Fig. 4, Marcel DUCHAMP – *Bottle Rack.* Paris 1914. Original lost

Fig. 5, Marcel DUCHAMP – *Apolinère Enameled*. 1916–17. Arensberg Collection, Philadelphia Museum of Art

Fig. 6, Linn FERNSTRÖM – *Absolut Fernström*. 2003. © Linn Fernström

Festivals of Colours: Ottoman Miniatures

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ABSTRACT

"Colours" of the miniatures were used effectively to reflect the historical reality during Ottoman period. While Ottoman contemplation used janissary band music to scare away the enemy on their way to the battle field, miniaturists (nakkaş) described the warriors with flowers in their hands. Along reflecting the hictorical facts, miniatures that are the products of the realm of colors and imagination, also reflect the fantastic world of the East. Festivals and daily life are also demonstrated by miniatures. The miniatures are called 'little paintings' throughout Europe. In our study, we will undertake the semiotical analysis of the miniatuares whose subjects are festivals.

Keywords: Miniature, Ottoman, festivals, semiotics, culture, colour, meaning, aesthetic, signs, semiotical analysis.

1 FESTIVALS

Festivals are somewhat abolishment of the cultural order and domination, where collective life is experienced and a released energy and and extravavancy prevail for a temporarary period[1]. As Bachtin argues, " in festivals it is possible to view the world from a different angle and we get a sensation that everything is relative in this world"[2]. In the laws of Platon, "Gods presented the annual thanksgivings to forget their problems (matters, issues) and they gave them to the God of Muses, Apollo and Dionysos who would accompany them in festivals. And with this holy unity the order among humans were always to be protected[3]. The realization of the festivals are based on the two basic units: Game and leisure.

1.1 Game

Game is apart from the rationality of actual life; there is no relation to the concepts of necessity, effectivesness or task and reality. According to Platon says, indeed game is an important factor of the festivities where young people can not control their bodies and voices and are in constant action in the field of festival.

1.2 Leisure

For Aristotales, apprehension, leisure and "spare time" is the core principal of the cosmos. It can be prefered to work, and in actually, this is the main goal at the end of the whole work.

According to Herbert Marcuse, concept of happiness in recent hedonist perception is reduced to consumption and free time which is distinct from working[4]. According to Thorstein Veblen, in Aristocrat Class Theory, the most important significant characteristics of aristocratic class, which consisted of clergy, soldiers, management group, is to be far from the manufacturer workers and use their leisure time to consume their wealth for luxury[5].

Our objective in this article is to analyze different aspects of the festivities in relation to the different perspectives of colour. In the light of this article, some samples will be taken[6] of the Surname-i Humayun, miniatures that is made for the occasion of the circumcision of Sultan Mehmed III in 1582.

2 OTTOMAN FESTIVALS

In Ottoman festivals, alongside with the leisure (free time) and games, different kinds of festival aspects are observed.

2.1 Social Aspect

In all festivals it is observed that people are either close to each other or stands in solidarity. Social relations are strengtened expecially in festival periods. In public festivals, all the

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institutionalized work units such as eraftsman, soldiers, paths come together.

This is a scene that Ottoman Sultan stands up and bestrews gold, silver and money. The main colour is red; the other colours are green, white, purple, pink and brick-red.

In the miniature 46, Sultan is sitting at Şahnişin (bay window). On the right bottom of corner, people are standing up. It is differentiated from the Christians, people who are carying nature maquette and walking in their apparels and turbans. In apparels, the main colour are red the rest of them are, colour of green, pink, purple, dark blue and white.

2.2 Religious Aspect

Though not seen as a religious activity, at fist sight, Ottoman festivals were not depicted as a religious activity. The feast of sacrifice, Sugar Feast, Mevlüd Kandili (Islamic Holy night). The master of the festival was the Sultan who was both the leader of Islam (Caliph) and the Empire. Thus the festivals were in a way a means of propaganda on the foreigners and symbolized the superiority of Islam.

The circumcision of many children during this festival may be associated to this aim, the promotion of Islam. In the miniature 30 green is the dominant color in Seyyid clothes. White, red, dark blue, brown and brick-red are the other colours.

Various factors and symbols of the festival had religious characteristics. Dominant non-religious attributions were dance, music, songs, bonfires, masked games and eating.

In the miniature no 33 musicians were illustrated in non-religious activities. Green, red and brown were dominant colours in the caftans worn by the musicians (sazende). Red is the dominant colour while green, purple, white and black are the other colors.

In these illustrations of the javelin game named Cündiyan (horse show – miniature 43), red colour is also dominant colour and green, white, pink, black and purple are the other colours.

A scene is from a snake charmer's show (miniature 54). Red is also dominant colour and white, purple, green, color mustard and dark blue are the other colors. The main show is performed on the attendance of Sultan.

A wrestling show takes place in the miniature no 64. Red, gray, brown are the dominant colours, while green, white and colour mustard are the others.

Shows of the jugglers are seen in no 67th miniature. Red, gray and brown are the dominant colours, while blue, green, color mustard and white are the other colours. Juggler is dressed in red.

2.3 Political Scene

The political aspect of the festival both within and outside of the Empire and was a demand to prove the dominance of sultan; the one and the only symbol of the government.

Those who witnessed the Ottoman festivals inform us that when a military expedition was declared, all the cities were in cheer and amusement. Flambeaus, candles and oil lamps were shining all over the city.

In the 75th miniature; with its extraordinary colours and appearance, mythical bird "simurgh", that is not proven to exist in the nature, symbolyzes the flamboyance of the festival and the Empire. In this scene, many statesmen are illustrated in the audience/ public gallery (seyirlik) both as a member of audience and the performers.

2.4 Aesthetic Appearance

In festivals, magnificent appearance, stage order, dress and finery, lighting, colour, motion, sound, contrast, that provided all the aesthetic necessities and requirements were presented together. Festivals can not be regarded as an art, but it is the natural source of arts. In Ottoman festivals, everyone worked for the achievement of the festival. There was no difference in this respect between an organizer and a viewer.

The happenings in Surname-i Humayun are shown in two places in order. One of them is the İbrahim Pasha Palace where Sultan Murad III. was watching the players and the displayers, and the public gallery with its three stages where the non-Muslims, foreigner guests and the ladies were seated.

The events are shown in complete, simple and detailed form in this work of art that was depicted by the muralist group under the direction of muralist (Nakkash) Osman. The muralist overwiev and decor are stable, subject -festival- is dynamic in Surname-i Humayun.

The scenes that are related to aesthetic appearance are shown in miniature numbered 38.

The main colours are red, purple, pink and the rest of them are white, blue and green.

In the miniature numbered 76 is shown the drapers (Kemhacı). They pass by holding the stick with fabric. The main colour is red and the rest of them are purple, green, blue and pink.

In the miniature numbered 79 loinclothers pass by holding the fabric stick with animal figure. The main colour is red; the rest of them are, green, purple and white.

In the miniature numbered 80 Egyptian spice sellers catch up the Garden of Heaven. They pass with the ceramic jar and plate on their hands. The main colour is red; the rest of them are green, blue, orange, white and beige.

3 CONCLUSION

In this analysis of miniatures, we made a research into th Surname-i Humayun festival, we analyzed the visual variables that constructed the miniatures. In another word especially colours out of the plastic elements (shapes, textures and colours) and the perception of these elements were inspected.. By emphasizing their functions (the meaning they transfered); we analyzed the imagery and content levels of these miniatures.

This kind of analysis is micro-semiotical analysis[7]. Our empirical analysis is based on the perception and interpretation of the symbols[8].

Multicoloured variability of human clothing and the decor that is used in the Festival, from the beginning to the end, is noticeable in the miniatures' rhetorical order of the Surname-i Humayun.. Multicolours and multiculturalism are observed among the Muslims and Non-Muslims as well as ine the public and the residents of the court and various craftsman.

The main colors in Surname-i Humayun are red, green, white, purple and blue, but the dominance of red in the miniatures is conspicious. And the colours as red, yellow, brown, green are used to communicate the power and the dynamism of the Sultan (miniature 84).

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Miniature 46

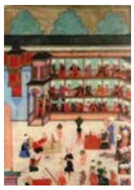

Miniature 30


Miniature 33


Miniature 43

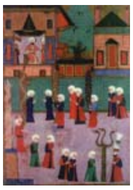

Miniature 54

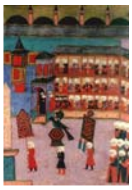

Miniature 64


Miniature 67


Miniature 75


Miniature 38


Miniature 76


Miniature 79


Miniature 80


Miniature 84

Colour	People(s)	Costumes	Space/Decor	Effects	Indicators
Red	Spice-seller Loincloth-seller A kind of silk glassman magician snake charmer javelin Musician Wrestler	hat clothes	Fence window blind a kind of a fairy bird	dynamism attraction action power	-Power of the Government and Sultan
Green **Green (Light)**	A kind of a silk magician musician wrestler glassman Loincloth-seller Spice-seller	clothes	hippodrome roof palace walls balcony (the sultans's seat) house	-balance -reality -belief -natural	-Religion -the naturality of Sultan -
White	Loincloth-seller Spice-seller javelin wrestler magician glassman	turban clothes	a kind of a fairy bird	-cleanliness -communication -purity -virtue	-Good Luck - The virtue and the lightness od Sultan
Purple	A kind of a silk glassman Snake charmer javelin Loincloth-seller	clothes		-freshness -hope	-Hope given by festival
Brown	Musicians Snake charmer wrestler magician	hat clothes		-fertility -comfort -Steadiness	-the fertility of Sultan -The steadiness of dynasty
Blue (Dark)	Snake charmer	clothes		-wisdom -the clolor of the Kingdom -nobility	-the wisdom of Sultan -Enthrone (Sultan)
Black	Javelin	hat clothes		-authority -seriosness -wisdom -nobility	- the wisdom of Sultan -the authority of Sultan
Grey	Wrestler magician	clothes		-realibility	-the realibility of the dynasty
Blue (Light)	Magician glassman a kind of a silk spice-seller	clothes	a kind of a fairy bird balcony (the sultans's seat) house	-realist -peaceful	-the realibility of the dynasty -the peacefulness of the dynasty
Orange	spice-seller	clothes	house palace walls balcony (the sultans's seat	-active -sociable	-the power of social relationship of the dynasty
Yellow (Light)	Spice-seller	clothes	Palace walls window	-gold -sun -the color of the Kingdom -success	-Power of the Government
Mustard	Wrestler magician	clothes		-intuition -revival	-thepower of intuition and wit of Sultan

Tales of Tiles in Ottoman Empire

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ABSTRACT

Ottoman tile art has many different techniques so called as "minai" technique, "mosaic tile" technique, "over glazed" technique (perdah technique), "colour glazed" technique. In the second half of the 16th century, innovation in the coloured glaze technique and under glaze technique can be seen. 17th century is the decline of the tile technique and art. Ottoman craftsman were seeking for colours; inspite of using only three colours they founded "naturalist style" which was independently improved from the Chinese, Iranian and Islamic traditions.

Keywords: Tile, Çin-i, tile colours, tile production techniques, Damascus Work, Ottoman Naturalist Style, Topkapı Palace, Sokollu Mosque, Rüstem Pasha Mosque.

INTRODUCTION

The origin of the word "tile" comes from Persian noun phrase "Çin-i" (tiles) which means the Chinese style. The same word has been used in Turkish for glazed pattern or coloured panel. Tile art, that has a great importance in Traditional Turkish art, has been used since ages. Tiles are widely used in the architecture of many Turkish, monuments, as well as other states in Asia (Figure 1). In conjuction with the Anatolian Seljuks, usage of Tile Art in both the interior and the exterior architecture is commonly seen where Turquise was dominant. During the expansion of the Ottoman Empire, optimize the endurance of tile art, various efforts were made. It's been the other way round during deterioration and decadence periods of the Ottoman Empire. The transparency of the glazed surface caused an aesthetical feeling that attenuates the mass of the architectural constitiution. Many techniques have been used during the developmental period.

1. "MINAI" TECHNIQUE

The colour of dough in "minai" technique is yellowish. Lime (alkalili) has been used as the binding material to form dough. It was turned into a moulded dough panel, and was glazed without undercoating. Seven colours were used in these tiles. Green, dark blue, purple and turquise colours that were temperature-resistant were painted, underglazed and were then patterned. Afterwards, black, brick red, white, gold leaf were painted again over, the glaze and the kiln was dried in low temperature. High-quality products were achieved with this method that was hard to practice. By this technique, star and cross shaped square tile panels and diamond shaped tile panels were produced on these art pieces, throne scenes that represented the court life, various animals that were hunted and special flowers can be seen[1]. Konya Alaaddin Köşkü (Kiosk) is the only building in Anatolia where tiles that were produced by this tecqnique were used [2] (Figure 2).

2. "MOSAIC TILE" TECHNIQUE

Pieces of tiles were glazed with various colours such as turquoise, purple, green, dark blue in "mosaic tile" technique and they were cut in accordance with its' patterns and were put together on a plaster base. Dome of the Konya

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[1] Ş. Yetkin, "*Çini Sanatı*" p.2, İstanbul University Fine Arts Department Lectures.
[2] O. Aslanapa, *Turkish Tile and Ceramic Art*, p.16, İstanbul, 1999.

Karatay Madrasaha (Figure 3) is an example that was produced with this technique were foliate and geometrical motifs, can be seen Sivas Gök Madrasaha (1272) is a monumental structure with its iwan of entrance[3].

3. "OVER GLAZED" TECHNIQUE

It's generally an adornment technique over glazed tiles (opaque). Glaze paints are kiln-dried on 750-800 degrees centigrate. This technique shows metallic glitter over glaze. In this process, a mixture of silver or copper oxide over matt white, purple are turquise glazed tiles are kiln-dried, again at low temperature. In this method, a metal oxide mixture covers tiles' surface as a thin layer. The tiles of Kubadabat Court is an important example where the walls are covered with stars and cross shaped human and animal figures[4] (Figure 4)

4. "COLOUR GLAZED" TECHNIQUE

In this technique, the contour outlines of the patterns are carved or pressed on a red dough, the inside is tilled in paint and then it's kiln-dried. Another way is after applying a red dough panel on a white undercoat, outlines of the patterns are drawn with a sugary mixture of chrome and manganese, then filled with coloured glaze paint and kiln-dried. Black outlines prevents mixing of colours[5]. At the end of the kiln-drying process, the melted glaze were prevented from pouring into each other with the help of outlines that was bloated. "Tiled Kiosk" is a building that belongs to the Early periods of the Ottoman Empire where the developments of the mosaic tile art techniques can be seen (Figure 5). It is appraised as an iwan (monumental entrance-door) covered with tiles.Geometric shapes and tile panels with Kufi and Sulus writing makes this affect more dominant. It's an important example in Ottoman Art where tiles are used as exterior ornaments. Karamans were also aware of this technique which was invented by Seljuq's. But, during Ottoman times, Konya lost its importance[6]. Bursa, The Green Mosque (1419-1422) tiles shows the conceptual level of the early Ottoman Art. The colour palette is richened with the addition of yellow, peanut green and lavender. Hatayi compositions[7] and peoni motifs of fareast origin were added to tile art.

4.1 Innovation in the Coloured Glaze Technique

Coloured glaze technique was still used in İstanbul during the 16th century. At the end of 15th century and the beginning of the 16th century, along with the fareast that has origins back to the Ming Period, chinese cloud, stylized dragon, peony and bunch of grapes, next to the symbol of "çintemani" (three ball design) Also, other patterns were existed such as curling branches of Rumi, bird, deer, fish, hunting, sytlized flowers, rosette, kufic ve nesih (rounish) writing were seen (Figure 6).

5. UNDER GLAZE TECHNIQUE

Craftsman started to use a new method called "underglaze" in the second half of the 16th century. In this method, they cover the tile panels with a lining and paint the inside. Tile panel is filled with glaze and then it's kiln-dried. The transparent glaze becomes a thin glass layer inside the oven and colours come out very shiny. Blue, turquise, olive green richens the color palette, they are put together and the patterns were drawn onto a white dough where chrysanthemum or cloud, bunches of hyacinth, tulip and rose were used. They were called "Damascus work" by mistake, because they were the parts of the walls of the architecture that belongs to the 16th century in Damascus[8] (Figure 7). By adding grass green and coral red to these colours, the best examples of İznik tiles were produced.

In the second half of the 16th century, in the samples of tiles competence and technical quality was seen.Tile patterns were handed by palace miniaturists in İstanbul and then they were sent to İznik. The tile patterns were colorized, with the colors of Cobalt-blue, turquoise, green, white, occcasionally brown, pink and gray.The coral red that symbolized the century - was in used as relief under the glazes. The black hardy lines that

[3] O.Aslanapa, *ibid*, p. 27.
[4] O.Aslanapa, *ibid*, p. 27.
[5] M.Sözen, U.Tanyeli, *Sanat Kavram veTerimleri Sözlüğü*, p. 200, Remzi Press, İstanbul., 1994.
[6] *O. Aslanapa, Yüzyıllar Boyunca Türk Sanatı (14.yüzyıl)*, p.45, MEB, İstanbul, 1977

[7] Baba Nakkaş was the first craftsman of the Palace and the inventor of Rumi and Hatayi. Ref. S. Ünver, *Fatih Devri Saray Nakkaşhanesi ve Baba Nakkaş Çalışmaları*, Kemal Press, İstanbul, 1958
[8] N. Ö. Fındık, *İznik Tiyatro Kazı Buluntuları (1980-1995) Arasındaki Osmanlı Keramikleri*, pp. 216-221, Ministry of Cultures, Ankara, 2001

formed the pattern is more effective on these multiple colours. This period was called as Naturalist style as we can see various kinds of flower styles, descriptions on the miniatures were tulip like and they were called as “Turkish Flower”, rose, carnation, pomegrate, flower nyacinth, violet, sprays, grape louse, and cupressus sempervirens. Rüstem Pasha Mosque (1561) is an example for a new technical development and patterns of tile art in the second half of the 16th century, the walls, attars and pillars of the whole mosque was covered by tiles[9] (Figure 8).

The Sokullu Mehmet Pasha Mosque, located in Kadırga, (1571) is a succesful pattern of tile art too, the contruction of the composition is not dominant on architecture. Tile patterns pass through the structure with pendant pelmets, circle of the marble altar, and the tiles covered the altar’s coif, may be eveluated as the competence patterns of the period. “Takkeci İbrahim Ağa Mosque” (1591) in İstanbul is a important example of the 16 th century Ottoman tile art.

The Hırka-i Saadet (relic) room at the Topkapı Palace is one of the places where high quality tiles exist. The tiles in Sultan III. Murad is Room (1578) cover the whole wall up to the dome.

It’s clear that, the miniaturists of the palace patterned the tiles on the panels which include rumi and birds on curly branchs that is smaller then the previous examples. Similar panels were seen in Baghdad Pavillion that was built in 1639.

6. DECLINE

As the result of the technical decline, coral red turned to brown and pale colours appeared the Glazes run out of white ground turned into dirty bluish and dots appeared on the glaze. The glazes lost their brilliant look and multiple breaks appeared on them. In spite of the technical backtrack in the second half of the 17th century, various patterns are still used, and also green turquise and dark blue are the dominant colours in tiles of *İstanbul New Mosque* (1663) (Figure 9). At the beginning of the 18th century, İznik tiles weren't produced anymore. Sultan Ahmed III built a small factory with tile ovens and its' materials for reproducing tile art in Tekfur Palace and tiles similar to İznik tiles were produced in the beginning[10]. But after these attempts that lasted for 25 years, production Tekfur tiles come to an end, too. On the other hand, tile production permanently shows itself in Kütahya as a traditional public style.

7. TURKISH RENAISSANCE

At the beginng of the 20th century, İznik tiles with classical patterns were reproduced again by the effects of Neo-classical understanding. But an art that belongs to an empire that was about to descend could not survive anylonger. Nevertheless the architect Kemalettin built a school in 1900 called “Çapa Trainers School” which represented a National Movement in architecture with Turquoise tiles on the facade.

7.1 New Interpretation

Turkish Cultural Ministry announced 1989 as “İznik Tiles Year” and arranged meetings and exibitions. While tile art takes an important place in museums all around the world as masterpieces, contemporary examples; a monument in Montreal is covered with tulips that symbolize the peace**.** İstanbul subway stations are covered with panels of tiles which was decorated like a classical style of İznik. These are new commentments of İznik tiles as postmodern thought.

CONCLUSION

According to the Pierce semiology, the present study is based on the concepts of “firstness”, “secondness” and “thirdness”. “Firstness” the grand and ambiguity in the concept of “tiles”, the concept of “secondness” is the point in question during the Ottoman Empire Period at the tiles and the tales of tiles. Tales of tiles in the Ottoman Empire is extrapolated as a special case on tiles. Colours, the order of the aesthetical and technical items are approached as diachronic, and thirdness, in other words, secondness (the figuration of the feasible) set up the outcome of the study based on the rules, the methods, technical and cultural extent and historical process.

[9] Ş.Yetkin, “*İstanbul Rüstem Paşa Camii Çinileri Üzerinde Bazı Gözlemler ve Saray Nakkaşlarının Bu Çizimler Üzerindeki Etkileri*”, p.19, Kültür ve Sanat Periodical, 4, 1989.

[10] A. Refik, “İznik Çinileri”, *Darülfünun Edebiyat Fakültesi Periodical*, pp. 48-49, VIII. Cilt, 4, 1932

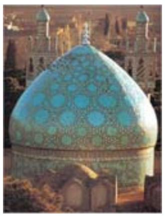

Figure 1. Shah Nimetullah's Tomb

Figure 2. Allaaddin Kiosk

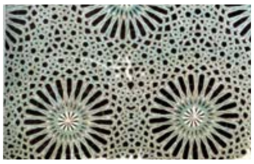

Figure 3. Karatay Madrasaha

Figure 4. Kubadabat Court

Figure 5. Iwan of the Tiled Kiosk

Figure 6. Ottoman Ware

Figure 7. Three coloured ware

Figure 8. New Mosque

Figure 9. Rüstem Pasha Mosque

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Symphony of Two City Colors

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ABSTRACT

This article will deal with the interplay of special colors and the smells identified with the colors of Mardin and Bursa. Strong rays of sun reflecting different tones of brown are an overture followed by different shades of yellows, coffee and orange colors. This symphony of colors is followed by a comparison between the natural browns of this Southeastern Turkish city of Mardin and the greens of the Western city of Bursa. The latter was called Green Bursa for centuries due to its gardens, orchards and the predominant greenery inside the city and the surrounding areas. We will apply the tools of Semiotics to the analysis of these two urban areas in Turkey located in the East and West respectively.

Keywords: Semiotics, history, seasons and colors, green, yellow, brown

1 INTRODUCTION

The art of past and recent cultures is an area that historians have delved deeply into[1]. There are a number of factors which influence the fabric, smell and color of cities. One of the most important factors is the historical evolution of cities. As history leaves the imprint of events during different periods, Nature contributes to this imprint. Nevertheless, over a period of historical evolution, human influence may change and even decrease the influence of colors on the city landscape. This article will undertake a color related semiotic analysis of to Turkish cities; Mardin in the East and Bursa in the West. The reason we have chosen these two cities are their history sating back for centuries and their importance in regional and world mythology. Cities that are far apart in geographic terms exhibit environmental (climate, natural resources) and cultural (language, art) differences. Nevertheless, despite these differences, there are also similarities such as the language spoken and religious beliefs. In our analysis we will study the differences and similarities between these two cities influenced by the natural environment, history and the cultures that existed and especially the colors of each area that have evolved under cultural influences. In our analysis we will refer to "Green" Bursa and "Yellow" Mardin and in our conclusions we will determine whether these colors are an appropriate description and proper fit from a Semiotic point of view.

2 THE HISTORICAL EVOLUTION OF THE CITY OF BURSA

Bursa has existed as a human settlement for five thousand years. Historical records indicate that it was established by Prusias in 232-192 B.C. Hannibal the king of Carthage, after losing the battle against the Roman Empire seeks the protection of Prusias 1. Hannibal is well received and builds a city to express his appreciation to give to Prusias 1 and names it Prusias. Later on the Roman Empire invades the city and names it Prusa ad Olympium. Mount Olimpus where the Mythical Greek gods dwelled is called Uludag in Turkish. This the Turkish name was Uludag Bursasi. During the 14th century the city of Bursa became the capital of the Ottoman Empire[2]. The city contains two historical mounds dating from antiquity. The "Demirtash Mound" from the Bronze Age, circa 2500 B. C. and the "Çayirkoy Mound" dating from 2700 B. C., contain ceramic artifacts and shards in gray, red, grayish brown and black. In addition to its archeological past the city is also a center of mythology. The Argonauts who searched for the Golden Fleece crossed the Black Sea and the Marmara Sea docking their ships in the ancient port of Mysia, which is called Mudanya today. One of the crew members the handsome Hylas ventured into woods in search of water and does not return. When he reaches the source of fresh water Zeus's daughters fall in love

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[1] Goldberg., "Careers for Color Connoisseurs and Other Visual Types", Blacklick, OH, USA: Mc Graw-Hill, p.2, 2005.

[2] E. Özendes., "Osmanlının ilk Başkenti Bursa" İstanbul, Yem Yayın, p.20-21, 2000.

with him and make him immortal. In an area near Mysia where the blues of the sea embrace the green of the land a new city is built named Prusa[3].The city leans against Mount Uludag and exhibits different colors during the four seasons of the year. The white and cream colored flowers of the apple orchards in the spring are accompanied by the pinks of peach orchards. In the springtime the pure tints of the orchards together with the bright green leaves and smells offer us a veritable symphony of colors. The romanticism and elegance of white and pink and the contrast of the bright green leaves gives a new meaning to a "live" description of freshness. (TDK) As the fields and trees spout their greenery reminding us of the deep color of emeralds it also brings to mind the conversion of fertility to wealth. The pink and cream colors of the fruits and flowers endow the city with romantic feelings. Pink suggests romance and "…added to red in varying and is the lightened value of red."[4]. It is important to note that different sources of light structurally contain different colors[5]. At different times of the day of a particular season or in different seasons the same light source can contain different colors.

3 SEASONS AND COLORS

The valley gives the city of Bursa green toned colors around and in the city. This green is deepened by the darker greens of the pine, oak and beech forests on Mount Uludag facing the city. As the mountain is covered with different tones of green the smell of fresh oregano accompanies this harmony of colors. "In works of art the relationship of the whole with its parts is called Harmony"[6]In Uludag there is an aesthetic harmony between the colors, and smells of Nature. Green is a calm and soft color and the bright green of the trees and grass reminds one of abundance and Spring. Nevertheless, there is strength and virility in green. Green in a negative and disagreement laden context can indicate poison and jealousy[7]. However, in our analyis we will deal exclusively with its positive aspects. In the Summer green matures all the light green leaves take on a deeper and nobler shade. Dark green also reflects the pine forests richness and nobility. Dark greens such as forest green and pine green provides a calm and peaceful alertness to the observer. As it gets darker it becomes a more dense and heavy color and reflects the city's immortality[8]. In the Fall the oak trees in Uludag are a warm potpourri of yellow and red. In the sunlight these colors seem much brighter and warm. Yellow represents life and happiness. It is the sun's color. The lighter versions of yellow remind one of a spring breeze[9]. In the winter Uludag is dressed in white. The mixture of snow white mixes with the sky's very light blue reflected by the sun's rays. Despite the cold nature of blue and white the sun's rays and their brightness adds a warm dimension to this interplay of colors. In Uludag the colors according to the seasons start off with light green, then dark green, yellow and red as components of a burning fire. As white is added on top of everything it is as if the fire and of autumn is about to be put off. The rhapsody of colors in Uludag extends from cold to hot colors and from there to colorless spaces.

4 HISTORICAL STRUCTURES AND COLORS

The urban core of Bursa is symbolized by the Green Mosque and the Green Mausoleum. From a horizontal and spatial point of view the green of the grass and the fields in addition to the blue-green of the sea extends over a broad area and provides a contrast and a show of strength to the vertical Green Mausoleum. The Green Mausoleum is an octagon shaped structure whose surface is covered with green turquoise tiles. This gives the city a unique color and smell. It is as if this vertical structure challenges the horizontal grass fields.

The people of Bursa have named their city Green Bursa[10]. Green has a sacred status in Islam while turquoise represents protection from the evil eye and curses. The color blue adds meaning and identity to the green in this city. The turquoise colors of the Mausoleum seem like a marriage of the valley's green with blue color of the sky. The frames of the windows are made of stone. They are light gray mixed with skin tones. All the Ottoman historical structures were built with cream colored stones and add elegance to the

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[8] C. Hideaki, p. 14.
[9] C. Hideaki, p. 13.
[10] www.bursa.gov.tr

panorama of the city. One of the special features of an elegant color is the mixture of white with yellow which provides us with a pastel cream. The architectural details adorned with natural light and few shadows provide an impression of modernity. "Elegant color combinations use only the pallets'' tints. For example, whisper of yellow combined with white makes a pastel cream"[11]

5 HISTORICAL EVOLUTION OF MARDIN

The province of Mardin was established by the Subaris almost seven thousand years ago. It is one of the oldest cities of Mesopotamia. The Subaris lived in this area from 4500 to 3500 BC.[12]. After its invasion by Shah Ishmael the Mardin castle fell into Ottoman hands during the reign of Sultan Selim[13]. Mardin is full of structures from antiquity which extend as far as the eye can see[14]. Mardin has been an Ottoman city since 1517. Within a heterogeneous population there have been Jews, Christians (Armenians, Sourianis and Chaldeans) Moslems and Zoroastrians who have lived here for centuries[15]. Mardin's original name was Merdin which meant castle. It is an eastern city surrounded by mountains. Its population consisted of transhumant that moved their herds and those that lived in settlements. The height of the mountains reaches 1500 meters and is 600 meters above a wide valley where the city originated. There are two climactic systems prevalent in the province. In the valley summers are hot and winters are mild and rainy. In the mountains the summers are cooler; winters are colder with more rain and snow. The valleys exhibit the colors and climactic characteristics of four seasons. In spring time nature awakens with the light green tones of vegetation. The green which is a combination of yellow and blue has a range of colors from yellow to dark green in the valley. In other words, the valley exhibits a whole range of tonal and shiny variations just like a green ocean. These valleys symbolize the rebirth and awakening of nature. With spring the fertile land mass between the Tigris and Euphrates rivers turn the blue waters of the rivers into blue. The blue green of the water brings us to a state of mind where "… we feel more freshly the value of the mere tints and shadings, and became aware of any lack of purely sensible harmony or balance which they show"[16]. Thus we observe a balance in the harmony of colors.

The mountains generally are bare and exhibit the effects of erosion after the disappearance of forests. Soils have clay and lime structure. We van not find the fertility and the green of the valleys in the mountainous regions of the province. These mountains with significant clay deposits and under the influence of a desert like climate give the impression of bare stones and earth. From a color point of view, this picture emphasizes the depth of its history, the nobility of the colors which have predominated the area providing a rich, warm and homey feeling. The rocks in the mountains as a result of the hot rays of the sun give the observer the feeling of polished terracotta copper. This coloring is similar to those observed in the Mayan pyramids in Mexico, which range from brown to yellow. This combination of colors is indicative of a natural union of the sun with nature and reflects the love, happiness and youth in our planet. The yellow tones of the earth are indicative not just of a natural union but an exciting union [17]. The yellows extend to a melon's greenish yellow and then to citrus and orange and then to red. Saffron flowers, which are common to the area, are yellow but turn to a reddish pink in acidic soils[18]. The mountains of Mardin exhibit a rhapsody of colors which resemble a melon colored velvet artificial saffron flower.

The most important characteristic of Mardin as far as its colors are concerned and which differentiates it from other cities, is the overlapping colors of its houses, historical structures, the earth and the stones. The stones used in residential construction have a predominating color combination of yellows and beige. Yellow is symbolic of life and happiness; it is the color of the sun and its rays. A faded yellow

[11] B. M. Whelan, "Color Harmony 2" USA. MA. Rockport Publishers, p. 62., 1994
[12] H. Dolaponu Metropolit, "Tarihte Mardin" İstanbul, Hilal Yayınları, p.14., 1972
[13] N. Göyünç, "XVI. Yüzyılda Mardin Sancağı", Ankara, Türk Tarih Kurumu Basımevi, p.37., 1991
[14] F. Katip, "Mardin Artuklu Melikleri Tarihi" İstanbul, İmak Ofset, p.2.,
[15] İ. Özcoşar, H. Dinç, F. Dinç "242 Nolu Mardin Şer'iye Sicili Belge Özetleri ve Mardin" İstanbul, İhtisas Kütüphanesi. Yayın No 1, p.96., 2006

[16] M. Barash,, "Modern of Art: From Impressionism to Kandinsky". Volume 2. New York. NY, USA. New York. University press. P. 42., 1998
[17] B, M Whelan, p.42.,
[18] V. Finlay, "Renkler: Boya Kutusunda Yolculuklar", Çev. Kudret Emiroğlu, Ankara Dost Yayınları. p.168., 2007.

reminds one of a spring breeze[19]. This yellow, together with the cool mountain breezes of the summer creates an aesthetic whole. When mixed with white the yellows soften the pale hue disappears and emanates romantic sensations[20]. Thus, "Landscape architects and designers bring their love of color outdoors, choosing the right combinations of plants, and flowers that thrive in a variety of climates and condition." [21] . The buildings in Mardin are a symphony of smells, colors and sounds, removed from history and yet as "data of pre-history "[22]. As colors are a special characteristic of cities and play an important role in the design of its structures[23]. Colors in Mardin change throughout the day. In early morning and late evening after sunset, the mountains and the houses on the hills exhibit tones of beige and blue. As darkness descends it adds a mysterious and cold curtain which accentuates the city's proud image. This image of pride is even more emphatic in the mid-day sun which represents Mardin's real colors. The city is dressed in a golden and warm yellow. In the afternoon as the sun is about to set the city seems to be aflame. All the tones between red and yellow of the city are reflected on the mountains. These are warm colors. The different tones of red-orange and yellow-orange are an important part of the emotional spectrum as they are warm and comforting.

6 CONCLUSION

Colour is powerful shorthand for conveying ideas and information. There is infinite number of colours and shades, hues and tints (some suggest as many as 16 million). Nature is a rich source of color perceptions. The flora, fauna, animals, minerals, mountains and stones and their composition attracts our attention. In describing and analyzing the symphony of colors of Bursa and Mardin, we started off with a brief review of their history and geological structure. We studied the colors of the historical structures and their relations with the colors influenced by seasons in the mountains and the valleys. We have presented a comparative analysis of the two symphonies of colors identifying similarities and differences. From a historical point of view both cities have existed for more that 5000 years. When we study them from a color and geological point of view, mountains and valleys play an important rile in both. Both cities have four seasons, and these seasons have an important role in determining the colors.

In Bursa and Mardin the colors change as the seasons do. In spring time the colors in both cities extend from yellow to light green and dark green. However, the white cream colors of apple and plum flowers and the pink flowers of peach orchards in Bursa are not observed in Mardin. Mount Uludag in Bursa expresses all the tones, tints and shades of green. Uludag lives different colors throughout the four seasons. During spring and summer the tones of green present a green symphony. In autumn the green symphony is aflame and dances with the colors of fire. In the winter months the flame is put out by a pure white. The mountains of Mardin, with its clay soils and earth tones start off with yellow and turns into beige, orange, copper and brown exhibiting an elegant presence. The two mountains, one green and the other beige are different than each other.

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Memorizing visuospatial and verbal colors in working memory: An fMRI study

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ABSTRACT

Using fMRI, the hypothesis that colors could be memorized either in verbal or visual working memory depending on the color category borders was tested. We introduced a 2-back task to investigate the involvement of verbal and visual working memory in color memory. Colors across the categories, defined by basic color names, strongly activated the left inferior frontal gyrus and left inferior parietal lobule corresponding to the phonological loop as verbal working memory, whereas colors within the same category strongly activated the right inferior frontal gyrus corresponding to the visuospatial sketchpad as visual working memory. The choice of colors to memorize might modulate the cognitive load balance between the phonological loop and the visuospatial sketchpad.

Keywords: Working memory, Memorized color, Color name, Visual color, fMRI

1 INTRODUCTION

How are colors memorized in working memory? Is it based on verbal- or visual-code under WM task? Furthermore, do both codes share dissociated brain areas? Although color is used broadly as a visual stimulus, considering the influence of verbal code, the representation of color in the brain could be equally manipulated both verbally and visually. The dual-code property of color evokes a conflict between the two codes. Colors that cross the borders of color hue categories could be verbally coded because of the involvement of the corresponding color names, whereas colors within a single color category are likely difficult to be verbally coded because of the involvement of slight hue differences.

A brain imaging study focused on colors in WM in a domain-dependent dissociable brain has not been reported previously. This study investigated the specific dissociated brain areas responsible for color memory under both verbal and visual coding, using functional magnetic resonance imaging (fMRI). In Baddeley's [1] model, WM is a limited capacity system that temporarily retains and manipulates information. The model involves an executive function as a supervisory system and two domain-specific subsystems: the phonological loop (PL) that is responsible for language processing involving color names, and the visuospatial sketchpad (VSSP) that manages visuospatial processing involving shade of colors. On the basis of current neuroimaging studies [2,3], PL is thought to be localized in the inferior parietal region in the left hemisphere (BA 40; working as short-term phonological store) in connection with Broca's area (BA 44 and ventral part of BA 6 known as the mirror system), whereas VSSP, especially the spatial component, is known to be distributed in the right hemisphere. We hypothesize that colors that cross different categories (Cross condition) would activate PL more easily because colors having large hue differences could be more easily coded verbally, as in the case of color words (Word condition), than colors within the same category with slight hue differences (Within condition). Under such Within condition, memory for adjacent colors should not rely on PL [4]. Thus, left frontoparietal network activation would be expected to increase under both Cross and Word conditions, whereas the right frontoparietal network activation would be expected to increase under Within condition.

2 METHODS

2.1 Procedures

Nine right-handed healthy participants aged 20–28 years were recruited. The n-back task has been employed in many human studies to investigate the neural basis of WM [3]. The task requires the participant to monitor, update, and manipulate the information he could remember. The participant is required to monitor whether the current stimulus is the same as the one presented in n trials previously, in which n is a preliminarily specified integer, usually 1, 2, or 3. This study introduced the 2-back task to achieve an adequate difficulty level under three conditions: Word, Cross, and Within. The experiment was based on block design. A series of nine stimuli was presented on the screen in a single block (36.5 s). Each stimulus was presented for 500 ms followed by a

4000ms interstimulus interval. Participants had to press a key with the left or right thumb as instructed.

2.2 Procedures

A single block had a color group consisting of three stimuli, from which one was selected as the specified color (red, yellow, green or blue). Under the Cross condition, the stimuli were presented as a colored square of a specified color along with two typical colors of adjacent hue categories (e.g. red group: purple, red and orange), whereas under the Within condition, the stimuli were a specified color along with two adjacent colors in the same category to minimize possible verbal labeling. Under the Word condition, stimuli were color names printed in Japanese. To cancel activation by the thumb press response, we also introduced a finger response condition. The four conditions were pseudorandomized (4 conditions x 4 color groups). Stimuli were presented with Presentation 9.20 and displayed in the center of a gray background on a backprojection screen that was viewed by the subjects via a mirror attached to the head coil. Before scanning, all participants received training for all conditions using stimuli differing from those used during image acquisition.

2.3 fMRI data

Whole brain imaging data were acquired on a 1.5-T wholebody magnetic resonance imaging scanner (Shimadzu-Marconi Magnex Eclipse) using a head coil. Head motion was minimized with a forehead strap. For functional imaging, we used a gradient-echo echo-planer imaging sequence with the following parameters: TR.2500 ms, TE.49 ms, flip angle.801, 6mm slice thickness, FOV.256mm_256mm, and pixel matrix.64_64. After collection of functional images, T1-weighted images (154 slices with no gap), using a conventional spin-echo pulse sequence (TR.12 ms, TE.5 ms, flip angle.81, FOV.220mm_220 mm, and pixel matrix.256_256), were collected for anatomical coregistration at the same location as the functional images.

After image construction, functional images were analyzed using SPM2 (Wellcome Department of Imaging Neuroscience). Six initial images were discarded from analysis to eliminate nonequilibrium effects of magnetization. All functional images were realigned to correct for head movement, which were less than 1mm within runs. The functional images were normalized and spatially smoothed with an isotropic Gaussian filter (8mm full-width at half-maximum). Low-frequency noise was removed with high-pass filtering (450 s). Data were modeled using a box-car regressor corresponding to a single block convolved with HRF. Group data were analyzed using a random effects model. We specified activation areas of all conditions at the threshold $P<0.05$, corrected for multiple comparisons (false discovery rate, FDR).

3 RESUTS & DISCUSSION

As for behavioral data, the mean proportions of correct responses were 93% (Word), 93% (Cross), and 87% (Within). The data were analyzed in one-way repeated measures analysis of variance (ANOVA). The main effect was not significant. Therefore, we confirmed sufficient task performance and slight differences in task difficulty among the three conditions. We selected cortical regions of interest (ROI) according to previous studies [2,3] and inspection of activated clusters: bilateral inferior frontal gyrus (IFG: BA 44/45; Talairach coordinates; -48, 6, 36; 42, 21, -1), bilateral premotor area (PM: BA 6; -36, 12, 44; 28, 6, 48), supplementary motor area (SMA: BA 6/8; -2, 24, 49), left inferior parietal lobule (IPL: BA 40; -32, -48, 41), and right intraparietal sulcus (IPS: BA 40; 44, -42, 50).The percentages of signal change in each ROI across the three conditions were calculated relative to control baseline (rest) by averaging the signal plateau. The radius of each ROI was 6mm. These data were submitted to two-way repeated measures ANOVA (condition x ROI). The main effects of ROI [$F(6,48)=6.440$, $P<0.001$] and interaction [$F(12,96)= 11.23$, $P<0.001$] were significant. The main effect of condition was not significant. On the basis of analysis of the interaction by Tukey's HSD, significant difference among the three conditions were found in the bilateral IFG, left PM, left IPL, and right IPS ($P<0.05$). In addition, the data in IFG, PM, and IPL/IPS were divided into two groups by the hemispheres and were submitted to two-way repeated measures ANOVA (condition x hemisphere). No significant effects of condition and hemisphere were found. Significant effect of interaction, however, found [$F(2,16)=79.57$, $P<0.001$]. From the result of multiple comparison test (Tukey's HSD: $P<0.05$), we found that the left hemisphere was strongly activated under the Word condition whereas the right hemisphere under the Within condition. Under the Cross condition, the signal intensity was intermediate between the Word and the Within condition.

Under the Word condition, we found dominant activation in the left IFG–IPL, although activated regions were generally the same for both the visual colors (Cross/Within) and verbal (Word) tasks. Although there have been previous studies addressing the possible influence of language on color memory at the behavioral level, our brain imaging study suggests that PL is surely employed when we memorize colors especially under the Cross condition. Furthermore, we investigated the involvement of PL and VSSP by analyzing signal changes in each ROI across the three conditions. Significant differences were found in the bilateral IFG, the left PM, the left IPL, and the right IPS. Considerable evidence of PL from neuroimaging studies and neurological patients has suggested that IPL, specifically the left supramarginal gyrus, subserving as a passive storage buffer, and frontal areas such as IFG and PM comprise the active rehearsal circuit, which is known to be involved in the preparation of active subvocal rehearsal [5]. It is assumed that the right IPS is a visual storage buffer, analogous to PL in the left, which is increasingly activated as the number of color patches increases [6]. Although a rehearsal process for color has not yet been clearly elucidated [7,8], considering that the ventral prefrontal region could subserve the buffer [9,10], the right IFG (BA 44 and related areas) would be expected to involve the right IPS as a buffer for visual color image. The right IFG activation uniquely observed under the Within condition might plausibly be considered recruitment of that area, instead of a verbal strategy in the left IFG, to retrieve visual colors under the Within condition. Another possibility is that the right IFG was related to visual attention. Previous study [11] of visual WM for color maintenance showed strong left hemispheric activation. Under the Within condition, demand on visual attention might be increased to hold two or more complicated color representations. It is difficult to investigate time-based functional segregation using the 2-back task, thus further study of the right IFG will be expected. On comparison of the Cross condition to the Within condition, memorizing colors across several categories strongly employed the left IFG and the left IPL, respectively. This suggests that an implicit verbal strategy was very effective when executing the 2-back task under the Cross condition. Colors within the same category, however, activated the right IFG instead of the left IFG and the left IPL, indicating that a visual strategy is more useful than a verbal strategy to achieve a good performance under the Within condition.

4 CONCLUSION

The present findings suggest that both PL and VSSP are employed depending on the property of the colors being memorized. Furthermore, colors across the categories increased the signal intensity toward the left IFG, whereas, to the contrary, colors within the same category increased the signal intensity toward the right IFG.

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Colour appearance reproduction from small to large Sizes

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ABSTRACT

An experiment was carried out to study the change of colour appearance between a small uniform patch and a large colour on a wall projected using a characterised data projector. Ten observers adjusted the projected light to match small colour patches presented in a viewing cabinet. The results showed that the projected large colours appear to be more colourful and lighter than the small uniform patches.

Keywords: psychophysical experiment, size effect, device characterisation.

1 INTRODUCTION

There is a need in industry to be able to accurately reproduce colours between different sizes. For example, in the paint industry, customers normally select colours from small colour patches in a shop and apply them in a variety of sizes of walls. It is often found that there is a large mismatch between the colour appearance of the desired colour based on the small patch in the shop and that painted on the wall. In the display and TV industries, the same problem occurs when an image needs to be accurately reproduced on displays with varying sizes.

Earlier work was conducted by Xiao *et al.* [1]. They conduct the experiment in a real room painted by real colours. Observers were asked to match room colours by adjusting colours on a CRT display and by selecting small size colours from a colour book. The results showed an increase of lightness and chroma for room colours.

The above problem triggered the motivation of the present study. The method used here was to project lights from a data projector onto a wall and to adjust its colour appearance to match a small uniform colour patch presented in a viewing cabinet. A group of 10 observers with normal colour vision participated in the experiment. The data projector was used because it is an easy and low-cost way to generate experimental colours. Software was implemented to control projected colours in terms of lightness, colourfulness and hue.

The experiment was designed to answer the following 3 questions:

- Can a projected light give a satisfactory match to a small size colour?
- Can the projected light on the wall surrounded by a dark border and a dim border give the same colour appearance?
- Is there a change of colour appearance due to the sizes of projection?

2 EXPERIMENTAL

2.1 Device Characterisation

A devise characterisation model[2] was first implemented to convert the device independent data (projector's RGB signals) into the device independent data (CIE tristimulus values), and vice versa.

A Minolta tele-spectroradiometer (TSR) was used to measure various colours on the projected colours. The projected colours on the wall are viewing condition dependent. They are affected by parameters such as the luminance of the peak white of projector, background and surround. Hence, the colour measurement was carried out at the same situation as the experiment.

Characterisation of the projector was based on the work of Berns[3]. The well known GOG (Gain-Offset-Gamma) model was implemented. It can be based upon either by measuring colours in terms of spectral radiance or tristimulus values. The relationship for the red channel can be expressed in equation (1).

$$L_{\lambda,r} = \begin{cases} L_{\lambda,r,max}\left[k_{g,r}\left[\frac{LUT_r(d_r)}{2^N-1}\right]+k_{0,r}\right]^{\gamma_r}; \\ \left[k_{g,r}\left[\frac{LUT_r(d_r)}{2^N-1}\right]+k_{0,r}\right]\geq 0 \\ 0; \left[k_{g,r}\left[\frac{LUT_r(d_r)}{2^N-1}\right]+k_{0,r}\right]<0 \end{cases} \quad (1)$$

where *LUT* represents the look-up-table, *N* is the number of bits in the digital-to-analogue converter (DAC), γ_r is an exponent accounting for the non-linearity between amplified video voltages and beam currents, constants $k_{g,r}$ and $k_{o,r}$ are referred to as the system *gain* and system *offset*, respectively. $L_{\lambda,r,max}$ defines the maximum spectral radiance of the red channel. The radiometric scalar R is defined as $L_{\lambda,r} = RL_{\lambda,r,max}$.

2.2 Experimental Setup

The experiment was conducted in a room with a size of 4 × 4 × 3 cubic meters. One side of the wall was used for colour projection. A software was developed for observers to adjust projected colours on the wall via CIELAB, L*, C* and hue attributes. The projector, observer and TSR were located about the same position with a distance of 3 meter from the wall. The TSR was used to measure[4] the projected colours by individual observers and the target colours presented in a viewing cabinet, which was placed between observer and the wall and had a viewing distance of 2 meters from the observer. The luminance level of the viewing cabinet was about 25 cd/m^2.

Ten observers matched fifteen target colours three times in each of the three viewing conditions, named ‘box’, ‘large’ and ‘small’, which are illustrated in Figures 1(a) to 1(c), respectively.

Each observer wore a helmet with a viewing field shown in Figure 1(a). The position of their head was fixed and could only view the large wall colour projected by the projector and the small physical colour presented in the cabinet. The ‘large’ viewing condition (Figure 2(b)) is the same as the ‘box’ condition except without the helmet. The difference between ‘large’ and ‘small’ conditions is the projected size on the wall. The latter size is about 25% of the former. There is a large difference of surround conditions between the ‘box’, and the ‘large’ and ‘small’ conditions. The former is much darker than the latter two due to the use of helmet.

The ages of observers were ranged between 20 and 30 years old. They were postgraduate students in the Department of Colour Science, University of Leeds, including four females and six males.

Each observer’s results in terms of RGB signals were first stored in a computer. They were then displayed and measured using the TSR. In addition, all target colours in the viewing cabinet were also measured using the TSR. The results were transformed to CIELAB values from the tristimulus values. (The reference white was set to the visual results of a white test colour projected on the wall.) The average results from all observers were used to represent overall panel results. The three sets of results corresponding to three viewing conditions together with the targeted colour in the viewing cabinet (named ‘cabinet’) were used for the subsequent data analysis.

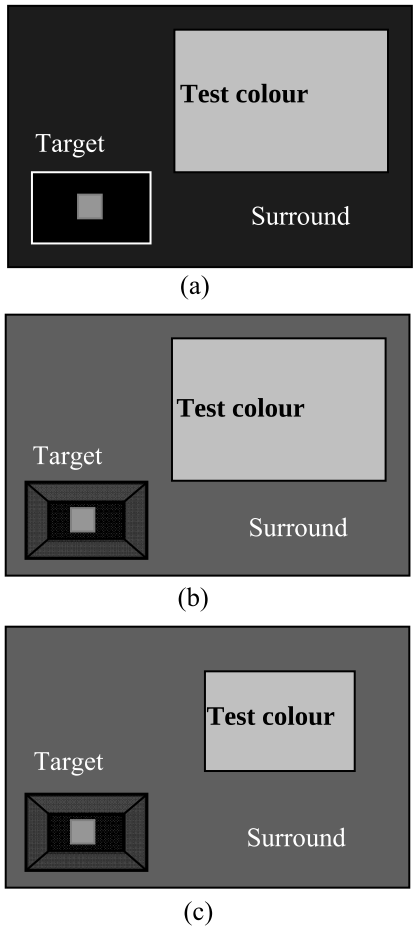

Figure 1 The 3 viewing conditions studied: a) ’box’, (b) ‘large’ and (c) ‘small’.

3 RESULTS AND DISCUSSION

The results are summarised in Figure 2 by plotting the visual results between ‘Box’ and ‘Cabinet’, ‘Large’ and ‘Cabinet’, ‘Small’ and ‘Cabinet’, ‘Box’ and ‘Large’, and ‘Large’ and ‘Small’ conditions. A 45° line is also drawn in Figure 2.

It can be seen in Figure 2 that the data points can be divided into two groups, those close to 45^o line and those well above 45° line. The former group includes the comparisons made between the ‘box’, and ‘large’ and ‘small’ conditions. The visual results in general agreed well between them. For all three attributes, L*, C* and hue angle.

Comparing the results between ‘cabinet’ and three viewing conditions (‘box’, ‘large’ and ‘small’), the results clearly showed that the projected large colours appear to be much brighter and more colourful than the small colours in the cabinet. However, there is hardly any change in hue.

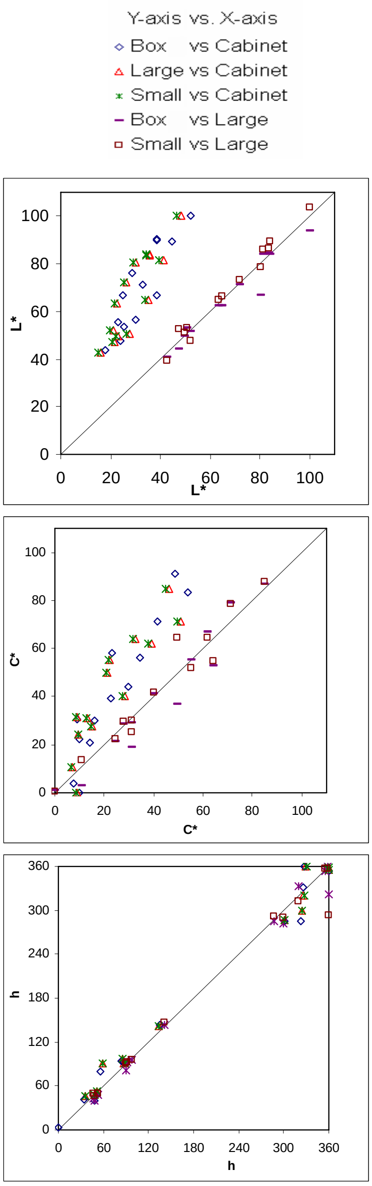

Figure 2 Comparing the visual results in terms of CIELAB L* (top), C* (middle) and hue angle (bottom). There are 5 comparisons in each diagram: between 'Box' and 'Cabinet', 'Large' and 'Cabinet', 'Small' and 'Cabinet', 'Box' and 'Large', and 'Large' and 'Small' conditions.

The results verified that the small target colour can be matched by the projected colour in a real room. The projected size ('large') and a ¼ size ('small') giving very similar results implies that typically a minimum of 70 by 62 cm on a wall should be sufficient to provide to paint customers to produce the same visual experience as the large wall, i.e. 162 by 120 cm^2.

Comparing the 'box' and 'large' conditions, the main difference is degree of adaptation due to surround. The former had a much darker surround than the latter. However, colour appearance is not affected by the surround conditions used.

Another way to look the results is to plot the data between a pair of results in CIELAB a*b* and L*C planes as shown in Figure 3(a) and 3(b), respectively. They showed the plots of the visual results between 'cabinet' and 'box', between 'cabinet' and 'large', and between 'box' and 'small', from top to boom respectively. Each of the 15 colours was plotted in vectors between the two conditions compared.

It can be seen that the patterns of colour shifts between three figures are all very similar. This again indicates a small difference between the visual results of the three viewing conditions studied. In L*C* planes, all vectors converge to the black point. This implies that all wall colours are lighter and more colourful than the target colours presented in the cabinet. In a*b* planes, it can be seen that all vectors converge towards the neutral origin. This strongly indicates almost no change in hue angle and large wall colours are more colourful than small target colours. Furthermore, there is a tendency that all vectors converge to a slightly yellowish neutral point. This could be caused by the size effect. Further study is required to clarify this shift.

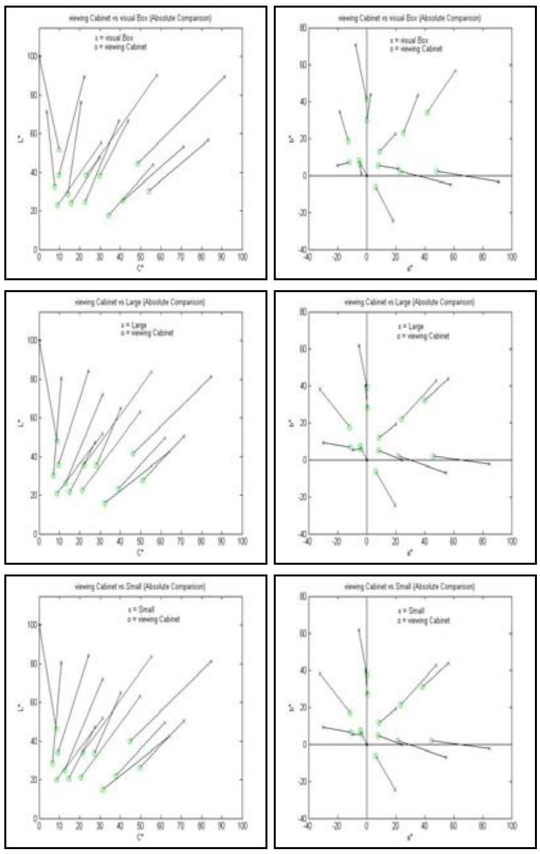

Figure 3 The colour shifts between the results from (top) 'box' and 'cabinet', (middle) 'large' and 'cabinet', and (bottom) 'small' and 'cabinet'. Each vector indicates the distance between the colour sample in the viewing cabinet (circle) and the colour in the three viewing conditions studied (cross).

The results from the present study were also compared with the earlier study by Xiao *et al.*[1]. Figure 4 shows comparisons of the results between the current work (left) and theirs (right).

Only the visual results from the 'large' condition were used to represent the present study because the viewing condition is similar to that used by Xiao *et al.* It can be seen that the trends are very similar, i.e. no difference in hue but an increase of lightness and chroma for small size colours is required to match large size colours. The magnitude of increase in C* values are similar in both experiments. However, the present results show a much larger increase of lightness than Xiao *et al's* study. This could be mainly caused by the surround conditions used. The latter experiment was conducted in a room with light in the ceiling. i.e. the wall was illuminated by the light. Hence, it had a much brighter surround than the present one.

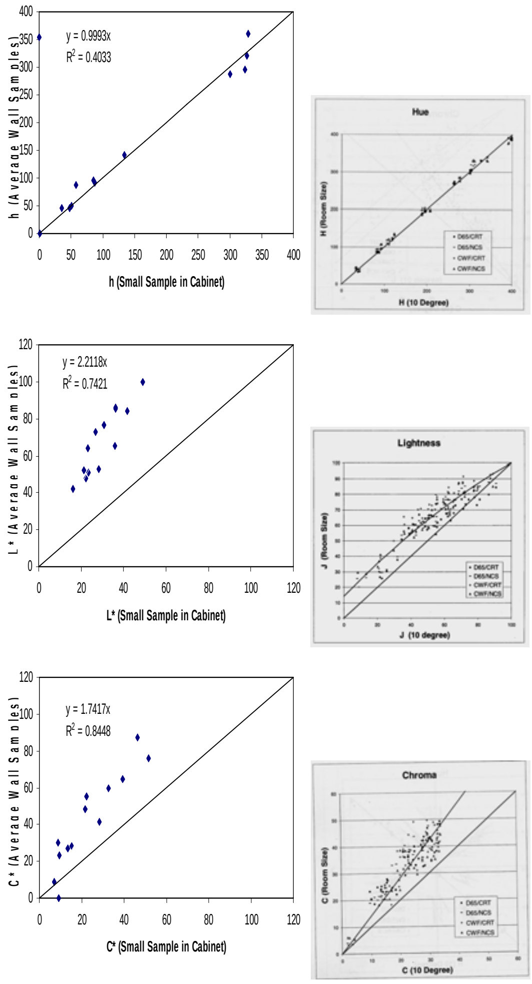

Figure 4 Current work results (left) vs. previous work results (right) to show size effect.

4 CONCLUSION

A psychophysical experiment was conducted to match small size physical samples in a viewing cabinet by the projected lights on a large wall. The results are summarized below:-

- A successful colour match can be achieved between small physical samples and large projected lights on a wall.
- Very similar results were found between the dark and dim surrounds used and between the two different projected sizes used.
- There is a need to increase lightness and chroma for small size colours to match large size colours. No change of hue is needed.
- The present results in general agreed well with those by Xiao *et al,* except a much larger lightness is required than theirs to match large colours. This is caused by the different surround conditions used.
- There is also a consistent shift of neutral point, i.e. the projected colour appears to be more bluish than the small physical samples.

ACKNOWLEDGMENTS

The authors would like to thank the State Scholarship Foundation (IKY) of Greece for the financial support.

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Investigation of Complementary Colour Harmony in CIELAB Colour Space

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ABSTRACT

This study is concerned with one aspect of colour harmony, the complementary relationships between colours. The relationships are most usually represented in colour wheels or hue circles such that opposite colours are assumed to be complementary. However, there is a lack of consistency if different colour wheels are compared. The primary focus of this work is to determine for each hue the optimal complementary hue using psychophysical experiments. The aim is to be able to define the complementary relationships between hues and ultimately to be able to produce a colour wheel that is specifically designed to represent these relationships. Experiments were conducted to ascertain the complementary relationships between hues. The null hypothesis was that opposite colours in CIELAB space would be optimally complementary, producing a maximal colour contrast. However, the experimental data showed systematic deviations from this hypothesis around the colour wheel. The results suggest that opposite relationships in CIELAB colour space do not accurately predict for complementary relationships. Of course, there are many different colour spaces from which we could attempt to predict complementary relationships. The results also indicated a curious asymmetry that merits further study.

INTRODUCTION

Applied researchers, colourists and artists (notably Munsell, Itten, and Ostwald) have long been interested in defining - and finding rules for - colour harmony [1-3]. This study is concerned with one aspect of colour harmony; that is, the complementary relationships between colours. Such relationships are most usually represented in colour wheels or hue circles and in such structures colours that are opposite to each other in the colour wheel are assumed to be complementary producing a maximal colour contrast [4-6]. However, there is a lack of consistency if different colour wheels are compared. For example, in colour wheels that represent colorant mixing, yellow is placed opposite to purple and orange is placed opposite to blue.

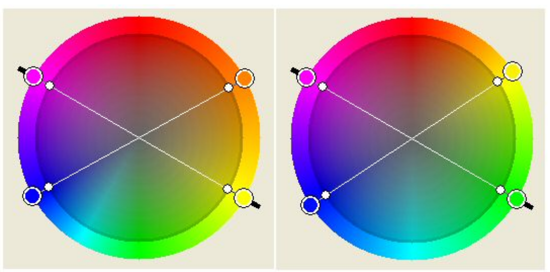

Figure 1: Colorant mixing (left) and visual (right) colour wheel show inconsistent complementary relationships**.**

In colour wheels that represent visual relationships, on the other hand, yellow is placed opposite to blue and green is placed opposite to purple (see Figure 1).

We may also consider colour spaces based upon properties of human vision such as CIELAB. In the CIELAB colour space yellow and blue are opposite each other (consistent with the right-hand part of Figure 1) and red and green are opposite each other (consistent with the left-hand part of Figure 1). We suggest that neither the colorant mixing wheels or the visual mixing wheels - nor indeed CIELAB – were specifically designed to represent complementary hue relationships. The primary focus of this work is to determine the optimal complementary for each hue using psychophysical experiments by asking observers to find a colour in a maximal contrast with another one. The aim is to be able to define the complementary relationships between hues and ultimately to be able to produce a colour wheel that is specifically designed to represent these relationships.

EXPERIMENTAL METHOD

A psychophysical experiment was carried out to investigate the complementary colour relationships for two-colour combinations. A "LACIE ELECTRON 19 blue IV" CRT with a

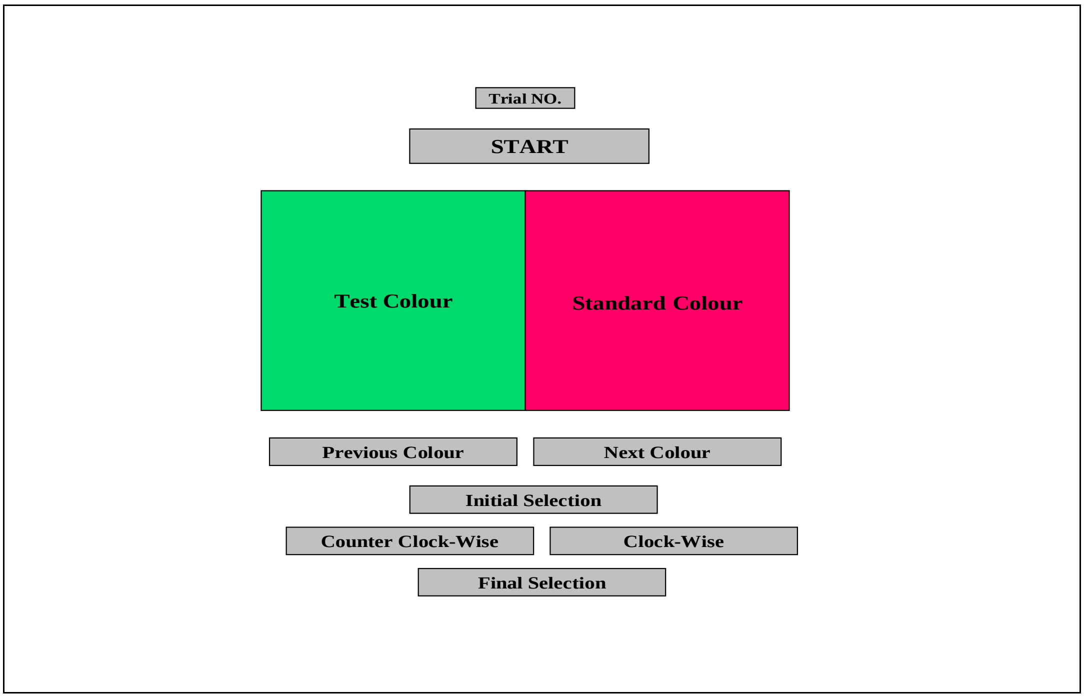

Figure 2 : The user interface used in the experiment

27.5cm × 37cm screen was used to display the colour patches. The stimuli were rectangles that measured 9.4 cm × 19.5 cm and contained two adjacent colours, whose common edge was vertical, displayed on a mid-grey background and viewed in a darkened room. All observers were asked to sit at a distance of 70 cm from the CRT. Measurements of the CRT were made using a Minolta CS-1000 telespectroradiometer and were used with the GOG model [8] to characterise the display so that colours of specific CIE coordinates could be displayed. The brightness and the contrast of the monitor were fixed at 81.3 and 80.0, respectively. Certain properties of the display unit (lack of channel independence and lack of spatial independence) were measured. The CIE colour difference between a measured white and the white predicted by an additive mix of the three primaries was 1.57. The colour difference between a white patch displayed on a black background and on a white background was 1.4. The measured values are typical for high-quality display devices.

In the psychophysical experiment (Figure 2) one of the colour patches was fixed (standard hue) and the hue of the other (test hue) could be varied by observers who were asked to vary the test hue until it was in maximal (hue) contrast to the standard hue. A total of twenty standard colours (evenly distributed around the hue circle at 18 degree intervals) were displayed randomly in turn. For each standard hue (H) the observers were asked to move around the whole colour circle in an unlimited range between 0 to 360 degrees (in steps of 18 degrees) in order to find the colour pair producing maximal colour contrast. The observer signified that they had found the optimal contrast by clicking on a button the screen and were then asked to fine-tune their selection by adjusting the test hue by intervals of 3.6 degrees. The reason for this two-part procedure was to enable the observers to freely choose any hue as the complementary colour (first part of the procedure) and yet do so with a fine level of precision (second part of the procedure).

Ten observers (including six females and four males with normal colour vision and different nationality in the age of 24 to 48) took part in the experiment. The lightness and chroma of all colours were fixed at L* = 52 and C* = 30. It was noted, of course, that not all CIELAB coordinates can be displayed on the RGB monitor because it has a limited gamut [7]. It was necessary to find a Lightness plane and a Chroma value that would result in the complete hue circle being within the gamut of the monitor. A MATLAB programme was written to find the largest hue circle (defined by an L* value and a C* values) that would be within the gamut of the display device and this is how the L* = 52 and C* = 30 parameters were arrived at. Figure 3 demonstrates the optimal hue circle with C* =30 (green circle) in comparison to that of C* = 34 (red circle) which is outside the gamut and C* = 25 (blue circle) which is inside the gamut. (The distortion in the shape of the hue circle with C* equal to 34 is due to producing the RGB values outside the range 0-255.)

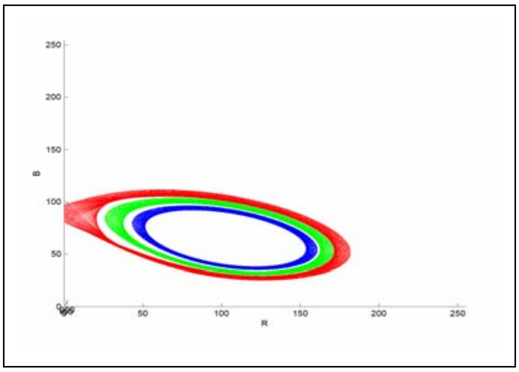

Figure 3a: Optimal Chroma Circle in comparison to the Monitor Gamut in R value vs. B value diagram

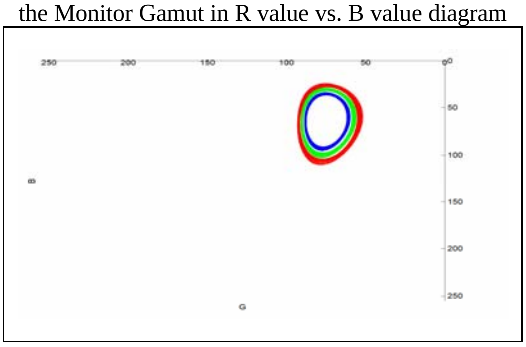

Figure 3b: Optimal Chroma Circle in comparison to the Monitor Gamut in G value vs. B value diagram

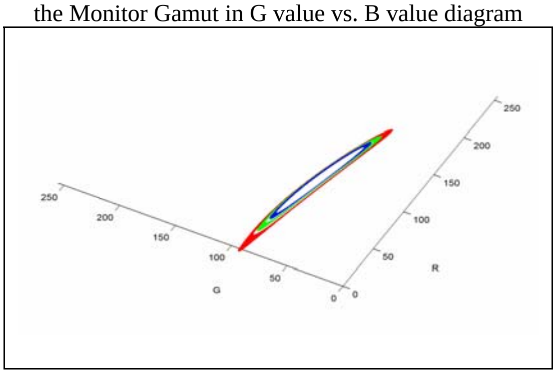

Figure 3c: Optimal Chroma Circle in comparison to the Monitor Gamut in R value vs. G value diagram

RESULTS

In Figure 4 the difference between the hue angle of the observers' preferred complementary hue from that of the CIELAB predicted values (the predicted hue for each standard hue H is 180-H) has been plotted. Note that if the deviations were all zero it would indicate that opposite colours in CIELAB space are optimally complementary. As shown in Figure 4, in some ranges of the standard hue (e.g. 306-72 and 162-252 degrees) the observers' colour selection was reasonably close to that predicted by opposite relations in CIELAB space (ΔE is less than 10). However, in the range of 90-150 and 260-300 degrees (corresponding to yellowish greens and blues) there are large differences between the selected and predicted colours. These departures appear to be significant and as demonstrated in Figure 5, the CIELAB colour difference between the predicted and the selected hues are greater than 10 CIELAB units. Notice that the change in sign of the differences that is seen in Figure 4 at around 180 degrees is simply a consequence of the way ΔH is calculated. The results would seem to indicate that opposite relationships in CIELAB do not accurately predict complementary relationships (at least not for all hues).

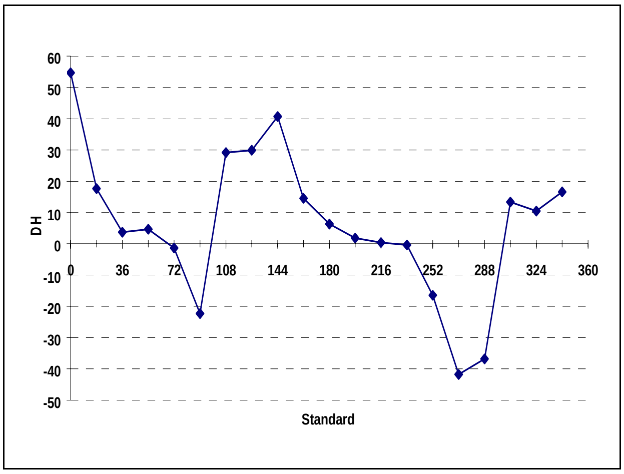

Figure 4: The Angle Difference between the selected test hue and the predicted test hue for each standard colour

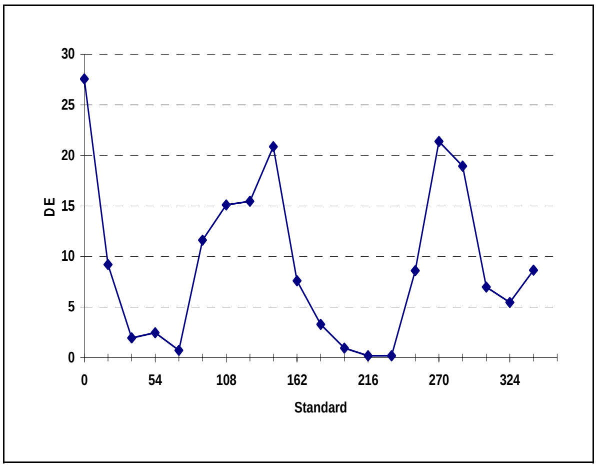

Figure 5: CIELAB Colour Difference between the selected and the opposite colours for each standard hue

For example, when the standard hue was 144 degrees the average contrasting hue chosen by the observers was 4.7; when the standard hue was 324 the average contrasting hue was 139.32. This is illustrated in Figure 6 where sRGB values have been calculated for these four colours and within the constraints of colour management should demonstrate the colour relationships. As shown in the Figure 6, one of the pair selections is consistent with the mixing colour wheel complementary relationship (144 and 4.7: green and pinkish red) and the other is consistent with the visual colour wheel relationship (324 and 154: green and purple). Figures 7 and 8 illustrate some additional pairs that also seem to support this dichotomous behaviour.

Figure 6 : The selected test colours for standard colour of 144 and its opposite colour (324)

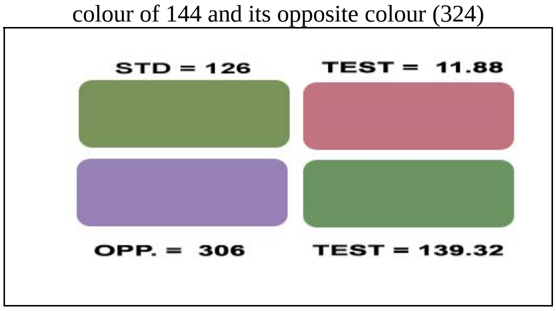

Figure 7 : The selected test colours for standard colour of 126 and its opposite colour (306)

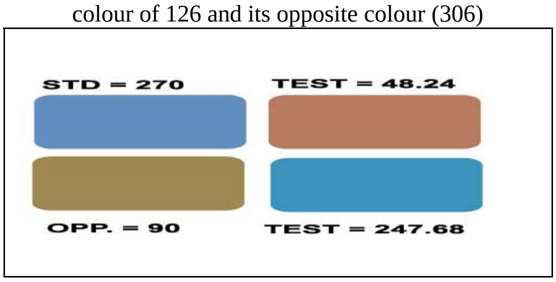

Figure 8 : The selected test colours for standard colour of 270 and its opposite colour (90)

However, the results need to be treated with caution because they also reveal an unusual asymmetry which is difficult to explain. For instance, in simple terms, when asked to find a colour that maximally contrasted with pinkish red observers consistently selected blue; however, when asked to do the same for that blue, observers consistently selected yellowish orange (Figure 9).

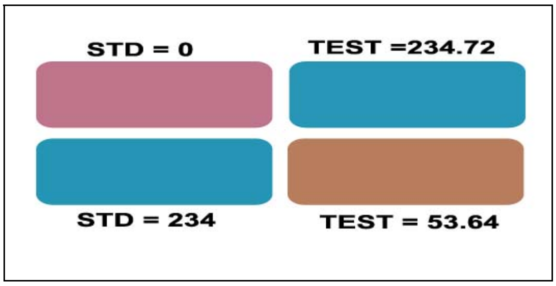

Figure 9 : Test colour selection for the same colour and different orientation

Having paid attention to the initial and final selections of the observers, there was generally an agreement between the observers' choices.

CONCLUSION

Experiments were conducted to ascertain the complementary relationships between hues (subject to the constraint of equal lightness and chroma). The null hypothesis was that opposite colours in CIELAB space would be optimally complementary which produce a maximal colour contrast between colours. However, the experimental data showed strong and consistent deviations from this hypothesis and the agreement of the observers do not support the hypothesis. Interestingly, the deviations gave some indication of a symmetric pattern in some parts of the colour circle. A curious asymmetry was revealed in the results. A weakness of the study is that the observers were instructed to select a test colour that maximally contrasted with the standard colour and we have assumed that this will provide information on complementary relationships. The reason that the words "complementary" and/or "harmony" were not used explicitly in the observer instructions was that these words have technical meanings (in the case of complementary) and various meanings (in the case of harmony) whereas most observers, we argue, understand what contrast means. However, it is possible that the asymmetrical results obtained are an artefact of syntax and understanding and further studies need to be carried to investigate this.

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Effect of Haze of Cataract Eyes to Color Perception of Elderlies

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ABSTRACT

When people become older it is inevitable to get cataract in their eyes and meet various new inconvenient situations about their visual perception. Change of color perception is one of them. It is caused by the yellowing of the crystalline lens, but more seriously by the haze of crystalline lens which desaturates all the color that they see. In the present paper we investigated the effect of the haze on desaturation by two experiments. Haze goggles with six different haze values were made to simulate different degree of cataract and used to judge color outdoors. In Experiment 1 the color of various objects such as tree leaves and signs at far distance was judged whether the color is perceived. With increase of haze value the colors gradually desaturated and finally faded out. The observers could not tell what colors they were. In Experiment 2 fourteen colored charts were used in stead of normal objects and the distance limit over which their colors became unperceivable was measured. The distance became shorter for heavier haze goggles because of desaturation of color of the test colored charts.

Keywords: cataract, haze, desaturation, color perception, elderlies

1 INTRODUCTION

The population ratio of aged to young people is increasing in many countries and the adjustment of the visual environment to suit the aged people is becoming an urgent subject. To achieve the adjustment the investigation of color perception of aged people is a first step and some researches have been reported in past meetings of the AIC[1-8)]. Obama et al. developed the cataract experiencing goggles to simulate the visual system of cataract aged people who began to feel visual inconveniences in their daily life[9)]. They investigated visual perception of 48 cataract patients who got cataract operation for one eye. They came to a conclusion that the visual perception of senile cataract eyes can be expressed by three elements, haze, brightness, and color, caused by the frosted crystalline lens, the overall decline of light transmittance, and the specific decline of transmittance at short wavelengths, respectively. The goggles were installed with these three elements. It was found in experiments using the goggles that the color perception of cataract eyes was influenced greatly by the opacity of the crystalline lens in such a way that all the colors were desaturated[10)]. The authors reasoned the desaturation to the environment light which enters the eyes from every direction of the outside and is scattered by the frosted crystalline lenses to fall on the entire retina. The environment light is white and thus it desaturates the color of any objects that the eyes are looking at.

In this paper the goggles with different degrees of haze were made and two experiments were conducted to investigate the effect of haze on the color desaturation. In Experiment 1 the color appearance of normal objects at far distance was judged with the goggles, and in Experiment 2 the distance limit for color perception was obtained for 14 colored charts with the goggles. This experiment was conducted in the outdoor also.

2 HAZE GOGGLES

Obama et al. employed a frosted plate for the cataract experiencing goggles. It was made by blasting glass powder onto the plate. By controlling the pressure of the blasting, number of blasting nozzles, and others, the haze value of the plate can be adjusted from low to high. Haze value is defined as the transmitting scattered light divided by the entire transmitting light. It is expressed by percentage. We made six goggles, G0, G1, G2, G3, G4, and G5, of different haze values, 0.1, 5.5, 13.4, 17.5, 23.8, and 25.5 %. The haze value almost linearly increases for the goggles. The goggle G3 is same as that of the cataract experiencing goggles and it represents the haze perception of cataract patients who just started feeling inconvenience in their daily life. No color filter was employed in these goggles. The goggles were made to have a clear plate at the left eye side. The color of the goggles frame was made clear as the frosted plate.

3 EXPERIMENT

3.1 Experiment 1: Color Perception of Outdoor Scene

The test targets that subjects observed with his/her right eye through the goggle were objects at various distances in the outdoor as seen in the first and second columns of Table 1. The measurement was conducted in a cloudy afternoon in Yokohama with the horizontal plane illuminance 2,000 lx at a clear space. Two subjects, KT (Japanese female, 41 years old) and MI (Japanese male, 73), participated in the experiment. The subject MI had IOL in both eyes after cataract operation. The subjects reported whether the color of the objects is seen when they looked outside from a window position of a residence.

3.2 Results of Color Perception

Results are shown in Table 1 by circles, triangles and exes. The circles indicate that both subjects responded with “Yes, I can see color”, exes “No, I can’t see color”, and triangles indicate that responses of two subjects disagreed. It is clear that the subjects could not see colors for already desaturated colors of leaves at very far distance when the degree of haze increased. The most significant result is exes for all goggles but G0 and G1 for yellow leaves seen against sky. Environment light heavily entered the goggle and the color of leaves became so much desaturated that the color was not seen at all.

It may not be serious for aged people when they can not enjoy beautiful color of scene, but is very serious when they can not discriminate traffic signs which utilize colors.

Table 1 Results of color appearance of objects with different haze goggles.

Distance	Test targets	G0	G1	G2	G3	G4	G5
Very far	Leaves colored in a mountain	○	○	○	×	×	×
Far	Yellow signboard	○	○	○	○	△	△
Far	Red signboard	○	○	○	△	×	×
Far	Green roof	○	○	○	○	△	×
Far	Brown roof	○	○	○	○	○	△
About 100m	Red signal for pedestrian	○	○	○	○	○	○
About 100m	Green t signal for pedestrian	○	○	○	○	△	△
Near	Red of no-parking sign	○	○	○	○	○	○
Near	Blue of no-parking sign	○	○	○	○	○	○
Near	Red small fruits	○	○	○	○	○	△
Near	Orange tangerine	○	○	○	○	○	○
Near	Blue water-pipe	○	○	○	○	○	○
Near	Yellow leaves against sky	○	○	×	×	×	×

3.3 Experiment 2: Distance limit for color perception of colored charts observed outdoors.

In this experiment we measured how far distance the color of colored charts can be recognized with goggles. We employed 14 colored charts for observation as summarized in Table 2. It appeared that some of charts were painted with fluorescent substance. Their chromaticity points are shown on the CIE xy chromaticity diagram in Fig. 1. Test charts of 1 through 10, shown by open squares and connected by a line, were chosen to cover hue and to represent typical color of Thailand. Their color names are written. The colors turned out to be vivid. So less saturated colors of 11 through 14 were added. They are shown by open circles and connected by another line. The size of the test chart was 20×20 cm^2.

Table 2 Color specifications of test charts.

No.	Color of charts	x	y	Y	L*
1	Yellow	0.431	0.480	72.4	87.9
2	Golden Yellow	0.464	0.450	57.5	80.1
3	Orange	0.554	0.401	28.2	60.0
4	Red	0.608	0.311	11.1	39.3
5	Pink	0.457	0.272	18.5	50.1
6	Purple	0.315	0.227	10.7	38.9
7	Blue	0.202	0.202	10.8	39.1
8	Sky Blue	0.185	0.252	23.3	55.4
9	Green	0.251	0.413	19.1	50.6
10	Yellow Green	0.345	0.527	36.6	67.2
11	Pale Yellow	0.375	0.430	76.9	90.2
12	Pale Pink	0.359	0.312	36.7	67.1
13	Blue Green	0.284	0.359	50.8	76.4
14	Deep Green	0.344	0.434	10.0	36.8

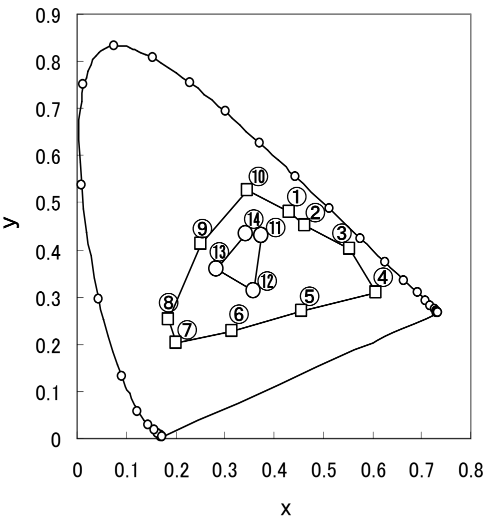

Fig. 1 Chromatic points of test charts.

A colored test chart was placed at the eye level in a shade of big trees planted at the edge of a large clear ground in Chulalongkorn University campus, Bangkok. An observer looked at the chart at various distance on the ground under the direct sunshine. The observer faced the sun so that the light from the sun directly hit the goggle. This was to maximize the effect of haze in the eye. He/she was not allowed to use a hat that might intercept the direct sun light. Only right eye was used. The task of the observer was to decide the distance from the test chart when its color became just indistinguishable. He walked back and forth on the ground along a fixed direction from the test chart until he found the distance. There was placed in the direction a rope of 100 m long with tags at every 5 m and the observer could measure the distance and wrote it down on a note.

The experiment was carried out in January and started at around 10 am on fine days without any clouds. The illuminance under the direct sun light varied depending on time, and was about from 50,000 to 90,000 lx. The illuminance in the shade under trees where the test chart was placed varied also from about 10,000 to 15,000 lx. One experimental session to complete measurement for 14 test charts took one to two hours and only one session was conducted with one person in one day. Three sessions were conducted with each observer on different days. Three observers, KT, MI and PP, participated in the experiment. The subjects KT and MI were the same persons as Experiment 1. The subject PP was a Thai female of 55 years old.

3.4 Results of distance limit

Results are shown for three subjects in Fig. 2. Along the abscissa the goggle is taken and along the ordinate the distance limit for recognition of color in m. Fourteen curves correspond to test charts. We repeated the measurement for three times and three, two or one experimental points were obtained for each goggle. In some case the distance limits were all within 100 m, but in some other case one or two distance limits went out beyond 100 m and not measurable. In this case the curve obtained within 100 m was used to estimate the shape of other one or two curves beyond 100 m, and the average was taken for three distance limits. The average curve obtained in this way has data points beyond 100 m, but the accuracy of the data points is not necessarily good. Dotted horizontal lines indicate 100 m.

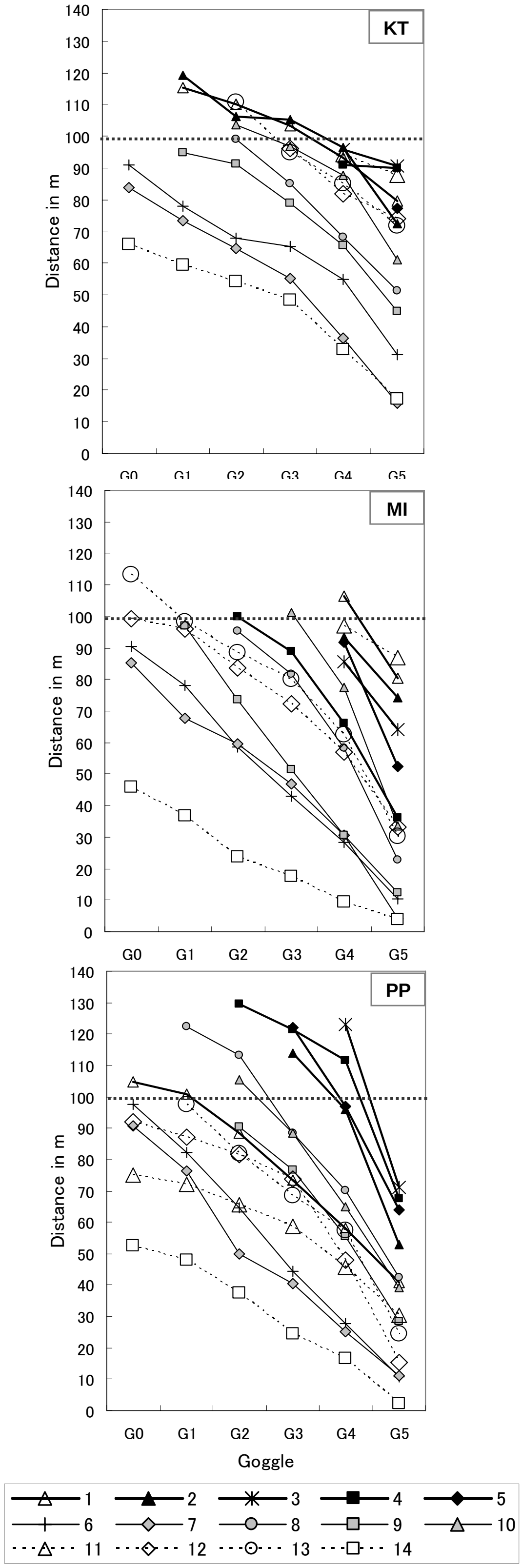

Fig. 2 Distance limit plotted for goggles. Symbols represent test charts. Sections correspond to subjects, KT, MI, and PP.

All curves have a similar shape. They decrease gradually for larger haze value of goggle. With the haze goggle the scene appears foggy and the color of test charts appears desaturated. When the observation distance is increased the color fades more and more, and finally at some distance the color completely fades out. When the observer changed to another goggle with a larger haze value, he/she had to come closer to the test patch in order to perceive its color again. The haze caused the color of test patches to desaturate and harder to recognize the color.

The vertical location of curves in Fig. 2 differs depending on the test patches. The higher curves indicate that the colors of the test patches were able to be perceived at far distances. They were test charts 3, orange, 2, golden yellow, and 5, pink. Those colors are vivid ones and/or bright ones. The lower curves indicate that the colors were hard to perceive at distance. They were test charts 14, deep green, 7, blue, and 6, purple. Those colors are all of low lightness.

4 DISCUSSION

The effect of haze installed in a goggle for color perception was investigated and we found that the larger the haze value the greater the desaturation of color. Objects at far distance in the outdoor became achromatic with goggle. The distance limit at which the color of test patches can be recognized became shorter for larger haze value. To derive a formula to get the distance limit as a function of haze value, we averaged six curves of purple, blue and deep green of KT and MI in Fig. 2. Those curves were complete up to 100 m. Figure 3 plots the averaged distance limit for haze value by circles. Except for G5 they approximately lie on a straight line and we can get a formula, DL(m) = -1.83×HV(%) + D0(m).

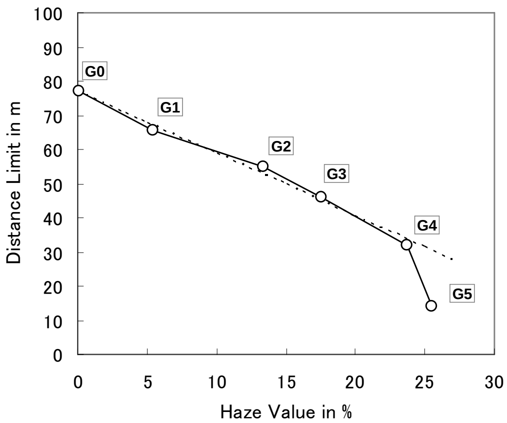

Fig. 3 Distance limit estimated from haze value.

HV represents haze value and D0 the distance limit without haze. It is shown by a straight dotted line. With the haze value 17.5% which is same as the cataract experiencing goggles, the DL becomes 45.1 m. D0 in the averaged curve is 77.1 m and the distance limit is shortened down to 58 %. It is firstly important to choose proper color that can be perceived at a far distance. , but we should not forget the distance limit for perceiving the color by elderlies becomes much shorter.

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Effect of Environment Light on Color Appearance with the Cataract Experiencing Goggles

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ABSTRACT

The effect of environment light on the color appearance with the cataract experiencing goggles was investigated. The experimental booth was composed of two rooms, the subject room and the test room separated by a wall with a window. The subjects observed a colored test patch placed in the test room through the window. In one case the effect of illuminance of the subject room was investigated by changing to 0, 30, 100, 200 and 300 lx. The chromaticness judged by the elementary color naming method decreased while the surrounding light increased. In another case the effect of the window size was investigated by changing to W1, W2, and W3. Even when the environment light from the subject room was zero, the desaturation took place when the window was enlarged to W3. This implies that the light in the test room started to work as the environment light with that window size.

Keywords: cataract, color perception, elder lies, desaturation

1 INTRODUCTION

Most of elderly people have problem of cataract which affect their visual ability. Obama et al. developed the cataract experiencing goggles to simulate the color perception of the senile cataract1). The goggles were composed of a haze filter and a colored filter, the former to represent the frosted crystalline lens and the latter the lowered light transmittance of the lens. The color perception with the goggles has been intensely investigated to understand the color perception of elderly people and one important result was obtained2-4). It is obviously supposed that the colored filter changes the color appearance of blue and green objects, but it was found unexpectedly that the haze filter also changed the color appearance of objects of any color in a way to desaturate it. The investigators concluded that the desaturation was caused by the environment light coming to the goggles from every direction. The light is scattered into the eyes to cover the retinal image of objects that the eyes are looking at. The environment light is normally white and the color of the objects is desaturated.

The objective of this study is to investigate the effect of environment light on the color appearance by changing the strength of the environment light. The same cataract experiencing goggles developed by Obama et al. were used.

2 APARATUS

The experimental booth was composed of two rooms, the subject room and the test room, separated by a wall with a window of variable sizes. Both rooms were furnished with the same achromatic wall paper of about N9.3 with some texture. The subject room had the size of 1.3 m long, 1 m wide and 2.4 m high and various objects were decorated on the shelf attached to the front wall such as a doll, real green leaves, and artificial flowers as seen at the bottom and at the top of Fig. 1. At the center in the figure there is a rectangular frame. This is the window through which a subject saw the test room. The window size was changed by replacing pieces of plywood on which apertures of 19 x 19, 60 x 60 and 270 mm x 320 mm were opened respectively. They were denoted as W1, W2, and W3, respectively.

Figure 1 Subject's view of the subject room and the test room.

The test room was also decorated by various objects such as a dog doll, real plant, towel, and others. The window in Fig. 1 is the case of W3, the largest window employed. Other window sizes W2 and W1 are indicated by squares with black lines. There is a placed test patch of the size 8 x 8 cm^2 locating at the center of the window seen by the subject. It was attached at the top of a supporting arm which was temporally fixed on a shelf. The arm was easily changed to another one when the test patch was to be changed. With the smallest window, W1 the test patch was larger than the window and the test patch filled the window completely. With W2 the window was slightly larger than the test patch. With W3 the subject could see wide range of the test room as seen in Fig. 1. Test patches were judged by one eye.

Both subject and test rooms were illuminated by fluorescent lamps of daylight type and their illuminance was controlled by light controllers, separately. The illuminance of the test room was kept constant at 200 lx measured vertically in front of the test patch. The illuminance of the subject room was adjusted to one of 5 levels; 0, 30, 100, 200 and 300 lx. It was measured by an illuminometer placed on the shelf.

Four different colors were employed for the test patch, 5R4/10, 5Y7/10, 5G5/10 and 5B4/9.

3 EXPERIMENTAL AIM

With the window W1 only the test patch is seen and no other area of the test room is seen by the subject. If the illuminance of the subject room is zero, no environment light comes in the subject eye and the desaturation of color of the test patch should not take place. The subject should see the original color of the test patch. If, however, the illuminance of the subject room is gradually increased, the environment light increases, and the color of the test patch should gradually appear desaturated. This is one point to investigate in the present experiment.

Next, the window becomes larger. Even when the subject room is dark and the environment light coming from the subject room is zero, if the window is made larger, the environment light may come to the eye from the test room. The desaturation of color of test patch may take place. The second point to investigate in the present experiment is to see whether the desaturation takes place for widening the window.

4 EXPERIMNET

The illuminance of the subject room was set at one of five levels, 0, 30, 100, 200 and 300 lx. The subject was asked to sit in the subject room and look around to adapt himself to the room illumination for few minutes. He was instructed to wear the cataract experiencing goggles, to look at the test patch, with one eye, through the window and to judge the color appearance of the color patch by the elementary color naming. Four test patches, R, G, Y, B, were randomly presented and three windows W1, W2, and W3 were also randomly employed. The experiment was repeated without goggles to complete one experimental session. Five such sessions were carried out for each illumination of the subject room.

Four subjects participated in the experiment, PH (Thai female, 26 years old, KT (Japanese female, 41, PP (Thai female, 55) and MI (Japanese male, 73). The subject MI had IOL in both eyes after cataract operation.

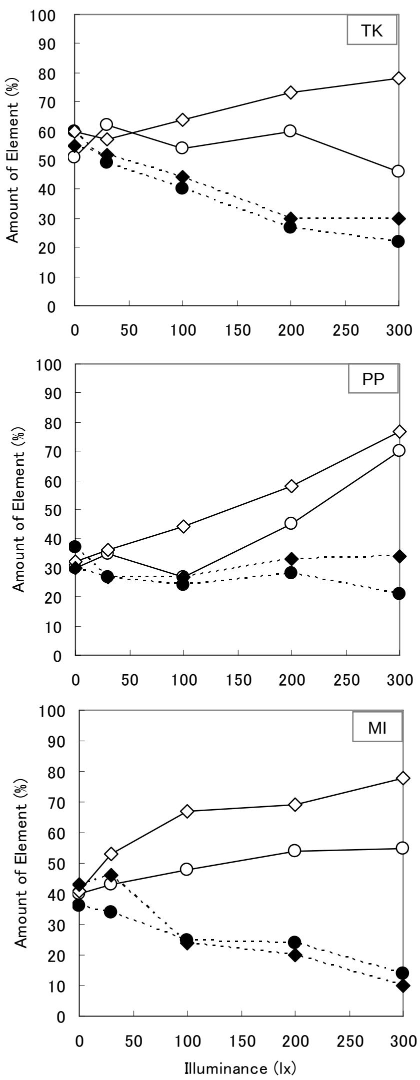

Figure 2 Effect of illuminance on chromaticness.

5 RESULTS

5.1 Effect of the illuminance

The results of the red and green test patches are shown in Fig. 2 for three subjects, KT, PP, and MI. The window size was the smallest one, W1. Those from PH are not shown here as her criterion for assessing the color appearance was different from these three subjects and gave quite different results. The abscissa gives the illuminance of the subject room and the ordinate the percentage of chromatic element. Circles are for the red test patch and diamonds for green. The open symbols show the results without the goggles and filled ones with goggles.

When the subject room was dark, without illumination, the amount of chromatic element was about the same with or without the goggles. Even with the cataract experiencing goggles the subjects could see the color of test patches clearly and equally as the case of no goggles. But when the room illuminance was increased the amounts of chromatic element went separatly. The difference between without-goggles condition and with-goggles condition became larger. The color appearance of the test patches relatively desaturated with the goggles compared to the without-goggles condition for higher illuminance. The change of absolute amount of element differed among subjects. In the case of KT the chromatic element stayed relatively constant for the increase of room illuminance without the goggles, but in the case of PP it increased rather rapidly. The subject MI showed the in-between result. But the relative decrease of the chromatic element with the goggles compared to without goggles was found for all the subjects. The goggles affected the color of test patches in the way to desaturate more with higher room illuminance. This is to confirm our first prediction given in experimental aim.

5.2 Effect of the window size

The effect of the window size on the color appearance is shown in Fig. 3. Here again, the results of only red and green test patches are given, circles for red and diamonds for green. The illuminance of the subject room is 0 lx. The abscissa represents the window size, 1, 2 and 3 corresponding to W1, W2, and W3. The ordinate gives the amount of chromaticness. Open symbols are from the result of with-goggles condition and filled symbols are from the result of without-goggles condition. We see that open symbols and filled symbols are about same in % at W1 and they slightly separate at W2, but not much. They greatly separate at W3 and filled symbols dropped down. There should be no effect of the environment light of the subject room and if there is any, it must be the effect from the test room. The environment light became effective when the window was enlarging to W3.

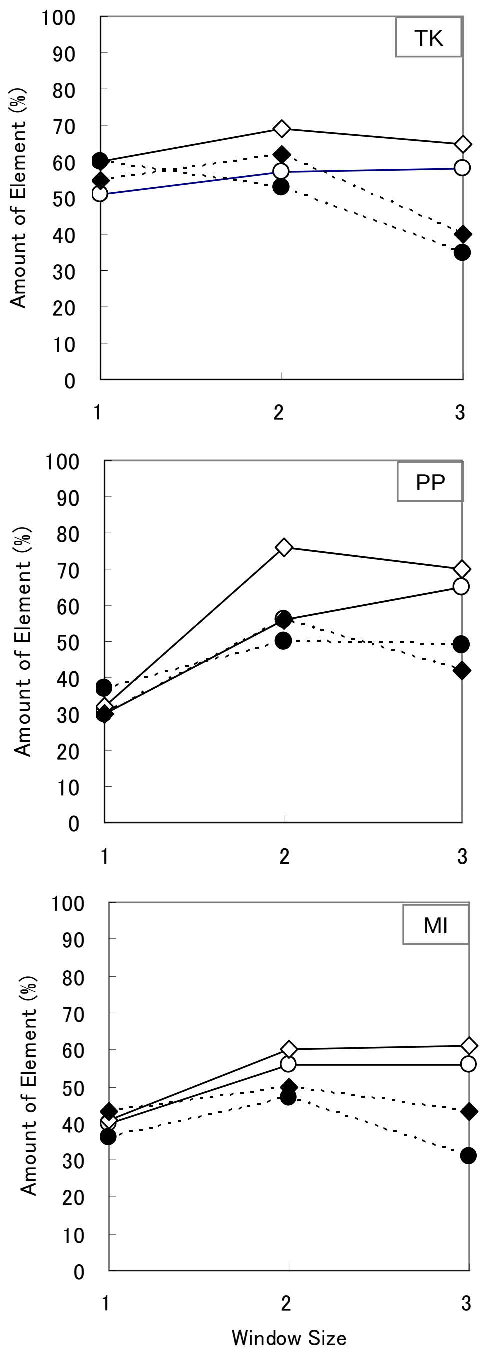

Figure 3 Effect of window size on chromaticness.

6 DISCUSSION

It was shown that the chromaticness deceased when the illuminance of the subject room was increased to imply the desaturation of color appearance. This phenomenon was clear with the window W1, when subjects could see only the test patch in the test room. According to the results, we suggest that if elderly people wish to see real color of objects the objects may be presented to them without the environment light. Such tool has been already developed by Shinoda et al.5) and the tool is placed in some department stores.

When the objects are only illuminated without the environment light as in the case of Shinoda et al.'s tool, it becomes a problem how widely the objects should be illuminated. Our second investigation where the window size was change, it was shown that up to W2 there was not much effect of the environment light. Through this window some objects of the test room were seen around the test patch. This indicates that the illumination area for the objects to be observed may be a little bit wider than the area of the object.

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Effects of natural and unnatural spatial structure on color constancy

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ABSTRACT

The recognition of spatial structure is important for color constancy because we cannot identify the color of an object under different illuminations without knowing which space it is in and how the space is illuminated. To show the importance of natural structure of environment to color constancy, it was investigated how color appearance was affected by an unnatural viewing condition where a spatial structure was distorted. Observers were judged color of a test patch placed in the center of a small room illuminated by white or reddish lights. In a natural viewing condition an observer saw the room(s) through a viewing window, whereas in an unnatural viewing condition the scene structure was jumbled by a kaleidoscope-type viewing box. Results showed that the degree of color constancy was decreased in the unnatural viewing condition, suggesting that naturalness and spatial factors play an important role in color constancy under a complex environment.

Keywords: Color appearance, Color constancy, illumination, Naturalness

1 INTRODUCTION

Color constancy has been studied by many researches in many years. It is often explained by mechanisms in lower levels of visual process such as an adaptation of photoreceptor on the retina and adaptation to the averaged color of a visual field. We, however, still do not have the consensus of the mechanisms. The degree of constancy differed depending on researches. This is most likely due to the difference of experimental environments. A study using nearly natural environment showed high degree[1] and that using a simple stimulus like Mondrian pattern on a monitor showed poor color constancy[2]. It also has found that the degree of color constancy decreased when a photograph was jumbled[3]. These results lead us an assumption that color constancy is not a low-level mechanism but much higher one and influenced by the naturalness of an environment. In other words, natural environment is necessary for color constancy.

The recognition of spatial structure is important for having a stable color appearance because we cannot identify the color of an object under different illuminations without knowing which space the object is placed and how the space is illuminated. In natural environments with three-dimensional structure, we have no difficulty on recognizing objects' color since we can recognize a space and illumination.

What happens if we are thrown into an unnatural environment? We might not be able to construct those recognitions correctly and fail to have good color constancy.

In this study we examine how color constancy is affected by an unnatural viewing condition where its spatial structure was distorted. It is predicted that the degree of color constancy decreased in the unnatural viewing condition due to the lack of naturalness.

2 EXPERIMENT

2.1 Apparatus

An experimental booth was built as shown in Figure 1. Size of the booth was 150 cm wide, 300 cm deep and 210 cm high. The booth consisted of two rooms arranged in depth and connected with a window; a back and a front room, and a dark space where an observer stayed and saw the rooms trough a viewing box installed on a wall facing the front room. Many objects with various colors were placed on both rooms to simulate a natural indoor environment. The back and front room were illuminated by fluorescent lamps with correlated color temperature of 5000 K (Toshiba FLR40S·N-SDL/M·A·NU, Ra 90) and 3000 K (FLR40S·L-EDL/M·A·NU, Ra 95), respectively. Illuminance was set at 500 lx on a desk at 70 cm high just below the test patches for color judgments (T_b, T_f) in both rooms.

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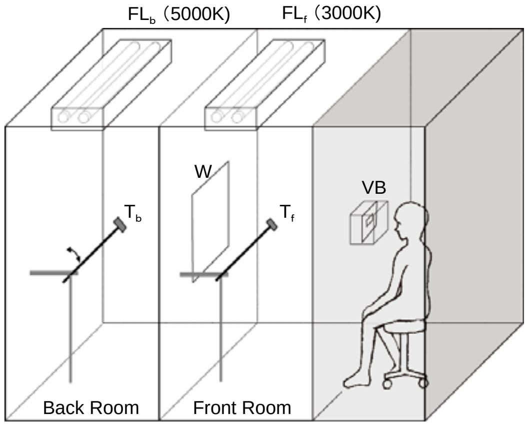

Figure 1 Scheme of an experimental booth. FLb, FLf, lamps at back and front room; Tb, Tf, test patches; VB, Viewing box; W, window between back and front room.

An observer saw the inside of the rooms through a viewing box and judged the color of a test patch which was supported by a black pole and placed in the center of either the back or the front room at the height of 115 cm. A viewing box with a rectangular aperture was used in the natural viewing condition. In the unnatural viewing condition it was replaced by a box with a kaleidoscope made of three rectangular mirrors of 25 x 60 mm that are the same size arranged in an equilateral triangle. The spatial structure of an observer's view was jumbled due to reflections from the mirrors. The test patch and its adjacent surround was the same as the natural viewing condition since the aperture of the kaleidoscope was aligned with the patch. The field of view and the averaged color of the visual field were roughly the same in both conditions. The observer viewed the rooms binocularly in the natural viewing condition and monocularly in the unnatural viewing condition.

Figure 2 shows the examples of a view from the observer. In 1-room condition (a), the window between the back and the front room (W in Fig. 1) was covered by a board with the same wall paper as that on the other walls so that the observer only saw the front room. In 2-rooms condition (b), the window was open and he/she saw both rooms at the same time. The natural and the unnatural viewing condition (c) were tested for both 1-room and 2-rooms conditions.

Test patches prepared for judgments covered a range of Munsell notation from 7.5YR5/3.0 to 5PB5/8 via N5 with 0.25 Chroma steps. Their chromaticity coordinates measured by spectroradiometer (Minolta CS-1000) from the position of an observer are shown in Figure 3. They vary approximately along the black body locus. Luminance of the test patches were approximately the same and about 60 cd/m^2. To make the visual angle of test patches 2 degree, 7 cm and 3 cm square patches were used in the back and the front room, respectively.

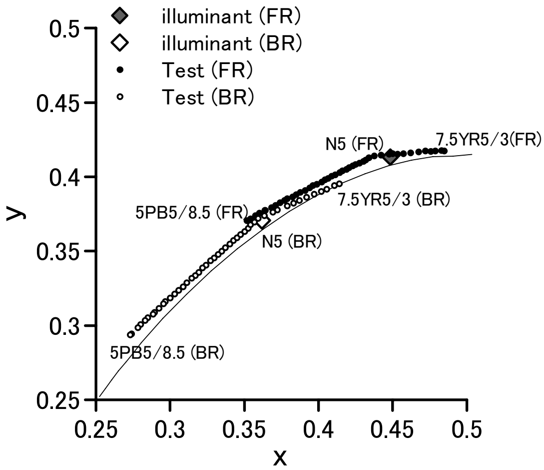

Figure 3 CIE1931 chromaticity coordinates of test patches with a range of 7.5YR5/0.25~3.0, N5, 5PB5/0.25~8 (circles) in front room (FR) and back room (BR). Diamond shows illuminant of each room. Thin curve indicates black body locus.

(a) (b) (c)

Figure 2 Examples of view from an observer. (a) 1-room condition (under natural viewing condition) (b) 2-rooms condition (under natural viewing condition) (c) Unnatural viewing condition at 2-rooms condition.

2.2 Procedure

An experimenter changed test patches one by one. The observer judged the color of each test patch by answering one or two hues out of Red, Green, Blue and Yellow. A series of test patches were tested and a color where the judgment changed from Y, R, or YR to B, G or BG was considered as a neutral perception point. This simplified color naming method was reasonable since the series of test patches changed along the black body locus shifting the color from YR to B.

One session consisted of judgments for test patches at the front room under 1-room condition, and at the back and the front room under 2-rooms condition. The natural and the unnatural viewing condition. The natural and the unnatural viewing conditions were tested for the three room conditions, respectively. The order of conditions tested was randomized in each session and each observer. Experiments were conducted by a method of adjustment for 12 observers. An observer made a judgment just once for each condition. Detailed data was also obtained from two observers by a method of constant stimuli. In this case, five test patches were judged five times each in each condition during one session and five sessions were conducted for each observer.

3 RESULTS AND DISCUSSION

Figure 4 shows results from 12 observers on CIE xy diagram. In the results of 1-room condition (a) neutral points of the natural and the unnatural condition are overlapped each other. They are close to the illuminant color of the front room which means color constancy was high in both viewing conditions. This suggests that the color of illumination can be recognized even if the spatial structure is jumbled in the case of an environment with a single illumination.

The results of the front room at 2-rooms condition (b) differed in the viewing conditions. Mean neutral point of the unnatural viewing condition (open triangle) is further from the illuminant color of the front room than that of the natural viewing condition (filled triangle). This means that the degree of color constancy for the front room degreased in the unnatural viewing condition. However, those differences are smaller than expected, mainly because the neutral perception point at the front room is shifted even in the natural viewing condition. This issue will be discussed later.

In the case of the back room (c), mean neutral points of both viewing conditions are overlapped and stay close to the illuminant color of the back room which means the degree of color constancy is high in both viewing conditions.

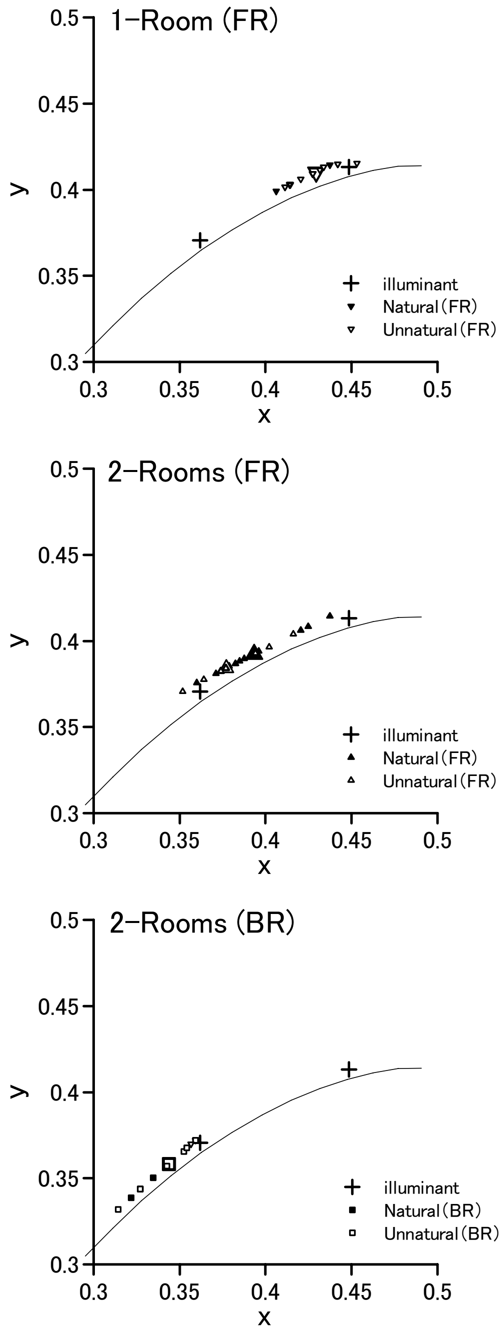

Figure 4 Results from 12 observers. (a) Front room in 1-room condition. (b) Front room in 2-room condition. (c) Back room in 2-rooms condition. Filled and open symbols indicate natural and unnatural viewing condition. Small symbols are individual neutral points and their means are shown by large symbols.

Although the individual difference of neutral points is large as shown by small symbols in each graph, the overall trend was the same in most observers. The variation was large in the front room at 2-rooms condition, suggesting the difficulty and unstableness of color judgments particularly in this condition.

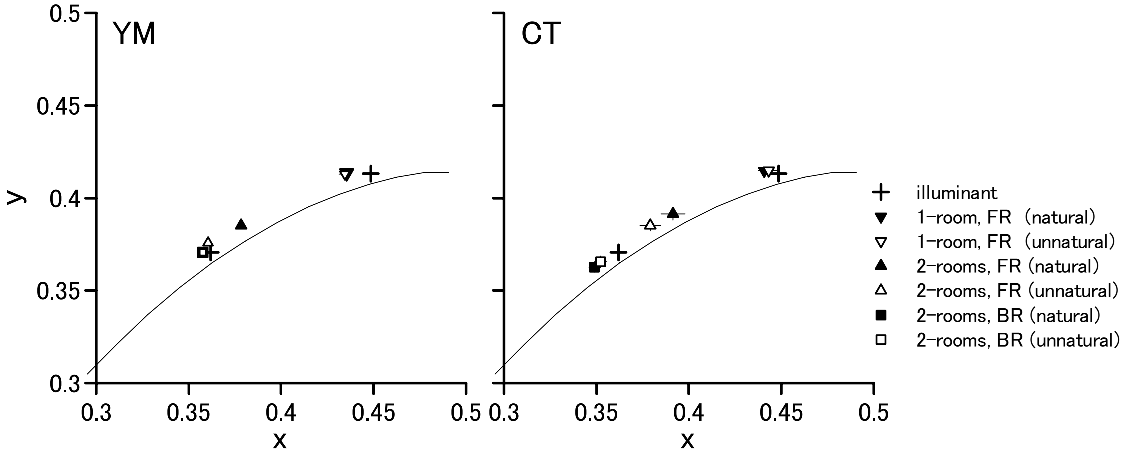

Figure 5 Results from observer YM and CT on xy chromaticity diagram. Filled and open symbols indicate natural and unnatural viewing condition, respectively. Standard deviations are shown by error bars. Inverted triangles, front room in 1-room condition; triangles, front room in 2-room condition; squares, back room in 2-rooms condition.

Figure 5 shows the results from two observers. The mean of five sessions is shown in each condition. Each symbol has error bars indicating standard deviation, but most of them are smaller than symbols, showing the reliability of judgments. Both observes showed similar trend to the results shown in Figure 4.

It is interesting that the difference between observers especially large in the neutral points of the front room at 2-room condition. The neutral point of YM under the unnatural condition is close to the illuminant color of the back room, or no color constancy and it also very close to the neutral point of the back room. This suggests that it was hard to locate the position of the test patches either in the back or in the front room and those colors were judged mainly based on the immediate background (i.e., the wall of the back room). In the case of CT, the neutral point of the front room is closer to that of the back room, but the shift is smaller than YM. The large individual difference in this particular condition implies that the color appearance under a complex environment tend to become unstable.

It should be mentioned that the neutral perception point at the front room is shifted even in the natural viewing condition. This shows that the back room largely influenced the neutral perception in the front room. Although the reason of the large influence is not clear at the present moment, there are some possibilities. One of them is the simultaneous color contrast effect. It has been reported that a local effect still existed even if a target and its surround was separated in depth[4]. However, there also have been shown that the color appearance was not determined only by local contrast[1]. In the present research the local contrast may have influenced to the color judgment. It may possible that the separation of two rooms was not enough because of the large window and bright background, or the white illumination gave a strong cue.

We did not find the difference between the natural and the unnatural viewing condition under 1-room condition in the present study. This suggests that there were rich cues of illumination color available even if the spatial structure is distorted. However, there is a possibility that the distortion by the kaleidoscope was not enough since it was able to recognize objects in each particle on the kaleidoscope image.

Although there are a number of factors should be examined further, the difference between the natural and the unnatural viewing condition in 2-rooms condition show that color appearance is influenced by an unnatural spatial structure.

To conclude, our results suggest that naturalness and spatial factors play important roles on color constancy in at least a complex environment, and should be considered when the color appearance of an object is predicted.

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A probability summation model for temporal characteristics of color discrimination threshold

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ABSTRACT

Psychophysical experiments of color discrimination give us important data for evaluating color difference formula as well as investigating the mechanism of human color vision. It is known that the post-receptoral channels, the luminance channel and two opponent-color channels contribute to the color discrimination threshold. In the present study, we measured color discrimination threshold using test stimuli of various temporal frequency profiles. Contrast thresholds were measured on the (L+M, S) plane, the (L, M) plane and on the (L-M, S) plane in the cone excitation space. Experimental results show that the threshold elevation due to the temporal frequency changes independently to the direction of L+M, L-M, and S. We apply the probability summation model to explain the effect of temporal frequency on the color discrimination threshold.

Keywords: Color discrimination, Contrast threshold, Probability summation model, Color vision, Contrast sensitivity function

1 INTRODUCTION

Color discrimination is one of the most important factors in human color vision. Color discrimination thresholds provide information of response properties of cones and post-receptoral channels, the luminance and the two opponent-color channels. Color discrimination depends on the experimental conditions such as spatiotemporal characteristics, background colors for adaptation as well as the stimulus color itself[1)-7)]. It is necessary to take into account these factors to evaluate color differences for general purposes. The analysis of quantitative influence of these factors to the color discrimination is also important to investigate the mechanisms of color vision.

In the present study, we focus on temporal characteristics of color discrimination. Temporal contrast sensitivity functions were studied by many researchers[8)-12)]. It is well known that the luminance temporal CSFs show band-path characteristics and the isoluminance chromatic temporal CSFs reveal low-path characteristics. We measure the discrimination on the (L+M, S) plane, the (L, M) plane and on the (L-M, S) plane in the cone excitation space and examine the temporal characteristics of the luminance (L+M) channel, red-green opponent color channel (L-M), and the channel deviated by the S-cone. We apply the probability summation model[13)] to explain the independency of these three channels and the effect of temporal frequency on the color discrimination threshold.

2 EXPERIMENT

We measured color discrimination thresholds using several temporal profiles of test the stimulus presentation.

2.1 Apparatus

The stimuli were generated on a color monitor (EIZO FlexScan T566) controlled by a Cambridge Research Systems VSG 2/4 graphics board, with 15-bit luminance-calibrated lookup tables. Each phosphor output was calibrated with a spectroradiometer (Minolta CS-100) and photometer (Cambridge Research System OptiCAL).

2.2 Stimuli

The spatial arrangement of the stimulus was shown in Figure 1. The observer saw a temporally modulated test stimulus with a color slightly different from a background color for adaptation. The test field was at the center of a 6º square background and consisted of a two by two array of four 1º squares with a 0.1º black separation. We employed the equal energy white in luminance of 34.5 cd/m^2 as a background stimulus. The test stimulus was modulated with sine Gabor profile with each temporal frequency of 1, 4, 8, and 16 Hz.

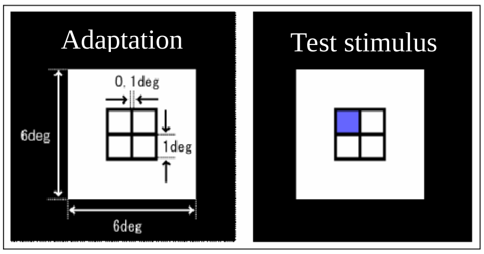

Figure1. Schematic view of the test stimulus.

Increment or decrement stimuli were presented on three planes: the (L+M, S) plane, the (L, M) plane and the (L-M, S) plane, in the cone excitation space. The excitations of L-, M- S-cones are calculated with the cone spectral sensitivity functions derived by Smith and Pokorny[14]. We defined the cone excitation values, L, M, S so that $L+M$ is equal to the luminance and L:M:S = 2:1:3 for the equal energy white. Consequently, the amount of L-2M is assumed to correspond to the red/green color opponent component. Contrast of the test stimulus was defined by the following equation,

$$C = \left[\left(\frac{\Delta L}{L} \right)^2 + \left(\frac{\Delta M}{M} \right)^2 + \left(\frac{\Delta S}{S} \right)^2 \right]^{1/2} \qquad (1)$$

where L, M, and S is cone excitation value of the L-, M-, and S-cone of the background color, respectively, and ΔL, ΔM, and ΔS is the increment or decrement cone excitation value of each cone.

2.3 Procedure

Before the trial start, observer adapted to the background field for one minute. Test was presented at one of four panes with the other three unchanged. The observer's task was to report which of the four panes contained the test stimulus. The test stimulus contrast changed following the observer's response by a typical, one-up-one-down staircase procedure.

2.4 Observers and viewing condition

The experiment was done in a dark room and the monitor screen was viewed binocularly at 50 cm distance with natural pupils. Four observers participated to the experiment. All observers had normal trichromats checked with the Ishihara pseudochromatic plates and Farnworth-Munsell 100-Hue test.

3 RESULTS

Thresholds obtained by the experiment were plotted on three planes: the luminance vs. S-cone excitation, the red/green vs. S-cone excitation, and the luminance vs. red/green plane in the cone contrast space.

3.1 The (S, L+M) plane

Figure 2 shows the thresholds for 1, 4, 8 and 16 Hz plotted on the (S, L+M) plane obtained from the observer TN. The threshold elevation due to the change of temporal frequency seems to be independent to the direction of change of the luminance and that of the S cone excitation except for 1 Hz. As expected by the temporal characteristics of the contrast sensitivity function of the luminance channel and the yellow-blue opponent color channel, the threshold in the direction of luminance is smaller than those of the direction of the S cone excitation at the high temporal frequency. On the other hand, at the low temporal frequency, the threshold of the S-cone direction is getting small rather than the luminance channel.

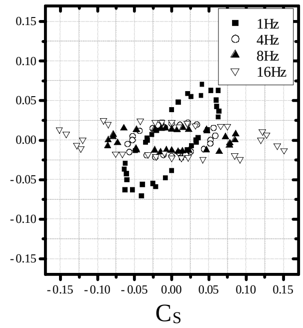

Figure 2. Contrast thresholds on the S-cone vs. luminance plane for the observer TN.

3.2 The (L-M, S) plane

Figure 3 shows the thresholds for 1, 4, 8 and 16 Hz plotted on the (L-M, S) plane obtained from the observer HU. Here again, the threshold elevation due to the change of temporal frequency seems to be independent to the direction of the red/green opponent color channel and that of the S-cone excitation. Thresholds elevate with increasing temporal frequency in both S-cone and red/green direction.

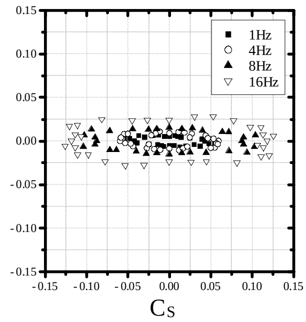

Figure 3. Contrast thresholds on the (S, L-2M) plane for the observer HU.

3.3 The (L, M) plane

Figure 4 shows the thresholds for 1, 4, 8 and 16 Hz plotted on the (L, M) plane obtained from the observer MO. In this plane, the direction of 45º roughly corresponds to the luminance change, and – 45º to the change of red/green opponent color direction. The independency between the luminance channel and thee red/green channel is observed in Figure 4. At a low temporal frequency, 1 Hz, threshold contour elongated to the direction of luminance channel. In contrast, at a high temporal frequency, 16 Hz, threshold elevated to the direction of red/green opponent channel.

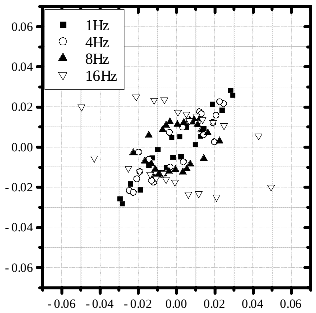

Figure 4. Contrast thresholds on the (L, M) plane for the observer MO.

4 DISCUSSION

We apply the probability summation model expressed in the following equation to explain the effect of temporal frequency on the color discrimination threshold.

$$\left[\frac{1}{T_{\mathrm{LUM}}}\left(W_{\mathrm{LUM,S}}C_{\mathrm{S}}+W_{\mathrm{LUM,LUM}}C_{\mathrm{LUM}}\right)\right]^{\beta} + \left[\frac{1}{T_{\mathrm{YB}}}\left(W_{\mathrm{YB,S}}C_{\mathrm{S}}+W_{\mathrm{YB,LUM}}C_{\mathrm{LUM}}\right)\right]^{\beta} = 1 \qquad (2)$$

In this equation, T_{LUM} and T_{YB} is the threshold coefficient for the luminance channel and the yellow-blue opponent color channels, respectively. $W_{\mathrm{X,Y}}$s are weighting coefficients of Y axis in the graph to determine the direction of X channel. β is the degree of the probability summation. Weighting coefficient of the luminance channel W_{LUM} depended on the temporal frequency of test stimulus presentation. Weighting coefficient of the yellow/blue opponent color channel was determined from the experimental data for the lowest temporal frequency, 1 Hz. The curves shown in Figure 5 are predicted by the probability summation model, where β=4 is adopted. The prediction seems to be quite well.

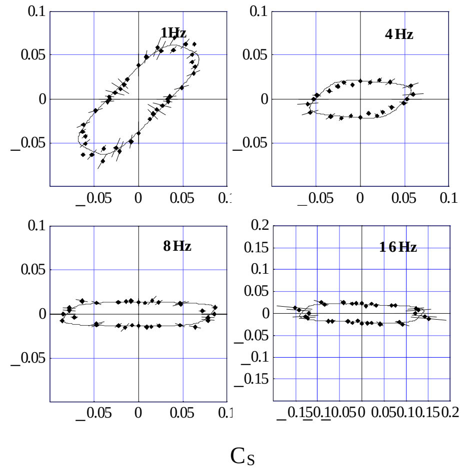

Figure 5. Contrast threshold curves on the (L+M, S) plane predicted by the probability summation model.

The equations of probability summation among the red/green opponent channel and the yellow/blue channel is described as the equations (3). In this equation, we assume that no contribution of S-cone to the red/green opponent color channel. Weighting coefficient of the yellow/blue opponent color channel, W_{YB} was determined from the experimental threshold contour for each temporal frequency. Predicted contrast threshold curves are shown in Figure 6.

$$\left[\frac{C_{\mathrm{L\text{-}2M}}}{T_{\mathrm{RG}}}\right]^{\beta} + \left[\frac{1}{T_{\mathrm{YB}}}\left(W_{\mathrm{YB,S}}C_{\mathrm{S}}+W_{\mathrm{YB,L\text{-}2M}}C_{\mathrm{L\text{-}2M}}\right)\right]^{\beta} = 1 \qquad (3)$$

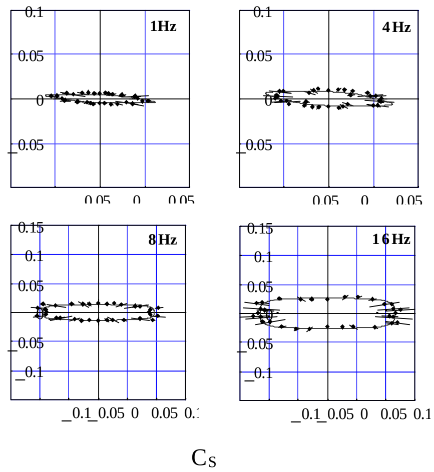

Figure 6. Contrast threshold curves on the (S, L-2M) plane predicted by the probability summation model.

The probability summation among the luminance channel and the red/green opponent color channel is described in the equation (4).

W_{LUM} and W_{RG} are determined from the experimental data of 16 Hz and 1 Hz, respectively. Predicted contrast threshold curves are shown in Figure 7.

$$\left[\frac{1}{T_{\mathrm{LUM}}}\left(W_{\mathrm{LUM,\,L}}\frac{\Lambda L}{L}+W_{\mathrm{LUM,\,M}}\frac{\Lambda M}{M}\right)\right]^{\beta}+\left[\frac{1}{T_{\mathrm{RG}}}\left(W_{\mathrm{RG,\,L}}\frac{\Lambda L}{L}+W_{\mathrm{RG,\,M}}\frac{\Lambda M}{M}\right)\right]^{\beta}=1 \qquad (4)$$

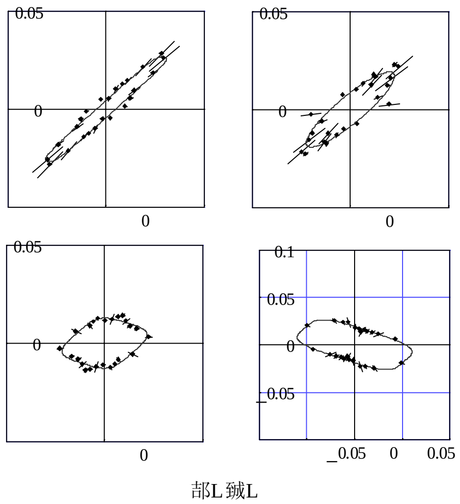

Figure 7. Contrast threshold curves on the (L, M) plane predicted by the probability summation model.

5 CONCLUSION

Contrast thresholds of test stimulus presentation for various temporal frequencies were measured on the (L+M, S) plane, the (L, M) plane and on the (L-M, S) plane in the cone excitation space. The threshold change due to the temporal frequency was obtained independently to the direction of luminance, red/green opponent color channel, and S-cone excitation. The temporal characteristics of the color discrimination was well predicted by a model assuming probability summation among independent channels in the post-receptoral stage.

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Illumination Estimation via Non-Negative Matrix Factorization

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ABSTRACT

The problem of illumination estimation for colour constancy and automatic white balancing of digital color imagery can be viewed as the separation of the image into illumination and reflectance components. We propose using nonnegative matrix factorization with sparseness constraints (NMFsc) to separate the components. Since illumination and reflectance are combined multiplicatively, the first step is to move to the logarithm domain so that the components are additive. The image data is then organized as a matrix to be factored into nonnegative components. Sparseness constraints imposed on the resulting factors help distinguish illumination from reflectance. Experiments on a large set of real images demonstrate accuracy that is competitive with other illumination-estimation algorithms. One advantage of the NMFsc approach is that, unlike statistics- or learning-based approaches, it requires no calibration or training.

Keywords: Color Constancy, Non-Negative Matrix Factorization, Automatic White Balancing

1. INTRODUCTION

A new approach to illumination estimation for color constancy and automatic white balancing is presented based on the technique of nonnegative matrix factorization with sparseness constraints (NMFsc). In essence, the logarithm of the input color image is viewed as a matrix to be factored into independent components. The resulting components represent the scene's illumination and the reflectance. The nonnegative constraint on the factorization is important because illumination and reflectance are both nonnegative physical quantities. The sparseness constraints---illumination is non-sparse, reflectance is sparse---guide the factorization to obtain an illumination component that is relatively constant across the scene, while allowing the reflectance component to vary. Experiments on a large data set of real images show that both methods are competitive with existing illumination estimation methods.

One advantage of the NMFsc illumination method is that like a few other methods[1-4], it avoids the training step required by the many methods that rely on image statistics[5-9] or finite-dimensional models of spectra[10].

For a particular pixel in a color image, the RGB sensor response is defined by the model in Equation (1). Let $E(\lambda)$ and $S(\lambda)$ be the illumination spectral power distribution and matte surface reflectance function respectively, let $R_k(\lambda)$ be the sensor sensitivity function for a colour channel k, then the model can be defined as

$$p_k = \int E(\lambda)S(\lambda)R_k(\lambda) \qquad k = R,G,B. \quad (1)$$

Assuming the camera has narrowband spectral sensitivity functions that can be modelled by a Dirac delta function, Equation (1) simplifies to:

$$p_k = E(\lambda_k)S(\lambda_k) \qquad k = R,G,B. \quad (2)$$

By taking logarithm on both sides of the Equation (2), we have

$$\log(p_k) = \log[E(\lambda_k)] + \log[S(\lambda_k)],\ k = R,G,B. \quad (3)$$

This has the advantage that the non-linear multiplicative combination of the illumination and reflectance becomes linear.

For an image or image subwindow arranged as a vector, Equation (2) yields

$$\mathbf{I} = \mathbf{E} \circ \mathbf{S}, \quad (4)$$

where **I** is a 2D image, and **E** and **S** are the illumination and surface reflectance images, respectively. The operator ∘ denotes element-wise multiplication. Applying logarithms again, we have

$$\log \mathbf{I} = \log \mathbf{E} + \log \mathbf{S}. \quad (5)$$

Here, log **E** is the illumination term, and log **S** is the reflectance term. They correspond to the

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"illumination image" and "reflectance image" in log space.

Generally, illumination is relatively constant across an image, while the reflectance varies. The reflectance image in log space can be further decomposed and represented as a weighted linear combination of "feature" reflectances.

$$\log \mathbf{S} = \sum_{i=1}^{M} \mathbf{F}_i h_i , \qquad (6)$$

where $\mathbf{F}_i$ are independent reflectance features and h_i are the weighting coefficients. In order to be independent, these features need to be "non-overlapping," which means that most entries of the vectors are zeros, and the non-zero entries appear at distinct locations. These non-overlapping, sparse features can be thought of as building blocks from which the image is constructed. Therefore, in log space, by Equation (5) and (6), the image can be represented in terms of the illumination and M surface features as

$$\log \mathbf{I} = \log \mathbf{E} + \sum_{i=1}^{M} \mathbf{F}_i h_i \qquad (7)$$

Since we expect the illumination to vary slowly across an image, log **E** should be a non-sparse vector. On the other hand, the reflectance term log **S** should be a sparse vector. Ideally, the feature vectors $\mathbf{F}_i$ should be sparse enough that there is no overlap between them so that they are completely independent features.

2. ESTIMATING ILLUMINATION USING NMFSC

Non-negative matrix factorization creates a non-negative approximation for a given set of input data that represents the data in terms of a linear combination of non-negative basis features[11]. In the context of color imagery, we will use it to represent the log image data in terms of a linear combination of log illumination and log reflectance.

Let us assume that the data consists of T measurements of N non-negative scalar variables. Denoting the (N-dimensional) measurement vectors by $\mathbf{v}^t$ ($t = 1, . . . ,T$), a linear approximation of each data vector is given by

$$\mathbf{v}^t \approx \sum_{i=1}^{M} \mathbf{w}_i h_i = \mathbf{W}\mathbf{h}^t , \qquad (8)$$

where **W** is an $N \times M$ matrix containing the basis vectors $\mathbf{w}_i$ as its columns, and $\mathbf{h}^t$ is the vector of coefficients h_i. Arranging vectors $\mathbf{v}^t$ as columns of an $N\times T$ matrix **V**, we have

$$\mathbf{V} \approx \mathbf{W}\mathbf{H} , \qquad (9)$$

where each column of **H** contains the coefficient vector $\mathbf{h}^t$ corresponding to the measurement vector $\mathbf{v}^t$. Written in this form, it becomes apparent that this linear data representation is simply a factorization of the data matrix. Principal component analysis, independent component analysis, vector quantization, and non-negative matrix factorization can all be viewed as matrix factorization methods, with different choices of objective functions or constraints. Whereas PCA and ICA do not restrict the signs of the entries of **W** and **H**, NMF requires all entries of both matrices to be non-negative, which means that the data is described in terms of additive components only.

The concept of 'sparse coding' refers to a representational scheme where only a few units are used to represent typical data vectors[12]. In effect, this implies that the majority of units take values close to zero, with only a few having significantly non-zero values.

Hoyer[12] adopts a sparseness measure based on the relationship between the *L1* norm and the *L2* norm defined as

$$s(\mathbf{x}) = \frac{\sqrt{n} - \frac{\Sigma |x_i|}{\sqrt{\Sigma x_i^2}}}{\sqrt{n} - 1} , \qquad (10)$$

where N is the dimensionality of x. $\Sigma |x_i|$ is the *L1* norm, and $\sqrt{\Sigma x_i^2}$ is the *L2* norm. This function evaluates to unity if and only if **x** contains a single non-zero component, and takes a value of zero if and only if all components are equal. It also interpolates smoothly between the two extremes.

Generally, an image will contain multiple surface reflectance features, so when subwindow sample blocks are drawn from the image, each block should contain some subset of those features. NMFsc provides a way to identify a set of basis vectors to represent these surface reflectance features plus a single illumination feature. Since each subwindow is described by using strictly additive positive components, it is a linear combination of those feature vectors.

The imaging model in Equation (7) and NMFsc in Equation (8) have parallel structure, so that the imaging model can be reformatted in terms of an NMF approximation:

$$\mathbf{v}^t \approx \sum_{i=0}^{M} \mathbf{w}_i h_i = \mathbf{w}_0 h_0 + \sum_{i=1}^{M} \mathbf{w}_i h_i$$
$$= \log \mathbf{E} + \sum_{i=1}^{M} \mathbf{F}_i h_i \qquad (11)$$

In this case, $\mathbf{v}^t$ corresponds to $\log \mathbf{I}$ in Equation (7) and represents the data from one of the image blocks. Since $\mathbf{w}_0 h_0$ takes the role of $\log \mathbf{E}$, the basis vector $\mathbf{w}_0$ is the "illumination" basis with weighting factor h_0. M represents the number of features present in the data. Since $\sum_{i=1}^{M} \mathbf{w}_i h_i$ takes the role of $\sum_{i=1}^{M} \mathbf{F}_i h_i$, the basis vectors $\mathbf{w}_i$ are the feature reflectance basis vectors with weighting factors h_i. The weighting factors determine how strongly the corresponding feature reflectances should appear in this image block. For instance, if h_i equals to zero, it means the feature is absent from this block; if h_i is large, it means the feature is strongly visible in this sample block.

By taking T sample sub-windows from the image and constructing the data matrix **V**, where the log RGB channels of each block are appended and stored as a column, we can then use NMFsc to solve for the basis matrix, **W,** and thereby obtain the illumination basis vector and the feature reflectance basis vectors. In other words, NMFsc decomposes **V** into the illumination and reflectance components that are the key to color constancy and automatic white balancing.

Equation (7) is a purely additive model, which means NMF is an appropriate approach to solving for the basis. All basis vectors, including the feature reflectance images (the "building blocks"), along with the illumination image, are required to be non-negative. This requires the input data matrix **V** to be non-negative too. The model is applied to the logarithm of the original image data, so there is the possibility of both positive and negative values. Simply scaling the original image data to (0,1] ensures that all pixel values in log space will be negative or zero. Since the coefficient matrix **H** is always non-negative, we negate both **V** and **W** to make everything completely non-negative.

NMFsc allows the sparseness for each basis vector to be controlled individually. In our model, the illumination basis vector is supposed to be non-sparse, making its components relatively similar, while the reflectance basis vectors are supposed to be sparse. In addition, with NMFsc the sparseness of each portion of a single basis vector can be controlled separately. This feature is important because in the formulation the RGB components needed to be packed into one vector. If a small sparseness value is set for the vector as a whole then the illumination basis will be similar across all the RGB channels, collectively leading to grey as the illumination estimate. To avoid this problem, the sparseness of the illumination basis vector needs to be controlled individually for the R, G, and B segments of the vector. In other words, the illumination vector must be divided into three segments and the same sparseness applied to each. For the reflectance basis vectors, a very sparse vector means that most of the entries are zeros. This property of high sparseness allows the reflectance basis vectors to be orthogonal and independent.

Hence, NMFsc is an approach for solving the illumination-reflectance model globally, in that the factorization aims to minimize the objective functions based on the data matrix that includes all three channels. This is an advantage over those methods that estimate the illumination and reflectance for each colour component independently.

The proposed algorithm based on Equation (9) using the NMFsc approach is:

1. Scale the input image values to (0,1]
2. Take N sample blocks from the image
3. Take the logarithm of the RGB values in these blocks.
4. For the data from each block, concatenate the color channels into a vector.
5. Suppose there are M different surfaces appearing in N blocks (M<N)
   - 5.1. Apply NMFsc to find M+1 basis vectors
   - 5.2. Set the sparseness constraint of the 1st basis close to 0 since it represents the illumination
   - 5.3. Set sparseness constraints of the 2nd to (M+1)th bases close to 1 since they represent the surface features
6. Antilog the illumination basis
7. The average R, G, B from the channels of the antilog of the illumination basis yields the RGB color of the scene illumination.

The parameter M represents the number of feature reflectances assumed to be present in the input image; however, the correct value of M is unknown and could differ from image to image. Experimentally, we found that fixing M at 5 for all images worked well.

In the above development, an image was assume to contain multiple reflectance features. An image contains M feature reflectances with at least one feature appearing in each image subwindow. Data was collected from multiple subwindows to form the data matrix for NMFsc. However, instead of M reflectance features, suppose that we describe the scene as a single more complex reflectance feature under a single illumination and apply NMFsc. In this case, there is only one subwindow—the entire image—and there will be only a single reflectance basis vector.

Equation (9) with $M = 1$ combined with Equation (6) becomes

$$\mathbf{v}^t \approx \sum_{i=0}^{1} \mathbf{w}_i h_i = \mathbf{w}_0 h_0 + \mathbf{w}_1 h_1$$

$$= \log \mathbf{E} + \log \mathbf{S} \qquad (12)$$

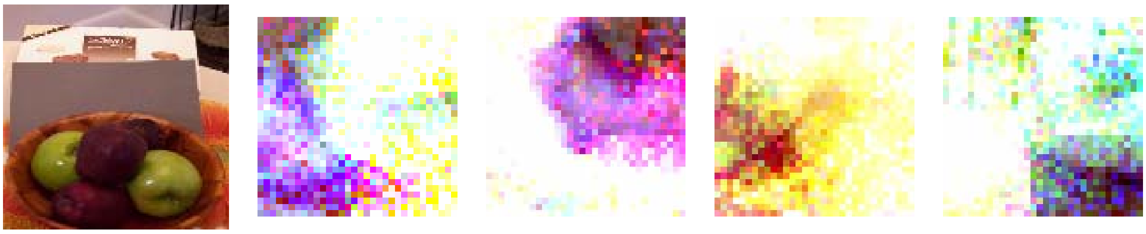
Here again, $\mathbf{w}_0 h_0 = \log \mathbf{E}$ so the basis vector $\mathbf{w}_0$ is the "illumination" basis with weighting factor h_0. Similarly, $\mathbf{w}_1 h_1 = \log \mathbf{S}$ so the basis vector $\mathbf{w}_1$ is the feature reflectance basis vector with weighting factor h_1. The goal in Equation (12) is to split the input color image into an illumination component and reflectance component in log space. How NMFsc does the split depends on the choice of sparseness constraints for the two components.

Since NMFsc should return two basis vectors $\mathbf{w}_1$ and $\mathbf{w}_2$, it requires an input data matrix of at least two columns. Rather than taking two distinct sample subwindows as the input data, we construct the data matrix $\mathbf{V}$ with two identical columns. Each column is a vectorized version of the full input image. It is no longer necessary to estimate the parameter M because in this case it always equals 1. Note also, that whereas the location of each pixel matters in the multiple-reflectance model, location has no effect in the single-reflectance model.

3. EXPERIMENTS

The NMFsc illumination estimation method is evaluated on a number of different image databases. Both the multiple-reflectance-feature reflectance and single-reflectance-feature approaches are tested.

The first set of tests is with multiple features. Figure 1 gives an example.



(a) (b) (c) (d) (e)

Figure 1. The reflectance basis vectors (contrast enhanced for visualization) based on the multiple-feature reflectance model: (a) 128x128 input image ; (b)-(e) are the reflectances basis vectors F_i using 32x32 subwindows.

Table 1. Comparison of NMFsc to SoG, Max RGB, Grayworld performance. The results involve testing on the large natural image dataset, with no real-data training required. Errors are reported in terms of both the RMS angular chromaticity and distance error measures.

Method	Angular Degrees			Distance($\times 10^2$)		
	Mean	RMS	Max	Mean	RMS	Max
GW	7.69	9.38	42.28	5.97	7.47	38.33
SoG	7.50	8.93	34.52	5.50	6.57	27.67
MAX RGB	9.99	11.76	27.42	7.24	8.60	21.72
NMFsc (M = 5)	7.66	8.96	34.79	5.59	6.57	26.99
NMFsc (M = 1)	6.82	8.15	38.27	5.11	6.18	32.74

NMFsc is applied with $M = 4$, sparseness of the illumination basis is set to 0.005 for the R, G, and B channels separately, and the sparseness of the feature reflectance basis is set to be 0.45. Figure 1 (b)-(e) shows the feature reflectance basis vectors (i.e., the antilog of the $\boldsymbol{w}_i$'s in Equation (11) with $1 \le i \le M$).

The second test provides statistical results about the accuracy of NMFsc-based illumination estimation. The test set is extracted from the large dataset of natural images representing a variety of indoor and outdoor scenes under different light conditions that Ciurea et. al.[13] measured with a grayball attached to a digital video camera. The original image database includes 11,346 images. However, many of these images have very good color balance (i.e., RGB of the gray ball is gray) which could bias the testing of the illumination-estimation methods. Therefore, we eliminated from the data set the majority of the correctly balanced images so that the overall distribution of the illumination color is more uniform. The resulting data set contains 7661 images. The grayball appears in the lower right-hand quadrant of every original image, so for testing that quadrant is cropped from every image.

The 7,661 images are tested based on the SoG, Max RGB, and Grayworld methods, as well as both our multiple-reflectance and single-reflectance methods. The accuracy of various illumination estimation methods (Shades of Gray, Max RGB, Grayworld, single-reflectance NMFsc, and multiple-reflectance NMFsc) applied to the 7,661 images is listed in Table 1. In the case of the multiple-reflectance based estimation, each image is resized to 64x64 pixels, and divided into sixteen 16x16 subwindows. The number of reflectance features *M* is set to be 5; the sparseness of the illumination and the reflectance bases are 0.001 and 0.45, respectively. The average computation time for processing one image is 0.83 seconds. In the case of the single-reflectance based estimation, each image is also resized to 64x64. The sparseness of the illumination and the reflectance bases are 0.001 and 0.45, respectively. With $M = 1$, the average computational time for processing one 64x64 image is 2.43 seconds.

4. CONCLUSION

The experiments show that nonnegative matrix factorization with sparseness constraints provides a method of separating a color image into its illumination and reflectance components. The accuracy of the NMFsc method is competitive with other illumination-estimation algorithms. One possible disadvantage of the approach is that existing factorization algorithms are iterative, and in comparison to some of the other illumination-estimation algorithms, somewhat costly in terms of computation. A particularly good feature of the NMFsc approach is that it requires no training.

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Real colour gamut in terms of reflectance functions

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ABSTRACT

Pointer and ISO TC130 derived colour gamuts for real surface colours. However, they are defined in terms of CIELAB specification under specific C/2 and D50/2 conditions. They can not be used to accurately define gamuts under the other illuminant/observer conditions. This paper describes a new method to define colour gamut in terms of reflectance functions.

Keywords: Real Surface Colour, Colour Gamut, Reflectance Function

1 INTRODUCTION

Colour photography, colour printing, colour television are concerned with the reproduction of colours of the real world, either natural or artificial. Effective colour scene reproduction needs to know and understand the gamut of the particular colour reproduction system and the gamut of all available real surface colours.

The first comprehensive consideration of the gamut of real surface colours was given by Pointer[1] in 1980. He accumulated 4089 colour coordinates of samples including: 768 colours from the Munselll Limit Colour Cascade; 310 colours from the Matte Munsell Atlas; 1393 colours from ink and paint samples, textiles, coloured plastics and papers; and 1618 colours describing flowers (tabulated by Royal Horticultural Society). The colour gamut was defined in terms of maximum CIELAB chroma (C^*) at 36 hue angles (h) from 0° to 350° at a 10° interval and 16 lightness (L^*) levels from 15 to 90 at a 5 unit interval. The number of total points of Pointer's colour gamut is 576 (i.e. 36 by 16). His gamut was defined under CIE illuminant C and CIE 1931 standard colorimetric observer (C/2°) condition.

More recently, ISO TC130[2] standardised a gamut named 'Reference Colour Gamut' defined under CIE D50 and CIE 1931 standard colorimetric observer (D50/2°) condition. It was established based on two different colour gamuts from two independent studies. The first gamut was derived mainly from the Pointer's gamut [1] for which his boundary points under the CIE C/2° conditions were transformed to D50/2° conditions via the Bradford chromatic adaptation transformation (CAT) embedded in CIECAM97s[3] Additional to the transformed Pointer data, CIE TC130 also accumulated the data of 1025 Pantone colours together with a series of new colour data measured from printed samples and the colorimetric data from a new ISO standard on Graphic Technology—Standard object colour spectra database for colour reproduction evaluation (known as SOCS)[4]. The second gamut was based upon a large number of colours generated by colour printers at Hewlett Packard. This gamut was offered to the International Colour Consortium (ICC) as a reference gamut for profile connection space for perceptual rendering. These two gamuts were finally combined to form the Reference Colour Gamut. The gamut boundary was defined under CIE D50/2° condition at 36 hue angles between 0° to 350° at 10° interval, and 19 L^* levels between 5 and 95 at an interval of 10. This results in a total of 684 data points (36 by 19).

The above two colour gamuts are defined under specific illuminant/observer conditions. If conditions are differed from those, there is no accurate gamut of real surfaced colour to be used. One possible solution is to use a CAT to transform colour coordinates of the above gamuts to those under an imaging device's white point. Figure 1 gives an example to show a display's colour gamut and a transformed Pointer's gamut in CIE u'v' diagram. The latter was transformed from C/2° to **Display's white point**/2° conditions via CAT02, which is embedded in the CIECAM02 colour appearance model[5].

However, there are two problems in this approach. One is that CAT was designed to obtain two sets of tristimulus values (corresponding colours) by assuming the colour being colour constant. In reality, none of the colours are colour constant. Hence, the transformed colours cannot give accurate prediction. The other problem is that some of the boundary coordinates are located

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near the chromaticity locus as shown in Figure 1. Transforming those data using CAT may give anomalous results as addressed by Brill[6]. The ideal solution is to describe gamut boundary in terms of reflectance functions, which is the main motivation of the current paper.

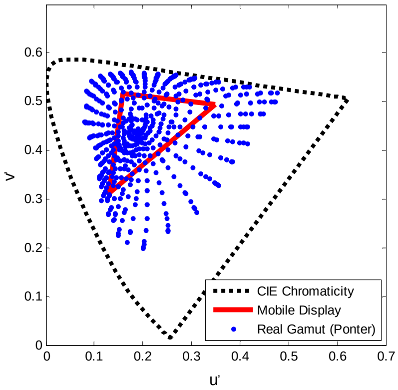

Figure 1: Colour gamuts of a display (triangle) and Pointer's (outer) CIE u'v' diagram

2 APPROACH FOR REFLECTANCE GENERATION

To generate reflectance based on given colour coordinates such as *L**, *C**, and *h* or *X*, *Y*, and *Z* has a long history. However, the problem is not yet solved satisfactorily. The difficulty is that the number of equations is much less than the number of unknowns. Thus the (inverse) problem is not well defined. We have to introduce more constraints such as basis vectors[7], smoothest conditions[8], and colour constancy[9] to reduce the dimensionality of the problem.

Firstly, transform the given coordinate *L**, *C**, and *h* under C/2° or D50/2°, to tristimulus values *X*, *Y*, and *Z*. Let $p^T = (X, Y, Z)$, and *W* (n by 3) be the weighting table and *f* (n by 1) be the wanted reflectance function or vector, then we have

$$p = W^T f \qquad (1)$$

Secondly, the singular value decomposition or PCA approach is used for deriving the basis vectors $\varepsilon^{(1)}, \varepsilon^{(2)}, \cdots, \varepsilon^{(n)}$. The main difference for searching the basis vectors from the literature is that we build the basis vectors using a subset of reflectance functions accumulated. Any function from the sub set has a hue angle close to h, the hue angle of the given coordinates. Under this constraint it is expected that the reconstructed reflectance function *f* is close to real. It is expected that $\varepsilon^{(1)}, \varepsilon^{(2)}, \cdots, \varepsilon^{(m)}$ with *m* being much less than *n* reflect fully the whole characteristics of the subset of reflectance functions. Hence the reconstructed *f* will satisfy

$$f = E\alpha \qquad (2)$$

where

$$E = (\varepsilon^{(1)}, \varepsilon^{(2)}, \cdots, \varepsilon^{(m)}), \text{ and } \alpha \in R^m. \quad (3)$$

Thirdly, the smoothness condition is also used. Let *G* be the smoothness operator[8], so that the smoothest condition is given below:

$$\underset{f \in R^n}{Min} \| Gf \|^2 = \underset{\alpha \in R^m}{Min} \| GE\alpha \|^2 \qquad (4)$$

Fourthly, the boundary constraints are used and given by

$$0 \le f = E\alpha \le 1 \qquad (5)$$

Finally, the colour constancy constraint[9] is added in as well. All considerations above lead to a constrained least squares problem:

Minimise $\| BE\alpha \|^2 + s \| GE\alpha \|^2$

Subject to: $0 \le E\alpha \le 1$, and $p = W^T E\alpha$

The matrix *B* is given in reference 9. Here *s* is the scaling factor which balances the smoothness of the reflectance and the colour inconstancy index.

3 REFLECTANCE FUNCTIONS CORRESPONDING TO POINTER'S GAMUT

At each point defined by Pointer's colour gamut, a reflectance function is successfully generated using the method described in the last section, resulting in 576 reflectance functions for describing the gamut. The reflectance functions have the following properties:

- to exactly match Pointer's colour gamut under illuminant C/2°.
- to be as smooth as reflectance functions of real surface colours;
- to have similar characteristics of real reflectance functions since they were derived based on basis vectors generated from localised real reflectance functions;
- to posses a better colour constancy since they were generated by minimising colour inconstancy index.

Figure 2 shows the generated reflectance functions corresponding to L* values of 60 and 30 on the left and right diagrams, respectively. Each diagram shows 36 reflectance functions corresponding to 36 hue angles from 0° to 350° at 10° intervals.

Figure 3 shows reflectance functions at hue angles 90° and 180° on the left and right diagrams, respectively. Each diagram shows 16 reflectance functions corresponding to 16 L* levels from 15 to 90 at a 5 unit interval. As expected, the magnitude of reflectance function increases with an increase of lightness.

4 CONCLUSIONS

In this paper a set of reflectance functions was generated based on Pointer's colour gamut. The reflectance functions are close to those of real objects, and have a better colour constancy. The new gamut can be applied under any illuminant/ colorimetric observer conditions. This overcomes the problems in using chromatic adaptation transforms.

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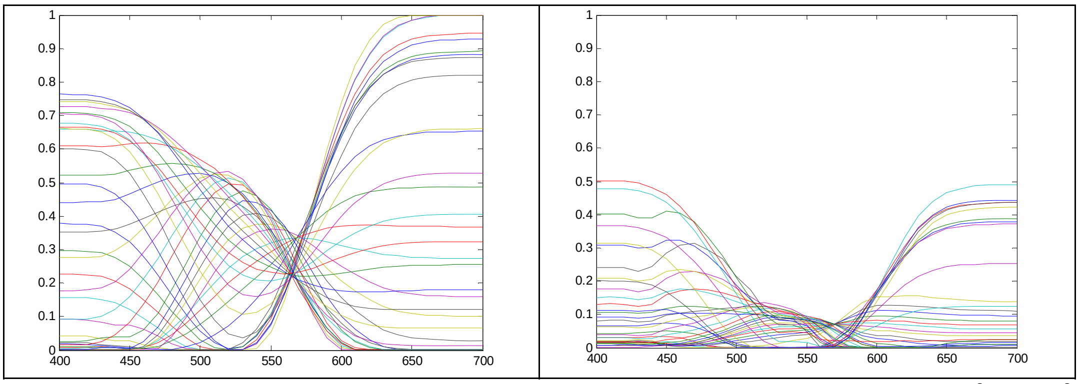

Figure 2: 36 reflectance functions of Pointer's gamut corresponding to 36 hue angles from 0 ^{o} to 350 ^{o} at 10 ^{o} intervals with lightness being: 60 (left); and 30 (right).

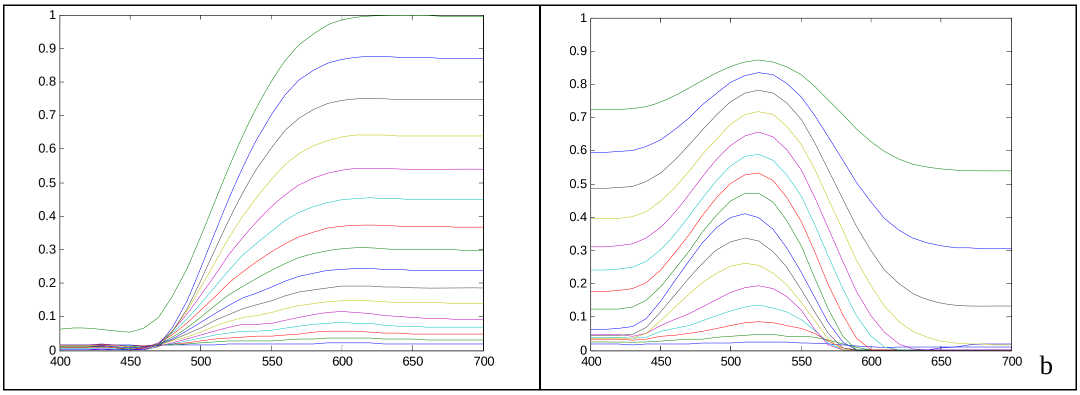

Figure 3: 16 reflectance functions of Pointer's gamut corresponding to 16 lightness levels from 15 to 90 at 5 lightness unit intervals with hue angle being: 90 ^{o} (left); 180 ^{o}.(right)

Obtaining proper initial clusters for the fuzzy c-mean algorithm for color reduction

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ABSTRACT

This paper introduces a novel initialization method for fuzzy c-mean (FCM) algorithm for clustering color images. FCM algorithm can give suboptimal solution, if the initial centers are almost optimal. However, the problem is to find the appropriate initial centers, which are commonly, chosen by random. We apply principal component analysis (PCA) to estimate the initial centers. PCA can find the axes along the color points, which are spread in color space. The first PCA vector shows the axes with the highest distribution of its color points so it can be used as the direction to find initial centers. At first, the 3-dimensional color points should be mapped on the first PCA. Then to obtain the dominant colors, the probability density function (pdf) of the new data is calculated, the points with the highest pdf values have more chance to be initial centers. By selecting a center, the data closed to it in a diameter of σ are eliminated. The term σ is estimated based on the number of clusters. The experimental results show that the proposed method performs well for clustering color images.

Keywords: color clustering, fuzzy c-mean clustering, initial centers

1 INTRODUCTION

The color images contain more information than gray scale ones. In a color space each color point is expressed by a three dimensional vector. True color images typically use one byte for each of the red, green and blue components. So the possible colors of each pixel may contain up to $2^{24} \approx 16.8$ million colors. Due to the limitations of the number of colors of color image printing and display devices, in many applications, it is preferable to have images with as less colors as possible and reducing the number of colors is essential. Therefore, color reduction of images that is usually called color image quantization is an important process that many researches concentrate on it.

Color image quantization algorithms normally consist of two major steps: The first step named color map or color palette design in which a reduced number of the best possible set of representative colors are chosen. The second step, called pixel mapping in which each color in the original image is mapped to the best appropriate color of the color palette. It is clear that the major goal of color quantization is to design the color palette that makes the least perceived difference between original image and quantized one. The algorithms exist for this purpose might be typically categorized in two groups. The first group is the class of splitting algorithms that divide the color space into disjoint regions. The most famous splitting algorithm is median-cut algorithm [1] and those based on it such as the center-cut algorithm [2], the mean-split algorithm [3]. The second group is clustering based algorithms, which perform clustering the color space into k cluster. Several clustering algorithms, based on optimization of a cost function or other method such as pairwise clustering method, genetic algorithm and etc have been used for color image quantization [4-9].

One of the most popular examples of the clustering based method is the fuzzy C-Mean (FCM) algorithm that was proposed by Bezdeck [10]. There are two major difficulties in implementation of FCM method. i) Determining the optimal number of clusters ii) Choosing the initial cluster centers.

If the initial clusters are almost optimal, the FCM algorithm can give suboptimal solution. Usually the user specifies the number of clusters and the initial cluster centers are chosen by a random generation technique. In this paper, we present a new method to guess the initial cluster centers via principal component analysis (PCA). For a color image, PCA can find the axes along the color points spread in the color space of the image. The first PCA vector obtained from a color image shows the axis with the highest distribution of its color points. So it can be used as the main direction to choose initial centers.

2 METHOD

We propose a novel initialization method for FCM in the context of color image clustering. Principal component analysis (PCA) method is used to find the dominant axis along the color points to estimate the initial cluster centers in one-dimensional space. In this section FCM algorithm and the concept of PCA are described, finally the proposed method for initialization is concluded.

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2.1 Fuzzy C-Mean algorithm (FCM)

FCM algorithm classifies a set of data points into c fuzzy groups. The objective function is defined as equation (1).

$$J_m = \sum_{i=1}^{c}\sum_{j=1}^{n}(\mu_{ij})^m \left\| x_j - v_i \right\|^2 \qquad (1)$$

Where μ_{ij} is the membership degree of data x_j to the ith cluster, m is the parameter of fuzziness, which is usually chosen equal to 2 and v_i shows the center of ith cluster. By minimizing the objective function (1), the membership function and the cluster centers are obtained by equations (2) and (3):

$$\mu_{ij} = \left[1 \Big/ \sum_{k=1}^{c} \left\| x_j - v_i \right\| / \left\| x_j - v_k \right\| \right]^{1/(m-1)} \qquad (2)$$

$$v_i = \sum_{j=1}^{n} \mu_{ij}{}^m x_j \Big/ \sum_{j=1}^{n} \mu_{ij}{}^m \qquad (3)$$

The FCM algorithm is outlined as follows:

a) Select c initial cluster centers

b) Assign all the data points to the nearest cluster

c) Calculate the new cluster centers according to equation (3)

d) Update the membership function values by equation (2)

e) If the overall objective function is smaller than a given tolerance or all the new cluster centers stand the same as previous centers then stop the algorithm, else continue from step b.

As mentioned before the most difficulties of FCM algorithm is to find the appropriate initial centers and there is no generally accepted initialization method. The initial centers affect the results and the final clusters may vary depending on the selected initial centers.

2.2 Principal Component Analysis (PCA)

Principal component analysis (PCA) is a well-known method to identify the most effective features in a data set [11]. The central goal of PCA is to represent the data in a reduced dimensionality space while preserving as much information as possible. If X is an n-dimensional of p random variables, by choosing m (m<n) feature vectors, low-dimensional data set can be expressed as equation (4).

$$Y_{(m\times p)} = FV'_{(m\times n)}.X_{(n\times p)} \qquad (4)$$

Where, *FV* is a matrix contains of m feature vectors in an n-dimensional space. The original data can be reconstructed by:

$$\hat{X}_{(n\times p)} = FV_{(n\times m)}.Y_{(m\times p)} \qquad (5)$$

The mean square error ($\overline{\varepsilon}^2$) is defined by equation 6:

$$\overline{\varepsilon}^2(m) = mean\left(\left\| X - \hat{X} \right\|^2 \right) \qquad (6)$$

It is provable that the optimum choice for feature vectors (*FV*) that minimizes the squared error is the eigenvectors of the covariance matrix of the original data, which named as basis vectors [11]. By calculating these basis vectors, PCA linearly transforms a high-dimensional input vector into a low-dimensional one whose components are uncorrelated. In this way, the mean square error becomes:

$$\overline{\varepsilon}^2(m)_{opt} = \sum_{i=m+1}^{n} \lambda_i \qquad (7)$$

Where, i is the index of each eigenvector which is not used and λ_i is the corresponded eigenvalue. Hence, the first PCA, which is corresponded to the highest eigenvalues, is the most important one that shows the direction of the highest distribution into a data set.

For a color image, PCA can find the axes along the color points spread in a color space. The first PCA indicates the axis with the highest variance of color distribution, so it can be used as the projection line.

2.3 Choosing the initial cluster centers by PCA

At first, the three PCA vectors of the color image are obtained and the image is presented on the first PCA vector. So the three-dimensional data transforms to one dimension while the color distribution is preserved well. Then the probability density function (pdf) of the new data should be calculated. Certainly, the points with the highest pdf values have the chance to be initial centers. To avoid too similar centers, when a point is selected to be a center, an area (σ) at its surround is eliminated. Therefore, it needs to have a guess for σ value. If there is an estimation of the number of clusters (N), then the σ can be calculated simply by equation (8):

$$\sigma = (\max(x) - \min(x))/N \qquad (8)$$

Where x demonstrate the presented data points on the first PCA vector.

The selection of initial centers can be performed in one-dimensional of the first PCA vector space in an iterative process. The point with the highest pdf value is chosen as a center in each iteration. By selecting a center, the data closed to it in a radius of σ/2 are eliminated (as shown in figure (1)). So a part of the pdf curve is subtracted out in every iteration and the process is continued to approach to N clusters. In the last step, the obtained initial centers in one-dimensional space of the first PCA should be mapped to their corresponding color points. To perform it we find the color points in the three-dimensional color image space which their values on the first PCA are identical to the values of the obtained initial centers.

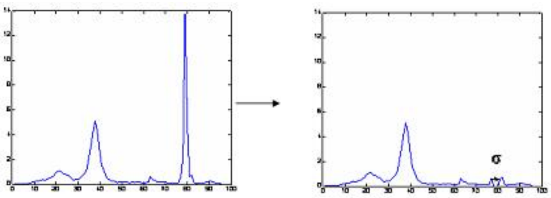


Figure 1 Elimination the area of σ diameter around the point with the highest pdf value chosen as a center.

3 EXPERIMENTAL RESULTS

To examine the accuracy of our proposed initialization method several experiments were implemented by applying the FCM algorithm with this initialization. To have a comparison, all the images were also clustered by FCM algorithm with random initialization method. The experiments were conducted for two true color images namely "Barbara" and "Masuda", taken from the Internet. The images are shown in figure (2) and their characteristics are given in table (1). All the experiments are implemented using RGB color space. The performance of color quantization algorithm is determined by S-CIELAB criteria. The S-CIELAB represents color image difference based upon the CIELAB color space. It adds a preprocessing step to the standard CIELAB equations, which relates to the spatial and color pattern abilities of the human visual system [12]. Table (2) shows the comparative performance in terms of S-CIELAB error by applying FCM algorithm with the proposed and random initialization methods. As mentioned before the results of FCM algorithm are varied based on the selected initial centers in random initialization, by applying the proposed initialization method in addition to the stability of results, it is indicated in table (2) that for all the images the proposed initialization method introduced lower S-CIELAB error in comparison with the random initialization. As illustrated in figure (3) and (4), some of the dominant colors with low frequency in the original image, which are neglected with random initialization method can be preserved using the proposed initialization. For instance, for "Barbara" image the colors of red and yellow objects on the table (figure (3)) do not preserved with random initialization even by increasing the number of colors to 64. The same results obtained for "Masuda" image too. As indicated in figure (4) the red color of her lip and nails is preserved by the proposed initialization method although this red color is eliminated with random initialization.

(b): Masuda

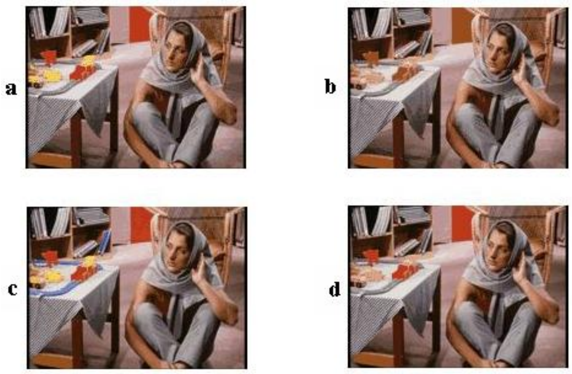
(a): Barbara

Figure 2 Original color images.

Table 1 the information of the four images

24-bit color images	Size	Color number
Barbara	132×180	7653
Masuda	120×128	2251

Figure 3 The quantized results of "Barbara";



(a) proposed initialization method with 35 colors;
(b) random initialization method with 35 colors;
(c) proposed initialization method with 64 colors;
(d) random initialization method with 64 colors

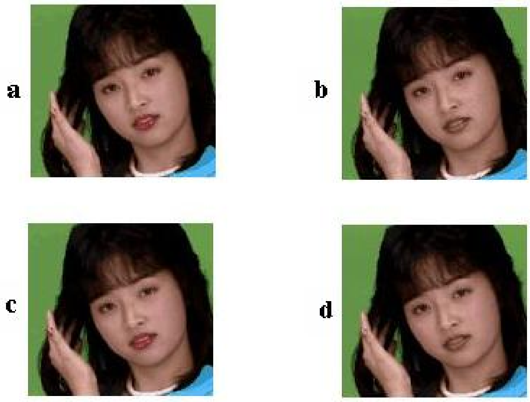


Figure 4 The quantized results of "Masuda";
(a) proposed initialization method with 37 colors;
(b) random initialization method with 37 colors;
(c) proposed initialization method with 64 colors;
(d) random initialization method with 64 colors

Table 2 Comparison of performance in terms of the mean of S-CIELAB values using conventional random initialization and the proposed initialization on two sample color images

Images	Mean S-CIELAB (random initialization)	Mean S-CIELAB (proposed initialization)	No. Colors
Barbara	5.1096	4.4524	35
Barbara	4.3190	3.5686	64
Masuda	2.2195	2.0617	37
Masuda	1.8290	1.7432	64

4 CONCLUSION

In this paper, we introduce a new approach to the initialization of the FCM algorithm in the context of color image clustering. The performance of the FCM is dependent on the initial centers and it is always desirable to have a good choice for initialization. Our proposed method is based on the idea of PCA tool. PCA can represent the data in a reduced dimensionality space while preserving as much information as possible. The three PCA vectors of the color image is obtained and the image is presented on the first PCA vector. The first PCA indicates the axis with the highest variance of the distribution of the image color points. The probability density function (pdf) of the one-dimensional data in first PCA space is calculated. Certainly, the points with the highest pdf values have the chance to be initial centers. The comparison of the proposed method with the typical random initialization method showed that in addition to the stability of the results, the quantized images presented by the proposed initialization method are more accurate in terms of S-CIELAB criteria. There are also some problems about preserving some dominant color points with low frequency in the original image that can be improved with the proposed method. These colors, which are neglected in color clustering by FCM algorithm with random initialization method, can be preserved using the proposed initialization.

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Color Image Compression Including Texture By Colorization Technique

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ABSTRACT

Colorization is a computerized process that adds color to a black and white print, movie, and TV program. The authors have studied automatic colorization algorithms by giving a partial color to a monochrome image. Our previous work proposed an image coding algorithm based on the colorization technique. The algorithm works well for image data including low frequency component. But, the algorithm was weak in compression of an image including a lot of high frequency components. The present paper solves the problem by improving the colorization algorithm. Furthermore, we preset a new method for determining the position to be seeded color pixels in the image. We confirm through some experiments that the proposed technique can improve the performance of the colorization image coding.

Keywords: Image compression, Image coding, Colorization, Texture image

1 INTRODUCTION

With the recent spread of the internet and multimedia technologies, digital images play more and more important role in human visual communications. In order to reduce image data quantity, several image compression algorithms have been developed. Most of them, such as JPEG2000, make use of the spatial correlation. In natural images, a strong correlation can also be observed among tri-color signals. The authors focused on luminance-chrominance redundancies, and proposed a novel algorithm for image compression in a previous paper[1]. The present paper stands on the extension of those works by using a different approach.

In this century, the study of *colorization* begins to attract attention. Colorization is a technology of coloring monochrome images automatically by giving simple hints of color. Welsh et al. proposed a semi-automatic algorithm by transferring color from a reference color image[2]. Levin et al. proposed an interactive colorization method by giving some color scribbles[3]. The authors also proposed a few colorization algorithms by sowing color pixels[4-7], and applied a colorization technique to image data compression (see Ref. 8). Figure 1 shows the overview of the colorization coding scheme. At first, luminance component is separated from an input color image. Next, selected color pixels from the original color image are seeded on the luminance image domain automatically and the monochrome image is colorized. The sowing process is continued until the colorized image satisfies a desired quality. Finally, both the luminance component coded by orthogonal transform and the set of color seeds are transmitted as coded data. Our colorization techniques[4-7] have an advantage than other techniques, because it is difficult to extract color hint by using the other colorization techniques such as reference images and color scribbles.

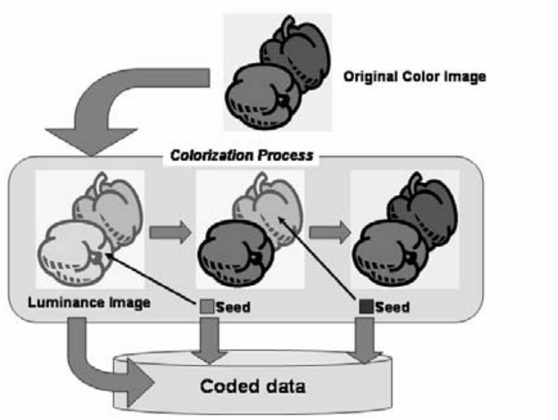

Figure 1 Procedure of colorization image coding.

The method in Ref. 8 works well for image data including low frequency component. The reference show better results for the images than JPEG image coding. But, the algorithm is weak in compression of an image including a lot of high frequency components such as texture regions. In this paper we improve the colorization algorithm for solving the problem. Furthermore, we propose a new method for determining the position where color is seeded in the image. The detailed algorithm will be explained in the following sections.

2 CONVENTIONAL ALGORITHM

This section shows the proposed image coding algorithm, which consists of luminance component decomposition, color seed selection, color propagation and data coding.

2.1 Decomposition of the Luminance Component

First of all, luminance component is separated from an input color image. In this paper, we would explain the colorization process in CIELAB color space, the color image transfers into $L^*a^*b^*$ planes here using the popular color transformation.

2.2 Color Seeds Selection

In order to colorize the luminance component, color pixels from the original color image are seeded on the luminance image domain automatically. In Ref. 8, the following three algorithms were proposed for placing of seeds.

2.2.1 Rondom

Obviously, a random setting of seeds resulted in the worst and a large number of seeds were required to colorize all pixels, because it is independent of image color distribution and seeds were sown on isolated regions. It is required to propagate many pixels by each color seed for reducing data size.

2.2.2 Selection from high luminance histogram

This method assumes that pixels in the same region have almost the same luminance. According to the assumption, a pixel with the luminance of high histogram may belong to a large region on the image. Seeds will be selected depending on the present luminance histogram.

2.2.3 Box center at higher pixel density in CIELAB space

To select more reliable seeds depending on the input image, we generated $M=m^3$ pieces of rectangular boxes in CIELAB color space surrounded by the regular lattice points inside the min-max color ranges of image color distribution.

The image color distribution is partitioned by a unit box with the size of $\Delta a \times \Delta b \times \Delta L$

$$\begin{aligned} \Delta \boldsymbol{L} &= [max\{L_n^*\} - min\{L_n^*\}]/m \\ \Delta \boldsymbol{a} &= [max\{a_n^*\} - min\{a_n^*\}]/m \\ \Delta \boldsymbol{b} &= [max\{b_n^*\} - min\{b_n^*\}]/m \end{aligned} \tag{1}$$

Let $\boldsymbol{a}$ color vector be $\boldsymbol{X_n}$ for n-th data point and $\boldsymbol{\mu}$ for the mean vector in CIELAB.

$$\boldsymbol{X_n} = [L_n^*, a_n^*, b_n^*]^t \; ; n = 1 \sim N \tag{2}$$

$$\boldsymbol{\mu} = E\{\boldsymbol{X}\} = [\overline{L}^*, \overline{a}^*, \overline{b}^*]^t \tag{3}$$

Here, we count up the pixel population $P(k)$ existing inside the each box $\boldsymbol{b}_k$; k=1~M. Next, a body center with the highest color population is selected as the position of a seed. This method requires a calculation time, but accurate color seed can be selected depending on the color distribution of the input image.

2.3 Color Propagation

Let $I = (x, y)$ be a pixel in an input monochrome image and let $\{S_p = (x_p, y_p)\}_{p=1}^{P}$ be a set of color seeds, where P is the total number of the seeds. The color seeds, which are color pixels strictly, are given manually as a prior knowledge by a user. The position of the seeds and their color are determined by the user. Note that the color must be chosen with keeping the luminance of the original monochrome pixels. We present our method in CIELAB color space, each monochrome pixel I is transformed into the luminance signal $L(I)$. Each color seeds S_p is also transformed into $L(S_p), a(S_p), b(S_p)$, respectively.

Each pixel I is colorized by $L(I), a(f(I)), b(f(I))$ in CIELAB color space. The function $f(\cdot)$ selects a color seeds which have the minimum Euclidean distance, and defined as:

$$f(I) = \left\{ S_p \middle| \min_p \|I - S_p\|^2 \right\} \tag{4}$$

where $\|\cdot\|^2$ means the Euclidean distance in the X-Y image space.

2.4 Data Coding

From the above, the input color image converted into luminance components and the small number of seed pixels. According to the human visual perception, the luminance components must be coded precisely. In our algorithm, the luminance components will be coded by an orthogonal transform, such as DCT and wavelet with high quality. The data of each seed pixel can be coded as four dimensional vector, that is coordinate (x,y) and chrominance components (a^*,b^*). If 2 Bytes will be assigned for each component, it takes 8 Byte for each color seed.

2.5 Decoding

The decoding process can be performed by tracing the colorization process in the coding algorithm. Therefore, the decoding is calculated fast. The monochrome data is restored and each monochrome color seeds are sown on the monochrome image. Then the reproduced image can be obtained by continuing the propagation of color seeds.

The conventional method works well for image data including much low frequency component. But, the algorithm was weak in compression of an image including a lot of high frequency components, because such an image consists of many small regions such as texture. Furthermore, we have to set the seeds' position by manual operation for obtaining a practical result. In the next section, a modified algorithm will be described for solving the problem.

3 MODIFIED COLORIZATION ALGORITHM

3.1 Color Seeds Selection

In the color seeds selection process, surely the method in 2.2.3 sets a better position than methods in 2.2.1 and 2.2.2 depending on image color distribution, but each seed is not placed at the center of each cluster but placed at each body center in uniformly divided unit box. In order to place these seeds at the right position, in this paper, k-means clustering method was introduced to make correction for the selected seed.

K-means algorithm partitions (or clustering) N data points into K disjoint subsets S_k containing N_k data points so as to minimize the sum-of-squares criterion,

$$J = \sum_{k=1}^{K} \sum_{n \subseteq \boldsymbol{S}_k} \left| \boldsymbol{X}_n - \boldsymbol{\mu}_k \right|^2 \tag{5}$$

where $\boldsymbol{\mu}_k$. is the geometric centroid of the data points in $\boldsymbol{S}_k$ First the initial seed points $\boldsymbol{\mu}_{seed}(k)$ are assigned to k=1~K classes, then the centroid is re-computed after clustering and the seed points are renewed. The renewal is continued until no further change occurs in the centroid by iteration.

Although k-means is used as unsupervised classifier by setting the initial seeds in random as shown in 2.2.1, here we applied this technique to relocate the initial seeds to the more reliable gravity centers in clusters.

3.2 Colorization

In order to reduce the color pixels for colorizing high frequency images, we propose a new colorization algorithm. In the proposed algorithm, we use two properties of natural images. The first property is that pixels with similar luminance values should have similar colors. This property was used for solving colorization problem in Levin's algorithm[3]. The second property is that near pixels should have similar colors. This property was used in our conventional algorithm. In the proposed method, we express those two properties by distances ***NED*** and ***NLD*** as follows.

(NED: Normalized Euclidean distance)

We define the first distance $d_1(I, S_p) \in [0,1]$ between I and S_p by:

$$d_1(I, S_p) := \frac{\left\| I, S_p \right\|^2}{\sqrt{width^2 + height^2}} \tag{6}$$

where $width$ and $height$ means the horizontal size and vertical size of the image, respectively.

(NLD: Normalized luminance distance)

We define the second distance $d_2(I, S_p) \in [0,1]$ between I and S_p by:

$$d_2(I, S_p) := \frac{\left| L(I) - L(S_p) \right|}{100} \tag{7}$$

Then a contribution distance $d(I, S_p) \in [0,1]$ between I and S_p is defined by the weighted sum of the both distances as follows:

$$d(I, S_p) := \alpha d_1(I, S_p)^r + (1-\alpha) d_2(I, S_p)^r \tag{8}$$

where, $\alpha \in [0,1]$ means the constant value for weighting distances. $\alpha = 0.5$ is appropriately in many cases. In the case $\alpha = 1$, we can obtain almost the same colorized result as Ref. 5. Symbol $r \in \Re^+$ means a factor which can change the influence of the color seeds, typically $r = 5$ is better in our experiments.

Equation (8) is translated into a weight for blending chrominance of color seeds $W(I, S_p) \in \Re^+$ as follows:

$$W(I, S_p) := \frac{d(I, S_p)^{-1}}{\sum_p d(I, S_p)^{-1}} \tag{9}$$

Then, the color for the pixel I can be represented by $L(I), a(I)$ and $b(I)$ as follows:

$$\begin{cases} L(I) \\ a(I) : \sum_p W(I, S_p) a(S_p) \\ b(I) := \sum_p W(I, S_p) b(S_p) \end{cases} \tag{10}$$

In our algorithm, we set K=1, which means only one color pixel is seeded by k-means clustering, and verify the colorized image quality. If the quality does not satisfy a requirement, we

(a) Original Image
(252Kbyte)


(b) Proposed method (c) Ref. 8
(k=18; 11.5Kbyte)


(d) Proposed method (e) Ref. 8
(k=100; 12.1Kbyte)

Figure 2 Experimental results.

add 1 to K. Then this process is repeated until the quality satisfies the requirement.

4 EXPERIMENTAL RESULTS

In order to verify the performance of the proposed method, we compared the proposed coding method with conventional algorithm in Ref. 8 using natural images. In our experiment, we use the JPEG coding for the luminance component.

Figure 2 shows an example of experimental results. The data quantity of the original image is 252 Kbyte (360x239 pixels). At first, we set 20[dB] for a desired PSNR between the original color image and the decoded image. Fig.2(b) shows the colorized result. In this case, we can satisfy the desired quality over 20[dB] by 18 color seeds. In this case, the compression ratio was less than 0.05 (11.5Kbyte). In the image data, 99% was the data for luminance components and data for chrominance components occupied only 1% (144 byte) of the total data quantity. This means that the coding in Fig.2(b) can be realized by almost the same data quantity as the monochrome data coding. Figure 2(c) shows a decoded result using the conventional algorithm expressed by the same number of color seeds as Fig.2(b). The color of the flower was lost, because conventional algorithm requires a large number of color seeds for expressing high frequency components such as the flower. Figures 2(d) and (e) show decoded results by 100 color seeds using the proposed method and the conventional method, respectively. The image quality such as green leaves can be improved by the proposed method without increasing the data quantity. On the other hand, 100 seeds are not enough to express the image by the conventional algorithm.

5 CONCLUSIONS

This paper improved the performance of the colorization image coding algorithm. We modified two steps in the algorithms. We applied k-means clustering algorithm for determining color seeds which express the chromaticity components of an image. Then we applied a modified colorization algorithm from a small number of color seeds. We verified the performance of the proposed algorithm using natural color images.

In this paper, we can improve the data quantity of the chrominance components, but in the colorization coding, the data quantity of the monochrome component is also important. In our experiment, we used JPEG for luminance coding. At first, as decreasing the quality, the colorized results were improved. However, if the quality decreases too much, the colorized results becomes worse and worse. We have to try to use other orthogonal transforms and investigate more suitable coding method for luminance component.

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Color simulation method using image processing software

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ABSTRACT

Two points to consider for color simulation using color processing software were examined in this study. They are how to reserve texture of surface in the image and how to change shadow part of the area of color alternation correctly as same as the bright part. For the first point, the technique which changes the luminance separately from the hue and saturation of the color can remain the information of the distribution of luminance. The author found the luminance value calculated by the formula L=0.3*R+0.6*G+0.1*B should change color correctly. For the second point, the mere color matching of the bright area couldn't change the shadow part correctly. According to the measurement of the gradation of several cubes covered by varying achromatic colors in a sample image, the modification method of the "tone curve" dialog in Adobe Photoshop is proposed. The tone curve should be a straight line and the gradient seems to vary according to the luminance distribution of the setting and the surface condition.

Keywords: color simulation, image processing software, lighting condition, tone curve, luminance distribution

1 INTRODUCTION

The image and impression of interiors, buildings or streetscapes would change when the surface color has changed. Color simulation on personal computer becomes a popular method to check the image of color alternation nowadays. Changing color itself isn't difficult if you use image processing software such as Adobe Photoshop. However, the color simulation considering lighting condition isn't simple. This study focuses the color simulation method which simulates the colors in a certain lighting condition of the setting.

The basic idea of this color simulation method which takes account of the lighting condition of the setting without complex calculation was proposed by Yoshiki NAKAMURA et al. at 1997.1 It needs another image of the scene taken from the same point, with color chip on the area for color alternation (Figure 1). The color chip illuminated in same lighting condition as the color simulation scene so that the assignment of the value of RGB gradation in the color chip area into the color alternation area would simulate the view of the color in the real setting.

This is enough for changing areas which have same color, no texture, are in same lighting condition. However, the scene we'd like to simulate colors often has texture and different lighting condition caused by different surface angle (such as table top and their legs) or merely the heterogeneity of illumination. These two points which are important to apply the basic idea of color simulation described above to the color simulation of everyday settings were examined in this study.

The images used in this examination were taken by digital camera. The image processing was carried out using Adobe Photoshop, the most popular image processing software on personal computer.

2 COLOR SIMULATION WHICH RESERVE THE TEXTURE OF OBJECT SURFACE

If the surface in the color simulation scene is uniform, we merely assign RGB gradation value of the color chip into RGB slider, and then paint the color simulation area using paint tool. In case the surface has texture, luminance should be changed apart from hue and saturation to reserve the information of luminance distribution. The gradation of luminance can be modified on brightness and contrast dialog in Photoshop. The author found the description that the formula L=0.3*R+0.6*G+0.1*B is used for calculation of luminance on NTSC (National Television System Committee) signal transmission.

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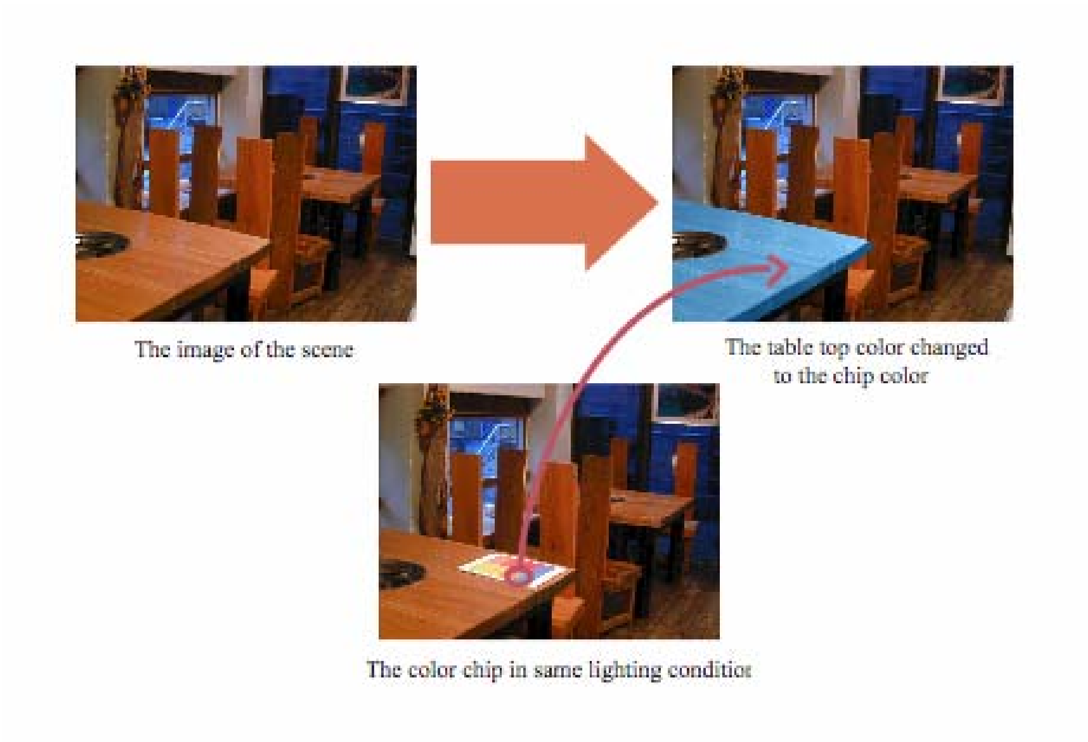


Figure 1 The basic idea of the color simulation method proposed in this paper.

In a sample case, the luminance value was changed using brightness and contrast dialog based on the value calculated by the formula above, and then, hue and saturation were altered by paint tool using "color" mode (which change hue and saturation only) based on the assignment of RGB values into RGB slider. This procedure makes the same color as the one which was assigned RGB values concurrently. Therefore, it is confirmed that this formula is used to calculate luminance from RGB gradation in Photoshop.

3 COLOR SIMULATION OF THE AREA OF SAME COLOR WHICH IS ILLUMINATED IN DIFFERENT CONDITIONS

We'd like to change the area of same object color concurrently. However, the color alternation based on the measurement of only one point in the area doesn't mean accurate color change of whole area. See Figure 2, the sample case to check the relationship between the luminance and Munsell value on three surfaces of the cubes. The surface value is larger, the luminance difference among top surface (the brightest), right surface (middle), left surface (the darkest) seems to be larger.

Figure 3 shows the relationship between the Munsell value and the gradation of luminance on three surfaces of varying value. The lines which connect the nine measured data are straight, and the gradients of them shift according to the surface value just as we see at figure 2. The color luminance alternation using brightness slider in brightness and contrast dialog couldn't express it.

To change surface color with keeping the difference of luminance which shifts depending on the lighting condition, we are able to use tone curve dialog in Photoshop. It's function is one kind of filter which transforms input gradation to output gradation as introduced at Figure 4.

The setting of the line which shows the transmission of gradation was calculated using the data shown in Figure 3. The gradient of the line was calculated by following steps.

(1) The straight lines which fits best to three surfaces' gradation was drawn.

(2) The point where all lines cross together was determined.

(3) The line setting in tone curve dialog is determined by this crossing point and the another point determined by the luminance of the original surface color of bright part and the target surface color of it.

The line is straight, and the gradient shifts depending on the difference between original color value and target color value. The distance from 45 degree line is larger when the value difference is larger.

The color simulation using this tone curve was more similar on the gradation of three surfaces than the one using brightness and contrast dialog.

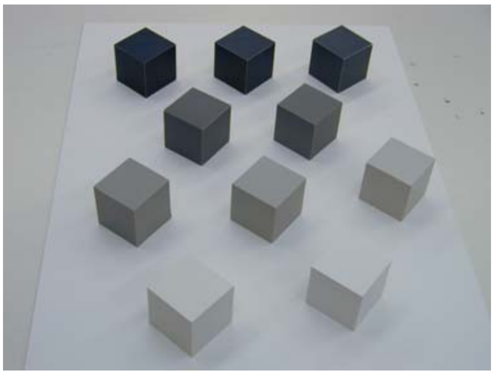


Figure 2 The image of cubes which surface has varying Munsell Values.

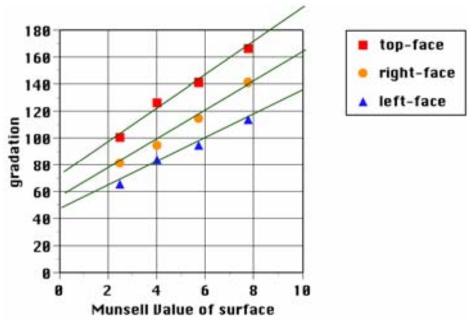


Figure 3 The relationship between Munsell Value and gradation of surfaces of cubes.

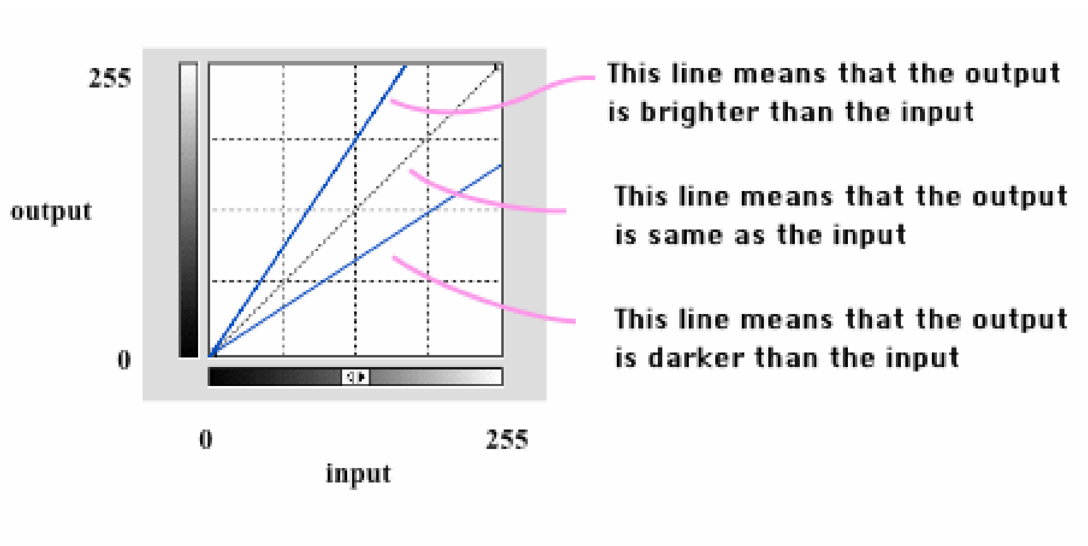


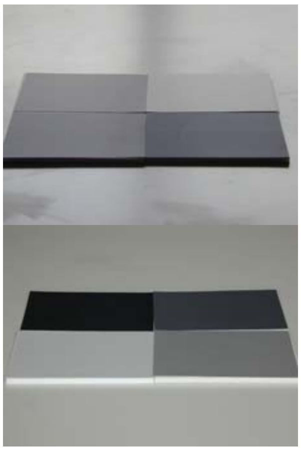
Figure 4 The tone curve dialog.

4 CONSIDERATION OF GROSS OF SURFACE

Color simulation considering the lighting condition to the surfaces succeeded in the sample case, however, the confirmation whether the gradient of tone curve is constant to every setting or not is necessary to apply the tone curve to the new scene for color simulation. Therefore, 8 pictures of interior or exterior with achromatic cube (value: 3, 6, 9) were taken.

Four of these samples are similar to the sample case shown at figure2, the lines of three surfaces on the value-gradation graph meet together, however, the rest four have the nearly parallel lines. Thus, it is clear that the line decided in sample case can't be applied to all color simulation scenes.

The another examination in which the relationship between gradation of luminance and the Munsell Value of four achromatic paper was conducted to find the clue of this question (See Figure 5). The gradation of papers on a table between window and camera vary less than the papers between camera and the wall in a room regardless of the background color. It is natural to explain this phenomenon by reflection; the high luminance in front of camera makes the change of the surface luminance less. Therefore, we should change the gradient of tone curve line in color simulation according to the surface condition and the luminance distribution of the setting, especially the one in the direction from observer or camera to color simulation area. On this point, further experiments are necessary.



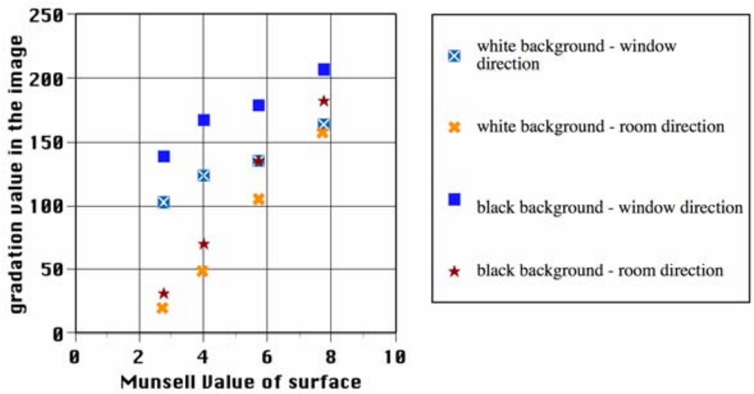


Figure 5 The relationship between Value and gradation of four achromatic papers in different four situations.

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Scene-to-Scene Color Transfer Model Based on Histogram Rescaling

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ABSTRACT

This paper proposes an image-dependent approach to interchange a color between different objects in different scenes. An unpleasant scene color is automatically corrected to match to that of reference pleasant scene. The paper introduces a "scene-to-scene color transfer model", based on Histogram Rescaling between color gamuts. The Histogram Rescaling method can easily adapt an image gamut to an objective target image gamut by simply setting the lowest and highest source values corresponding to the end points of the destination. Where source and target image center points on the CIELAB color space are separately set. The source image's gamut is expand or compressed by histogram rescaling referencing target image's gamut. Finally a center of source image is transferred into a center of target image and scene color interchange is performed. Proposed system is applied to preferred color reproduction, scene simulation, industrial design, etc. Experiments on total scene color interchange are presented, where a color atmosphere is transferred from one scene to another. An objective evaluation method to compare an interchange image is examined by color gamut volume.

Keywords: scene color transfer; histogram rescaling; image gamut volume; pleasant color reproduction

1 INTRODUCTION

Now digital imaging technology plays a leading role in visual communication. One of the most common tasks in image processing is to alter an image's color. Recently, E. Reinhard et al[1] tried to transfer the scene color from one image to another using vision-based $l\alpha\beta$ color space and M. Zhang et al[2] applied it to correct the color imbalance between the right and left image in a panoramic scene. Although $l\alpha\beta$ is a de-correlated color space, its axes don't always match to the principal axes in the real image and doesn't always work in stable. On the other hand, H. Kotera et al[3,,4,5] first introduced a scene color transfer model by region-based principal component (PC) matching in color clusters of CIELAB color space. This model presented two basic scene color interchange models of "Total" and "Segment" based on *PC matching*. The "Segment" PC matching model was reported very well, but optimum automatic classification is very hard.

We introduced a generalized *histogram rescaling* method for a versatile gamut mapping algorithm (GMA) through automatic gamut comparison using the gamut boundary descriptor (GBD) of the image and device[6,7]. The *histogram rescaling* method can easily adapt an image gamut to an objective target device gamut by simply setting the lowest and highest source values corresponding to the end points of the destination. We proposed a color interchange between different objects in different scenes, based on *histogram rescaling* between color gamuts[8]. An unpleasant scene color is corrected to match to that of reference pleasant scene. In paper [8], the chroma components were divided into 16 segments by ΔH at hue angle H. It, however, cannot deal in the same number of chroma segments for all images.

This paper investigated optimum number of chroma segments of various images. On the other hand, we propose an objective evaluation method to compare an interchange result image at color gamut volume.

2 SCENE COLOR TRANSFER USING HISTOGRAM RESCALING

Figure 1 illustrates an explanatory *histogram rescaling*. In the original histogram $p_1(x)$, lowest value a and highest value b are flexibly expanded or compressed for adaptation to the histogram of the target gamut using Equation (1) as follows:

$$x' = k(x-a)+a'; \quad k = {(b'-a')}\big/{(b-a)} \quad (1)$$

Where, b' and a' denote the highest and lowest end points to be rescaled matching the gamut boundaries of target and k means a scaling factor working compression for $0 < k < 1$ or expansion for $k > 1$. First, the lightness rescaling is performed by assigning the valuables x' and x to L and L' before and after, and next the chroma is rescaled by setting x' and x to C and C' before and after as well.

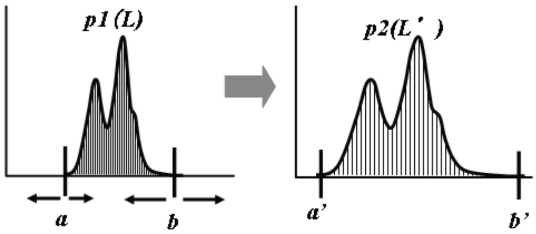

Figure 1 Histogram rescaling.

Figure 2 shows scene interchange model for chroma by histogram rescaling. Where source and target image center points on the CIELAB color space are separately set. Then source image's chroma C of each segment is expand or compressed by histogram rescaling referencing target image's chroma. Finally a center of source image is transferred into a center of target image and scene color interchange is performed.

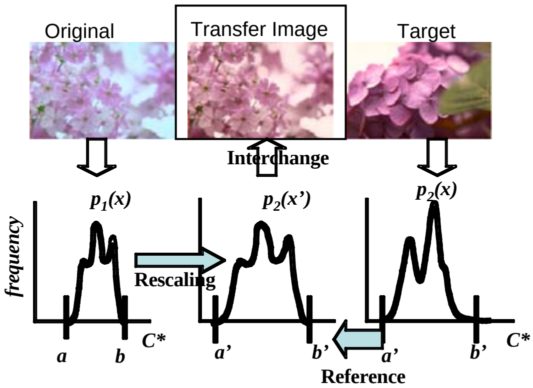

Figure 2 Scene interchange model for chroma by histogram rescaling.

3 CHROMA SEGMENTATION

In paper [8], after the histogram rescaling of lightness L, the chroma components were divided into 16 segments by ΔH at hue angle H. Figure 3 shows scene color of sunset view (A) changed into that in sunrise by looking another reference hazy-lake scene (B) with 16 chroma segments. Without chroma segmentation, it changed like a just purplish atmosphere. The Chroma segmentation succeeded in this sample. On the other hand, next sample image was failed with chroma segmentation. Figure 4 shows sRGB portrait image of bride (A) changed into that in too bluish by looking another reference lady portrait (B) with 16 chroma segments. Conversely, without chroma segmentation, it successfully changed to get a comfortable result. Necessity of the chroma segmentation depends on the image contents.

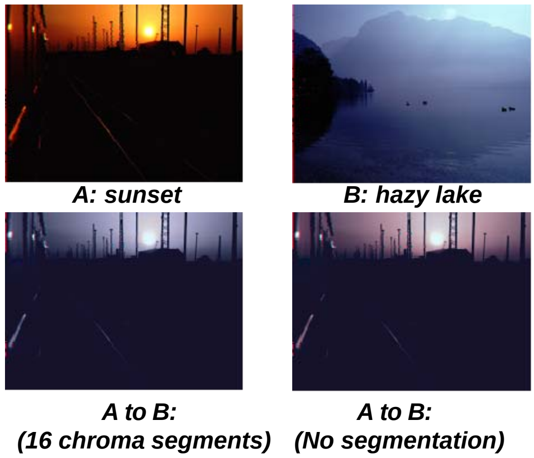

Figure 3 Interchange result of with or without chroma segmentation (scene image: "sunset" and "hazy lake").

Figure 4 Interchange result of with or without chroma segmentation (portrait image: "bride" and "lady").

4 EVALUATION OF IMAGE GAMUT VOLUME

Figure 5 shows result of each color interchange models in image Vincent van Gogh's "Café-terrace de nuit (Café)" and scene image "castle." Interchange models were compared with 1) Reinhard's lαβ color space model, 2) Kotera's "Total" PC, 3) "Segment" PC and 4) proposed histogram rescaling model. This figure shows original sample images and their CIELAB color surface in first column, A to B color interchange results in second column, its color surface in third column, B to A color interchange results in forth column and its color surface in fifth column.

Where the pictorial atmosphere of Gogh's "Café" is transferred into real scene "castle." Reinhard's model has extremely changed the color of interchange image. "Total" PC and "Segment" PC models also didn't worked very well. On the other hand, proposed model worked best in comfortable color rendition.

The size of the gamut is a fundamental imaging characteristic of that image. The volume of image gamut is calculated in the following steps[9].

1. The entire color gamut is divided by a discrete polar angle and the points farthest from an image center are extracted.
2. The gamut surface is constructed by joining the triangles according to the ordered points, where the surfaces are decided outward or inward.
3. The inward triangle is assigned a minus volume, and the entire color gamut is calculated by summing up the volume of each tetrahedron.

Table 1 shows an example of image gamut calculation result on CIELAB color space.

Table 1 Volume of image gamut on CIELAB.

	A: GohÕs Caf˝	B: Castle
original	208782	94815
	A to B	B to A
Reinhard model	412309	23880
Total PC	153488	211323
Segment PC	263104	86487
Proposed model	194113	110118

A volume of Rainhard's model is extremely big and small values comparing with original volume. This corresponds with visual evaluation result above. Volumes of "Total" PC and "Segment" PC also show big or small comparing with original volume. On the other hand, a volume of proposed model is corresponds well in gamut of an original image. The same thing is also observed with each color surface in third column and fifth column of figure 5, and these volume values correspond with visual evaluation result.

5 CONCLUSION

This paper proposed a scene color transfer model by *histogram rescaling* in CIELAB color space. Our model based on *histogram rescaling* worked robust to transfer the total color atmosphere from one scene to another. The *histogram rescaling* method can easily adapt an image gamut. This model was good performance for rescaling by hue segmentation in color space.

We proposed an objective evaluation method to compare an interchange image by color gamut volume. This method corresponds with visual evaluation result well.

Many problems are still left in a practical use for every kind of images. But the proposed approach would be a clue to a "*pleasant*" or "*comfortable*" color imaging applicable to scene simulation, industrial design, and/or computer graphics.

ACKNOWLEDGEMENTS

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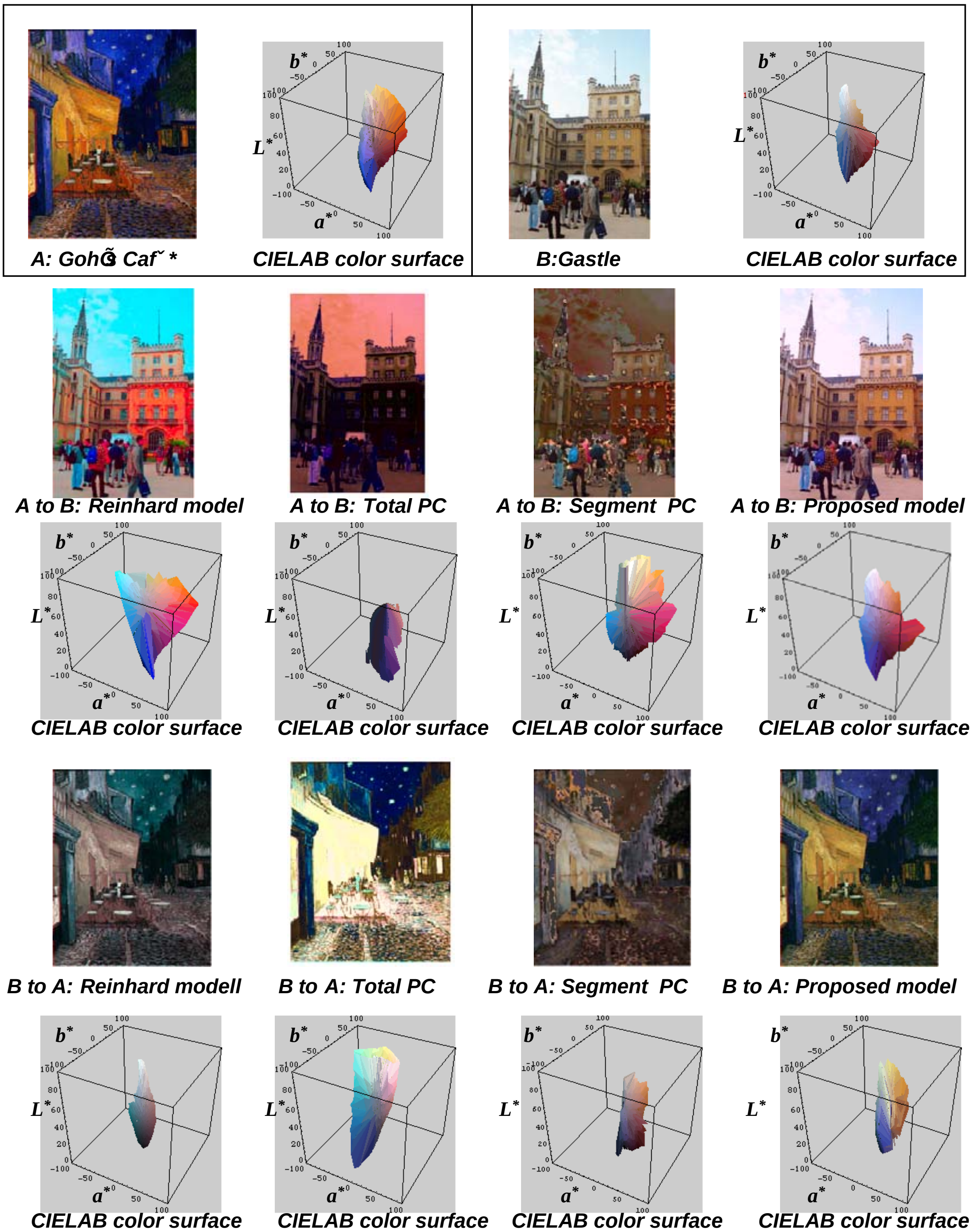

*The source: IPA http://www2.edu.ipa.go.jp/gz/

Figure 5 Result of each color interchange models in image Gogh's "Café" and "castle."

Technologies of Light in Contemporary Public Art

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ABSTRACT

The purpose of the paper is to investigate the relation between light and colour technologies and politically committed art carried out in the public sphere. The paper begins by giving a description of the ideological and social context in which "the new genre of public art" (Lacy, 1995) is developed. This tendency in contemporary art is examined in relation to artificial light as an expressive tool able to convey messages of social criticism. Such study reveals that light technologies can be subverted and extracted from the context of glamour where a fascination for the technology is displayed by artists yet the work is empty of content. It would be necessary to develop further the undervalued field of light technology as a constitutive element of the languages which actively intervene in the creation of an artistic image.

Keywords: Technologies of Light, Macrosystem of Appearance, Public Art, Art Activism.

FROM PUBLIC ART TO ACTIVIST PRACTICES

The damaging consequences of globalisation on society in advanced capitalism, including social, economic and environmental deterioration, have driven a great number of artists to collective action operating in association with political groups and non-governmental organisations in the production of critical discourses and in seeking practical solutions which can alleviate the complexity of the problem.

Thus current cultural practice devotes its energies not so much to the creation of an aesthetic object *per se*, but rather to constructing participatory spaces which favour dialogue and social confrontation (Úbeda, 2006:36-38). This fresh approach derives from performative activism requiring effective actions designated as "ways of doing" (De Certeau, 2001:391-425). What is the importance of the use of light as a resource in what we call "social art"? How does this affect the audience? What changes have occurred in post-modernity with respect to these issues?

Our discourse is shaped by key philosophical theories in European post-modernity such as Habermas´s monumental work *Theory of Communicative Action* about communicative inter-subjectivity or linguistic understanding. He considers that the model which social art must take is no longer that of subjective action oriented towards the egotistical ends of individual subjects, but rather that of an action oriented towards understanding whereby subjects co-ordinate their planes of action on the basis of agreements mediated with the audience. The most paradigmatic example of his theory is the notion of communicative action, which proposes a close link between action and communication. For him, the concept of action is based on mastering situations. The integration of a system of action is produced by means of consensus ensured by norms or obtained communicatively (Jokisch, 2000: 81-128).

François Lyotard´s theories of "performative action" or the writings of Gilles Deleuze are also important in understanding the grade of the effect between heterogeneous agent elements which mutually co-determinate each other (Úbeda, 2006:503-563). As Mary Jane Jacob says, "the new generation of public art requires and invites the communication and commitment of audience participation" (Jacob, 1995: 50-59). Artists working with light technology in public spaces position the spectator as an integral part of the work, displaying the work in an open air setting whilst participating in the framework of political criticism so vindicated by public artists from post-modernity to this day (Vida, 2006).

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ART ACTIVISM FOR SOCIAL CHANGE THROUGH LIGHT AND COLOUR TECHNOLOGIES

It is possible to systematize and extend the potential expressive uses and meanings of light through an application of the morphology of languages based on the System of Appearance where three levels of approximation are intimately related: physiology, psychophysics and the study of language (García, 2000:105-113). Light is one of the most ductile materials in the creation of phenomological spaces which physically involve the spectator and which allow the implication of a context that is wider than merely perceiving a work of art as a physical object. Light also implies Matter, Space and Time in an indissoluble Macro-System.

Figure 1 "*Projection onto Hirshhorn Museum",* Krysztof Wodiczko. *Washington DC,* 1988.

The use of the latest generation of light technology is exemplified in the work of Krysztof Wodiczko where his proposed objectives are in perfect fusion. (Fig. 1) Wodiczko superimposes the negative consequences generated by advanced capitalism onto pure, sanitised images of the contemporary city. Marginalisation and poverty are displayed on the façade of the commemorative monument. The artist thus creates an *anti-monument* with the technology provided by the spotlights he uses to project slides and videos, breaking with the tradition of the commemorative monument and with traditional forms of intervention in public spaces (Úbeda, 2006: 629).

Texts and images projected through light in the public sphere can be the tools of diffusion of political messages. Wodiczko´s projections through Light in the public sphere are the tool used to diffuse political messages. Wodiczko´s projections permanently re-open the debate on democracy, confronting "consensus" promoted by the rationalist philosopher Jurgen Habermas, with his concept of "antagonism", developed more recently by Chantal Mouffe and Ernesto Laclau (Phillips, 2003: 32-47; Úbeda, 2006: 580, 609, 623).

Mischa Kuball is best known for activating spaces in spectacular ways by means of light. He talks of the transformation of the medium and the existence of absence as metaphorical concepts of composition in his installation work with light. His large-scale projections do not stop him using more rudimentary elements such as slide projectors or the shimmering surface of compact discs. For Kuball, art predominantly means mediatising the conditions of construction for the representation or discussion of problems. His works are primarily with light projection and illumination. The process-orientated content of art blends with the strategies of its organisation; for example, "Megazeichen" (1990) includes many people whose actions, motivations and attitudes are crucial for the realisation of the symbol impact of interior lighting systems combined to form certain figures (Fig. 2).

Kuball´s work cannot or should not be restricted to the use of light projection. In fact, he uses slide projections and other existing or newly installed sources of light to mark specific locational qualities of light in a broad sense. The use of light as a shaping force (form, medium, projection impact) creates a sculptural approach resulting in a transitory architecture. The materially established course of sculptural lines adds dimension to the fleeting figuration, site and arquitectural phenomena.

Figure 2 "Megazeichen", Mischa Kuball. Dusseldorf, Germany, 1990.

The sites selected by Kuball in the urban public sphere are intended for a specific cultural use or may have no proper name. They are blurred, passing, transitory or anonymous, unobtrusive. Mischa Kuball does without any mythological, context-orientated reminiscence in his light themes as is shown in his work "Light Bridge" (Fig. 3).

Figure 3 "Light Bridge", Mischa Kuball. Berlin, 2006.

However Kuball shares Newton´s rather objective view of the character of light and of its colour spectrum. That is why he works primarily with specific qualities of light, which are defined by the rather "cold" nature of light fixtures. Although light is the medium of expression of a form that comprises sensual values such as colour formalities, it mainly serves to capture and label a site for a certain process of perception. But it undergoes a specifically challenging rejection by the eye through the introversive enhancement of an illuminating and illuminated room, which appears hermetic and thus works as a metaphor of a historic problem and a complex challenge to the mind and memory. The light image, a wandering projection of the diaphanous image, an interplay of various light sources in a regular circuit, constitutes the specific character of Kuball´s light technology works.

Figure 4 "Ruheraum mit Tränen Abtropofmaschine", Thomas Hirschhorn. Sweden, 1996.

The use of fluorescent tubes, such a feature of daily use, acquires value and political meaning in the work of Thomas Hirschhorn. (Fig. 4) His proposals influence the awakening of critical behaviour in the spectator through the relation "light-blindness-pain" (Úbeda, 2006: 355-357). His showcases and kiosks placed in public spaces combine the use of fluorescent light with silver foil and other reflecting surfaces which render unbearable any calm appreciation of the documentation of a political nature that he offers the public through his installations.

Creating discomfort in the visual perception of the public is an effective way of appealing to its corporal and conceptual involvement in the socio-ethical problem which the piece addresses. The excess of light, as does its absence, provokes an effect of blindness, and both prevent the perception of the object (Úbeda, 2006: 243).

Lastly, Jaume Plensa´s work highlights the importance of light imbued with poetic content interacting within a public urban space, raising awareness in the spectator by means of light. (Fig. 5). In his work *Blake in Gateshead*, he used a beam of light emitted from an iron circle in which can be read the words in relief of a line from William Blake´s *Proverbs of Hell*. Blake´s idea of an inseparable union of opposites is thus projected upwards along a line of light before our eyes by means of a wisely calculated reduction, creating an ephemeral bridge of light which unites the sky with the earth (Plensa, 2003).

The use of light in Plensa´s works has always intended to speak about inner conceptual reflections. Light appears on the scene; red light, neons that have something innocent about them, but that are also as threatening as any fatal weapon. Light is simply that which exists in reality and Plensa uses it as the main manifestation in the body of his works.

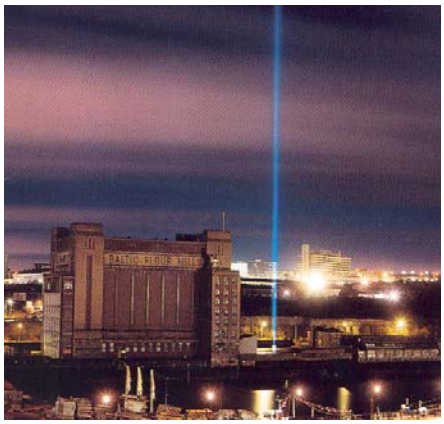

Figure 5 "Blake in Gateshead", Jaume Plensa. England, 1996.

Plensa´s outdoor laser beam was switched on for special occasions, but only after permission was granted by the airport authorities. The official opening to the public at midnight 13th July 2002 was performed by the first two people in the queue, who then instantly achieved fifteen minutes of fame.

CONCLUSIONS

The art practices of Krzysztof Wodiczko, Mischa Kuball, Thomas Hirschhorn and Jaume Plensa are optimum examples of hybridisation between the technological tool of lighting and a critical social content. The study of such practices carried out in the public sphere of opposition reveals the wide range of expressive possibilities and the media diffusion which Light Technologies can develop when in direct contact with the spectator in public spaces. The study of light as part of the academic programme at Fine Art institutions is increasingly necessary in order to systematize Light as a tool of plastic and visual language.

Translated by Corinne Stewart.

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Geometrical Structures of Fundamental Color Space

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ABSTRACT

Human Color Vision is characterized by *metamerism*. J. B. Cohen interpreted *metamerism* by a projector called "*matrix* ***R***" onto **HVSS** (Human Visual Sub-Space) and founded **FCS** (Fundamental Color Space) spanned by a "*matrix* ***F***" with a selected triplet of column vectors in ***R***. This paper presents a new **FCS** created by a different from the choice of *matrix* ***F***. First, a *pseudo-inverse projector* P_{INV} from *XYZ* to *fundamental metamer* is introduced. Next, the base functions of P_{INV} are transformed to an orthogonal *matrix* ***F*** by Gram Schmidt method. This *matrix* ***F*** proves to be an orthonormal linear transformation of *xyz* color matching function and spans a new **FCS.** The paper discusses the geometrical structure of **FCS** in relation to *matrix* ***F*** and introduces its application to the spectral design of color input devices.

Keywords: human vision, color space, fundamental metamer, spectral response

1 INTRODUCTION

A color matching function (CMF) transforms *n*-dimensional spectral input ***C*** into 3-dimensional tri-stimulus vector ***T*** =*XYZ*. While, according to Cohen[2], ***C*** is decomposed into the *fundamental* ***C**** and *metameric black* ***B*** in spectral space as

$$\mathbf{C} = \left[C(\lambda_1), C(\lambda_2), \cdots, C(\lambda_n)\right]^t \quad (1)$$

$$\boldsymbol{C} = \boldsymbol{C}^* + \boldsymbol{B},\ \boldsymbol{C}^* = \boldsymbol{P}_V \boldsymbol{C},\ \boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{P}_V)\boldsymbol{C} \quad (2)$$

I denotes unit matrix and P_V is the projector onto **HVSS** derived from CMF ***A*** as

$$\mathbf{P_V} = \mathbf{A}(\mathbf{A}^t\mathbf{A})^{-1}\mathbf{A}^t \quad (3)$$

A denotes 1931CIE $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ CMF.

$$\boldsymbol{A} = [\bar{\boldsymbol{x}}, \bar{\boldsymbol{y}}, \bar{\boldsymbol{z}}] = \begin{bmatrix} \bar{x}(\lambda_1), \bar{y}(\lambda_1), \bar{z}(\lambda_1) \\ \bar{x}(\lambda_2), \bar{y}(\lambda_2), \bar{z}(\lambda_2) \\ \vdots \quad \vdots \quad \vdots \\ \bar{x}(\lambda_n), \bar{y}(\lambda_n), \bar{z}(\lambda_n) \end{bmatrix} \quad (4)$$

The *fundamental* ***C**** is the intrinsic color stimulus that causes a unique *XYZ* sensation to human vision. The *metameric black* ***B*** is the residue insensitive to human vision and spans *n*-3 dimensional null space.

$$\boldsymbol{T} = [X, Y, Z]^t = \boldsymbol{A}^t\boldsymbol{C} = \boldsymbol{A}^t\boldsymbol{C}^*, \boldsymbol{T}_B = \boldsymbol{A}^t\boldsymbol{B} = 0 \quad (5)$$

The projector P_V is the $n \times n$ symmetric matrix whose *i*-th column vector E_i is composed of the fundamental metamer corresponding to the mono-chromatic spectra for λ_i (380~730nm).

$$\boldsymbol{P}_V = [\boldsymbol{E}_1, \boldsymbol{E}_2, \cdots\cdots, \boldsymbol{E}_n] \quad (6)$$

$$\boldsymbol{E}_i = [e_i(\lambda_1), e_i(\lambda_1), \cdots\cdots, e_i(\lambda_n)]^t \quad (7)$$

Since the rank of P_V is 3, it has only 3 independent vectors and the remaining *n*-3 are redundant. We can reconstruct P_V by choosing arbitrary triplet from the column (row) vectors. The selected triplet is called "*matrix* ***E***" and *i=r, g, b* show the spectral primaries at wavelength λ_r, λ_g, λ_b as follows.

$$\boldsymbol{E} = [\boldsymbol{E}_r, \boldsymbol{E}_g, \boldsymbol{E}_b]^t \quad (8)$$

$$\boldsymbol{P}_V = \boldsymbol{E}(\boldsymbol{E}^t\boldsymbol{E})^{-1}\boldsymbol{E}^t \quad (9)$$

Indeed, Fig.1 shows the reconstructed projector P_V from the middle three entries [E_1, E_2, E_3].
The ***FCS*** is a color space spanned by a triplet of basis vectors called "*matrix* ***F***", which is generated by ortho-normalization of matrix ***E*** using Gram Schmidt method as

$$\boldsymbol{F} = [\boldsymbol{F}_1, \boldsymbol{F}_2, \boldsymbol{F}_3] = GramSchmidt[\boldsymbol{E}_r, \boldsymbol{E}_g, \boldsymbol{E}_b]$$

$$\boldsymbol{F}^t\boldsymbol{F} = \boldsymbol{I};\ \langle \boldsymbol{F}_j \bullet \boldsymbol{F}_k \rangle = \begin{cases} 1 & for\ \ j = k \\ 0 & for\ \ j \neq k \end{cases} \quad (10)$$

The symbol $\langle \boldsymbol{u} \bullet \boldsymbol{v} \rangle$ denotes the inner product of ***u*** and ***v***. ***F*** is the $n \times 3$ matrix whose triplet of $n \times 1$ column vectors spans its own ***FCS***.

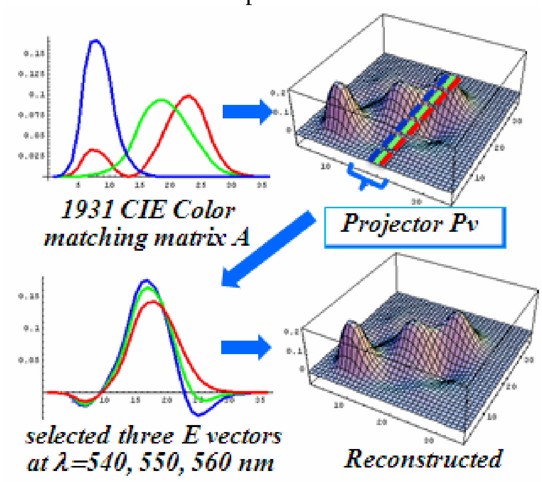

Figure.1 Projector ***Pv*** and its reconstruction

The selection of primary wavelengths is very important to construct **FCS** as suggested by Brill, Finlayson, et al[6]. Burns, Cohen, and Kuznetsov[3] created two types of **FCS** called *"R-L-V"* selecting the quasi-orthogonal axes of primary monochromatic vectors as *Red, Luminousity, and Violet,* and *"r-C-v",* another triplet of *red, Illuminant C*, and *violet*.

Of course, 1931 CIE *xyz* CMF is to be a basis of "*matrix* ***F***" that is transformed into orthonormal CMF by Eq. (10) and its spectral locus spans a **FCS**. Historically, an orthogonal CMF is given by MacAdam[1] as a linear transform of CIE *xyz*. Recently, Worthey[8] created a new **FCS** from an orthogonal normalization of Guth's opponent CMF. It's different from Cohen's **FCS**.

2 RELATION BETWEEN XYZ AND FUNDAMENTAL SPACE

The $\boldsymbol{P_V}$ is understood as a *forward* projector from *n*-dimensional spectral space to *3*-dimensional **HVSS**. It transforms a spectral input $\boldsymbol{C}$ into its fundamental metamer $\boldsymbol{C^*}$ that carries the unique *XYZ* tri-stimulus value. Since $\boldsymbol{C^*}$ is equivalent to *XYZ* tri-stimulus vector, the following simple question arises here.

"Is it possible to calculate the fundamental $\boldsymbol{C^*}$ *from a XYZ tri-stimulus value?*

The answer *is* "*yes*". We can get the *backward* projection from $\boldsymbol{T}$ to $\boldsymbol{C^*}$ in Eq. (5) by the generalized pseudo-inverse matrix $\boldsymbol{P_{INV}}$[7] as

$$\boldsymbol{C^*} = \boldsymbol{P_{INV}} \boldsymbol{T} \qquad (11)$$

$$\boldsymbol{P_{INV}} = [\boldsymbol{P_{inv1}}, \boldsymbol{P_{inv2}}, \boldsymbol{P_{inv3}}] = \boldsymbol{A}(\boldsymbol{A}^t\boldsymbol{A})^{-1} \qquad (12)$$

$\boldsymbol{P_{INV}}$ operator simply generates the fundamental $\boldsymbol{C^*}$ for a given *XYZ* and spans its own **FCS**.

Thus the projector $\boldsymbol{P_V}$ is connected to $\boldsymbol{P_{INV}}$ as

$$\boldsymbol{P_V} = \boldsymbol{P_{INV}} \boldsymbol{A}^t \qquad (13)$$

Fig.2 overviews a go/back relation in spectral space to/from tri-stimulus space transforms.

3 FOUNDATION OF NEW FCS

Combining Eq. (5) and Eq. (11), we get

$$\boldsymbol{A}^t \boldsymbol{P_{INV}} = \boldsymbol{I} \quad or \quad \boldsymbol{P_{INV}}^t \boldsymbol{A} = \boldsymbol{I} \qquad (14)$$

This means the pseudo-inverse projector $\boldsymbol{P_{INV}}^t$ is a matrix orthogonal to the CIE CMF $\boldsymbol{A}$. Hence, the base function of projector $\boldsymbol{P_{INV}}$ may be a candidate for "*matrix* ***F***" to create an orthogonal **FCS**. Because the CIE CMF $\boldsymbol{A}$ is not orthogonal, $\boldsymbol{P_{INV}}$ is not an orthogonal function. Thus a new "*matrix* $\boldsymbol{F_{INV}}$" is generated by applying Gram Schmidt for $\boldsymbol{P_{INV}}$ using Eq. (10).

$$\begin{aligned}\boldsymbol{F_{INV}} &= [\boldsymbol{F_{inv1}}, \boldsymbol{F_{inv2}}, \boldsymbol{F_{inv3}}] \\ &= GramSchmidt[\boldsymbol{P_{inv1}}, \boldsymbol{P_{inv2}}, \boldsymbol{P_{inv3}}]\end{aligned} \qquad (15)$$

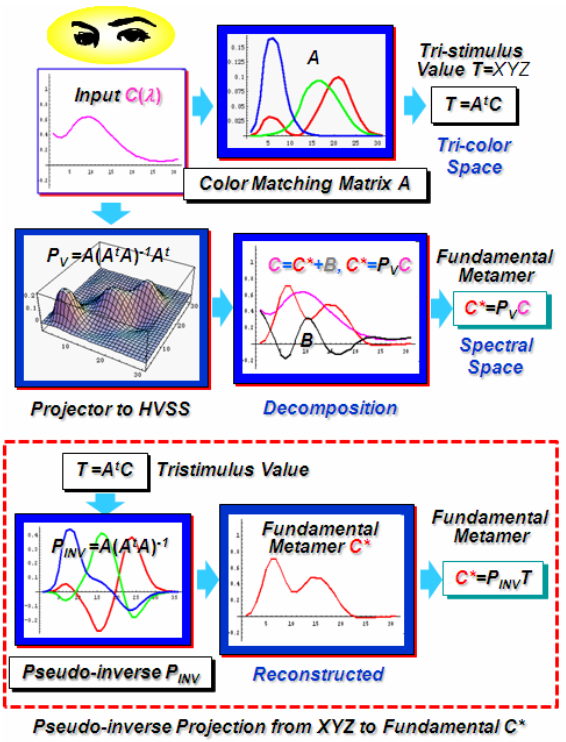

Figure 2 Fundamental to/from XYZ transformations

Since Gram Schmidt starts from the first entry $\boldsymbol{P_{inv1}}$, the resultant vector $\boldsymbol{F_{inv2}}$ orthogonal to $\boldsymbol{P_{inv1}}$ is firstly obtained, then $\boldsymbol{F_{inv3}}$ orthogonal to $\boldsymbol{F_{inv1}}$ and $\boldsymbol{F_{inv2}}$ is calculated under $\boldsymbol{F_{inv1}} = \boldsymbol{P_{inv1}}$.
The first vector in Eq. (15) maybe changed to any. Since the first entry is unchanged, the vector reflecting the luminance channel (Green) is mostly selected as the first.
In practice, the new matrix $\boldsymbol{F_{INV}}$ can be used as an orthonormal CMF $\boldsymbol{A_{Pinv}}$ by normalizing the luminance channel to

$$\begin{aligned}\boldsymbol{A_{Pinv}} &= [\boldsymbol{p_{inv1}}, \boldsymbol{p_{inv2}}, \boldsymbol{p_{inv3}}] = k^{-1}\boldsymbol{F_{INV}} \\ & where, \ k = \int_{vis} F_{inv2}(\lambda)d\lambda\end{aligned} \qquad (16)$$

Thus we get a new CMF orthonormal to $\boldsymbol{A}$ as

$$\boldsymbol{A}^t_{Pinv} = \boldsymbol{M}\boldsymbol{A}^t = \begin{bmatrix} 1.772 & -1.273 & -0.296 \\ 0.0000 & 1.065 & -0.065 \\ 0.0000 & 0.0000 & 0.788 \end{bmatrix} \begin{bmatrix} \bar{x}(\lambda) \\ \bar{y}(\lambda) \\ \bar{z}(\lambda) \end{bmatrix} \qquad (17)$$

The created new orthonormal CMF has a very simple functional shape as illustrated in Fig.3.

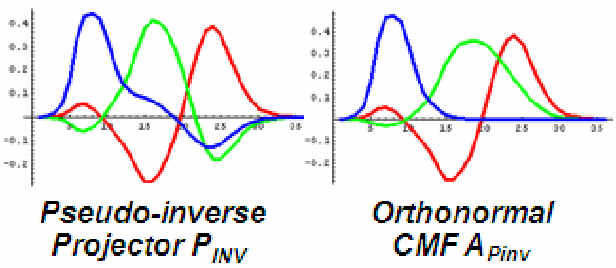

Figure 3 Orthonormal CMF created from pseudo-inverse projector

4 RESULTS

The structures of typical **FCS** created by the following *matrix* ***F*** are summarized in Fig. 4.

4.1 CIE *xyz* Orthonormal FCS

The orthonormal CIE ***xyz*** **FCS** is created by Gram Schmidt for CIE *xyz* as shown in Fig.4 (a).

4.2 MacAdam's Orthonormal FCS

MacAdam[1] introduced an orthogonal CMF,

$$\boldsymbol{A}^t_{MacAdam} = \begin{bmatrix} 0.5670 & -0.3695 & -0.1651 \\ 0.0000 & 0.3598 & 0.0000 \\ 0.2032 & -0.1738 & 0.2239 \end{bmatrix} \begin{bmatrix} \bar{x}(\lambda) \\ \bar{y}(\lambda) \\ \bar{z}(\lambda) \end{bmatrix} \quad (18)$$

Since MacAdam's CMF is already orthogonal, the orthonormal **FCS** is simply created by just normalizing Eq. (18) as shown in Fig.4 (b).

4.3 Cohen's Orthonormal FCS

"*R-L-V*" and "*r-C-v*" **FCS**s by Cohen are shown in Fig.4 (c) and (d). "*L*" base vector is the *fundamental* of λ=563 nm single spectrum reflecting the luminosity, while "*C*" is the *fundamental* of illuminant *C* not a single spectrum. Hence the humps like camel back appear in the second base function of "*r-C-v*".

4.4 Guth's Opponent Color FCS by Worthey

Guth's opponent color model is given by

$$\boldsymbol{A}^t_{Guth} = \begin{bmatrix} 0.0000 & 0.9341 & 0.0000 \\ 0.7401 & -0.6801 & -0.1567 \\ -0.0061 & -0.0211 & 0.0314 \end{bmatrix} \begin{bmatrix} \bar{x}(\lambda) \\ \bar{y}(\lambda) \\ \bar{z}(\lambda) \end{bmatrix} \quad (19)$$

Guth's original spans a non-orthogonal **FCS** as shown in Fig.4 (e-1). Worthey[8] orthogonalized Guth's CMF by Gram Schmidt. The resultant *matrix* ***F*** holds its clear opponent color feature and spans orthonormal **FCS** as shown in (e-2).

4.5 Wandell's Opponent Color FCS

Wandell[4] founded the opponent color model as a linear transform of *LMS* cone responses. Connecting *LMS* with *XYZ*, its CMF is given by

$$\boldsymbol{A}^t_{Wandell} = \begin{bmatrix} 0.2430 & 0.8560 & -0.0440 \\ -0.4574 & 0.4279 & 0.0280 \\ -0.0303 & -0.4266 & 0.5290 \end{bmatrix} \begin{bmatrix} \bar{x}(\lambda) \\ \bar{y}(\lambda) \\ \bar{z}(\lambda) \end{bmatrix} \quad (20)$$

Since the original Wandell's opponent color model is non-orthogonal, it spans the unique shaped **FCS** as shown in Fig.4 (f).

4.6 S-CIELAB FCS

S-CIELAB by Zhang[5] is modified from the first Wandell's model as

$$\boldsymbol{A}^t_{S-CIELAB} = \begin{bmatrix} 0.279 & 0.720 & -0.107 \\ -0.449 & 0.290 & -0.077 \\ 0.086 & -0.590 & 0.501 \end{bmatrix} \begin{bmatrix} \bar{x}(\lambda) \\ \bar{y}(\lambda) \\ \bar{z}(\lambda) \end{bmatrix} \quad (21)$$

Its **FCS** also has a unique shape (not shown).

4.7 Proposed Pseudo-inverse FCS

Lastly, the proposed pseudo-inverse **FCS** is created based on the above-mentioned model in Section.3. The *matrix* ***F*** has mostly single-peaked blue and green curves and a "*red-green*" opponent channel. The resultant orthonormal **FCS** from $\boldsymbol{P}_{INV}$ by Eq. (15) is shown in Fig.4 (g).

Fig. 5 shows a comparison of 3-D shapes between the proposed and the typical **FCS.**
The proposed *matrix* ***F*** spans a "*Boomerang*" **FCS** similar to MacAdam, Guth, and Cohen, but has a specialized axes oblique from them.

5 APPLICATION

Since **FCS** reflects a fundamental structure of human color vision, it will be useful for estimating the spectral response of color input devices[7]. Fig.6 shows an example applied to a commercial digital camera. First, the color filter spectral response of camera is matched to CIE *xyz* CMF by linear matrix. Next applying Gram Schmidt, the orthonormalized *matrix* ***F*** of camera is obtained and camera **FCS** is created. Finally, the spectral response of camera **FCS** is compared with CIE ***xyz*** orthonormal **FCS**. The gap in loci shows where the large design errors for color filters happen in the spectral space.

6 CONCLUSIONS

The paper proposed a new orthonormal **FCS** and discussed the geometrical structures.
The following characteristics are clarified.

1) MacAdam's orthogonal CMF is very old, but its **FCS** has an excellent geometrical structure closest to the modern Cohen's *R-L-V* with a common "*Boomerang*" or "*Butterfly*" shape.
2) Cohen's *r-C-v* **FCS** has a different structure from *R-L-V*, because its basis includes the *fundamental* of illuminant *C* in *matrix* ***F***.
3) Guth's CMF, orthogonalized by Worthey, spans a **FCS** close to MacAdam and Cohen.
4) Wandell's opponent CMF and S-CIELAB are basically non-orthogonal. They span unique **FCS** quite different from the other orthonormal **FCS**s.
5) The proposed "*pseudo-inverse*" **FCS** is created by a different way from Cohen or Worthey. Its *matrix* ***F*** has almost single-peaked *B* and *G* channels and unique "*red-green*" opponent color response.
6) **FCS** is useful for estimating the naïve spectral responses of color input devices and designing the better color filters.

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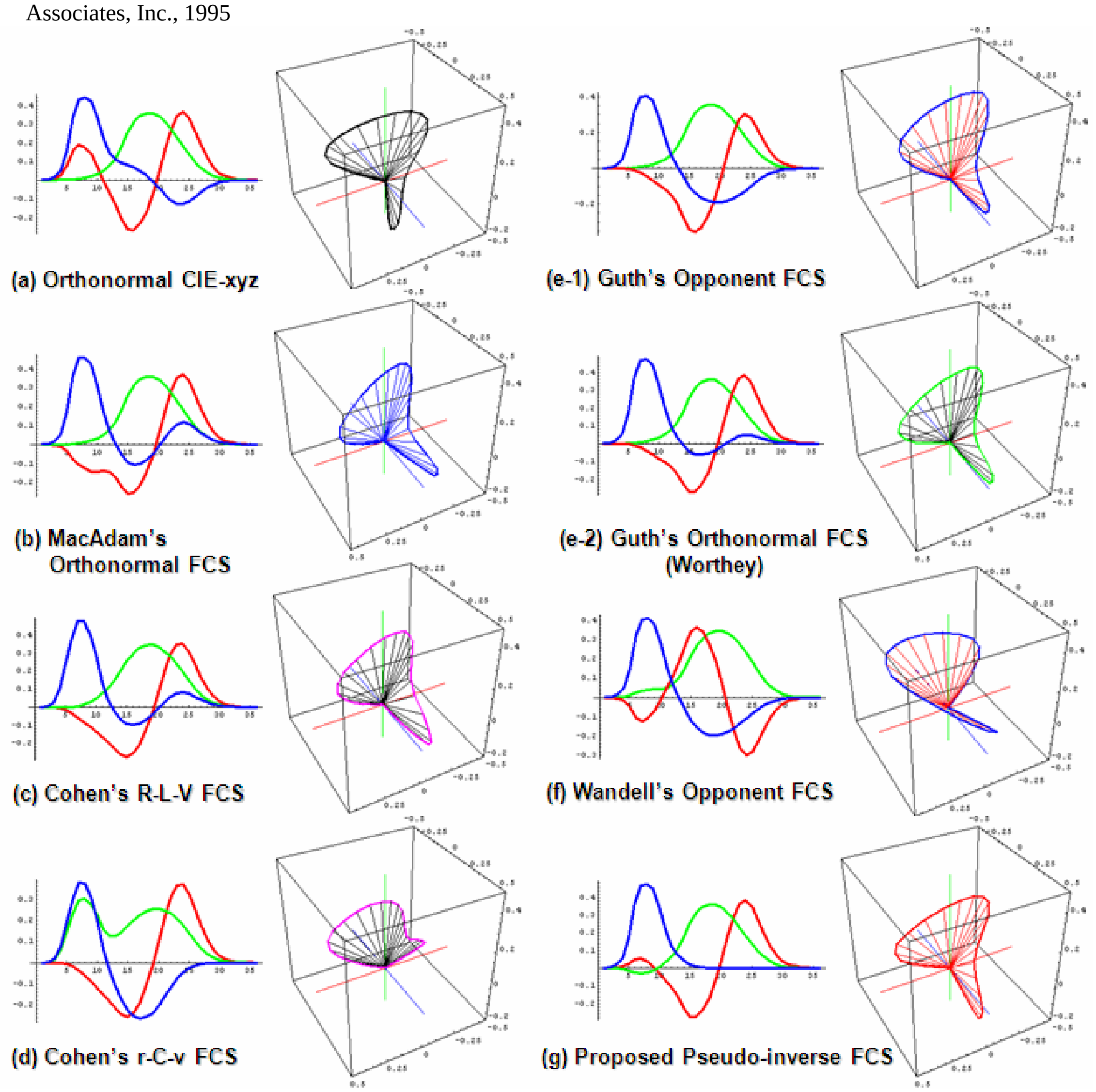
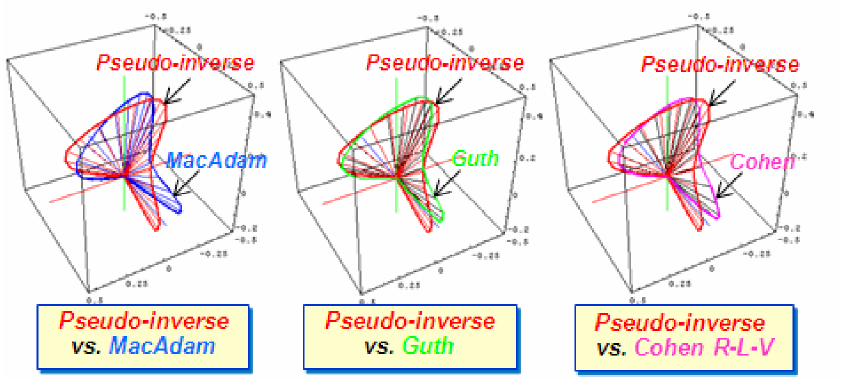


Figure 4 Base functions of *matrix* ***F*** and geometrical structures of typical **FCS**s



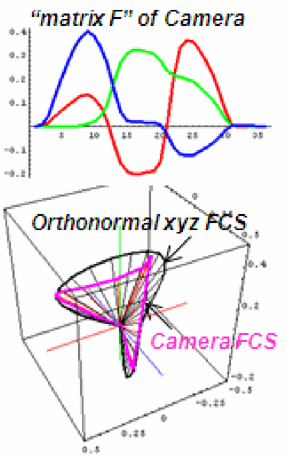


Figure 5 *Boomerang* shape of proposed **FCS** in comparison with typical **FCS**s **Figure 6** Estimated **FCS** of Camera

FCS-based Prediction in Color Changes under Different Illuminants

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ABSTRACT

Spectral imaging has advanced to reproduce the real colors under different illuminants. Since multi-spectral camera is expensive, the more simple ways to predict the color renditions by *RGB* camera have been proposed actively. Human vision is characterized by *metamerism* that pair of colors match under one illuminant but differ under another illuminant. The projection from spectral to tri-color space is many-to-one and non-invertible. The projector from spectral to Human Visual Sub-Space is mathematically described by J. B. Cohen in FCS (Fundamental Color Space). This paper discusses a FCS-based estimation of color changes under different illuminants by using only *XYZ* or *RGB* tri-color data. In FCS, a spectral color input is decomposed into two components, *fundamental* and *metameric black*. Since the *fundamental* carries the intrinsic *XYZ* sensation to human vision and is invertible by a *pseudo-inverse* projection from XYZ, first, the color change is roughly estimated by biasing the *fundamental* with SPD (Spectral Power Distribution) of a given illuminant. Though the *metameric black* is an independent variable and unpredictable, next, the paper proposes a parametric prediction method for *metameric black* component using a correlation analysis back to *XYZ* space from FCS. Experimental results are presented for IT8 standard color target or a set of inkjet color chips under the illuminant changes from D65 to D50 or D65 to tungsten lamp A.

Keywords: human vision, color rendition, spectral estimation, illuminant change

1 INTRODUCTION

Spectral imaging has advanced to reproduce the real colors under different illuminants[1-4]. Since multi-spectral camera is expensive, the more simple ways to predict the color renditions by RGB tri-color devices have been requested. Estimation of reflectance spectra from reduced low-dimensions has been attempted to meet this requirement[5-10]. Karhunen-Loeve (K-L) transform or Principal Component Analysis (PCA) provided a mathematical solution to this problem. However, to guarantee the high precision restoration, these methods still need multi-band sensors more than three channels.

Human vision is basically tri-chromatic and characterized by *metamerism* that pair of colors match under one illuminant but differ under another illuminant. The projection from spectral to tri-color space is many-to-one and non-invertible. J. B. Cohen[11] derived the projector $\boldsymbol{P_V}$ onto HVSS (Human Visual Sub-Space) and founded FCS (Fundamental Color Space).

This paper discusses a new approach by FCS-based estimation of color changes under different illuminants using *XYZ* or *RGB* tri-color data. The projector $\boldsymbol{P_V}$ decomposes *n*-dimensional color spectrum into *fundamental metamer* that carries *XYZ* tri-stimulus value sensitive to human eye and residual *metameric black* insensitive to human eye.

Since the *fundamental metamer* carries the intrinsic *XYZ* sensation to human vision, the spectral change in *fundamental metamer* may be strongly reflected to the color changes under another illuminant. However the *metameric black* spectrum also changes with the spectral power distribution of illuminant and can't be bypassed.

This paper presents the following two approaches.

[***Method-1***] Nonparametric color rendition only from *XYZ* value without *metameric black*.

[***Method-2***] Parametric color rendition with a single mean vector of *metameric black*.

2 SPECTRAL COLOR RENDITION FROM XYZ WITHOUT METAMERIC BLACK

The first nonparametric method tries to estimate the color changes under different illuminants only from *XYZ* tri-stimulus value or *sRGB* camera data.

In FCS, according to Cohen, a *n*-dimensional spectral input $\boldsymbol{C}$ is decomposed into fundamental metamer $\boldsymbol{C}$*and its residual $\boldsymbol{B}$ in spectral space as

$$\boldsymbol{C} = \boldsymbol{C}^* + \boldsymbol{B},\ \boldsymbol{C}^* = \boldsymbol{P_V}\boldsymbol{C},\ \boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{P_V})\boldsymbol{C} \quad (1)$$

$\boldsymbol{I}$ denotes unit matrix and $\boldsymbol{P_V}$ means $n \times n$ projector onto HVSS derived from color matching matrix $\boldsymbol{A}$.

$$\boldsymbol{P_V} = \boldsymbol{A}(\boldsymbol{A}^t\boldsymbol{A})^{-1}\boldsymbol{A}^t \quad (2)$$

Where $\boldsymbol{C}^*$ carries 3-D tri-stimulus value $\boldsymbol{T}$ and $\boldsymbol{B}$ spans *n*-3 dimensional null space to human vision

$$\boldsymbol{T} = \boldsymbol{A}^t\boldsymbol{C} = \boldsymbol{A}^t\boldsymbol{C}^*,\ \boldsymbol{T_B} = \boldsymbol{A}^t\boldsymbol{B} = 0 \quad (3)$$

Here we can make the inverse projection from $\boldsymbol{T}$ to $\boldsymbol{C}^*$ by the generalized pseudo-inverse matrix $\boldsymbol{P_{INV}}$[12] as

$$\boldsymbol{C}^* = \boldsymbol{P_{INV}}\boldsymbol{T},\quad \boldsymbol{P_{INV}} = \boldsymbol{A}(\boldsymbol{A}^t\boldsymbol{A})^{-1} \quad (4)$$

Thus the matrix $\boldsymbol{P_V}$ is simply related to $\boldsymbol{P_{INV}}$ by

$$\boldsymbol{P_V} = \boldsymbol{P_{INV}}\boldsymbol{A}^t \quad (5)$$

Using Eq. (4) we can generate the fundamental metamer $\boldsymbol{C_{D65}}^*$ from a *XYZ* input $\boldsymbol{T_{D65}}$ taken by a *sRGB* camera under the illuminant D65 as

$$C_{D65}^* = P_{INV} T_{D65} \tag{6}$$

Since an input C is given by the product of reflectance ρ and illuminant L, the fundamental metamer C_L^* biased by L in Eq.(1) is

$$C = L\rho,\ C_L^* = P_V L\rho \tag{7}$$

If C_L^* is estimated, the color T_L under illuminant L is simply predicted by Eq. (3), because C_L^* carries the intrinsic tri-stimulus value.
In the case of L=W (Tungsten lamp), Eq.(7) reflects the fundamental metamer under illuminant W that carries correct T_W.
Although the reflectance ρ is unknown, the objective C_W^* is approximated by weighting the *fundamental metamer* C_{D65}^* with the SPD ratio of illuminant W vs. $D65$ and T_W is estimated by

$$\hat{C}_W^* \cong (W / D_{65}) C_{D65}^*,\quad thus\quad \hat{T}_W \cong A^t \hat{C}_W^* \tag{8}$$

The spectral error in *fundamental metamer* is evaluated by the difference between the true fundamental C_W^* and the estimated $\hat{C}_W^*$ as

$$error_{fund} = \left\| C_W^* - \hat{C}_W^* \right\| = \left\| P_V W\rho - \hat{C}_W^* \right\| \tag{9}$$

However the component B in Eq. (1) also changes with the SPD of illuminant, then Eq. (8) includes an inevitable estimation error due to the unpredictable component B.
Fig.1 illustrates the first nonparametric method.

3 SPECTRAL COLOR RENDITION WITH PREDICTION OF METAMERIC BLACK

Though the *metameric black* is an independent variable with *n-3* freedom of dimension, any correlation may exist in the spectral distribution of actual color imaging materials. Here we make a priori that a *metameric black* B_i for pixel i is simply approximated by a linear equation of its mean vector B_{ave}

$$B_i(X,Y,Z) = k(X,Y,Z) B_{ave}(D_{65}) \tag{10}$$

Where, coefficient k is given as a function of color coordinate in XYZ space.
As a result of statistical analysis for the spectral data set of IT8 color chips, coefficient k proved to have a very strong correlation in the 2-D X-Y coordinates.
For example, coefficient k is very well fitted by the following function for 264 IT8 chips under D65

$$k(X,Y) \cong 4.553X - 1.906Y - 0.447XY + 0.0646 \tag{11}$$

Since we can predict the *metameric black* B_i(D65) using a single parameter of mean vector B_{ave} in Eq. (10), the objective B_L for a given illuminant L is estimated as

$$B_L(X,Y) \cong (L / D_{65}) k(X,Y) B_{ave}(D_{65}) \tag{12}$$

Finally the spectral distribution of color pixel i is estimated by adding Eq.(12) to Eq. (8) as

$$\begin{aligned} \hat{C}_L &\cong (L / D_{65})(C_{D65}^* + k(X,Y) B_{ave}(D_{65})) \\ &= (L / D_{65})(P_{INV} T_{D65} + k(X,Y) B_{ave}(D_{65})) \end{aligned} \tag{13}$$

Eq. (13) needs only a trained single parameter B_{ave}(D$_{65}$).

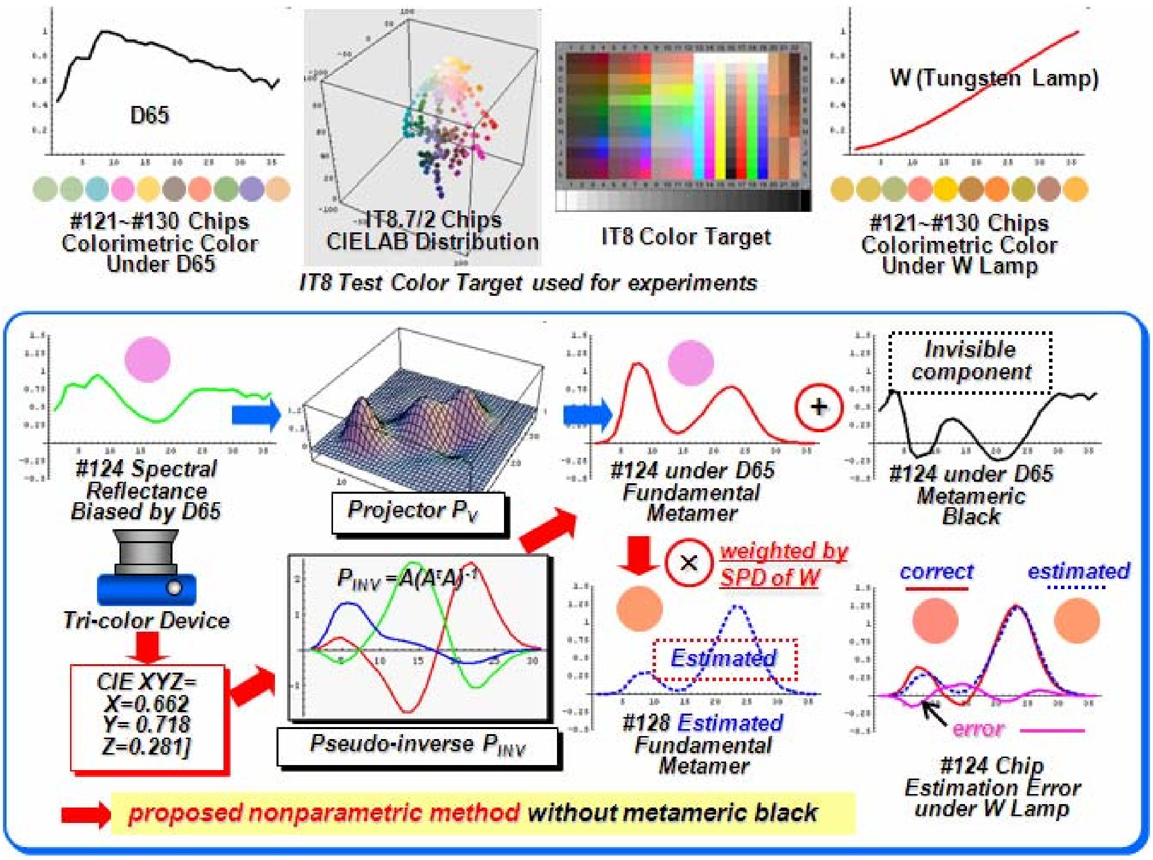

Figure 1 Overview of nonparametric ***Method-1***

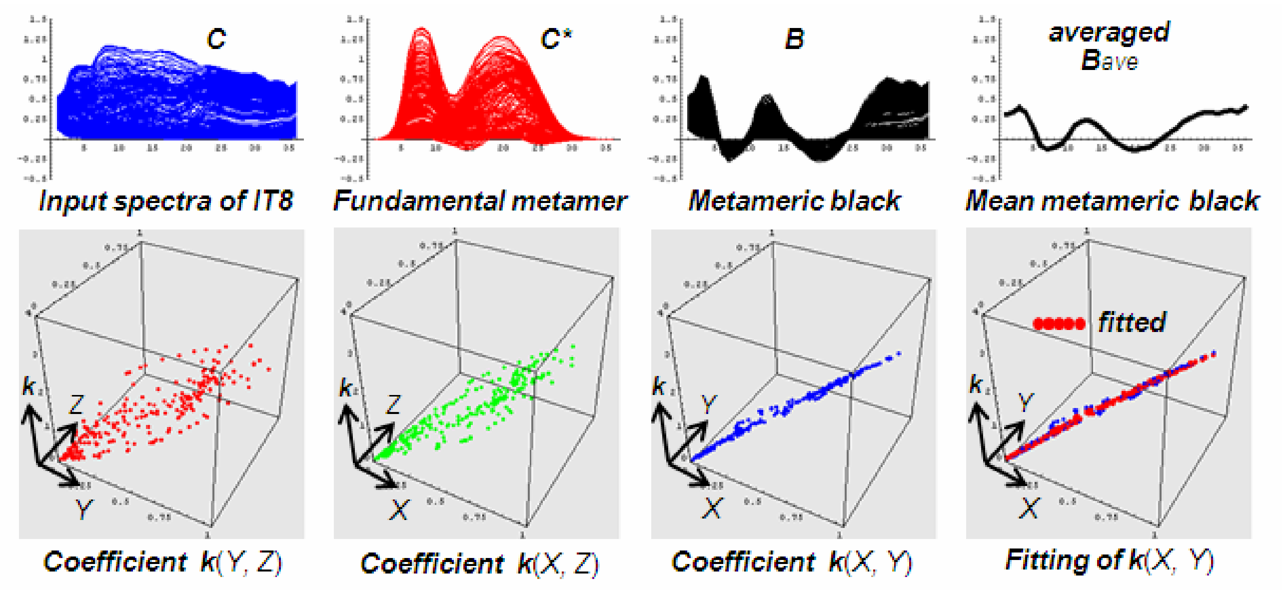

Figure 2 Correlation of coefficient *k* observed in *X-Y* plane to be used for prediction of metameric black

Fig.2 shows how the coefficient *k* is distributed with strong correlation depending on the coordinates (*X, Y*). Using this correlation, we can predict the *metameric black* component. Finally, the total spectral distribution of each pixel is estimated by adding the predicted *metameric black* to the already estimated *fundamental metamer* according to Eq. (13). Thus the estimation errors are reduced as compared with nonparametric case.

4 EXPERIMANTAL RESULTS

Experimental results are presented using standard color target IT8.7/2 (264 colors) and Epson Inkjet (1331colors) chips. Fig.3 summarizes the simulated results for the illuminant change from D65 to A (Tungsten lamp).
The colorimetric color reproducibility is listed in Table 1. The *fundamental metamer* ***C**** under D65 is exactly restored from *XYZ* value for a given *sRGB* camera input and its change under illuminant A is estimated by biasing with the SPD ratio of ***A***/***D65***. At a glance, this biased fundamental ***C**** by ***method-1*** looks to give almost similar rendition to the correct colors, because the *fundamental* error is so small for the illuminant change. However it includes inevitable errors due to neglecting the *metameric black.* While, the parametric ***method-2*** recovers the lost *metameric black* using its mean vector and the fitting function by *X-Y* values. As shown for IT8 #124 color chip in Fig.3, ***method-2*** proved to work very well. By supplementing the *metameric black*, ***method-2*** improved the colorimetric errors as shown in Table 1. However the prediction of *metameric black* still includes unacceptable errors for the large change in SPD from D65 to A. In the case of illuminant change from D65 to D50, ***method-1*** resulted in almost sufficient for practical use and ***method-2*** in the higher precision. The parametric prediction of *metameric black* by ***method-2*** worked well for inkjet chips even with non-trained default parameter for IT8 chips as shown in Table 1. Fig. 4 shows the colorimetric color renditions of IT8 chart. The rendition under illuminant A may be unrealistic, because the results are colorimetric without CAM (Color Appearance Model) at present.

5 CONCLUSION

The paper challenged the spectral color rendition from a new point of FCS-based view.
The proposed ***mehod-1***is very simple and nonparametric but worked very well. It proved that *fundamental metamer* can be almost perfectly restored by the biasing technique with SPD of illuminant and carries the major colorimetric information for the illuminant change.
On the other hand, *metameric black* component is independent variable and basically unpredictable, but it can be restored to some extent for an actual spectral set of colorants by applying a parametric estimation model.
Comparison with the existing other methods such as PCA or SVD based model and more improvement in the estimation of *metameric black* are left for the future work.

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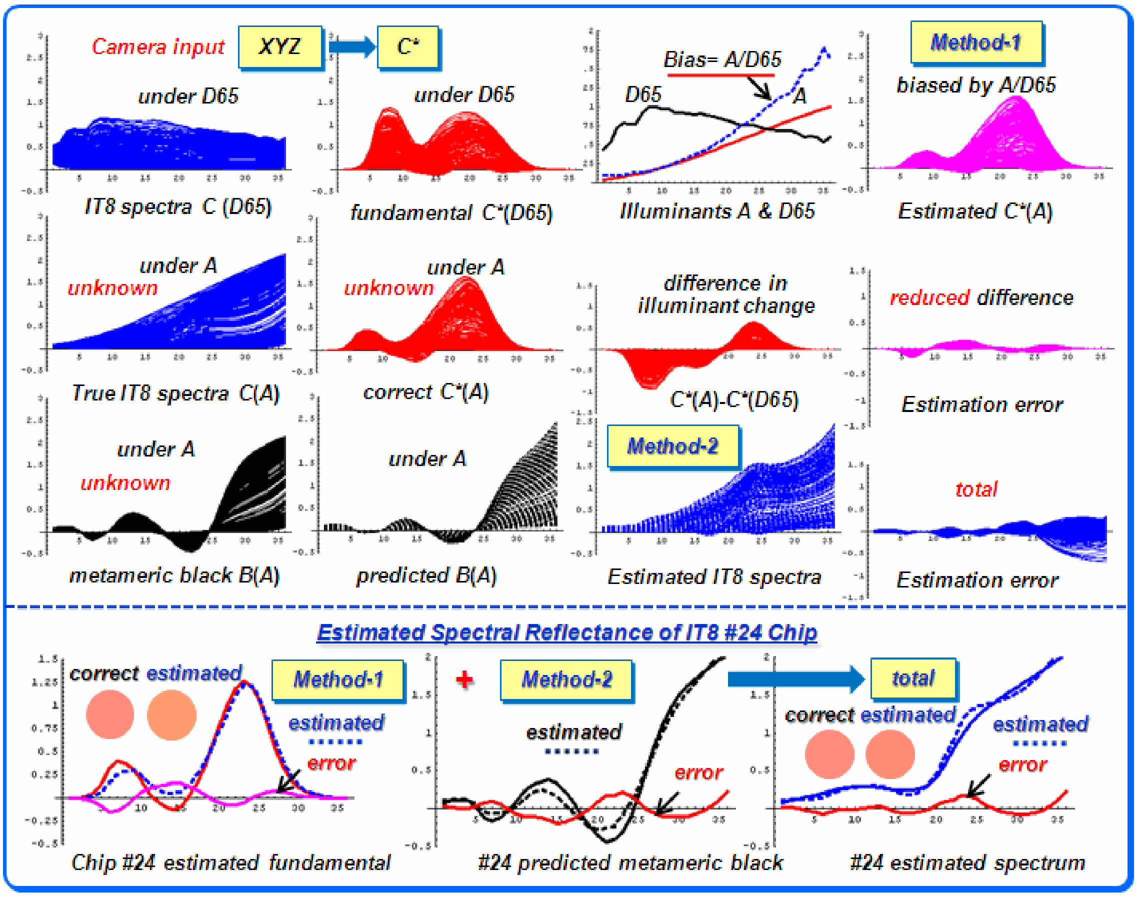

Figure 3 Simulated color rendition under illuminant change from D65 to A(Tungsten lamp) for IT8 color chips

Table 1 Estimated color differences in CIELAB $\Delta E_{ab}{}^*$

Combination		D65 to A	D65 to D50
Method-1	IT8	11.43	6.59
	Inkjet	14.12	6.41
Method-2	IT8	7.95	3.03
	Inkjet (trained)	8.63	3.75
	Inkjet (non-trained)	9.24	2.22

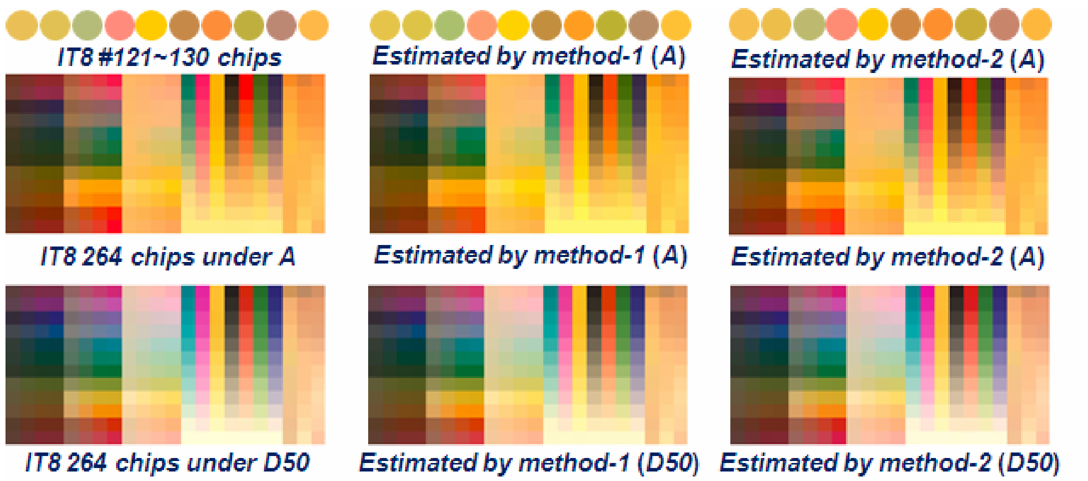

Figure 4 Colorimetric color rendition for illuminant changes from D65 to A and D65 to D50 (without CAM)

Multi-spectral Imaging Acquisition and Spectral Reconstruction using Monochromatic Camera and Narrow-band Filters

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ABSTRACT

Multi-spectral imaging technology, integrated with the capabilities of spatial imaging and spectral detecting, can acquire both spatial information and spectral information simultaneously, thus it is highly emphasized in acquisition and process of image. Based on the narrow band multi-spectral imaging technology a eight channel multi-spectral imaging system is set up which can acquire eight images in real time and eight Spectral responses ranging from 420 nm to 940 nm for a certain element. Each image must be aligned before more spectral reflectance can be obtained by interpolation .After calculation, spectral reflectance and related color parameter of each point can be obtained. The experiment indicated the interpolation by cube spine functions proved effective which could simulated spectral characteristics precisely at a certain degree. The system can be widely used in the field of moving target recognition and accurate color reproductions for acts.

Keywords: Multi-spectral imaging, spectral reflectance

1 INTRODUCTION

As a specific character of the object, the spectral reflectance is most important to accurate components analysis and color reproduction. Multi-spectral imaging (MSI) is such a technique that can be used to acquire the spectral reflectance at every pixel of the image, providing both spectral and spatial information. This technique is very suitable to applications where high quality images are required, such as agriculture, artworks, environmental inspection, etc.

This paper summarizes our research to evaluate the feasibility of using monochromatic CCD camera with narrowband filters to reconstruct the spectral reflectance of images. A MSI system is developed using eight monochromatic CCD cameras with narrowband filters. Using the images from eight channels, spectral reflectance of each pixel is estimated on the basis of cube spine functions.

This paper consists of four parts. Part 2 explains the principle of MSI systems, followed by experiments to verify the feasibility of using this technique in real imaging systems in Part 3. In the end conclusions are drawn in the fourth part.

2 PRINCIPLE OF MSI SYSTEMS

This section describes the normal structure of a manuscript and how each part should be handled. The appropriate vertical spacing between various parts of this template is achieved in MS Word by using the required paragraph spacing for each entry in the style list. Figure 1 illustrates a typical 8-channel narrowband MSI system, which is composed of a set of narrowband interference filters with different central wavelengths, optical lenses, monochromatic CCD cameras, parallel video capture card, PC, color monitor and imaging processing software.

The incident light from the object is filtered first by eight filters in parallel, with central wavelength 420nm，450nm，492nm，546nm，589nm ， 633nm ， 780nm ， 940nm and bandwidth 8 nm. Then eight filtered images are captured by the following monochromatic CCD cameras and video capture card in real-time. After image processing in the PC, the spectral reflectance of each point of the object can be acquired.

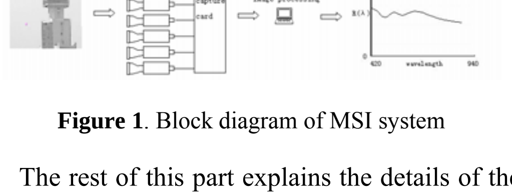

Figure 1. Block diagram of MSI system

The rest of this part explains the details of the system.

2.1 Image acquisition

Eight CCD monochromatic cameras are used with resolution 768×576 for each, mounted with filters of different central wavelength. These cameras are arranged by 2 rows, with 4 in a row. The object is captured simultaneously by eight channels, then the signal is transferred to PC via parallel video capture card and 8 bit gray image for each channel is produced.

2.2 Image registration

Because of the mutual shift between acquired images, the process of establishing point-by-point correspondence between two images of a scene is needed. One image is selected as the reference and should be kept unchanged, while others are geometrically transformed to align with the reference. In the experiment, a semiautomatic image registration method is introduced .This method is conducted with the following three steps: edge detection, feature extraction and transformation.

In the first step five edge detection algorithms are evaluated by the human vision system, including Roberts, Sobel, Prewitt, Laplacian and LoG (Laplacian of Gaussian), which suggests that LoG algorithm is able to provide both clear contour and sharp details and is the best choice for feature extraction.

The second step, feature extraction, is to extract key points, lines, regions, etc. from each image. In this experiment we manually extracted points from the edges of each grayscale image by LoG algorithm.

Finally, affine transformation is adopted because registering images are taken from a distant platform of a flat scene. The transformation can be done in this way:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix} \quad (1)$$

where x and y are the original coordinates;

x' and y' are the coordinates after transformation;

$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ is a real matrix;

$[t_x\ t_y]^T$ is a real vector.

After the transformation, the line in the original coordinate system remains unchanged in the new one. Knowing the coordinates of three corresponding feature points in the two images, the six parameters (a_{11}, a_{12}, a_{21}, a_{22}, t_x, t_y) in the transformation can be determined. In this way, all the images can be rearranged to the coordinate system of the reference image.

2.3 Reconstruction of spectral reflectance

With the help of a standard white board with known spectral reflectance as a reference, the spectral reflectance of the object can be determined as follows:

$$W(\lambda) = k\Phi_W(\lambda) = k\Phi_0(\lambda)B(\lambda) \quad (2)$$

$$S(\lambda) = k\Phi_S(\lambda) = k\Phi_0(\lambda)R(\lambda) \quad (3)$$

$$R(\lambda) = \frac{S(\lambda)}{W(\lambda)} \bullet B(\lambda) \quad (4)$$

where W(λ) and S (λ) are the spectral response of standard white board and object, respectively;

k is a constant;

$\Phi_W(\lambda)$ and $\Phi_S(\lambda)$ are reflected flux of the white board and object, respectively;

$\Phi_0(\lambda)$ is incident radiation flux;

B(λ) is the spectral reflectance of the standard white board;

R(λ) is the spectral reflectance of the object to be determined.

The spectral reflectance of each pixel of the image is only calculated at certain wavelengths. To construct a smooth spectral reflectance curve, methods like cubic spine interpolation can be used.

3 RESULTS

Figure 2 shows the image from one of the CCD cameras with filter wavelength 420nm. W(λ), S (λ), B(λ) and R(λ) of one selected point (circular area) in this figure are listed in the second column of table 1, where W(λ) and S (λ) are the response from CCD camera, and B(λ) is measured by spectrometer. In other columns of table 1, listed are the W(λ), S (λ), B(λ) and R(λ) of this point at different wavelengths (450nm , 492nm , 546nm, 589nm, 633nm, 780nm, 940nm).

Ideally, the standard white board should have B(λ) equal to 1 at all wavelengths. But in reality it is impossible to find such a perfect white board. In our experiment, a white-like board with B(λ) close to 1 is used as the reference.

Cubic spine interpolation is used to get R(λ) at other wavelengths ranging from 400nm to 940nm in 5nm intervals. Finally we have 106 values to reconstruct the spectral reflectance for each pixel and the result is plotted in figure 3.

Figure 2. Image from one of the CCD cameras with filter wavelength 420nm

Table 1. W(λ), S (λ), B(λ) and R(λ) of one selected point in figure 2

λ (nm)	420	450	492	546	589	633	780	940
S (λ)	232	220	198	213	203	216	195	176
W(λ)	211	222	224	224	223	221	218	215
B(λ) (%)	84.3	88.8	89.5	89.5	89.3	88.3	87.3	86
R(λ)	92.8	87.9	79.3	85.3	81.2	86.5	78.0	70.4

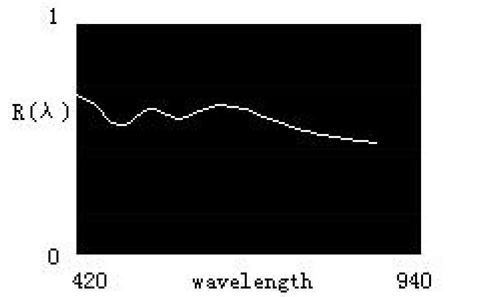

Figure 3. R(λ) after interpolation

4 CONCLUSION

The experiments suggest the imaging system has the advantages in speed and efficiency. It makes the image acquisition with high speed since it is a parallel capturing system and there are no moving parts. It is a crucial factor to take real-time image. These techniques should be able to be used in many fields such as target recognition, photographic color reproductions, environmental and agricultural detection.

Our study showed the feasibility of using this method to reconstruct spectral reflectance. The next step of our research will consist of the automatic image registration for each channel and an evaluation of colorimetric and spectral accuracy of the reconstructions.

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Natural Colour Reproduction in the Diagnosis of Plant Diseases and Insect Pests

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ABSTRACT

For a reliable diagnosis of plant diseases and insect pests, it is very important to reproduce the original colour of the object. But it is not certain by conventional colour imaging systems. Natural colour system is capable of reproducing the original colour of objects using multispectral images. In this paper a natural colour reproduction system for the diagnosis is presented. The images of the cucumbers' leaves are captured under the illumination of incandescent lamp by the narrow-band multispectral system and reproduction on a display device. For accurate colour reproduction, the spectral reflectance of plant diseases and insect pests is calculated using Spline Interpolation in the process. In the experiment, it is confirmed that the system realizes good accuracy in the colour reproduction of plant diseases and insect pests from 14 narrow bands multispectral image..

Keywords: multispectral images; colour reproduction; plant diseases and insect pests

1 INTRODUCTION

To diagnose plant diseases and insect pests, the conventional methods are contrast with the pictures. Along with the development of digital technologies, the database of plant disease and insect pest are established with colour digital images to realized the expert diagnosis systems[1-4]. Whatever the colour picture or colour digital images, there is a strong need to reproduce the plant colour accurately. However, the accuracy of the reproduced colour in conventional diagnosis methods is not sufficient for these applications. The reason of the difficulty is that the reflected spectrum from the object's surface depends on the spectrum of the illumination light. When the illumination environments of the image capture and observation sites are different, the difference is not properly corrected.

Therefore, in order to reproduce the natural colour, it is required to adjust the colour of the object as if it is placed under the illumination of the observation environment. Based on this concept, this paper proposed narrow-band multispectral camera system and demonstrated natural colour reproduction of the cucumber leaves which are sickening for Pseudoperonospora cubensis using 14-band images. Statistical characteristics of the spectral reflectance of the cucumber leaves, which are healthy and diseased, are obtained experimentally by measuring 105 samples of cucumber leaves.

2 METHOD

A natural colour reproduction method is proposed by M. Yamaguchi et al[5]. The spectrum of the illumination light is assumed to be spatially uniform for simplification, therefore indices expressing spatial coordinates are omitted. Let the spectral distribution of illumination light at the image capturing site be $E_s(\lambda)$. Supposing that the image capturing system is linear, the observed intensity $g_k(k=1,2,\ldots N)$ is given by

$$g_k = \int S_k(\lambda) E_s(\lambda) f(\lambda) d\lambda \qquad (1)$$

Where $\boldsymbol{k}$ is the index for each colour band, $\boldsymbol{N}$ is the number of colour bands, $S_k(\lambda)$ is the spectral sensitivity of the k-th colour band of the camera, and the $f(\lambda)$ is the spectral reflectance of the object.

To obtained g_k, spectral reflectance $f(\lambda)$ is required. In order to obtain the spectral reflectance $f(\lambda)$ of the object accurately, narrow-band multispectral camera is applied, which can get much spectral information of object than ordinary RGB camera. Let us assume that the spectral reflectance of standard white, $B(\lambda)$ was obtained, and the spectral distribution of the light reflected by the standard white and the object, $W(\lambda)$ and $S(\lambda)$ both can be measured from the narrow-band multispectral images. $W(\lambda)$ and $S(\lambda)$ are given by

$$S(\lambda) = k\Phi_s(\lambda) = k\Phi_0(\lambda) f(\lambda) \qquad (2)$$

$$W(\lambda) = k\Phi_W(\lambda) = k\Phi_0(\lambda)B(\lambda) \quad (3)$$

Where ***k*** is coefficient of the narrow-band multispectral camera, $\Phi_0(\lambda)$ is the radiant flux of illumination light , $\Phi_s(\lambda)$ and $\Phi_W(\lambda)$ are the reflect flux of the object and the standard white. From eq.(2) and eq.(3) , the spectral reflectance of the object is given by

$$f(\lambda) = \frac{S(\lambda)}{W(\lambda)}.B(\lambda) \quad (4)$$

After Spectral reflectance $f(\lambda)$ is estimated, the curves of spectral reflectance of object are obtained using Spline Interpolation. CIE tristimulus value $t_i(i = X, Y, Z)$ is calculated from eq.(5).

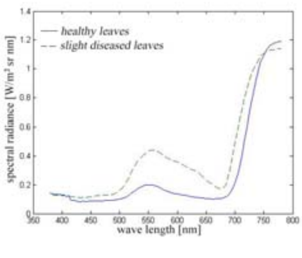
$$t_i = k\sum_{\lambda} E_o(\lambda)f(\lambda)\bar{t}_i(\lambda)\Delta\lambda \quad (5)$$

Where ***k*** is coefficient given by eq.(6)

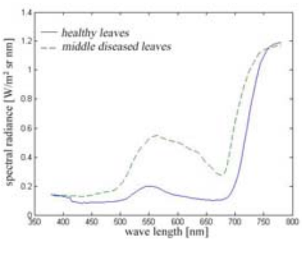
$$k = \frac{100}{\sum_{\lambda} f(\lambda)\bar{y}(\lambda)\Delta\lambda} \quad (6)$$

3 MESUREMENTS AND ANALYSIS OF THE CUCUMBER LEAVES' SPECTRAL REFLECTANCE

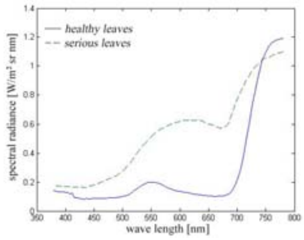
In this section, 105 spectral reflectance of cumber leaves sickening for Pseudoperonospora cubensis are obtained which belong to 4 kinds degrees according to the leaves sickening time: healthy degree, slight degree, middle degree and serious degree. All samples were measured using PhotoResearch PR-715 spectoradiometer with a sampling width of 2nm. This data was in 380-780nm ranges under CIE standard illumination tungsten lamp.



(a) healthy and slight disease

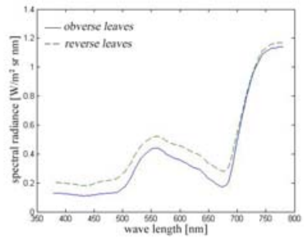


(b) healthy and middle disease

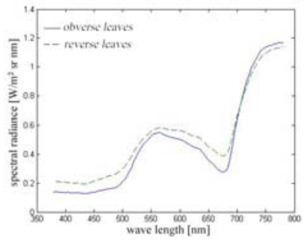


(c) healthy and serious disease

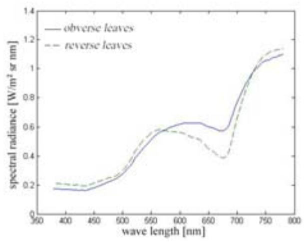
Figure 1: The spectral radiance distributions of leaves



(a) The slight diseased leaves



(b) The middle diseased leaves



(c) The serious diseased leave*s*

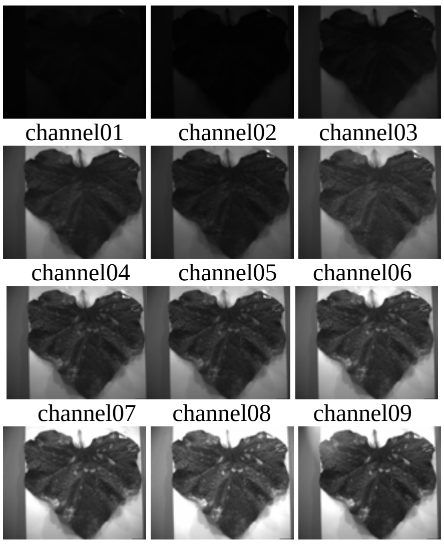
Figure 2: The spectral radiance distributions of obverse and reverse leave*s*

All 105 samples are analyzed. This analysis aim is obtaining the character of spectral reflectance between healthy and diseased leaves. The spectral reflectance of healthy and diseased leaves are shown in the Fig.1. and Fig. 2.The result reveals the spectral reflectance of cucumber leaves of different diseased degree between 380nm to 780nm. The figures for healthy leaves show that the spectral radiance distributions increase from 500nm to 550nm, and it then decline steadily at 550nm. The peak of spectral radiance distributions expresses the green information of the cucumber's leaves. The curve of slight diseased degree shows that the spectral radiance distributions grow sharply from 500nm to 550nm. Then it decreases substantially until about 670nm. The trend of curve turned to express the green and yellow information. The curve of middle degree disease has similar information compare with the slight diseased degree. However, the spectral radiance distributions occur great change to the serious diseased leaves. The data go up sharply from 500nm to 550nm, when there was little change until 650nm. It indicates that the colour of leaves has not any green information. On the other side, there are no great differences of trend between obverse and reverse leaves

4 COLOUR REPRODUCTION OF DISEASED LEAVES

To demonstrate the colour reproduction capability, the diseased leaves which sicken Pseudoperonospora cubensis is used as subject. The images are captured under the illumination of tungsten lamp which curve is Fig.4. In the experiment, a narrow-band mutilspectral camera was used as image capturing device. It is consists of a monochrome CCD camera whose resolving power is 1300×1024,and 14 interference filters. 14 interference filters in this experiment have about 10nm bandwidth, and each filter's central wavelength is 400nm, 434.8nm, 460nm, 490nm, 515.7nm, 530nm, 546nm, 589nm, 600nm, 620nm, 635nm, 650nm, 670nm, and 700nm respectively. The 14 multispectral images are shown in Fig.3.

Firstly, recording information is obtained using captured images. The spectral reflectance of every pixel of 14 images is employed by software. Secondly, we calculate 63 spectral reflectance of every pixel from 400nm to 700nm by Spline Interpoliation. Lastly the XYZ tristimulus coordinates of the object colour are calculated by eq.(4) and eq.(5) with the spectral data of Fig.4. The estimated image data are displayed on the CRT. The displayed colour of the diseased cucumber leaves is shown in Fig.5.



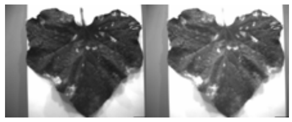


Figure 3: The 14 narrow-bands multispectral images

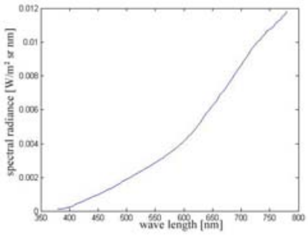


Figure 4: The spectral radiance distributions of the illumination light in this experiment: Tungsten lamp

Figure 5: The colour reproduction of diseased lea

5 DISCUSSIONS AND CONCLUSION

This paper presents a method for the diagnosis of plant disease and insect pest using narrow-band multispectral camera. In the multispectral system mentioned above, colour reproduction under standard illumination environment is achieved. Measured colour information can be used for reference as a colour image database or the examination of temporal colour changes by saving the colour data. Moreover, the measured and analysis spectral information also can be applied to investigate the disease. However, various problems are still remained to be investigated as follows:.

The condition of illumination plays an important role in this multispectral system. By using the presented method, natural colour can be reproduced using 14 filters from 400nm to 700nm. The filter whose central wavelength is less than 400nm cannot be application because the spectral power distribution of the light illumination using in this experiment is weak under 400nm. The result caused missing some information that occurred under near UV spectrum. Therefore, the selection of illumination for the object is important.

To diagnose plant diseases and insect pests from the changing of plant colour, this experiment focused on 400nm-700nm, which part is controlled by the plant colouring matter and lutein .The plant inside structure and space between cells strongly affect the spectral information from 750 to1350nm where the dynamic range of CCD has response but human beings detect nothing. To advancing the accuracy of diagnosis, the information of near infrared spectrum is absolutely necessary.

By using the presented method, natural colour image can be reproduced even if the illuminations for the object and observation environment are different. However, natural colour is reconstructed only for the same illumination environment though the experiment. One of the next jobs is to reproduce the colour under various kinds of illumination environment.

ACKNOWLEDGMENTS

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Evaluating Objective and Subjective Assessment of Fabric Pilling

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ABSTRACT

Over the years, numerous methods have been proposed to assess the degree of textile fabric pilling. The traditional subjective assessment method is by far the most widely-used method in industry, however it suffers from inconsistency. For this reason, several objective methods were proposed to overcome the challenge. One of the recent objective methods uses an imaging system based on a digital camera. Its performance was evaluated and compared to the subjective method presented in this paper.

Keywords: pilling, fuzzing, pilling visual assessment, digital grading system.

1 INTRODUCTION

Pilling is a well-known defect of textile fabrics. The presence of pills can totally ruin the appearance of a fabric, leading to the rejection of entire batches of garments. As a result, the evaluation of pilling is critical. Currently, this process of evaluation relies heavily on subjective human assessment and the results often suffer from considerable inconsistency[1,2]. (Formal definitions of pills, pilling and fuzzing can be found in the ISO standard[3].) The illumination geometry, procedure and grading scheme for visual pilling-assessment were also defined by the ISO standard. In addition, the standard specifically states that a minimum of *sixteen* assessments should be made for each sample when conducting a visual assessment of pilling[3]. Due to the amount of time and effort required, pilling assessment which strictly follows the ISO recommendation is not industrially feasible; hence, there is a strong demand to develop an automated assessment system.

Several methods have been proposed to develop an objective pilling-assessment system; however their limited success rates on highly textured fabrics precludes them from being practically adopted[1,2,4,5]. In response to this issue, the DigiEye system has attempted to overcome the problem of texture through the use of low angle-of-incidence illumination and texture removal techniques. DigiEye is a unique non-contact digital-grading system for assessing colours, and its application to assessing colour fastness has already been commercially proven[6]. Pilling assessment is a new technique which is planned for incorporation into DigiEye; however due to its developmental status, only a preliminary evaluation was carried out.

Visual assessments based on the ISO standard were conducted by naïve observers, and their repeatability, deviation and agreement to expert grades were investigated. DigiEye assessment was also made in a similar fashion. The visual assessment results were then compared to DigiEye's results to determine whether the objective assessment performed in a similar way to the subjective assessment. Furthermore, the possibility of replacing expert observers by naïve observers was also investigated.

2 EXPERIMENT

Two groups of assessments on pilling were conducted: visual and DigiEye. The thirty-sample test set consisted of the five fabric types which are shown in Figure 1. These samples were prepared using the modified Martindale method[3,6] and pre-graded by a group of experts about two years earlier. The experimental setups and procedures are explained in detail in the following paragraphs.

2.1 Visual Assessment

Visual assessment was based upon the procedure defined by ISO and was performed in dark surround conditions. An illumination device for pilling assessment was used which satisfies the illumination geometry defined by ISO[5]. The experimental setup is shown in Figure 2. A reference sample, written definitions and instructions, and a grading scheme were provided to a group of fifteen naïve observers. The observer group consisted of seven male and eight female observers whose ages ranged from 23 to 35 with various cultural backgrounds. The term "naïve observer" refers to an observer who had never done pilling visual assessment before, or who had done the assessment very few times and was therefore unfamiliar with the procedure. The visual assessment experiment was divided into one training session followed by three non-consecutive assessment sessions. The training session was fifteen-minutes long, with the definitions and instructions being explained during the session. Each assessment session was thirty-minutes long, and sixty assessments were made in random order during each session. The observers were required to perform assessments in three different days.

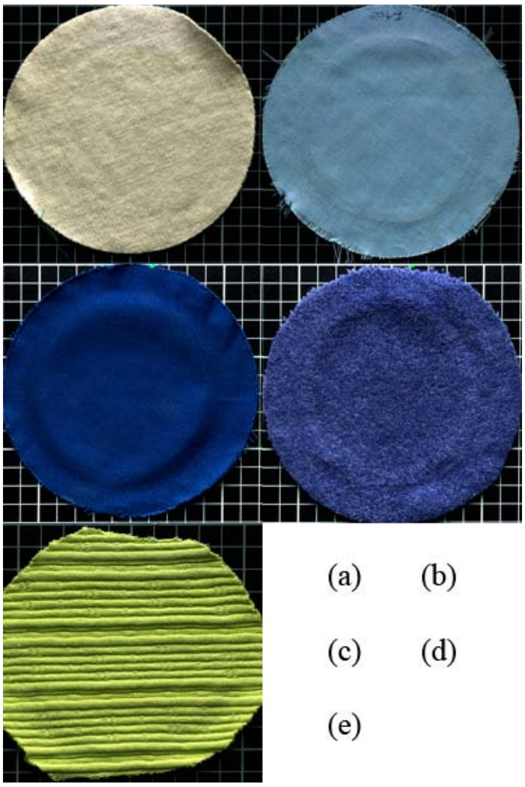

Figure 1 Fabric samples used in the experiment. (a) cream plain knit sample, (b) light blue shirt sample, (c) denim jeans sample, (d) dark blue fleecy sample and (e) yellow ridged knit sample.

Figure 2 Actual experimental setup including the test sample (left), the reference sample (right) and the written instructions (far right).

In each session, the observers were asked to assess the degree of pilling on the test samples according to the reference sample and the descriptive grading scheme on a 1-5 scale to an accuracy of within half a grade. The reference sample was classified as grade 1, and all test samples were graded in relation to the maximum perception of pilling. In order to perceive the maximum pilling on each test sample, observers were encouraged to rotate the samples but not to destroy or introduce further pilling to the samples.

2.2 DigiEye Assessment

Two D65 simulators with mirrors providing low angle-of-incidence illumination were used in the DigiEye system. The light sources were located either side of the fabric samples. A high-end CCD-based digital camera was placed directly above the samples. Two samples were required for each assessment: one pilled fabric sample and one unpilled fabric sample. The unpilled samples were used to discount the fabric texture. Pill identification is based on highlighting the pills instead of the shadow. The degree of pilling was assigned based on the total number of pills and their sizes using image processing techniques.

For each pilled sample, three images were obtained under the same conditions to determine repeatability, and six images were captured at different orientation angles; one image was captured at every sixty degrees. The DigiEye software then computed pilling grade according to the number and size of pilling, partial formed pills and fuzzing. The final grade of a particular test sample was obtained by computing the average of all six grades.

3 RESULTS AND DISCUSSIONS

The results from visual and DigiEye assessments were evaluated. In addition, the results from both assessments were contrasted with expert grades and, finally, with each other in order to obtain a detailed comparison of objective versus subjective assessment.

3.1 Visual Assessment

For visual assessment, each sample was judged six times by a particular observer; hence a total of ninety assessments were carried out for each sample. Three measures were derived from the trials: percentage intra-observer error, and intra-observer and inter-observer errors (in grade units). The intra-observer error represents the percentage of times that one observer assessed the same grade for a particular sample. The intra-observer error in grade is the standard deviation of the grade differences between the mode and the assessments within an observer for one fabric sample. The inter-observer error in grade is the the standard deviation of the grade differences between all assessments and the mode of one fabric sample. The intra-observer errors were found to be 65% and 0.39 grades respectively. The inter-observer error was found to be 0.72 grades, which is larger than the 0.5 grade difference demanded by the ISO standard[5]. From these results, the repeatability of individual observers is considered to be acceptable, although the overall agreement is considered to be low. This is believed to be caused by the observers' inexperience in judging pilling. The grade differences between the mode of all the observers and individual observers are shown in Figure 3.

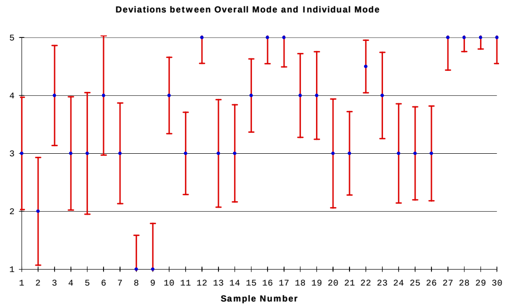

Figure 3 Inter-observer error in grade units. The dot indicates the mode of all trials for a particular sample and the lines correspond to the maximum deviations between the mode and all trials.

3.2 DigiEye Assessment

For DigiEye assessment, the repeatability at the same orientation was stable; no more than 0.5 grade differences were found. This demonstrates that DigiEye system is capable of giving consistent grades under the same conditions, but the grades do not necessarily reflect the degree of pilling accurately. A further six assessments were made using the DigiEye system for each sample during which the same sample was placed at different angles. Repeatability was calculated as a percentage of assessments had the same grade for a particular fabric sample. Variation is the standard deviation of the grade differences between the mode and all of the assessments for one sample. The repeatability was found to be 52% on average, with a mean variation of 0.73 grades. The grade differences between the mode and each trial are shown in Figure 4. Comparing between the visual assessment results (inter-observer error) and the repeatability of DigiEye system, it is about 0.7 grades which is unacceptable according to the ISO standard[5].

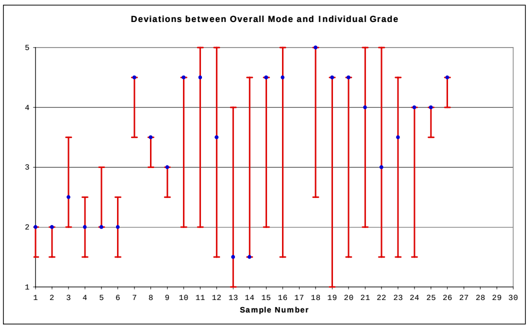

Figure 4 DigiEye repeatability in grade units. The dot indicates the mode of all trials for a particular sample, and the lines correspond to the maximum deviations between the mode and all trials.

3.3 Comparison between Visual and DigiEye Assessment to Expert Grading

When comparing the overall visual assessment grades to expert grades, the mean standard deviation of grade differences between naïve grades and expert grades was calculated to be 0.73 grades. The correlation coefficient was found to be 0.71, which demonstrates a positive, but not a strong correlation. Similarly, when comparing DigiEye grades to expert grades, the mean standard deviation of grade differences between DigiEye grades and expert grades was calculated to be 1.01 grades. The correlation coefficient was found to be 0.66.

The same analyses were conducted for each type of fabric and the results in terms of correlation coefficient are given in Table 1. It can be clearly seen that a strong correlation existed for less-textured fabric and a weak correlation was seen for highly-textured fabric such as ridged knit and fleecy samples for both visual and DigiEye methods. In addition, both naïve grades and DigiEye grades showed significant differences with expert grades. This may be caused by the tendency of pills to become 'flattened' or to be destroyed over the two-year period between the samples being assessed by the naïve and expert assessors.

Table 1 Correlation coefficients between visual and DigiEye assessments and expert grading.

Fabric Type	Correlation Coefficient	
	Visual	DigiEye
Dark Blue Fleecy	0.71	-0.13
Cream Plain Knit	0.79	0.35
Denim Jeans	0.95	0.89
Yellow Ridged Knit	0.44	-0.95
Light Blue Shirt	0.91	0.96
Overall	0.71	0.66

3.4 Comparison between Visual and DigiEye Assessment

When comparing the naive observers' results to the DigiEye results, a strong and positive correlation existed: the correlation coefficient was 0.96 (see Table 2). The finding suggests that the naïve observers' results agree with the DigiEye results. This confirms that the DigiEye system is capable of assessing pilling in a similar manner to a human; however its repeatability requires further improvement. This finding was quite surprising as the DigiEye system was originally trained with expert grades, but nevertheless seemed to agree with naïve grades. As previously mentioned, this may be caused by the two-year interval between the visual assessments and the samples' storage condition. The answer to the question of whether expert observers could be replaced by naïve observers is still inconclusive. More comprehensive work must therefore be done to evaluate expert observers' performance.

Table 2 Correlation coefficients between visual assessments and DigiEye assessments.

Fabric Type	Correlation Coefficient
dark blue fleecy	0.98
cream plain knit	0.93
denim jeans	0.98
yellow ridged knit	1.00
light blue shirt	0.93
overall	0.96

4 CONCLUSION

Two types of pilling assessment were done on thirty fabric samples which consisted of five different fabric types. Visual assessment was conducted according to the ISO standard and using a group of naïve observers.

It was found that while intra-observer agreement was acceptable, this was not the case for the inter-observer agreement. The DigiEye system exhibited a similar trend, having a repeatability performance of 0.73 grades. In comparison with expert grading, both the visual and DigiEye assessments indicated a strong correlation for less-textured fabric and a weak correlation for highly-textured fabric. The mean standard-deviation of grade differences between naïve and expert grades was 0.66 grades, and 0.71 grades between DigiEye and expert grades. Both naïve observers' and DigiEye results disagree with the expert visual results. This is due to the expert grading being done separately to the visual and DigiEye assessments.

Comparing visual assessment results with the DigiEye assessment results, a correlation coefficient of 0.96 was found which indicated that the DigiEye system is capable of assessing pilling as a human does.

The question of whether expert observers could be replaced by naïve observers still cannot be answered with any certainty. It is therefore desirable that expert and naïve observers assess same set of samples under the same viewing conditions at the same location in order to fully answer this question.

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The comparison between PCA and simplex methods for reflectance recovery

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ABSTRACT

In this paper the modified simplex, classical principle component analysis (PCA) as well as pseudo inverse (PI) methods have been applied for the reconstruction of the spectrum of 1269 Munsell color chips and 140 colored samples of Digital ColorChecker DC from GretagMacbeth. The synthesized reflectance curves, achieved from different techniques, have been compared by using color difference values under different illuminants and the root mean square (RMS) errors between the synthesized and original reflectance values.

The color difference values under D65 as well as under A and Tl84 light sources have been minimized by the simplex method. In order to minimize the spiky outputs of simplex, sixteen different bell shape curves are applied on the estimated reflectance values. The color coordinates under D65, A and TL84 are used to recover the reflectance curves by using PCA technique. So, three and nine basis functions have been used in this method of recovery. Results show the priority of classical principle component technique over the simplex method.

Keywords: Reflectance Recovery, Simplex Method, Principle Component Analysis, Pseudo Inverse

1 INTRODUCTION

The reflectance behaviors of surface colors are recognized as the fingerprint of the objects and provide the most fundamental data which are not achievable by colorimetric information. The importance of the spectral data has been emphasized in different aspects of color engineering especially in E-commerce. However, in some cases the tristimulus colorimetric values of surfaces, such as CIEXYZ, are available and the more expensive spectral data are not obtainable.

Many papers have been published to extract the reflectance curve of samples from the colorimetric data and tried to overcome the mathematically poor conditions. Different methods have been developed for synthesizing the reflectance curves from the colorimetric coordinates such as simulated annealing, neural networks, genetic algorithm and application of ideal subtractive or additive Gaussian Primaries.[1] Among them, the principle component analysis, abbreviated by PCA, developed by Karhunen-Loeve (KL) expansion[2], shows the best performance, depending on the numbers of the selected principals. The surface spectral reflectance can be represented by a linear combination of the KL bases function as showed in Equation (1):

$$\hat{R}(\lambda) = V_0(\lambda) + V(\lambda)C \qquad (1)$$

$V_0(\lambda)$ shows the mean of the spectral reflectance values of the suitable data set and $V(\lambda)$ is the selected basis vectors (or the most important eigenvectors) and C is the principal component coordinates[3].

The principal components of dataset could be determined by selection of the correct eigenvectors of the covariance matrix of data which benefit from greater eigenvalues. Equations 2 and 3 show the proposed relations for estimation of reflectance data from the tristimulus values.

$$Q = A^T.V_0 + A^T.V.C \qquad (2)$$

$$C = T^{-1}\left(Q - Q_{V_0}\right) \qquad (3)$$

Where Q shows the tristimulus values of sample which its reflectance is followed. $A^T.V$ shows the tristimulus values of the selected eigenvectors which is showed by T in Equation 2 and $A^T.V_0$ refers to tristimulus values of mean vector. Simply, C could be determined from Equation 3 and $\hat{R}(\lambda)$ is calculated from Equation 1[4]. The dimensions of matrix T could be increased by using more than one viewing condition such as the application of 2 or 3 light sources[3].

Cohen was the first to analyze the surface spectral reflectance of 433 randomly selected Munsell color chips and came to the conclusion that surface spectral reflectance data can be described by this linear model using three or four parameters (n = 3 or 4). Sobagaki *et al.* extended Cohen's analysis to 1257 Munsell color chips and concluded that 7 or 8 of these linear parameters are required[2]. An adapted method has been recently introduced by Ansari et al. to reconstruct the reflectance curves by a small number of principles[3].

On the other hand, the Simplex method is generally implemented for optimization problems with acceptable results. The implementation of this technique for the reflectance recovery has been briefly described by Dupont[1]. The work was limited to the result of one sample and the algorithm was not examined to the standard datasets such as Munsell color chips.

Within the different simplex methods, the Nelder-Mead simplex method is the most popular direct-search method. This algorithm is schematically showed in figure 1[5].

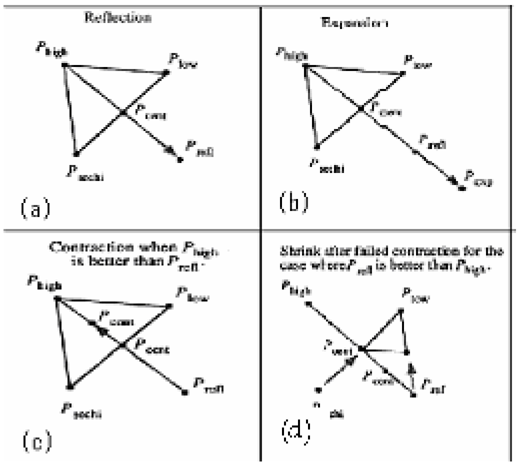

Figure 1 Nelder-Mead pivot operation.(a) Reflection, (b) Expansion, (c) Contraction and (d) is shrink.

For a function of n parameters, n+ 1 extreme points must be chosen. Hence in the case of spectral recovery, since the spectral reflectance data have been analyzed in the ranges of 400-700 nm with 20 nm interval, the initial simplex consists of 16+1 extreme points[5].

In this paper the modified Nelder-Mead simplex method is tested on two standard databases, including Munsell and Macbeth ColorChecker and the results are compared with those obtained from PCA technique. In order to deeply evaluate the results, they have been also judged by the results of solving the under-determined system by pseudo inverse method.

2 EXPERIMENTAL

The reflectance data including of 1269 Munsell color chips and 140 samples of Digital ColorChecker DC from GretagMacbeth in the ranges of 400 to 700 nm with 20 nm intervals were collected. Matlab programming language was used in this study. In order to modify the classical Nelder-Mead simplex routine, the "FMINSEARCH" build in function was not used and programs were written by authors.

3 RESULTS AND DISCUSSION

The most important decisive factor in application of simplex would be finding of suitable function which should be minimized. The color difference under D65 was selected first but it did not lead to reasonable results. Hence, it was decided to implement the color differences under three illuminants as well as the metamarism indeces under light source A and TL84. The applied function is showed in Equation 4.

$$C = \Delta E_{D65} + \Delta E_A + \Delta E_{TL84} + Met_A + Met_{TL84} \quad (4)$$

Since the reflectance factor of non-fluorescent materials are within 0 to 1 and the simplex output could be out of the desired range, the sinus function was used to limit the outputs between 0 and 1. Totally, as Table 1 shows, the modification led to a significant improvement but some types of discordance between the recovered and actual reflectance values were observed.

To avoid obtaining a very chaotic reflectance curve, 16 bell shape curves which their maximum changed from 400 to 700 nm in 20 nm intervals were applied on the estimated reflectance values. The resultant spectra were smooth and generally close to the reflectance spectra of natural surfaces. By using the trial and error technique, the curves with 35 nm of half band width was found as a best one.

Table 1 Recovery of ColorChecker by simplex method with and without implementation of sinus.

Non modified simplex method											
ΔE									RMS		
A			D65			TL84					
Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	Mean	Max	Median
0.25	4.19	0.06	0.14	2.74	0.03	0.14	2.74	0.03	1.71	13.35	0.55
Modified simplex method (using sinus function)											
ΔE									RMS		
A			D65			TL84					
Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	Mean	Max	Median
1.92	15.07	0.23	1.64	13.36	0.14	1.90	13.53	0.25	0.13	1.18	0.06

Table 2 Changing of RMS values by reducing the spectral data from 16 to 14 wavelengths, using simplex method.

	RMS		
16 wavelengths recovered	Mean	Max	Median
	0.0526	0.0597	0.0527
14 wavelengths recovered	Mean	Max	Median
	0.0228	0.1217	0.0099
%Improvement	56%	-100%	81%

As another approach, we assigned weights to color difference values in Equation (4) and the greatest weight was fixed for light source A. This illuminant was selected due to its high values in long wavelength which may reduce the impact of the observer. Table (3) demonstrates the results and a slight improvement in RMS values is detectable.

Table 3 Changing of RMS values by weighting ΔEA in minimizing function.

	RMS		
Original simplex method	Mean	Max	Median
	0.0645	0.3214	0.0385
Modified simplex method	Mean	Max	Median
	0.0644	0.3753	0.03
%Improvement	0.15%	-16%	22%

Our analysis showed that the result of reflectance recovery of light samples by using the simplex method were not as good as similar samples with lower value of lightness. Figure 2 shows the changing of RMS values with the values of Munsell chips.

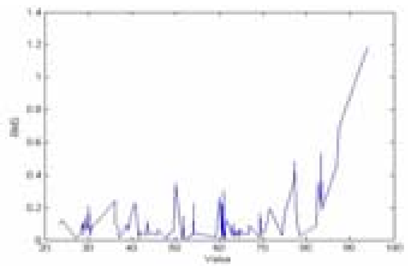

Figure 2 RMS values in different lightness.

Results of implementing Simplex Method for recovery of Munsell color chips are showed in Table (4). According to results, very suitable outcomes were obtained by using simplex method in green and blue hues, regardless of the lightness of sample.

In order to compare the results of modified simplex method with the most successful method, the PCA technique in reconstruction of reflectance data from tristimulus values was implemented. In running the method, the numbers of available colorimetric data were gradually increased from a set of tristimulus under D65 illuminant to three sets of tristimulus data under D65, A and TL84 light sources. Table 5 shows the resultant errors for synthesizing reflectance spectrum of Munsell samples by using PCA technique. The degree of precision in the application of PCA deeply depends on the singularity of Matrix T in Equation 3 and some combinations of light sources could worst the results. In order to evaluate the application of simplex method, Equation (5) was also applied to determine the under-determined reflectance value from tristimulus data.

$$\hat{R}(\lambda)=\begin{bmatrix}\bar{x}_{400}E_{400}\cdots\cdots\bar{x}_{700}E_{700}\\ \bar{y}_{400}E_{400}\cdots\cdots\bar{y}_{700}E_{700}\\ \bar{z}_{400}E_{400}\cdots\cdots\bar{z}_{700}E_{700}\end{bmatrix}^{+}\cdot\begin{bmatrix}X\\ Y\\ Z\end{bmatrix} \quad (5)$$

Results are illustrated in Table (6). The targets and the reconstructed reflectance curves of the best and the worst samples as well as two random selected samples are shown in Figure (3).

4 CONCLUSION

Simplex, principle component analysis and pseudo-inverse methods were applied in reconstruction of reflectance curves from colorimetric tristimulus data under one, two and three light sources for two large color data sets, named Munsell color chips and Macbeth ColorChecker. The classical simplex method was modified by using sinus function to limit the outputs between 0 and 1 as expected for spectral data. Besides, a series of bell shape curves were used to smooth the simplex outputs. Finally, different weights were assigned for the value of color differences under applied light sources.

The modified simplex methods performed much better than the original method and the effect of different modifications were studied. By using the bell curves, the results became smooth to a considerable extent. The deviation of reconstructed curves from the corresponded realistic reflectances in the long wavelengths is not too critical due to insignificant effect of this region in the color specifications. The running time for the reconstruction of sample was longer for simplex in comparison with PCA.

PCA, as an instant response method for reflectance recovery yielded to better results in comparison with simplex method, especially when a set of color coordinates under one illuminant was desired. However, the results obtained in this research showed that the simplex method led to better results in comparison to the straight forward pseudo inverse routine.

Table 4 Results of spectral recovery of Munsell chips by modified simplex method. Sixteen wavelengths are estimated.

ΔE									RMS			
A			D65			TL84						
Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	STD
0.66	10.90	0.08	0.68	10.89	0.04	0.66	10.58	0.06	0.06	0.74	0.04	0.08

Table 5 Results of spectral recovery of Munsell chips by PCA method.

XYZ under D65 Illuminant												
ΔE									RMS			
A			D65			TL84						
Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	STD
1.69	11.98	1.25	0.00	0.00	0.00	2.16	14.34	1.42	0.10	0.65	0.08	0.07
XYZ under D65 and A Illuminants												
ΔE									RMS			
A			D65			TL84						
Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	STD
0.00	0.00	0.00	0.00	0.00	0.00	7.10	64.68	5.01	0.26	1.49	0.18	0.24
XYZ under D65, A and TL84 Illuminants												
ΔE									RMS			
A			D65			TL84						
Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	Mean	Max	Median	STD
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.4	0.05	0.06

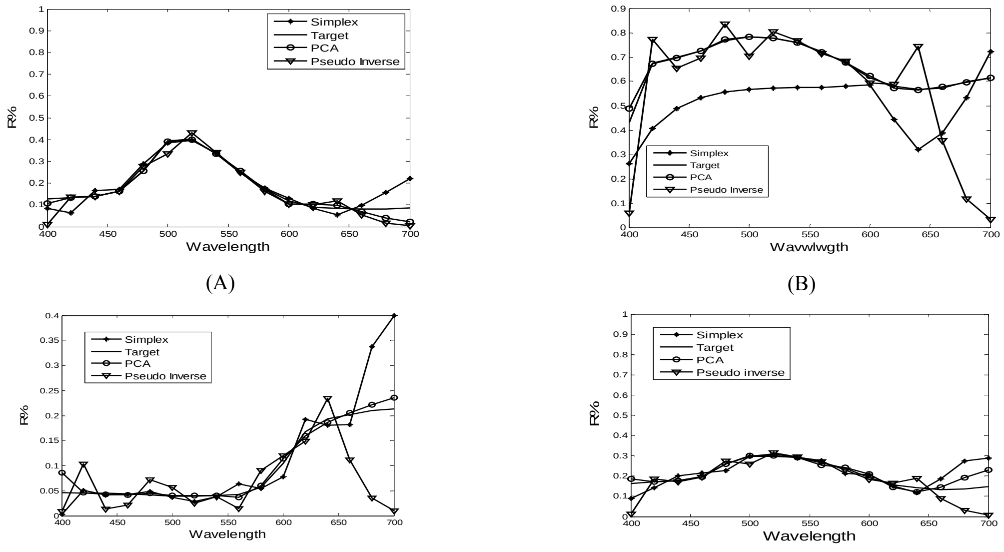

Figure 3 Results of reflectance recovery by using different methods in comparison with actual reflectance curves for A: the best, B: the worst and two randomly (C) and (D) selected samples.

Table 6 The RMS between the actual and the recovered reflectances using PI method.

	Mean	Max	Median	STD
1 source	0.65	1.64	0.58	0.40
2 sources	0.56	1.41	0.49	0.35
3 sources	0.47	1.16	0.41	0.29

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The Total Colorant Sensitivity of a Color Matching Recipe

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ABSTRACT

The repeatability of dyeing is affected by several types of small inevitable inaccuracies in the coloration process. Two of the major causes of poor target color reproducibility are random weighing inaccuracy, as well as proportional strength error. This article describes alternative definitions for colorant strength sensitivity and total colorant sensitivity of a recipe color. A method for calculating numerical estimates of the related quantities is also presented.

Disaggregating of the color positions resulting from Oulton's pattern of recipe sensitivity to the maximal dye concentration error is evaluated and compared with this newly proposed measure for the total colorant sensitivity of the recipe. The results show that the sensitivity of a recipe to maximal dye concentration errors can be described using this new measure of the total colorant sensitivity. It was also observed that the sensitivity of a recipe to the colorant strength error was the greatest at the middle dye concentration level. In addition, the weighing sensitivity was the highest at low concentrations and it decreased with increasing dye concentration.

Keywords: color formulation; color sensitivity; color strength

1. INTRODUCTION

The color of a product can be affected by small changes in the dyeing process and conditions of coloration. In 1986, Alman[1] published results obtained by computer simulating the impact of concentration-independent weighing errors and concentration-dependent strength errors in quaternary pigmented systems. Later, the concept of the color sensitivity of a recipe was developed by Sluban and Nobbs.[2,3]

The color strength of a dye could be defined as a measure of its ability to impart color to other material.[4] The relative strength of a colorant is the color yield of a given quantity of dye in regard to an arbitrarily chosen standard.[5] Accordingly, for calculating the percentage strength of a trial dye relative to that of a standard dye for equal concentrations, the value of $(K/S)_{dye}$ for the trial dye should be divided by that for the standard one.[6] It follows that the strength factor of i-th colorant could be calculated at wavelength λ_j as follows:

$$p_{i,j} = \frac{F_{i,j}(c_i)_{trl}}{F_{i,j}(c_i)_{std}} \tag{1}$$

where the indices *trl* and *std* refer to the trial and standard samples, respectively, and $F_{i,j} = F_{i,j}(c_i)$ denote the *K/S* value of *i*-th colorant at wavelength λ_j, at concentration *c*. The concentrations $(c_i)_{trl}$ and $(c_i)_{std}$ are meant to be equal in Eq. (1), any off-shade in the trial relative to the standard color should be attributed to deviation in the slope of the linear Kubelka-Munk function[7] of the *i*-th colorant's concentration. Consequently, the strength factor $p_{i,j}$ could be constructed by the following equation:

$$p_i = p_{i,j} = \frac{slope_{trl}}{slope_{std}} = \frac{\left(dF_{i,j}(c_i) / dc_i \right)_{trl}}{\left(dF_{i,j}(c_i) / dc_i \right)_{std}} \tag{2}$$

in which it is assumed that the strength factor of a colorant is independent of the wavelength. If the linearity of the K-M function of the applied dyestuff concentration c_i is assumed, the concentration of trial dyestuff (yielding the same resultant off-shade) could be calculated by multiplying the corresponding relative strength factor by the concentration of the standard color:

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$$(c_i)_{trl} = p_i\,(c_i)_{std} \tag{3}$$

Following the ideas of simulations by Alman,[1] the strength factor p is modeled as a random variable, its sampling distribution is assumed to be normal with a mean of 1. Eq. (4) is created after differentiation of Eq. (3).

$$dc_{trl,i} = c_{std,i}\, dp_i \tag{4}$$

Eq. (4) can be transformed to the approximation Eq. (5), for small changes in the concentration $c_{trl,i}$ and strength factor p_i :

$$\Delta c_{trl,i} = c_{std,i}\,\Delta p_i\,. \tag{5}$$

Eqs. (5) can be written in the form of the matrix equation (6),

$$(\Delta c_1, \Delta c_2, ..., \Delta c_N)^T = \mathbf{C}\,(\Delta p_1, \Delta p_2, ..., \Delta p_N)^T \tag{6}$$

where $\mathbf{C} = diag\,(c_{std,1}, c_{std,2}, \cdots, c_{std,N})$, is the $N \times N$ diagonal matrix in which the diagonal elements are concentrations of particular components in a recipe matching the standard sample.

2. THE LINKAGE BETWEEN SMALL COLORANT STRENGTH CHANGES AND COLOR CHANGE

The iterational equation for colorimetric matching, which links (small) changes in colorant concentrations $(\Delta c_1, \Delta c_2, ..., \Delta c_N)$ with the (small) resulting color change $(\Delta L^*, \Delta a^*, \Delta b^*)$, is presented by Eq. (7):

$$(\Delta L^*, \Delta a^*, \Delta b^*)^T = \mathbf{J}_{\mathbf{Lab}}\,\mathbf{B}\,(\Delta c_1, \Delta c_2, ..., \Delta c_N)^T \tag{7}$$

where $\mathbf{J} = \mathbf{J}_{Lab}$, is the matrix developed by Cogno, Jungman and Conno[8] and $\mathbf{B}$ is the generalized matrix from Allen's iterational equation $\mathbf{B}\,\Delta\mathbf{c} = \mathbf{\Delta t}$ to the case of N colorants.[7]

Now, by combining Eqs. (6) and (7), the linkage between (small) variation in strength factors $(\Delta p_1, \Delta p_2, ..., \Delta p_N)$ and the (small) resulting color change $(\Delta L^*, \Delta a^*, \Delta b^*)$ is created:

$$(\Delta L^*, \Delta a^*, \Delta b^*)^T = \mathbf{J}_{Lab}\,\mathbf{B}\,\mathbf{C}\,(\Delta p_1, \Delta p_2, ..., \Delta p_N)^T \tag{8}$$

3. TOTAL COLORANT SENSITIVITY OF A RECIPE COLOR

It might be valuable to develop a kind of measure of total sensitivity to colorant concentration errors, which would act as a combined measure for both sensitivities to colorant strength and weighing errors.

The maximal color difference due to maximal colorant weighing error can be estimated by Eq. (9).

$$\begin{aligned} \Delta E_{weighing} &\le \|\mathbf{J}_{Lab}\mathbf{B}\|_2 \cdot \|\Delta\mathbf{c}\|_{\max} \\ &= \sqrt{N}\,|\Delta c_{w,\max}|\,\|\mathbf{J}_{Lab}\mathbf{B}\|_2 \\ &= \sqrt{N}\,|\Delta c_{w,\max}|\,s_w \end{aligned} \tag{9}$$

Similarly, we obtain the following estimate of the maximal color error due to strength error:

$$\begin{aligned} \Delta E_{strength} &\le \|\mathbf{J}_{Lab}\mathbf{BC}\|_2 \cdot \|\Delta\mathbf{p}\|_{\max} \\ &= \sqrt{N}\,|\Delta p_{\max}|\,\|\mathbf{J}_{Lab}\mathbf{BC}\|_2 \\ &= \sqrt{N}\,|\Delta p_{\max}|\,s_s\,. \end{aligned} \tag{10}$$

Now, estimation of the total colorant sensitivity value is presented, which includes the technological tolerance $\Delta c_{w,\max}$ for the weighing error (in an individual dyeing process) and the standardization limit $\Delta p_{\max}$ for deviations in strength of the colorants. The total color sensitivity s_{total} could be defined by Eq. (11).

$$\begin{aligned} s_{total} &= \sqrt{N}\,|\Delta c_{w,\max}| \cdot s_w + \sqrt{N}\,|\Delta p_{\max}| \cdot s_s \\ &= \|\mathbf{J}_{Lab}\,\mathbf{B}\|_2\,\sqrt{N}\,|\Delta c_{w,\max}| + \\ &\quad \|\mathbf{J}_{Lab}\,\mathbf{B}\,\mathbf{C}\|_2\,\sqrt{N}\,|\Delta p_{\max}| \end{aligned} \tag{11}$$

Therefore, the meaning of the total colorant sensitivity's value s_{total} is an upper bound for the maximal color error, resulting from weighing and strength errors.

4. ALTERNATIVE QUANTITIES FOR THE COLORANT SENSITIVITIES OF A RECIPE

The impact level of dye concentration errors on the resulting color of a recipe could be simulated by the effect of systematically changing the dye concentrations $c_1, c_2, ..., c_N$ in the recipe $\mathbf{c} = (c_1, c_2, ..., c_N)^T$ according to a perturbation scheme, such as the one that Oulton and Chen[9] presented for the case of a recipe containing three colorants. The standard deviation of the resulting color positions around the target can serve as a measure of a recipe color's sensitivity to a particular dye concentration error. The range of scattering of the color positions (resulting from this pattern) depends upon which kinds and which amounts of coloration errors would be considered when calculating the standard deviation of color positions. This range should be related to the associated colorant sensitivity. The partial effect of random weighing dye concentration error, the partial effect of the colorant strength error, and the combined effects of both of them (as the total colorant error) can be quantified by considering appropriately chosen concentration changes Δc_i, $i = 1,2,3$ in the initial recipe $\mathbf{c} = (c_1, c_2, c_3)^T$. The dye concentration changes Δc_i, $i = 1,2,3$ for 27 different combinations of perturbations should be selected as, $\Delta c_{i,w} = \Delta c_{fix}$, $\Delta c_{i,s} = c_i \cdot \Delta p$ and $\Delta c_{i,\max} = c_i \cdot \Delta p_{\max} + \Delta c_{fix}$ where $\Delta c_{fix} = \Delta c_{w,\max}$ is the maximal random dye concentration error of each individual dye and $\Delta p_{\max}$ is the maximal strength error of each particular colorant and subscripts *w*, *s* and *max* refer to weighing, strength and maximal errors, respectively. So, the standard deviation of color positions (σ) resulting from the perturbation pattern can be used as an alternative measure of sensitivity to a particular kind of error. It is calculated as the root mean square color difference obtained from 27 color changes by Eq.(12):

$$\sigma = RMS = \left(\frac{1}{26} \sum_{k=1}^{27} (\Delta E_k)^2 \right)^{1/2} \qquad (12)$$

where ΔE_k is the color difference between the color position of the unperturbed recipe and *k*-th perturbed combination of the pattern.[9-11]

5. ANALYSIS OF THE TINCTORIAL STRENGTH, COLORANT WEIGHING AND TOTAL COLORANT SENSITIVITIES OF A RECIPE

The optical properties of basic dyes named C.I. Basic Yellow 28, C.I. Basic Red 46, and C.I. Basic Blue 41 were used to investigate the quantities and concepts described earlier. Matching trials were followed on acrylic fabric with these three cationic dyes as primaries.

The recipes for 150 randomly selected targets on different fabrics were considered in order to analysis of the tinctorial strength, weighing and total colorant sensitivities.

Let $\sigma_{\max}$ denotes the standard deviation of color positions resulting from the pattern of 27 color changes[9] when the maximal weighing error of $\Delta c_1 = \Delta c_2 = \Delta c_3 = \Delta c_{w,\max} = 0.001\%$ and the maximal strength error of 0.05=5% are applied in the perturbation pattern. The CIE $L^*a^*b^*$ total colorant sensitivities s_{total} of the recipes matching the 150 standard samples under Illuminant D65 and 1964 standard observer were predicted and plotted against the root mean square color differences $\sigma_{\max}$ of these recipes, as presented in Figure 1. It is clear from the figure that root mean square difference $\sigma_{\max}$ is in high correlation with the total colorant sensitivity s_{total}.

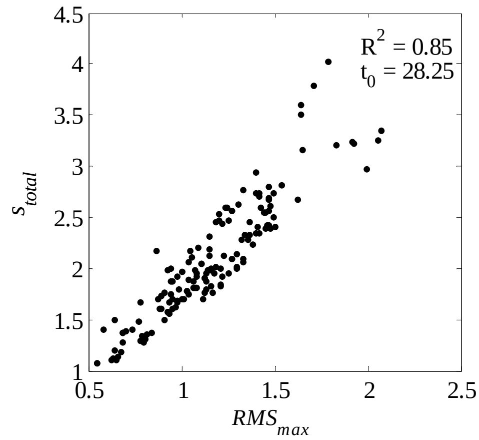
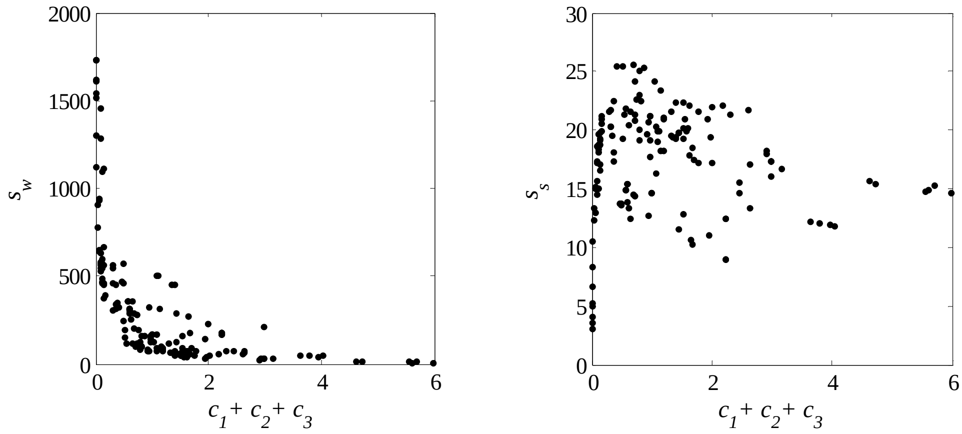


Figure 1. Plot of the total colorant sensitivity s_{total} predicted by applying the technological tolerances $\Delta c_{w,\max} = 0.001$ for maximal weighing concentration error, and $\Delta p_{\max} = 0.05 = 5\%$ for maximal strength error, versus the predicted standard deviation $\sigma_{\max}$ simulating the scattering of color positions resulting from the maximal dye concentration errors.

For each of the 150 recipes, the sensitivities to weighing and strength concentration errors in the recipe (the numbers s_w and s_s, respectively) are plotted versus the sum $c_1 + c_2 + c_3$ of dye concentrations in the recipe. As shown in Figure 2, the overall weighing sensitivity s_w rapidly decreases with increasing dye concentration. In addition, overall strength sensitivity s_s has a very steep increase at low concentration that is followed by a somewhat moderate and smoother decrease in s_s at middle and high concentrations.



(a) (b)

Figure 2. Plot of the predicted CIE $L^* a^* b^*$ overall sensitivities s_w to the colorant weighing (a) and overall sensitivities s_s to color strength (b) errors versus the sum $c_1 + c_2 + c_3$ of the recipe concentrations for each of the 150 recipes considered.

5.1 Numerical Example

Table I presents the predicted values of the scaled versions of weighing sensitivities s'_w, strength sensitivities s'_s and total colorant sensitivities s'_{total} of the recipes for six gray targets with chroma $C^* = 0$ and lightnesses L^* equal to 30, 40, 50, 60, 70 and 80, respectively. The alternative measures of recipe sensitivity, the *RMS* color differences σ_w, σ_s and $\sigma_{\max}$, resulting from the perturbation pattern[9] for standard weighing error, standard strength error and maximal dye concentration errors, are outlined in Table I. The maximal error in the concentration of the *i*-th colorant, the number $\Delta c_{i,\max} = c_i \cdot \Delta p_{\max} + \Delta c_{w,\max}$, is obtained by applying the technological limits $\Delta c_{w,\max} = 0.001$ for maximal weighing concentration error and $\Delta p_{\max} = 0.05$ for the maximal strength error. The eighth column of the table presents the number $\Delta E_k = \max\{\Delta E_k, k = 1,2,...,27\}$, the maximum of the 27 color deviations ΔE_k according to the perturbation pattern of a particular recipe, applied with the maximal individual dye concentration errors $\Delta c_{i,\max} = c_i \cdot \Delta p_{\max} + \Delta c_{w,\max}$. Therefore, the numbers in this eighth column indicate the worst-case error of recipe color originating from the dye concentration errors only. This table also shows the ratio s'_w / s'_s of scaled weighing sensitivity s'_w to the scaled strength sensitivity s'_s and the ratio σ_w / σ_s of the (*RMS*)s resulting from the pattern of 27 color changes due to standard weighing and standard strength errors, respectively.

In Table I the various sensitivities are ordered according to the increasing lightness of the target. We notice that an increase in weighing sensitivity s'_w of a recipe is regularly (and almost proportionally) followed by an increase in the corresponding alternative weighing sensitivity σ_w. Also, an almost linear correlation can be observed between the colorant strength sensitivity s'_s and its corresponding alternative measure σ_s, and between the total colorant sensitivity s_{total} and the root mean square $\sigma_{\max}$. Similarly, the maximal color difference $\Delta E_{\max}$ regularly increases with any increase in the total colorant sensitivity s_{total}. We notice, that the ratios s'_w / s'_s are approximately of the same order as the ratios σ_w / σ_s. Furthermore, when the lightness of the recipe color increases, the weighing sensitivity s'_w of the recipes increases, and, consequently, the ratio s_{total} / s'_w decreases. For the lightest-shade recipe ($L^* = 80$, $C^* = 0$), the ratio s_{total} / s'_w is 1.22 – close to unity, signifying that for the light-shade recipes and the case treated ($\Delta c_{w,\max} = 0.001$ and $\Delta p_{\max} = 0.05$), the strength sensitivity represents a smaller contribution to the total sensitivity than the contribution of their weighing sensitivity.

Table 1. The predicted values of scaled weighing sensitivities s'_w, strength sensitivities s'_s and total colorant sensitivities s_{total} accompanied by the calculated root mean square color deviations σ_w, σ_s in $\sigma_{\max}$ as the related alternative sensitivity measures of recipes containing a single combination of a yellow, a red and a blue basic dye. Recipes match the six gray targets of chroma $C^* = 0$ and lightness $L^* = 0$ indicated.

Lightness L^*	s'_w	s'_s	s_{total}	σ_w	σ_s	$\sigma_{\max}$	$\Delta E_{\max}$	$\frac{s'_w}{s'_s}$	$\frac{\sigma_w}{\sigma_s}$	$\frac{s_{total}}{s'_w}$
30	0.24	3.27	3.52	0.04	0.53	1.68	2.57	0.07	0.08	14.37
40	0.47	3.46	3.93	0.07	0.57	1.87	2.86	0.14	0.12	8.37
50	0.87	3.39	4.27	0.13	0.56	2.03	3.09	0.25	0.23	4.88
60	1.72	3.31	5.04	0.25	0.54	2.38	3.67	0.52	0.46	2.93
70	3.26	2.67	5.94	0.47	0.44	2.80	4.34	1.22	1.07	1.82
80	5.89	1.28	7.18	0.85	0.26	3.56	5.49	4.60	3.27	1.22

6. CONCLUSION

The colorant strength sensitivity of a recipe was defined as a measure of the effect of colorant strength error on the recipe color. The total colorant sensitivity of a recipe color has been defined as a combined value of the colorant strength sensitivity and the colorant weighing sensitivity of the recipe.

The newly introduced quantities "colorant strength sensitivity" and "total colorant sensitivity" were compared with the alternative measures of sensitivities to strength and total colorant errors, based on the perturbation schemes presented by Oulton and Chen.[9] The results of numerical experiments showed a high correlation between the colorant strength sensitivity s_s and its *RMS*-alternative σ_s, and also a high correlation between total colorant sensitivity s_{total} and its appropriate *RMS*-alternative $\sigma_{\max}$.

Finally, numerical estimation of the total colorant sensitivity of the recipe color can be applied for selecting the most repeatable recipe from among the different suggested formulations that match a target color.

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Ecology and colour in the 90's

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ABSTRACT

It is interesting to discover how the use of colour reflected and accompanied the thinking and behaviour in western countries, how a complex use of colour was shown as a clear expression of the social premises of the time, and how in a large part of the 90's colours followed the main subject in trends, ecology.

Keywords: Colour charts in the 90's, Ecology and textiles, Coloured cotton agriculture, Natural fibres, Natural colours, Natural Lines in textiles

1 INTRODUCTION

As an example we can mention how the early 70's kept the euphoric creativity of the 60's as the sense of prosperity and expansion was still present. So, the predominant colours were the same of the 60's. But in 1973, however, great structural changes were brought about by the deep crude oil crisis, which hit the markets and the economic structures. The feeling of uncertainty and lack of stability got hold of society and had influence in the colours. The colours most proposed, whether light or dark, were faded, non-saturated.

1980 was the decade of appearance: egocentricity together with hedonism and obsession for social status were the more significant features in the group engaged in a blind and swift consumerism. It was a decade of a remarkable awareness of colour, colour was the protagonist. Black made its appearance, alone, or associated with white and red, as well as with metallic colours, silver and gold, so as to emphasize the sought luxury effect.

2 ECOLOGICAL TREND

In the 90's, the end of the Cold War brought about a hope for the end of the nuclear menace.

A new trend of thought set forward of a deeper awareness of the environment in danger.

A new conservative attitude was the most remarkable trend, and it subjects were: ecology, the protective home, the native roots and traditions.

The new commandments were avoiding pollution, the efficient use of means and resources, the importance of quality instead of quantity, the respect for nature.

This was the beginning of a new way of thinking, which would give birth to the desire for a simpler way of living that rejected unnecessary consuming. The search for true moral values was shown by the use of noble materials and, in the choice of colour, the main one was that of unbleached linen.

European Companies from Italy, France, and Germany, as well as American companies began to propose textiles and its colours related whit this way of thinking. Everyone celebrated nature in his own way, by the choice of material, subject or colour.

2.1 Facts accompanying this movement

Negative headlines were widespread at this time and indiscriminately branded all chemicals across the board used in textile manufacturing as negative and dangerous to health.

The Austrian Textile Research Institute, in Vienna developed in 1989 a test standard for measuring harmful substances in textiles. In 1991 the German Textile Association was carrying a similar work. The cooperation of the two organisations gave birth to the Oeko-Tex Standard.

The Oeko-Tex Standard 100 was introduced as a response to the needs of consumers for textiles that posed no risk to health. It was presented to the textile and clothing industry for the first time in 1992 at the Interstoff trade fair at the beginning, for manufacturers of underwear, baby wear and home textiles in Germany, Austria and Switzerland. But just one year after the launch of the product label, there were 214 companies showing it.

At the Heimtextil Fair, in January 1993, in Frankfurt, Natural Lines in textiles for bed-wear and decoration appeared, through undyed, unbleached fabrics with no chemical processes.

Among others, some companies presenting such products were: for Italy, Zucchi, Bassetti, Madival; for France, Descamps, Jalla, le Cotonier; for U.S.A, Fieldcrest.

They were using organic cotton, not treated with chemicals.

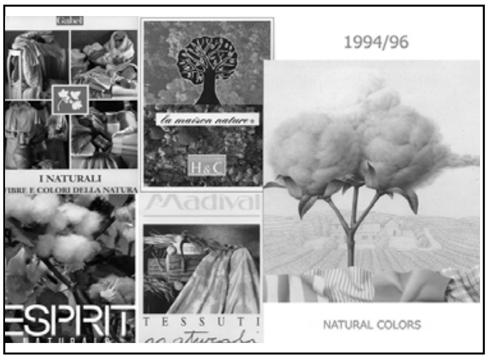

Figure 1 Natural Lines in textiles

2.2 About the history of coloured cotton

Coloured cotton agriculture began around 2700 B.C. in Indo-Pakistan, Egypt and Peru. It was then common for cotton to grow in a variety of natural colours. The Mochica culture, in Peru, developed an extraordinary palette of natural cotton fibre colours, ranging from white, gray, beige, brown, and reddish brown to chocolate and mauve. Small villages kept the coloured strains alive and growing through the past several hundred years. Today Indian descendants of ancient Peruvian cultures still harvest, gin and spin by hand the natural coloured cottons. In their original, natural state the fibres are not long enough for industrial spinners and cannot be used for mass-produced textiles.

2.3 Coloured cotton developement

Sally Fox was introduced to coloured cotton while working for a cotton breeder, whose focus was developing pest-resistant strains of cotton. With her Masters degree in Integrated Pest Management, she rediscovered a small amount of brown cotton seeds in 1982. Fox spent years crossbreeding coloured cotton plants to produce a commercially viable long-fibered coloured cotton. The Sally Fox's motto was: "No Dyes, No Pesticides. Just pure cotton". After only three years of plant breeding, she realized that the brown colour was actually hiding green, red, and pink. These unexpected cotton lint's were given to handspinner study groups who helped her to discover other qualities .The task was not only improving the fibre quality, but also increasing the colour spectrum. Experimental machine processing by John Price at the International Centre for Textile Research and Development first demonstrated the improvements that had been made. It takes seven to ten years of selective crossbreeding before a new variety develops. That is to say, a line of plants whose seeds always produce plants identical to the parent but distinctly different from others of the same species. Sally Fox has been successful in increasing the average length of coloured cotton fibres from about one-half inch to over one inch long, more than adequate for commercial spinning. She registered the trade name Fox Fibre® in six distinct shades: Coyote and New Brown, both of which are reddish browns, milk-chocolate-coloured Buffalo, sage-coloured Palo Verde, Green Fox Fibre®, and a dark forest New Green.

The raw colours of the cotton yarns may display only a hint of the colours to come once "developed" by washing and/or boiling. Some of the techniques to develop the colour before weaving take into account the ph of the water. The higher the ph of the water used to wash or boil the cotton, the darker the colours will become. The more minerals in the water, the brighter your colours may be. The colours darken in warm or hot water and when dried with as much heat as possible. It is the heat and the moisture that bring the colour out. These colours do not wash out, but they do fade in the sun. The exposure to sunlight wears them colours out. Two of the numerous advantages of naturally coloured cottons are: they eliminate the need for the dyeing and finishing steps so detrimental to the environment, and they are innately more fire-resistant than white cotton.

Kitan, from Israel, lunched at Heimtextil Frankfurt, in 1994 the line of naturally grown coloured cotton products, Colorcot, in response to consumer demand for chemical-free products. Colorcot signifies Kitan's commitment to improving the quality of the environment. The strategic partners were Fieldcrest-Cannon, Bassetti, Coats-Viyela (Dorma), Ichida, Dodwell & CO. The products were offered in North America and Europe followed, in early 1995, in Asia and Australia.

2.4 1994, the year of ecology

The trend forum in 1994 Heimtextil, Frankfurt, was devoted to raising awareness as to the preservation of nature: protect, select and recycle, rather than pollute. Traditional unbleached linen fabrics, cotton fabrics from the environmentally friendly Green Cotton, jute and linen blends, lambs wool, Indian silk and cotton, fine Chinese cashmere, were used in the different textile products for the home. The colours were neutral, colours of natural fibres, colours obtained from coloured cotton, pale greens, combinations of white with blue or beige, and light colours, slightly dull. Colour charts reflected natural phenomena: the world of rain, blue, brown; the world of snow, whites and light pastels; the world of the sun, colours of the sun from midday to sunset. Colours were named after the elements of nature: straw, olive, linen; browns from lianas and dark wood; sand, ivory, saffron, honey, ocean blue, lake green, slate, indigo. Sandy and greyish beiges were predominant, in some cases highlighted with vivid colours: yellow, orange or turquoise.

2.5 Following the trend

In 1995 The Cotton Incorporated trends for women's and men's wear were named as Land, inspired by colours of the Arizona desserts; Reflections from moon twilight, thunder, shadow and dusk; and so on, Atmosphere; Liquids; Typhoon. Neutrals were more colourful than in past seasons. The cool tones, inspired by raindrops and cool filtered light, mix with the warmer darks, the colours of Fall foliage, berries and the Autumn harvest; purple; serene pales and frosty darks, as an alternative to white. Trends for 1996/7 pointed toward influences from people from geographically remote areas with emphasis on rural life, frontier spirit and communal living, where function and simplicity are the keys. Shaker and Zen ideas were major influences of this way of living.

Intense, brilliant colours, combined with black, blue or white, white and black, greys with browns and red brick were nevertheless present, in others styles, whit a lesser extent.

Looking forward for 1998/1999 their direction was "A Sense of Home" following the so-called house of the five senses, displayed at the Salon du Meuble in Paris in January 1996. It intended to show that the habitat is a domestic space for well being, and the free reflection of a personality, marking a clear distinction with the quite rigid design of the 80's.

Natural motifs such as water-coloured botanicals, clouds, waves and spirals signify the return to the ephemeral, and give rise to feelings that allow us to imagine new products, patterns and textures, fabrics inspired by natural structures, soft organic textures, complemented by calming colours.

Towards the end of the century a new questioning was added in order to sort out the fundamental needs that would help achieve a new approach to design. Then, the main statement seemed to be the production of goods that are lasting, of high quality, simple and environmentally friendly. There was a preference for simple and refined products, made with care for every detail and a perfect finish. High quality, simplicity, lightness put forward the importance of avoiding the superfluous. Every object has an essential identity concerning its form, its material, its colour and its function. Home was seen as a cosy shelter in a world that lacks stability, as the expression of a simple and true atmosphere, in search for the essential, the honest and the spiritual features.

3 DISCUSSION

At the beginning of the new millennium there were others priorities in mind, and now we are suffering the evidences of our lack of engagement with the environment and the ecological human needs. We move into 2008 with an enhanced awareness of the environments and influencing factors that surround us. Recently released scientific reports are raising the consumer's consciousness to new heights of awareness about global warming and environmental issues affecting our planet and our lives. The Global Lifestyle Monitor, a biennial consumer research study, conducted by Cotton Council International in 2006 pointed to increasing consumer concerns about environmental issues. The survey included nine countries: Brazil, Colombia, Italy, Germany, the United Kingdom, India, China, Japan, and Thailand. On average, 42% of consumers were extremely/very concerned about global issues on the environment. So far, concern is one thing and actions are another. Surprisingly, according to the study, taking into account the environmental friendliness of a product was least important to consumers' purchase decisions compared to other factors. In spite of that, more manufacturers and retailers are taking the eco-movement seriously.

In textiles, up until the introduction of the Oeko-Tex Standard there was neither a reliable product label for consumers to assess the human ecological quality of textiles nor a uniform safety standard for companies within the textile and clothing industry which enabled a practical assessment of potential harmful substances in textile products. There are currently over 7,000 textile and clothing manufacturers throughout the textile processing chain in around 80 countries certified according to this standard. The country with the most certificates is Germany, followed by China and Italy.

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Textile design: a specific planning

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ABSTRACT

In this digital time everyone can plan a printing textile design importing each image through a scanner and repeating it several times. When a digital ink jet print transfers the design result on the fabric, the trick is done. In this way, it seems that a professional design project is unnecessary, because everyone believes to be a professional designer. On the contrary, professionalism in planning textile design is specific and unique in relation to every other visual approach (graphics, art, photo, etc.).
This oral paper will demonstrate the specificity in question.

1. INTRODUCTION

Digital technology has deeply modified the entire textile production process, from the planning phase to production and distribution.
In my courses I teach colour and planning of printed fabric, a sector in which Italy has achieved a leading position as far as quality, fancy, taste and refinement are concerned. In this sector, High Quality production has introduced digital technology in almost all phases, starting from stocking fabric to be printed in warehouses to engraving screen-printing (fig. 1) and rotary printing (Fig. 2), to the actual printing phase.

Figure 1

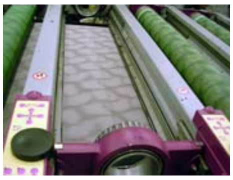

Figure 2

High End, as people know, still prefers screen-printing, which makes it possible to achieve special effects like pigments and metallizations, and which is made even quicker and more precise by means of electronic printing. However, rotary printing, used for less prestigious production lines, is also very widespread.

The real breakthrough of the printing project, however, is the constant technical evolution of ink jet digital printing (fig. 3), in which the traditional colouring agents are replaced by 8 colour cartridges, which make it possible to print even considerable amounts of fabric, with almost all types of chromatic ranges and pictorial effects, while avoiding, however, overlapping or any further treatments. The executive project, contained in a CD-ROM, is included in the ink jet machine and it is ready to be printed.

Figure 3

Figure 4

My presentation aims to analyze how the digital revolution has affected the planning of printed fabric, in the passage from traditional pictorial procedures to the use of digital images (fig. 4).

Nowadays, it is possible to create a pattern to be printed by simply acquiring an image by means of a scanner, which can be modified at a later stage by means of virtual tools (ranging from brushes to aerographs), register it by modifying its proportion, preparing the colourways, choosing among millions of colours. In addition to this, technology enables operators to see the final result without needing to start the production process.

These facilitations, however, do not change the basic problem designers have to tackle, namely that printed textiles are peculiar visual planned actions, different from any other one.

In this work, my intention is to share the experience I have achieved in a long time of teaching, rewarded by the professional success of my students, which led me to devise a very simple didactic method to understand printed textile projects, a few examples of which will be reported below[i].

2. TO PERCEIVE

In any visual planning operation, the meaning of an image stems from the choice of figurative elements, their mutual relations and their relations with the space in which they are contained (field).

If you choose any non-figurative and achromatic element, for instance a small black square, and place it on a white surface which contains it, this element will express its position with reference to the space margins.

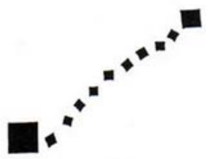

Figure 5

Figure 6

Its position makes it possible to perceive it as on the right side or on the left side or on top or at the bottom, even more so if it moves from the centre of the area where it is placed, an area which I will call the "field"[ii].

The position of this element in space also creates the impression that it is either stable or unstable, the former situation is suggested, for instance, by its being located in the centre of the diagonals of the field, its parallel sides being the margins. If we rotate the element in an asymmetrical way with reference to the sides of the areas in which it is contained, and move it away from the centre of the field, it creates an impression of unstability and direction.

If we evolve from this simple exercise on the element/field relation into the use of several elements of various sizes, the relation of reciprocity is added to the first one; this new relation takes place between the elements, depending on their sizes and positions. It is possible to suggest a direction of the movement, which can be interpreted from right to left or vice versa (Fig. 5), or from top to bottom or vice versa. Or it is possible to suggest an aggregation movement towards the centre or a dispersion one towards the periphery (Fig. 6).

The presence of several elements facilitates abstract communication of shape and composition.

3. TO ORGANIZE

I stated that the planning phase of printed fabric differs from any other type of visual planning. Indeed, in textile design, each single component is repeated a large number of time, or rather a virtually infinite one, as this scheme shows. This process, which is called *all-over*, deeply affects the overall sense of the composition, since it may modify the sense attributed to the basic module (Fig. 7, 8).

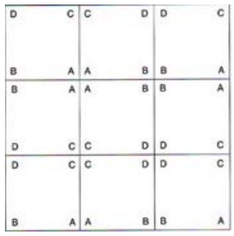

Figure 7

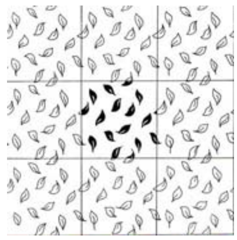

Figure 8

In *all-over* reproductions, the margins of the field cease to exist, therefore the elements in the composition do not establish any relations with the space in which they are contained and lose the traditional right-left, top-bottom, large-small and direction references.

I believe that this is a key point in the designing phase, especially now that everyone thinks s/he is able to make drawings for printing operations by working in a traditional way, that is by means of a wonderful project enclosed in a space, while the designer is not interested in its repetition. As a matter of fact, drawings in which the register is made at a later stage by a tracer are often carried out and bought. In this way, the designer loses full control of the composition and the meaning of his/her project.

I will explain also how colours work in the *all-over* process, in ways which are sometimes different and independent from those of the shape, thus making the management of results even more complex.

3.1 Shape and all-over

When a module in which an element placed within a field seems to move rightwards is reproduced in an *all-over* process, the direction disappears as you may see by comparing the module within the field and its multiplication.

The curious thing in this is that by multiplying all the modules taken into consideration before, regardless of the position of the abstract element, they all seem to give rise to the same results, that is to compose a regular and static texture. The same thing also happens when modules with an abstract element, which does not lose its space references, are reproduced several times.

Since the design for printed fabric has no definite space/field, it loses all references of measurement, proportion and spatial collocation, therefore, in order to suggest them, it has to be resort to the reciprocal relations which are established between the elements and their positions.

At this point, it is of paramount importance that designs also take into consideration the elimination of the sides of the original module as a characteristic to strengthen, in order to avoid its repetition from becoming monotonous.

In order to appreciate the unique specificity of textile design of having a virtually endless space/field requires some dynamic compositive solutions.

3.2 Colour and all-over

This long foreword on shapes is fundamental in order to deal with the specificity of textile design, with reference to colours.

Colours are the most important element in a textile design: the first pattern which is seen and for which a certain fabric is chosen and bought. Those who work in this sector know that an unattractive design with beautiful colours may be sold, whereas a beautiful design with unattractive colours may not. A good colourways expert may determine the success of a whole collection.

In the *all-over* method, colours interfere with shapes and their perception, due to its luminosity, weight and movement (Fig.9).

An achromatic composition of square elements which remain placed in a dynamic and varied way in the *all-over* system may be appreciated, or depreciated, by a wrong distribution of colours.

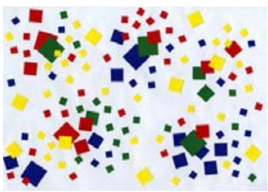

Figure 9

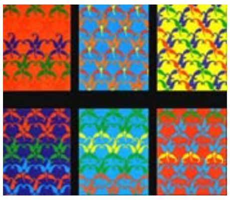

Figure 10

By “wrong” I mean a way of colouring which contradicts the original meaning of the module, which creates different routes or which draws people’s attention to some spots, thus unbalancing the visual concentration (Fig. 9).

A design devoid of visual foci, which forms a continuous texture, can modify the type of the composition depending on its colouring. In the relation between background colour and the colours of coloured figurative elements, it is possible to create lines (Fig. 10), aggregates, groups, textures or other types of compositions, on the basis of the chromatic qualities of hue, clarity and intensity.

This is why my students, after doing exercises in which they place shapes in the all-over space, practice placing colours in their mutual relations and with reference to the background colour.

4. TO EXPRESS

I explained how the printed textile design project is made up of several phases: from choosing the subject to its implementation in the *all-over* module, from selecting the colours to their placement, in addition, it goes without saying, to the colouring technique and the subsequent finishing operations which enrich the surface.

Colours are cultural signs which play a role in the evolution of the historical and social implications of fashion, its culture, its techniques, as well as its expressions.

The choice of the colours in the project, besides being perceptive, is also aesthetic and expressive, since it expresses a taste, a mood, a trend[iii].

Figure 11

Figure 12

A reduced and desaturated palette expresses a minimal-conceptual trend, a soft and warm palette represents a romantic trend, a rich and exuberant palette conveys the idea of a sparkling trend, or you may also choose a pictorial palette and the printing intertwines with three-dimensional solutions more and more often.

The fabric speaks its own language, a tactile and visual one, in which colours play a privileged role.

4.1 To recognize

The last few years have been characterized by gigantic intermingling of populations, cultures and ethnic groups, unfortunately saddened by a large number of ethnic wars: from Bosnia to Sri Lanka, from Rwanda to Somalia, from the Kurds to Darfur.

Globalization has on the one hand gathered the entire world to form a single large village, while on the other hand it has given rise to considerable social insecurity, including the fear of losing one’s identity. As a reaction to these factors, many nationalisms have risen, which have been absorbed by the fashion market as declarative proposals, especially when they refer to sports. The specificity of places and local traditions, used to attribute value to the symbolic dimension which characterizes the specificity of national culture [iv] have been rediscovered and appreciated.

As a consequence, in many countries selecting traditional clothes or some of their aspects aims to strengthen one’s pride for his/her geographic and cultural origins, including from a nationalist point of view. In the global Fashion market, this is also exploited in a hybrid version, by intermingling quotations, historical periods and geographic origins, and with a contemporary interpretation, or sometimes even a future one, the image of the mixing of civilizations and cultures.

This is how the colours/icons of the various cultures are rediscovered in our common culture, in fashion as well as in advertising and the arts which, through the colours of local tissues, mirror "identity and belonging", as the two examples which I am explaining below prove.

4.2 Fabric, identity, art

I chose two examples from contemporary art, which is a sensitive tool to anticipate social tendencies, in which fabric is utilized as the main expressive instrument in a work of art, due to its cultural recognizability, which is expressed, first and foremost, by colours. They are two artists who declare with fabrics their belonging to Africa and Korean.

Yinka Shonibare, a well-known Anglo-Nigerian artist, uses the vital polychromies of typical African fabrics in a very ironic way in order to express the concept of identity. He made his debut on the London scene in 1994, when he exhibited the work "Double Dutch", made of 50 different types of African printed cotton called "Dutch wax", sold in little marketplaces in Brixton, the London district characterized by a high concentration of Africans, framed like pictures. Shonibare chose very lively fabric samples, with patterns which remind of the age-old African textile tradition and propose it again as a stereotype. The same stereotype which had been used in the Sixties as a symbol of identity and emblem of the "Black pride".

Figure 13

Figure 14

The African colours/icons are also exploited by the artist in order to re-interpret the European and western history from the point of view of Africa (Fig. 13), and are used to reproduce the most typical images of the western artistic (and not merely artistic) culture as three-dimensional installations.

As a matter of fact, African colours are used by Shonibare in order to reproduce typical images, such as the "19th century" female dress shown here, or the overall used for landing on the moon or the tissue of a spaceman's overall made of African cotton, or the representation of aliens in an African version (Fig. 14), as a metaphor of diversity.

Kim So-Ja, a well-known Korean artist, uses traditional Korean fabrics (Fig. 15, 16) which were previously used in a range of ways, such as table cloths, blankets, garments and bags. These tissues, with their typical patterns and warm and intense colours, are not selected by Kim So-Ja to bear witness of her national identity only, but also as a symbol of material and feminine culture.

Figure 15

Figure 16

She was invited to the prestigious Biannual Art Exhibition of Venice (Italy), to which she sent a truck stuffed with large bundles made of traditional Korean fabric samples, symbolically representing a wandering route towards her own origins. In some installations she lays fabrics in alternate rows, thus creating an itinerary through fabric and colours, which marks and defines the territory.

5. CONCLUSIONS

In conclusion I hope to have showed that the colours of textiles are aesthetical, commercial, artistic and also identitary expression.

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Some Remarks on Colour in Paint

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ABSTRACT

Points of departure for my presentation to the AIC 2007 *Color Science for Industry* is the relationship between *visual perception of colour* and *paint as a material*. It is impossible to separate the visual perception and the paint material from one another without losing any vital aspects in the viewing of colour. In paint production as well as in colouring and in surface treatment these aspects are worth taking into consideration.

Keywords: colour, paint, colour in architecture, visual perception, description models of colour

INTRODUCTION

A blue wall is blue, it has a blue colour. But the blue colour also owns a material, and a structure, a surface, a materiality. And how, in what way, the blue colour appears on the wall, and in space, depends on the colour's paint material.

Fig. 1 Yves Klein *Blue Globe* (1957).

The selected colour is built up with pigments, binders, solvents, and fillers. When the painted colours grow older the differences intensify between the colour materials. Two surfaces painted in the same colour hue but in different materials look quite different, as the American architect **Steven Holl** (born 1947) points out in the following example: ”A Mexican cobolt blue surface becomes distinctly different from, for example, the same colour and saturation on a surface of plastic laminate in a Minnesota shopping center.” (1994, p. 61)

The appearance of the visible colour depends on the physical and chemical qualities of the surface layer. In this analysis on colour appearance dependent on natural paint or plastic paint, three different paint materials will be treated in a comparative study: linseed oil, latex paint, and coloured concrete. – To *describe* colour, one needs tools to express what the eye and the hand experience. Using the description models of Tryggve Johansson, Moholy-Nagy, Hesselgren and Katz we have considerable prospects of assimilating and describing the depth and width of the colour.

Description models of colour

Sweden's first colour researcher is the physicist **Tryggve Johansson** (1905–60). In his book *Färg. Den allmänna färglärans grunder* (1937/52, ”Colour. The principles of general chromatics”) he divides colour materials in *glazing paint* and *top coat paint*. The two sorts are distinguished by different *optical qualities.*

The Hungarian artist and Bauhaus-school teatcher **László Moholy-Nagy** (1895–1946), for his part, created a terminology for describing different appearances of materials in architecture, colour and paint included. In *The New Vision* (1938) four component terms were used: *structure, texture, surface treatment*, and *mass arrangement*. With this terminology Moholy-Nagy could describe a colour's surface, its chemical build up and how it was processed. The *structure* is ”the unalterable manner in which the material is built up” (1938/ 2005 p. 35). Each material has its own structure, and the structure describes the material's internal organisation. For colours this involves pigments, binders, solvents, and fillers. The *texture* is ”the organically resulting outward surface, like the exterior layer of a plant, the plant's visible surface (p. 40). The *surface treatment* means ”the sensorically perceptible result (the effect) of the working process” (p. 42).

Surface treatment comes from the Latin word *facere* and means "to do". This refers to the process of manufacture: a metal may be waxed, hammered, polished, brushed etc. A painted surface can be roughed, polished, sponged or varnished. And finally, the *mass arrangement* is "the regular, rhythmical, or else irregular, massing" (p. 45). With mass arrangement Moholy-Nagy described an accumulation or quantity of something, for example screw heads screwed in metal. An accumulation entails a repetition of something that through repetition reinforces expression. A brush drawn with the same lines over a surface enhances expression of the brush strokes and also provides a pattern effect.

The Swedish architect **Sven Hesselgren** (1907–93) introduced Moholy-Nagy's concepts to a Swedish public in *Arkitekturens uttrycksmedel* (1954, "Means of Expression in Architecture"). Hesselgren borrowed Moholy-Nagy's descriptions and also added several concepts. One example is the word *grain (gräng* in Swedish). Hesselgren relates the word to the haptic sense. It relates to the sensation of touching a surface. One can experience the sensation of grain as firm and smooth, firm and rough, soft and rough or soft and smooth (p. 9). Using these words, Hesselgren points out the difference between "the visual phenomenon of texture and the tactile phenomenon of grain" (ibid.). In addition, Hesselgren mentions two forms of the concept of *texture*: *top coat-texture* which means that the surface contains small multi-coloured spots, and *deep-texture* which signifies a granular surface (1985). One perceives the texture as arranged or unarranged. In that way the surface can change over to a *pattern*.

In *The World of Colour* (1935), the German psychologist **David Katz** (1884–1953) writes that a certain colour, one and the same, may appear in different *modes of appearance*. The experience of space is described by Katz making use of the three concepts: *surface colour* (the surface of an object, like for example a painted chair; the colour is attached to the surface of the chair), *volume colour* (transparent, like for example wine in a glass; when we look through the glass, we perceive the liquid volume filled with e.g., red colour), and *film colour* (with no location in space, e.g., the sky; we perceive neither surface colour nor volume colour).

Paint material

As mentioned, three paint materials will be examined in this study: linseed oil, latex paint, and coloured concrete.

Linseed oil is experienced, at least by professionals, as a living and natural material interplaying with light and other components in the room. The linseed oil has lustre. The rays of light spread into the pigment granule – and the light reflects in all directions. In this way, materials and spaces are not confined.

Water based paints such as **latex paint** enclose the pigments in plastic, and give the wall and thereby the entire room an inelastic and dull expression. The reflecting light is due to the coat of paint. In a bright and glossy latex paint, the rays of light have no power to permeate the paint surface.

A wall of **concrete coloured** with e.g., **iron oxide** is a material that changes over time in a progressive process. This surface treatment gives variations from dark patchy rust to luminous orange. The wall appears soft with the highly matt colour. When one passes a hand over the wall, one also feels the concrete's softness.

THREE ARCHITECTURAL EXAMPLES

A question of significance for colour design is: What is the difference in space for the perception between paint materials such as linseed oil, and latex paint, and coloured concrete?

Linseed oil

In a permanent exhibition on the Middle Ages at Historiska museet (the Swedish historical museum) in Stockholm linseed oil is painted both on walls and on pedestals. The medieval church art in Sweden is unique in abundance. These objects of art are considered to be among the most valuable items in the entire museum.

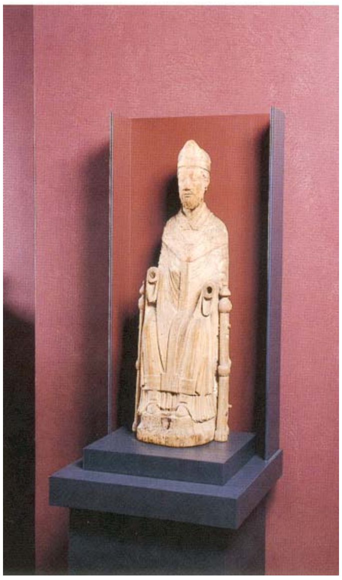

Fig. 2 Holy Bishop, 12th Century.

The objects, from the 12th–14th centuries, chiefly consist of figure sculpture in wood, frequently with medieval original colours preserved. Visitors need to be able to contemplate the sculptures – Christ, Madonna with Child, Saints and Holy Bishops in solemn expressions – as precious *objets d'art*. Simultaneously, the statues and altarpieces will convey to us some idea of the importance they held to people during medieval times. For this reason pedestals and exhibition cases are painted in colours accentuating the sculpture's own colours and devotional character.

The exhibition walls in *lampblack* and *caput mortuum* are applied in linseed oil with a specially design roller. By this surface treatment and the material, the *texture*, with Moholy-Nagy's concept, gains optical qualities. The rays of light have power to spread into the pigment granule and the light reflects in all directions. The surface treatment becomes a *mass arrangement* in a rhythmical repetition, not a real pattern but a *top coat-texture* giving life on the surface (concepts of Moholy-Nagy and Hesselgren).

The pedestals in linseed oil are, with Johansson's word, *top coat painted* with brush. This surface treatment gives a slender character of grain on the surface and thereby tactile qualities. In Johansson's description of top coat paint, the paint coat consists of a conglomerate of small granules "embedded" in the binders (1952, p. 72). In this paint material, the light has the power to spread out the colour hue in different directions.

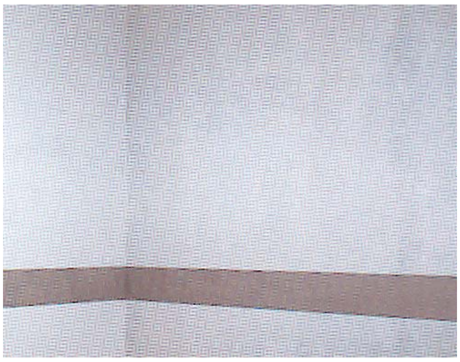

Fig. 3 Wall of glazing linseed oil paint.

Latex paint

In an exhibition at Länsmuseet Gotland (Gotland county museum) the walls, the pillars and the interior are painted in latex material. The exhibition *The meal with the food* displays traditional food and eating habits in a historical perspective, from the Hanseatic age (that is, the Middle Ages) to present time. The whole is taken from the prosperous Swedish island situated in the very middle of the Baltic Sea.

Fig. 4 View from *The meal with the food.*

The room's surface treatment in latex paint, reflects light inelastically on the pillar. The rays of light reflect solely as through a looking glass. The wall – that is, the underlying material – is concealed behind a skin, as if covered in a plastic bag. Owing to this, one perceives a wall painted in latex paint as inactive – the paint and the colour do not co-operate in space. The paint and the colour give a perception of colour hue only.

Fig. 5 Detail of play sculpture.

A *Play sculpture* on Eriksdalsbadet (an outdoor public baths) in Stockholm is also painted in latex paint. The light reflects hard and inelastic on the bedding and brings out thick coats of the paint material. The light, so to say, catches in the *deep-texture* (with the concept of Hesselgren) and this reinforces the expression of the surface material and the surface treatment.

Coloured concrete

Stellwerk Vorbahnhof Zürich (1999) in Switzerland is designed by the Swiss architect duo Gigon/Guyer, i.e. Annette Gigon (born 1959) and Mike Guyer (born 1958), in colour collaboration with the artist Harald F. Müller (born 1950). Working deliberately and conceptually with colour as its own parameter within architecture, the railway switching station is an *orange-rust* coloured box in concrete. It is placed in the shunting yard near the Gottlieb Duttweiler Bridge in Zürich.

Fig. 6 Stellwerk Vorbahnhof Zürich.

The building rises three storeys with offices on the top floor. The first and second floors contain technical equipment. The façade is coloured with *iron oxide*, that is to say a material that changes over time in a progressive process. The pigments actually "have the same chemical basis as the dust from the trains' brakes – oxidized particles of iron" (*Gigon/Guyer* 2000, p. 192).

This surface treatment gives variations from dark patchy rust to luminous orange. Some parts of the façade possess the same colour tone as the railway tracks. The building becomes a reverse *volume colour,* with Katz concept, a solidified concrete mass with dimension of depth. It consists of a single colour, but a colour that shifts with the seasons, with warmth and cold, and with the continuous chemical process.

Fig. 7 Wall of iron oxide coloured concrete.

The surface (the *texture* and the *grain* with Moholy-Nagy's and Hesselgren's concepts) of the concrete is visible, one sees porousness and small holes. The nuances shift depending on depth of colour layer and observer distance. The aspects change between aged and new surface, patchy surface, brown concrete, brilliant orange, brown-red, rusty and oxidised surface. At 40 metres the signal box appears apricot. At this distance the trees reflect in the yellow-orange metallic surface of the windows. The signal box is fully integrated into the railway context.

CONCLUSION

In this presentation I want to emphasize that paint materials own different qualities. Further, I want to pay attention to these qualities in the choice of colour and paint in order to enhance the architectural experience. Accordingly, to study how the eye perceives the room, and the interplay between different components in space. The way in which colours emit light depends on the paint material applied. The light and the luminous reveal the characteristics of the paint, or the lack of characteristics. – The paper discusses the modification of colour due to the ageing process of the paint material. For example, from the beginning a surface of linseed oil is highly glossy but changes in course of time to become matt. This ageing process gives the surface and the room an additional dimension.

I also want to point out that colours are easy to paint, to paint over and paint out. By repainting, a space vanishes and is replaced with another. This replacement also counts for paint material. If we unthinkingly change paint material, we run the risk of losing the room we tried to obtain – and the conceived distinction of the colours is lost.

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Measurement and Analysis of Reflection Properties of Art Paints

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ABSTRACT

This paper deals with measurement and analysis of the 3D reflection properties of painting materials such as oil paints and water paints. First, we measure light reflected from a variety of painting surfaces by using a goniophotometer and acquire the surface reflectance data at different incident and viewing geometries. Next, the surface reflection is described by a mathematical model using the Torrance-Sparrow model. An algorithm is presented for determining the model parameters, including spectral reflectance, specular intensity, surface roughness, and refraction index, from the observed reflectance data. Some difference in reflection properties is suggested between oil paints and water paints. Finally, images of objects with the two paints are rendered.

Keywords: Oil paints, Water paints, 3D reflection property, Torrance-Sparrow model,

1 INTRODUCTION

In recent years, a digital archive attracts attention for recording historic buildings, arts and crafts, folklore shows, and natural landscape by digital image information. Especially, the authors are much interested in digital archiving of art paintings. We note that the digital archives are appreciated under various illumination and viewing conditions. For these conditions, it is necessary to render the images based on inherent information of the recording objects. The surface-spectral reflectance has an inherent physical property of the painting material that is independent of both light source and camera characteristics. Therefore the surface-spectral reflectance is recorded in each pixel point for reproducing the art painting in an arbitrary visual environment [1]-[2].

Moreover, it is necessary to simulate the light reflection from an object surface accurately to render realistic images. For this purpose we have to estimate the optical reflection characteristic on the object surface precisely. The light reflection model describes the reflection characteristic on the object surface mathematically, and therefore affects color appearance.

In the previous work [3], we measured some reflection properties of art paintings. However the materials were limited. Since the reflection properties depend greatly on its surface material. It is essential to investigate the reflection properties and determine the reflection model on different materials used for art paintings.

In this paper, we measure and analyze the surface reflection property for oil paints and water paints on an acrylic board, canvas and watercolor paper. First, we use a goniophotometer for precisely measuring light reflected from various painting surfaces painted by a film applicator. Next, we present an algorithm for determining various model parameters including spectral reflectance, specular intensity, surface roughness, and refraction index from the observed spectral reflectance data. Finally, we have rendered color images of the two types of objects for both water and oil paints by using the estimated reflection parameters.

2 3D LIGHT REFLECTION MODEL

Surface materials used for art paintings are regarded as an inhomogeneous dielectric material like plastics. The painting surfaces have often certain gloss or highlight. Light reflection for this material is decomposed into two reflection components, diffuse (body) reflection component and specular (interface) reflection component.

We describe this dichromatic reflection property using the Torrance-Sparrow model [4].

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The spectral radiance $Y(\lambda)$ of light reflected from a surface is represented as

$$Y(\lambda) = \alpha \cos\theta_i S(\lambda) E(\lambda) + \beta \frac{D(\varphi,\gamma) F(\theta_i, n)}{\cos\theta_r} E(\lambda) \quad (1)$$

where the first term represents the diffuse reflection and the second term represents the specular reflection, respectively. α and β are the weighting coefficients. **N, V,** and **L** are the vectors of surface normal, viewing, and incident light. θ_r, θ_r and φ are the angles of incidence, viewing, and the angle between **N** and normal vector of micro facet. $S(\lambda)$ is the spectral reflectance function and $E(\lambda)$ is the spectral distribution of illumination.

The term D is the distribution function representing the micro facet orientation. A Gaussian distribution function is assumed as.

$$D(\varphi,\gamma) = \exp\left\{-\ln(2)\varphi^2 / \gamma^2\right\} \quad (2)$$

where γ is constant that represents surface roughness.

The term F is Fresnel reflection. Although this function requires incident angle, refractive index and absorption coefficient, we assume the absorption coefficient to be 0 because of an inhomogeneous dielectric material. Moreover, the refractive index n can be assumed to be constant. Then the Fresnel reflectance is described as the function of viewing angle and refractive index.

$$F(\theta_i,\lambda) = \frac{1}{2}\frac{(g-\cos\theta_i)^2}{(g+\cos\theta_i)^2}\left[1+\frac{\{\cos\theta_i(g+\cos\theta_i)-1\}^2}{\{\cos\theta_i(g-\cos\theta_i)+1\}^2}\right] \quad (3)$$

where $g^2 = n^2 + \cos\theta_i - 1$.

3 REFLECTION MEASUREMENT

A goniophotometer measures the spectral radiance of a color sample and of a reference white board, and calculates the spectral radiance factor. Figure 1 illustrates the measurement of the spectral radiance factor. The spectral radiance of the reference white board is expressed as

$$Y_R(\lambda) = \alpha \cos\theta_i E(\lambda). \quad (4)$$

The spectral radiance factor $r(\lambda)$ measured by goniophotometer is a ratio of Eq.(1) and Eq.(4). as expressed as follows.

$$r(\lambda) = \frac{Y(\lambda)}{Y_R(\lambda)} = S(\lambda) + \beta' \frac{D(\varphi,\gamma) F(\theta_i, n)}{\cos\theta_i \cos\theta_r} \quad (5)$$

where $\beta' = \beta / \alpha$.

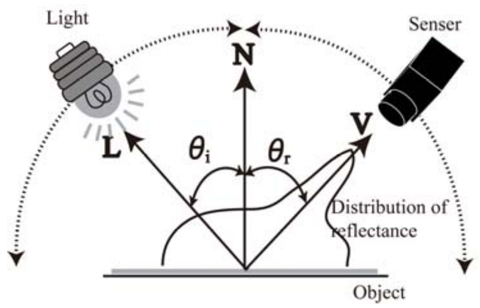

Figure 1 Surface reflectance measurements.

4 ESTIMATION OF REFLECTION PROPERTIES

We estimate the surface reflection model of paints by fitting the spectral radiance factor measured using the goniophotometer to the Torrance-Sparrow model. Figure 2 shows the radiance factor measured from a vermilion paint, in which the incident angle is 40 degrees. The diffuse reflection component takes a definite value with change in the viewing angle, by contrast the specular reflection component makes big peaks around the specular reflection angle.

The measured spectral radiance factors are fitted to the above reflection model. The diffuse reflection component can be considered as a bias term within the total reflection. Therefore we take the mean value of the diffuse reflectance $E[S(\lambda)]$ over the visible wavelength region. Finally, the measured specular reflectance is fitted to the specular function of the model to determine the parameter of the second term in Eq.(5).

The unknown parameters to be estimated are the refractive index n, the intensity of the specular coefficient β' and the surface roughness γ. The refractive index is guessed from 1.3 to 2.0 because the object is an inhomogeneous dielectric material. Moreover, we set the range of surface roughness based on empirical knowledge. Therefore, it can be fitted by setting the specular coefficient β' within the arbitrary range and by changing the refractive index and surface roughness to each β' within the possible range.

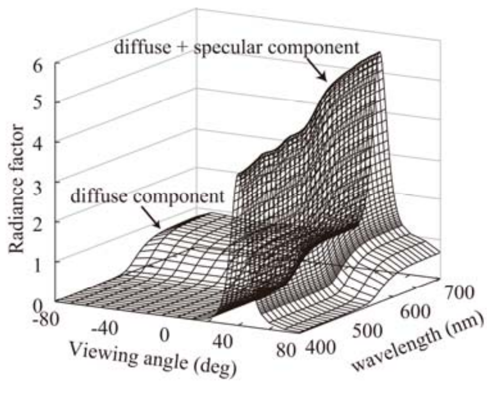

Figure 2 Measurements from a vermilion paint.

We minimize the sum of the fitting error.

$$e = \sum_j \left\{ r_j(\lambda) - \hat{r}(\lambda) \right\}^2 \qquad (6)$$

where $r_j(\lambda)$ is the measurement and $\hat{r}(\lambda)$ is the estimate. The optimal parameters are searched within the possible range by evaluating with the round robin method.

5 EXPERIMENTS

In order to measure the reflection properties, we prepared the sample that painted oil and water paints on an acrylic board respectively. Moreover, we prepared the sample that painted oil paint on the canvas and the sample that painted water paints on the watercolor paper. These samples were created by the applicator which thickness is 100 microns to uniform the surface of samples and the film thickness.

We measured the spectral reflectance for each sample in the range of light incidence from 10 to 60 degrees at 10 degrees interval. For each incident angle, the viewing angle was changed from -80 to 80 degrees. In order to increase the measurement accuracy, we sampled the viewing angle at 0.5 degree interval within the range from -10 to 10 degrees on highlight peak. As shown in Fig.2, the diffuse reflection component is almost constant value for a viewing angle in the each incident angle and the specular reflection component appeared remarkably in the specular reflection angle neighborhood with the diffuse reflection component was assumed to be a bias term

Figure 3 and Figure 4 shows the fitting results of the model function to the measured radiance factor. The samples that oil paints were colored on an acrylic board were used in Fig.3 and the samples that water paints were colored on an acrylic board were used in Fig.4. Although there are some discrepancies between the model and the measurements at the lower sides of the highlight peaks in each results, we have a good fitting result at highlight peak regions. Overall, the radiance factor of oil paints are lower than that of water paints, and the half bandwidth is wider too. However, water paints are painted directly on an acrylic board without dissolving in water. This is because we wanted to examine the reflection characteristic of paints themselves. Therefore, note that the peak of the specular reflection component is extremely high compared with an actual watercolor painting.

Next, the result of change in spectral radiance factor of oil paints by difference of the ground was shown in Figure 5. In each samples, the pigment and the amount of the solvent is same. Therefore, it can be considered that the difference of two reflection properties depends on the state

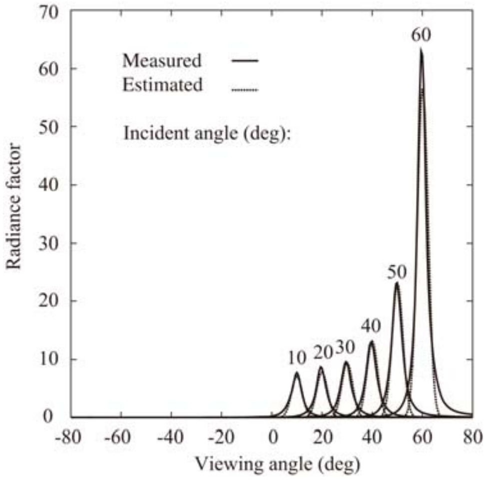

Figure 4 Fitting results of water paint on an acrylic board.

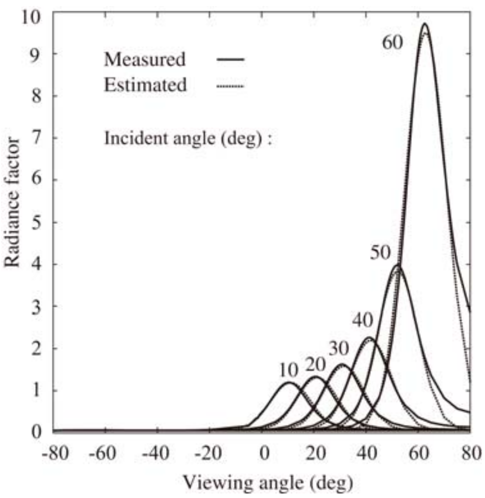

Figure 3 Fitting result of oil paint on an acrylic board.

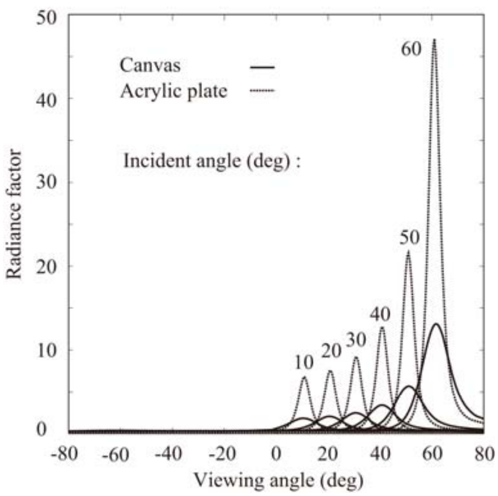

Figure 5 Change in spectral radiance factor by difference of the support.

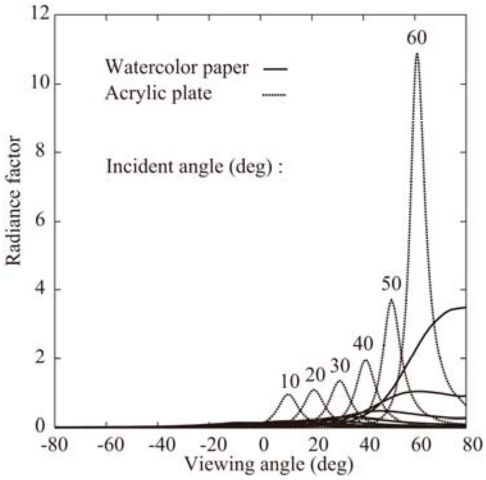

Figure 6 Fitting result of water paint on an acrylic board.

of the support. The specular reflection light is scattered because the surface of the canvas is rougher than the surface of the acrylic board. As shown in Figure 6, this phenomenon is more remarkable for water paints. Especially, the fitting analysis to the model function is difficult because the specular reflection might not be occurred on the watercolor paper.

Next, we estimate parameters of model function by minimizing the squared error between the observed radiance factor and the estimate value. Although there were a few samples which can not fit to the observed value, we obtained good estimation results except those samples. These differences remarkably appeared in each parameters. The specular coefficient β and the refractive index n on painted acrylic board were larger than the parameter that corresponded on the canvas and on the watercolor paper, and the surface roughness γ became smaller oppositely. Moreover, the feature in the reflection property of paints on the canvas and the watercolor is that the surface roughness increases.

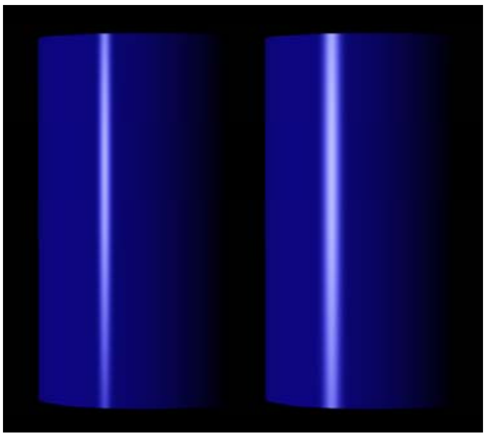

Figure 7 Computer graphic images of water paint (left) and oil paint (right) with the estimated parameter.

Finally, we render color images of the two types of objects for both water and oil paints by using the estimated reflection parameters on the painted acrylic board. The illuminant was assumed D65 with parallel beam and the ray-tracing algorithm was used. Figure 7 demonstrates the computer graphics images of a cylinder with blue paints. The left image is for water paint and the right is for oil paint. The same spectral reflection value of $S(\lambda)$ is used for both objects. Comparison between two pictures in Figure 7 shows clearly difference in the specular reflection between oil paint and water paint that is rendered by the estimated reflection parameters.

6 CONCLUSION

We have analyzed the surface reflection property for oil paints and water paints. First, we have used a goniophotometer for precisely measuring light reflected from the surface of four kind of samples painted by film applicator. Although there were a few samples which can not fit to the model function, the Torrance-Sparrow model has been used for describing the 3D reflection properties of painting materials. It is necessary for the water paints and the water painting to verify in detail in the future. Next, an algorithm has been presented for determining various model parameters from the observed spectral reflectance data. We obtained good estimation results except the sample which can not fit the model. The differences of model parameter appeared remarkably by the difference of medium and ground. Finally, we have rendered color images of the two types of objects for both water and oil paints by using the estimated reflection parameters.

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Effect of small deviations from normal colour vision on colour matching of display and surface colours

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ABSTRACT

Eleven observers made colour matches between LCD and CRT monitors and paint samples in viewing conditions similar to those of soft-proofing. Nine observers had normal colour vision, whereas two observers were slightly anomalous. The only colours in which the anomalous observers made matches significantly different from the mean were neutrals and yellow, while the magnitude and direction of deviations depended on the spectral properties of the display primaries. We conclude that the practical effect of deviations from normal colour vision in industrial applications depends on the spatial separation between the samples being matched, as well as on the spectral reflectance or emittance properties of these samples. A metameric rule test is the most effective method of detecting slight colour vision deficiencies, being superior to Ishihara pseudoisochromatic plates and to the Farnsworth-Munsell 100 hue test.

Keywords: Cross-media colour matching, colour vision deficiencies, observer metamerism, asymmetric colour matching

1 INTRODUCTION

Many colour-related decisions in industry are based on the results of visual evaluation of a metameric colour pair: matching a dyed textile sample to a reference, or matching the colour of a soft-proofed image to the original. Consequently, it is important that the colour vision of the personnel who carry out colour judgments be representative of the average colour vision of the population; i.e. be a "normal" colour vision.

Several tests for colour deficiencies are used in industry for the evaluation of colour vision. The Ishihara pseudoisochromatic test[1] evaluates the ability to discriminate between opponent colours. This test is easy to use, fast, and perhaps the most common. The Farnsworth-Munsell 100 (FH100) test evaluates sensitivity to small hue differences; colour deficiencies are detected by the appearance of specific patterns of confusion in different colour regions.[2] Both tests have proved to be effective in detecting colour deficiencies. However, some observers who do not classify as colour deficient can still have slight deviations from normal colour vision due to, for example, excessive density of prereceptoral pigments. Such observers will pass the standard colour vision tests successfully, but their judgments of metameric colour matches can be significantly different from those with normal colour vision.

Metameric colour rules ("Munsell Match-Point" and "Davidson and Hemmendinger"[3]) work on a principle different from the other tests: they are based on metameric colour matching, whereby colour vision deficiency is manifested by making colour matches significantly different from ones made by the "standard" observer. Metameric colour rules were reported in the past to be more effective in detecting slight deviations from normal colour vision than other tests.[4]

The aims of the study reported here were as follows:

1. To evaluate the effectiveness of colour vision tests in detecting small deviations from normal colour vision
2. To evaluate the practical implications of small deviations from normal colour vision on making metameric matches between spatially separated surface colour and self-luminous display stimuli.

2 THE EXPERIMENT

2.1 The setup

In a cross-media asymmetric[5] (p. 281) colour matching experiment, observers matched the

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colour of a paint samples by manipulating LCD and CRT monitors, arranged as shown in Figure 1.

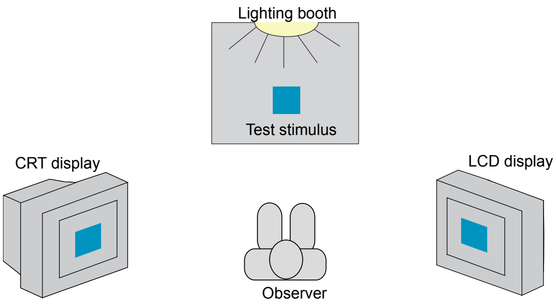

Figure 1 Experimental setup.

The CRT and LCD displays were an LaCIE BlueIV and an LaCIE 321, equipped with hoods to minimise stray light reflections. The viewing booth was a VeriVide DTP-60, with a fluorescent light source having a CCT of approximately 6000K; the inner surface was covered with black velvet, and the luminance was monitored by a luminance meter affixed to the booth floor. The spectral power distributions (SPD) of the grey paint sample and the lights emitted by the two displays all having same CIE 1964 XYZ values are shown in Figure 2.

Ten paint samples were used as test stimuli (Figure 3): two achromatic (white and medium grey) and eight chromatic: yellow, brown, magenta, purple, blue, cyan, light green and dark green. All stimuli subtended 6° at the experimental viewing distance (approximately 80 cm), and were surrounded by a grey background of approximately 60°×40°.

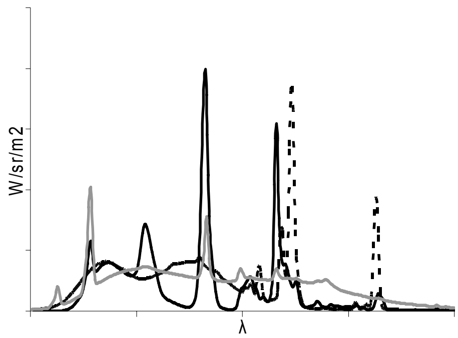

Figure 2 SPD of the grey sample displayed on the LCD and CRT, matching in colour the grey paint sample in the viewing booth for the CIE 1964 Standard Observer. Grey line: paint sample; black solid line: LCD display; black dashed line: CRT display.

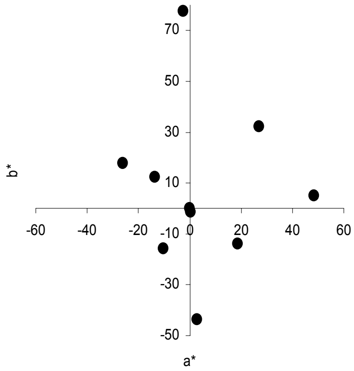

Figure 3 a*b* projection of the CIELAB coordinates of the paint samples.

2.2 The colour matching procedure

On each of the monitors, the observers accomplished the colour matching task in two stages:

1. At the beginning of the first session, the observers adjusted, starting from black, the colour of the background on both monitors to match the grey background in the viewing booth. In this stage, the observers established the viewing conditions on both monitors to be identical to those in the viewing booth: i.e. the colour of the background on the monitors matched that in the booth for the particular observer, but not necessarily for the Standard Observer.
2. Once the background colours matched, the observers altered the colour of the central patch on each of the monitors in turn to match the colour of each of the ten paint samples in turn.

The initial position from which the observers started to adjust the colour was always black. Observers controlled the monitor colour by rotating the mouse wheel, in one of two modes:

– CIELAB L*, C* and h* (used for chromatic stimuli)

– CIELAB L*, a* and b* (used for achromatic stimuli)

The duration of the adjustment was not limited; the average session lasted about one hour. Radiometric measurements of the matches made on both monitors, and of the surface samples, were taken upon completion of the observation sessions on the same day. The radiometric data were used to calculate CIE 1964 XYZ tristimulus values. The CIE 1964 XYZ tristimulus values of the booth illuminant were calculated from radiometric measurement of a white ceramic tile of known reflectance, and were used as the reference white in the CIELAB calculations.

Eleven observers took part in the experiment, eight males and three females. The average age was 32 years, with a standard deviation of five years. All were colour science postgraduate students, experienced in making colour judgements and in performing psychophysical tasks. Each observer performed five repetitions of each of 10 matches, all on different days. In total, 1100 matches were made.

3 RESULTS AND CONCLUSIONS

The observers' colour vision was tested by Ishihara pseudoisochromatic plates, a Farnsworth-Munsell 100 Hue Test, a D&H Colour Rule and a Munsell Matchpoint Rule. All the tests were done in the same viewing cabinet as was used in the colour matching experiment.

With Ishihara and FM100 Hue tests all the observers performed well; none showing any indication of colour vision anomaly. However, the D&H and Munsell Matchpoint rules revealed some differences (Figure 4). Two observers consistently stood out of the group with one of them – A6 – showing results particularly far from the average.

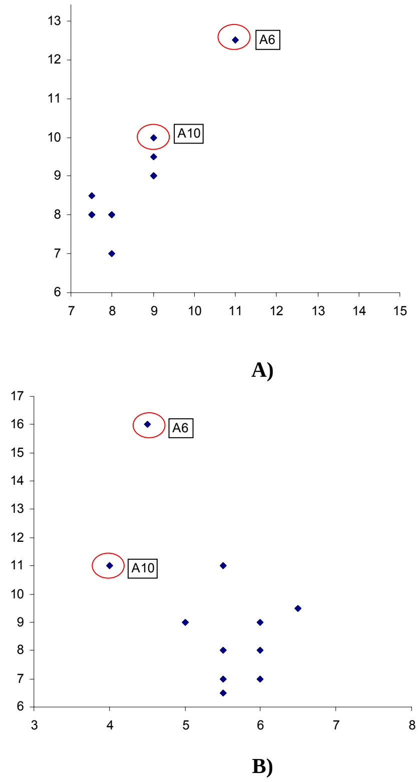

Figure 4 Plots of the results of tests by the metameric rules. A) D&H; B) Munsell Matchpoint. Labelled datapoints mark results of observers who made anomalous matches in the cross-media setup (see text).

Pobboravsky[4] reported an observation that the D&H rule is the most sensitive of the available hardcopy tests for normal colour vision. In his experiment, anomalous observers made matches unacceptable to normal observers - and vice versa. In Figure 5, we reproduce 95% confidence ellipses in the a*b* plane constructed from eleven observers' matches, for colour centres in which there was a significant difference between the observers who made "deviating" matches with the metameric rule and the mean: white, grey and yellow. Each data point on the plot corresponds to the mean of five matches made by each observer. The points are generally grouped well; however, there are "stray" points which stand out. These "anomalous" points indeed are produced by observers A6 and A10. The distributions of matches of the other seven colours do not have any outliers; i.e. observers who made anomalous judgments with the metameric rules and in cross-media matches of neutrals and yellow colours made matches not significantly different from other observers for the rest of the colours.

Furthermore, deviations in matches appear to be dependent on the display type. In neutral colours, the matches of observer A6 deviate from the mean towards green - but only in matches made on the CRT; there are no deviations in LCD matches. The matches of observer A10, on the other hand, are significantly "bluer" than the mean ones – but only in the LCD matches; the CRT ones are not different from the rest of the group's matches. In the yellow match, A6's matches deviate in a similar "green" direction – again in the CRT match only; matches made by A10 on both displays are within the common group's distribution.

Attempts to analyse the origins of the anomalies will be reduced to speculation, as objective tools of assessing the properties of the colour vision path elements of our observers – such as cone peak sensitivities or macular pigment and lens densities – are not available to us. We can, however, arrive at some conclusions regarding the effectiveness of the colour vision tests, and the practical implications of slightly anomalous colour vision. The following features are evident:

1. Results of colour vision tests based on metameric matches of adjoining samples, such as in metameric rules, are not necessarily indicative of a subject's ability to make matches of spatially separated stimuli.
2. Some observers with colour vision deviating from normal will make matches indistinguishable from colour-normals on spatially separated stimuli on all colours except neutrals and yellows. This implies that in many colour matching tasks the deviations from normal colour vision will not have an effect on the personnel's performance. The reasons could lie in different vision

mechanisms operating in the two setups,[6] higher uncertainty of spatially-separated matches, and/or different degrees of metamerism of display-surface colour matches.

3. Judgments by the same anomalous observer made on metameric spatially separated samples might vary dependent on their spectral power distribution, as indicated by the results of observer A10. An observer who made judgments indistinguishable from normal on a CRT monitor might make anomalous judgments on an LCD monitor, and vice versa.
4. Colour matching performance with adjoining samples (as indicated by the metameric rule matches) and with spatially-separated samples (as in a typical soft-proofing situation) is different: observers who show anomalous matches with former may do normal judgments with the latter.
5. The metameric rule test is a more sensitive colour vision test than Ishihara plates or the Farnsworth-Munsell 100 hue test.

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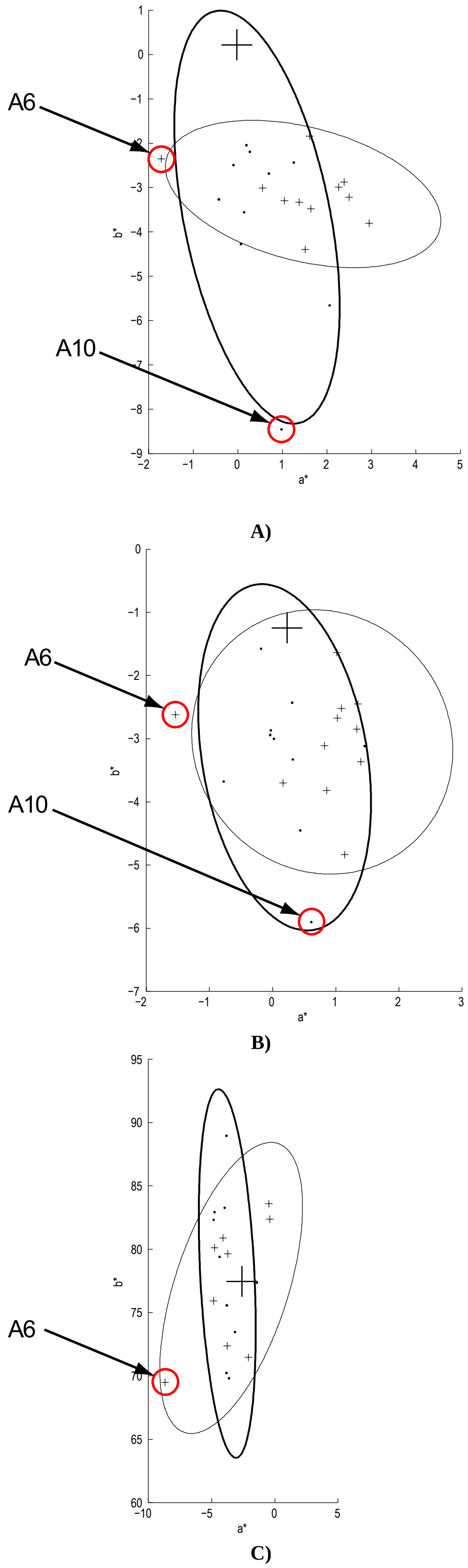

Figure 5 95% inter-observer confidence ellipses in the CIELAB a*b* plane, with anomalous observations marked and labelled with the observer code. A) White; B) Grey; C) Yellow. Dots and thick line: LCD; small crosses and thin line: CRT; large cross: paint sample.

The key attributes that influence the image quality of a large display

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ABSTRACT

This paper investigates the perceptual attributes that have a major impact on the quality of images viewed on a large plasma display panel. An experiment was conducted that included 5 perceptual attributes that might combine to form the concept of Image Quality: colourfulness, contrast, sharpness, naturalness and visual information. They were assessed using a categorical judgement method when the display was viewed with a dark surround. The 8 test images were manipulated to produce variations in the rendering of lightness, chroma and sharpness. Approximately 79,000 observations were made by 14 observers. The influence of each of the 5 perceptual attributes on image quality was investigated using principal component analysis and multiple regression analysis. The results showed contrast, naturalness and colourfulness to be key factors affecting image quality.

Keywords: Image quality, contrast, naturalness, sharpness, colourfulness, visual information

1 INTRODUCTION

The image quality of a display can be evaluated either by objective or by subjective measurement. Objective measurements, which are widely used by display manufacturers, include physical properties that traditionally have been used in the development of televisions, such as luminance, colour gamut, resolution and contrast, defined as a ratio between the darkest and the lightest colour. Displays are viewed, however, by human observers, so subjective measurement is essential. Much effort has been made to quantify image quality by human observers through psychophysics. There are two approaches to achieve this aim. The first approach is to judge the image quality difference between an original and its reproduced image. The visual results can then be used to develop an image quality difference metric such as the iCAM framework's image difference metric[1], JND (Just Noticeable Differences)[2] and SQRI (Square Root Integral) measures[3]. Thus while measures of differences between an image pair can be calculated, the fundamental question "What is image quality?" remains unanswered. A related question is "What exactly is the 'original' of an image"? [4] For the other approach, image quality is considered as the combination of a number of perceptual attributes, often called the "nesses".[5] This concept only considers individual images, not a pair. For example, Janssen and Blommaert[6] applied 'usefulness' and 'naturalness' to predict image quality.

This study was carried out in order to identify perceptual attributes that describe the quality of images viewed on a large display. The experiment was conducted in a dark surround condition and 6 attributes were assessed: image quality, contrast, naturalness, sharpness, colourfulness and visual information. Moreover, the influences of image lightness, chroma and sharpness transforms on these attributes were examined.

2 EXPERIMENTAL

2.1 Visual Assessment Experiment

A 42-inch Samsung Plasma Display Panel (model PPM42H3) whose pixel resolution is 1024×768 with an aspect ratio of 16:9 was used for this study. The colorimetric characterisation model was built using a 3D-LUT and tetrahedral interpolation, to give an error about 1.25 and 1.74 ΔE^*_{ab} units for forward and reverse models. Eight test images, 5 natural scenes, 1 fruit and 2 portraits, were chosen (Figure 1).

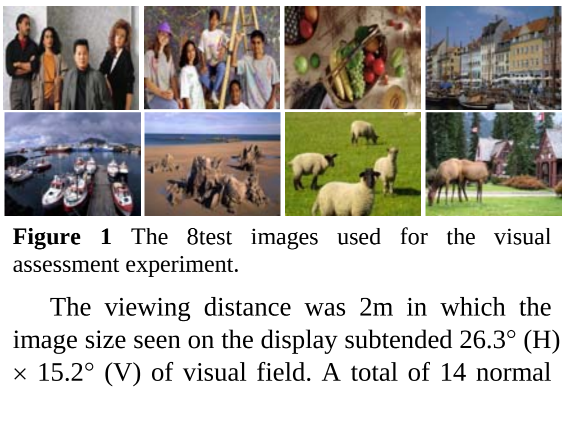

Figure 1 The 8test images used for the visual assessment experiment.

The viewing distance was 2m in which the image size seen on the display subtended 26.3° (H) × 15.2° (V) of visual field. A total of 14 normal colour vision observers including postgraduate students at the Colour & Imaging Group of the University of Leeds participated. To scale their perception of the above 6 attributes, a categorical judgment method following Case V of Thurstone's Law was adopted.[5] Observers were asked to rate an image using a 9-point verbally-labelled category scale. For example, '9' corresponded to the 'highest quality', '5' to the 'average quality' and '1' to the 'lowest quality '.

2.2 Image-Manipulation Functions

The tristimulus values of each pixel in a test image were obtained using the characterisation model. The CIECAM02 colour appearance model[7] was then used to manipulate each original image in the attributes of lightness (J) and chroma (C). Table 1 describes the 22 manipulation functions used. For rendering lightness, four types of function were used: 4 linear, 3 sigmoid, 3 inverse-sigmoid and one local colour correction method.[7,8] For rendering chroma, 4 linear, 1 sigmoid and 1 inverse-sigmoid functions were employed. For manipulating different degrees of sharpness, 4 high-frequency emphasis filters were applied to the lightness channel. Additionally, the Barten's contrast sensitivity function[3] was also used. Each method was designated in 3 parts: the attribute rendered, the type of function and the amount of the effect. For example, LISL is a lightness manipulation (L) by inverse-sigmoid function (IS) with a large change (L).

3 RESULTS AND DISCUSSIONS

3.1 Image Depenency

Two comparisons were made to examine whether the visual results for the 6 attributes were image dependent. For the first comparison, the mean Z-scores for the 8 test images were plotted together with the Z-scores of each of 8 test images for each of the 22 image-manipulations and for each of the 6 attributes. All z-scores of the 8 test images fell within the 95% confidence interval from the mean of the 8 test images for most image-manipulations and for each of the 6 attributes. For the second comparison, Z-scores of the individual test images for the 22 image-manipulations were plotted against the mean Z-scores of the 8 test images for those. Furthermore, Pearson Correlation Coefficients explaining linear relationship were computed for each image and for each of the 6 attributes. The resulting coefficient range was between 0.88 and 0.95. These values indicate a good agreement between the individual test image and the mean data of all 8-test images. In conclusion therefore, the 6 attributes could be scaled in an image independent manner. Hence, the comparisons will be made using the mean Z-scores for the following results.

Table 1 The summary of image manipulation functions

Linear function
Output $A = A \cdot f$ ▪ f is a scaling factor. When A is lightness, *the f were set at* 0.95, 0.90, 0.85, 0.80 and at 0.9, 0.8, 0.7, 0.6 when A is chroma. ▪ The rendered images are named **LL095**, **LL09**, **LL085**, **LL08 and CL09**, **CL08**, **CL07**, **CL06** respectively.
Sigmoid function
Output $G = 100 \cdot 1/\{[(1/(1+p^q)] \cdot [1+(p/G)^q)]\}$ ▪ When $G=J/100$, there are 3 manipulations: p=1.23 and q=1.45 **(LSS)**, p=0.75 and q=1.9 **(LSM)**, and p=0.63 and q=2.35 **(LSL)**.When p is smaller and q is larger, an increase of lightness contrast of an image occurs. ▪ When $G=C/C_{max}$, p=0.63 and q=2.35 **(CS)**. C_{max} is the maximum chroma in an image.
Inverse-Sigmoid function
Output $G = 100 \cdot p \cdot \{1-G \cdot [(1/(1+p^q)] / [G \cdot [(1/(1+p^q)]\}^{-1/q}$ ▪ When G is lightness, p=1.23 and q=1.45 **(LISS)**, p=0.75, and q=1.9 **(LISM)**, and p=0.63 and q=2.35 **(LISL)**. ▪ When G is chroma, p=0.63 and q=2.35 **(CIS)**.
Local Colour Correction (LLCC)
▪ The original lightness values of the image were rendered at each pixel by computing background luminance factor (Y_b) in CIECAM02 from the absolute luminance value of each pixel. ▪ This is a nonlinear lightness contrast reduction method.
Contrast Sensitivity Function (SCSF)
▪ The two frequency ranges were enhanced: 0.6 – 9.3 cpd corresponding to the top 50% sensitivity according to Barten's contrast sensitivity function, and 23.97 – 31.96 cpd corresponding to the edge areas.
High Frequency Emphasis Filter
Filter = $1 + 1.5 \cdot [1 - \exp(-\text{frequency}^2 / 2 \cdot d^2)]$ and $d = 1024 \times p$ ▪ *p equals 1/3, 1/5, 1/7, and 1/11 for* **SHFE1/3**, **SHFE1/5**, **SHFE1/7**, **and SHFE1/11** respectively. A smaller d will generate a more sharpened image. ▪ The constant, 1024, is the horizontal resolution of the display used for this study.

The next 5 sections reveal the relationships between image quality and the other 5 perceptual attributes. Firstly, mean Z-scores calculated from 8 test images for image quality are plotted against those for each of the 5 corresponding perceptual attributes (colourfulness, sharpness, contrast, naturalness and visual information) in Figures 2 to 6 respectively. The data points are plotted with four different symbols (filled circle, square, triangle and cross) corresponding to the lightness-, chroma-, and sharpness- manipulation, together with the original image, respectively. A best fit curve was also given so as to indicate the trend in the relationship between two sets of visual results.

3.2 Image Quality versus Colourfulness

Figure 2 shows that image quality increases with an increase in colourfulness, and stabilises when colourfulness reaches a certain level. The CIS image (low chromatic areas appear more chromatic but high chromatic areas appear less chromatic than in the original image) appears more colourful than the original image but without improved image quality.

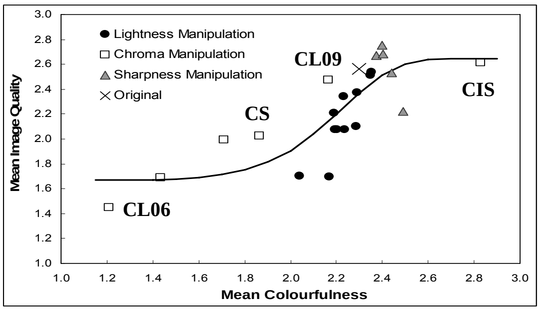

Figure 2 Image quality scale versus perceived colourfulness scale. Also shown is a Weibull fitting curve.

3.3 Image Quality versus Sharpness

Figure 3 shows that image quality increases to a certain sharpness level (SHEF1/5) and then falls. Amongst all the sharpness manipulations, the SHFE method (enhancing edge information) is more noticeable than the SCSF method (enhancing the frequency range covering the top 50% of the human contrast sensitivity function).

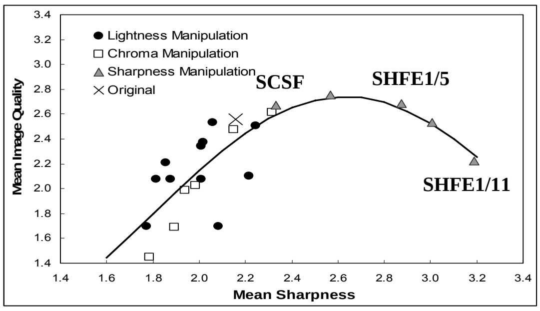

Figure 3 Image quality scale versus perceived sharpness scale. Also shown is a Sinusoidal fitting curve.

3.4 Image Quality versus Contrast

Figure 4 shows that image quality first increases and then decreases as a function of contrast. The extremely sharpened image (SHEF11) and the image with a loss in shadow details (LSL) have lower image quality. Additionally, it was found that there are three criteria used by observers for judging image contrast: vividness, colourfulness and lightness contrast. This explains why the image manipulated by LISL reducing lightness contrast appears to have the lowest perceived contrast. Also, the most colourful image (CIS) appears to have higher perceived contrast than the original image.

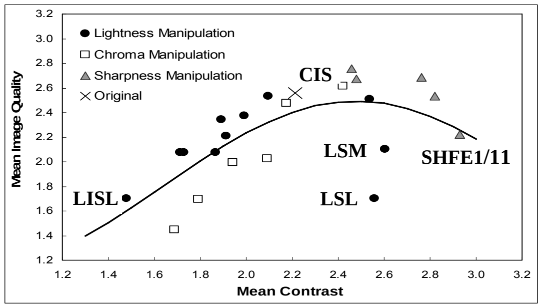

Figure 4 Image quality scale versus perceived contrast scale. Also shown is a Sinusoidal fitting curve.

3.5 Image Quality versus Naturalness

Figure 5 shows that there is a clear positive linear relationship between image quality and naturalness. The two images (CL06 and LSL) give the lowest perceived naturalness. In the latter dark areas of the original image were transformed to be even darker, which resulted in a loss of detail in the shadows. This suggests that colourfulness and the reproduction of shadow details can be considered as important factors contributing to the perception of naturalness.

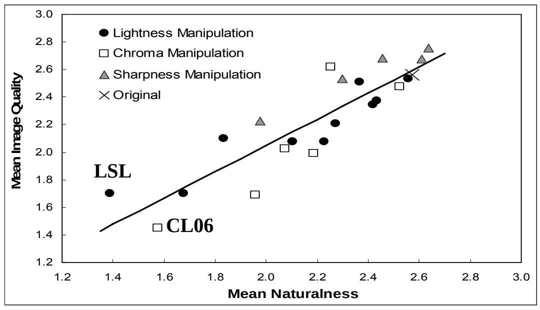

Figure 5 Image quality scale versus perceived naturalness scale. Also shown is a fitting line.

3.6 Image Quality versus Visual Information

The attribute, visual information, was adopted from the image quality semantics study of Janssen and Blommaert, in which the term 'usefulness' was used instead of visual information.[6] In the current experiment, observers were instructed to judge 'visual information' as "Does an image provide enough visual information which you are expecting to get?" Plotting image quality scale against visual information scale shows that image quality rises and then is slightly saturated with an increment of visual information (Figure 6). Overall, more sharpened images provided more texture details and thus provided more visual information.

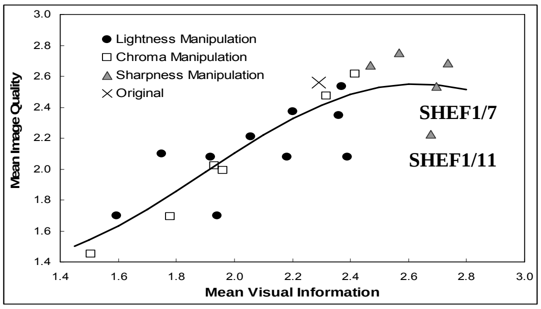

Figure 6 Image quality scale versus visual information scale. Also shown is a Sinusoidal fitting curve.

3.7 Empirical Image Quality Model

Empirical models were derived to predict image quality from the other 5 perceptual attributes through multiple regression and factor analysis. Factor analysis using the principal component method was used to extract highly correlated variables from the 5 perceptual attributes. Table 2 shows two components are sufficient to represent the 5 perceptual attributes. Contrast and naturalness will be better representatives of the

Table 2 The correlations between 5 perceptual appearances attributes and their principal components.

5 Perceptual Attributes	Component	
	1	2
Contrast	**.941**	.138
Sharpness	**.893**	.307
Naturalness	.012	**.919**
Visual Information	.453	**.794**
Colourfulness	.367	.656

two components, because they gave the largest correlation within their own component. Tables 3 gives the coefficient for each independent variable for each model and the R-value (multiple correlation coefficient) for each model. In addition, the Pearson Correlation coefficients calculated between image quality and each of the other 5 attributes are given in the bottom row of Table 3 and are expressed as R-value for the model with 2 coefficients. Although the model with 6 coefficients gave the highest R-value, there existed high inter-correlation between sharpness and contrast. The model with 4 coefficients having an R of 0.925 may give a satisfactory prediction for the quality of images viewed on large size displays. The R-values for the model with 2 coefficients showed that the 5 perceptual attributes studied give reasonable correlations with image quality, i.e. more than 0.5 with the highest for naturalness.

4 CONCLUSION

Psychophysical experiments were carried out to reveal the important perceptual attributes responsible for the overall image quality. In total, 79,000 judgements were made. The results showed that a strong positive linear relationship existed between image quality and naturalness. For colourfulness and visual information, image quality first increased and then stabilised at the high end. For the two spatial attributes (contrast and sharpness), image quality first rose and then fell from the certain sharpness and contrast levels. Finally, image quality was modelled empirically in terms of the 5 perceptual attributes. Colourfulness, contrast and naturalness were found to be important perceived attributes affecting image quality.

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Table 3 The empirical image quality models with different independent variables.

	Contrast	Sharpness	Natural-ness	Visual-Information	Colourful-ness	Constant	**R**
6-coef. model	**.198**	.114	**.683**	.024	**.211**	**-.458**	.927
5-coef. model	**.192**	**.131**	**.694**	-	**.214**	**-.461**	.927
4-coef. model	**.282**	-	**.705**	-	**.226**	**-.424**	.925
3-coef. model	**.353**	-	**.787**	-	-	**-.263**	.906
R for 2-coef. model	**.532**	**.570**	**.831**	**.765**	**.628**	**-**	-

A new model for accurate colorimetric characterization of liquid crystal displays

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ABSTRACT

For accurate colorimetric characterization of liquid crystal displays (LCDs), a new model, piecewise partition model (PP model), was proposed. The PP model divides the digital input values into three segments for each color channel and the device space into three kinds of subspaces according to the properties of the channel chromaticity and their interactions. The characterization process mainly involves two steps. Firstly, the relationship between the CIE1931 tristimulus values and their corresponding digital input values of primary channels are regressed with piecewise quadratic polynomial. Secondly, the two- or three-channels' crosstalk items, expressed with the production of two- or three-channels' digital input values, respectively, are inserted into the model to represent the subspaces' color characteristics. Comparing with Three Dimension Look-up Table (3D-LUT), Masking, S-Curve, and Two-Primary Crosstalk models, the accuracy of the PP model surpassed all other models except for the 3D-LUT, while the number of training samples for 3D-LUT was about 11 times of that for the PP model. Hereby, in the case of less training samples, the PP model achieved comparatively the best performance.

Keywords: display, liquid crystal display, colorimetric characterization, piecewise partition model

1 INTRODUCTION

Liquid crystal displays (LCDs) have become increasingly popular because of its high luminance, low power consumption, versatility with respect to placement, and have begun to replace cathode-ray tube displays (CRTs) in different applications. However, the colorimetric characterization of LCDs is more complex than that of CRTs since many of them dissatisfy the constraints of primary channel chromaticity invariance and channel independence, which are the foundation assumptions for most conventional display characterization models[1-4]. Hence for these LCDs, some models not based on these assumptions were used to LCD's colorimetric characterization, such as Three Dimension Look-up Table (3D-LUT)[5], Masking[6], S-Curve[7], and TPC[8] models. In this study, a new model, called piecewise partition model or, shortly, PP model, was proposed for accurate colorimetric characterization of LCDs.

2 CONVENTIONAL MODELS

Most of the conventional models for colorimetric characterization of displays consist of two stages. Firstly, assuming that the primary channel chromaticity across digital input values is invariance, the channel's CIE tristimulus values can be characterized simply. As an instance, for the red channel,

$$T_{Ri}(d_r, 0, 0) = L_R(d_r) \cdot x_{Ri} \tag{1}$$

where T_{Ri} (i = X, Y, Z) denotes the three tristimulus values X, Y and Z, d_r the digital input value of the red channel, $L_R(d_r)$ the intensity depending upon the d_r, and x_{Ri} (i = x, y, z) the three primary chromaticity coordinates of this red channel. The same expressions would hold for the green and blue channels. Secondly, with the assumption of channel independence, i.e. the joint color of the three channels is the additive mixture of the individual channels, the total CIE tristimulus values, T_i, can be modeled as

$$T_i(d_r, d_g, d_b) = L_R(d_r) \cdot x_{Ri} + L_G(d_g) \cdot x_{Gi} + L_B(d_b) \cdot x_{Bi} \tag{2}$$

where d_r, d_g, and d_b are the digital input values of the red, green, and blue channels, respectively.

The displays reasonably satisfying these above two constraints can be accurately characterized using the conventional models.

3 NON-CONSTANCY OF PRIMARY CHANNEL CHROMATICITY AND CHANNEL INTERACTION

A plenty of displays, especially the LCDs, usually dissatisfy the constraints of primary channel

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chromaticity invariance and primary channel independence. Furthermore, the variation extent of primary channel chromaticity and channel dependence vary with the digital input values.

3.1 Non-constancy of primary channel chromaticity

Figure 1 shows the measured chromaticity of a LCD (Neso LD500) for the three primary channels, where the abscissa, *d*, is the digital input values ranged from 16 to 255 with the interval of 16, and the ordinate is the *x*, *y*, and *z* chromaticity of the red, green, and blue channels after the black point subtractions[9], respectively. As can be seen, the chromaticity varied obviously with the lower digital input values, while less with the higher *d* values, and the least for the highest *d* values. It indicated that the variation of the primary channel chromaticity depended on the digital input values for the LCD.

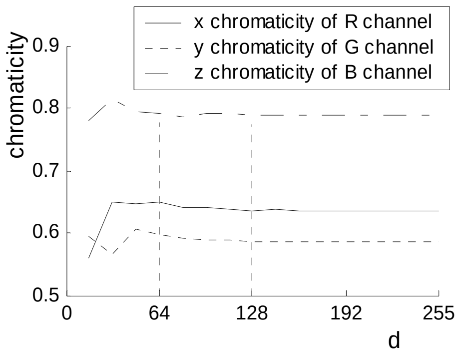

Figure 1 The primary channel chromaticity varied with the digital input values of LCD.

3.2 Primary channel interaction

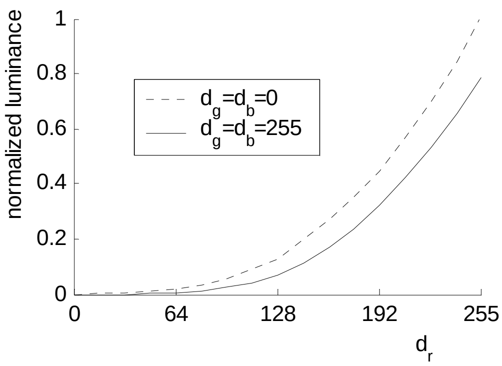

Figure 2 Deviation of red channel tune reproductive curve caused by green and blue channel interactions.

Two electro-optical transfer functions of the Neso LCD are illustrated in Figure 2 for the red channel, where the digital input values of the other two channels were kept at 0 or 255, respectively. The abscissa, d_r, is the red channel's digital input values ranged from 16 to 255 with the interval of 16, and the ordinate is the normalized luminance with removals of the black point. Note that the interference of red channel's luminance with green and blue channels was dr-dependent, i.e. the interaction was little for the lower digital input values, and became severer with the higher dr values, which implied that the primary channel interaction varied with the digital input values of the LCD.

4 PIECEWISE PARTITION MODEL

The polynomial model, usually consisting of the terms of an offset, one-color, two-color products, three-color products, and so on, is widely used for the colorimetric characterization of scanners, digital still cameras, displays, and printers. The polynomial model is universal and simple, but its color prediction accuracy is not high and the prediction errors are evenly distributed throughout the whole device space as the variations of chromaticity and interaction are not considered for different digital input values. The PP model is the improvement of the polynomial model. It divides the device space into several subspaces according to the variation of primary channel chromaticity and channel interaction. The division of the device space does not introduce much complexity to the PP model as it needs fewer terms with comparison to the usual polynomial model. With PP model, the characterization procedure is described as follows.

Firstly, the digital input values of each channel are divided into three segments according to the variation of primary channel chromaticity and channel interaction, and the CIE1931 tristimulus values of each segment are regressed with the quadratic functions. For example, the tristimulus values of the red channel can be expressed as

$$\begin{cases} T_{Ri} = a_{1i} + b_{1i} \cdot r + c_{1i} \cdot r^2 & d_r <= M_R \\ T_{Ri} = a_{2i} + b_{2i} \cdot r + c_{2i} \cdot r^2 & M_R < d_r <= N_R \\ T_{Ri} = a_{3i} + b_{3i} \cdot r + c_{3i} \cdot r^2 & d_r > N_R \end{cases} \quad (3)$$

where T_{Ri} ($i = X, Y, Z$) is the same with that in Eq. (1), r the normalized digital input value, a_{ji}, b_{ji} and c_{ji} (j =1, 2, 3) the constant coefficients, and M_R and N_R the separate points for the red channel. The same expressions can be given for the green and blue channels with the digital input values replaced by g and b and the separate points by (M_G, N_G) and (M_B, N_B), respectively.

Secondly, the device space is divided into 27 subspaces according to the 6 separate points, M_R, N_R, M_G, N_G, M_B, and N_B. Then the subspaces are further generalized into three kinds of subspaces as (1) with only one digital input value greater than the corresponding M_i ($i = R, G, B$) at most, (2) with two digital input values greater than M_i, and

(3) with all the digital input values greater than M_i, which consists of 7, 12, and 8 subspaces, respectively.

The tristimulus values of the digital input values in the first kind of subspace are directly represented by the summation of the tristimulus values of black point and those calculated using the three digital input values' corresponding piecewise functions. For instance, when the digital input values are in the subspace of dr<MR, dg<MG, and db<MB, their tristimulus values can be computed as

$$T_i = T_{Black} + T_{Ri} + T_{Gi} + T_{Bi} \quad (4)$$

where T_{Black} denotes the tristimulus values of black point, T_{Ri}, T_{Gi}, and T_{Bi} are calculated with the corresponding piecewise functions for the red, green, and blue channels, respectively. The other 6 subspaces in this first kind of subspace can also be dealt with in the same way. Note that the channel interaction is not considered here as it is negligible in the first kind of subspace.

For the second kind of subspace, the tristimulus values of the digital input values should include the terms representing the interactions between the two channels with larger digital input values. As an instance, if the digital input values are in the subspace of $M_R<d_r<=N_R$, $M_G<d_g<=N_G$, and $d_b<M_B$, their tristimulus values will be

$$T_i = T_{Black} + T_{Ri} + T_{Gi} + T_{Bi} + d_i + e_i \cdot r \cdot g \quad (5)$$

where the last two terms represent the interactions between the red and green channels, d_i and e_i are the constant coefficients, which can be estimated using the training samples in this subspace. Similarly, the tristimulus values of the other 11 subspaces in this second kind of subspace can also be obtained.

All the channels' interactions must be considered for the third kind of subspace. Taken the subspace with $M_R<d_r<=N_R$, $M_G<d_g<=N_G$, and $M_B<d_b<=N_B$ as an example, the tristimulus values will be calculated as

$$\begin{aligned} T_i = & T_{Black} + T_{Ri} + T_{Gi} + T_{Bi} + d_i + e_i \cdot r \cdot g \\ & + f_i \cdot g \cdot b + h_i \cdot r \cdot b + k_i \cdot r \cdot g \cdot b \end{aligned} \quad (6)$$

where the last five terms represent the interactions among the three channels, d_i, e_i, f_i, h_i, and k_i are constant coefficients, which can be estimated according to the training samples in this subspace. The other 7 subspaces in this third kind of subspace should be processed in the same way.

5 EXPERIMENTS AND RESULTS

A 15-inch LCD, Neso LD500, was tested, whose color resolution is 24 bits and the refresh rate is 60 Hz. The display was controlled by a personal computer and warmed up for two hours before measurement. The configuration of the setup was settled according to IEC standards[10], the color patches, displayed at the center of the screen, were measured with the spectroradiometer PR650 in a dark room.

The separate points, *M* and *N*, of the three channels were estimated as 64 and 128, respectively, according to the variation of primary channel chromaticity and interactions as shown in Figures 1 and 2. In order to effectively make use of the training samples and to maintain the continuation of the tristimulus values at separate points, the colors at the separate points were involved in the training samples. The first set of training colors included (d_r, d_g, d_b) = (I_R, 0, 0), (0, I_G, 0), (0, 0, I_B), where I_R, I_G, and I_B are 0, 16, 32, 48, 64, 80, 96, 112, 128, 160, 192, 224, and 255. The second set included colors of (d_r, d_g, d_b) = (J_R, J_G, 32), (J_R, 32, J_B), (32, J_G, J_B), where J_R, J_G, and J_B are 64, 128, and 255. The third set included (d_r, d_g, d_b) = (M_R, M_G, M_B), where M_R, M_G, and M_B are 64, 128, and 255.

After the black point subtraction, the first training set was used to estimate the constant coefficients of the three channels' piecewise functions, and the second and third sets were used to determine the constant coefficients of the interaction terms in the second and third kind of subspaces, respectively. Meanwhile, the training colors at separate points were used to estimate the coefficients of the neighboring piecewise functions or subspace expressions. In such way, every piecewise function had 5 training samples, and every subspace in the second and third kind of subspaces had 4 and 8 training samples, respectively.

The training samples of 3D-LUT, Masking, S-Curve, TPC models, together with the 512 test samples evenly distributed in the device space, were also measured for the comparison with PP model.

Figure 3 gives the statistics of the color differences, ΔE^*_{ab}, for the 512 test samples with respect to the five models, in which the data with ΔE^*_{ab} larger than 10 was counted in the slot from 9.5 to 10.0. The 3D-LUT model was the most accurate among all, and the PP model followed. The Masking model also performed very well except for the range of ΔE^*_{ab} from 2 to 4, where its count was larger than those of 3D-LUT and PP models. The S-Curve model performed poorly, which mainly due to the fact that the Neso LCD tested in this experiment did not satisfy the constraint of additivity very well. Though the TPC model also considered the non-constancy of channel chromaticity and interaction, since the extent of chromaticity variation and channel interaction varied with the digital input values for this LCD, the TPC model did not perform satisfactorily.

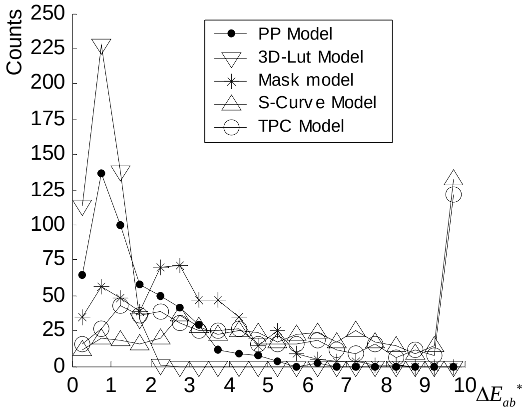

Figure 3 Color difference distributions of different models.

The average, minimum and maximum color differences for the five models are listed in Table 1. The numbers of training samples were marked in the brackets under the corresponding models. The 3D-LUT model outperformed all others again, however, its number of training samples was much larger than those of all other models. On the other hand, all the performance parameters of PP model were the minimum comparing with other models except for 3D-LUT model, and its number of training samples was much less than that of 3D-LUT model.

Table 1 Color difference comparison of different models for 512 test samples

ΔE_{ab}^*	PP (91)	3D-LUT (1000)	Mask (119)	S-Curve (54)	TPC (195)
Avg.	1.5881	0.8328	2.6990	6.6260	7.7088
Min.	0.0373	0.0844	0.0699	0.1420	0.1606
Max.	6.0249	2.1325	7.2953	18.5790	33.3550

6 CONCLUSIONS

The displays that reasonably satisfy the constraints of primary channel chromaticity invariance and channel independence can be accurately characterized with simple conventional models. However, for most LCDs, which do not satisfy these two constraints, more complex models should be used for colorimetric characterization. By taking into account the variation of channel chromaticity and interaction with the digital input values, the PP model, presented in this article, divides the device space into several subspaces and uses fewer terms than usual polynomial models to characterize the LCDs. To effectively make use of the training samples and to maintain the tristimulus values to continue at the separate points, the training samples at separate points were used to estimate the coefficients of the neighboring piecewise functions or subspace expressions. The experimental results showed that the PP model performed best among all except for the 3D-LUT model, which needed much more training samples than PP model.

ACKNOWLEDGMENTS

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Importance of colour recordings during the documentation process within the conservation and restoration applications

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ABSTRACT

A detailed architectural survey of a historical building before conservation and restoration applications has a great importance in order to get a reliable future intervention. In this context, the colour specifications of the building's materials should also be determined at the physical documentation as a part of process the architectural survey. In this paper, colour records role in the conservation and restoration applications is emphasized and colour records of some historical buildings worked on at the CAHRISMA and ERATO Research Projects, which were supported by the EC 5th Framework INCO-MED Program, are presented.

Keywords: Colour, Conservation, Architecture

1 INTRODUCTION

It is a fact that conscious societies accept the historical buildings covering the features related to edifice -and/or its era- range from the relationship with their environment, architectural expressions, functions and materials, to the application techniques, as a cultural heritage. Architecture is the most basic and indisputable field of the cultural heritage concept.

Conservation of the historical buildings covers all sorts of efforts to protect and transfer the historical document to future, in its complite authenticity (1). In this context, determination of the color specifications of the building materials, in other words "color records of the building" should also be done in scope of the original physical documentation of the building. Those analysis will serve in choosing new materials to be selected/designed in order to be used in the future restoration applications, furthermore it will enable to create the most real image when the virtual reconstruction of the building is considered.

Advancement of computer technology and concurrent developments at the 3D modeling and virtual reality softwares provided new developments to the conservation concept. Today it is possible to simulate a space, building or settlement in a virtual environment with its physical environments properties such as light, colour and sound beside their cultural and architectural features. After the monument was once formed in a virtual environment, its virtual restitutions for different periods of use can be easily produce by using the data related to aimed period.

In this context, two interdisciplinary research projects, CAHRISMA and ERATO which were supported by the EC 5th Framework INCO-MED Program, were realized in the field of architectural conservation. The aims of these projects are the identification and revival as well as the restoration and conservation of the acoustical and visual heritage of the monuments in a virtual environment.

At the project of the CAHRISMA (**C**onservation of the **A**coustical **H**eritage by the **R**evival and **I**dentification of **S**inan's **M**osque's **A**coustics) three of Sinan's mosques from 16th Century; Kadırga Sokullu, Süleymaniye, Selimiye and three Byzantine churches from 6th Century which are thought have to influenced Sinan's architecture; SS.Sergius and Bachus, Saint Irene (Hagia Eirene), Saint Sophie (Hagia Sophia) were selected as the worship spaces to work on. In this project, Saint Sophie, SS. Sergius and Bacchus, Süleymaniye Mosque and Kadırga Sokullu Mosque have been chosen for a combined visual and acoustical virtual reconstruction and they were modelled and conserved at the virtual environment of different function configurations. The time period for the reconstruction has been chosen to be around 11th century.

At the project of the ERATO (Identification, **E**valuation and **R**evival of the **A**coustical Heritage of Ancient **T**heatres and **O**dea), three antic theatres; Aspendos-Turkey, Jerash South-Jordan and Syracuse-Italy and two odeas (antic roofed theatres); Aphrodisias-Turkey and Aosta-

Italy were selected as the monuments to work on. Among these, Aspendos Theater and Aphrodisias Odeon have been chosen for a combined visual and acoustical virtual reconstruction and they were modelled and conserved at the virtual environment of different function configurations. The time period for the virtual reconstruction has been chosen to be around the first century AD.

This paper aims to emphasize colour records' role in the real and virtual conservation and restoration applications and to present colour record examples of the buildings which were chosen to be modelled as interactive 3D virtual environments for the CAHRISMA and ERATO Projects.

2 COLOUR RECORDS IN THE CONSERVATION

There are different works for architectural conservation such as, determination (analytic survey/documentation) of the current/present situation of the building, reconstruction of the building by using the documentations on the original construction period, restoration of the building according to the present and past (original) documentations. At the conservation, restoration and reconstruction works of a historical building, the most important subject is to collect the appropriate and accurate documents. Therefore, within the documentation works in the analytic survey process, necessary data on the colour properties of the existing building materials should be collected by colour measurement.

Colour measurements of the materials carried out before the conservation works of the historical buildings will provide;

- a record of the surface materials' inherent colours,
- a choice of new materials having inherent colours to be used or designed at future restoration applications to get a reliable future intervention.
- a possibility for creating a realistic environment (the most real image) when a virtual reconstruction is considered (2).

Therefore, inherent colours of the surface materials should be correctly determined. In this context, selection of the colour measurement device specifications has a great importance. Many methods and devices were developed in order to measure the colour of object. As known, there are two types of optic instruments in common use for measuring the object colours, "reflectance spectrophotometers" and "tristimulus colorimeters" (3, 4). In both cases light is sent onto the object and part of the reflected light is collected, analyzed and the intensity is recorded. In general, the reflectance spectrophotometer which is more reliable is used to get a precise colour measurement and colorimeters are most useful for quick comparison of near-matching colours as they are not very accurate. Therefore, spectrophotometers should be prefer for colour measurements of the materials in the conservation works of the historical buildings

3 COLOUR RECORDS OF THE BUILDINGS

In both projects, inherent colours of surface materials of the selected buildings were recorded with in situ measurements by using Spectrophotometer (Minolta - CM-2600D).

Measurements were realized under the Standard D65 illuminant recommended by CIE to record inherent colours. Measurements' results were evaluated through the Spectra Magic (Ver.3.6) Software Program to get data according to Lab, Lch, Yxy and Munsell Colour Systems.

Colour records' samples of the CAHRISMA and ERATO buildings according to Lab and Munsell Colour Systems are given in the Table 1 and some photos showing the buildings and measurement process are presented in Figures 1-7 (5-7).

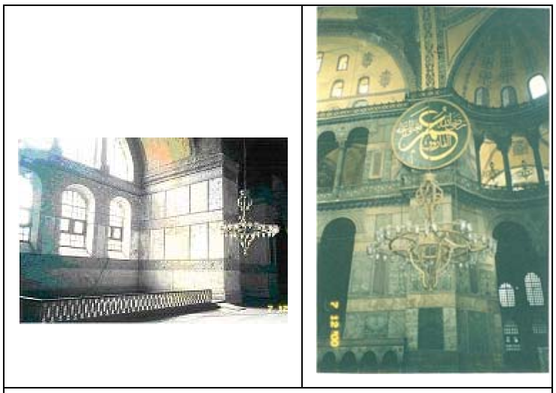

Figure 1 Saint Sophie (Hagia Sophia)

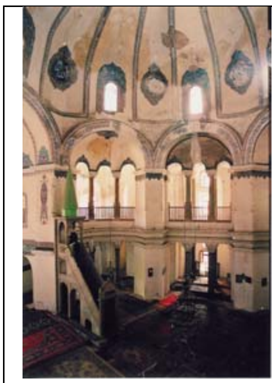

Figure 2 SS.Sergius and Bachus

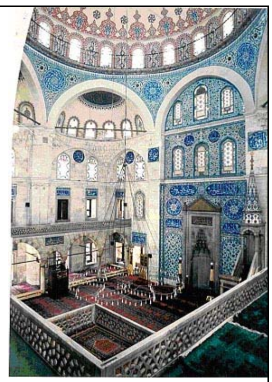

Figure 3 Kadırga Sokullu Mosque

Figure 4 Süleymaniye Mosque

Figure 5 Aspendos Theater

Figure 6 Jerash Theater

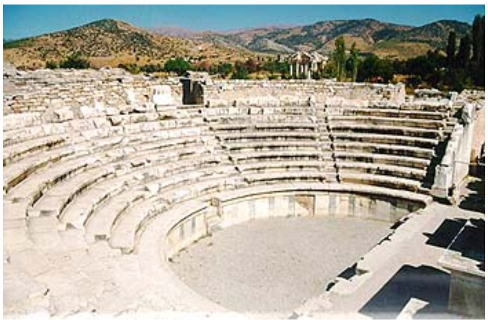

Figure 7 Aphrodisias Odeon

Colour properties of the extend building materials were recorded by these measurements and they will provide an accurate data for real or virtual reconstruction of the projects' buildings. At the virtual reconstruction process of buildings, the related partners (EPFL and UNIGE) of the projects used the colour records in the 3D model of the buildings. Some examples of the virtual model of the Aspendos Theatre for different daylighting conditions (colour) are presented in Figure 8.

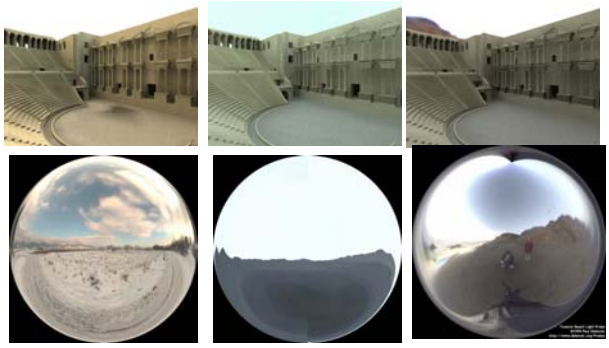

Figure 8 HDR (High Dynamic Range) and IBL (Image Based Lighting) (MIRALab - University of Geneva) (8).

4 CONCLUSION

Conservation of the cultural heritage concisely covers all sorts of works to protect and transfer the historical document to future, in its all authenticity. Considered from this perspective, determination of the materials' color, which is mostly neglected before the conservation and restoration applications, will provide documentation of the surface materials' colors without any inaccuracy. It also gives the possibility of choosing new materials to be used or designed in future restoration applications to get a reliable future intervention. Furthermore, when a virtual reconstruction/visual simulation of recent situation is considered, color properties of the materials used at the buildings should give the most real image as much as possible. In consequence of the items mentioned above, one can be affirmed that "color records" should take place within the context of documentation works of the architectural heritage.
Colours of the surface materials of the buildings selected within the CAHRISMA and ERATO Projects are documented in order to determine their recent conditions for being able to transfer them into the future for monitoring future conditions in any case of disappearing.

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Table 1 Colour records' samples of the CAHRISMA and ERATO project buildings (Lab and Munsell Colour Systems)

Project	**Building**	**Material**	**Lab (D65)**			**Munsell (C)**		
			L	**a**	**b**	**H**	**V**	**C**
CAHRISMA	SAINT SOPHIE	Mihrap Marble	85,66	9,46	11,40	2,0YR	8,5	2,9
		Gallery Paint	77,71	11,01	51,36	0,1Y	7,7	8,1
		Column	45,38	-3,60	10,28	1,0GY	4,4	1,6
	SS SERGIUS & BACHUSS	Stone (küfeki)	90,01	0,04	4,47	0,5Y	6,6	1,5
		Mihrap marble	57.16	1.08	7.99	1,6Y	5,6	1,2
		Mihrap tiles	40.49	34.67	29.12	9,6R	4,0	8,3
	KADIRGA SOKULLU MOSQUE	Stone (küfeki)	90,01	0,04	4,47	0,5Y	6,6	1,5
		Mihrap marble	57.16	1.08	7.99	1,6Y	5,6	1,2
		Mihrap tiles	40.49	34.67	29.12	9,6R	4,0	8,3
	SÜLEYMANİYE MOSQUE	Stone (küfeki)	74,43	1,24	10,60	1,0Y	7,3	1,5
		Mihrap marble	61,80	0,38	5,49	2,1Y	6,0	0,8
		Mihrap tiles	84,03	-2,85	2,16	0,7G	8,3	0,4
ERATO	ASPENDOS THEATRE	Seating row (Vertical)	53,24	0,57	6,92	2,7 Y	5,2	1,0
		Seating row (horizontal)	57,54	1,41	10,27	1,6 Y	5,6	1,5
		Diazoma (Pavement)	63,36	0,48	8,32	2,3 Y	6,2	1,2
	JERASH THEATRE	Seating row (Vertical)	69,77	1,41	11,51	1,2 Y	6,8	1,7
		Seating row (horizontal)	66,81	0,91	11,97	2,0 Y	6,5	1,7
		Orchestra floor	84,71	0,96	9,40	0,7 Y	8,3	1,3
	APHRODISIAS ODEON	Orchestra wall	44,10	-0,57	0,12	8,5 G	4,3	0,1
		Seating Row	62,81	2,28	12,44	0,7 Y	6,1	1,9
		Upper Wall	69,63	0,45	5,89	1,6 Y	6,8	0,8

Reconstruction of the reflectance curves by using interpolation method

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ABSTRACT

The linear interpolation method is applied to reconstruct the reflectance curves of the Munsell color chips, by converting colorimetric data under a given viewing conditions, using the look-up-table (LUT) interpolation technique. The source space has been formed by calculation of the tristimulus values of the 1269 Munsell color chips under different illuminants, while the corresponding reflectance data is considered as destination space. The CIE color specifications of Munsell color chips, i.e. tristimulus values under different illuminants and the colorimetric shift of the samples are considered for creating different LUTs. As results show, the reconstructed reflectance curves significantly improve by increasing the dimensions of source space. Totally, recovered reflectance curves are good when the source space is a three dimensional CIEXYZ space. Besides, it was shown that the metamerism index between the samples and their recovered ones decrease by increasing the dimensions of the source space. It is concluded that a type of balance should be considered between the reliable prediction of the reflectance curve and the dimensions of the source space as well as the number of samples which their reflectance curves could be reconstructed.

Keywords: reflectance curve, interpolation, reconstruction, tristimulus value.

1 INTRODUCTION

The overall appearance of any object is affected by its color and its geometric attributes. These attributes should be visually or instrumentally measured for assessment of appearance. In the field of instrumental measurement of color, two popular devices are colorimeters and spectrophotometers. A colorimeter is a device that describes the color by colorimetric values mostly in 3D dimensional space, such as CIELAB. On the other hand, a spectrophotometer is an instrument for measuring or comparing the reflection spectrums. Consequently, spectrophotometers are much more expensive and more accurate than colorimeters. The reflectance curve can be considered as the principle element that completely characterizes an object color. In fact each color has a unique reflectance curve that can be considered as the “fingerprint” of that color. Reflectance curve is also independent of the observer as well as the light source for non-fluorescent colors. Correspondingly, there are two main types of color measurement methods, spectrophotometeric measurements, which reflectance curve is measured, and colorimetric measurements, which provide the tristimulus values.

Calculation of colorimetric values such as CIEXYZ or CIELAB from spectral behaviors of object is too easy while, determination of spectral reflectance from the tristimulus values is not possible with the classic mathematical methods. Several methods were presented[1,2,3] to synthesize the reflectance curve using optimization methods as well as other mathematical methods such as Neural Network and PCA.

In this study, linear interpolation method is used to reconstruct the reflectance behavior of Munsell color chips from the CIEXYZ values. In fact the LUT information is used to reconstruct the reflectance curve using neighborhood points instead of colorimetric values.

2 THEORY

The problem of scattered data interpolation consists of constructing a continuous function of two, three, or more independent variables that interpolates data values which are only known at some scattered points in the two dimensional (2D plane) or, respectively, in the n-dimensional space[5]. Interpolation methods have been widely used in the field of electronic color reproduction systems to characterize input/output devices (such as scanners or printers)[4].

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In interpolation methods the interpolated value is only influenced by the values at ‘‘nearby’’ points. This makes these methods to be capable of treating large data sets, with the less sensitivity to data modifications. The interpolation operates in two main steps: First, the scattered point set is triangulated (in the 2D case), tetrahedrized (in the 3D case) or tessellated (in n-D space); and then, an interpolation scheme is used within each triangle (or tetrahedron or n-simplex)[5].

Let's start in the 3D case. Clearly a given point set in the 3D space has many different tetrahedrals. It may be therefore desirable to find among these tetrahedrals an optimal one which avoids as much as possible poorly shaped tetrahedrals (such as thin and elongated tetrahedrals). One of the “nicer” candidates is the Delaunay tetrahedrization[5,6], that the tetrahed-rization obtained by connecting all the neighboring points in the Voronoi diagram of the given point set[6].

In the 3D space, suppose that the scattered points (x_i, y_i, z_i) are first tetrahedrized. Every one of these tetrahedrals is used to interpolate any arbitrary point inside it. Given the four vertices P_1, P_2, P_3, P_4 of any such tetrahedron, in the locations (x_1, y_1, z_1), (x_2, y_2, z_2), (x_3, y_3, z_3), (x_4, y_4, z_4) of its four vertices and have their values R, the color values at any arbitrary point P located at (x, y, z) in this tetrahedron can be found by writing the linear interpolation polynomial[5],

$$P = aP_1 + bP_2 + cP_3 + dP_4, \quad (1)$$

and finding its coefficients *a, b, c, d* by solving the linear system of equations:

$$\begin{aligned} &ax_1+bx_2+cx_3+dx_4 = x \\ &ay_1+by_2+cy_3+dy_4 = y \\ &az_1+bz_2+cz_3+dz_4 = z \\ &a+b+c+d=1. \end{aligned} \quad (2)$$

Alternatively, the value R at any point P located at *(x, y, z)* within the tetrahedron is:

$$R_j = a\,R_{jP1} + bR_{jP2} + c\,R_{jP3} + d\,R_{jP4}, \quad (3)$$

where the weights *a, b, c, d* are the barycentric coordinates of the point P in the tetrahedron $P_1P_2P_3P_4$. It can be shown that *a, b, c, d* are given using Equation 4.

$$\begin{pmatrix} a \\ b \\ c \\ d \end{pmatrix} = \begin{pmatrix} x_1 & x_2 & x_3 & x_4 \\ y_1 & y_2 & y_3 & y_4 \\ z_1 & z_2 & z_3 & z_4 \\ 1 & 1 & 1 & 1 \end{pmatrix}^{-1} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} \quad (4)$$

It is also possible to extend this algorithm simply to higher 4 or 6-dimensional spaces. For example in 4D space, the scattered points can be located by (x_i, y_i, z_i, t_i) and the color values at any arbitrary point P located at (x, y, z, t) inside 4-simplex $P_1P_2P_3P_4P_5$ can be calculated:

$$R_j = a\,R_{jP1} + bR_{jP2} + c\,R_{jP3} + d\,R_{jP4} + e\,R_{jP5}, \quad (5)$$

where coefficients *a, b, c, d, e* are found by extending Eq. (1) in 3D space:

$$\begin{pmatrix} a \\ b \\ c \\ d \\ e \end{pmatrix} = \begin{pmatrix} x_1 & x_2 & x_3 & x_4 & x_5 \\ y_1 & y_2 & y_3 & y_4 & y_5 \\ z_1 & z_2 & z_3 & z_4 & z_5 \\ t_1 & t_2 & t_3 & t_4 & t_5 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}^{-1} \begin{pmatrix} x \\ y \\ z \\ t \\ 1 \end{pmatrix} \quad (6)$$

Note that there are several different methods for linear interpolation however the interpolated values obtained by the different methods are identical.

3 EXPERIMENTAL

The reflectance spectra of 1269 matt Munsell color chips were aimed. The reflectance data were collected from 400 to 700 nm by 20 nm intervals. The CIEXYZ values for each sample were calculated using D56, A and TL84 illuminants and 10^o standard observer.

Different color attributes of Munsell color chips were considered to make 3 different kinds of look-up tables to interpolate the reflectance curve in 16-Dimenstional space as follows:

1. $CIEXYZ_{D65}$ values for illuminant D65
2. $CIEXYZ_{D65}$ values D65 and Colorimetric shift for illuminant A
3. $CIEXZ_{D65}$ and $CIEXYZ_{A}$ for illuminant D56 and illuminant A

3.1 Interpolation method

In the present study, the work was concentrated on the local linear interpolation method to obtain reflectance curve in 16-dimentional space form tristimulus values that were derived form CIEXYZ values. In order to interpolate the target points, the scatted color points in CIEXYZ space were tetrahedrized (or tessellated) and then interpolation scheme was used within each tetrahedral (or simplex).

The first LUT was used to reconstruct reflectance space in 16-dimentional space from $CIEXYZ_{D65}$ so the scattered points tetrahedrized by applying Delaunay tetrahedrization method in CIEXYZ space that was a 3D space. Once the given scattered point set was tetrahedrized or tessellated, a procedure is needed to find the tetrahedron (or simplex) encloses any arbitrary new point. Then linear interpolation scheme was used within the tetrahedral (or simplex) to calculate the reflectance curve. As the reflectance curve was sampled in 16 wavelengths, the 16-dimensional spaces were considered as the reflectance space. Therefore, in all methods the color traited in first multi dimensional space was used to interpolate the reflectance curve in 16-dimensional spectrophotometric domain.

The color values of 1269 matt Munsell color chips was assumed as distinct points $P_1, \ldots, P_n$ that was made scattered data set in an N-dimensional space (N = 3, 4 and 6). Figure 1 shows the color values of 1269 matt Munsell color chips in CIEXYZ space under D65 illumination and 10^o. Each point P_i was located at the vector position and had a numerical value $R_{\lambda,i}$ (λ = 1...16). Our task was to find good interpolation $\hat{f}(x)$ such that $R_{\lambda,i} = \hat{f}(x)$ for all λ = 1…16. Then The interpolation methods were used to estimate the R_i in the 16-dimentional as mentioned in Eqs. (1) and (2). Figure 2 shows the 1269 Munsell color points in CIEXYZ that are tetrahedrized by Delaunay method.

To measure the amount of fitness, the mean of the root mean square (RMS) error between the target and the estimated reflectance spectral values was calculated for all Munsell color patches. Also to evaluate the effectiveness of the method, the metamerism indices under two different standard light sources for illuminant A and source TL84 were calculated.

4 RESULT AND DISCUSSION

Totally, the interpolation methods yielded very good results as it presented in Tables 1 and 2. However, a difference is noticeable for 3D method that only CIEXYZ values were used to estimate the reflection curve. It seems that the differences originate from the color-matching functions of 10^o standard observer. It can be seen that they tend toward 0 at the extremities. So, during calculation of tristimulus values, the reflectance curve are multiplied to very small values and led to small values in the extremities. Although the maximum of metamerism index under A and TL84 is high, the mean of metamerism index shows the acceptable values. It means that the reflectance curves were estimated for some out of gamut points because of Delaunay tetrahedrization method gives the convex hull of the point set. This problem is almost solved in other methods in higher dimensional spaces with using more samples to interpolate the reflectance curve. Table 2 shows the acceptable values for mean of metamerism index under A and TL84 illuminants respectively in first method.

However, due to differences of A and D65 spectral power distribution near 400nm and 700nm, in 4-dinemtioal space, when the colorimetric shift was used to calculate the reflection curve, better estimation was obtained. In this case, the mean of RMS values was decreased. RMS values are much less when the color values under two light sources have been considered in the 6-dinemtioanl method because of direct effect of A and D65 spectral power distribution. So, higher dimensional models that contain color values under different illuminants lead to better estimation of the reflectance curve. The RMSs in Table 1 shows the excellent curve fitness in both second and third methods, especially in third method. Also Table 2 shows that the metamerism index is zero under 2 illuminants A and D65. The maximum of metamerism index for 6D method is about 0.6894, which shows the nearly complete estimation of standard reflection curve.

However, even though the higher dimensional models led to more accurate results, they suffer from large amount of mathematical processing because of increasing the possibility of creating vertices in higher spaces in tetrahedrization step. This problem could be solved by saving Delaney tessellation for a given LUT data set. So, the tessellation process could be calculated and saved just one time for each look up table. In this way, the interpolation could be performed faster without needing recalculate of all simplexes, again. This solution could be also used for lower dimensional space to increase the speed of interpolation process, although the 3rd and 4th dimensional methods already executed with suitable speed, in the case of large number of color pixels in digital images the process speed would be considerable.

The out of gamut points in this method could be seriously considered. The out of gamut points could increase while the space dimension increases. Therefore, the numbers of target points that could be interpolated, reduce in comparison with lower dimensional spaces. As a result, in order to be able to interpolate a suitable number of color points in higher dimensional spaces, the LUT should contains more range of color points to cover almost all color space in a high-dimensional space.

Finally, in order to choose the best model, the time of processes should be considered in addition to the final precision. Also it is possible to increase the first space dimension to 9 or more by adding all three CIEXYZ values under D56, A and another light source such as TL84. Consequently, the amount of calculation and the time that are needed to calculate the reflection curve will be increased as well.

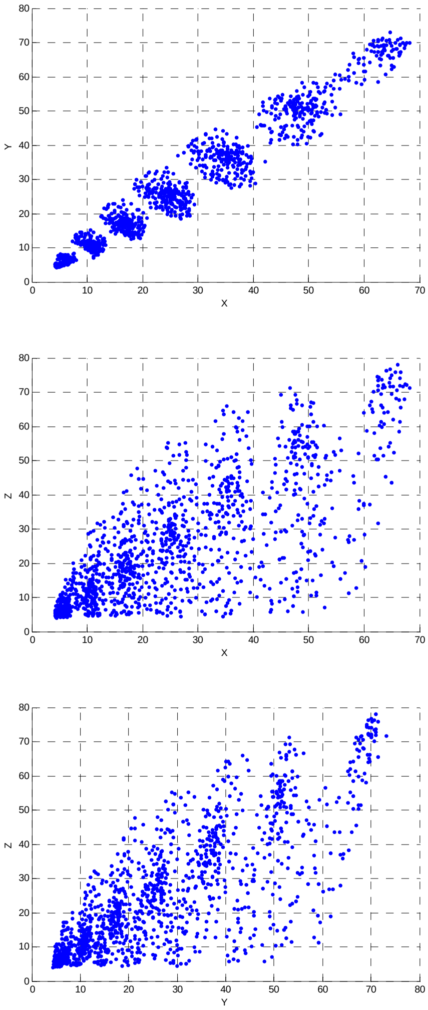

Figure 1 tristimulus values of 1269 matt Munsell color chips in CIEXYZ space under D65 illumination and 10°.

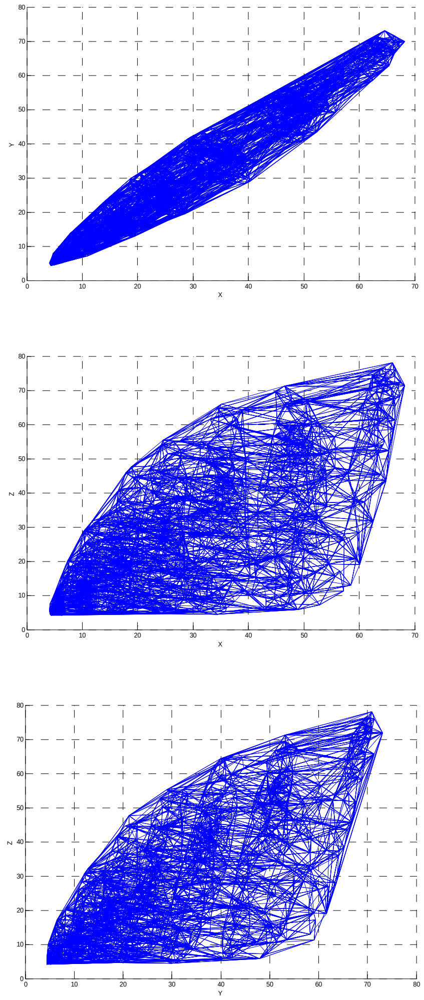

Figure 2 1269 Munsell color points in CIEXYZ tetrahedrized by Delaunay method.

Table 1 The root mean square (RMS) error between the actual and reconstructed reflectance values.

No.	First space in LUT	Dimension	Number of Interpolated points	RMS		
				Mean	Maximum	Variance
1	$XYZD_{65}$	3	1151	0.0046	0.1631	1.77×10^{-4}
2	$XYZD_{65}$ and Colorimetric shift	4	1076	0.0023	0.0852	4.74×10^{-5}
3	$XYZD_{65}$ and XYZ_A	6	825	2.84×10^{-4}	0.008	3.53×10^{-7}

Table 2 Metamerism index under three different standard light sources, illuminant D65, A and source TL84.

No.	First space in LUT	Metamerism Index								
		Mean			Maximum			Variance		
		D65	A	TL84	D65	A	TL84	D65	A	TL84
1	$XYZD_{65}$	0.0000	0.4917	0.6573	0.0000	5.5268	6.9026	0.0000	0.3009	0.5301
2	$XYZD_{65}$ and Colorimetric shift	0.0000	0.2948	0.4159	0.0000	3.7465	4.8962	0.0000	0.1594	0.2814
3	$XYZD_{65}$ and XYZ_A	0.0000	0.0000	0.1002	0.0000	0.0000	0.6894	0.0000	0.0000	0.0055

5 CONCLUSION

In this study, linear interpolation method is used to reconstruct the reflectance behavior by using the CIEXYZ values in three different kinds of look-up tables.

In the first definded LUT, which CIEXYZ values for illuminant D65 were used for interpolation, the acceptable mean of metamerism index and RMS shows the proper fitness of the estimated reflectance curves. The number of out of gamut points are fewer in comparison with other methods.

In other two methods, more color values added to make the source LUT space that led to better curve fitness. As a result in 6 and 4 dimensional methods, RMSs and metamerism index were decreased. Although higher dimensional methods show better results, larger amount of mathematical processing is needed and the number of out of gamut points increased as well. So, in such cases, number of samples that are used to create the first space in LUT should cover entire color gamut properly to decrease out of gamut points. So the number of the color samples that are used to create an LUT would be considered as well as process speed and accuracy in selecting each method in view of specific application.

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Investigation of colorimetry for samples on fluorescent paper

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ABSTRACT

Fluorescent Whitening Agents (FWA) have been widely used in the surface colour industries. However, there are problems to apply colorimetry involving samples containing FWA. The main problem is large variations of UV content in the light sources used for instrumental measurements and visual assessments. In this study, printed samples were prepared on substrates containing with and without FWA. They were measured by spectrophotometers and visually assessed in a viewing cabinet to study the effect of the inclusion and exclusion of UV component. It was found that instrumental results did show a slight effect due to the presence of FWA, while there was hardly any difference in visual perception.

Keywords: Fluorescent whitening agent, Spectrophotometer, Colorimetry, Colour appearance.

1 INTRODUCTION

To achieve successful colour reproduction on printed substrates is the aim for the graphic art industry. However, since the application of Fluorescent Whitening Agent (FWA) in paper, there are problems to achieve this. Fluorescent materials absorb light energy at UV region of the spectrum while re-emit at the other. Although accurate measurement of fluorescent materials is achievable using a spectrophotometer equipped with two monochromators, they are expensive and require complicated method to analyze huge amount of data. Modern spectrophotometers use CIE D65 simulator as light source. The large discrepancies between the spectral power distributions of the CIE D65 illuminant and of its simulator, as well as between those of the simulators used in different instruments, introduce poor reproducibility.[2,3] Methods have been developed to improve this by calibrating the UV content of the light source in an instrument. Typically, a plastic plaque with a nominal whiteness index[1] is used. However, there is still no accurate and simple means for calibrating UV in terms of reflectance. Also, the FWA inclusion in calibration white tiles of spectrophotometers raises uncertainty[4,5]. On the other hand, large disagreements arise during the visual assessments due to a lack of effective methods for controlling the UV content in the light source used in viewing cabinets.

Several studies have been conducted to investigate the quantification of whiteness of paper samples containing FWA.[1,6] However, no standard is established so far. A report published by International Commission on Illumination (CIE) Division 8[7] also recommended to study on how to improve reproducibility for measuring colorimetric data and spectral total radiance factor of specimens containing FWA.

The objective of this work is to investigate the difference of instrumental results measured by two spectrophotometers with different measuring conditions, of visual results obtained under light sources with different UV contents for measuring samples containing FWA. In addition, methods will be established for future study on fluorescent colorimetry to recommend robust practical methods for instrumental measurements and visual assessments.

2 EXPERIMENT

Experiments were conducted to instrumentally measure and visually assess ink samples on paper containing FWA.

2.1 Sample Preparation

Two papers from a range of ten were chosen: Hahnemuhle Photoreg (HAHNE) and HP Photo Matte (HPM). All 10 substrates were first measured in terms of gloss by a Sheen Tri-microgloss 160/T gloss-meter. They were then measured by a GretagMacbeth ColorEye7000A (CE7000A) spectrophotometer to obtain reflectance under UV included (UVI) and excluded (UVX) conditions. The reflectance functions were used to calculate CIE whiteness index. The gloss units and whiteness indices of the chosen ones are given in Table 1. It can be seen that they are similar in gloss but quite different in whiteness (or FWA content). The HAHNE had almost no FWA content according to the reflectance function measured.

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Table 1 Gloss unit and CIE whiteness index of the two substrates investigated.

	Gloss 60°	Gloss 20°	Gloss 85°	CIE W
HAHNE	1.3	2.5	1.8	92
HPM	1.3	2.6	3.2	139

For each substrate, the experimental samples were selected from a gamut target which was designed to define the colour gamut of digital media (ink on paper). The target includes 432 patches printed using an HP DesignJet 10ps inkjet printer. All patches were measured by the CE7000A with UVI condition. The CIELAB values of all patches were calculated under CIE D65 and 1964 standard colorimetric observer. The colour coordinates of all patches were then plotted in CIELAB space. Finally, 24 patches for each substrate were selected for each substrate to give a reasonable coverage of the space.

2.2 Instrumental Measurements

Two instruments were used: the CE7000A (see Section 2.1) and a HunterLab UltraScan Pro (Huntlab). They all have a *CIE (di:8°)* geometry and D65 simulators. Each instrument is equipped with a white ceramic tile and a black wedge to calibrate the photometric scale and set black level, together with a standard whiteness tile for UV calibration. All samples were first measured using CE7000A under UVI and UVX conditions. Only UVI condition was used for Huterlab because it did not have UVX condition.

2.3 Visual Assessments

It is well known that different UV contents in the light sources used will also have a large impact of colour appearance of samples containing FWA. Hence, experiments were carried out by visual assessment.

Each sample was assessed by a group of 10 normal colour vision observers according the Ishihara test in a GretagMacbeth SpectraLight II viewing cabinet. It has a unique feature using a filtered tungsten daylight source with additional UV to give an accurate approximation of CIE D65 illuminant. Two sources were used in the experiment: the GM source alone, (GM), and GM source with an additional UV lamp, (GM+UV).

The Colour Rendering Index (CRI)[8] and Metamerism Index (MI)[9] of the booth used are given in Table 2. The magnitude estimation method[10] was used to scale each colour in terms of lightness (J), colourfulness (C) and hue (H). The former was judged each colour against a patch of HAHNE paper having lightness assigned as 100. The colorfulness was assessed according to a reference patch with a C_{ab}* around 40. Each sample was assessed twice by each observer under two daylight conditions: additional UV on and additional UV off.

Table 2 Colour Rendering Index and Metamerism Index of SpectraLight II booth. The grade for the latter is also given in the bracket.

	CRI	$MI_{Visible}$	MI_{UV}
GM	96.8	0.45 (B)	2.065 (D)
GM+UV	97.0	0.42 (B)	0.403 (B)

Table 2 shows that the additional UV lamp did improve the quality of the source, i.e. much smaller MI_{UV} value and higher grade for GM+UV than those for GM**.**

3 RESULT AND DISSCUSION

When comparing two data sets, the Coefficient of Variation (CV) was used to indicate the agreement in terms of percentage error. The formula of CV is given in Equation (1).

$$CV = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - fy_i)^2}}{\bar{x}} *100, \quad (1)$$

where $f = \frac{\sum_{i=1}^{N}(x_i \cdot y_i)}{\sum_{i=1}^{N}(y_i)^2}$, $\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$;

and x_i and y_i are the ith sample in *x* and *y* datasets and *f* is a scaling factor.

3.1 Spectrophotometer UVI vs. UVX

The reflectance function of each sample measured was transformed to CIELAB coordinates under the conditions of CIE D65 illuminant and 1964 colorimetric observer for the subsequent analysis. The first analysis was carried out to reveal the difference between the CE7000A results under UVI and UVX conditions. It is represented by CIELAB and CIEDE2000[11] colour differences. Table 3 shows the mean CIELAB and CIEDE2000 colour differences. Figures 1 and 2 shows the CIEDE2000 colour differences plotted against the L* and C* values for all pairs, respectively.

Table 3 Colour difference between UV-included (UVI) and UV-excluded (UVX), for CE7000A.

ΔE	HAHNE		HPM	
	ΔE^*_{ab}	ΔE^*_{00}	ΔE^*_{ab}	ΔE^*_{00}
Mean	0.57	0.33	3.00	1.70
Max	1.81	1.87	10.82	8.76

Table 3 shows a large difference between UVI and UVX measuring conditions for the low fluorescent HAHNE samples than that of fluorescent HPM samples, i.e. mean ΔE^*_{ab} of 0.6

and 3.0, respectively. This is expected to have a large impact for fluorescent samples. Figures 1a and 1b show clearly that larger colour differences occur for lighter and less chroma samples, respectively. These colours had less colorants, and thus had less covering power to cover the paper substrate with FWA.

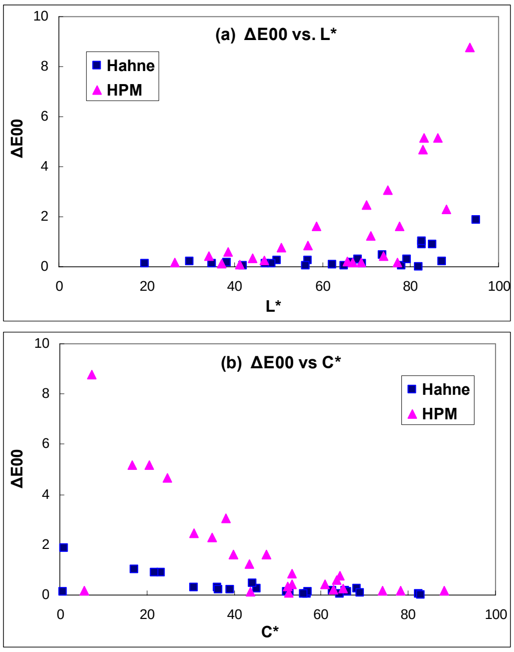


Figure 1 Colour differences(CIEDE2000) between UVI and UVX plotted against sample L*(a) and C*(b). (■-sample on HAHNE, ▲-sample on HPM)

Previous work[7] reported a mean ΔE^*_{ab} of 8.4 with a maximum 12.3 for inkjet-paper. The difference between his and the present study may be caused by different test colours and substrates used. They[7] concluded that the discrepancy of measurement data between UVI and UVX conditions is mainly caused by the combination of influence of substrate fluorescence and the masking effect of halftone target. The lighter colours are less covered by ink, and thus some substrate colour (white) is shown.

The measured reflectance functions were also transformed to CIECAM02 attributes: Lightness (J), Colorfulness (M) and Hue (H). Figures 2a to 2c are the visual results calculated based on CE7000A UVI condition plotted with those of CE7000A UVX condition for J, M and H, respectively. The results showed that most of the data points are located in 45° line (representing perfect agreement. A larger scatter in low colourfulness region (Figure 2b) is caused by samples having low colorants.

3.2 Inter-Instrument Agreement

The second analysis was conducted by comparing the reflectance functions obtained by CE7000A and HunterLab (both under the UVI condition). The performances are given in Table 4. The results showed that a reasonably small difference (mean ΔE^*_{ab} about 1.0) between CE7000A and Hunterlab spectrophotometers and also much difference between two sets of paper group, i.e. mean ΔE^*_{ab} of 1.2 and 1.0 for HAHNE and HPM substrates, respectively.

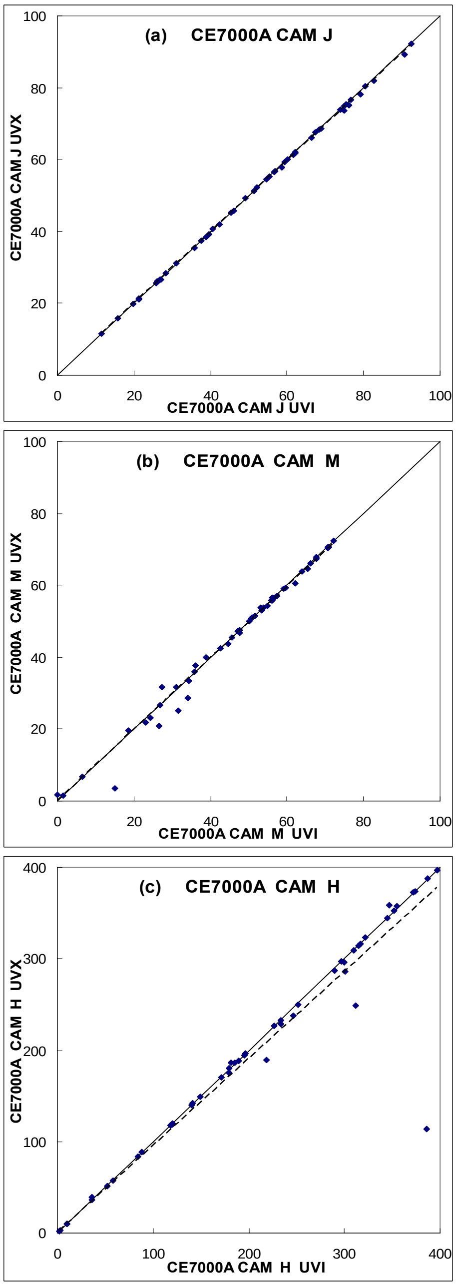


Figure 2 J(a), M(b), H(c) of CE7000A UVX plotted against UVI. (Dash-line: linear fit)

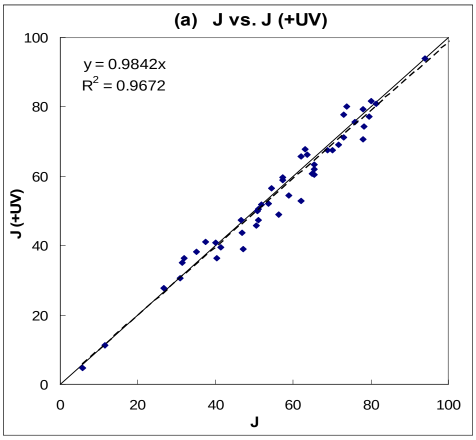
Table 4 Colour differences between results of CE7000A and Huntlab.

ΔE	HAHNE		HPM	
	ΔE^*_{ab}	ΔE^*_{00}	ΔE^*_{ab}	ΔE^*_{00}
Mean	1.16	0.56	1.03	0.42
Max	2.72	1.25	3.10	1.24

3.3 Visual Assessment

Two sets of visual data in terms of mean visual results under light sources of GM and GM+UV were compared here.

Figures 3a and 3b are the plots of the lightness and colourfulness visual results under the two sources. It showed that there is hardly any influence caused by UV for lightness results, while the samples appear to be slightly more colorful under GM+UV than those under GM. The CV value (equation 1) was also calculated to indicate the degree of variation between two datasets. It was found that two sets of results agreed well with each having small CV values of 6, 12 and 4 for lightness, colourfulness and hue, respectively.



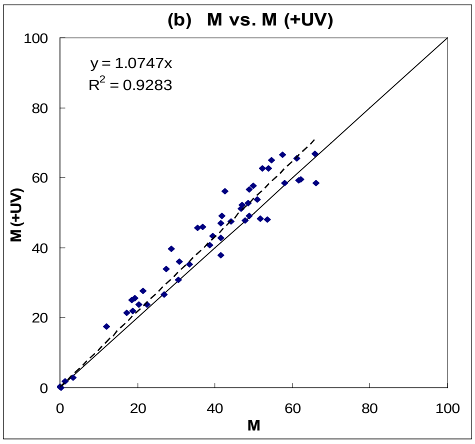


Figure 3 Plots of J and M with additional UV(a) on against UV-off(b). (Dash-line: linear fit)

4 CONCLUSION

The fluorescence had noticeable difference if colours were measured with variation of UV component in the measuring illuminating source. Studied spectrophotometers shown acceptable repeatability but existing variation would be considerable if accurate measurement is oriented. In visual assessment, additional UV component in viewing source did not show significant influence on the result which is possibly because of the insufficient fluorescence content in the testing substrate. Higher fluorescent content and larger difference in measuring source might be utilized in future study.

Experiments were carried out to investigate the impact of colour measurements and visual assessments on samples containing FWA. The results are summarised below:-

- There will be somewhat large differences between UVI and UVX conditions, i.e. about 3.0 ΔE^*_{ab}. The large differences were found for samples having less colorants.
- There will be a reasonable agreement between different modern spectrophotometers, i.e. about 1 ΔE^*_{ab}.
- It is difficult to discriminate the differences in terms of lightness, colourfulness and hue appearance between the two sources used, i.e. GM and GM+UV.

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Gloss effect on colour difference evaluation

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ABSTRACT

An experiment was carried out to reveal the effect of gloss on colour differences evaluation. The samples were prepared by printing inks on three papers with different gloss levels. Sample pairs were visually assessed and instrumentally measured. The results showed a small gloss effect that lightness differences are more noticeable than chromatic differences by about 25% for evaluating higher gloss sample pairs.

Keywords: Colour difference, parametric effect, gloss effect

1 INTRODUCTION

It is well known that the perceived colour difference of a pair of samples could change according to different viewing conditions. Many viewing parameters have been studied including sample separation, background colour, illuminant, luminance level, physical size, colour difference magnitude, texture, and media (surface or self-luminous). Gloss is also an important parameter, especially for the graphic art industry involving different paper substrates with a large variety of gloss. However, the gloss parameter has not been well studied. This experiment was carried out to investigate gloss effect.

2 EXPERIMENTAL

Three groups of samples were prepared by printing colours having same colorants onto three different papers: newspaper (N), and papers with gloss units of 10 (10GU) and 30 (30GU). The sample distribution in CIELAB a*b* plane is plotted in Figure 1. It can be seen that they covered a large range of colour gamut. In general, glossy samples covered a larger area than matte samples. There were 30 pairs of samples in each substrate group, and the colour differences of three groups were similar, close to 4.0 ΔE^*_{ab} units. This ensures the perceived differences between three groups of samples mainly caused by gloss, not by colour difference magnitudes.

The widely used grey-scale psychophysical method[1] as shown in **Figure 2** was adopted. Ten observers with normal colour vision participated the visual assessments twice and were the undergraduate students from the University of Leeds. They had little experience in assessing colour differences and were trained to be familiar with the experimental technique, before commencing the experiment.

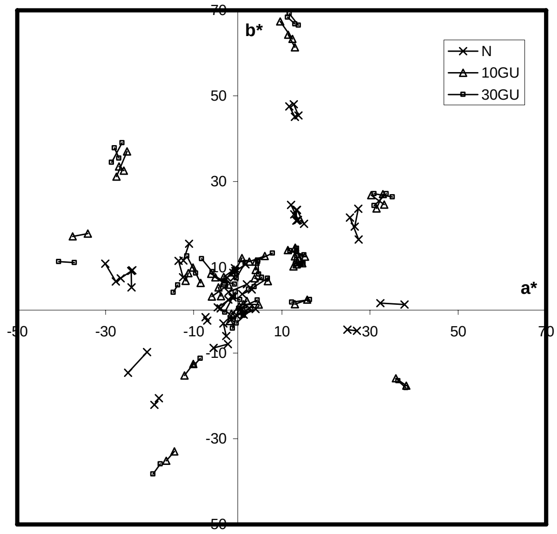

Figure 1 The sample distribution in CIELAB a*b* plane. Vectors represent the colour difference pairs used in the experiment.

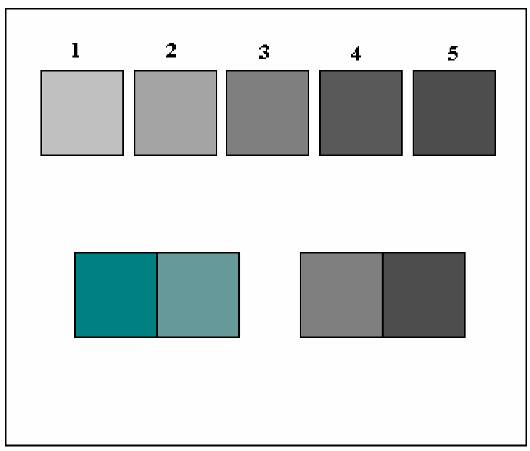

Figure 2 Sample arrangement of the grey scale experiment.

The details of the grey scale method can be found in reference 1. The sample arrangement is illustrated in Figure 2 including a set of matte grey scale samples, a grey pair and a sample pair located on the floor of a viewing cabinet. All samples were illuminated by a D65 simulator. The observer sat in front of the cabinet with an illumination/viewing geometry of 0/45. Each was asked to assess the sample pair by giving a grade from 1 to 5 against the grey pairs formed by the grey scale samples. The reported grades were then converted to visual colour differences, (ΔV), using a 3^{rd}-order polynomial, which was a best fitted equation between visual grades and ΔE^*_{ab} colour differences of the grey scale pairs.

3 RESULTS AND DISCUSSIONS

All the samples were measured using two instruments: an X-Rite spectrophotometer, and a GretagMacbeth CE7000A with specular included (SI) and specular excluded (SE) conditions. They represent different measuring geometries recommended by CIE, *(45^oa: 0^o)*, *(di: 8^o)* and *(de: 8^o)*, respectively. The spectrophotometers were regularly maintained and verified with a set of certificated NPL-CERAM tiles.

3.1 Performance of colour difference formulae

Four colour difference formulae, CIELAB[2], CIE94[3], CMC[4] and CIEDE2000[5] were tested using the current dataset. The latter three formulae were all a modified version from CIELAB. The CIEDE2000 is the recent recommendation by the CIE.

The STRESS[6] in Equation (1), a newly proposed measure of fit, was used to indicate the disagreement between a formula's predictions (ΔE) and visual results (ΔV). For a perfect agreement between two datasets, STRESS should equal to zero, a 10% of STRESS approximates a 10% disagreement between two datasets.

$$STRESS = 100\sqrt{\frac{\sum\left(f\Delta E_i - \Delta V_i\right)^2}{\sum \Delta V_i^2}} \quad (1)$$

with $f = \frac{\sum \Delta E_i \Delta V_i}{\sum \Delta E_i^2}$

The STRESS values of the four colour difference formulae are summarised in Table 1 under the column of 'Original'. The colour differences from the measurements using CE7000A (SI) are plotted against visual results (ΔV) as shown in **Figure 3**(a)-(d). The 'original' formula means that all 3 parametric factors in each formula are set to one, i.e. k_L=k_C=k_H=1.

The STRESS values together with the optimised k_L values (in brackets) for the four colour difference formulae tested using current data are also listed in Table 1. It can be seen in Table 1 .that the measurements using CE7000A (SI) agreed best to the visual differences, followed by those measured by CE7000A (SE), and the X-Rite performing the worst. This implies that it is more accurate to measure glossy samples using a *(di: 8^o)* spectrophotometer than the others for colour quality control.

Table 1 also showed that the best optimised k_L values for gloss substrate datasets are about 25% less than those for the newspaper dataset regardless the formula used. This implies that for assessing high gloss samples, lightness differences are 25% more noticeable than the chromatic differences.

The calculated colour differences of the optimised formulae from the measurements using CE7000A (SI) for four formulae are plotted against visual results (ΔV) as shown in **Figure 4**(a)-(d). It can be seen that there are less scatters from the predictions from the optimised formulae than those from the original formulae as shown in **Figure 3**(a)-(d) respectively. Also, most of the data points for the optimised formulae are closer to those of the corresponding original formulae.

The results also showed that CIE94 performed the best, followed by CIEDE2000, CMC, and CIELAB performing the worst. Note that it is not possible to compare different formulae based on limited pairs of samples in this study.

3.2 Observer uncertainty

Another analysis was carried out to investigate the observer uncertainty, which was calculated using STRESS factor [equation (1)] except that the ΔE_i and ΔV_i were replaced by the individual and mean visual results for pair *i*, also *f* was set to one. The STRESS factors for all observers were then averaged to represent observer uncertainty for each of three substrates. The results are 29.6, 30.0, and 32.7 for N, 10GU, and 30GU substrates, respectively. This implies that gloss levels hardly affect observer uncertainty.

The overall mean value is 31.9. This value is higher than the performances of most of the optimised k_L formulae (see Table 1). This implies that almost of the colour difference formulae tested can give a more accurate prediction than the uncertainty of the visual results obtained from a group of observers.

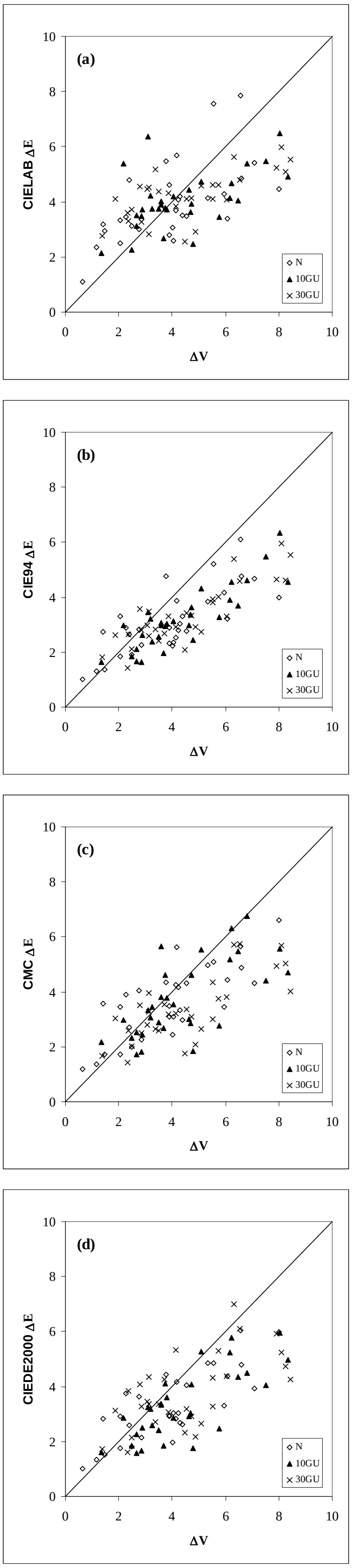

Figure 3 The colour differences from the original (a) CIELAB, (b) CIE94, (c) CMC, and (d) CIEDE2000 plotted against visual results (ΔV).

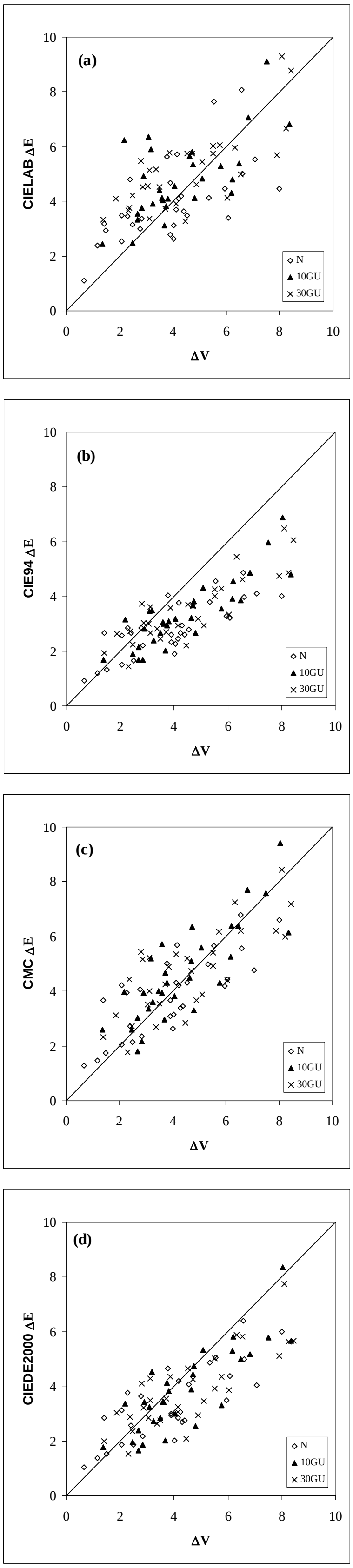

Figure 4 The colour differences from the optimised (a) CIELAB, (b) CIE94, (c) CMC, and (d) CIEDE2000 plotted against visual results (ΔV).

Table 1 Performance of the original and optimised colour difference formulae tested using current data in terms of STRESS.

Spectro	Substrate	CIELAB		CIE94		CMC		CIEDE2000	
		Original	Opt. (k_L)	Original	Opt. (k_L)	Original	Opt. (k_L)	Original	Opt. (k_L)
CE7000A (SE)	N	34.5	34.4(0.9)	28.2	27.4(1.2)	29.9	28.7(0.8)	27.0	26.7(0.9)
	10GU	34.6	29.7(0.6)	21.8	21.7(0.9)	30.5	25.4(0.6)	26.8	24.2(0.7)
	30GU	36.6	30.2(0.5)	25.5	24.6(0.8)	35.2	30.4(0.6)	30.3	27.1(0.7)
CE7000A (SI)	N	33.5	33.5(1.0)	27.4	26.0(1.3)	26.8	26.0(0.8)	25.6	25.5(0.9)
	10GU	32.1	27.1(0.6)	18.9	18.7(0.9)	28.9	21.3(0.6)	25.1	21.4(0.7)
	30GU	30.5	26.4(0.6)	20.9	20.6(0.9)	31.3	25.4(0.6)	26.4	23.3(0.7)
X-Rite	N	38.4	38.4(1.1)	34.6	33.2(1.4)	36.0	35.9(0.9)	35.1	35.1(1.0)
	10GU	41.7	34.6(0.5)	28.6	28.0(0.8)	37.5	35.0(0.7)	33.2	30.6(0.7)
	30GU	38.5	33.5(0.5)	28.4	28.1(0.9)	39.7	37.6(0.7)	32.3	30.5(0.7)

4 CONSLUSIONS

The major findings are summarized below:-

- For assessing the gloss samples having between 10-30 GU, lightness differences are 25% more noticeable than the chromatic differences.
- For typical colour quality control, the instrument having CIE geometry of *(di: 8^o)* performs better than those with the other geometries. However, in practice, 45^o geometries are most widely used for the graphic art industry.
- The current study found not very large gloss effect. This could be due to the limited range of gloss of the samples (less than 30GU) used in the present study.

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Effect of the Chromatic Components on the Whiteness Evaluation of Skin

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ABSTRACT

In general, the whiteness of skin is evaluated using L^* or Munsell Value V obtained by the colorimeter. However, in our experience these indices are not necessarily correspond to the perceived brightness and whiteness. To investigate the factors affecting the whiteness of skin, the whiteness evaluations of the face images and the color patch images were performed. These images were changed to have the various hue and chroma with its original lightness, and were evaluated their whiteness in the experiment (test image). Besides, these images were changed to have the average hue angle and chroma, and were used as the whiteness scale (scale image). Twenty Japanese women were instructed to adjust the lightness of the scale image to have the same whiteness as the test image. The results showed that reddish hue and low chroma increase the perceived whiteness in the evaluation of the face image. But the chroma effect on the whiteness was not so strong, and the hue effect on the whiteness was not observed in the evaluation of the color patch. In conclusion, the perceived whiteness is affected by not only the lightness but the hue and chroma in the face skin color.

Keywords: Skin color, Lightness, Whiteness, Brightness, Face recognition

1 INTRODUCTION

Whiteness and Brightness of skin is one of the most significant element in skin beauty especially for Asian women. In general, L^* or Munsell Value obtained by the colorimeter used for the subjective evaluation of skin whiteness. However, the disagreement between perceived whiteness and measured lightness has been seen frequently in the preliminary experiment. Suzuki and Munakata[1)] reported the redness-yellowness perception was affected by the lightness, however, little research focusing on the whiteness of skin has yet been carried out. We framed the hypothesis that the perceived whiteness of skin color was affected not only by the lightness but also by the chromatic component (hue and chroma). For testing this hypothesis, two experiments were conducted.

First, the skin color of 120 Japanese females were evaluated. Second, to examine the effect of hue and chroma on the whiteness evaluation more closely, a psychophysical experiment was conducted. In this experiment, the face images and the color patch images, whose hue and chroma were changed independently, were used for the whiteness evaluation. The results showed that reddish hue and low chroma color increase the perceived whiteness in the facial skin. But the chroma effect on the whiteness was not so strong, and the hue effect on the whiteness was not observed in the color patch.

In conclusion, the perceived whiteness is affected not only by the lightness but also by the hue, the chroma and the face recognition.

2 EXPERIMENT 1

2.1 Method

To investigate disagreement between perceived brightness and measured lightness in the skin color, brightness evaluation and color measurement were performed. 120 Japanese females (18-60age) were took part in the experiment as the subject. The brightness of lower cheek was evaluated by the 6 cosmetic experts (Japanese) visually, and by measuring the L^*, C^*_{ab}, and h_{ab} in CIELAB with the spectrophotometer CM-1000RH (Konica Minolta Sensing, Tokyo, Japan). The Visual evaluation was performed in the room illuminated by the high color-rendering (Ra=99) fluorescent lamps FL20SN — EDL

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(Toshiba Lighting & Technology, Tokyo, Japan) at the 920 lx (vertical illuminance at the subject's face level). In the visual evaluation, the experts were required to keep the score at 5 levels; 1-dark, 2-slightly dark, 3- standard, 4-, slightly bright, and 5-bright. L^*, C^*_{ab}, and h_{ab} were calculated using the measured spectral reflectance, color-matching functions of the 2° field, and the spectral distribution of the fluorescent lamp used in the visual evaluation.

2.2 Correction of *C*ab*

The CIELAB color space is suitable for our analysis, because L^*, C^*_{ab}, and h_{ab} can be calculated under the various illuminant including the lamp used in the visual evaluation unlike the Munsell color system. However, the contours of constant Munsell Chroma (C) plotted in the a^*b^* plane shows that C^*_{ab} is distorted especially near 5Y compared to C [2)], which is known to agree well with our chroma perception empirically. Due to this distortion, the reddish skin is transformed into the lower C^*_{ab} than yellowish one with same C.

To correct the distortion of C^*_{ab}, 144 Munsell color data in skin color range were transformed to the corresponding colors under the lamp used in the visual evaluation using the CIECAM02. As a result, it is found that C^*_{ab} of the skin color with the same C were varied depending on L^* and h_{ab}. The corrected C^*_{ab}, C_c could be expressed by the following equation.

$$C_c = C^*_{ab} + 0.02L^* + 0.17h_{ab} + 7.89, \quad (1)$$

The viewing condition parameters used in CIECAM02 are; Averaged Surround, L_A = 318 cd/m^2, Y_b = 20. The correlation coefficients between C_c and C is 0.99, and better than that between C^*_{ab} and C, 0.97 in the 120 skin data.

2.3 Results and discussion

Figure 1 shows the relationship between measured L^*, h_{ab} and the evaluated brightness. In Figure 1, the bubble size shows the averaged brightness evaluation value. Fig. 1 shows that the perceived brightness of the skin color depend in large part on the measured L^*, however there seems to be the hue effect on the perceived brightness focusing attention on the narrow L^* range.

To ascertain the hue effect, the data were divided into the 5 categories; L^*:64.0-65.5, 65.5-67.0, 67.0-68.5, 68.5-70.0, 70.0- and the correlation coefficients between h_{ab} and the brightness evaluation value were calculated in each category. The correlation coefficients between C_c and the brightness evaluation value was also calculated in the same way. These results are shown in Table 1 (the data of the category 1 and 3 were not analyzed, because there is not enough data to analyze.).

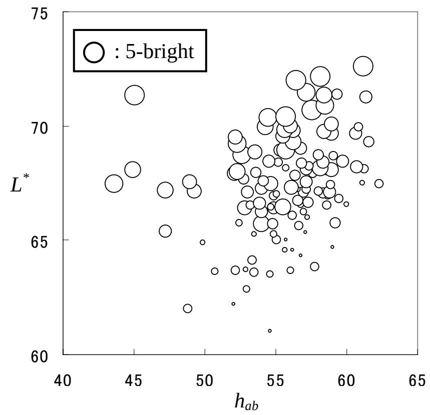

Figure 1 Relationship between measured L^*, h_{ab} and the evaluated brightness. The bubble size shows the averaged brightness evaluation value. The size of explanatory note corresponds the evaluation of "5-bright".

Table 1 Correlation coefficients between CIELAB three attributes and brightness evaluation value.

category	L^* range	correlation coefficients		
		L^*	hab	Cc
2	64.0-65.5	0.31	-0.70	-0.20
4	67.0-68.5	0.03	-0.59	-0.37
5	68.5-70.0	0.00	-0.69	-0.55
6	70.0-	0.16	-0.49	-0.62

The brightness evaluation value shows little correlation with L^*, and strong negative correlation with h_{ab} in the all category. C_c has negative correlation with the brightness evaluation value especially in the high L^* category. From these results, we found that the reddish and low chroma skin color looked brighter than the yellowish and high chroma one with the same lightness. Therefore L^* should be corrected depending on h_{ab}, C_c for matching to the perceived brightness. However the brightness evaluation of the facial skin color has a possibility of being affected with the factors except skin color, e.g. features, wrinkles, and sagging. Therefore the results in this experiment appear not to be the genuine effect of the chromatic component. It is required to use the single face whose h_{ab} and C_c were changed independently as the stimuli.

3 EXPERIMENT 2

3.1 Method

To examine the effect of hue and chroma on the whiteness evaluation more closely, a psychophysical experiment using the displayed image was conducted.

Instead of "brightness", "whiteness" was adopted in this experiment, because it is more suitable for the expression of the skin color change from light to dark, and similar to brightness (correlation coefficient is 0.92).

3.1.1 Stimulus

A face image of young Japanese women and a color patch image were used. The features of the face image were morphed into those of the averaged young Japanese women face, which is made by the morphing of 40 women, so that the effect of features on the evaluation was minimized. These images were displayed with a 20% gray background and a reference white frame having the chromaticity coordinates of CIE supplementary standard illuminant D_{50}.

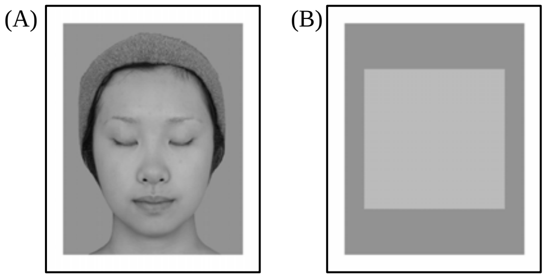

Figure 2 Face image (A) and color patch image (B).

The color change of these images applied to the averaged L^*, C_c, and h_{ab} of skin color area based on the 560 facial skin colors of Japanese women. "Scale images" were made to have L^* = 56-73 at intervals of 1, average h_{ab}, and appropriate C_c for each L^*. These images reproduce the skin color change from dark skin to light skin naturally. "Test images" in the hue-change series were made to have L^* = 60-68 at intervals of 2, h_{ab}, = 45-60 at intervals of 3, and appropriate C_c for each L^*. In the chroma-change series, they were made to have L^* = 60-68 at intervals of 4, h_{ab} = 48-60 at intervals of 6, and appropriate C_c for each L^*, that +2 and that -2. The colors of all images used in the experiment are shown in the Figure 3.

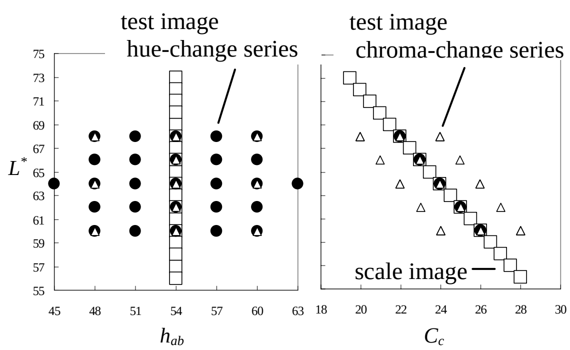

Figure 3 Scale images and test images used in experiment 2, plotted in h_{ab} - L^* and C_c - L^* plane.

3.1.2 procedure

A matching experiment using the method of adjustment was conducted with 20 Japanese women observers having normal color vision. Half the observers were in their 20's and the rest of observer was in their 50's, and they were all naive in the experiment. After they adapted to the darkened room and white point for a minute each, they were instructed to select the scale image having the same whiteness as the test image. L^* of the selected scale image corresponds to the perceived whiteness of the test image.

3.1.3 Apparatus

The stimuli were displayed on the CRT display CDT2141A (TOTOKU Electric, Tokyo, Japan), whose white point was setted to D_{50}. The calibration of the display was made by the spectroradiometer CS-1000 (Konica Minolta Sensing), and was proved to have enough accuracy for our experiment. The observer seated at a distance of 0.60 m from the screen in a darkened room. Figure 4 shows the display arrangement in the experiment 2.

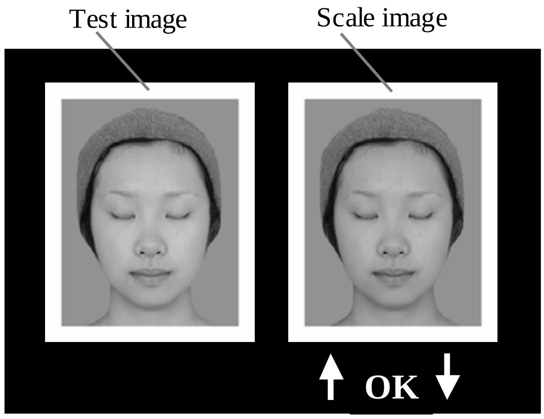

Figure 4 Illustration of the display arrangement. The observer set whiteness match using the up and down arrow buttons.

3.2 Correction of C^*_{ab}

The correction of C^*_{ab} was performed using the corresponding colors under D_{50} by the CIECAM02 in the same way as that in the experiment 1.

3.3 Results and discussion

The L^* of the selected scale image was averaged separately divided into 20's observer and 50's observer. Figure 5 shows the L^* of the selected scale image as a function of h_{ab} in 20's observer for the L^* = 64 image. Figure 6 shows the L^* of the selected scale image as a function of C_c in 20's observer for the L^* = 64 image. It is clear form Fig. 5 and 6 that reddish hue and low chroma color increase the perceived whiteness for the face image, although L^* is fixed, and the hue effect on the perceived whiteness was not confirmed in the color patch image, and the chroma effect on the perceived whiteness in the color patch image was weaker than that in the face image. From these results, the effect of the hue and chroma on the whiteness evaluation of facial skin color was confirmed quantitatively, and these effects depend on the type of stimulus, and they work better for the face image than the color patch image. It was suggested that the face recognition have a some effect on the whiteness perception of the skin color. Additionally, the variation of the scale image L^* by the h_{ab} change within the Japanese women's facial color area is about 2, and that by the C_c change is about 4 in the face image. This results show that the chroma effect on the whiteness evaluation was about double the hue effect for the facial skin color.

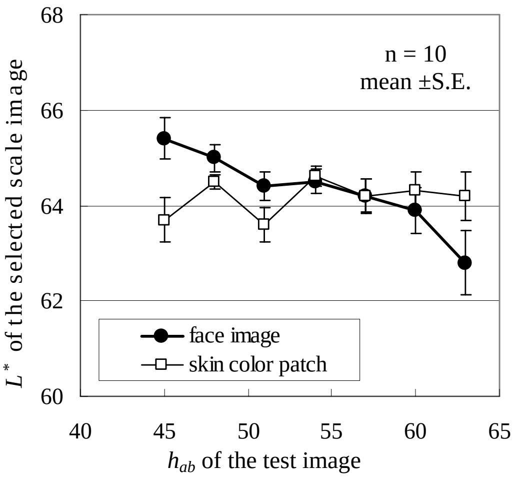

Figure 5 Variation in the L^* of the selected scale image with h_{ab} of the test image (L^* = 64).

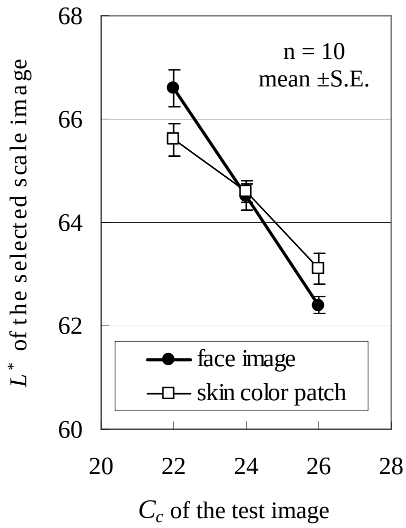

Figure 6 Variation in the L^* of the selected scale image with C_c of the test image (L^* = 64).

In 50's observer, hue effect was not confirmed for the face image, and yellowish hue increases the perceived whiteness for the color patch image unlike the results in 20's observer. There is a possibility that yellow discoloration of lenses by aging raises these results. Considering the results for the color patch image, the results for the face image can be thought to be similar to these in the 20's observer.

4 CONCLUSION

To investigate the factors affecting whiteness evaluation of facial skin psychophysically, The whiteness (or brightness) evaluation of real facial skin, the face image, and color patch image were conducted.

From two experiments, we can conclude that;

(1) Perceived whiteness of facial skin color is affected not only by the lightness but also by the hue and chroma.

(2) Reddish hue and low chroma color increase the perceived whiteness in the facial skin, although L* is fixed.

(3) Hue effect on the perceived whiteness was not confirmed in the color patch.

(4) Chroma effect on the perceived whiteness in the color patch image was weaker than that in the facial skin color.

(5) Chroma effect on the whiteness evaluation was about double the hue effect in the facial skin color.

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Quantitative assessment of perceived gloss and roughness of material surfaces based on two-dimensional luminance distribution data

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ABSTRACT

Color is a major factor that determines appearance of an object surface. The overall appearance of an object surface, however, consists of many other attributes such as gloss, roughness or translucency. This study examined quantitative assessments of perceived gloss and roughness of surfaces of several materials based on two-dimensional luminance distribution data. In the experiment, subjects viewed a surface of the test material and assessed perceptual gloss and roughness of the material using magnitude estimation. We obtained perceptual judgments of the gloss and roughness of the test materials made by 15 subjects. In the analysis, we tried to find physical characteristics of the surface that determine the perceptual appearance of the materials. For the gloss assessment, we assumed that the luminance distribution produced by the test material could be approximated by the addition of the luminance distribution by a specular surface and that by the diffusing surface. The results indicated that the additivity coefficient gave good estimation for the perceived gloss of the materials. Quantitative methods to describe perceived gloss and roughness of a material surface based on luminance distribution data are discussed.

Keywords: gloss, roughness, visual appearance, material surface

1 INTRODUCTION

The appearance of the object surface is composed not only of a color but of visual properties such as gloss, roughness and translucency. Among those visual properties, a color can be quantitatively described using colorimetric values. In addition, the color appearance model which outputs perceptual attributes of a color has been developed. As for the other visual properties, in the research of textiles for example, relations between some features of a surface extracted using an image analysis method and its visual appearance were examined[1-7]. However, the quantitative method has not been established for describing the overall visual appearance of a material surface. The purpose of this study is to examine relations between luminance distribution on a material surface and visual appearance (gloss and roughness) of the surface.

2 METHODS

In the experiment, subjects viewed a surface of a test material and assessed perceptual gloss or roughness of the surface using the magnitude estimation method. The reference material presented aside served as an anchor (gloss or roughness =100) for the appearance judgments. As shown in Figure 1, the material was illuminated by a halogen lamp attached right above it. Also, the angle (θ) of the material surface to the horizontal was changed in seven steps.

We tested twelve materials; sandpaper#40, sandpaper#60, sandpaper#100, sandpaper#280, sandpaper#400, plaster tile, glossy photo paper, mat photo paper, fine quality paper, plastic plate, drawing paper, cardboard. The examples were shown in Figure 2. The test material was covered by a gray (N5.5) board with a square aperture (8 x 8 cm). The subjects viewed the surface of the

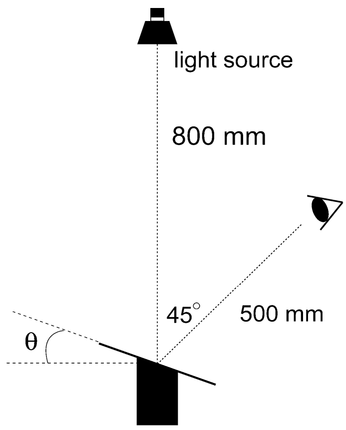

Figure 1 The schematic diagram of the material presentation and viewing.

material through the aperture from the visual distance of 50 cm. The angle θ was set to one of seven angles; 0, 20, 22.5, 27, 45, 80 deg. The specular reflection light was viewed at the angles of 20, 22.5 and 27 deg. In the reference box, a mat photo paper was placed in the same settings as the test material. The angle θ of the reference material was fixed to 22.5 deg.

The subjects were instructed to observe the test material and the reference material and to evaluate perceptual gloss or roughness of the test by giving a numeric score in comparison with those of the reference material (gloss, roughness = 100) Fifteen subjects participated in the experiments.

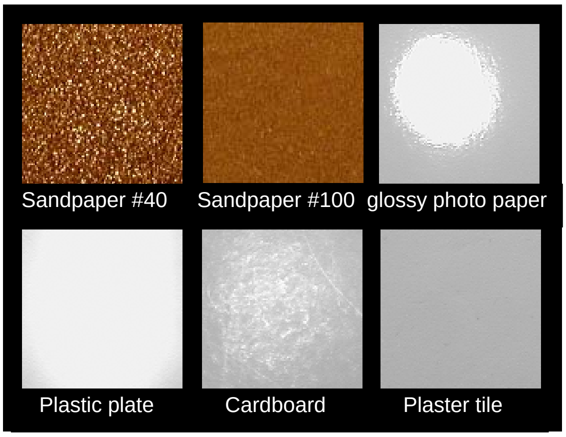

Figure 2 Examples of test materials.

3 RESULTS AND DISCUSSION

3.1 Evaluation of perceptual gloss

Figure 3 shows the typical examples of the results of the gloss evaluation. The median of evaluation scores given by fifteen subjects to the perceptual gloss is plotted against the angle θ for three test materials. Error bars shows 75 and 25 percentile ranges.

The perceptual gloss of the test "plastic plate" and "glossy photo paper" has a peak near 22.5 deg, indicating existence of specular reflections on the test surface has strong influences on judgments of the gloss. The gloss score of the test "plaster tile" was low and did not show significant changes in the angle.

3.2 Evaluation of perceptual roughness

Figure 4 shows the typical example of the results of the roughness evaluation. The median of evaluation scores given by fifteen subjects to the perceptual roughness is plotted against the angle θ for three test materials as in Figure 3.

There are large differences in the perceptual roughness of the test materials. The test "sandpaper #40" was given the highest roughness score and the test "plastic plate" was given the lowest score. The angle did not give strong effects in the roughness judgments.

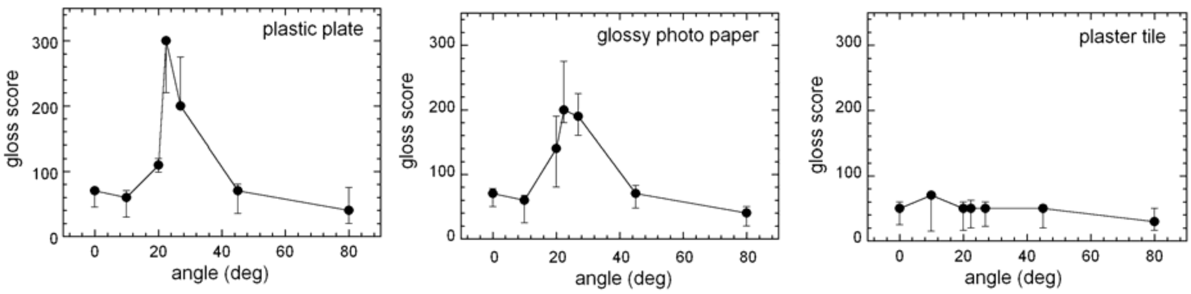

Figure 3 Examples of the results of the gloss evaluation. The median of the evaluation scores given by fifteen subjects to the perceptual gloss is plotted against the angle θ.

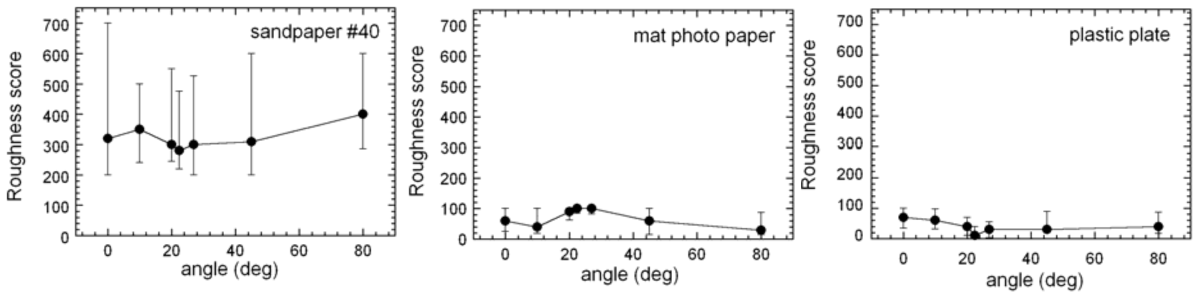

Figure 4 Examples of the results of the roughness evaluation. The median of the evaluation scores given by fifteen subjects to the perceptual roughness is plotted against the angle θ.

3.3 Quantitative index of gloss

Our main concern in this study is to explore characteristics of luminance distribution of the material surface that closely relate to the perceptual gloss and roughness. For this purpose, the two-dimensional luminance distribution of each of all test conditions was measured using a digital camera. Then we obtained an original luminance distribution data for the surface of the test material as a 180 x 180 matrix. In the calculations below, the original luminance distribution was transformed into the 60 x 60 matrix in the gloss evaluation and the 90 x 90 matrix in the roughness evaluation. The size of luminance distribution data was tentative in this stage of our study.

First, we assumed that the luminance distribution produced by a test material could be approximated by the addition of the luminance distribution by a specular surface and that by the diffusing surface.

That is,

$$L_t(x,y) \approx \alpha L_s(x,y) + (1-\alpha) L_d(x,y) \quad (1)$$

$L_t(x,y)$; Luminance distribution of a test material
$L_s(x,y)$; Luminance distribution of a specular surface
$L_d(x,y)$; Luminance distribution of a diffusing surface
α, additivity coefficient
x, y; position on the surface

We employed the luminance distribution produced by a mirror as $L_s(x,y)$ and the luminance distribution produced by a plaster plate as $L_d(x,y)$. The luminance distribution $L_s(x,y)$ produced by a mirror is presented in Figure 5.

Then we considered the residual difference δ between Luminance of the test material and the additive luminance of the specular and diffusing surface. That is,

$$\delta = L_t(x,y) - \{\alpha L_s(x,y) + (1-\alpha) L_d(x,y)\} \quad (2)$$

We computed the optimal α value that gave the minimum residual δ. The larger α indicates that the surface has more specular components of the reflection. Thus we considered that the optimal α value can be an index of the perceptual gloss. The optimal α value is referred as the index of the gloss *G*.

The evaluation scores for the perceptual gloss of the test materials are plotted against the index of gloss *G* in Figure 6 for the angle 0, 20, 22.5 and 80 deg. The index of gloss *G* is strongly correlated to the subject's evaluation of the gloss in 20 and 22.5 deg where he/she could view specular images on the surface of the test materials. The results indicate that the index *G* gives good estimation for the perceived gloss of the materials.

3.4 Quantitative index of roughness

Next, we tried to find the quantitative index of the perceptual roughness. We assumed that perceived roughness was determined by how the material surface fluctuated in luminance. Figure 7 presents an example of the luminance distribution on the test "sandpaper#40". We extracted the fluctuation of luminance as follows.

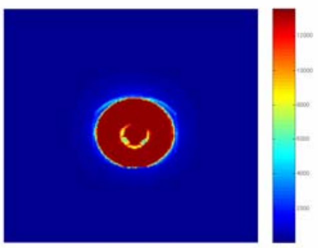

Figure 5 Luminance distribution $L_s(x,y)$ produced by the mirror surface.

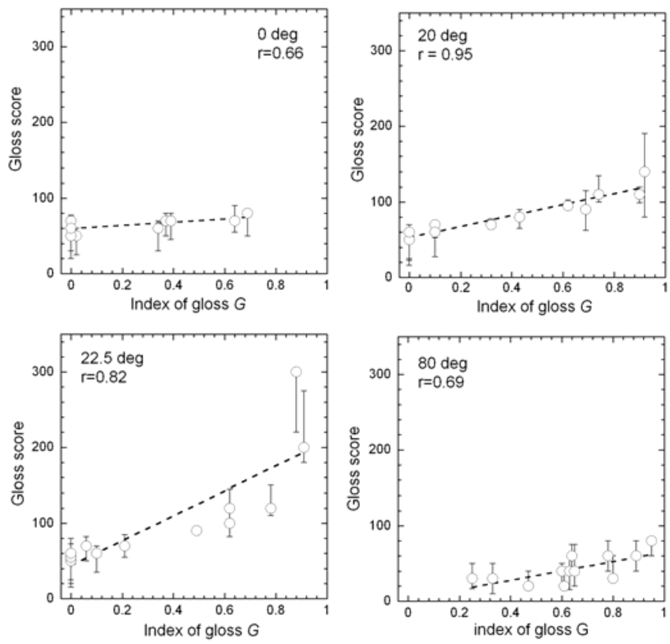

Figure 6 The evaluation scores for the perceptual gloss of the test materials are plotted against the index of gloss *G* for 0, 20, 22.5 and 80 deg.

Figure 8 illustrates the luminance distribution *L* that has fluctuations in luminance. First, we computed smoothing luminance distribution *F* as shown by a broken line in figure. The fluctuations of the luminance distribution were evaluated by computing the difference between *L* and *F*. The smoothing luminance $F(x,y)$ was obtained by applying a spatial filter **M** to the original luminance distribution $L(x,y)$.

$$\mathbf{M} = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \quad (3)$$

The index of the roughness *R* was defined as follows.

$$R = \frac{1}{nm} \sum_{x=1}^{n} \sum_{y=1}^{m} \left| \log_{10} L(x,y) - \log_{10} F(x,y) \right| \quad (4)$$

The evaluation scores for the perceptual gloss of the test materials are plotted against the index of roughness *R* in Figure 9 for the angle 0, 22.5, 45 and 80 deg. The subject's evaluation of the perceptual roughness shows good correlation to the index of the roughness *R*. The results indicate that the index *R* gives good estimation for the perceived roughness of the materials.

There remain many points to be improved in our methods for describing perceptual gloss and roughness using luminance distribution. The basic approach shown in this study, however, must have potentials to realize quantitative description of visual appearance of an object surface.

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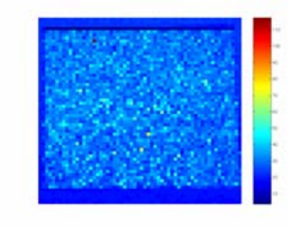

Figure 7 An example of the luminance distribution of the test "sandpaper#40"

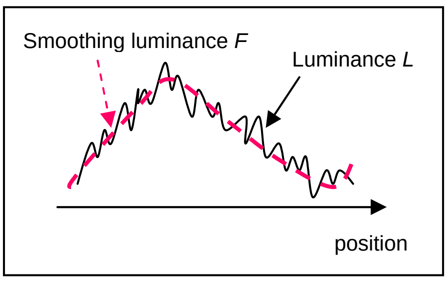

Figure 8 Illustration of the luminance distribution *L* and the smoothing luminance *F*.

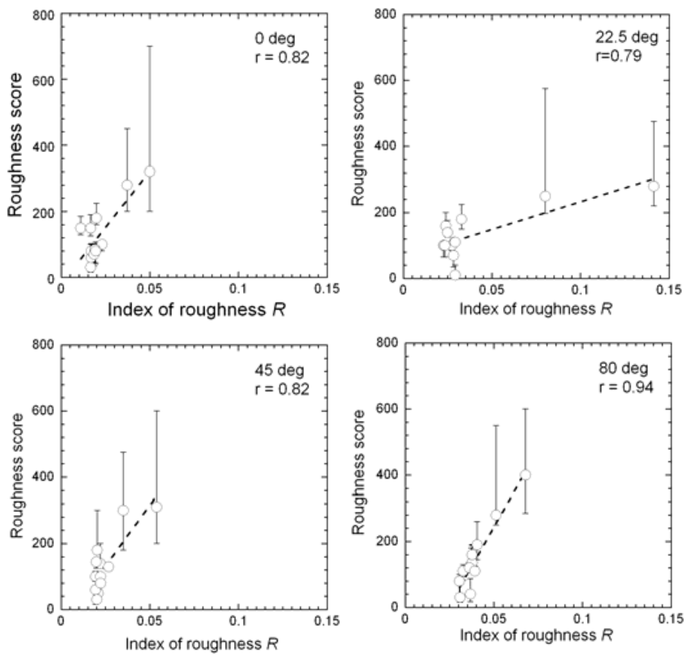

Figure 9 The evaluation scores for the perceptual roughness of the test materials are plotted against the index of roughness *R* for 0, 22.5, 45 and 80 deg.

The use of spectral decomposition theory to improve the performance of Kubelka-Munk two constant spectrophotometric color matching

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ABSTRACT

In the present investigation, attempts were made to color match mass colored polypropylene by the use of spectrophotometric as well as colorimetric color matching methods. Six different colored master-batches of six colored pigments and together with a white master-batch of Titanium dioxide were prepared; Color matching was carried out using five different colorimetric and spectrophotometric techniques by the aid of the Kubelka-Munk two constant theory. The obtained results illustrated that the use of the fundamental color stimulus, generally gave superior results compared to the four other techniques in the color matching of mass colored polypropylene.

Keyword: Kubelka-Munk theory, Mass coloration, Colorimetric color matching, Spectrophotometric color matching, Fundamental color stimulus

1 INTRODUCTION

A wide variety of materials found in daily life contain components that scatter and absorb light. Textiles, printing inks, paints and plastics being obvious examples. The manufacturer can control the color of a material by adjusting the type and the amount of components present. The adjustment can either be carried out empirically, by a skilled colorist based on his past experience or mathematically, by means of numerical methods [1].

There are two major approaches to computer color matching: *the colorimetric approach* and *the spectrophotometric approach* [2-4]. The colorimetric color matching (tristimulus matching) is based on minimizing the CIE tristmulus differences ΔX, ΔY, ΔZ between a target and a predicted match. These matchings are very fast to compute and provide a number of alternate recipes, from which objective choices could be made. Even if a pair of object colors have identical tristmulus values under a particular illuminant (i.e. *D65*), they do not necessarily match under all other possible illuminants. In other words, tristmulus matchings inherently produce color matches which are metameric in nature [2].

Algorithms for such tristimulus matchings are frequently attributed to *Allen* [4]. He showed that, the color matching procedure could be divided in to two parts, a rough matching as a starting point and an iteration to achieve an exact match to any desired degree of accuracy [4]. It is assumed that the reflectance curves of the target and the match are not too far different from each other. With a fair degree of accuracy it can also be assumed that the same is true for the absorption and scattering coefficients. Therefore for a rough match, *Allen* showed that for calculating the concentrations of the colorants by the "Two-constant K-M theory" equation 1 could be used:

$$\mathbf{c} = \left(\mathbf{TE}\left[\mathbf{D}_k \times \Phi_k + \mathbf{D}_s \times \Phi_s\right]\right)^{-1} \times \mathbf{TE}\left\{\mathbf{D}_k[\mathbf{K}^t - \mathbf{K}^s] + \mathbf{D}_s[\mathbf{S}^t - \mathbf{S}^s]\right\} \quad (1)$$

where c is a (3 × 1) matrix of colorant concentration, T is a (3 × *n*) color-matching function matrix, *n* is the total number of wavelengths , E is a (*n* × *n*) diagonal matrix for the illuminant spectral power distribution. D_k and D_s are (*n* × *n*) diagonal matrices for the derivative weighting functions for absorption and scattering respectively. Φ_k and Φ_s are (*n* × 3) matrices of the three colorants' K-M absorption and scattering coefficients, while K and S are (*n* × *1*) matrices of K-M absorption and scattering coefficients.

An exact solution to any desired degree of accuracy may be obtained by an iterative method which starts with a rough solution which is subsequently improved by the use of the same inverted matrix [4].

Δt represents the differences in the tristmulus values between the target and the rough match and Δc refers to the changes in the composition of the rough match needed to reduce Δt to zero. Thence:

$$\Delta\mathbf{t} = \mathbf{B} \times \Delta\mathbf{c} \quad (2)$$

where $\mathbf{B} = \mathbf{TE}[\mathbf{D}_k \times \Phi_k + \mathbf{D}_s \times \Phi_s]$ from which:

$$\Delta\mathbf{c} = (\mathbf{TE}[\mathbf{D}_k \times \Phi_k + \mathbf{D}_s \times \Phi_s])^{-1} \times \Delta\mathbf{t} \quad (3)$$

One limitation to Allen's color matching algorithm is the possible number of used colorants; the degree of freedom for Allen's equations is therefore 3, so only three colorants could be used in the color matching algorithm. The most popular method to solve this problem is known as *the combinational program*, as it tries one combination after another until all possible three combinations of all available colorants are covered. The matching combination of the colorants must have tristimulus values very close to the standard; otherwise the combination is rejected [4].

A completely different approach to increase the number of colorants is making use of a spectrophotometric color matching technique instead of a tristimulus color matching equivalent. As is known, in a normal spectrophotometric method, for a 10 nm wavelength increments throughout the 400-700 nm visible spectrum, 31 equations could available instead of 3; hence the number of colorants could theoretically be increased up to 31. A spectrophotometric color matching algorithm was illustrated by Park and Stearns [5]. A spectrophotometric color matching tries to equalize the remission curves of target and match [6-8] and in this way indirectly produces small color differences. This equalization automatically implies that the color difference would also equal zero, however in practice such a complete equality would only be possible for non metameric matches. Minimizing the weighted least-square fitting (equation 4) of the remission curve is the usual spectrophotometric color matching strategy [2].

$$\sum_i w_i^2 [\Delta R_i]^2 \rightarrow \min \quad (4)$$

Here the weighting function *w* should reflect the changing importance of different wavelengths in visual perceptions. These weights should help to restrict the residual division to those part of the spectrum were their relative influence on color difference would be as small as possible [2].

Most suggested algorithms for spectrophotometric matches are devised for the single constant K-M theory, however limited research has been carried out on non-linear least square fitting of the two constant spectrophotometeric color matching [7, 8]. Furthermore, the practical implications of the algorithms of such limited research are not revealed.

McGinnis [6] states that the spectrophotometric matching is not as successful in diminishing the color difference for a particular illuminant as the colorimetric matching; however it can produce more balanced color difference over several different illuminants. For these reason, the spectrophotometric matches are non metameric (i.e. parameric) in nature.

1.1 Spectrophotometric color matching with Kubelka-Munk two constant theory

For the spectrophotometric match algorithm, ΔR is the difference between the reflectance data for target and match and Δc refers to the changes in composition of the match needed to reduce ΔR to zero. We can write:

$$\Delta\mathbf{R} = \left[\frac{\partial R_i}{\partial c_j} \right] \times \Delta\mathbf{c} \quad (5)$$

The reflectance curves of the target and match are assumed not to be too far different from each other. With a reasonable degree of accuracy we can also assume that the same to be true for the absorption and scattering coefficients, so we can write:

$$\frac{\partial R_i}{\partial c_j} = \left(\frac{\partial R}{\partial K} \right)_i \frac{\partial K_i}{\partial c_j} + \left(\frac{\partial R}{\partial S} \right)_i \frac{\partial S_i}{\partial c_j} \quad (6)$$

Then for all wavelengths, equation 7 arises:

$$\left[\frac{\partial R_i}{\partial c_j} \right] = [\mathbf{D}_k \times \Phi_k + \mathbf{D}_s \times \Phi_s] \quad (7)$$

Appling weighting functions would result in equation 20:

$$\mathbf{w} \times [\mathbf{D}_k \times \Phi_k + \mathbf{D}_s \times \Phi_s] \times \Delta\mathbf{c} = \mathbf{w} \times \Delta\mathbf{R} \quad (8)$$

where w is a ($n \times n$) diagonal matrix of weighting functions. If $\mathbf{P} = \mathbf{w} \times [\mathbf{D}_k \times \Phi_k + \mathbf{D}_s \times \Phi_s]$, with a least-square fitting:

$$\Delta\mathbf{c} = (\mathbf{P}^T\mathbf{P})^{-1} \times \mathbf{P}^T \times \mathbf{w} \times \Delta\mathbf{R} \quad (9)$$

1.2 Spectrophotometric color matching with fundamental color stimulus

Based on the spectral decomposition theory, to minimize the difference between the fundamental color stimulus of target and predicted match, ΔR_{FCS} (i.e. matrixR×ΔR) must be minimized. According to such spectrophotometric color matching algorithm, equation 9 becomes equation 10:

$$\Delta \mathbf{R}_{FCS} = \mathbf{matrixR} \times \left[\frac{\partial R_i}{\partial c_j} \right] \Delta \mathbf{c} \qquad (10)$$

This article explored the ranking of different color matching procedures, and to provide techniques for their improvements. The best technique used to achieve this is the decomposition of the spectral data as proposed by *Cohen and Kappauf* [9, 10].

2 EXPERIMENTAL

2.1 Materials and sample preparation

Six different colored master-batches of six colored pigments and together with a white master-batch of Titanium dioxide were prepared. These were then used to mass color of Polypropylene (PP) V30S (Arak Petrochemical Co., Iran) used as the base polymer.

70 colored samples using different combinations and amounts of colored pigments were prepared (i.e. single, two and three combinational amounts of pigments). The concentration of the white pigment in all samples was kept constant at 0.5% in order to provide sufficient opacity.

2.2 Error estimation

The CIELab76 color difference under D65/10° (Illuminant / Observer combination) between each target and predicted match was determined. A general index of metamerism i.e. MI6 of *Moradian - Rigg* [11], together with a special index of metamerism i.e. maximum CIELab76 color difference (ΔE_{MAX}) under A, C, D65 and F11 were used as an indication of degrees of metamerism.

Since calculated color differences could lead to misinterpretations compared to visual assessments, therefore the performance of color matching methods were also determined by a concentration difference (ΔC) between the actually known and the correspondingly predicted concentrations [12].

2.3 Reflectance Measurement and Coefficient Determination

Reflectance spectra of all samples were measured at 10 nm intervals within 400-700nm on a Gretag Macbeth, Color eye 7000A spectrophotometer having a 2°/d measurement geometry. The average of three measurements was taken to be the reflectance. The reflectances were then converted to the corresponding absorption and scattering coefficients of the K-M two constant theory. The K-M coefficients of each colorant were determined by using of the *Allen's* tint-ladder method [3].

2.4 Practical color matching

The K-M two constant theory was used in all computer color matching techniques. All the tristimulus color matching procedures were carried out for the 1964 CIE standard observer and the D65 standard illuminant combination. The rough match and iteration procedure with CIE 1976 ΔE were carried out in order to rank the best algorithm for color matching. All the possible 3 pigment combinations from the 6 available colored pigments (i.e. 20) were tried in order to calculate possible recipes fore 70 color centers.

Non-weighted, weighted, and fundamental color stimulus matchings were also used in the spectrophotometric color matching approach. **matrixR** was calculated from the spectrophotometric data for the 1964 CIE standard observer and D65 standard illuminant combination. The used weighting functions were recommended by Kuehni [2] and are given in equation 11:

$$w_i = \sum_{A,D65,F11} \left[\left(\bar{x}_i + \bar{y}_i + \bar{z}_i \right) E_i \right]^{1/4} \left[R_i^t \right]^{-2/3} \qquad (11)$$

The performance of each combination was evaluated using the ΔE Lab76. Combinations having positive concentrations and a color difference lower than 0.5 were chosen to evaluate the performance of the color matching procedures.

3 RESULTS AND DISCUSSION

Table 1 illustrate the color gamut of the 70 color centers, illustrating a wide range of color coordinates.

Table 1 The encompassed color gamut for the 70 colored samples

	*L**	*a**	*b**	*C**	*h°*
Min	26.42	-46.62	-39.54	0.79	3.434
Max	93.1	43.82	75.74	76.19	354.97

The average color differences together with average values of the general and special indices of metamerism obtained using different procedures for all 70 colored centers are summarized in figures 1 and 2.

As can be realized from Figure 1, the ranked order of merit for the average ΔE_{D65} is R_{FCS} > 76> Rough Match> Weighted Spectrophotometric> Non Weighted Spectrophotometric. This means that the R_{FCS} procedure shows greater superiority in predicting recipes with an average ΔE_{D65} units less than half of its nearest rival (i.e. iteration 76).

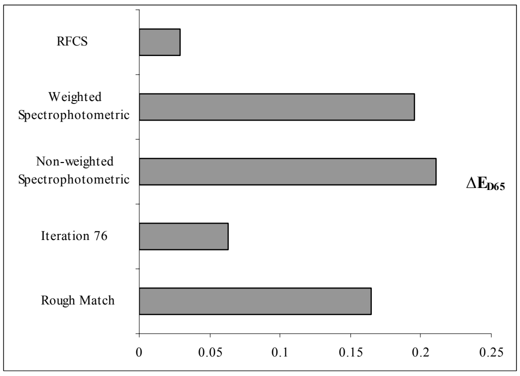

Figure 1 Average color differences obtained using different procedures

It is also evident from figure 2, except for the two constant spectrophotometric matching, the MI6 and ΔE_{MAX} value (indicative of degree of metamerism) for the R_{FCS} procedure is always lower than all other prediction procedure.

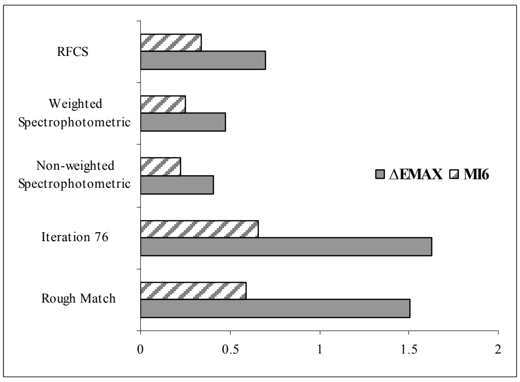

Figure 2 Average values of the general and special metameric index obtained using different procedures

Some may argue that concentration differences are more important than color differences in such match prediction systems. For this reason, the average concentration differences [12] were determined for different procedures where the same pigment combinations were used; the results are shown in figure 3.

Again in all cases R_{FCS} also gives superior predictions in terms of average concentration differences.

Furthermore using R_{FCS} instead of a colorimetric color matching procedure has added advantages of increasing the number of equations and hence the number of colorants (from 3 to 31) usable in the matching operation.

It can therefore be concluded that the use of R_{FCS} gives an all round advantage in color matching procedures.

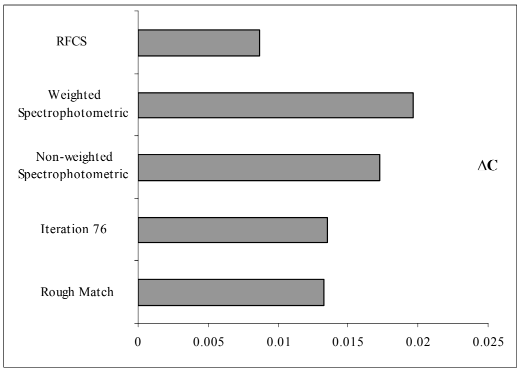

Figure 3 Average ΔC values obtained with comparable recipes

4 CONCLUSION

The aim of the present study was to rank the performance of various procedures for color matching. The ranking showed that the use of spectral decomposition theory greatly improved performance and the following final conclusions could be made:

- The procedure based on R_{FCS} was ranked superior in both ΔE_{76} and ΔC terms in accurately predicting the known concentrations of 70 color centers.
- The R_{FCS} procedure theoretically enables the use of infinite number of colorants in a match if need be.

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Coloured Surfaces – Architecture's Expanded Field: An Inquiry into Colour Application in Switzerland's Contemporary Architecture

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ABSTRACT

Early twentieth-century modern architecture liberated colour from ornamentation, historical styles and representational meanings of the past. 'White' was established as an ideal that perfectly displayed light and shade upon modern architecture's pure volumes. Set in competition to white, all other colours acquired the possibility to play abstract, autonomous roles. Borrowing from fashion and design, postmodernism, however, has acknowledged further – and contradictory – possibilities for colour. Distinctive, saturated colours vividly express the will to seduce and the desire for freedom, wealth, pleasure and luxury. Combined with new aspects of translucent, transparent materials and reflective, glossy or matte surfaces, as well as being enhanced through the use of sophisticated techniques, colour has not only been enabled to change its appearance and effects, but also its semantic, semiotic and cultural meaning. Especially since the mid-1990s the meaning of colour in architecture has been extended through the refined sensibilities of Swiss architects, such as Herzog & de Meuron, Gigon/Guyer, Burkhalter & Sumi, and architecture in Switzerland designed by international architects, such as Jean Nouvel, Frank O. Gehry and Adolf Krischanitz. This impressive development has been underscored by the highly selective eye of contemporary artists working parallel or in collaboration with architects, as well as the emerging consciousness of special clients.

Keywords: Colour in Architecture, Contemporary Architecture in Switzerland, Surface Colour

1 INTRODUCTION

Since the mid-1990s the ways that colour has been employed in architecture – not only by architects working alone, but also in collaboration with artists – have changed so strikingly that one can rightfully claim that a paradigm shift has occurred. Demarcating the surfaces of building facades, saturated, bright, vivid colours arranged in combination with the selective hues of building materials have led to a change of meaning. No longer considered as a feature of underdevelopment, poor conditions, commercialism, exoticism or tourist attraction, the presence of such luminous colours has become the expression of an aim towards pleasure, sensuality, freedom, wealth and luxury.

Under scrutiny here are the ways that colour has become part of the architectural project in Switzerland. Realized buildings of such architects as Herzog & de Meuron (1, 2), Gigon & Guyer (3), Burkhalter & Sumi (4), Marcel Meili and Markus Peter Architects (5), Miller & Maranta (6), Diener & Diener (7), Daniele Marques (8), Devanthéry & Lamunière (9) as well as Arthur Rüegg impart qualities to colour in architecture that were hitherto reserved for other fields, such as in art. Notable here, however, is the fact that many of these colour concepts were conceived in collaboration with artists, such as Rémy Zaugg (10), Adrian Schiess (11), Harald F. Müller, Günther Förg, Helmut Federle (12), Jean Pfaff (13), Pierre-André Ferrand (14) and Jörg Niederberger (15).

In the almost ten years of development of an interdisciplinary approach in developing colour applications in architecture, a main debate has been, 'Should the colour concept be considered as a piece of art to be realized only by the artist or should the artist rather in collaboration with or even simply serve the architect's goals without having any independent input?' The practical result of this line of thinking about the application of colour in association with architecture is represented by such notions as 'art on buildings' or 'art in buildings' (in German, *Kunst am Bau* or *Kunst im Bau* respectively) in which the contribution of the artist is generally decided upon after the conception of the architectural project and judged as an independent piece of art.

This way of understanding the issue, however, suppresses the fact that the architect's own explorations into the properties of materials and further experiments inspired by related fields such as photography, ornamental design, textile industry, haute-couture, new technologies, or nature itself are major components in defining the appearance of architecture and thereby generally instrumental in determining colour. In other words, as expressed by Herzog & de Meuron, 'Architecture cannot be neutral.' (16)

Thus used on the inner and outer surface – architecture's expanded field (17) – colour interacts with many other factors, such as light and the properties of materials. Colour not only defines the surface, but makes it dynamically expressive and responsive, like the skin of the human body, i.e. colour not only establishes the surface of a building as a spatial zone, but extends beyond, like a membrane, as an expansion – or contraction – of the building's periphery.

2 PERHAPS YOU SEE NOTHING

Rémy Zaugg (1943-2005) used vividly painted canvas and walls as a platform for text in which he reflected upon human existence and visual perception. In one work he writes, 'Perhaps you see nothing / but I, I see you / not here.' On the left side of the same painting is written, 'Deadened wiped out muffled withered finished painting / washed out ground down suffocated extinguished smothered / muffled elapsed finished deleted effaced extinct.' His words, like his colours, inevitably not only evoke associations, but affect and challenge individual perception compelling the viewer to enter into an intriguing dialogue with the artist's work, as in James Joyce's mandate, 'Shut your eyes and see!' In the Roche Pharma Research Building (1993-2000) in Basel, the artist worked with architects Jacques Herzog and Pierre de Meuron not only to develop the colour concept for the entire project, but also through an integrated artwork to inquire into thinking about perception itself and qualities of perception, about the city, about architecture, and about painting. For Herzog and de Meuron, a work of art expresses 'creative vitality' and 'perceptual energy' much more than is entailed in the usual mode of perceiving things in daily life. In the Pharma Research Building the architects and artist create an interesting sense of depth at the public side of the building through the play of the glass façade with a blue background wall – with various short texts – extending the entire height of the building. Serving like a second façade as well as painting surface like a canvas, the blue wall establishes the border and threshold space between the public and private areas of the company's field of action. In the words of Herzog, 'It is a little like walking into the tableau.' This shifting of the building's architectonic limits through the extension of the exterior skin beyond the front to within the building expresses a vital and also de-stabilising spatial experience. The space is further articulated by the play between the transparency and colour of the rose glass and the colours of the text and the blue wall. Additionally, the entire space is cast day and night in neon light. The result of the doubling of the façade and the play of colour is irritation and thereby perception is heightened and sharpened through the surprise of difference.

Why did the architects collaborate with the artist to establish a special colour concept and effects? Herzog answers, 'We are believers of professionalism. Ideally, the "professional" for words is a poet. Others simply make technical or technocratic use of language, although some are more gifted than others. The same is true of colour. When an architect selects a colour, he does so according to his own taste. There is nothing worse than such recourse to individual taste. If the choice of a given colour (all colours are marvellous) is not conceptually grounded, what will be missing is forcefulness, precision: all the things that make architecture interesting.'(1)

Another example is the Basel Football Stadium (1996-2002) where red light is used on the interior and is visible from the exterior through the translucent skin. The architects explain the intention for this application of colour as, 'because red prepares the human eye for the more intense perception of the green of the pitch.' The effect of this staging of colour and light is described as to '…see the green of the pitch under floodlights it is a bit like arriving at the opera!'(2) The passage or transition from one space to another, from the exterior to the interior is one of the many 'details' charged to the architects' responsibility. Herzog continues, 'We then asked Rémy to advise us on which red to choose. His answer was, of course, "It depends which green". But in the open air, in the three-dimensional world, there is not just one green, there are a thousand. That was a very interesting experience and in the end we still opted for a red. Even if the effect is not as hallucinatory as I imagined, it is still very powerful.'(1) Because of the capability of colour to surround us fully as we move in it, step out of it, walk through and around it, people are particularly sensitive to colour and the energy that it represents and signifies. Colour, however, is more than an associative atmosphere. As Herzog states in quoting Ad Reinhardt who searched his entire life for the blackest black, it is the extremely physical property of colour that is most fascinating to Herzog & de Meuron.

Yet another way of colouring walls is manifest in another Herzog & de Meuron's project 'Zaugg's Studio' (1995-1996) in Mulhouse (FR). Rainwater runs down the fair-faced concrete walls to seep into the earth. This same principle was used earlier in the Ricola-Europe SA Production and Storage Building (1992-1993), also in Mulhouse, where rainwater runs down over black concrete walls creating a fine film of natural traces and irregular striped configurations.

In a similar way Annette Gigon and Mike Guyer used nature to design patterns on the extension building of the Oskar Reinhart Collection ‘Am Römerholz’ (1998) in Winterthur. The cladding of the new exhibition hall is composed of large, pre-fabricated concrete elements. Limestone and copper powders were mixed into the skylight lanterns and the roof. As they write, 'The combination of limestone and copper powders contributes to quick-acting oxidation and, as such, to a green shift in the colouration of the concrete slabs. As the roof water is enriched by copper ions over time the process of the façade turning even greener will be intensified. By virtue of this accelerated patinisation, the new building will undergo an alchemical adaptation and make a kind of journey through time towards the *genius loci* of the two older, historicizing elements.'(3) Thus applied, colour will slowly appear with time to become more and more intense, which is just the inverse of the typical understanding of paint’s tendency to bleach with age.

3 THE FLOW OF COLOUR

The role and contributions of the artist Adrian Schiess in and to architecture remains ambiguous, complex and contradictory in many different ways. The twofold 'Flat Work' for the entrance area of the Suva House (1992-1993) in Basel was his first work in direct connection with a building designed by Herzog & de Meuron. Two huge panels, one red and the other beige, with a glassy surface achieved via a thin layer of industrial paint are arranged vertically at a small distance from the wall. Not only blending with the walls so that space and colour interact, they also reflect light. Depending on the surrounding conditions, the effect is either to widen or close up the wall and space. Are the colour panels a piece of art or are they architectural elements? Regardless, the twofold 'Flat Work' represents a space-defining screen that expands and contracts like a living membrane.

Used horizontally and even outdoors, this kind of panel serves to reflect sunlight and sky as a mirror of heaven such as in the outdoor water pool at the University of Zurich located above a newly built auditorium (1999-2003) designed by the Swiss architects Annette Gigon and Mike Guyer. Chromatically conceived by Schiess, the water displaces the pink colour from the painted surface to the bottom of the pool. Recalling the kind of saturated and vivid hue of Luis Barragan’s buildings in Mexico, water and light reflections change the pink colour considerably, sometimes even completely annihilating it. In turn, the pink colour changes the colour appearance of the water. Below the auditorium is painted in flashy yellow-green, dark and light pink and light blue. Only the front wall remains white to be solely, but richly painted by the changing reflected coloured light.

In another kind of approach, three layers of airy curtains in different colours and of varying density are arranged just behind the glass wall in the interior of the Ricola Marketing Building in Laufen (1997-1998) by Herzog & de Meuron. Free to move and be arranged, this inner skin not only provides a special light effect, but also the flexible means of accommodating fluctuating individual needs and desires. Seen from the outside, colour transforms the façade into an interactive wall with its own autonomous expression.

The notion of blurring one colour into another is also essential to the colour scheme of the retaining wall along the street of the new extension of the Zurich University. The gradation value of the colour stripes changes from bottom to top from dark to light pink. The pigmented concrete wall creates an unfamiliar atmosphere of non-precisely shaped colour stripes similar to the strokes of watercolor pencils. This blurring of irregular colour stripes to alter the appearance of space and volume was also employed by Devanthéry & Lamunière in the Psychiatric Clinic (1995-2003) in Yverdon-les-Bains as a representation of the ambivalent potential of the state of vagueness or an unfocussed perception of the world. Colour moves with a confusing uncertainty.

The blurring of coloured wall surfaces with direct and reflected light is also manifest in the Sports Centre Davos (1992-1996) by Gigon/Guyer. Combining a few saturated colours with daylight or artificial light at night the corridor could be described as representing a delirium of colour. Not only does light materialise through colour, but colour itself also reveals a strong physical, though ephemeral presence, similar to a situation in which the artist Adrian Schiess worked in 1989 through painting his own face as a changing exhibition to be achieved freshly and differently everyday.

4 RED LIKE BLOOD, WRATH, SHAME, LOVE – COLOURS FOR SCHOOL BUILDINGS

Such is the title of a text by the artist Jörg Niederberger: 'Red like blood, wrath, shame, love – colours for school buildings.' But aren’t these words too powerful to be used in such a connection? Aren’t such colours too powerful to be endured during the whole day? Since 2000 the artist has been conceiving of colour concepts for school buildings and housing. In the Ecole Villa Thérèse in Freiburg (2002), the extension Eichhölzli in Glattfelden, the Regional School in Turgi (2005-2006), as well as the School Building 'Hinter Gärten' in Riehen (2006) saturated colours – flashy greens or blues combined with bright yellows – completely invade the space. How has it happened that colour has been given such a primordial role? How has the clients' point of view been changed to accept artists' proposals for bright, luminous colours? And why? As Heinrich Helfenstein states, '…the gods are smiling kindly on colour's desire for freedom. For years now, colour has been debated and used in architecture with ever-increasing intensity. Moreover, it is apparent just how open-mindedly, non-dogmatically, and perhaps also light-heartedly, people have proceeded in many cases....'(13)

On the other hand, the work of artist Jean Pfaff stands in sharp contrast to that of Niederberger. He does not want to add anything to the building, but rather to reinforce and enhance what is already there. This is the case in Peter Zumthor's 'Sogn Benedetg Chapel' (1985-1988) where people wonder where his colour intervention is. At first you don't notice it. The silvery matt-finish of the interior wall surface gives the daylight a velvet tinge. Thereby the small space acquires a special luminous atmosphere and wideness. Here colour is given the role of a fine membrane, an amplifier or an intensifier. Its impact is almost immaterial. And Helfenstein's assertion, 'Colour and architecture, it seems, have belonged together from the very start,'(13) underscores the simplicity of Pfaff's intervention.

5 CONCLUSION

In fact, isn't the whole debate about 'art on buildings' or 'art in buildings' vs. artists working in collaboration or in the service of architects in vain? Rather the more important consideration is how colour creates, reveals, connects, rejects, contracts or opens up space and volumes by the means of light, materials and its tactile aspects to establish an atmosphere for the viewer.

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Colour as a Communication Device in Urbanism and Architecture: A Case Study of the New Town of La Croix-Bonnet, Bois d'Arcy, France

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ABSTRACT

The oral presentation will feature the case study of La Croix-Bonnet as one of the *Chromatic Studies* of the Atelier France & Michel Cler that best exemplifies how colour can be applied to an urban district or new town. It inquires into the ways and means of using and understanding colour as a communication device as well as the tools of the *Chromatic Chart*. Most important is the notion of *Colour Appearance*, an essential concept in understanding chromatic studies in processes of building and structuring architectural and urban space.

Keywords: Colour in Urban Space and Architecture, Colour Communication, Colour Appearance

1 INTRODUCTION

Underway since 2004, the case study of La Croix-Bonnet is one of the *Chromatic Studies* of the Atelier France & Michel Cler that best exemplifies the way that colour can serve as a means of communication in urbanism, i.e., how colour can be applied to an urban district or a new town.

The creation of the new town La Croix-Bonnet, an extension of the urban fabric of Bois d'Arcy some 20 km from the city of Paris, is part of a new policy of urban renewal of the surroundings of the French metropolitan area. Covering 120 hectares, the site is located in a forest domain. A highway runs alongside the main axis of the industrial area, while a water canal runs across the habitat zone. One of the goals of the *Chromatic Studies* is to take into account these two completely different areas to ensure and coordinate a visual link between them and the surroundings.

2 COLOUR AS A WAY AND MEANS OF COMMUNICATION

The oral presentation will discuss advantages and disadvantages of ways and means of using and understanding colour conceptually as a communication device. The intended addressee is a whole range of professionals involved in urbanism, such as local politicians, developers, urban planners, architects, industrialists, craftsmen and others. As well, the presentation will address topics relevant in informing urban inhabitants and the general public about colour as in exhibitions, newsletters and talks concerning prospective projects and developments.

3 COLOUR TOOLS FOR USE AS A BASIS OF COMMUNICATION

The understanding and practice of colour as a communication device in urbanism and architecture implies a whole range of factors which also includes communicating about colour. Therefore, *Chromatic Studies* applied to urban space is not just an aesthetic issue; it is a mode of research entailing middle- to long-term processes and particular outlooks on colour.

In a first stage *Chromatic Studies* explores the context and the constituent chromatic aspects found on-site as well as the changing light conditions that influence mood and identity of a place.

In a second stage colour findings are orchestrated to form a *Chromatic Chart* which proposes a general chromatic ambiance of the site. As a guideline, the *Chromatic Chart* is integrated into the master plan as an appendix.

In a third stage in accordance with different architectural themes, the chromatic treatment of different sectors is addressed as a significant element in the creation of a higher quality of environmental, urban and habitat space.

Finally, communicating about colour often means to launch and moderate an exchange and discussion about its meanings and properties among diverse addressees, such as local and regional councils and politicians, as well as planners, architects, industrialists, developers, private clients and the general public.

4 COLOUR APPEARANCE

Before communicating about colour it is useful to talk about *Colour Appearance*.

4.1 Materials

Making distinctions between *Colour* and *Colour Appearance* is essential in exploring the chromatic qualities applied to and in urban and architectural space. In effect, it is not the colour of a material that we see, but its colour appearance. Further, the appearance of the material varies according to the treatment of the surface and light and shade conditions. For example, a thick-coating surface can be smooth, scraped, crushed or sprayed; paint can be applied with a matte, satin or glossy finish; and, stone can be *layée*, granulated or polished. In short, depending on its texture, a material will appear to be a different colour. The colour appearance of surface applications also depends on rather uncontrollable factors such as atmospheric humidity or the quantity of water used in the mixture. Colour appearance sets up a determinant range of possible visual results which pre-determine meanings and interpretations. Thereby, colour appearance cannot be simply transferred systematically to another material as colour, but the interaction of the various properties determining colour appearance has to be considered.

4.2 Distance

During both day and night we are surrounded and affected by what we believe to be the inherent colour of various kinds of matter, such as wood, stone, or water. Colour appears, however, only when we are looking at an object that is directly or indirectly in contact with some form of light. Only then can our eyes and brain receive and interpret the electromagnetic wavelengths of the reflected light and thereby sensually and mentally construct the respective colour appearance. In this sense, our perception of colour is based in a world of inescapable illusions. Pigmented matter changes its appearance according to both natural and manmade light. The variables are countless, e.g., natural light depends upon the course of the day, the season and the geographical position relative to the angle of incidence of sunlight. What is then the physically true colour identity of a thing? Colorimetry provides one way of precisely specifying the colour of such an appearance which is rigorously independent of the variations of light and the receptor's way of perception. The Natural Colour System (NCS) provides a second way of specifying colour identity, a system based solely on defining the visual colour appearance. Both ways of defining and identifying colour are useful according to the function and situation in which they are applied.

Some examples will show how drastically colour appearance can change under the influence of light. For instance, looking at two pictures of a church in Stockholm taken on the same day but at different times, i.e., in the morning and in the evening, we ask: Which colour appearance is nearest to the colour of the real building? Another example is that of a mountainous landscape. With increasing distance from the mountains, the colour appearance of their planes becomes less saturated and increasingly shifts to blue. Such an everyday experience is verified with colour samples in a NCS study in which green begins to shift to blue at a distance of several hundred meters.

Another striking example of how distance changes colour appearance is demonstrated by a series of photographs of a village in the M'Zab Valley in southern Algeria. Perfectly adapted to the arid desert environment at a distance of three to four km the colour appearance of the conglomerate of the traditional human habitat becomes less saturated and shifts to white against the golden and reddish ochre mineral landscape with its slightly purplish sky in the background. The closer we approach, the more chromatic differences appear until soft ochre and light blue buildings are visible. From the distance, this broad chromatic diversity had blurred into a light ochre off-white. Therefore, in order to better insert individual architecture into a site, it is important to consider such respective colour shifts of distance in chromatic studies of urban space. The better the chromatic insertion, the greater is the evoked harmony of all elements in space. In fact, such a harmonious colour scheme can actually be conceived by 'borrowing' from the colour appearance of the surrounding distant landscape, a traditional strategy developed and applied by Japanese architects and landscape architects.

4.3 Light and Shadow

As a fundamental condition of colour appearance, light not only enables the reflection of electromagnetic wavelengths, but it also enables the casting of shadows. In accordance with the trajectory of the constantly moving sun or the more stationary animation of artificial light, shade enwraps volumes and projected shadows, situates the more-or-less distorted volumes in space. Shadow belongs to human existence. An Indian story tells of a princess who is able to recognize her beloved among five suitors because of his shadow. As deities, the four pretenders could take on exactly the same human shape as her fiancé, but as gods they could not cast a human shadow.

Although the natural progression of the sun is our primary means of structuring time, the exact movement of the sun is not perceptible to naked eye. Technical aids, such as film, are necessary for such an observation. Still sunrise and sunset are special times of day through which the progression of the sun is nearly always notable. The actual duration of dawn and twilight, however, varies considerably according to the distance of any concrete location from the equator. For example, in the tropics the transition of sunrise from night to day and of sunset from day to night is rapid and appears as a sudden, dramatic change. Here insects mark the transition creating a sonorous space replacing the visual one. On the other hand, in countries near the Poles, such as in northern Scandinavia, the slow, long transition of dawn or twilight can extend over several weeks or even months. Further, in mid-latitudes with their temperate climates, transitions are more perceptible to the eye. There weather conditions can especially influence the duration of dawn or twilight, e.g., clouds can shorten it.

The darkness of night is itself only a big shadow, a kind of regular shade provided by the earth. A world unto itself, night darkness fosters richly ambiguous re-definitions of colours and spaces. Under decreasing light conditions the peak of the vision curve shifts to values of short wavelengths, i.e., to the blue end of the visible spectrum. This means that the sensitivity to longer wavelength colours, such as red, is more-or-less lost. General sensitivity to light, however, is increased as the human eye adapts to the changing level of the light. In more technical terms, the activity of the cones switches to rod activity. Amplified or reduced, blurred or distorted, simplified or submerged in a quilted atmosphere, in the darkness of night volumes, forms, dimensions, as well as colour appearances, are all perceived differently.

Reflected as moonlight, indirect sunlight varies in intensity according to its own trajectory either blurring or sharpening the field of vision. As the night progresses, this light changes from greenish-yellow to greenish-blue.

4.4 Natural and Artificial Light

In both urban and natural micro-sites, the dark ‘sculpture of obscurity’ has been modified by artificial light revealing new spatial and chromatic aspects. Some consider any artificial light cast by cities as a kind of pollution of the ‘virgin’ field of nocturnal space, while others find beauty and purpose in restructuring this same field through artificial light.

For example, at night a whole range of colour appearances can be projected upon the façade of a Romanesque church. Thereby, sculptures can be dressed with symbolic colours, which fade away with the dawn as sunlight emerges to chase away nocturnal phantasms and reveal a façade of bare stone.

As a kind of final frontier, normally de-materialised, fallow nocturnal spaces can be newly cultivated through artificial light. As cyclic movement in regular rhythms or through other durations, coloured light can be used to complete or manipulate the appearances of coloured materials.

4.5 Protection/Seduction

Colour appearances are always deciphered as signs. Yet colour appearances are also always interpreted differently according to the social and cultural nature of the context, as well as personal characteristics and experiences of the interpreter. Some of the resulting meanings are seemingly permanent, while others are more ephemeral.

Scarification, tattoos, face painting or cosmetic make-up are various ways of strengthening or modifying personal and group identity. Thereby, theatrical make-up or the mask is an extreme transposition of the correspondence of colour appearance to cultural context and personal identity. A diversity of individualized characters emerges as the symbolic depiction of standardized and perfected forms and colours. For example, the ‘natural’ face and expression are hidden behind Pierrot’s ‘floured face’, the white mask of the Noh Theatre actor or behind the red, yellow, blue, white, black, purple, green, gold and silver coloured patterns of Peking Opera masks and facial make-up. Another correspondence of colour appearance to cultural context and personal identity is the ornamental patterns of fabrics, a kind of second skin of individuals or communities. This sort of support of colour appearances can be extended to the interior walls of habitats and beyond to exterior facades and architectural volumes.

Such mask or ‘skin’ chromatic appearances serve doubly – and paradoxically – to both protect and seduce. An integral aspect of the life of *homo sapiens* since its origins ‘protection-seduction’ is evident in Carnival’s joyful costumes and masks, which aim to protect the community from the perils of everyday life through rupturing from it and representing or seducing the very evil which threatens it. In contemporary times the military dress and face painting of camouflage is intended to protect through blending in with diverse environments, such as the desert, tropical forest, mountainous or snow landscapes, a dress which is completed by prosthesis, such as infrared artefacts. At the same time, each country produces its own patterns and camouflage identity, so that camouflage becomes the seductive uniform of the national soldier.

4.6 Cities' Colour Identities

In ancient cities, as in new urban developments, colour appearances or the totality of 'light/shadow–material/colour–day/night' are the composite traces representing the quintessence of the way of life of a district as a whole, the representation of the identity of the city itself.

As a chromatic landscape, the atmosphere of any urban space is a process of the on-going construction, de-construction and reconstruction of 'colour appearance/shadow' which is performed through and upon buildings, voids, vegetation, and networks of various systems of activities and events, including those of the city's inhabitants.

Considering the richness and diversity of colour appearances and their ephemeral, as well as semi-permanent and permanent aspects, chromatic studies of any particular context need to be built upon aspects of the geographical environment as well as upon issues related to the cultural context, e.g., such as social memory. Dealing with various environmental concerns in combination with diverse ways of life and cultures requires both openness and a focused approach.

In our contemporary age of globalization, addressing cultural concerns is especially challenging. Certainly the special qualities of unique locations need to be carefully considered. However, often a kind of protective regionalism means that 'tradition' is used to promote formal fetishism, a kind of historic compensation of an individual's or group's view point in a particular time period. Thereby a kind of colour appearance is systematically reconstructed despite its lack of content and evocations. Shouldn't 'tradition' rather be better understood as a more open state of mind, capable of changing and adapting to a diversity of contexts, light conditions, and ways of life?

5 CONCLUSION

Harmony, equilibrium, and sometimes the coherence *a posteriori* of colour appearances, shadows, and materials are an essential part of the chromatic approach. Chromatic consonances are always preferable to voluntary dissonances of appearances. Based on a variety of concerns, including light/shadow and material/colour appearances, the cycle of day/night and natural/artificial light, here the notion of colour appearance evolves like a saga extending in time and engaging the simulations of diverse individuals and groups. In essence, it is useless to de-materialise colour appearance.

5.1 Colour as a Vocabulary for Communication

Colour provides a vocabulary that is adapted to different cultural systems, changing aspects of light, and the effects of specific geographical sites. Colour is subversive because identical colours can stand for opposite meanings. Colour is a *diablerie* or magically diabolic since colour always suggests variety, chaos, and cacophony.

Therefore, using *colour* is mostly related to questions of power, such as in cultural heritage, colour standards, colours associated with national identification, brand colours, colours representing security, etc. Thus identifying and naming colours still remains a delicate thing to do.

5.2 Colour Culture

Communicating about colour is richly ambiguous. Influenced by trends and cultural meanings, *Colour Culture* is always evolving and renewing its ways of expression according to the inhabitants' ways of life and the diversity of meanings attributed to colour. For many years now it is just this understanding and approach to *Colour Culture* which the Atelier France & Michel Cler has defined and developed through the diurnal and nocturnal '*Chromatic Urban Landscape*', as in French '*le paysage chromatique urbain*' *– diurne et nocturne*.

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The contribution of the industrial to the shaped colour

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ABSTRACT

The possibility of making tradition, industry and innovation meet.

Keywords: Natural exploitation, geography of colour, local materials, industrialization and evolution of material uses, supplement qualities of building materials, trends, styles, fashion, design, HQE, cooperation between local and global.

INTRODUCTION

The Art of building, between aesthetic and technical considerations, takes on a multiple character. As an essential component of this art, colour accounts for the innumerable apprehensions of architectural space.

Thus, as the evolution of technology and the change of our way of life go by, the building materials as well as colour have been synthesized.

Their natural exploitation has been reduced by the development of the scientific fields such as physics and chemistry, and the industrialists have little by little globalized the parameters. Then, what are the real impacts of these evolutions on the chromaticity of our architectural environment?

1. LOCAL, GLOBAL, PATRIMONIAL COLOUR

Jean Philippe Lenclos with his geography of colour proposes the following definition: "One can point out, under the term of general palette, architectural chromatics dominants constituted by the colour of the roofs and the walls which usually represent the major part of a construction".

Consequently, according to him, the architecture of a place depends on the local traditions and on the geological and climatic conditions.

These various data affect the aspect of constructions which, in the case of the traditional settlement, depends on local materials. An example among others may inform us on the "local" material practice: at the beginning of the 20th century, the margin between stone-built houses and brick-built houses deviated of a maximum of ten kilometres from the geological limits between hard stone and loose ground, which corresponds to the distance of the reasonable operating range of old cartages. That enables us to understand that the means which were used depended among other things on the means of transport.

Figure 1 Smith guide of the dyer, 1851, files Industry of the Trade and Industry of the town of Amiens (France) - Chromatic Charter of the town of Amiens.

Today the relation between local materials and constructions evolved with the industrialization and evolution of the uses of material.

Nowadays the relation between local materials and constructions has evolved with industrialization and the evolution of the material uses.

The clay of today's brick-makers is transported from all over France in order to offer a richer palette to the customers, hence the evolution of chromaticity.

In addition to that, the colour charts of 20 colours for France standardize the landscapes and make us lose the local approach and the genuine wealth to be found in the secular traditions.

But the industrialists are increasingly sensitive to that and are trying to renew their palettes, expecting them to be richer and richer and original. Painting, contemporary material, is taking an increasing role in particular as far as joinery and walls are concerned. The use in masonry of new building materials, such as cement, fibrocement or air-entrained concrete, requires the application on the walls of a coating able to reinforce their solidity and to mitigate their brittleness, and painting fulfils this purpose, as distemper used to. Beyond aesthetically covering a surface, painting makes it possible to supplement qualities of building materials.

The towns of Europe, while being provided with chromatic charter, a tool of valorisation and management of the urban chromatic inheritance, seek to join again with their last and current identity, their traditions and their stories. These charters, often entrusted to expert colourists, are based on the precise analysis of what constitutes the local colour: material statements, analyses of stratigraphies operated on the oldest walls and indices of a certain practice of the colour (...). In the workshop, the statements are contertyped. It is the crucial point of work, because the colourist, by means of the reduced panels of colours proposed by the industrialists of coating and painting, will have to restore as close as possible, the chromatic integrity of a material. To confine itself with the system NCS, which comprises 1950 colours, is tempting but impossible. It is thus necessary to cross colour indexes (RAL, ACC...) to find the best translation. But the exactitude of the counterpart is unattainable, even useless. It is allocated to industrialists to enrich their colour charts to allow an expression of the colour in agreement with the patrimonial diversity of our cities.

Some industrials like Akzo Nobel for Dinant in Wallonia, lend assistance to the municipalities within the framework of the development of

Figure 2 Chromatic charter of Amiens (France), raised colors using nuancier NCS. Agence Nacarat.

chromatic charters.

Proof that some people try to promote an industrial patronage in favor of the safeguarding of the chromatic inheritance.

2. AN EVOLUTION INSPIRED BY TRENDS

Other parameters of renewal, innovation and research also take part in the creation of trends, in the emergence of styles: the recent marketing of a range of iridescent decorative coatings (terrastyl) by Weber and Broutin is a good testimony. It was directly inspired by the current vogue of the interferential pigments and strass in fashion and design. Will industrialists dare reproduce fashion short cycles transforming architecture a true interface of short-lived life and not of perennial life any longer?

The architects early made handle all the tools with their range. Like visionaries, they are as well able as the dressmaker to aspire and carry the modes. Its the task of the industrials to promote – and supply- innovation.

Who did not notice on architectures of today the myriad of colours which equip from now on certain frontages. Decomplexed of the single colour brought by material, the architects lend themselves to the plays of the colour with complete freedom, handling such as the virtuosos, the art of the chromatic harmonies. Sauerbruch and Hutton, german architects, represent this catch of freedom with regard to material, and do not finish any imagining the coloured skins: kaleidoscopes on the sinuous walls from offices in Cologne, renewable on the frontage of the GSW headquarters of Berlin (camaïeu of red, pink and orange), progressive animation for the federal agency of the environment with Dessau. True colourist architects, the colour is always in the center of their projects. They are, at the side of other architects of the city, actors of one period the aesthetic expression.

3. THE GLOBAL COLOUR REINTRODUCED IN THE LOCAL PRATICE

Last parameter of the renewal - and not the least - the question of the re-appropriation of the global colour in the local environment. Does the contextualisation of the global colour make it a local colour? Let us take the example of the Algerian city of Mzab whose walls gradually adopted industrial paintings by replacing their traditional coatings. There is no denaturation of the landscape. The result was a perfect integration of these colours in the landscape and even a significant evolution of monochrome. How did the inhabitants integrate these new medium inside their chromatic tradition? Does it act as a loss of know-how or as a necessary change of it adapted to our modern world?

The colour emancipation of the knowledge to be made to preserve what is essential for him: its identity value which makes evolve the popular tradition not towards a sullying but to an adaptation necessary in a context of globalization.

The new environmental requirements, illustrated in France in particular by the HQE (High Environnmental Quality), in Europe by diary 21, encourage industrialists to re-examine their globalising logic, to deconstruct it in order to return to local procedures. It is about taking into account idiosyncrasies of each context inside the very principle of industrialization, of production to distribution, of a co-operation between global and local.

The management of energy and optimization and energy is one of the fourteen targets enacted by the HQE (Environmental High Quality). From a point of view of reduction of greenhouse emission, to minimize the use of transport is one of the instructions which also take part to reintroduce the exploitation of local materials (target n°2).

On a building site, it is not any more a question of having its raw material come from the ends of the earth but from the close perimeter. To make his mortar, the mason will rather choose sand resulting from the close river than that of distant sea-beds. One can thus legitimately think that it is a question of a rehabilitation of the local colour in industrial fabric.

Each industrialist's intervention in this type of process must be thought meticulously and in constant collaboration with various experts (colourists, restorers, geographers...), but the result is often reasoned: it is the meeting of two practices, from the local one to the global one and it constantly re-questions about our urban landscapes.

Could we here foresee the possibility of making tradition, industry and innovation meet?

One can think that yes. Indeed another target of the HQE preaches the harmony of the buildings with the vicinity, a good integration in the landscape. It can be a question here of reinsufflated the aesthetic but so identity character of the local colour within the architectural project.

To some extent a direct echo with the environment which will tend to melt the building in the landscape. Traditional of patrimonial, corollary logic of protections of the Historic buildings. But the harmony results just as easily from contrast, as from the moment when this one is controlled. We do not have to make syncretism here any more but rather to build a cohabitation of the heterogeneous ones, who far from pushing back the ones the others will manage to dialogue. In the recent work testifies to the agency Vasconi, the bank center of DEXIA on an old iron and steel pole of Belval, in Luxembourg. To compete with the blast furnaces remained in place on the unused site and classified national monuments, the architects imagined a high tower of 19 stages in the shape of orange district whose profile varies according to the orientation. But more extremely than the form is the colour: a red emblematic, sharp and powerful, with the light "dyed with carmine" reflections which contrasts with the two black and austere silhouettes of completed times. Active red, as an ember aglow, which wants to be rebirth of the site, manifest of the history, without, vestige loss of memory and prestige of a place which joined again with its history. The material colour is a right proportioning between knowing to make and innovation: enamelled steel covers the walls with the building, and brings plasticity, depth and variability to him. A chromatic inconstancy finishes humanizing the work. Proof is thus that the colour is one of the components which contributes to accompany the architectural heritage through the ages, marrying emulously tradition and innovation, thus projecting the urban screen in its future looks.

Figure 3 The bank center of Dexia by Vasconi on an old iron and steel pole of Belval in Luxembourg.

4. COLOUR LIGHT, PROJECTION OF THE TOWN IN THE FUTUR

In our 21st century, new practices of the colour were pushed to test all its physical parameters: to the colour-matter represented by material or the film forming one (painting and coating in any kind), the colour-light increasingly used in the architectural and urban project is added.

The technology of the LED which thanks to its operation in RVB, is able to restore nearly 256 colours, is rightly the new whooping-cough of our makers of industrial towns. Industrials like Philips or Osram (and it list is long) develop these technologies since more than one decade to answer the architectural constraints always more exigent, with the obsession of the innovation and renewing aesthetic and technical. The architects, conscious of the potential of this innovation, work together with the lighting designer to deliver creations which break the field of the colour registered in the shape: the colour-light, like a prism of unreality, likes being opalescent, iridescent, dichroic.

Without light, colour is nothing.

Figure 4 luminous Fresque by François Schuiten for the festival of Lyon Lumière (France), photo E. Bécheras.

At the 20th century, the "electricity fairy" colonized the darkness of our nights by the orange clouds of sodium lightings. Face with the uniformity of the night faces, the practice of the design light, attached at the origin with the performing art and with scenography, gradually the project of town. The colour-light infiltrated "gives day to the night", creates a new space time.Let us remember the film "2001, of the space" by Stanley Kubrick. At the first day of humanity, the black monolith and opaque mark the beginning of the civilization and evolution of the men towards an inescapable progress, four million years later, the individual is lost in unsoundable space times, symbolized by multicoloured lines of lights. The scenarios of coloured lights gradually mixe the walls of our cities. The projects flower everywhere in the world. Material with immaterial, two faces of the city where the colour light wants to be an answer dreamed of the immediate future, but still concretely unimaginable. To project the city in all the sens of the term.

The project of the agency a Studio and Rogier Van der Heide, the store Galleria West of Seoul is an example among many others. At the beginning an inert, mineral concrete block and without attraction, the wish expressed by the direction is to regenerate the envelope to renovate its public image. The team in load of the project proposes "a perforated skin" of 4330 discs. These transparent discs on the iridescent surface, containing a dichroic film, react to the natural light the day, creating soft coloured variations; the night, on the other hand, a genuine screen of pixels of colour transfigures the frontage. Each disc is ordered individually by a data-processing program, transmission wifi, and can generate more than 16 million colours. Then open infinite possibilities of coloured scenarios.

The light becomes genuine material of architecture, transfers the static form in dynamics, from perennial to ephemera. The ephemera of a bullfighter's costume which metamorphoses the frontage in true interface of the air of time, exceeds the tendency like embracing the one day eternity.

CONCLUSION

The relation which maintains industries with our environment is relatively complex and wider than a simple use or not of the industrial products in architecture. Between development and obligation, industry is dual because it multiplies its ranges and its aspects of completions and ceases testing new materials to distribute often only one negligible part of it. It would thus act that the industrialists are based on the expertise of the makers of city and the specialists in the colour and material so that expresses all the aesthetic and technological potential resulting from the research and the development.

Figure 5 Set in light of the Hôtel dieu in Lyon (France), photo E. Bécheras.

The Development of Color in Roof in Ancient China

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ABSTRACT

The roof in ancient Chinese building is slop roof. Therefore, roof color is very important in chromatic townscape. In earlier time, the colors in roofs were all Qing (a color of dark blue mixed black). Nevertheless, with the development of technique in tiles making, tiles color was becoming more colorful.

However, the color usage in architecture in ancient China is regulated according to hierarchy and the theory of five colors and five essences. Even there were a lot of color tiles, only very few colors were used in emperors' and temples' roof. Those regulations and laws make the characters of roof colors in different zones outstanding and legible.

With related laws and documentations, as well as the theory of five colors and five essences, this paper is going to research on the characters of the scape of roof colors in zones in different period, to draw out the turning points and reasons of roof color changes in crucial periods.

Keywords: roof color, technique, regulations and laws, five colors and five essences

1 INTRODUCTION

Roof in China had tile, grass, clay, wood and stone. In Eolithic time, grass was commonly used. Tile hadn't been invented till Shang dynasty. Even tile had been made from clay, copper, iron, wood and bamboo etc. but clay ones were used broadly through the Chinese history. Colored glaze tiles were also made from clay first and decorated with lead oxide, ferric oxide, copper oxide, powder blue and manganese oxide etc. then bake again after adding quartz follows the first burn[1].

Chinese ancient roof mostly were composed of surface, fastigium, eaves and ornaments like animals. As fastigium, eaves and ornaments occupyed small proportion and the roof color was usually decided by the materials of roof surface which were usually common black tiles (usually called Qing tile) and colored glaze tiles, this paper will discuss on that mainly.

The history of roof color development can be assorted into three phases.

Tile's invention and application: from Shang dynasty to Liang Han;

Colored glaze tile's appeared and developed: from North Wei to Yuan dynasty;

Under restrict hierarchy: Ming and Qing dynasty. Documentation shows that the colored glaze enriched greatly with the development of technique.

As a result, this paper point out that the roof color in ancient China was affected by three elements of technique, hierarchy, and philosophy. Especially that of hierarchy and philosophy formed the color sections in the capital cities which might be regarded as the earliest urban color plan in China.

2 THE DEVELOPMENT OF COLOR IN ROOF

2.1 The first phase: tile's invention and application — from Shang to Liang Han

The earliest tiles were found in 2000 in Shang dynasty (1600 BC—1046 BC) site with grey pottery material (here grey might not be pure grey but mixed with some other colors), lying on the roof and around the foundation of columniation of the palace to protect from moisture[2].

Tiles in Western Zhou dynasty (1046 BC — 771 BC) can be assorted into early, middle and later stages. With the temperature from lower in early to higher in later, the color changes from brown to dark grey[3] (might be called Qing-grey).

There had another kind of semicircle tiles called Wa-dang put in front of eaves to hold on the roof tiles. Wa-dang is Qing-grey (grey mixed with black and blue) with red color on the surface to decorate which is inherited by Qing and Han dynasty[4]

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After that, the technique of tiles making basically followed that invented in Western Zhou dynasty. In Han dynasty (206 BC — 220 BC), with the mature of technique, tile was broadly used with color fixed in Qing-grey. This technique for common tiles lasts till now. As color Qing is always used to identify lower class, common people's construction can only use that even the colored glaze tiles invented.

2.2 The second phase: colored glaze tile's appeared and developed — from North Wei to Yuan dynasty

A small quantity of colored glaze pearls and other decorations were founded in Shang and Zhou dynasty, but it was not used for roof until in North Wei[5] (4 AD).

South dynasty (420 — 581) has a stable social environment absorbing greatly the technique brought by the people from North which forms the foundation for colored glaze used for building. As it is still precious, the colored glaze is only used in ornaments on roof with yellow and green only[6].

However, in the later part of South dynasty, the technique of colored glaze was disturbed by wars. Until 581 AD, that the emperor of Sui dynasty who unified China promoted the economy. Architect He-chou got back and developed the colored glaze technique[7].

Tang dynasty (618—907) is a golden era for colored glaze technique development. There had one kind of tile with three-colors of yellow, green and blue merged in one piece might from the inspiration of Tang san-cai[8] (colored glaze animal ornament with three colors or more in one piece). In later part of Tang dynasty, Qing (green mixed with blue) tiles prevailed followed by Gan (dark Qing mixed with light red) colored glaze tiles[9]. Colored glaze tiles were used in palace and temple roofs. In most case, colored glaze tiles were decorated at the margin of the roof with common tiles in the middle which called "Jian-bian".

As the emperor Zhengzong in Song dynasty (997 — 1022) adored Taoism[10] and also the color yellow stays in the middle of Chinese five color and five essence theory, a great amount of yellow colored glaze tiles were used in the palace roofs[11]. The type of tiles in Song dynasty had three of common tile with Qing and grey, Qing-kun tile with black and colored glaze tiles of white and light yellow.

The colored glaze tiles were abuse used in Yuan dynasty (1206-1367). White colored glaze tiles had been used in Song dynasty but also adopted in Yuan as it looked like Mongolia abode[12]. Further more, white roof was decorated with Qing green in the margin[13]. The colored glaze tiles had yellow, green, blue, white, red, reddish brown, brown, and soy sauce brown colors.

Yellow was also broadly used to exhibit luxuriance and affected by Song dynasty. Other buildings can also apply colored glaze tiles besides palace[14]. There had few regulations on roof color in Yuan dynasty showing the broad manner and culture mixed with many folks.

2.3 The third phase: under restrict hierarchy — Ming and Qing dynasty

In the beginning of Ming dynasty (1368 – 1644), there had a series of methods of promoting economy. The architectural technique got a great progress in South and North. Colored glaze technique had surpassed those before. The colors in colored glaze tiles in Ming dynasty were more abundance than that in Yuan dynasty with yellow, purple, reddish brown, soy sauce color, brown, green, black, blue, Da-Qing (dark Qing)，white, peacock blue, peacock green, etc. But the color usage in roof is rigidly regulated as the authority thought that because of lack of related regulations on colored roofs caused they were abusively used resulting in social chaos in Yuan dynasty. Therefore, in Ming dynasty, the colored glaze tiles could only be used in palace, emperor's gardens, emperor's mausoleum, temples and infante mansion etc. Official and common people had no right of applying that. The color ranking can be assorted from higher to lower: pure yellow — yellow in the middle with green decorated in the margin or green in the middle with yellow in the margin—pure green—black or common Qing tiles in the middle with green decorated in the margin—black—other colors[15]. Infante palaces and city gate building use green, black or common tiles in middle and green in the margin. Empress or Ranis' building can use green or black colored glaze in the roof[16]. But colored glaze tiles were forbidden to common people.

The Kangxi era (1661-1772) and Qianlong era (1735-1795) in Qing dynasty (1644-1911) had stable in social environment and boom in economy. The technique for colored glaze making enhanced greatly. The color in colored glaze tiles arrived the peak of Chinese history which had sky-Qing, peach-red, cochineal, gem blue, autumn yellow, plum red, milk white, light yellow and crystal color etc. And the flourishing of emperors' gardens promoted the color expansion in colored glaze tiles. But Qing still has restricted regulations like Ming. Yellow is the most honor used for the roofs of emperor's palace and temples; green is the second used for that of infante palace as it symbols pullulating of East. Blue symbols heaven used for Sky altar. Black, purple and red is always used for palace in suburb[17].

3 ANALYSIS

We can be aware that the ancient roof color is restricted by three elements under specific social background: (1) tiles making technique especially that of colored glaze techniques; (2) hierarchy, different color for different rank; (3) the philosophy of *five colors and five essences*.

3.1 tiles making technic

3.1.1 Common tiles

Common tiles in the early time in West Zhou dynasty showed in brown, yellow brown, grey brown, yellow grey and some in light grey white as the clay is rough, embryo is massiness, temperature for bake is lower.

In the middle time of West Zhou dynasty, as tiles were made from rough clay, had more flimsy embryo than that of early time and higher temperature in baking, tiles were in grey brown, yellow brown, black brown and mostly grey. The technique in tile making in the later time of West Zhou was more advanced. Still with rough clay, but more flimsy and higher in temperature, the character was hard and lasting in Qing-grey[18] which is still used in today.

3.1.2 Colored glaze tiles

As colored glaze tiles has the character of smooth surface for water flowing and lower ratio of absorbing water makes it avoids aggrandizing the weight of roof and keeps the stability, it is important for great buildings like palace[19].

The superior in colored glaze tiles technique in Han dynasty than that of Western Zhou is to change alumina to lead oxide. The colorant mainly includes ferric oxide, copper oxide, manganese oxide and powder blue ect. The value varies according to the quantity of lead. This technology have used thousands years[20].

Before Yuan dynasty, the colored glaze tiles embryo were brick red made from pottery clay or pastern clay. But in Yuan, Ming and Qing dynasty, the embryo were milk white as it was made from an ore called “Gan-zi clay” from “Liu-li Qu”village in western Beijing which could get vivid color and quality for the final effect[21]. Qing dynasty inherited the technique of Ming but has more scientific technique in making procedure[22] in documentation.

3.2 Five essence and five colors

“Five essences and five colors” is the origin of Chinese traditional color culture. “Five essences” which means “wood”, “fire”, “water”, “gold”, “earth” emphasis unity and variability, reflects the movement and change of word through forces among five essences.

Early in Zhou dynasty, the character about “Five essences” appeared. Zhou manner says “painting includes five color: eastern means Qing (blue or black), southern means Chi(red or light red), western means Bai(white), North means Hei(black), heaven means Xuan(purple), earth means Huang(yellow).”

The “Five essences and five colors” circle formed according to the negative & positive five essences theory puts yellow in the middle, and circles according to the order of Qing, Chi, White and Black which correspond east, west, south and noth accordingly. The five colors are regarded as “pure colors” while “compound colors” are the mixture of adjacent colors. The theory of “pure color” and “compound color” has great meaning in Chinese color culture and regulates the color usage for about three thousands years.

As the secondary colors are the result of the denying of “five essences” to each other, they are regarded as sinisterly. Therefore, colors in roof for palaces mostly are pure colors like yellow, green. However, many color still used for roof for the reason of technique and idea transition. For example, purple is adored as Qi hen-gong of the pre-Qin dynasty likes purple very much and Qi people dress in purple consequently[23].

But still the five pure color broadly used.

3.3 color and hierarchy

3.3.1 Yellow

Yellow is the color for emperor that locates in the heart of five colors, controlling the other directions; symbolizes the centralization of power; and shows the adoration to earth. It is only used in emperors’ roof or temple.

3.3.2 Qing

Qing is the beginning of growing. Therefore, Qing symbols the firstborn plant. Qing is a light blue color, and also used for blue, dark green or black, grass color, grey white color, water color and jade color etc. Qing roofs are usually for princes for growing.

3.3.3 Chi

Chi is the color of South, fire, heart, sun. Later, it has the same meaning with Zhu. Zhu is a noble color which mostly used in the palace wall and gate, or in the noble gate if get the emperor’s permission. Might for the reason of contrast, it is not commonly used in roof but only for some recreation place garden.

3.3.4 White

In China, white is the color of west, symbols the meaning of bereavement; refers to the color of snow in winter and symbols a cleanly personal integrity. White is broadly used in Yuan dynasty as for the Mongolian preference.

3.3.5 Black

Black is the color of north and heaven. In daily life, black is usually used to refer to lower class. Qian is also has the meaning of black. In the 26th year of Qin dynasty, the emperor named common people Qian head, holding that common people wrap head with black cloth[24].

Black is broadly used in roof and the common people can use only black common tiles.

4 CONCLUSION

It is obviously that the compulsive regulations from authorities base on the" *five essences and five colors*" and hierarchy prevent not only the applying broadly the colored roofs, but also the forming color character in roofs under different geographical or psychological conditions in the whole country. But those superincumbent regulations formed different color area of colored palace area and grey-black civilian's in capital city. Chromatic and achromatic contrast each other to stand out the inner city, especially the golden axes.

And other places in the country, the yellow roof can only be used in the temple; Confucian temple which is the memorial temple for Confucius is specially favored by emperor could use yellow, but other roofs had no such right.

This might could be regarded as the earliest roof color plan in China.

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An Examination of Japanese Color at Nikko Toshogu Shrines

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ABSTRACT

Nikko Toshogu shrines are registered on UNESCO's World Heritage list and typify the Japanese architecture of temples and shrines. There are two types of color in Japan. One is "color in the sunlight"; the other is the "color under the moonlight". Nikko colors typify "color in the sunlight". Such color tone is vivid and brilliant. The other type of color is sometimes called "Wabi and Sabi" in Japan. These are low-keyed and calm colors. Nikko's color is represented by Gokusaishiki and golden coloring. Gokusaishiki is the assemblage of three or four pure colors, which gives us a strong impression. Most golden colorings are made from gold leaves and Japanese lacquer. Yomeimon is the most famous gate in Toshogu and it is decorated by Gokusaishiki and gold. This paper examines the use of Japanese color in Nikko's shrines.

Keywords: Nikko Toshogu Shrines, Gokusaishiki, Golden coloring, Color in sunlight

1 INTRODUCTION

Nikko Toshogu shrines are located in the northwestern part of Tochigi Prefecture, Japan. They were built by the second Shogun Hidetada to enshrine the first Tokugawa Shogun Ieyasu in 1617. Today's main shrines were rebuilt by the third Shogun Iemitsu in 1636. Eight of them were designated as national treasures. Yomeimon is the main gate to the main shrine, and typifies Nikko's architecture and color. "Higurashi no mon" is the nickname for Yomeimon because if you had been watching them through the day, you would never be tired of the decorations. In its day, it served as a symbol of the power and authority of the Tokugawa shogunate. I propose that Japanese color be divided into two groups[1]. One is "color in the sunlight": colorful, lively, and brilliant. The other is the "color under the moonlight": low-keyed color and traditional, also known as "Wabi and Sabi" in Japan.

2 NATURE AND ZEN

We can't talk about Japanese color without talking about nature in Japan. Japanese color tones are related to the nature of Japan. Japan is located in the Far East and is a long island from north to south. There are a lot of mountains, lakes, and saw-toothed coastlines formed by volcanic activity. Having four clear seasons is one of the main factors in making such a beautiful environment. The change in the season brings lovely weather all year around. It has every kind of sky: warm and cold, dry and humid every season. That helps plants to grow. As a result, there are lots of trees, from coniferous to hardwood. We have beautiful four seasons and country.

Thinking of this color from another viewpoint, it seems to have been influenced by Zen. Zen is a kind of Buddhism, and one of the most important traditional Japanese cultures. Zen hasn't any shape, so we can't see it. It is the problem in our mind[2]; this is to say the problem of a sense of beauty. To make the colors of Japan, we need a sense of beauty, and then the sense of beauty is influenced by Zen. So Zen is very important for our sense of beauty. Zen is mental, so we can see the mind of Zen such as style of Sukiya. Sukiya, a house for Tea Ceremony, is simple, gracious architecture with a garden in a quiet color. Both the garden and the house are low-keyed, like Zen as a whole.

But in Japanese Shinto, there was animism, a type of nature worship, Buddhism temples changed to Shinto shrines. It seems these give powerful influence to color tones. Many objects of religion had been represented by vivid color and gold. Hoodo of Byodoin temple in Kyoto is a famous example. The inside of the Hoodo is

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painted in colorful coloration and represents paradise where the Buddha lives. The image of Buddha in the temple is painted by gold and Hitens are glorious. Colorfulness and gold have gorgeousness and vividness, and those stay in the mind as venerable color. It seems to be the opposite pole to "Wabi and Sabi".

Nature and four seasons constitute the base of the beauty of Japan and the foundations of color. The color is divided into two parts: that is the color in the sunlight and color under the moonlight in Japan. The color in the sunlight istypified in Nikko(Figure1), and the color under the moonlight is typified in Katsura Imperial Villa(Figure2) in Kyoto. These are opposite ways of thinking, but both describe color in Japan. Yomeimon represents individual architecture of Nikko. The color in the sunlight is researched by the color of Yomeimon.

Figure 1 Yomeimon, that means the sun gate and main entrance to the main shrine which enshrines the first Shogun Tokugawa Ieyasu. This gate was built by third Shogun Iemitsu in 1636.

Figure 2 Katsura Imperial Villa was applauded by a famous architect Bruno Taut. And he said "So beautiful that I feel like crying". The Villa was built by Prince Toshihito and Prince Toshitada in 17th century.

3 YOMEIMON

Yomeimon means brilliant sun gate. At Yomeimon there is a typical example of coloring, and has colorful features containing golden coloring. When we see Yomeimon for the first time, we are shocked by the gold and the vivid color. The brilliant gate suggests the entrance for a special place, imaged in Japanese lacquer and gold looks more beautiful in contrast. Gold color is defined as "yellow color with metallic polish". Yellow is the most high luminosity color in chromatic color. But coloring can't be represented by the definition. At Yomeimon, there is a big difference in the brightness between the gold and black (the most low luminosity color) of black Japanese lacquer. If gold was reflected in the sunlight, it is shining brilliantly. And we believe in the reality of god. Nikko is the place where Tokugawa Ieyasu was enshrined as a god "Toshodaigongen" (sunlight great god), and Yomeimon is an important gate put the god's name in it. This gate is built toward south. As south side is imaged the rising sun and sunshine of the daylight; when we visited Nikko and looked up at Yomeimon in the afternoon one cold winter day, we feel warmth and thankfulness by the grace of god. The warmth and thankfulness were given to us by a sun-god that is named "Toshodaigongen". And then people recall the prestige of Tokugawa Ieyasu. Thus golden coloring represents not only the beauty of this place, but also the existence of the god's mysterious power. It gives multiple effects, and that intensifies the beauty of the place.

The upper part of Yomeimon is structured by two tiers, both of them are carried by Kumimono that holds the weight of the roof and others. Kumimono is painted in black Japanese lacquer, and under the Kumimono, there are a lot of white carvings. Their columns are white too. Here is a contrast of black and white, and white is the most high luminosity color, so the difference of brightness is bigger than yellow and black. Looking at the Yomeimon from the perspective of color, there is a contrast like gold and black, or black and white. It seems that the colorfulness of colors stands out with this contrast.

Shoro building (Bell tower) is located at the right side of the way to Yomeimon and that is a radiant glow of gold. Low part of Shoro, which holds this building, and makes a contrast with gold and black. The middle part of the Shoro building is overlapped with Kumimono, and its color almost makes a contrast with green and red. One of them is only contrasted with green and red, but when all of them gather and make a base of this building, it creates more big power. We fully realize how gorgeous and vividness of Gokusaishiki are. If we look at the upper part of

Shoro building, we can see the more complex Kumimono, sculptured in the four corners and so on. That is elaborate construction. The colors used there are gold, red, green, blue and white, and those are very colorful. Those colors came down from China, and represent Chinese philosophy. Compared with these colors, down part of them described above, had only two colors black and gold. If we watched at this part with half-opened eye, it looks black for their area space. Namely Shoro building have a lot of contrast with upper part (including middle part) and down part, like gold and black, colorful and monochrome, complex and simple.

4 GOKUSAISHIKI

The color in the sunlight looks beautiful under the sunshine; the characters are their decorations and the usage of vivid color. The color in the sunlight is colorful, decorative, active and gorgeous. Against this color, the color under the moonlight has the beauty of color when you watch something under the full moon at night. It has low-keyed color and we feel quiet and calm environment from that color. Gokusaishiki is a keyword of the color in the sunlight. Gokusaishiki is made with three or four pure-colors, and each of them is contrasted with each other. We find the colors used in Gokusaishiki are blue, red, green and purple in an old book. There are two groups of patterns, that is to say, contrasted with blue to red and green to purple. Pure colors contrast effects are vivid and brilliant, and give strong visual stimuli. We can find first the word of Gokusaishiki in an old book in about 420 years ago. But the meaning of the word is a little different from what we think now. Those days we think Gokusaishiki is a coloring of pure and strong colors, but at that time it represented mysterious power that Buddha and God have. We can't see the word of Gokusaishiki about 500 years ago, but we can see it on Funchisaienohakkakuki (the objects of virtue in Syosoin) 1200~1300 years ago that we call Gokusaishiki now. Articles of Gokusaishiki existed at that time, so it seems we call them another words. Articles of Gokusaishiki at that time were used for Buddhism, for example, an image of Buddha, Buddhist altar fittings and so on. It seems Gokusaishiki is the color that represents the mystic power that Buddha and God have. We can see such a color at Hoodo in kyoto.

5 GOLDEN COLORING

Byobu (folding screen) and Fusuma (a framed and papered sliding door used as a room partition) coloring used gold leafs that were very prosperous from Muromachi-period and next Momoyama-period; they arrived at their peak at that time. Azuchi-castle was built by Oda Nobunaga who had strong power at that time. It was said that castle was decorated with gorgeous Fusuma coloring and gold leaf, but it was lost now. Similarly Toyotomi Hideyoshi made a golden tea room in there everything was made from gold. The men who had power want to show their power by displaying gold at everywhere in everytime. And actually in Japan, the man showed power by gold. Gold had mystic power.

The famous architect Bruno・Taut visited Japan in 1933. He pointed out Nikko's decorated buildings were "vulgar" and "kitsch". But he applauded the Katsura Imperial Villa as "so beautiful that I feel like crying". He denied the color in the sunlight. Then there is a Japanese proverb "Never say Kekko (fine) before you see Nikko".

6 CONCLUSION

The contrast of big Japanese cedar trees with the magnificent shrines in Nikko is vivid to our eye. This is one example of the usage in Japanese color. In China, there is a proverb. "As there is a paradise in the sky, there is beauty in Suzhou and Hangzhou on the Earth". Similarly we can say "There is a heavenly beautifulness in Nikko".

"Goku" of Gokusaishiki means beams and ridges of the building. "Saishiki" of Gokusaishiki means coloring, so it seems Gokusaishiki is named from colored beams and ridges of the building. Originally, Gokusaishiki was decorative coloring of the architecture. We have two styles of the architecture in Japan. One fall into color in the sunlight that is painted by Gokusaishiki. The other falls into color under the moonlight that is unvarnished wood and isn't painted by any color. The color in the sunlight is Gokusaishiki. The shrine of Isejingu typifies the architecture that is built by unvarnished wood. The shrine is reconstructed every 20 years to keep the beauty of the whiteness of the wood. Gokusaishiki is constructed of pure and strong color. The outline of two colors is clear it doesn't become dim and blot. And it gives us visual effects distinctly. That is one of the beauties of color in Japan. We can feel the beauty of color in Nikko where the best places in Japan.

"Ungen" gradation coloring is related to Gokusaishiki, and it came down from Tou (China) to our country in 7th century. It is confirmed at the wall coloring in Dunhuang, China or in Horyuji, Japan. In those days, we wouldn't say Gokusaishiki instead of "Ungen" gradation coloring but it has substantially the same meaning. In a certain sense, Gokusaishiki is an "Ungen" gradation coloring and "Ungen" gradation coloring is a Gokusaishiki. Shosoin is said that a final terminal of the Silk Roads, and there we have a lot of objects of virtue of “Ungen” gradation coloring. These are articles from the 7th century downward, but it still keeps their beauties of Gokusaishiki today.

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The guideline of the color plan for the facilities and landscape of seven districts in a new administrative city in Korea

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ABSTRACT

In Korea, the color planning to consider structural features, function, shape of the building was not performed yet. Furthermore, since it is not general idea to consider individual building as an important component in the city structure related with overall city context, building planning focused on a harmony with surrounding environment has not been performed. Therefore, in the present study, we proposed the guideline on the environmental color for a new administrative city to produce the images suitable for the individual district function.

The detailed procedures were as follows. 1) Identification of the characteristics of the city district by analyzing the landscape plan in the development plan of the city. 2) Extraction of the applicable images matched with the characteristic of the city district and production of adequate materials and color range fitted in each district. 3) Analysis of the elements (dot, line, and surface) composed of the city landscape and proposal of the color range for each element.

Keywords: District, Facilities, Color harmony, Hue, Value, Chroma

1 INTRODUCTION

In Korea, the color planning considering structural features, functions, shapes of buildings was not performed yet. Furthermore, since it is not general idea to consider an individual building as an important component in the city structure related with the overall city context, the building planning focused on a harmony with the surrounding environment has not been performed. Therefore, in the present study, we proposed the guideline on the environmental color for a new administrative city to produce the images suitable for the individual district function.

The detailed procedures were as follows. 1) Identification of the characteristics of the city districts by analyzing the landscape plan in the development plan of the city. 2) Extraction of the applicable images matched with the characteristic of the city district and production of adequate materials and color range fitted in each district. 3) Analysis of the elements (dot, line, and surface) composed of the city landscape and proposal of the color range for each element.

2 ESTABLISHMENT OF THE BASIC DIRECTION OF THE CITY ENVIRONMENT COLOR DESIGN

2.1 Purpose of the City Environment Color Design

The landscape districts were determined based on visibility and geographical characteristics. A large landscape district is being formed centering on the Jangnam plain. A landscape district in highlands in the Northwest district and the Northeast district was formed visually separated from outside area due to geographical characteristics. The Bonggi district and the Walsan district were classified as independent landscape districts. Although the Deapyungd and Songwan districts could have been classified as a large landscape district like the Jangnam plain in a visual aspect, the two districts were divided into different districts because they are separated by Geumgang and the 1st national highway.

On the basis of the analysis of the basic frame of a landscape in city construction, basic objectives of a color plan were established as follows:

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The landscape district is developed by comprehensively considering city functions and geographical characteristics to realize the ring-shaped city structure and the decentralization concept. The themes for each landscape district were specified by reviewing and comparing functions, major activities and environmental and geographical characteristics.

① Formation of a color landscape as an environment-friendly eco-city to harmonize with nature and maximize the potential of land,

② Formation of a dynamic color landscape to express a variety of city functions as a multi-fuctional city,

③ Formation of a consistent color landscape of flow and connection that reflect non-central characteristics of spatial structure of the city,

④ Creation of a color landscape that describes identity and symbol of an administration-centered multi-functional city

⑤ Formation of a color landscape where people want to walk and see.

⑥ Establishment of the step-by-step color application concept to respond to social changes according to city development phases.

2.2 The Basic Structure of City Environment Color Design

The basic structure of city environment color design is as follows:

1) Application of City Main Colors

Main color of a city is determined to harmonize with natural environment color and match with the city images. The main colors are applied according to annular composition centering on the whole residential complex of a development region.

2) Selection of Districts for Use of Colors and Establishment of Identity

Seven districts are selected based on main functions of a city. Colors are applied to the districts to give identities to each district.

3) Establishment of Identities for Each Life Zone

The color concept, that emphasizes cohesion of each life zone, is applied to community facilities in the central part of each life zone, forming identities for each life zone.

3 COLOR PLANS FOR EACH LANDSCAPE DISTRICT

3.1 Landscape District

According to the function and geographical characteristic, the landscape districts in the city development plan were divided into seven districts such as Songwon district of Cross-Cultural City, Kojeong district of Coexistent City, Worlsan district of Creative City. Yongho district of Clean City, Bonggi district of Connective City, Daepyeong district of Civil City, and Changnam district of Green Heart.

3.2 Color Plans for Each Landscape District

In this study, we developed the color application method suitable for the landscape theme and its function of each landscape district.

District	Classification	Contents
Kojeong district	Function	Central administration / Coexistent City
	Image	Modern, Dignified, Sophisticated
	Basic direction	• application of colors to produce the image of the central administrative function which is the main function of the administrative city.
	Color match	Monochromatic color harmony, Analogous color harmony, Achromatic color harmony
	Recommendable materials	Stone, metal, glass, exposed concrete
Worlsan district	Function	High-tech industry / Creative City
	Image	Advanced, High-tech, Dynamic
	Basic direction	• application of future- oriented materials and colors to express the image suitable for the high technology function.
	Color match	Monochromatic color harmony, Achromatic color harmony
	Recommendable materials	glass, metal, Stone, exposed concrete
Yongho district	Function	Health．Welfare / Clean City
	Image	Clean, Organized, Simple
	Basic direction	• application of colors to produce the clean and organized image for the health care and welfare function.
	Color match	Monochromatic color harmony, Achromatic color harmony
	Recommendable materials	Stone, tiles, enamel, glass
Bonggi district	Function	University．Research / Connective City
	Image	Intelligent, Creative, Comfortable
	Basic direction	• application of material's own color to produce an intellectual

		environment suitable for the university/research complex function.
	Color match	Monochromatic color harmony, Achromatic color harmony
	Recommendable materials	Exposed concrete, bricks, wood
Daepyeong district	Function	City administration Civil City
	Image	Friendly, Gentle, Convenient
	Basic direction	• application of materials and color to produce the friendly image appropriate for the city administrative function.
	Color match	Monochromatic color harmony, Analogous color harmony
	Recommendable materials	Bricks, stones, wood
Songwon district	Function	Cultural exchanges / Cross-Cultural City
	Image	Open, Active, Dynamic
	Basic direction	• production of refined cultural image to connected with its environs as a cultural/ international exchange function. • creation of specialized color district in a medium and low density residential area of life zones.
	Color match	Monochromatic color harmony, Analogous color harmony, Achromatic color harmony
	Recommendable materials	Glass, metal, stone
Changnam district	Function	Central green area conservation / Green Heart
	Image	Natural
	Basic direction	• application of the colors and materials to produce a harmonious image with a green belt and natural environs.
	Color match	Monochromatic color harmony, Analogous color harmony, Achromatic color harmony
	Recommendable materials	Stone, glass, wood

1) Kojeong district : Application of colors to produce the image of the central administrative function which is the main function of the administrative city, using high and middle brightness and non- chromatic colors (above N5, off-white), and limit on painting color use, using materials such as stone, metal, glass and exposed concrete.

2) Worlsan district : Application of future-oriented materials and colors to express the image suitable for the high technology function, using the same color harmony or achromatic color harmony method using light gray and dark gray colors(above N6, off-white), and using materials such as glass, metal, stone, exposed concrete.

3) Yongho district : Application of colors to produce the clean and organized image for the health care and welfare function, using the achromatic color harmony method with off white, light gray(above N6, off-white), and using materials such as stone, tiles, enamel, glass.

4) Bonggi district : Application of material's own color to produce an intellectual environment suitable for the university/research complex function, using yellow-red with high brightness and low chroma (above brightness 7 and below chroma 2 in YR,Y series), and using materials such as exposed concrete, bricks, stone.

5) Daepyeong district : Application of materials and color to produce the friendly image appropriate for the city administrative function, using yellow-red colors with high an middle brightness and low chroma(above N6, off-white), and using materials such as bricks, stone, wood.

6) Songwon district : Production of refined cultural image to connected with its environs as a cultural/ international exchange function, using off-white colors above N6, and using materials such as glass, metal and stone.

7) Changnam district ; Application of the colors and materials to produce a harmonious image with a green belt and natural environs, using the achromatic color harmony method with off-white colors above N7, and using materials such as stone, glass.

4 COLOR PLANS FOR EACH TYPE

4.1 Classification of Types

The components of a city were classified into three types such dot, line and surface.

① The dot type includes public facilities, outdoor advertisement signs and city structures.

② The line type includes special roads and central roads for public transportation, water fronts, sidewalks, bicycle roads, pedestrian roads.

③ The surface type includes multi-community zone as a central life zone and parks and green areas.

4.2 Color Guideline for Each Type

1) The Dot Type

① Public facilities : Application of transparent materials or using colors from brightness 3 to 9 to express materials' own colors.

② Outdoor advertisements : Establishment of standards for using letters, figures and background colors to promote the harmony with surrounding areas. Specification of the range of background colors.

③ City structures such as overpasses and bridges : Application of achromatic colors from brightness 3 to 8.5 after classification of the structures into each type.

2) The Line Type

① Special roads : Use of a little stronger colors than those of surrounding areas to provide a visual cohesion for each district. Application of the colors designated for each functional district.

② The central roads for public transportation : Differentiation of materials and colors from surrounding main colors in order to create unique images and provide a visual variation for pedestrians.

③ Water fronts : Use of natural exterior materials to harmonize with a surrounding natural landscape and application of bright colors to highlight the images of water front on the basis of a environment-friendly concept.

④ Sidewalks : Use of color variations to provide a spatial recognition and application of a pattern concept of sidewalk block for each district and each street.

⑤ Bicycle road : Separation from other roads by a simple pattern and application of environment-friendly materials.

⑥ Pedestrian road : Application of materials with natural(soil) colors.

3) The Surface Type

① Multi-community area located in the center of two to five life zones classified by functional districts : Application of colors that can provide visual enjoyment and attraction.

② Parks and green areas : Application of environment-friendly materials.

5 CONCLUSION

A Multi-functional administrative city is being constructed as the central administrative city of Korea and as a self-sufficient city with multi-functions in a 71.91 ㎢ site. I expect this guideline to be applied to the city construction process in a consistent way so that the new city can become a exemplary model of the color formation of a city landscape .

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Terminal of fashion color

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ABSTRACT

Fashion color as a means to lead market is paid attention by enterprise and fashion design.The paper discusses the necessary analysis on the fashion color forecast from side of designer and enterprise ,how to come into being fashion color forecast ,as well as the value of terminal of fashion color. Pointing out If only deeply understand the essential and characteristics of color, can designers freely use the imagination and design more creative works.

Keywords: Fashion color, forecast, terminal

1 NECESSARY ANALYSIS ON THE FASHION COLOR FORECAST

Gary W. Macquarie, the vice-president of marketing in Hershey Chocolates Company, expressed his opinion about the result of forecast. He said developed commodity was the same as duck hunting that you couldn't shoot the place where the duck appeared but aimed at the next pot it would get. Shearson Leman, worked in American Express, had the same opinion " It could be showed the understanding to forecasts in the financial community from the 'Minds over money' which came from one of advertisements, that we should go with people side by side before people known where to go." Therefore, it's necessary for designers and enterprises to forecast and use fashion color.

Nowadays, more and more enterprisers get the principle and begin the innovation on the "productivity of color". They ground for the stratagem of color marketing from the first day that open up the products. Products design evolves from the fashion color. It is the point to solve the problems on the relationship between color and mould, color and texture of material, color and specialty shop, also color and the thought of consumers. Commercial benefits are the fundamentality of the theory and appliance in the international fashion color which modality are as follows: theory and appliance of fashion color --- significance of society, theory research., modern science technology --- social contribution, discussion for the leading edge science, research of consumptive psychology --- choices to the way of social life, appliance of modern science technology, return of products sales --- fulfill the goal of commercial benefits in fashion color.

1.1 Side of designers

Fashion forecast gives the designers more room for imagination and also enlighten their originality in fashion. Today, what the consumers pursue for is not only the functionality of products but also the corresponding of psychological value and pleasant consumptive experience. They are all the directions for decision. Fashion makes the need of exterior beauty and internal quality that two come one. Most of people who work for fashion trends need the sensitivity and actuation of artists, skills of designers, observation of sociologists, consideration of philosophers, and way of communication of business men. They must deep into the observing the myriads of changes in daily life, follow and orient the values which are confirming or updating during the mixing of culture and change of society. They observantly take apart the hidden emotional needs from consumers, then through these observation and general consideration to make a judgment. They organize the fashion inspiration and subjects by lots of imagination, people's favorite art and way of expression to life. At the same time, this kind of thought also stands for new times' fashion aesthetics. Designers find the new plan in designing from the viewpoint of fashion originality. The creativity comes from the language of fashion information which stands for the designers' inspirational origin. It's the most valuable resource for fashion originality.

1.2 Side of enterprise

During the evolvement, the experts of fashion forecasting are always far away from consumers because of the characters of the job. However, in fact, the forming of a complete trend is a success which the experts of forecasting and correlative people work hard together to make the judgment. From the parts of retail, the experts of fashion

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forecasting are the most important activators who would lead the trend to mature. Taking the clothing industry as examples, when we know the production process of the whole industry and correlative time tables clearly, it's helpful for us to know more about the fashion color forecasting. Clothing enterprises will according to the factors of seasons to divide one year into spring/summer, fall/winter. And they'll make relevant arrangement bases on the changing of seasons.

Time table for exploitation to the products in spring/summer: February, making the analysis on color, fabric and some factors like that --- February to May, finishing the material designs --- the end of June, lying out series of sample clothing -- -July to September, ordering --- October to December, production --- January to February of next year, sending products to every point of sales according to the orders. The first batch of products for spring/summer must come into the market in February.

Time table for the exploitation to the products in fall/winter: September, making the analysis on the fashion trends of clothing for fall/winter --- December to November, ending up the producing of sample clothing and lying out series of clothes for fall/winter of next year --- January to March, ordering --- April to June, production --- June to July, sending products to every points of sales --- August, clothes for fall/winter coming into the market. It's a long period (around 2 years), including many processes such as color forecasting, Fabric Company, yarn maker, weave maker, designers and ready-to-wear clothing maker, selling department, financial department and so on. Color forecasting is at the first place during the whole process. Therefore, as for a successful exploitation of products, it's effective to forecast fashion in color accurately and on time.

2 HOW TO DO THE FASHION COLOR FORECAST

The forecast of fashion information is formed by actual observation to social life and man-made conclusion. Combining with the specialization of fashion information forecast Adviser Company, after colligating to structural information; it makes a difference by professional exhibition and correlative media to send the fashion information.

2.1 Character of science

China joined in Inter Color formally in 1984. And from then on, the research of fashion color forecast in China jointed track with aboard. By usage, members of Inter Color will invite all member states to join the meeting 20 months earlier to discuss the trends of fashion color in future, and make an agreement without being published. After 5 months, the institution of every member state can bases on its own characteristics to forecast fashion color, such as every the first days of June, the international exhibition of yarn in Paris, every October the Interstoff exhibition of fabric in Honking and so on. Some professional institution and large companies, such as International Wool Secretariat, USA Cotton, DuPont and so on also will publish fashion color according to their own characteristics of next year. Every year there are many experts of fashion color come from all over the world who take with different kinds of overtures to Paris. They are researching on which color the consumers used the most last season, and spay into the mind of consumers. They guess the politics in next season and which color the consumers would like in the new situation of economy and society. After an all-sided discussion and analysis, they vote to decide the fashion color in next season. Every group of fashion color gets its own origin of inspiration: tropical rain forest, blue sky, sea, sunshine, Tang sancai.

The results of fashion color forecast also are influenced by the investigating and survey in the markets of color. And the result of survey is limited by the quality of the way of reliability and the character of science. Except the traditional way like visual method or questionnaire, there also are some researchers by using advanced instrument such as Color Cue TX.

2.2 Artistry

Fashion color forecast has both sides on science and artistry. It's a material civilization, ideology, and mental outlook of one origin or a person, also a visual embodiment. There's a bright sense of modern life. If it's a scientific process for the survey, as for analysis and conclusion of fashion color, we must add into the parts of art while sending the fashion information to receivers. Fashion information is like a color pen of dressers, deducting inspirit and thoughts of fashionable inspiration by means of artistic expression. They use the way of title, word or summary pictures to show in the advertisement of fabric companies and clothing brands. This way don't only make the receivers understand easily, but also give them more room for imagination.

3 TERMINAL OF FASHION COLOR

3.1 Base upon the industry, lead ahead the market

From the side of industry, every different professional institution has stronger pertinence. It can help the producers to produce the right products. There is a leading influence to the exploitation of enterprise that the new products can fit for the trends of fashion and the need of the market. Sun ruize, Director of China Textile information center, said that “the original intention we built the system to research and publish fashion trend is to make a closer relationship between the need of backward position and upper position in business.” There is no obvious difference with fashion color between the international market and ours. But, what should be noticed is the influence from the nation of the fashion color receivers and their favorite interests to the traditional regional color, also the relationship between fashionable color and traditional color. The forecast in fashion color must know the international fashion well and be established in the changing of market in our country. First is the traditional regional color. Namely, the treasure which was left from the long river of human history, also named classical color. It formed from the cultural custom that was affected by the factors of regional environment, named color of nation, color of culture too. It’s a mainly expression about emotion, namely, emotion of country, emotion of nation, and emotion of religion. It pursues for a kind of spirit and culture. Second is the color of personal style. In 21 century, the word “humanization” gradually being hot. Therefore, it’s a need to emphasize personality and multielement, also respecting of humanity. It’s very important for individuation and establishment of visual products, because it can make clients know the complete situation about the clothing brands by these differential products. Usually, there are at least 15% visual products for every brand every season. For example, “Blake embroider suit” is the visual product of Chanel, no matter Mrs. Chanel or Karl Lagerfeld who is in the charge of Chanel’s design now, “Blake embroider suit” will always appear on the show stage every season. The reason is wherever the consumers see this product, they will all associate with “Chanel”, also her elegance and capable.

3.2 Search for the point of agreement

As for the same usage of fashion trend or color, every enterprise or brand has its own way for arrangement. The brand is more popular and low-end, they use more direct way. What they want is to play for safety, avoid the dangerous, and take most of parts in fashion. The brand is more advanced and individual, they use more different color. What they want is to do with unconscious and lead the trends of fashion while it innovating and pursuing for the difference on color.

“The best is what fit for you” said Wang xiaokai, the head manager of ZheJiang Xingfa Company, “Every enterprise has its actual situation. As for the trends of fashion, enterprise is difficult to use particular standard of quantization to judge which one is more helpful. We use a kind of testing attitude---we won’t completely use this trend as the direction of production because of the risk, but we can’t care noting about the result which is analyzed by the experts and authoritative institutions. So, as for the trends of fashion, we won’t simply follow with but to get some information about the development of enterprise, and combine with the actual situation of enterprise to decide how to use it.” This viewpoint is representative; it truly reflects the actual situation of color forecasting institutions and the receivers. It shows that our enterprises have been mature gradually. As for fashion forecasting, they neither bolt nor exclude absolutely. Also as for the offers of services---institutions of fashion color forecast, they should be consummating themselves.

4 CONCLUSION

Color is not only the physical characteristics in the surface of objects, but also deeply influence modern art design in different area. In every link of clothing brand building, the influence of color is so important. As for the appliance of international fashion color, we can start with these ways as follows: First is to built a net of information in enterprise to get a statistic number of color in sales at every points of sales on time, and combine with the situation of storage to find out the color of good sales, color of normal sales, and color of bad sales in existing product. Second is according to the difference between the market of regions and areas to compare the international fashion color chart with the three kinds of color chart that we just mentioned above which concluded in the enterprise. Then, we can know obviously about the distance between the color in enterprise and color in international fashion. At last is to build a system of color marketing, namely, exploitation of products --- production --- sales --- advertisement --- storefront --- guilder of sales. If only deeply understand the essential and characteristics of color, can designers freely use the room for imagination and design more creative works.

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Limit of color constancy for illumination of vivid colors

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ABSTRACT

The color appearance was judged by the elementary color naming method for a test patch which was placed in a test room illuminated by one of eight colored illuminations, four red illuminations of different saturation and four yellow illuminations of different saturations. Subjects observed the test patch from a subject room illuminated by fluorescent lamps of daylight type through a window. It was found that the color constancy failed to hold for the red illuminations. Only the lowest saturation the color constancy took place. For the yellow illumination the color constancy took place for any saturation varying from saturation near white to the most saturated condition. Only exception was for the test patch 5B5/3.

Keywords: color constancy, space recognition, illumination, color appearance, Recognized Visual Space of Illumination

1 INTRODUCTION

Our visual system has an ability to understand about the illumination and to discount its effect. When the light source turns to reddish as an incandescent lamp the visual system understands the illumination to be reddish and discounts the redness. Then we can perceive the right color of objects all the time and all the places. The understanding about the illumination and the discounting the effect of the illumination change is called the adaptation to the illumination. The phenomenon that we see the right color of objects for any illumination is called the color constancy. Ikeda and his colleagues[1-5] have proposed the concept of recognized visual space of illumination RVSI to explain the color constancy. The concept of RVSI was introduced to express the state of an observer's recognition for a space in terms of illumination. When one enters a room he/she almost instantly understands how the room is illuminated. This state is expressed as he/she obtained the RVSI in his/her brain, which was constructed based on what he/she saw first in the room. The objects he/she sees first in the room are called initial visual information. That is to say, we first get the initial visual information about the space, and construct the RVSI for the space, and then we can perceive the real color of objects in the space. This claim has been proved by the experiment done by Pungrassamee et al.[6]

In this experiment we will present a subject physically different spaces, the subject room and the test room, separated by a wall with a window and illuminated differently. We increase vividness of the test room illumination and see how far vivid the color constancy holds for the illumination.

2 APPARATUS

The experimental booth was composed of two rooms, the subject room Rs and the test room Rt, separated by a wall with a window W as shown in Fig. 1. T indicates the test patch of which color the subject judges in the experiment. The subject room was decorated with various objects to simulate a normal living room. The window W was opened on the front wall at the eye level of the subject and he/she could see the test room through it. The size of the window was 270 mm × 320 mm, large enough the subject can recognize the test room as another space. The test room was also furnished with various objects. A test patch T of the size 8 cm × 8 cm was placed in the test room and one could be replaced with another test patch. The subject room Rs was illuminated by fluorescent lamps FLs of the daylight type and the test room Rt by two fluorescent lamps FLt of the daylight type also. The upper lamp of FLt was covered with one of two color films, red and yellow, in order to give a colored illumination for the test room. The lower lamp was not covered by any colored film and it was used to desaturate color of illumination. Both illuminance of the subject and the test room were controlled by the respective light controllers. In the subject room the horizontal plane illuminance was kept constant at 30 lx when measured on the shelf Sh. In the test room the vertical plane illuminance

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was also kept constant at 25 lx when measured in front of the test patch T.

Two colored illuminations, red and yellow, were employed for the test room. By combining one of these colored illuminations with the daylight type illumination in different intensities we prepared four illuminations of different saturation for each color. The four combinations were 5+20, 12+13, 19+6 and 25+0, where the former value indicated the illuminance of the colored light and the latter that of the daylight. Their chromaticity points are shown in Fig. 2 by filled circles for red and filled triangles for yellow illumination. The curved line shows the color loci of the black body and an open circle the fluorescent lamp without color film.

Four different colors were employed for the test patch, 5R5/3, 5Y5/3, 5G5/3 and 5B5/3.

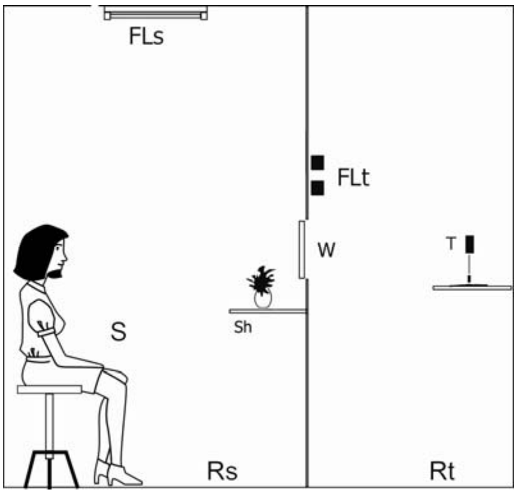

Figure 1 Experimental booth

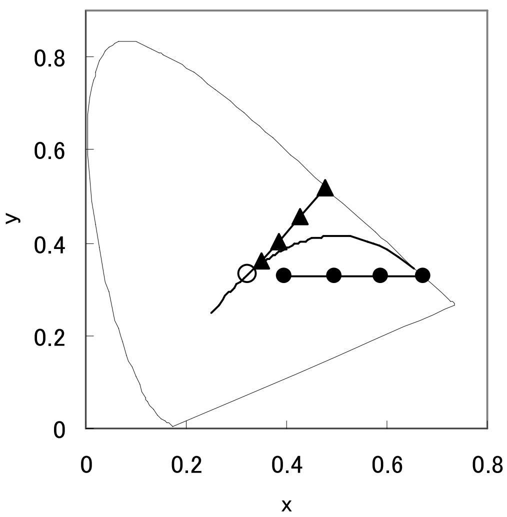

Figure 2 Color of illumination

3 PROCEDURE

Subjects' task was to look at the test patch by one eye through the window and judge the color appearance of the test patch by using the elementary color naming method, namely the judgment of the amounts of chromaticness, whiteness and blackness in percentage, and the amounts of unique hues in percentage. An experimenter set up the color of the test room to one of eight illuminations. For this illumination the experimenter presented the subject four test patches to complete one session. Five such sessions were carried out for each color of illumination.

Besides the above experiment the control experiment was carried out. It was to measure the original color appearance of the test patches by observing the test patches through the window when both subject room and test room were lit with the daylight type fluorescent lamps.

Five subjects participated in the experiment: PP (54 years old, female), DH (44, male), JJ (26, female), PH (25, female), and MW (24, male). The subjects PP and PH used their left eye while DH, JJ and MW used their right eye to observe the test patch. The subjects were asked not to gaze at the test patch except when they made the color judgment of the test patch.

4 RESULTS

The results are shown by using a color appearance diagram of hue and chromaticness elements as shown in Fig. 3. The amount of chromaticness is given by the distance from the center and the outermost corresponds to 100%. The angle gives the hue appearance in terms of the percentage of the unique hues, R, Y, G and B. As all five subjects showed similar results their average is shown in Fig. 3. Two diagrams correspond to colored illumination used in the test room, on the upper the red illumination and on the lower the yellow illumination. Filled circles connected by dotted lines are original color of the test patches which were obtained by the control experiment. Symbols correspond to the saturation of illumination, open squares to the least saturation, and open triangles, open diamonds, open circles follow. The coordinates of four colored test patches are connected by solid lines to form a quadrangle.

When we connect four data points and draw a quadrangle, we can easily see how the color appearance of test patches change from the original color shown by the quadrangle of dotted lines. If the quadrangle is same as that of the original color, the color constancy is very good and normal. But if it is not same, the color constancy is not good. With red illumination we see clearly that the connected quadrangle rapidly shrinks as the saturation of the illumination increases. The color constancy holds for the least saturated illumination shown by open squares, but for the next saturation shown by open triangles the quadrangle shrinks a little bit to indicate less color constancy. Chromaticness of the blue test patch decreased slightly and that of the green test patch decreased greatly. For a further increase of the saturation of illumination the chromaticness of all the test patches decreased and the quadrangle became small. The color constancy gradually became poorer and poorer. The shrinkage of quadrangle is quite large for the highest saturation. The color appearance of the test patches is far from their original color. The green and blue patches appeared almost neutral and yellow and red patches appeared slightly reddish. The color constancy is very poor under this very vivid red illumination.

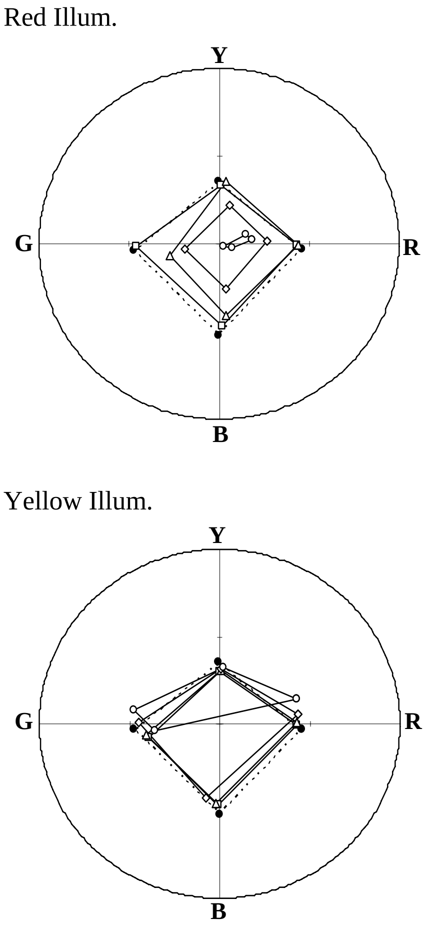

Figure 3 Results for the red and yellow illumination and for test patches: 5R5/3, 5Y5/3, 5G5/3 and 5B5/3

In the yellow illumination the situation is quite different. The connected quadrangle remains almost as that of the original color for the first three saturations. Evident departure from the color constancy occurs only with the highest saturation of yellow illumination. The red and green test patches appeared a bit yellowish, while the yellow test patch appeared as the original color. But the blue test patch went a large change in the color appearance. It appeared as almost original color of the green patch.

5 DISCUSSION

Why did the color constancy hold quite well in the yellow illumination and not in the red illumination? We present one explanation. It is known that the psychological saturation of yellow color is not high even with the spectral light of about 570 nm. Figure 4 shows resemble lines of constant psychological saturation calculated by Stiles based on his line element theory[7]. On the diagram the colored illuminations that we used are plotted by taking data from Fig. 2. We see here that the psychological saturation of the least saturated yellow illumination is very low and close to the neutral light at the center. The second point of the yellow illumination and the least saturated red illumination almost lie on a same contour. Both gave good color constancy. The third point of the yellow illumination did not have the red illumination with the equivalent psychological saturation. Now the psychological saturation of the second point of the red illumination is about the same as the most vivid yellow illumination. With these illuminations the color constancy began to break down. It is interesting to note that with these illuminations the departure of the color appearance of test patches took place mainly with the test patch of which original color is opposite to the color of illumination. In the case of red illumination it was the green test patch, and in the case of yellow illumination it was the blue test patch that departed from the original color. We may conclude that the color constancy has a good correlation to the psychophysical saturation.

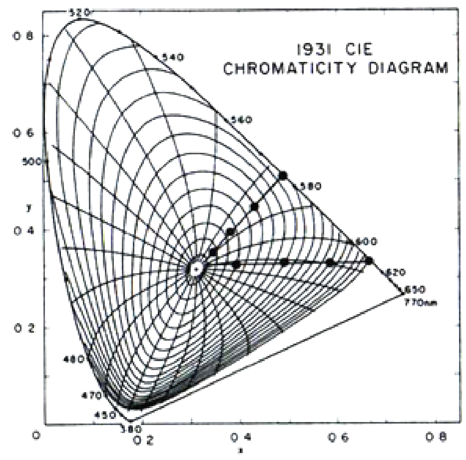

Figure 4 1931 CIE chromaticity diagram with resemble lines of constant hue and saturation

It is difficult to define where the color constancy begins to break down for higher saturation of illumination, but from the above analysis we may suggest that it begins to break down with illumination of which psychological saturation is on the contour next to the contour on which the third point of yellow illumination lies.

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An analysis of color preferences for nail colors according to skin tones — In case of Japanese —

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ABSTRACT

The color preferences for nail colors according to skin tones were investigated by paired comparison method. In the experiment, the hand models were constructed by 3D computer graphics using three skin colors and nine nail colors. It was clarified that the combinations of the colors that have similar tones are suitable. The evaluated value of the model of clear nail polish was relatively high because of the same reason. Any nail color was in conformity with the neutral skin color and the distribution of the evaluation was small. The evaluations of vivid purple and black nail color were lower than other colors. The reason for violet is the difference of Hue from skin color, and for black is the lower Value.

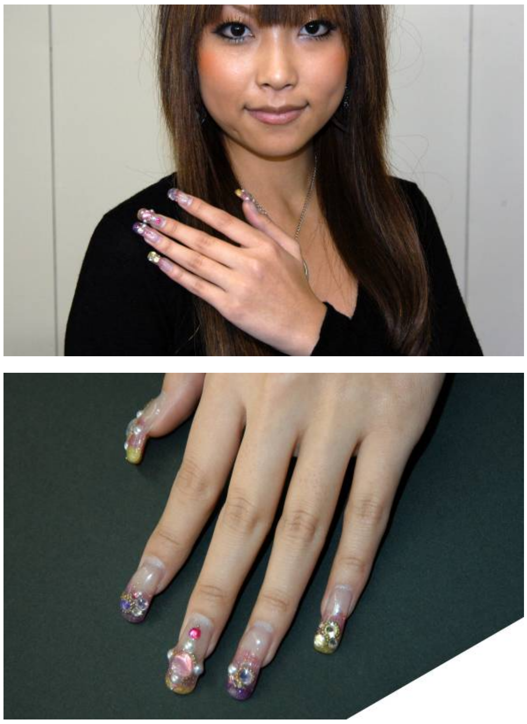
Keywords: Color preferences, skin color, nail color, nail polish, personal color, computer

1 INTRODUCTION

Today in Japan, decoration of nails called 'nail arts' (Figure 1) is popular particularly with women of around 20 years old. Therefore, they take an interest in the color of nail polish.

On the other hand, Japanese 'colorists' who advices how to select the color of clothing, cosmetics, and so on, judges whether the color is well-matched or ill-matched by using the techniques which based on the assumption that there are two color category namely the "warm" group and the "cool" group, and the colors belong in the same category are well matched[1,2].

However, warm – cool feature in these techniques is contrary to generalities[3,4], and the scientific bases for these techniques are not shown clearly. In this study, color preferences for nail colors according to skin tones were investigated by paired comparison method.



2 METHODS

2.1 Hand Models and Color Used

The hand models, as shown in **Figure 2**, were constructed by using 'Shade', a 3D graphics software, and a data offered as a typical woman model named 'Jessie' with texture data like **Figure 3**. The size of the hand model adjusted to the Japanese female standards[5] shown in Table 1 and colored with the skin colors and the nail colors shown in **Table 2** and **3**. The skin colors used were selected from 'Skin color card'[6,7] considering the warm – cool evaluation in the previous study[3,4]. The OI, as the coolest skin color, NII, as neutral, and PkIII, as the warmest, were used for the hand model.

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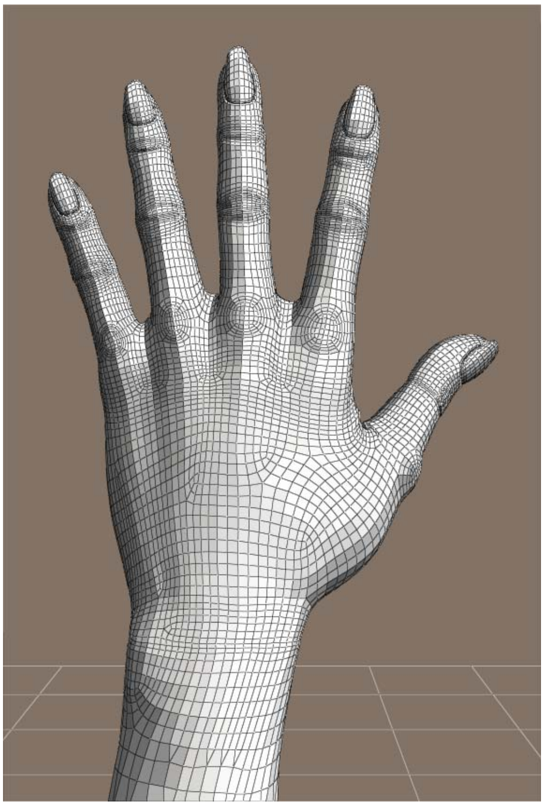

Figure 2 Wire frame of hand model.

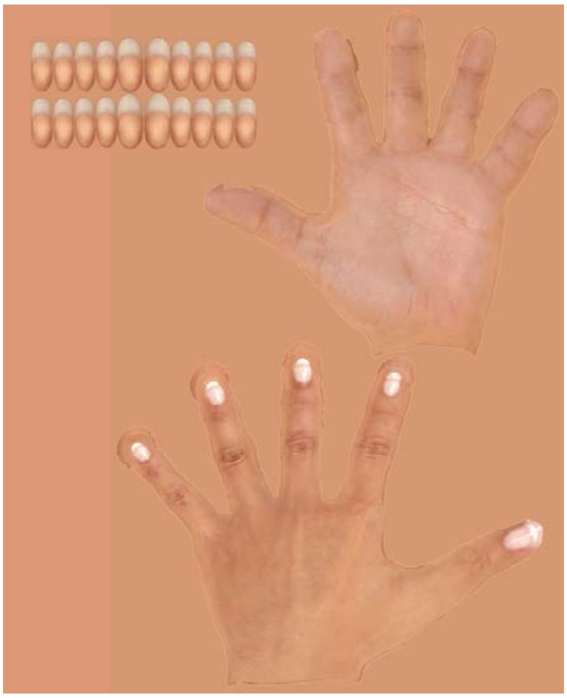

Figure 3 Example of texture for hand model.

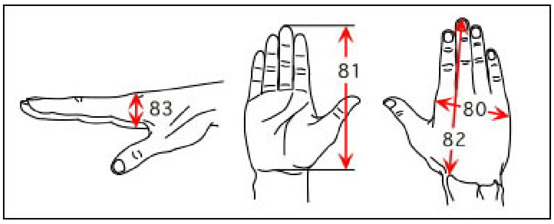

Figure 4 Subject number of size[5].

Table 1 Standard size of Japanese female[5].

No.*	Subject	Ave.	S.D.
	Age	20.2	1.1
80	Hand breadth	73.6	3.2
81	Hand length from crease	167.8	7.9
82	Hand length from stylion	177.1	8.6
83	Hand thickness	25.7	1.4

*: See **Figure 4**

Table 2 Skin colour used in experiment.

symbol	OI	NII	PkIII
skin color			
Munsell notation	7.5YR 8/4	5YR 7/4	2.5YR 6/4
Y	57.50	41.84	29.17
x	0.3571	0.3775	0.3833
y	0.3598	0.3695	0.3569

Table 3 Nail colour used in experiment.

symbol	ltR	vR	ltPk	vPk	ltP	vP	Bk	W	Cl
nail color									
Munsell notation	5R8/4	5R5/14	5RP8/4	5RP5/12	5P8/4	5P4/12	N1	N9.5	-
Y	57.44	18.98	57.50	19.06	57.57	11.61	1.18	76.69	-
x	0.3542	0.5378	0.3341	0.4082	0.3044	0.2825	0.3127	0.3127	-
y	0.3338	0.3204	0.3173	0.2609	0.2997	0.1906	0.3291	0.3291	-

Figure 5 The stimulus portrait used for paired comparison method.

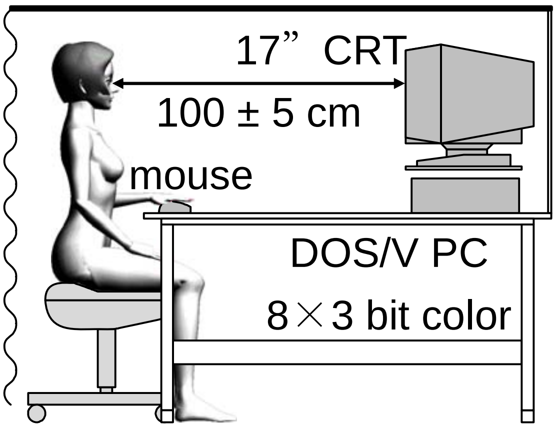

Figure 6 Illustration of experimental environment.

Colors used were controlled by *RGB* value in the computer programs by using

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = [M][K] \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

where [*M*] is the determinant indicating the *XYZ* value of *R*, *G*, and *B* primary colors of the display used and [*K*] is the determinant indicating the unit value of each primary colors.

2.2 Experimental Condition

A DOS/V computer system with 17 inch CRT display (1024 × 768 pixels^2) was used for indication of the color combination stimulus, as shown in **Figure 5**. The computer system was set in the dark booth for prevent the external lights, and the experimental subject (n = 30, female university students) sat in 100 ± 5 cm front of the displays as shown in **Figure 6**. The experimental subjects judged the color preference and selected the combination by the mouse operation. Then the stimuli were changed to another pair and the selection repeated until all the stimuli combinations were used out.

3 RESULTS

In the paired comparison experiments, three skin colors were used, and the sensory scale σ were calculated independently by the Thurstone's case V method for each skin color.

Table 4 shows the results by numerical value and **Figure 7**, **Figure 8** show the order and the σ value respectively.

4 CONCLUSIONS

The evaluation of light nail colors was higher than that of vivid ones in each Hue. The Value of the light nail color is 8.0 and that of the skin color is equal or is lower than 8.0. On the other hand, the Chroma was 4.0 in each case. Therefore, the combinations of the colors that have similar tones are suitable. The value of Cl, the model of Clear nail polish, was relatively high because of the same reason.

The σ value obtained with the neutral skin color NII were distributed in narrow range. In other words, any nail color was in conformity with the neutral skin color and the distribution was small.

The evaluations of vivid purple and black nail were lower than other colors. The reason for violet is the difference of Hue from skin color, and for black is the lower Value. However, these colors are often used in daily life. In this case, it was suggested that there was the effect of color of clothing and so on.

In the previous study[3,4], the lip stick color was investigated and Hue of red especially vivid red had got high evaluation. However, the result obtained here is very different.

Table 4 σ value and order obtained.

No.	nail color	skin color		
		OI	NII	PkIII
1	ltR	1.28 (1)	0.95 (1)	1.08 (2)
2	vR	-0.31 (6)	-0.33 (7)	-0.40 (7)
3	ltPk	0.77 (2)	0.56 (3)	1.22 (1)
4	vPk	-0.04 (5)	0.10 (4)	-0.13 (5)
5	ltP	-0.43 (7)	-0.28 (6)	-0.23 (6)
6	vP	-1.60 (9)	-1.19 (9)	-1.69 (9)
7	Bk	-0.76 (8)	-0.52 (8)	-0.47 (8)
8	W	0.49 (4)	-0.04 (5)	0.03 (4)
9	Cl	0.59 (3)	0.76 (2)	0.59 (3)

( ); order

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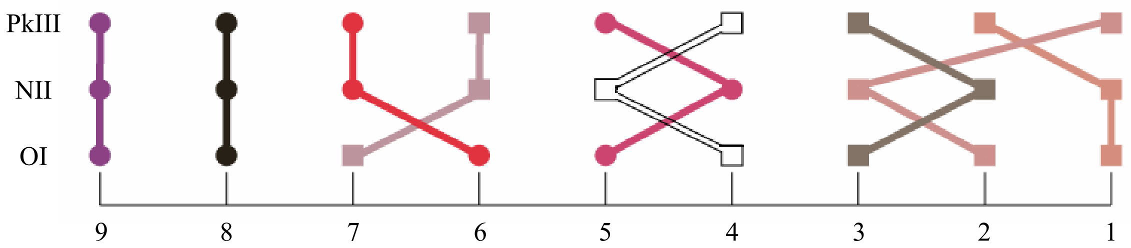

Figure 7 Order of σ value obtained by paired comparison method.
●; vR, ■; ltR, ●; vPk, ■; ltPk, ●; vV, ■; ltV, □; W, ●; Bk, ■; Cl

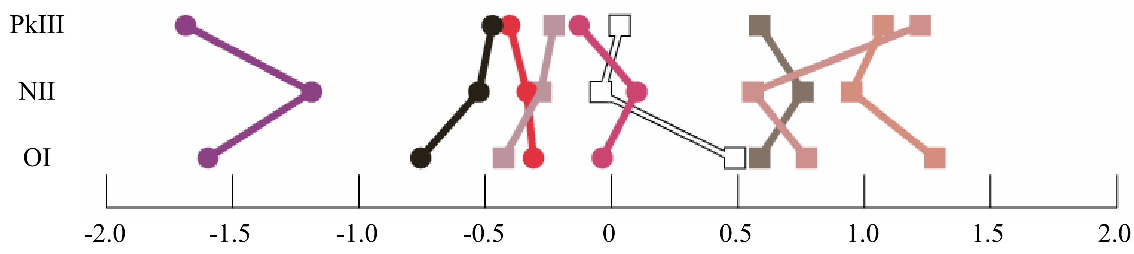

Figure 8 σ value obtained by paired comparison method.
●; vR, ■; ltR, ●; vPk, ■; ltPk, ●; vV, ■; ltV, □; W, ●; Bk, ■; Cl

Use of colour in ephemeral space intervention projects: "stage design, environmental design and visual/plastic arts"

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ABSTRACT

This poster shows some experiences developed in an university class context within the experimental subjet called "Stage design, environmental design and plastic Arts" ("Diseño escenográfico, diseño ambiental y Artes Plásticas") which is taught in the Fine Arts Faculty of the University of Granada (Spain). Students are encouraged to walk among the blurring edges of the three big knowledge areas introduced (stage design, environmental design, plastic/visual art) raising and developing projects of ephemeral constructions in which space is the object of intervention. Projectual methodology includes a pre-project guide wich focuses on eight main well defined objectives planned in a form of "Guide to the intervention project". This "Guide..." includes an attached "Colour Guide to the project" in wich aspects such as perception of colour in space related to time, movement, rithm, etc. are taken into consideration. Some innovative contents and proposals are formulated to the artistic production that are, in some aspects unique in the context of the mentioned Faculty curriculum.

Keywords: Environmental design, stage design, scenography, visual art, plastic art, ephemeral architecture, colour in environment.

1 INTRODUCTION

Based on the idea of convergence of the arts (those related to lighting, space, time, movement) Environmental Design is introduced to students as a linking vehicle to communicate Stage Arts and Plastic and Visual Arts. This approach is carried out onto a re-formulation of the term Stage Design (Scenography), finding a new and wider notion of its meaning that could embrace a wider range of fields. In this new context, scenography can be settled over a new and deeper theoretical assumption in which the solving of environmental approaches by the artist' intervention in a particular space can be assumed.

At the beginning of the instructional tutorials, students are invited to walk among the blurring edges of those three big knowledge areas (stage design/scenography, environmental art/design, plastic/visual art) proposing class projects in which space is the object of intervention to create ephemeral constructions.

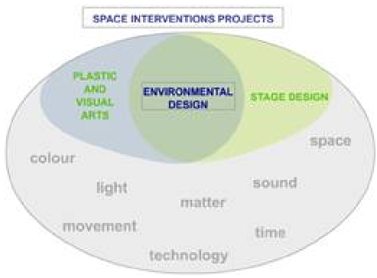

Figure 1 "Stage Design, Environmental Design and Plastic/Visual Arts" Diagram of subject conceptual basis.

It is worth mentioning the nature of this course which is based on a partially virtual teaching methodology (60% of its contents are lectured on-line). This constitutes an additional challenge for the implementation of some new strategies, methodologies and developments in teaching strategies and contributes to develop the objectives that will be explained in an extensive new approach.

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Also, we find interesting to focus on the student profile. As an open access subjetc (“Asignatura de Libre Configuración Específica”) it can be reached from students of many other degrees such as Arquitecture, Enginering, Anthropology, Visual Communication, etc. and countries. This facts offers the opportunity to enrich approaches and work in organized multicisciplinary groups.

2 METHODOLOGY.

Environmental Design is introduced as a problem-solving tool to ephemeral space intervention projects which are to be developed though a “scenographical sense”. In fact, and taking into consideration that the subject introduced is lectured within a Fine Arts Faculty curriculum, students are strongly encouraged to approach Scenography from Plastic and Visual Arts fields as point of departure. Being considered a sound and multi-disciplinary branch of knowledge, Environmental Design can agglutinate many of the fields of study in space intervention projects developed from scenographical conceptual basis on plastic and visual arts.

This constitutes a first projectual aproach. Thus, methodology has been developed onto the above mentioned main idea, focusing on eight well defined objectives planned in a form of “Guide to the intervention project”. Students must work on a strategy-based methodology settled on a project process and decision-making basis. This Guide must be fulfilled by each student and is developed during the work in progress (partialy or substantialy) in order to achieve, define, set and fix the starting idea.

This Guide is widely proposed on the basis of the folowing main items (we will just introduce them in order to go deep and analize best the item related to colour use, section B):

A. GENERAL GUIDE TO THE PROJECT

1. Idea, concept. Pattern: nature of the idea underneath the project structure: textual, plastic/visual, musical, mixted, etc.
2. Shape of the rough space prior to intervention: size, setting, scope.
3. Structural devices: materiality, mutability, technology, physic aspects.
4. Sound devices: sources, installation, manipulation, modification.
5. Lighting devices : sources, installation, manipulation, modification
6. Space-Time strategy : time processing related with time perception. Time perception modified by means of noise or sound used in transformed space.
7. Performative strategy: corporeal property as essential element in contemporary art: dance, performance, theater, sound art,...
8. Active strategy: body action and movement in objets, structures, compositive lines, movement affecting the whole device, in the sense of creating and modifying space.

B. COLOUR APPROACH TO THE PROJECT: perception of colour in space: relation with perception of time, movement, rythm, etc. Incidence and use of colour in space intervention projects.

Use of colour constitutes a separate part of the questionnaire and is fulfilled by the students after project is over and always after the main Guide is reviewed. This way, every student is asked to look into the own art project, start a researching approach to the work done and throw a deep analytical view to processes, experiences and results. This approach must be specific in terms of the incidence of some aspects in chromatic use, its relation with light and matter, and the effects achieved, in terms of perceptual concern, when certain chromatical changes are applied to their starting project proposals. Lets focus on this part of the project guide.

Space perception constitutes an inherent visual experience which takes place when a certain quantity of light penetrates in a certain space; then, finite boundaries are perceived delimited so much in real borders (matter) as in metaphorical ones (psychological, virtual, …).

Light capacity to change the perception of a space is definitively powerful: it can modify it filling and reinforcing the limits, or it can void space borders as to make them disappear, it can focus on some point, displace the approach, modify dimensions, vanish in the emptiness, take shape and materialize its presence, show and modify relations with time... Definitively, light is capable of transforming the own three-dimensional nature of the space that fills, allowing the observer, either from inside or from outside, to enjoy a aesthetic singular and total spatial experience.

In the *setting-in-space* process of an art project, the lighting work, and consequently the use of color, forces the artist to deal with the laws of sensation. The degree of subjectivity or objectivity of certain colour temperatures has relation of direct proportionality with the iconical reference of the recipient; therefore, it is not possible to overlook this main consideration in the constants of the observer’s sensibility.

Then a final approach to matter used in the project is suggested as well as a further research on its own capabilities in texture, colour, transparency, translucency, etc

3 WORKS

3.1 Urban spaces intervention projects

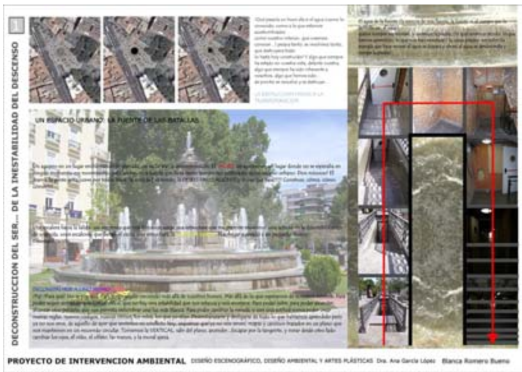

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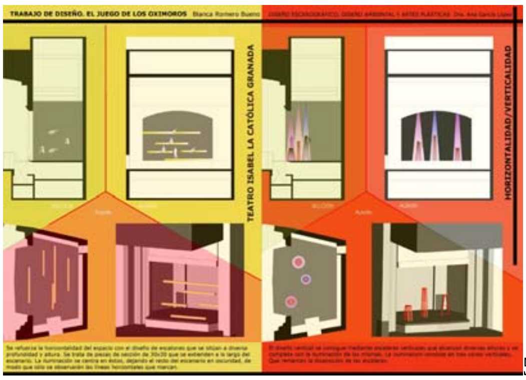
Figure 2, 3, 4. Blanca Romero Bueno. *"Deconstruction of being... of descending instability"* Public art project. Urban space: Fuente de las Batallas. City: Granada. (Spain)

3.2 Stage intervention projects



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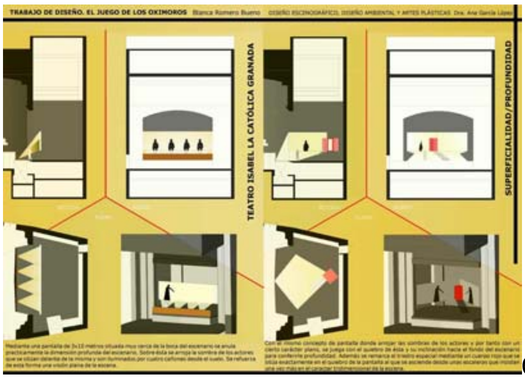

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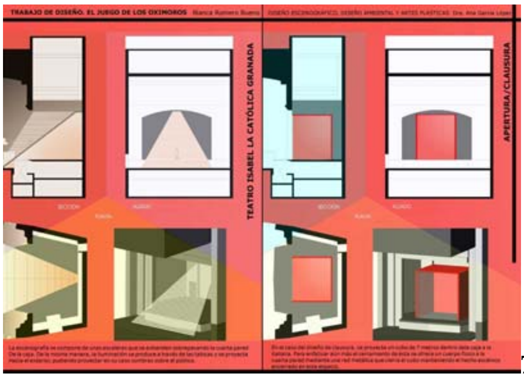

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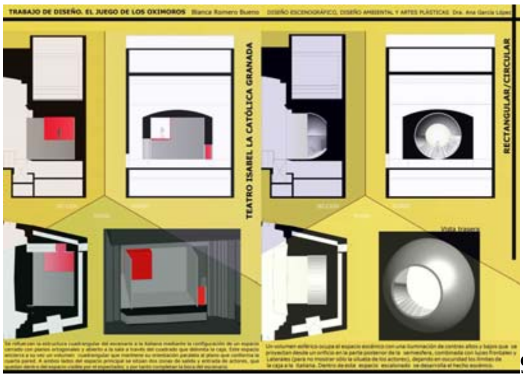

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Figure 5 to 9. Blancanieves Romero. Stage design. Spatial approach on a chromatic and parameter changes basis. Space perception based on colour changes. Teatro Isabel la Católica. City: Granada (Spain).

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Figure 10-11. Paulina Micolajcvac. Stage design for a concert hall. Poland

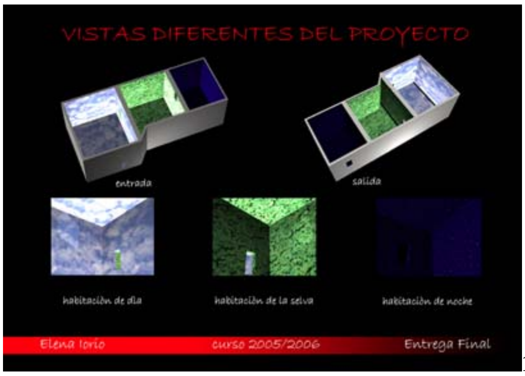

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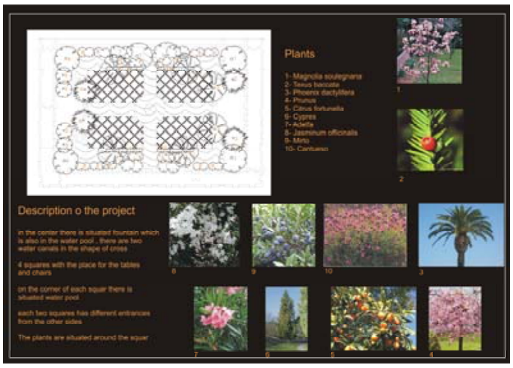
Figure 13. Elena Iorio. *"The Flight"*. Stage structure on urban space "Campo del Principe". City: Granada (Spain)

3.3 Nature works.



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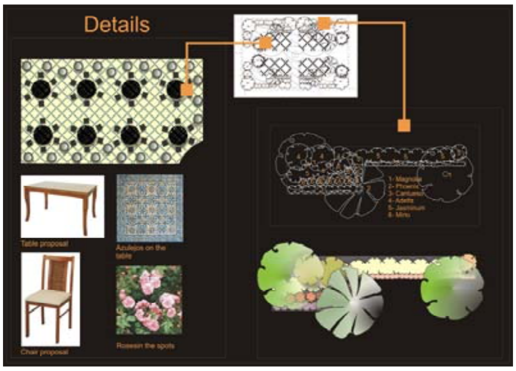

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Figure 14-15. Aleksandra Krupa. Garden design for an outdoor restaurant. City: Granada.

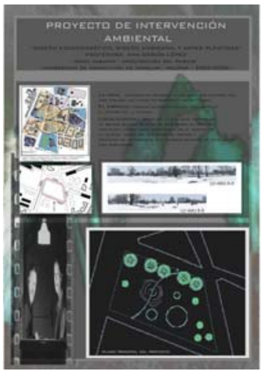

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Figure 16-17. Agata Cabanek. Polish Actors Memorial Intervention project. City: Wroclaw (South-west Poland).

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The Difference of Categorical Color Perception between Young Adults, Elderly People and Color Deficiencies

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ABSTRACT

We carried out a categorical color naming experiment using young adults, elderly people and color deficiencies as observers. The experiment was designed to investigate the effects of illuminant (four types of fluorescent: D-EDL-D65, N-EDL, EX-L and W) and illuminance (three levels: 10, 100, 1000lx). The experiment used a series of Munsell chips which were presented separately, and the observers were asked to categorize them into one of 11 categories (red, pink, orange, yellow, green, blue, purple, brown, white, gray, and black). The consensus of the categorization results was relative high for the young adults but not for the elderly observers and severely color deficiencies. The elderly observers categorization consensus was low for chips with hues RP, R, YR, and Y. It also much deteriorated when either the illuminance was low, or the lightness of the chips was either low or high in the elderly group. The categorization of severely color deficiencies were quite different from the young adults regardless of the illuminant or illuminance.

Keywords: categorical color perception, elderly people, color deficiencies, illuminant, illuminance

1 INTRODUCTION

Categorical color naming is often used to communicate. It is generally useful to designate or distinct objects then colors are widely used on application like signals, signs and so on. Meanwhile, it is pointed out that color is insufficient in this purpose for elderly people or color deficiencies caused by deterioration of their visual abilities. In this case, the categorical color perception may be not same as younger people.

It is important that the same surface (i.e., object) is seen same color category to communicate by color. For example, if someone sees red and another sees green on the same surface, it would be dangerous to use the surface for traffic signals. Therefore it is necessary to consider the characteristics of the color perception across various people when the colors are used for this purpose.

Categorical color concept is widely used in experimental and practical purpose. However, there are small number of studies of categorical color perception especially for elderly people and color deficiencies[1,2]. The data of color categorization which depend on viewing condition and type of observers are still insufficient. We carried out some categorical color naming experiments to young adults, elderly people and color deficiencies under some illuminants and levels of illuminance. The results of the experiments would be useful to consider the effectiveness of color category for communication and industrial use.

2 METHOD

2.1 Design

The experiments were designed to investigate the effects of illuminant and illuminance on the color categorization for young adults, elderly people and color deficiencies.

2.2 Illuminant

Four types of fluorescent (D-EDL-D65, N-EDL, EX-L/M, W/M) were used to investigate the effects of illuminant. Meanwhile, only D-EDL-D65 (D65) fluorescent was used to investigate the effects of illuminance.

2.3 Illuminance

Three levels of illuminance (10, 100, 1000lx) were employed as experimental condition to investigate the effects of the illuminance. The luminance was set at 1000lx to investigate the effects of illuminant.

2.4 Participants

Totally, 47 young adults (aged in 20s), 17 elderly people (aged in 60-80s), and 11 color deficiencies (2 protanopia, 1 slight protanomaly; 2 deuteranopia, 1 severely deuteranomaly, 4 slight deuteranomalies) participated in the experiment as observer. All the observers had enough visual acuity to make their dairy living, and no specific visual pathologies which affect the experiment. None of the young adults or elderly people had been pointed out their color vision abnormally during their life.

2.5 Stimuli and apparatus

A series of Munsell color chips was used as stimulus. The chips which fit for the hue, lightness and chroma listed below were chosen: the hue is either 5 or 10 in Munsell hue, the lightness is either 1, 2, 4, 6 or 8 in Munsell value, and the chroma is either N (0) , 1, or from 2 from 8 in every 2 in Munsell chroma. Totally, 332 chips were used.

The experiment was carried on in a viewing box, which has adjustable illumination and N6 surface inside. The stimulus were presented in the box. Each chips were placed on the N9 background which extended 57 (H) x 42 (V) degrees in visual angle, separately. Viewing was binocular from distance of approximately 30cm with natural pupil.

2.6 Procedure

Each color chips were presented separately. Observers were asked to categorize the chip into one of the 11 basic color terms[3] (red, pink, orange, yellow, green, blue, purple, brown, white, gray, black) in each trial. No time limitation was set to answer. Five-minute adaptation to the illuminant was carried out before each experiment.

3 RESULTS

3.1 Effects of illuminant

The effects of illuminant depended on the observer group as shown in Figure 1. Illuminant did not affect the categorization for the young adults very much, the consensus of categorization results was high regardless of the illuminants. Meanwhile, relative large effects were found in the results of the elderly people and severely color deficiencies. The consensus was low for the chips with hues P, RP, R, YR, and Y in the elderly. The consensus within individual elderly observer tended to deteriorate across the illuminants. The categorization of the slight color deficiencies were almost the same as the young but the results of the severely color deficiencies was quit different.

3.2 Effects of illuminance

Illuminance affected the results of the categorization for all the observer groups although the extents for each group were different as shown Table 2. In the young adults, the consensus of categorization results was high and

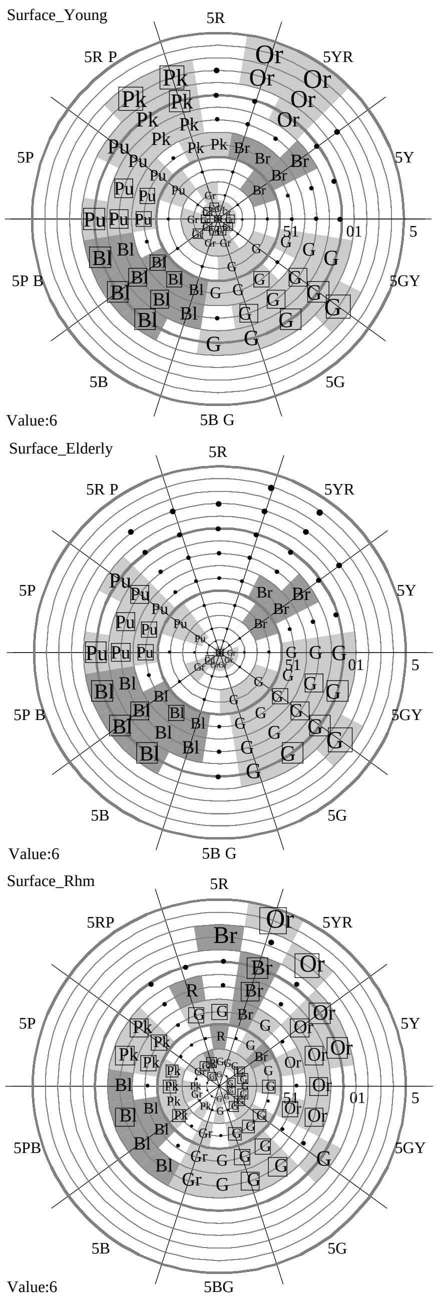

Figure 1 Responses of color categories for each Munsell chip (upper: young adults, middle: elderly people, lower: a severely color deficiency (deuteranopia)). To show the results of the effects of illuminant, the each results were calculated from all the responses under the four illuminants of all the observers in each observer group, except for the color deficiency (the lower plot shows the result of only one observer). Symbols mean the coordinates of the chip and consensus of color naming for each chip. The responses were indicated by initials (R: red, Or: orange, Y: yellow, Br: brown, G: green, Bl: blue, Pu: purple, Pk: pink, Gr: gray, W: white, Bk: Black) and initials with and without squares mean 90% and 70% consensus, respectively. Dot means under 70% consensus.

Table 1 Number and ratio of chips with 90% or higher consensus in the young and elderly group.

	Lightness	V2	V4	V6	V8
	Number of Chips	57	103	103	69
Young	1000lx	27（47.37）	64（62.14）	56（54.37）	27（39.13）
	100lx	27（47.37）	57（55.34）	51（49.51）	28（40.58）
	10lx	**11（19.30）**	31（30.10）	47（45.63）	28（40.58）
Elderly	1000lx	**9（15.79）**	53（51.46）	42（40.78）	**19（27.54）**
	100lx	**15（26.32）**	47（45.63）	44（42.72）	25（36.23）
	10lx	**8（14.04）**	**12（11.65）**	**18（17.48）**	**6（8.70）**

Number in the parentheses means the consensus within the each condition in percentage and bold number means under 30% consensus.

Table 2 Number and ratio of chips with 90% or higher consensus across the young and elderly group.

Lightness	V2	V4	V6	V8
Number of Chips	57	103	103	69
1000lx	6（10.53）	49（47.57）	39（37.86）	16（23.19）
100lx	9（15.79）	39（37.86）	35（33.98）	18（26.09）
10lx	2（3.51）	8（7.77）	15（14.56）	5（7.25）

Number in the parentheses means the consensus within the each condition in percentage.

the categorization was almost same at 100 and 1000lx. The consensus was slightly deteriorated and the categorization differed from other illuminance condition when the evaluating chips were with value 2 or 8 at 10lx. Meanwhile, the consensus of categorization results much deteriorated when either the illuminance was low, or the lightness of the chips was either low or high in the elderly group. It was low at 10lx through all lightness of the chip and it was also low even if at 100 or 1000lx when the lightness was value 2 or 8.

3.3 Consensus on color categorization

The number of chips obtained high consensus on categorization in the elderly (i.e., categorized same color in the elderly group) was almost same as the number of chips of the young adults at 1000lx (Table 3). But the number declined as the illuminance was lower, because the number of chips with high consensus was mostly declined in the elderly.

The consensus of categorization was low for protanopia across the different illuminance, the categorization was quite different from the young adults as well as the experiments with a series of the illuminants.

4 DISCUSSION

4.1 Common color categorization between young adults and elderly people

We found some color chips which were not affected by illuminant or illuminance to be categorized into basic color across the young adults and elderly people. The chips with value 6 listed below were categorized into the same color regardless of the illuminants as shown in Figure 2: 5P-10PB with high chroma as purple, 5PB-5B with high chroma as blue, 10GY-5G as green. The chips listed below were categorized into the same color regardless of levels of illuminance under the illuminant D65 as shown in Figure 3: 10RP-5P with value 4 and 5P-10P with value 6 as purple, 5PB4/12 and 5PB6/8 as blue, 10GY4/8 and 10GY-5G with value 6, and 5GY-10GY with value 8 as green.

4.2 Comparison with previous study

Sagawa and Takahashi[1] assessed spans of categorical colors (i.e., color categorization) of young adults and elderly people by using similarity of colors. They concluded that the spans of fundamental colors are slightly depend on age, and more largely on the luminance level. Our results are in general agreement with their results in regard to the luminance level.

Meanwhile, we found the much larger difference between the young and elderly on the color categorization than their results. Our results did not show high consensus for the chips with hues P, RP, R, YR, and Y for the elderly. This disagreement is may caused by the difference of the procedure.

4.3 Proposal for practical usage of color based on this study

The results might suggest that purple, green and blue are suitable on the usage to communicate information by color categories. Meanwhile, warm color (like red, orange, yellow, pink) is not sufficient in this purpose. But it needs more consideration to conclude, especially for color deficiencies.

5 SUMMARY

Color categorization was relative robust for the young people but it was relative unstable for the elderly people, illuminant and illuminance much affected them. Common categorization for some color chips was found across the young and elderly, which were not affected by illuminant or illuminance to be categorized into purple, green and blue. Severely color deficiencies categorized quite differently from the young adults.

ACKNOWLEDGMENTS

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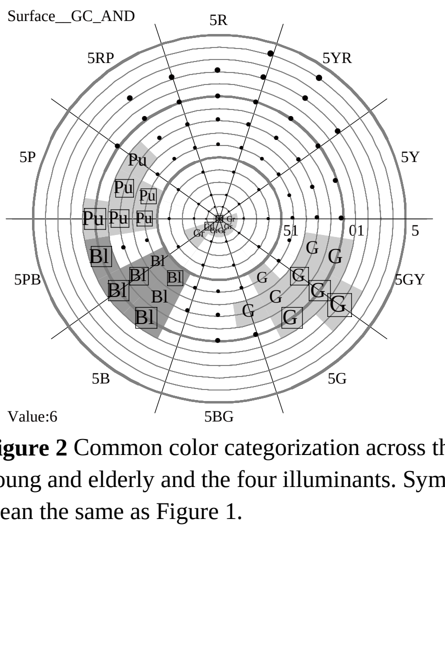

Figure 2 Common color categorization across the young and elderly and the four illuminants. Symbols mean the same as Figure 1.

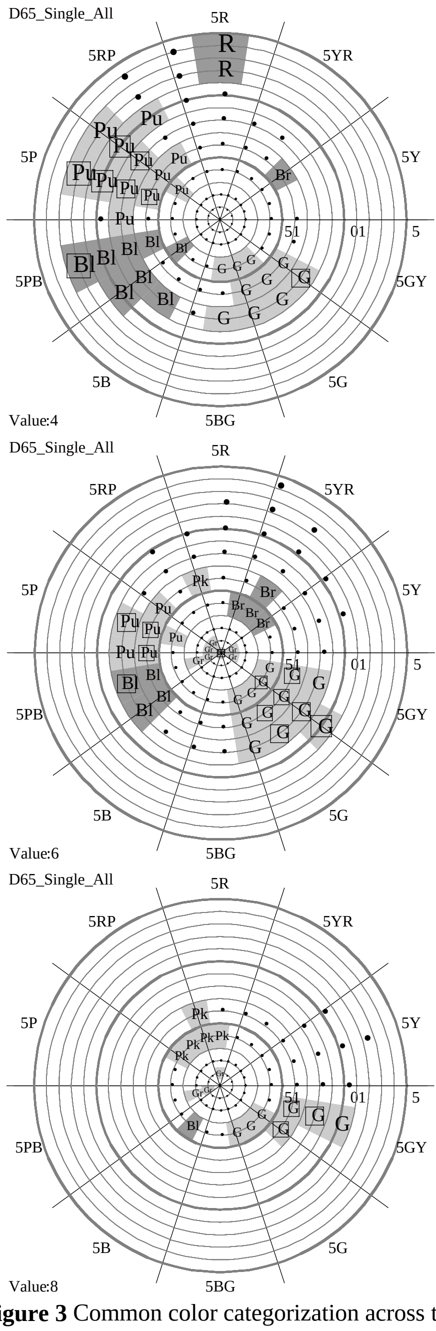

Figure 3 Common color categorization across the young and elderly, and all the levels of illuminance (upper: value 4, middle: value 6, lower: value 8). Symbols mean the same as Figure 1.

A study on evaluation of the interior atmospheres and the choice of behaviors with effects of lighting, color and gloss: Part 3

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ABSTRACT

This study shows the results of the experiment that aims to gather the useful data for the interior design. The outlines of the effects on the gloss of the finished surfaces were clarified. Introducing the level of semi-gloss the further information on the effects of gloss was found. A part of the movements that gloss influences the space was clarified.

Keywords: Gloss, Furniture arrangement, Partition, Evaluation of atmospheres, Choice of behaviors

1 INTRODUCTION

This study aims to gather the useful data for the interior design. Some elements composing the interior space were selected; illuminant, color of the finished surface of the room, gloss of these surfaces and the arrangement of furniture. As a result, nine elements were chosen and arranged according to the design of experiment.

Psychological experiments were carried out, and two questions were asked for subjects. One was attempted to evaluate the atmospheres of the scale-model space, another was aimed to be asked for the suitability of the several behaviors.

By many foresighted researches, psychological effects of lighting and color were individually clarified, and this knowledge has been applied for the interior design. Therefore the effects of gloss, one of the important elements, have not been clarified because they are difficult to quantify. This study aims to clarify not only the main factors of lighting, color and gloss but also the interactions of them by use of design of experiment-table of orthogonal arrays L_{27}.

2 METHOD

In this study, above shown, nine factors were adopted; A: illuminant, B: hue of wall and floor, C: gloss of wall, D: chroma of wall, E: gloss of wall, F: gloss of wall, G: gloss of partition, H: height of partition, I: furniture type(arrangement of furniture)(as shown Table 1). Value of wall, floor and partition were fixed at 8, 4 and 6 respectively. These nine factors were arranged according to the orthogonal table L_{27}. By use of this design of experiment, main effects of these nine factors and some interactions were to be examined.

The scale-model was made on a scale of 1:10. This scale-model was lit by fluorescent lamps or incandescent lamps. Two ceilings were made for each illuminant, and these colors were fixed at N9. These surfaces of wall and floor boards were changeable. Pieces of furniture(table and chair) were arranged for imparting reality, and these colors were also fixed at N9

In this study, 27 stimuli were presented by the projector connected to the computer giving priority to the efficiency of the experiment practice and the reality of the stimuli (Figure 1).

Questionnaire was composed of two questions; one was attempted to evaluate atmospheres of the interior space by semantic differential method, another was attempted to evaluate suitability of 20 behaviors in these spaces.

As shown Table 2, 27 stimuli were combined by nine factors, were presented for subjects. These 27 stimuli were presented by random order.

Table 1 Factors and levels settled in this experiment

Factors	Levels
A: Illuminant	A_0: Fluorecent,A_1: Incandescent
B: Hue of wall , floor	B_0: 10YR, B_1: 10B
C: Gloss of wall	C_0: G, C_1: S, C_2: M
D: Chroma of floor	D_0: 2 , D_1: 4
E: Gloss of floor	E_0: G , E_1: S, E_2: M
F: Hue of partition	F_0: 10YR , F_1: 10B
G: Gloss of partition	G_0: G, G_1: S, G_2: M
H: Height of partition	H_0: High , H_1: Middle, H_2:Low
I: Furniture type	I_0: Type A, I_1: Type B

G: Gloss, S: Semi-gloss, M: Matte

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Table 2 The layout of the experiment by design of experiment-orthogonal table L_{27}.

No.	Illuminant	Wall(Gloss)	Floor(Gloss)	Partition(Gloss)-Height	Furniture
1	Fluorescent	10B8/2(Gloss)	10B4/2(Gloss)	10YR6/2(Gloss)-High	Type A
2	Fluorescent	10YR8/2(Semi-gloss)	10YR4/4(Gloss)	10B6/2(Semi-gloss)-Medium	Type A
3	Incandescent	10YR8/2(Matte)	10YR4/2(Gloss)	10YR6/2(Matte)-Low	Type A
4	Incandescent	10YR8/2(Semi-gloss)	10YR4/4(Semi-gloss)	10YR6/2(Matte)-High	Type A
5	Fluorescent	10YR8/2(Matte)	10YR4/2(Semi-gloss)	10YR6/2(Gloss)-Medium	Type A
6	Fluorescent	10B8/2(Gloss)	10B4/2(Semi-gloss)	10B6/2(Semi-gloss)-Low	Type A
7	Fluorescent	10YR8/2(Matte)	10YR4/2(Matte)	10B6/2(Semi-gloss)-High	Type A
8	Incandescent	10B8/2(Gloss)	10B4/2(Matte)	10YR6/2(Matte)-Medium	Type A
9	Fluorescent	10YR8/2(Semi-gloss)	10YR4/4(Matte)	10YR6/2(Gloss)-Low	Type A
10	Fluorescent	10YR8/2(Gloss)	10YR4/2(Gloss)	10YR6/2(Matte)-High	Type B
11	Incandescent	10YR8/2(Semi-gloss)	10YR4/2(Gloss)	10B6/2(Gloss)-Medium	Type B
12	Fluorescent	10B8/2(Matte)	10B4/4(Gloss)	10YR6/2(Semi-gloss)-Low	Type B
13	Fluorescent	10YR8/2(Semi-gloss)	10YR4/2(Semi-gloss)	10YR6/2(Semi-gloss)-High	Type B
14	Fluorescent	10B8/2(Matte)	10B4/4(Semi-gloss)	10YR6/2(Matte)-Medium	Type B
15	Incandescent	10YR8/2(Gloss)	10YR4/2(Semi-gloss)	10B6/2(Gloss)-Low	Type B
16	Incandescent	10B8/2(Matte)	10B4/4(Matte)	10B6/2(Gloss)-High	Type B
17	Fluorescent	10YR8/2(Gloss)	10YR4/2(Matte)	10YR6/2(Semi-gloss)-Medium	Type B
18	Fluorescent	10YR8/2(Semi-gloss)	10YR4/2(Matte)	10YR6/2(Matte)-Low	Type B
19	Incandescent	10YR8/2(Gloss)	10YR4/4(Gloss)	10YR6/2(Semi-gloss)-High	Type A
20	Fluorescent	10B8/2(Semi-gloss)	10B4/2(Gloss)	10B6/2(Matte)-Medium	Type A
21	Fluorescent	10YR8/2(Matte)	10YR4/2(Gloss)	10YR6/2(Gloss)-Low	Type A
22	Fluorescent	10B8/2(Semi-gloss)	10B4/2(Semi-gloss)	10YR6/2(Gloss)-High	Type A
23	Incandescent	10YR8/2(Matte)	10YR4/2(Semi-gloss)	10YR6/2(Semi-gloss)-Medium	Type A
24	Fluorescent	10YR8/2(Gloss)	10YR4/4(Semi-gloss)	10B6/2(Matte) –Low	Type A
25	Fluorescent	10YR8/2(Matte)	10YR4/2(Matte)	10B6/2(Matte)-High	Type A
26	Fluorescent	10YR8/2(Gloss)	10YR4/4(Matte)	10YR6/2(Gloss)-Medium	Type A
27	Incandescent	10B8/2(Semi-gloss)	10B4/2(Matte)	10YR6/2(Semi-gloss)-Low	Type A

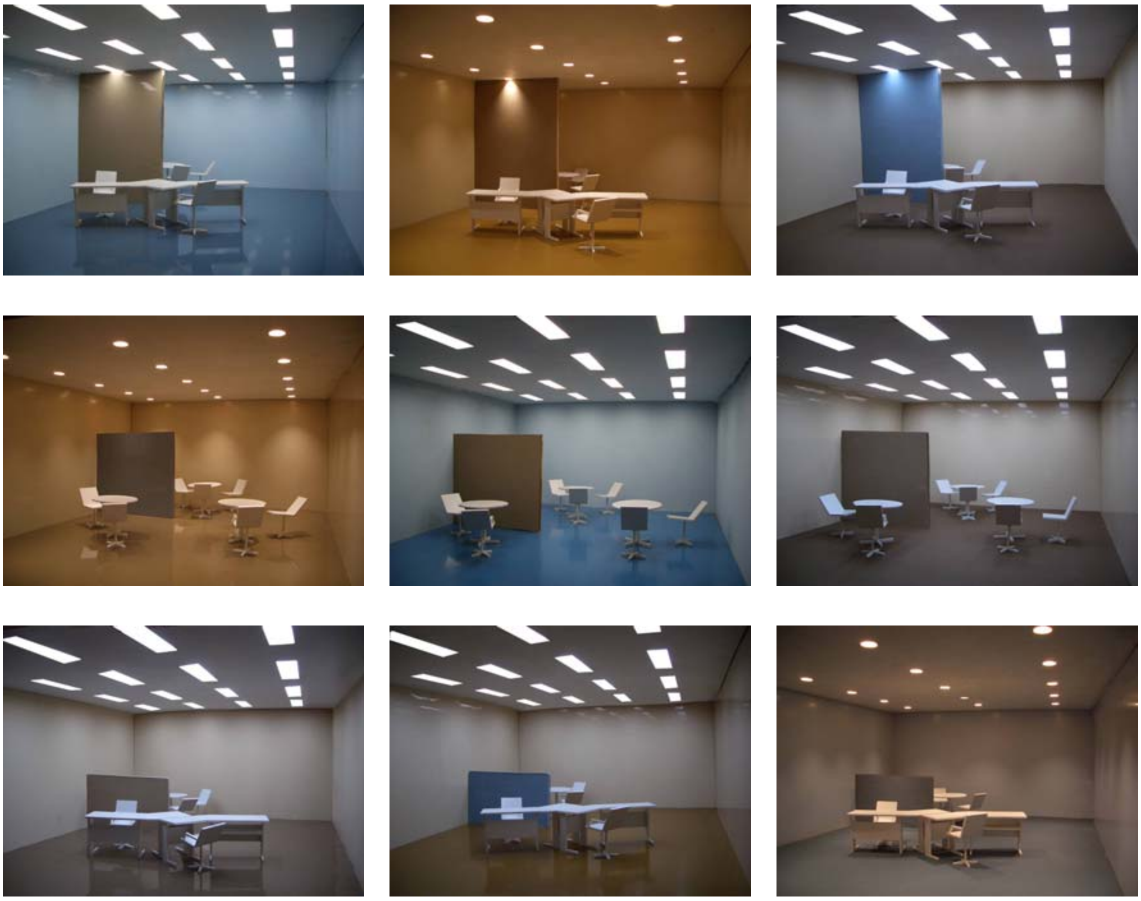

Figure 1 Samples of the stimuli.

Subjects were 20 architecture major(10 male and 10 female).

3 RESULTS

Obtained data were examined, as a result significant difference based on sex was not noticed for all questions. Consequently the following results are based on the mean value of the evaluation about all subjects.

3.1 Evaluation on Atmospheres

Data was processed by factor analysis, then three factors were extracted and they were named Warmth, Calmness and Freshness for convenience's sake.

An analysis of variance was carried out more, and the main effects and the interactions which nine elements of space bring to each factor(Table 4).

Some adjectives(warm, soft, feminine, luxury, convenient and favorite) are integrated into Factor 1 : warmth. Factor 1 is interpreted as comfortable warmth which the space brings, and as the comprehensive evaluation of the space.

By analysis of variance, two main effects and one interaction were recognized for factor 1.

The use of the fluorescent lamps and semi-glossy finished floor make the interior atmospheres cool. As for interactions, the combination of Type B furniture arrangement and low partition increases the warmth of the space, otherwise that of Type A and low partition brings the inverse effect.

Factor 2 symbolizes the calmness of the space, and mainly semi-glossy finished wall and chroma 4 of the floor spoil the calmness. One interaction is confirmed about factor 2. The combination of the medium height partition and Type B, as shown Figure 2, makes the interior atmospheres noisy.

Factor 3 signifies the clean impression that the space brings. The cool color and glossy-finished partition make the interior atmospheres clean and new. On the contrary, matte-finished wall and high partition make the room unclean, as shown Figure 3. The interactions about factor 3 are not recognized.

3.2 Choice of Behaviors

By factor analysis, three dimensions were extracted; they were named Relaxation, Intelligence and Solitude(Table 4).

Factor 1 includes many company behaviors with close people, but has negative factor loadings like office work or meeting. Factor 2 symbolizes not only the intellectual aspect but also the wholesome amusement. Factor 3 comprehends behaviors that people accomplish alone.

Table 3 Factor analysis in evaluation on atmospheres.

Adjectives	Factor 1	Factor 2	Factor 3
warm	**0.9420**	-0.1814	-0.1543
soft	**0.9389**	-0.1423	-0.1806
feminine	**0.9378**	-0.1623	-0.0673
luxury	**0.8913**	-0.1810	0.2429
convenient	**0.8771**	0.1749	0.3051
favorite	**0.8552**	0.0767	0.3698
calm	**0.6716**	0.4866	0.2780
dark	**0.6339**	0.4379	-0.2773
plain	-0.0736	**0.8049**	-0.0028
quiet	0.3024	**0.7766**	-0.1163
usual	-0.5361	**0.6494**	-0.0485
routine	-0.3987	**0.5033**	-0.0480
clean	0.1615	0.1223	**0.8623**
new	-0.3363	-0.1347	**0.8150**
spacious	0.1615	-0.1351	0.2955
contribution	42.80%	16.83%	13.61%
cumulative contribution	-----------	59.63%	73.24%

Numbers mean factor loadings.

Table 4 Analysis of variance in evaluation on atmospheres.

Factors	Factor 1	Factor 2	Factor 3
A: Illuminant	*		
B: Hue of Wall & Floor		*	*
C: Gloss of Wall		**	*
D: Chroma of Floor		**	
E: Gloss of Floor	**		
F: Hue of Partition			*
G: Gloss of Partition		*	*
H: Height of Partition		*	*
I: Furniture		*	
I × E			
I × H	*	*	

** : very significant, * : significant, × : interaction

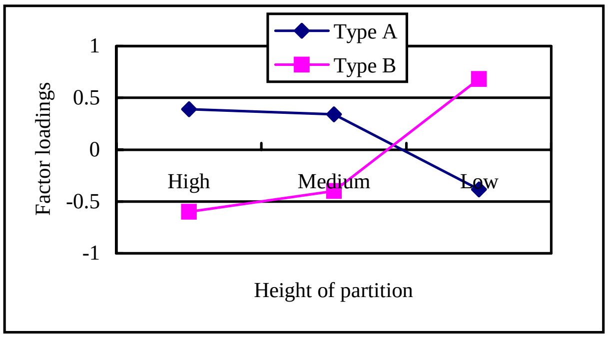

Figure 2 Effects of the interaction in factor 1.

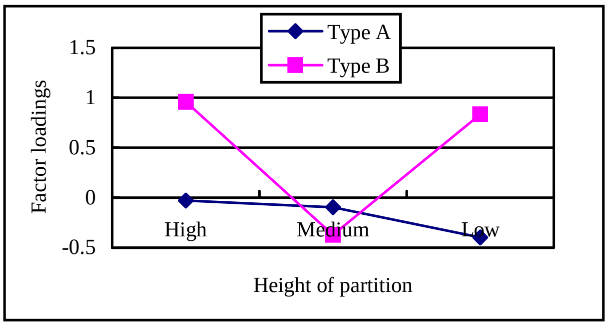

Figure 3 Effects of the interaction in factor 2.

An analysis of variance was carried out, and some main effects and interactions were confirmed in the same way as 3.1.

As for factor 1, it was found that semi-glossy finished floor don't relax people's feeling. Also the interaction between the height of partition and the furniture arrangement was significant. As shown Figure 4, the combination of the low partition and Type B makes people relax, otherwise that of the same low partition and Type A doesn't make people feel at home.

In factor 2, we found that chroma 2 of the floor leads the intellectual behaviors, but don't find the interaction.

As for factor 3, we found that the semi-glossy finished floor and the glossy finished partition were suitable for the behavior such thinking alone.

Compared with the evaluation of atmospheres, we found limited significant factors, so the choice of behaviors was influenced by complicated factors.

Table 5 Factor analysis in the choice of behaviors.

Behaviors	Factor 1	Factor 2	Factor 3
have a meal	**0.9196**	0.0423	-0.1633
spend a time with friend	**0.9148**	-0.2761	0.0011
spend a time with lover	**0.8771**	0.1013	-0.1853
drink	**0.8762**	-0.4045	-0.0640
have a tea	**0.8686**	0.0522	0.0172
do office work	**-0.8563**	0.4485	0.0793
spend a time with family	**0.8367**	-0.1940	0.0553
study	**-0.8317**	0.4682	0.2530
take a seminar	**-0.8169**	0.4857	0.1120
have a party	**0.7698**	-0.4334	-0.0712
listen to the music	**0.7413**	0.1201	0.2881
have a meeting	**-0.7385**	**0.5450**	0.0267
relax	**0.7325**	0.0834	0.3065
take a nap	**0.6802**	-0.2303	**0.5247**
play a game	-0.0650	**0.6662**	-0.2043
paint a picture	-0.1559	**0.6437**	0.3470
read books	**-0.5148**	**0.6141**	0.3726
watch the television	-0.4054	**0.4970**	0.1218
think about something	0.0214	0.0228	**0.7510**
exercise	0.0387	-0.1313	-0.2500
do nothing	-0.0371	-0.0863	-0.0257
contribution	43.96%	17.76%	6.49%
cumulative contribution	----------	61.73%	68.22%

Numbers mean factor loadings.

4 CONCLUSIONS

This study shows the results of the experiment with factors having three levels. Authors can acquire the knowledge on the complex effect by the gloss of finished surfaces in the interior space.

Table 6 Analysis of variance in the choice of behaviors.

Factors	Factor 1	Factor 2	Factor 3
A: Illuminant			
B: Hue of Wall & Floor			
C: Gloss of Wall			
D: Chroma of Floor		*	
E: Gloss of Floor	**		*
F: Hue of Partition			
G: Gloss of Partition			*
H: Height of Partition			
I: Furniture			
I × E			
I × H	*		*

** : very significant, * : significant, × : interaction

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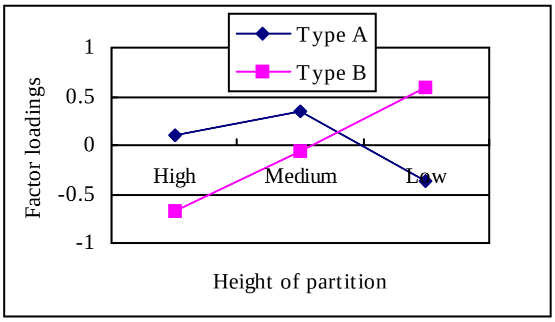

Figure 4 Effects of the interaction in factor 1

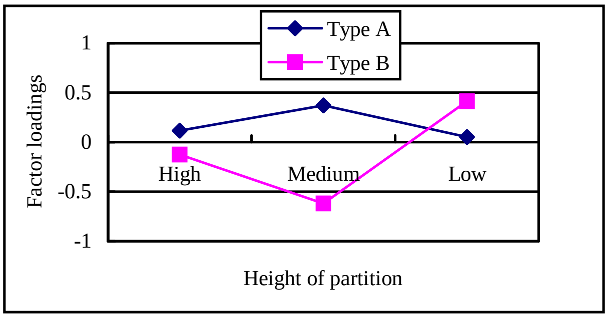

Figure 5 Effects of the interaction in factor 3

A computer system for estimating season reminded from colour

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ABSTRACT

We are reminded of various things and impressions from colours. Seasons such as ‘spring’ and ‘summer’ are one of them. One of the purposes of this study was to investigate the relationship between colour and season, and also to analyze the difference of the colour cognition in two countries. Another was to develop an assisting tool for making coloured products in industry. Actually, in this study, equations for estimating the relationship between colour and season quantitatively were derived, and a computer system applied equations was developed.

Keywords: Season, numerical expression, colour association

1 INTRODUCTION

We associate colours with various things[1] and impressions. Seasons are one of them. Colours are used to express the season in our daily life. Although Japan and Spain both have four seasons, the climate and culture fairly differ from each other. This difference makes different sense of season.

In our previous study[2], a visual experiment was carried out in Japan and Spain. In the experiment, each observer was asked to be reminded of a season from a colour of PCCS 199c colour chip system[3,4]. The seasons judged were five kinds of ‘spring’, ‘summer’, ‘autumn’, ‘winter’ and ‘not reminded’. The observers were asked to choose one of what they felt. For example, ‘dk4: brown’ was reminded of ‘autumn’ by high percentage, and ‘lt2: pink’ was reminded

Table 1 The top 10 of colours reminded four seasons in Japan and Spain, and its percentage

Spring										Summer									
Japan					Spain					Japan					Spain				
Rank	Tone	Hue	%	Col.	Rank	Tone	Hue	%	Col.	Rank	Tone	Hue	%	Col.	Rank	Tone	Hue	%	Col.
1	PI	2	92.86		1	p	12	81.08		1	V	18	88.10		1	V	8	89.47	
2	p	2	88.10		2	p	10	62.16		2	b	18	83.33		2	V	7	83.78	
3	PI	1	88.10		3	p	14	62.16		3	lt	16	79.07		3	V	6	81.08	
4	lt	24	85.71		4	ltg	10	60.00		4	b	16	78.57		4	V	9	74.36	
5	PI	5	85.71		5	p	6	58.97		5	V	17	78.57		5	b	4	73.68	
6	FL	1	78.57		6	lt	2	57.89		6	dp	12	73.81		6	V	5	72.97	
7	lt	2	76.19		7	sf	14	57.89		7	V	12	69.05		7	lt	8	71.79	
8	b	2	74.42		8	PI	2	56.76		8	V	8	66.67		8	V	17	71.05	
9	PI	6	74.42		9	b	24	56.41		9	V	16	66.67		9	b	6	70.27	
10	PI	7	73.81		10	PI	9	56.41		10	p	16	64.29		10	b	8	70.27	

Autumn										Winter									
Japan					Spain					Japan					Spain				
Rank	Tone	Hue	%	Col.	Rank	Tone	Hue	%	Col.	Rank	Tone	Hue	%	Col.	Rank	Tone	Hue	%	Col.
1	dp	6	90.48		1	dp	4	81.08		1	Gy	6.0	76.19		1	Gy	3.5	78.95	
2	d	2	90.48		2	g	10	80.00		2	dk	16	76.19		2	dkg	20	75.00	
3	dp	4	85.71		3	BR	3	79.49		3	Gy	8.5	76.19		3	dkg	18	75.00	
4	d	10	85.71		4	BR	4	74.36		4	p	20	73.81		4	Gy	2.5	72.50	
5	dk	6	85.71		5	dk	8	71.79		5	Gy	8.0	71.43		5	Gy	4.0	71.79	
6	d	4	85.71		6	FL	6	71.05		6	Gy	3.5	71.43		6	Gy	2.0	71.05	
7	dk	4	83.33		7	d	6	71.05		7	Gy	4.0	69.05		7	Bk		70.00	
8	BR	3	83.33		8	dk	2	71.05		8	sf	18	67.44		8	g	18	70.00	
9	FL	6	80.95		9	dk	4	70.00		9	N	6	66.67		9	dkg	8	70.00	
10	d	6	76.19		10	dp	6	69.23		10	Gy	7.5	66.67		10	dk	18	69.23	

of 'spring' in Japan. The number of colour samples was one hundred ninety nine. The observers judged under D65 light condition with using a viewing cabinet. 32 Spanish and 30 Japanese participated in total. Their ages ranged from 18 to 63 years old. Table 1 shows the top 10 colours of four each seasons in two countries.

The raw data in terms of seasons for each colour were counted and calculated the percentages for all the colours of PCCS 199 system. The correlation coefficient between Japan and Spain judgement data was calculated with the percentage of the same colour sample [Table 2]. It was 0.70. The colour reminded from 'spring' was had the highest correlation as 0.81. The correlation coefficients of colour reminded from 'summer', 'autumn' and 'winter' were 0.67, 0.75 and 0.73, respectively. The most influenced factors for each country were mainly hue in Japan, and colour tone in Spain.

Table 2 Correlation coefficient r between Japan and Spain assessment

	Spring	Summer	Autumn	Winter	Total
r	0.80	0.67	0.75	0.73	0.70

Table 3 Correlation coefficient r, slope, and intercept of derived equations

	Season	r	Slope	Intercept
Japan	Spring	0.87	0.82	1.94
	Summer	0.88	1.19	0.30
	Autumn	0.88	1.15	-1.32
	Winter	0.91	1.15	-0.52
Spain	Spring	0.84	0.96	6.47
	Summer	0.90	0.88	-0.37
	Autumn	0.84	1.28	-0.13
	Winter	0.90	0.99	-1.31

2 EQUATIONS FOR PREDICTING SEASON REMINDED FROM COLOUR

2.1 Method

An equation for predicting season reminded from colour is equals to a model of human sense. In this study, we expressed the strength to remind as Colour Emotion Value (CEV) with using the percentage of the replies. Those equations to calculate CEV which are based on CIELAB colour values have been derived. The characteristic of the equations is that the equations have the shape of ellipsoid[5,6]. It is important to determine some parameters of the ellipsoid equation for the derivation, because the parameters contribute for the correspondence of the predicted value by derived equation with the result of visual assessment. In order to obtain higher correspondence, it is essential for equations to have some good relationships with the visual result, which are shown as the followings:

1) Correlation coefficient between result of visual experiment and estimated value from the equation should be close to 1.
2) The slope and intercept of regression line should be close to 1 and 0, respectively.

The ellipsoid equations were insufficient for fitting perfectly to visual results, because the visual assessment values change complicatedly in CIELAB colour space. Then, we tried to derive high performance equations optimizing between visual assessment values and predicted values, through Genetic Algorithm technique.

$$CS_{jpsp} = 0.36\left[35.17(L*-21.39)^2 + 1.49(a*+11.68)^2\right]^{\frac{1}{2}} - 0.89|b*-4.32| - \frac{488.49}{|C*-0.22|+0.09} - \frac{171.47}{|h-78.71|+0.37} - 25.47 \quad (1)$$

$$CS_{jpsm} = \left[2.80(L*+49.89)^2 + 27.66(a*-12.46)^2 + 17.26(b*-22.97)^2\right]^{\frac{1}{2}} - \frac{90.26}{|a*-35.35|+1.28} - \frac{54.35}{|b*-127.79|+0.45} - 235.45 \quad (2)$$

$$CS_{jpat} = 173.46 - \left[15.55(L*-48.27)^2 + 10.44(a*-14.09)^2 + 3.15(b*-44.76)^2\right]^{\frac{1}{2}} - \frac{199.36}{|C*-0.92|+0.01} \quad (3)$$

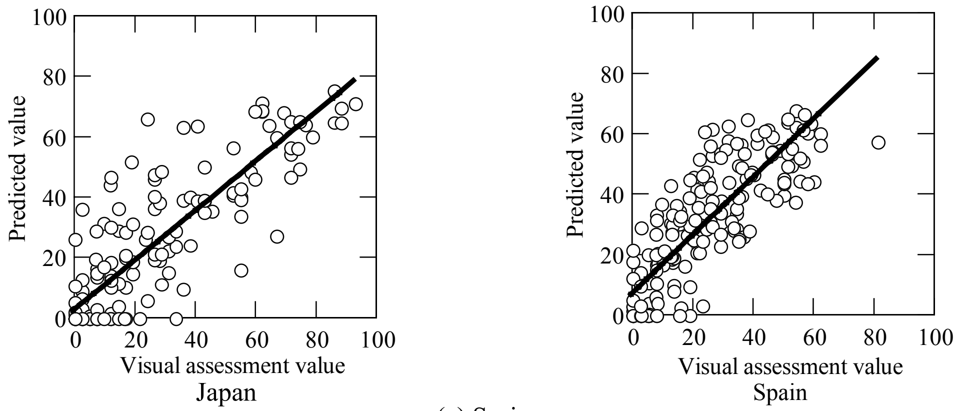
$$CS_{jpwt} = 37.19 - 0.38\left[104.68(L*-83.53)^2 + 217.88(a*+0.63)^2 + 26.59(b*+5.21)^2\right]^{\frac{1}{2}} + 0.62\left[45.56(L*-83.45)^2 + 13.06(C*-32.37)^2\right]^{\frac{1}{2}} \quad (4)$$

$$CS_{essp} = -0.17\left[17.90(L^* + 64.22)^2 + 1.43(a^* + 29.17)^2 + 60.98(b^* + 21.09)^2\right]^{\frac{1}{2}} 7.46 + 0.83\left[6.12(L^* - 178.86) + 16.38(C^* - 44.43)\right] - \frac{14.98}{|C^* + 0.37| + 0.39} + 38 \quad (5)$$

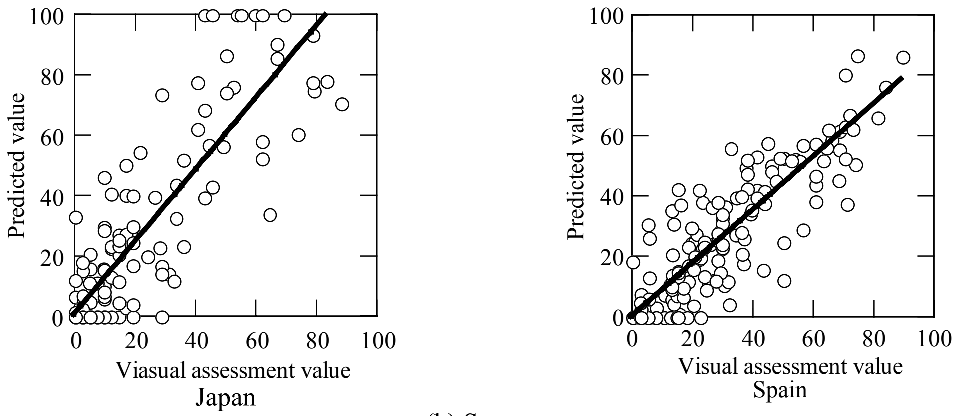
$$CS_{essm} = -0.06\left[10.16(L^* + 95.69)^2 + 28.27(a^* + 88.12)^2 + 170.89(b^* + 57.57)^2\right]^{\frac{1}{2}} + 0.94\left[4.12(L^* - 197.62)^2 + 6.00(C^* - 144.38)^2\right]^{\frac{1}{2}} + 461.42 \quad (6)$$

$$CS_{esat} = -\left[19.97(L^* - 49.98)^2 + 13.42(a^* - 7.36)^2 + 4.46\left(b^* - 30.69\right)^2\right]^{\frac{1}{2}} - \frac{68.80}{|C^* - 0.39| + 0.88} + 166.31 \quad (7)$$

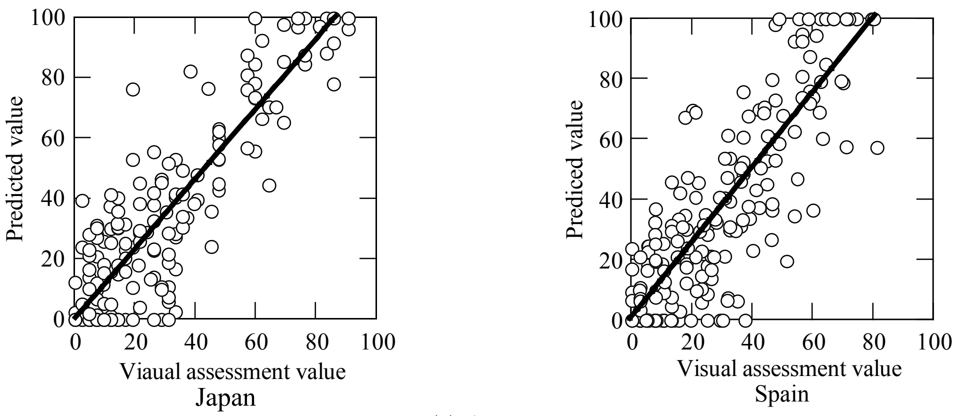
$$CS_{eswt} = -\left[1.51(L^* + 72.55)^2 + 28.91(a^* - 1.52)^2 + 11.60(b^* + 4.71)^2\right]^{\frac{1}{2}} - \frac{69.64}{|C^* + 4.50| + 0.73} + 204.65 \quad (8)$$



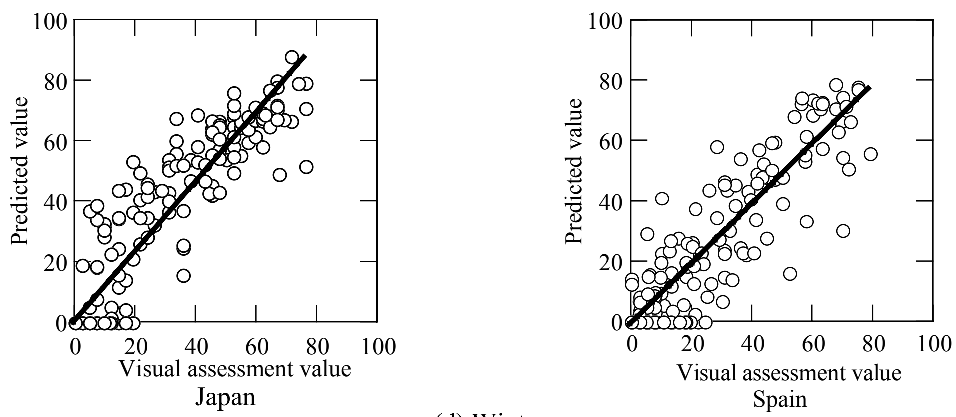
(a) Spring



(b) Summer



(c) Autumn



(d) Winter

Figure 1 Relation between visual assessment value and predicted value

2.2 Result

We derived eights colour-season equations for 'spring', 'summer', 'autumn', 'winter' in Japan and Spain as described below. Equations (1) to (4) are colour-season equations of spring through winter in Japan, and (5) to (8) are equation of spring through winter in Spain. Where CS determine estimated CEV, L* is CIELAB metric lightness, a* and b* are CIELAB metric choromaticness, C* is CIELAB metric chroma, h is CIELAB metric hue angle. The subscripts 'jp' and 'es' express country, 'sp', 'sm', 'at', and 'wt' express four seasons, respectively. Table 3 shows the correlation coefficients r; the slopes and the intercepts of regression line, which were calculated with CEV as the results by visual assessment and estimated CEV by the equations. All the correlation coefficients were over 0.80, the slopes were between 0.8 and 1.3, and the intercepts were between -2 and 7.

The relation between visual percentage and predicted values in each season are shown in Figure 1. As shown in Table 3, those derived colour-season equations could predict precisely. However, big differences between visual and predicted values exist in some colour samples as shown in Figure 1. The biggest differences were 57.1 in summer of Japan and 57.0 in autumn of Japan. The samples, which have caused big difference in summer of Japan and in autumn of Japan, were 'v13: vivid green' and 'dkg8: dark yellowish brown'.

3 COMPUTER SYSTEM FOR ESTIMATING SEASON REMINDED FROM COLOUR

A computer system for estimating season reminded from colour, which is slotted derived colour-season equations, were developed. The software of this system is coded by JAVA language as a java applet program, and it works on a web browser. This feature bring an ability to use this system from anywhere of world by WWW network to users. Figure 2 shows a display interface of the system. On the interface, two cross-sections of colour space are displayed. The cross-section of left hand side is L*-C*, and the right one is a*-b*. Colour values in CIELAB (LCH), RGB, RGB for monitors, XYZ (Yxy), and CEV of a colour are displayed on the right hand side of the interface. Chosen colour is displayed on the low left hand side, and also previous chosen colours are displayed on centre.

When an optional point in a cross-section of colour space is clicked, another cross-section and the values of clicked colour in each colour space are renewed automatically. Bottom part of display interface is also renewed when a user clicks a

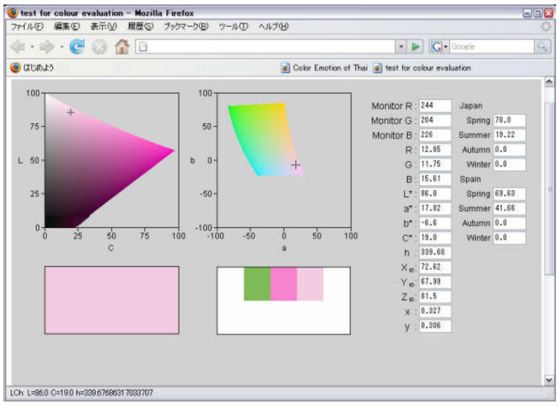


Figure 2 Display interface of the computer season colour system developed in this study

colour on the cross-section. It is able to be operated by inputting value into a cell of right hand side.

4 CONCLUSION

Season reminded from colour is also colour emotion. We totally derived eight equations to predict season reminded from colour in four each seasons of Japan and Spain. And a computer system, which was slotted the derived equations, was developed. The correlation coefficients between visual assessment and predicted values are fairly high, and the equations can predict season reminding precisely. However, actually, some colours have some gaps between result of visual assessment and predicted values. As a further research, it is necessary to improve the precision of equations and versatility of computer system in function for practical use.

ACKNOWLEDGEMENTS

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The contribution of CI colours for the brand identities of companies

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ABSTRACT

The aim of this research is to know how the images which a colour gives customers influence company's construction of their own brand identity. To know that, in this research, there had some questionnaires and a visual assessment, and also collected real CI (Corporate Identity) colour from company web site. With the results of these researches, it was discussed about the relations between company's brand identity and customer's image with colours.

Keywords: Colour marketing, CI colour, Colour association

1 INTRODUCTION

In modern society, there are so many similar products made by numerous companies to choose from that competition between these has become very intense. Establishing brand loyalty and brand recognition is essential to success. A customer will respond to effective adverting, the most important component in overall brand strategy, because this will establish brand image. Since customer's interests and behavior are always changing, it is essential that a firm keep constant attention to the marketplace. There are many ways to construct an effective brand image and certainly one of the most useful is the use of colour. One of the strongest human senses is through our visual system. For many years companies have been so successful in linking a particular colour with their product that a specific colour has frequency become their CI (Corporate Identity) colour.

In this study, we tried to know how the images which a colour gives customers influence company's construction of their own brand identity, through questionnaires and a visual assessment. We also tried to investigate about colorimetric areas of the colours used as CI colour.

2 EXPERIMENTAL

The experimental was divided into three parts as follows:

2.1 Investigation of consumer's colour association: company

To determine the importance of colour to a consumer's image with a company, we utilized a questionnaire (Questionnaire No.1). Eight colours were selected from the Munsell Colour System. They were Red, Yellow, Green, Blue, and Purple as chromatic colours. Black, White, and a Grey were used as achoromatic colours. In the questionnaire, we asked a total of 49 Japanese students ranging in age from 19-25. In another questionnaire (Questionnaire No.2), we asked the same students to indicate which colours they either liked or disliked.

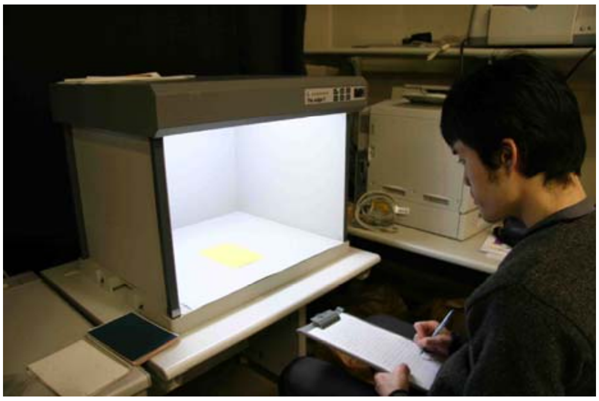

Figure 1 Visual assessment carried out in this study

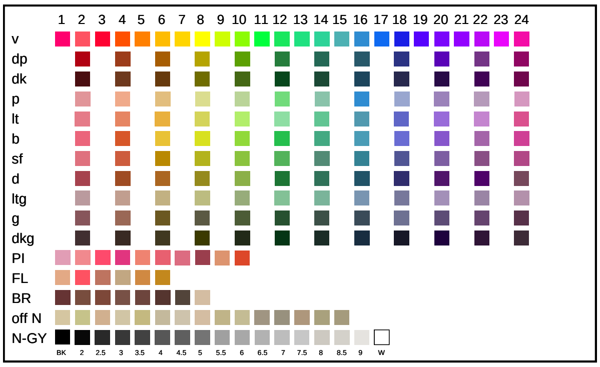

Figure 2 Colour samples used in visual assessment

Table 1 Number of reply for company imaged from every colour

Colour	The number of reply	The percentage of not imaged reply (%)
red	74	1.3
yellow	54	5.6
green	63	9.5
blue	56	4.8
purple	48	43.8
white	50	8.0
grey	50	26.0
black	48	18.8

Table 2 Japanese student's like colour

Rank	Colour	Percentage (%)
1	blue	28.6
2	green	28.6
3	black	26.5
4	red	22.4
5	white	10.2

Table 3 Japanese student's dislike colour

Rank	Colour	Percentage (%)
1	purple	20.4
2	pink	16.3
3	ocher	10.2
4	yellow	8.2
5	vivid-pink	6.1

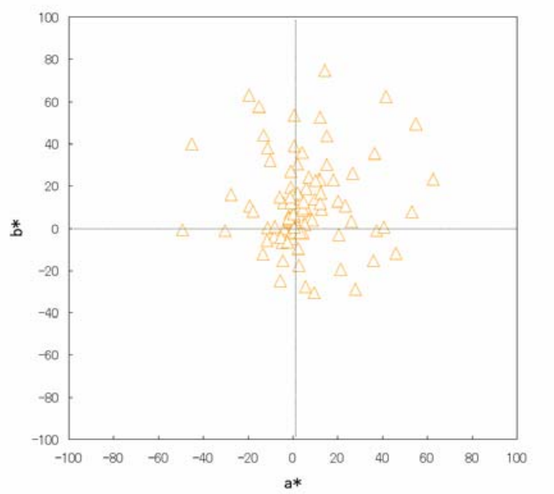

Figure 3 Colour association of paper manufacturing industrial category

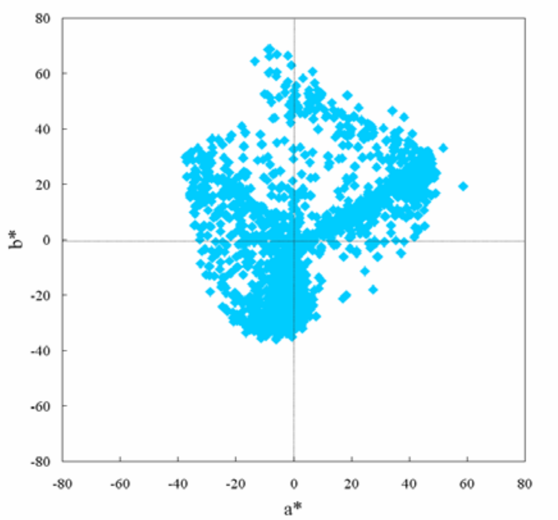

Figure 4 CI colours of Japanese companies

2.2 Investigation of consumer's colour association: industrial category

To make the widest investigation of consumer's colour associations, the third questionnaire (Questionnaire No.3) was used to investigate a consumer's colour association by industrial category. We also investigated a consumer's colour association by visual assessment. After being shown colour samples, participants were asked to visually assess how they identified a specific colour with an industrial category.

The visual assessment was carried out under D65 light source with using a viewing cabinet The Judge II (manufactured by Gretag Macbeth), and a colour sample set PCCS 199c (manufactured by Nihon Shikiken Jigyo) was presented at random to observers. Figures 1 and 2 show the visual assessment and 199 colours used in this visual assessment, respectively.

The participants of Questionnaire No.3 was 50 Japanese students and it of visual assessment was 30 Japanese students, the both ages between19-25

The data obtained from the investigations was compared and analysed. In this assessment, the 1,625 chosen companies were listed in the 1st division of the Tokyo Stock Exchange.

2.3 Measurement of CI colours

The CI colours used by the whole and printing companies were found on material they published on the internet. This information was downloaded and printed out. Then it was measured with a Minolta CM-2002 Spectrophotometer under illuminant D65 using the 10 degree standard observer conditions.

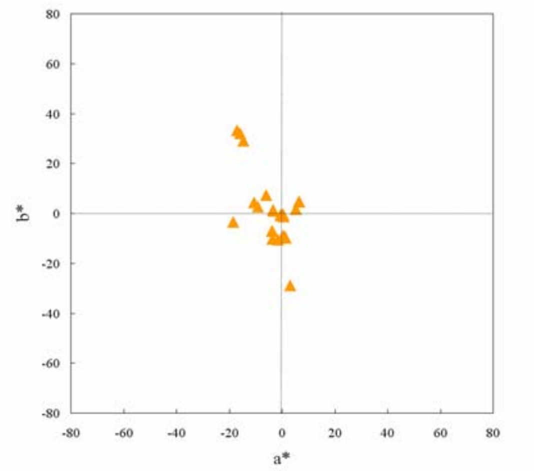

Figure 5 CI colours of paper manufacturing companies

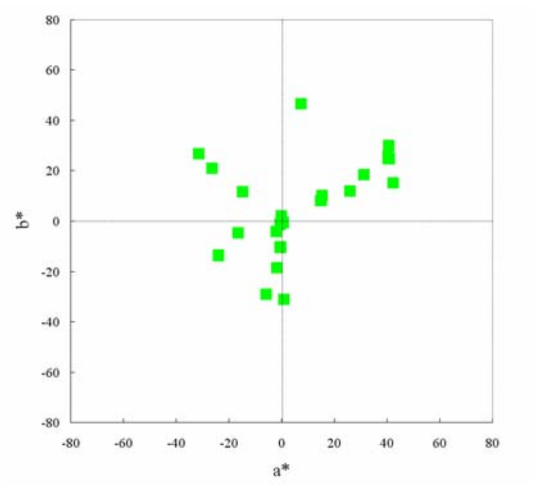

Figure 6 CI colours of paint manufacturing companies

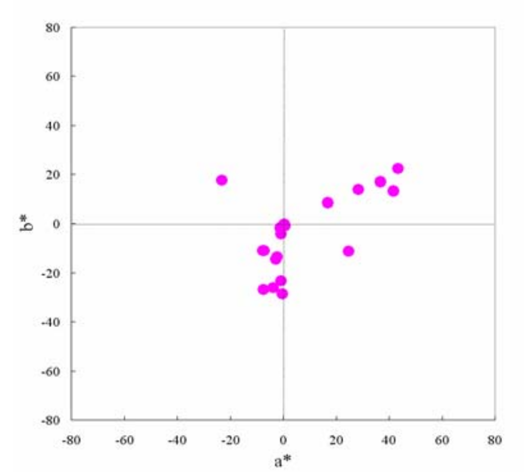

Figure 7 CI colours of printing companies

3 RESULT AND DISCUSSION

From the questionnaires, it was found that companies that used the colour Red were most common whilst Purple was the least popular [Table 1]. It was also found that Blue and Green were most favoured by Japanese students that took part in the survey and Purple and Pink the least preferred [Tables 2 and 3].

Comparing the results of the Questionnaires No.1 and 2, we found there is some relationship between ‘like/dislike’ and imaging. Like colour is easy to image companies, but dislike colour is not so easy. But it needs much data to make sure whether this relationship between them is correct or not.

Figure 3 shows colour association of paper manufacturing industrial category by Questionnaire No.3. Observers associated various colours from the category.

The measurement value of CI colours showed that most Japanese companies used the hue of Red-Orange and Blue [Figure 4]. Purple was used only rarely. These results suggest that there is a relationship between CI colour and national sentiment.

Figures 5, 6 and 7 show the graphic results of the analysis of CI colour coordinates, a*, b*, in paper, paint and printing companies, respectively. That is found that CI colours for paper manufacturing company are in achromatic area, those for paint manufacturing company are various, and those for printing company are mainly in Red, Blue and achromatic areas. This implies that CI colours for each industry category showed be different from another.

This research has enabled us to collect a substantial amount of useful data – information we need to continue our efforts to establish with greater precision the relationship between a consumer’s colour image and the industrial CI. Future research will also enable us to determine whether a company’s brand strategy is succeeding and how it might be improved.

ACKNOWLEDGEMENTS

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The Symbolization of Clothing Color and the Construction of Ethnic Group Culture

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ABSTRACT

The paper discusses the function of communication of clothing color based on the certain culture background and explores the symbolization of color sign from semiology. The information of folk-custom hiding in the deep mind expressed through the symblization is the signified of color language and the object is signifer of semiology. The integration of signifer and signified constructs the complete symbolization system of ethnic costume which is worth to be explored deeply.

Keywords: ethnic group; clothing color; semiology; symbolization; culture

1 INTRODUCTION

To define the color as a language because the color has the function of communication based on the certain culture background, therefore, it has the symbolization of sign. The information of folk-custom hiding in the deep mind expressed through the symblization of color language is the signified .The integration of signifer and signified constructs the complete symbolization system of ethnic costume.

We can see, to the important part of clothing ,the value of clothing color is not just abundant to the world ,meanwhile ,as a non-language communication system, from the semiology, it combines the color with significance and conveys the connotation of ethnic group culture. During the research we can see the clothing color is not only the folk-custom in ethnic society, but also the effect of accumulation of historical culture,which is the indispensible in ethnic group culture.[1]

About the concept of ethnic group, as to Wang Shui-xiong's view, the structure is a relevant mode which people have possessed originally or accumulated during the interaction and other social behavior and have certain regularity or at least have got indentity by a quite quantity of practicers.The construction can be stable in time and space in virtue of substance condition and also can be deepened further to an operable symbol system Therefore , it is not difficult to understand that clothing color exits in the ethnic group as symbol system .

2 THE INDENTITY SYMBOL BETWEEN THE ETHNIC GROUPS

Near the east of Qinghai lake, there is an ethnic group named Tu people wearing "flowery sleeve robe" which is the most characteristic and get identity widely among the ethnic people. At the same time, the "flowery sleeve robe" is also called "multcolored sleeve" .The "flowery sleeve robe" is "xiu su" in Tu's language which is a kind of raglan sleeve sewed together with robe in red ,yellow ,white , black and green and other colors cloth or silk .According to the <the county annals of Datong>: "The women of Tu wear hat, plait hair behind head, wear big earrings made silver or copper .The clothing is multcolored no matter what the clothing makes in cloth or silk…" Obviously, the "multcolored " is the typical feature of Tu's women clothing all the time from of old. The county of Tu has praised "rainbow county". It

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is clear that colors in Tu's clothing are the "signifer" of color language and all of them have respective "signified" that is symbol significance. The black means land, the green represents woods and prairie, yellow means harvest ,white symbolizes the milk and immaculacy and red is the symbol of sun. As to Roland Barthes emphasizes "how the significance come into being" instead of "what the significance is" .The application of color of Tu comes from life practice .Because the ancestors of Tu were nomad and engaged in farm gradually after Yuan dynasty. Hence, the green and white symbolizing the grassland and milk in clothing, which are the embodiment of the life trail.

3 THE DISTINGUISHABLE SYMBOL OF INNER ETHNIC GROUP

The holistic change of natural geographic environment system and subsystem changes directly or indirectly act on the culture factors in humanistic geographic environment and affects the development of culture. Therefore, the regional difference come into being numerous ethnic culture and also take difference inner ethnic group. For instance, the Hui an women, who live in the eastern Huian county of Fujian province, are Han people. They take short coat, loose trousers, charming floral scarf as well as delicate yellow bamboo hat, which make up of local feature style of Hui-an women.

However, the geographic culture divides the inner ethnic group into two systems, one is Dazuo, another is Xiaozuo. They keep the high coherence in style, but the color style is different.The color of Dazuo is elegant and comely, like pearl blue, lilac, pea green while in Xiaozuo the bright color or high saturation, such as scarlet and bright green, forms the hue.

4 THE SYMBOLIZATION OF MYTHIC HISTORY OF ETHNIC GROUP

An ethnic group called "Heiyizhuang" living in Napo County of the western Guangxi, is quite different from others. In China, most ethnic people, especially the south-west area, have colorful clothing, even if there is black which just serves as a foil for other vivid color .While the branch of Zhuang people call themselves "Buzhuang", "Bumin" is famous for their whole black clothing from head to foot. Their scarf is black, coat, skirt, trousers and shoes, all of them are black. Black are the conspicuous sign in this ethnic group. Consequently, they are called "black crow", "black belly". It is considerable which the costume color is just black in colorful ethnic people's clothings.

There is a best-known legend in Heiyizhuang people, which is heroic epic and nearly myth: in ancient age, their ancestors came to a place where was abundant. They worked hard and raised up offspring and enjoyed autarkic life. However, they were aggressed by other ethnic people. A chief named Longlaofa leaded clansman to fight bravely. Unfortunately, he was strong hurt and had to hide in forest, a wild woad cured his hurt miraculously and ralled to beat back enemy and safeguarded homeland finally. Naturally, the chife had hierolatry to the wild woads and called on the whole clansman to wear the black clothing dyed with wild woads. In the legend, black has been taken godhood due to the myteriousness of wild woads and the grandeur of Longlafa, in other words, the myteriousness of wild woads and the grandeue of Longlafa proved the black holiness. From here, black as the signifer of color language, and the wild woads and Longlafa are the signified. As Barthes called the literature as "literature myth" and the significance of myth is translate the history into nature.

Mythe is system of connotation ,that is there is a language symbol system in inner of myth,the effect of double significance makes the signifer and signified complicated. As a symbol, “black” is the signifer of myth system,the signified is “woads and Longlafa”. In the relationship of connotation, corresponding “heavenliness and braveness”. This concept has been inherited to be a spiritual culture of Heiyizhuang people after hundreds years. From semiology, a signified could have several signifers. Barthes argued that the concept of myth is: it has unlimited signifer. He pointed out further: “the view of myth is not fixed, it can be formed and transformed and disassembled and even disappear.”

5 THE DISTINGUISHING OF SOCIAL ROLE

“If we take the symbolization thinking and behaviour as the representative characteristic of humankind life. The ethnic people’s clothings as symbol convey the regularity of identity, state, and hierarchy”. As a part of clothing, color has the symbolization of social role distinguished.

In Tu’s clothing, “multcolored sleeve” , as a kind of Tu’s emblem ,is the sign of identity of ethnic group member .While “wantian” color means the social member different role. The “wantie” is part of trousers edge .The women have got married whose “wantia” is black with blue hem,while the maid is red with white hem. It is easy to realise the marital status.

In Sinkiang, according to Uigur’s traditonal view, when a pair of young man and woman will get married, people pay more attention to whether the women are virgin before marriage. To the woman, she needs something to manifest her behavior according with the traditional criteria. Thus, red based on this background becomes the symbolization of social role transition, which represents the woman obeying the ethic before being a wife.

Therefore, red has double significances, the one represents the woman has been a wife, on the other hand, it can show that the woman’s behavior accords with traditional moral standard. It is obviously that red as a special sign represents the woman be a wife from a maid and is symbolization of getting really significant happiness. It is the same symbolization with the Japanese bride wearing white silk kimono in wedding. The white means the beginning of new life and the terminating of former life. In wedding, the bride should change several suits, firstly she must wear “baiwugou” representing sanctitude and then take off white dress, wearing gold, silver and red color dresses respectively, the last dressing dark color kimono to represent the terminating of her maid age. So, we can see the signified is coherent even though the signifer of color is different.

6 THE SYMBOL OF CULTURE TABOO

As a special folklore item, “taboo” has two meanings, one of them emphasizes the respectable thing could not be used freely, because the thing has holiness and sanctity. To use it optionally is a behaviour of desecration and disobeying the taboo will take doom. Another significance means the restriction of certain behavior by social ethic and is a signal of evading. Dark blue is Tu’s taboo which is showed in all kinds of life or fete ceremony. First of all, the dark blue is endowed with gravity. They believe that it is sacred and can not be infringed. In many ceremonies, people often wear dark blue clothing or this kind hue. In Huzhu area of Qinghai province, the women of Tu all take off the floral sleeve dress and change the dark blue to convey the sobriety when they go to sacrifice montain god in 15^{th} of the first month of lunar year. And the Tu’s girl gets married, there must be a dark blue dress in the marriage portion. This clothing is her grand toilette wearing in all kinds of ceremony. For instance, she must wear the clothing when taking relax after procreating because the woman is not clean and taboo. Moreover, wearing the dark blue clothing transmites another signal which man could not be close to the woman excessively.

7 SYMBOLIZATION OF

clothing in many happy occasions to impetrate safety and luck which is quite obvious in wedding. When getting married, the matchmaker must wear white robe, young men wear white hat and young women like wearing silver ornaments, the wine bottle as gift must tie white sheep fur, all of them are for impetrating happiness.

In many ethnic people's wedding gown, the red or white is dominanted, while the Zhuang's bride, living in the northern Guangdong, wears black clothing and is accompanied by matron dressing black and takes black umbrellar to groom's home. The wedding gown is sewed by the groom relative and send it to bride just before wedding by matchmaker. As to them, it is just black that can represent the happiness.

To the Mongol who adore white color, white sheep, white milk, white Mongolian house which all of them are relative to their life. Hence, white is a color to inspire them to take association to wonderful life, that is happiness of esthetic. Naturally, in folk songs white mother represents kindness and longevity blessing; white man symbolizes the goodness and moral; Hada made in white silk means the most wish to guest.

8 CONCLUSION

Through the exploring above, it is easy to find that the color language abides by a transmission mode, that is the people of society endow certain singnificance with some colors or combination

AUSPICIOUS AND ESTHETICS

Almost in most ethnic culture structure, it can be found everywhere the auspicious and blessing can be conveyed through color symbol. Especially, in some special situations or ceremony. White is a symbol of propitious in Tu's mind, therefore, they like wearing white

of color, and the other people can understand .This is a process of coding and decoding in semiology, is also a process of integrating of signifer and signified, as well as a process from the phenomena to nature. It conveys connotation of the heavy history, unique esthetic, complex totem adoration and auspicious wish with simple colors which forms the complete color symbol system and riches the ethnic clothing culture. As the important part of ethnic culture, the symbolization significance is worth to explore and research further.

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The effects of stimuli sizes on colour appearance for unrelated colour under photopic and mesopic vision

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ABSTRACT

This study investigates the change of colour appearance between different sizes of unrelated colours under different luminance levels. Six phases of psychophysical experiments were conducted to obtain visual data assessed by a panel of observers. The viewing conditions studied included two stimuli sizes (0.5° and 10°) and three luminance levels (60, 5 and 1 cd/m^2). It was found that colours in general appear brighter and more colourful for 10° stimuli than those for 0.5° stimuli. Under lower luminance levels, 5 and 1 cd/m^2, the colourfulness was similar between the two different stimuli sizes studied.

Keywords: unrelated colour, stimuli size, photopic vision, mesopic vision

1. INTRODUCTION

A colour stimulus could be viewed in isolation or in a complex field. The objects viewed in the latter are known as 'related' colours[1], which is defined as "colours perceived to belong to areas seen in relation to other colours"[1]. On the other hand, an unrelated colour[1] is perceived by itself, which is isolated from any other colours. Typical examples of unrelated colours are signal lights or traffic lights viewed on a dark night[1].

Colour appearance models have been developed to predict the colour appearance under different viewing conditions such as different illuminants, luminances, background colours, surround conditions[2]. Many previous studies investigated the related colours or to model the visual results based on related colours. However, Fairchild[3] highlighted that "the distinction between related and unrelated colour is critical for a firm understanding of colour appearance". The studies about unrelated colours could provide the foundations for understanding colour vision.

It is well known that the human eye has two kinds of retinal photoreceptors, the rods and the cones. They are not uniformly distributed on the retina. Outside the foveola, the light receptors are cones and rods; inside the foveola, only cones. The area beyond about 40° from the visual axis, there are nearly all rods and very few cones[1].

Normally an unrelated colour is seen in a dark field. The function of the rods is to provide monochromatic vision under low luminance levels. This scotopic vision[1] is in operation when only rods are active, and the luminance level of stimuli is less than some hundredths of a cd/m^2. Between this level and a few cd/m^2, vision involves a mixture of rod and cone activities, which is referred to as mesopic vision[1]. It requires luminances of at least several cd/m^2 for photopic vision[1] in which only cones are active.

Although Kwak[4] has done some studies for related colours with 2° and 10° viewing fields under mesopic vision. She concluded that it is insufficient to predict colour appearance simply using different colour matching functions. Hence, in this study, particularly effort was paid to the investigation unrelated colours using different sizes of stimuli under photopic and mesopic vision.

2. EXPERIMENTAL CONDITIONS

The viewing conditions investigated in this study include two different stimuli sizes (0.5° and 10°) and three luminance levels ranged from 60 to 1cd/m^2. Table 1 summarises the viewing conditions in the six phases studied.

Table 1: Experimental phases

Phase	Luminance of Yw cd/m^2	Viewing angle of stimuli	Filter name
1	60	0.5	0
2	(photopic)	10	
3	5	0.5	1
4	(mesopic)	10	
5	1	0.5	2
6	(mesopic)	10	

A 24-bit CRT monitor was used to display colour stimuli. It was set at a correlated colour temperature of 6500K with a luminance of peak white at 60 cd/m^2. The monitor was carefully characterised using the GOG (gain-offset-gamma) model[5].

Fifty test colour patches were carefully selected to cover a wide colour gamut and brightness range. These colours were displayed on the full CRT screen in a darken room. A piece of black cardboard with a hole in the middle was used to mask the rest of screen. Figure1 illustrates the viewing field with different stimuli sizes.

Figure 1: The experimental viewing fields: (Left) 0.5° stimuli and (right) 10° stimuli.

The desired luminance level was achieved using three neutral density filters (named 0, 1 and 2 in Table 1). The filters were used to cover the test colour (the hole in the middle). Figure 2 shows all the test colours in CIELAB a*b* plane. They covered a large colour area. Note that each colour was measured using a Minolta CS1000 tele-spectroradiometer (TSR).

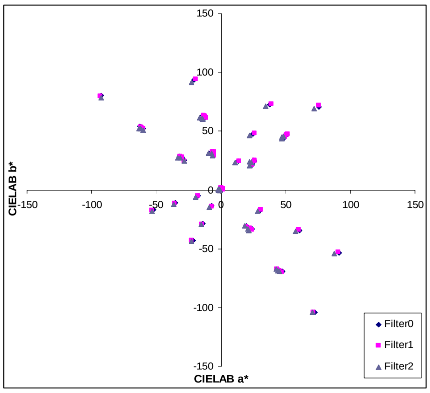

Figure 2: Distribution of test colours in CIELAB a*b* plane.

Psychophysical experiments were conducted to obtain visual data by 9 normal colour vision observers using the magnitude estimation method[6]. The three colour appearance attributes were applied to scale colour appearance for all phases: brightness, colourfulness and hue. The other two commonly used attributes, lightness and chroma, are 'relative' perceptual attributes of colours. These attributes do not apply to unrelated colours which do not include the reference samples such as reference white in the viewing field.

A sample having colourfulness of 40 and a brightness of 100 was assigned as the anchoring colour for scaling these two attributes. Observers were asked to memorise this reference colour viewed in a viewing cabinet before conducting the experiment.

It is important for observers to adapt fully under dark adaptation, which occurs when the level of illumination is decreased. In this study, the experiment was conducted in a completely dark room with 20 minutes for adaptation before starting the experiment.

3. RESULT AND DISCUSSION

3.1 Observer Variation

The magnitude estimation data were collected and the Coefficient of Variation (CV) given in equation (1) was used to indicate the agreement between any two sets of data. For a perfect agreement, CV should be zero. The larger the CV value, the poorer the agreement is.

$$CV = 100\frac{\sqrt{\sum (x_i - y_i)^2 / n}}{\bar{y}} \quad (1)$$

where x_i and y_i are the *i* samples in the x and y data sets; *n* is the number of samples; $\bar{y}$ is the mean of the y data set.

For the three colour appearance attributes studied, CV values were calculated between each individual observer's and the mean visual results, and between observer's results with two repeats, to represent the performance of observer accuracy and repeatability, respectively. The results of observer repeatability and accuracy are summarised in Table 2 in terms of mean CV values for brightness, coloufulness and hue, respectively.

The results of observer accuracy and repeatability are summarised in Table 2 in terms of mean CV values for brightness, coloufulness and hue attributes, respectively.

Table 2: The performance of observer variation

Accuracy		60 cd/m²	5 cd/m	1 cd/m	Mean
0.5	B	28	34	40	34
	C	48	48	44	47
	H	13	15	13	14
10	B	29	36	38	34
	C	39	43	37	40
	H	17	15	15	16

Repeatability		60 cd/m²	5 cd/m	1 cd/m	Mean
0.5	B	15	18	20	18
	C	26	17	29	24
	H	5	5	9	6
10	B	15	18	15	16
	C	21	17	27	22
	H	6	7	7	7

In Table 2, it can be seen in Table 2 that for assessing colour appearance under unrelated viewing conditions, observer repeatability performance is almost twice as good as that of observer accuracy.

For observer accuracy results, there are larger CV values for assessing brightness in the low luminance-level phases for both stimuli size. This implies that observers are more accurate under the high than low luminance levels. The difference between two stimuli sizes at the same luminance level was not obvious. For colourfulness, a poorer accuracy was shown with lower luminance and smaller field size stimuli.

The results of hue attribute are similar with six phases. The above trend can also be found in the observer repeatability results, i.e. observers are more accurate for assessing colours under a higher luminance level and a larger physical size.

3.2 Effects of luminance level of stimuli

The change of colour appearance of a colour due to different luminance levels is investigated in this section. The comparisons were made between different phases with different luminance levels of stimuli. The results from each phase were plotted against each other. The more scatter of the points, the poorer the agreement is.

The results of 0.5° and 10° stimuli are summarised in Figure 3-1 and Figure 3-2, respectively. It was found that a similar trend is shown for two size stimuli, i.e. colours appear brighter and more colourful at higher luminance level than at lower luminance level. There is hardly any change in hue.

The disagreements between each pair of phases are also given in Table 3 in terms of CV values. Similar results can be found that in the same comparison between high and low luminance phases, the difference between different viewing sizes was not obvious. The larger the difference between luminance levels, the larger CV value will be.

Table 3: Comparisons of six phases with different luminance levels in terms of CV value.

Lw	Viewing angle	B	C	H
60 vs 5	0.5	44	36	7
	10	49	39	6
60 vs 1	0.5	63	50	12
	10	64	53	7
5 vs 1	0.5	34	27	8
	10	27	24	6

X: P3 (5) Y: P1 (60) X: P5 (1) Y: P1 (60) X: P5 (1) Y: P3 (5)

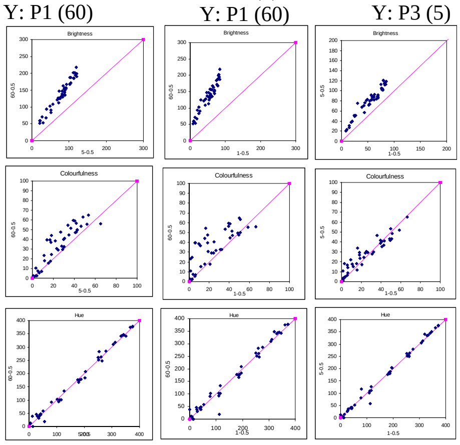

Fig. 3-1: Comparisons of mean brightness (top), colourfulness (middle) and hue (bottom) visual results between three pairs of phases. The number in bracket is the luminance level in cd/m^2 unit. All samples had the same size stimuli, 0.5°.

X: P4 (5) Y: P2 (60) X: P6 (1) Y: P2 (60) X: P6 (1) Y: P4 (5)

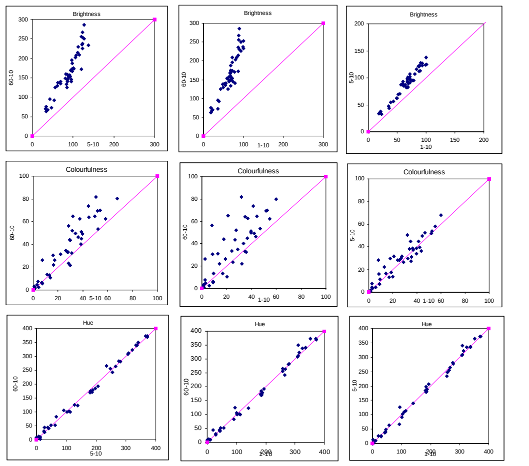

Fig. 3-2: Comparisons of mean brightness (top), colourfulness (middle) and hue (bottom) visual results between three pairs of phases. The number in bracket is the luminance level in cd/m^2 unit. All samples had the same size stimuli, 10°.

3.3 Effects of size of stimuli

The change of colour appearance of a colour due to different sizes of stimulus is investigated in this section. Two different size of stimuli, 0.5° and 10°, were compared. For the phases having same luminance level, the visual results of 0.5° stimuli are plotted against those of the 10° stimuli as shown in Figure 4. The CV value for each pair of the phases compared is summarised in Table 4.

It can be seen, for hue attribute, differences in colour appearance between each of the comparisons were small.

X: P2-10° Y: P1-0.5° X: P4-10° Y: P3-0.5° X: P6-10° Y: P5-0.5°

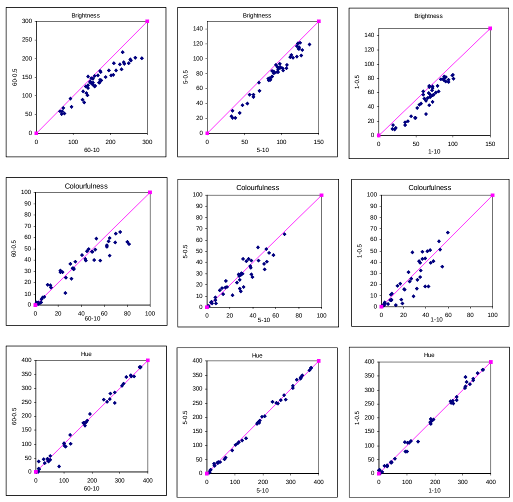

Fig. 4: Comparisons of mean visual results for brightness (top), colourfulness (middle) and hue (bottom) between three pairs of phases. The number after a hyphen is the viewing angle of stimuli, 0.5° (ordinate) and 10° (abscissa).

Table 4: Comparisons of 0.5° and 10° mean visual results in terms of CV value.

Lw	B	C	H
60 (P1 vs P2)	21	26	9
5(P3 vs P4)	13	26	4
1(P5 vs P6)	22	39	7

Comparing brightness results in Figure 4, all larger size (10^o) colours appear brighter than smaller size (0.5^o) colours. Figure 4 also shows that most of larger size (10^o) colours appear more colourful than smaller size (0.5^o) colours. This effect is mostly marked between Phases 5 and 6, both having very low luminance level, 1 cd/m^2.

4. CONCLUSIONS

Six phases of experiments were conducted to investigate the change of colour appearance due to different sizes and different luminance levels for unrelated colours. The results are summarised below:

- Observer accuracy improves from low to high luminance levels. Observer is also more accurate for assessing larger stimuli than smaller stimuli.
- Observer accuracy performance is about 200% better than that of observer repeatability for assessing unrelated colours.
- When luminance level increases, colours become brighter and more colourful.
- All larger size colours appear brighter and more colourful than smaller size colours.
- Hue perception is most consistent, i.e. do not change according to the viewing parameters studied here.

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Contrast effect of colors and textures

Part 1: Subjective contrast of the visual difference between chromatic patch and the background of N7

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ABSTRACT

This research aimed at understanding the contrast effect of surface color and texture used for living environments. We define the subjective contrast as the subjective and comprehensive differences between a patch and its background. We carried out an experiment in which subjects selected the combination of an achromatic patch and achromatic background that had the same visual differences as a test patch and its background. The results clarified the relation between subjective contrast and surface color. Subjective contrast is high with higher Munsell value and chroma.

Keywords: Contrast effect, Subjective contrast, Chromatic color, Achromatic color, Equivalent luminance contrast

1 INTRODUCTION

1.1 Subjective contrast based on the surface appearance

The visual differences between a patch and its background are based on factors such as surface texture and color, and the lighting environment.

A color specification and color measurement system is established to describe surface color with a numerical value. However, perceived color cannot be expressed yet. Even if two measured colors are the same, the perceived color may differ according to the target size and adjacent colors.

There is not specification for describing surface textures. As with color, even if surface textures are the same, appearance differs with target size and in combination with adjacent textures.

Both perceived color and texture are influenced by surrounding surfaces so that the contrast effect of colors and textures exists. Their contrast effects have to be finally integrated to apply them to the real surface.

This research focuses on understanding the contrast effect on surface color and texture. We define subjective contrast as the subjective and comprehensive differences between a visual target and its background. Part 1 discusses the relation between subjective contrast and the color combinations of targets and backgrounds. Part 2 reports on the relationship between the subjective contrast of textures and the position of light source.

1.2 Subjective contrast for color combination

We consider the subjective contrast of a color combination can be determined by an equivalent luminance contrast. This is the contrast of an achromatic patch and achromatic background that provides the same visual differences. The equivalent luminance contrast is the contrast of an achromatic target and its achromatic background.

We established the relationship between color combinations and their equivalent luminance contrasts.

2 METHODS

Subjects were asked to select a reference target with the same visual differences as the test target. The test target consisted of a chromatic patch and achromatic background. The reference target consisted of an achromatic patch and its

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achromatic background. The backgrounds of the test and reference targets were same as N7.0.

Fig. 1 shows the apparatus.

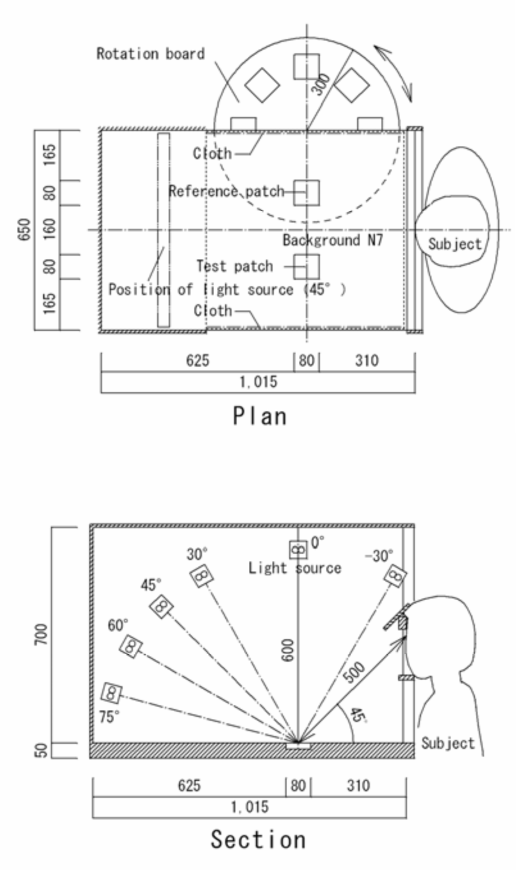


Figure 1. Apparatus

The finishes of the walls and ceiling in the apparatus were black or gray (N7) according to the conditions, but for this experiment they were gray (N7). Test targets were on the left and the reference targets on the right. All had matt surfaces and the patches were the same sizes as 80 x 80 mm squares, located at a visual distance of about 50 cm. The reference patches were arranged on a rotating board that allowed the subject to select the reference patches one by one.

Fluorescent light with a color temperature of 5000K illuminated the targets with an average luminance of about 500 lx. The light source could be positioned at 0°, 30°, 45°, 60° and 75°, but it was fixed at 0° for this experiment.

Test target colors (shown in Table.1) were selected systematically based on Munsell hue, value and chroma. Patch hues were 5R, 5Y, 5G, 5B and 5P. Patch values were 3, 5 and 7. And patch chromas were 2, 4, 6 and 8. There were 45 colors, plus two achromatic colors, 6 safety colors and 6 material colors. The material colors were made for the same colors as the materials. Total number of test patches was 59 colors.

Table 1. The colors of the test patches

Chromatic colors (45)			Achromatic colors (2)
Hue	Value	Chroma	N3.0, N5.0
5R	3	2, 4, 5.24	Safety colors (6)
	5	2, 4, 6, 8	10G4/6.5 :Safety
	7	2, 4, 6, 8	2.5PB3.5/8 :Caution
5Y	3	1.74	2.5RP4/7 :Radioactive
	5	2, 4, 6	7.5R4/11 :Stop
	7	2, 4, 6, 8	2.5Y8/13.5 :Attention
5G	3	2, 3.24	2.5YR6/13 :Danger
	5	2, 4, 6, 8	
	7	2, 4, 6, 7.56	Material colors (6)
5B	3	2, 3.5	7.5Y9/1 :Fabric wall paper(matt)
	5	2, 4, 6	5Y9/1 :Vinyl wall paper(smooth)
	7	2, 4, 6	10YR8/4 :Printed finish veneer(ceder)
5P	3	2, 4	7.5YR6/6 :Plywood(teak, light)
	5	2, 4, 6	7.5YR5/6 :Plywood(teak, dark)
	7	2, 4, 6	5YR5/4 :Brick tile

As reference targets 10 achromatic colors in the range from N2.5 to N7.0 served.

There were 14 subjects with normal color vision, aged about 20 years old. After they adapted themselves to the brightness in the apparatus for 5 minutes, they turned the rotation board by themselves, and selected the reference target which has the equivalent visual difference of test target. Each subject made three attempts per condition.

3 RESULTS

Using five hues selected systematically, we considered the relation between subjective contrast and difference of Munsell value or chroma for each Munsell hue.

3.1 Relation between difference (ΔVt) and equivalent difference (ΔVe) in Mu nsell value

Fig. 2 shows, for the subject IM, the relation between the difference in the Munsell value of a test target (ΔVt) and the equivalent difference in the Munsell Value of test target (ΔVe) under each difference of Munsell chroma with the hue of 5R and the achromatic color as chroma 0. The void and filled symbols in Fig.2 indicate the raw and averaged values of ΔVe respectively. The dotted line shows ΔVt .

Fig.2-1 shows that ΔVe with a constant differrence in Munsell chroma is high with higher ΔVt.

Fig.2-2 shows the relation between ΔVt and the averaged ΔVe about each difference in Munsell chroma. With a constant ΔVt, ΔVe is high with difference in Munsell chroma being large. The smaller ΔVt is, the larger the increase of ΔVe to ΔVt is.

3.2 Relation between luminance contrast (Ce) and equivalent luminance contrast (Ct)

Fig. 3 shows, for the subject IM, the relation between luminance contrast of the test target (Ct) and equivalent luminance contrast of the test target (Ce) under each difference of Munsell chroma with the hue of 5R and the achromatic color. The luminance contrast was calculated using the reflectance referred to the formula of JIS Z 8721, because there was little difference between the calculated luminance contrast and the luminance contrast measured by the luminance meter.

The void and filled symbols in Fig.3 indicate the raw and averaged values of Ce respectively. The dotted line shows Ct.

Fig.3-1 shows that Ce with a constant difference in Munsell chroma is high with higher Ct.

Fig.3-2 shows the relation between Ct and the averaged Ce about each difference in Munsell chroma. With a constant Ct, Ce is high with higher difference in Munsell chroma. The smaller Ct is, the larger the increase of Ce to Ct is.

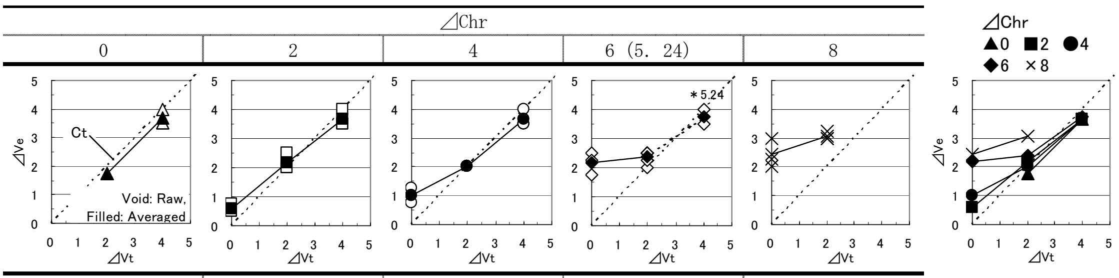
The tendencies are similar even if using Ce shown in Fig.3, and ΔVe shown in Fig. 2.

Fig.4-1 shows, for all subjects, the relation between Ct and the averaged Ce under each difference in Munsell chroma with the hue of 5R and the achromatic color. It shows also the 20th, the 50th and the 80th percentile values of the Ce averaged for each subject by the solid line.

Fig.4-2 shows that the relation between Ct and 50th percentile values of Ce about each difference in Munsell chroma. The tendencies shown in Fig. 4-2 by the 50th percentile values were similar with that shown in Fig.3-2 by the averaged Ce of subject IM.

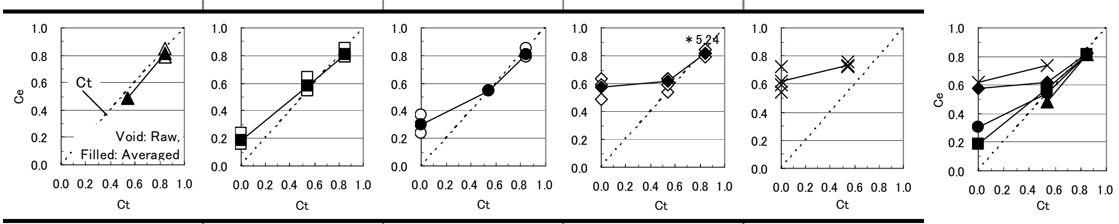
The percentile values represent well the averaged values. Therefore, in the following consideration, the 50th percentile value is used as a representative value Ce^{50th} .

Fig.5 shows the relation between Ct and Ce^{50th} of the five hues about each difference in Munsell chroma. The tendencies for hue of 5Y, 5G, 5B and 5P are similar tendency to that of 5R shown in Fig. 4-2.



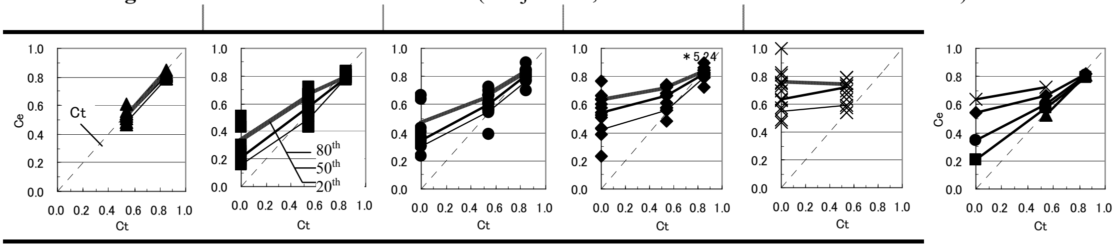
1) Under each ΔC_{hr} 2) Under all ΔC_{hr}

Figure 2. Relation between ΔVt and ΔVe (Subject IM, The hue of 5R and achromatic colors)



1) Under each ΔC_{hr} 2) Under all ΔC_{hr}

Figure 3. Relation between Ct and Ce (Subject IM, The hue of 5R and achromatic colors)



1) Under each ΔC_{hr} 2) Under all ΔC_{hr}

Figure 4. Relation between Ct and Ce (All subjects, The hue of 5R and achromatic colors)

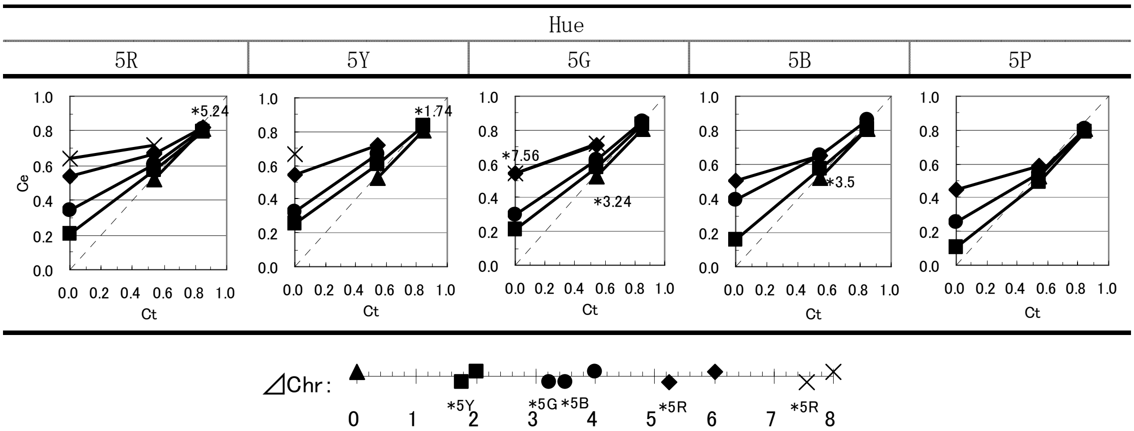


Figure 5. Relation between Ct and Ce^{50th} (The hues of 5R, 5Y, 5G, 5B and 5P, and achromatic colors)

3.3 Relation between difference in Munsell chroma (ΔC_{hr}) and equivalent luminance contrast (Ce^{50th})

Fig.6 shows the relation between the difference in the Munsell chroma (ΔC_{hr}) and Ce^{50th} of each hue under each Ct.

For all hues Ce^{50th} is high with higher ΔC_{hr}. The increase of Ce^{50th} with ΔC_{hr} is different with Ct. The lower Ct is, the larger the increase of Ce^{50th} is. For Ct of 0.85, there are no difference of Ce^{50th} with ΔC_{hr}, and Ce^{50th} is the almost same as Ct shown in Fig.6 as the dotted line.

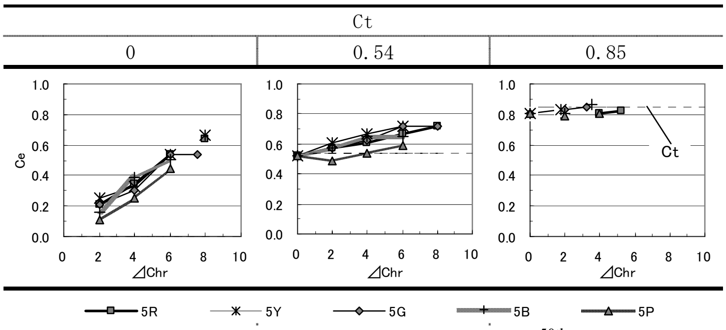


Figure 6. Relation between ⊿Chr and Ce^{50th}

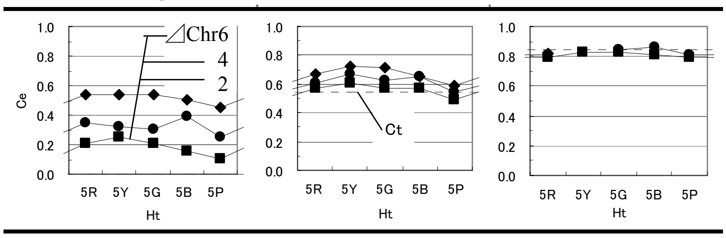


Figure 7. Ce^{50th} of H_t

3.4 Equivalent luminance contrast (Ce^{50th}) of Munsell hues (H_t)

Fig.7 shows Ce^{50th} of Munsell hue of test target (H_t) for each ΔC_{hr} under each Ct. There is little difference of Ce^{50th} with H_t.

4 CONCLUSIONS

It appears as mentioned above that the subjective contrast between a chromatic patch and its achromatic background can be represented by reference to the luminance contrast between an achromatic patch and its achromatic background.

ACKNOWLEDGMENTS

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Contrast effect of colors and textures

Part 2: Variation on subjective contrast of textures along with incident angle

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ABSTRACT

This investigation aims to gain a basic understanding on contrast effect of color and appearance used for living environment. We define the substantial contrast as an extent of subjective and comprehensive variation between a visual target and its back ground. In this report, we tried to clarify the relations between the subjective contrast and the incident angle. The results show that the relations between subjective contrast and the incident angle fall into 3 types.

Keywords: Subjective contrast, Texture, Color, Interior material, Incident angle of light

1 INTRODUCTION

It is thought that subjective visual texture of the material mainly causes the texture and the color as the attribute of its surfaces, additionally the lighting environment and the forecast of the tactile impression compose the subjective visual texture. The color system and the colorimetry method corresponding to it are established, and the color can be described as information. The color appearance is denoted by using the color system and the colorimetry method, and also the color area effect and contrast effect can be described. Meanwhile, the method for describing the texture objectively and simply has not been established to this yet.

However, it is suggested that there be a contrast effect and an area effect also in the texture1) as well as the color, and is thought that the contrast effect and the area effect of the texture can be described by the method used for the color experiment.

This research has aimed to obtain a basic finding concerning the visual contrast effect about the finishing material with various colors and the surface shape used for the living environment. In this research, the subjective contrast is defined, "Content of the effect of the adaptation level, and subjective overall difference of the visual target and its background"2)3). It is thought that the contrast effect arising from the combination of two colors or the combination of two textures can be expressed by using the subjective contrast.

Followed by Part.1, this Part.2 aims to understand the subjective contrast of the texture of various interior materials by applying the method commonly used in the experiment on the color contrast effect. In addition, it reports on the relation between the subjective contrast and the angle of incidence of light.

2 METHOD

It experimented by selecting the reference target to become equivalent to the subjective contrast of the test target. The test specimen consisted of the interior material and its achromatic N7.0 (matt finish) backgrounds of 80×80mm. The reference target that consisted of reference target and its achromatic N7.0 backgrounds (matt finish) of 80×80mm appeared according to the rotation of the rotation board.

The experiment device was same as Part.1. The floor where evaluation material and reference target were put was assumed to be N7.0 (matt finish), and the wall and the ceiling were assumed to be N7 or a black according to the condition. The illuminance on the targets was assumed to be about 500lx by using one fluorescent lamp (5000K) for the light source. The light source was made to come to the position of 0°, 30°, 45°, 60°, and 75°. The test subject was fixed the positions of eyes was to the position of -45° as the normal of the specimen was 0°. So as not to see the light source directly from the test subject, eaves in the upper part of the test subject have been adjusted.

The test materials were ten kinds of the

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interior materials with a peculiar color and six material colors (hereafter, material color) made for the same color as the five materials. Reference target was assumed to be the achromatic color chart of Munsell value of N2.5 from N7.0.

After the test subject had been made to adapt oneself by about five minutes by the jaw stand of the experiment device, it was instructed, "Please move the rotation board and select one reference target so that the level of the comprehensive difference between the left material and its background and the level of comprehensive difference between the right reference target and its background may become the same". The test subjects were 5 of the twenty-twenty vision, and it experimented three times of each test subject. It experimented on February, 17th through March, 2nd, 2005.

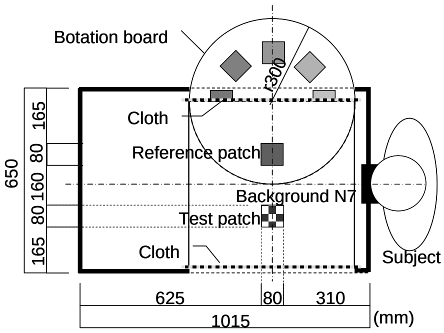

Fig. 1 experimental apparatus (plan)

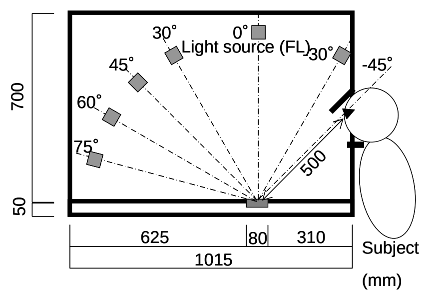

Fig.2 experimental apparatus (section)

3 RESULTS AND DISCUSSION

It was evaluated for most samples in a range of a two reference scales. And some specimens were evaluated over the feeling of subjective contrast used as reference target. The samples which subjects could not evaluate in range of the presented reference target were observed commonly.

Table 1. Interior materials and colors for specimen

Interior materials	Material colors
Vinyl wall paper (smooth)	5Y9/1
Vinyl wall paper (smooth embossed)	
Vinyl wall paper (rough embossed)	
Vinyl wall paper (stucco-like embossed)	
Vinyl wall paper (fabric-like embossed)	
Vinyl wall paper (marble pattern)	
Vinyl wall paper (granite pattern)	
Vinyl wall paper (concrete pattern)	
Printed finish veneer (ceder)	10YR8/4
Printed finish veneer (teak)	
Printed finish veneer (walnut)	
Plywood (teak)	(Light) 7.5YR6/6
	(Dark) 7.5YR5/6
Fabric wall paper (matt)	7.5Y9/1
Fabric wall paper (sheen)	
Loop carpet	
Cut carpet	
Cork	
Brick tile	5YR5/4
Porcelain tile	

3.1 Comparison between interior materials and its same colored patch

Fig. 3 shows the comparison between interior finish material sample and its same colored patch (material color) with the difference of a test target from its background (N7) in Munsell Value. Both figures show the mean of three times of trials. An incidence angle is 45 degrees. As for subject TK, there are several answers that do not appear in a graph from what TK evaluated over the range of presented reference target.

Subjective contrast for material samples were evaluated in larger range than that of material color samples. It had expected that material samples were higher in a subjective contrast than material color patch, because materials were rough than material color patch. As a result of experiment, However, subjective contrast of materials was evaluated whichever over high side and low side of material color evaluation.

Though a vinyl wall paper (smooth) had smooth surface and little sheen, it was evaluated comparatively higher side than its same material color patch with all subjects. There were the case that material color patch had bigger subjective contrast than material sample with bumpy texture, for example, brick tile

The subjective contrast of material color can be explained with the Munsell Hue / Value / Chroma as had spoken in Part1, but it is thought that the subjective contrast of materials should be explained by its surface property of materials.

3.2 Variation of subjective contrast along with incidence angle of light

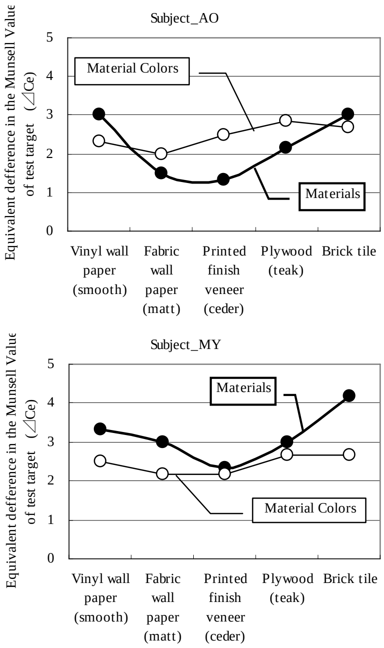

Fig. 3 Comparison between interior materials and its same colored patch

1) Variation caused by surface roughness

By comparison vinyl wall paper smooth embossed and rough embossed, subjective contrast that each subject evaluated did not have a size difference at incidence angle 0-45 degree. There were subject (AO, MY) which judged subjective contrast to be big at 60 degrees and 75 degrees than 0-45 degrees and subject (MZ, TK) to judge to be small for this. This difference was more remarkable in rough embossed than smooth embossed.

Rough embossed has both area bumpy and flat texture, and the flat area is bigger than smooth embossed. Accordingly, rough embossed has a specular reflection in incident angle 60-75 degrees. It is thought that the individual variation of subjective contrast in incident angle 60-75 degrees is caused by the point of evaluation either the shadow in bumpy area or the specular reflection in flat area.

2) Variation caused by surface gloss

There was a tendency that subjective contrast of fabric wall paper (sheen) was bigger than that of (matt). The reason was thought that sheen spread on its whole surface caused bigger subjective contrast than matt wall paper. A similar thing applied to a loop carpet and a cut carpet.

3) Variation caused by pattern (directionality)

As for the plywood (teak), there was a remarkable tendency of subjective contrast. Subjects (AO, MY, MZ) judged subjective contrast to be smallest at incidence angle 45 degree, and subject (TK) judged that to be biggest at 45 degree. According to a subject, incidence angle 45 degrees show a specular reflection. It is guessed that plywood (teak) which color is dark presents a clear specular reflection in 45 degree. Along with the variation caused by surface roughness, there are cases which point subject focuses the surface dark color and the clear specular reflection.

4) Variation caused by pattern (no-directionality)

Subjective contrast of vinyl wall paper (granite) was evaluated bigger in incidence angle 60-75 degree than that in 0-45 degree (subject AO, MY, NK, TK). Vinyl wall paper (marble) and (concrete) had not above tendency much and subjective contrast got unvaried depending on an incidence angle.

3.3 Categorization of the variation of subjective roughness

The feature of the subjective contrast is shown by the difference of the Munsell value of reference target. The subjective contrast became the range of about 1.0 to 4.5 shown by the difference of the Munsell value. In material color, some amount of tendency that the subjective contrast grows by the color difference from N7.0 great was seen. On the other hand, this tendency was not seen in the interior material. The smooth vinyl wall paper and the brick tile were evaluated that the subjective contrast was higher than the matt wall cloth and the plywood print vinyl.

Next, the subjective contrast is discussed with the relation of the angle of incidence. The following three tendencies were seen by the relation the subjective contrast and the angle of incidence. That is, group A becomes small the subjective contrast in 45° neighborhood that lies in the direction of the specular. Group B grows the subjective contrast as the angle of incidence grows. Group C grows the subjective contrast in 45° neighborhood. Bumpy vinyl wall paper and plywood with grained pattern were included in group A. Rough wall cloth and vinyl wall paper were included in group B. Brick tile with bumpy corrugation and smooth tile that had the specular gloss were included in group C.

The materials used in this experiment were classified into three groups depending on the feature of the subjective contrast as stated above. It was, however, different which material to which group entered depending on the test subject, it was suggested that the factor to pay attention when the visual texture was evaluated be different.

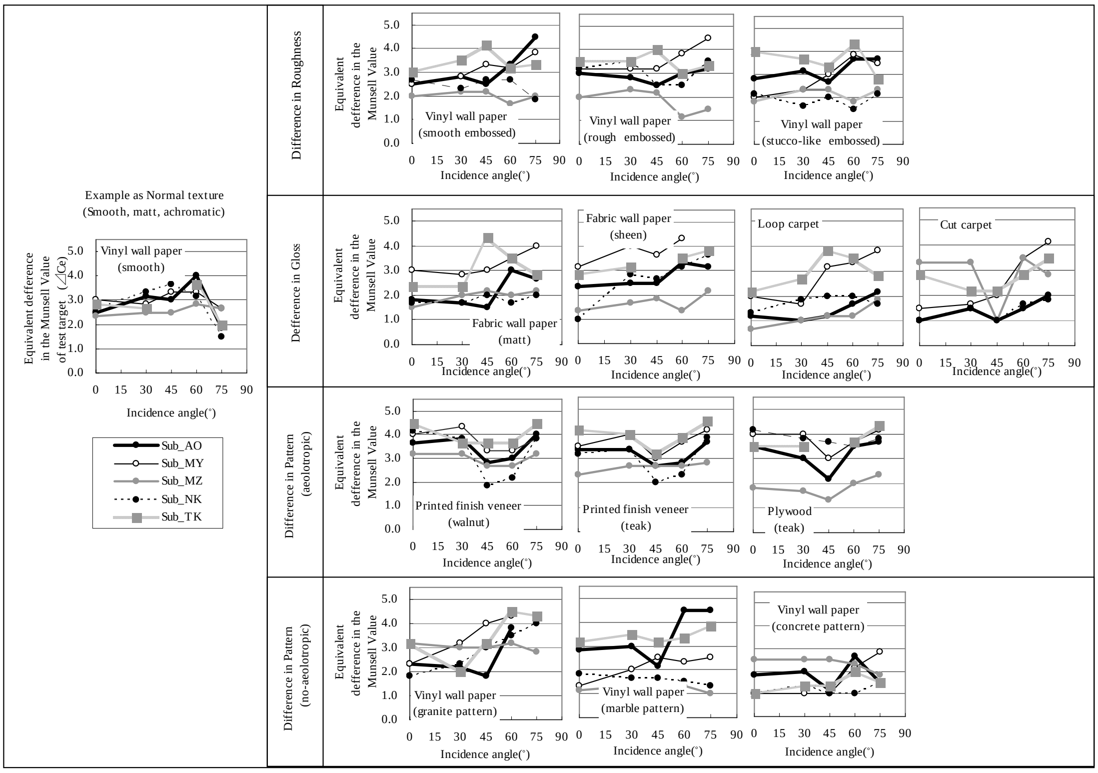

Fig. 4 Variation of subjective contrast along with incidence angle of light

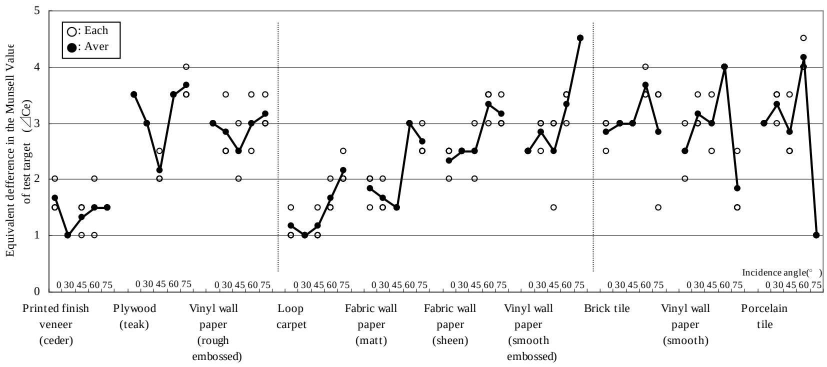

Fig. 5 Categorization of the variation of subjective roughness

4 CONCLUSION

The subjective contrast was evaluated with interior finish materials, and the followings were clarified. First, complex texture such as embossed texture and sheen surface was evaluated along with the point that subject focused. Second, the variations caused by surface roughness could be categorized into three tendencies.

After this, surface property will be caught from the luminance distribution, and the relationship between the subjective contrast and surface property will be considered.

ACKNOWLEDGEMENTS

Our research was supported by the grant of the Housing Research Foundation. We gratefully would like to thank to Dr. T. Noguchi.

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Improvement of the Assessment of the Recognized Illuminant by Depth Separation

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ABSTRACT

Perceptual achromatic setting has been claimed to be a method of assessing the recognized illuminant in an environment. The result, however, is not spatially valid because of some effect of an immediate area of the test (local effect). We considered a method to improve the assessment. We hypothesized that a depth separation between the test and its immediate area would be an effective way. Subjects made the perceptual achromatic setting under one whitish illumination and four chromatic illuminations. The setting results were compared among depth and no depth separation configuration. We found that the assessment of the recognized illuminant can be improved by the depth separation configuration. The local effect is decreased and shows less influence on the perceptual achromatic setting. Under the chromatic illumination, depth separation is more effective to exclude the local effect than under whitish illumination.

Keywords: Perceptual achromatic setting, recognized illuminant, local effect, depth separation,

1 INTRODUCTION

Previous research has shown that physical illumination is not a reference of visual system for perceiving appearance of a stimulus. On the contrary, some representation that visual system constructs for understanding the state of illumination is used for determining appearance of the stimulus. We call the representation as "*recognized illuminant*". In order to assess the recognized illuminant a method called "*perceptual achromatic setting*" is generally used. Subject adjusts chromaticity of a test while its luminance is generally held constant until it appears achromatic. Perceptual achromatic locus (*PAL*) of that test is claimed to be chromaticity of the recognized illuminant. However, it is also well known that appearance of stimulus also depends on immediate area surrounding the stimulus. We call the effect of immediate area as a "*local effect*". Some research has presented that magnitude of the local effect is substantial and significantly affects *PAL*.[1]

In this study, we investigated an improvement of the method for assessing the recognized illuminant. We hypothesized based on the Recognized Visual Space of Illumination theory[2] that the local effect occurs because of belongingness of the test to its immediate area. If belongingness of the test to its immediate area is destructed, we expect the local effect would be excluded. We thought fronto-parallel separation of the test from its immediate area ("*depth separation*") would be an effective way to destruct the belongingness without changing retinal image of the stimulus. Subjects made the perceptual achromatic setting under one whitish illumination and four chromatic illuminations. *PALs* were compared among depth and no depth separation configuration. If depth separation is effective to exclude the local effect under the chromatic illumination, *PALs* setting on the different local surround should be identical.

2 METHOD

The apparatus was a 75 x 140 x 120 cm^3 box decorated with wall paper as shown in Figure 1. The box was illuminated by a set of controllable color fluorescence lamps (*FL*). The chromaticity of illumination can be varied by mixing light from *D65* fluorescence lamp and *D65* fluorescence lamp covered with color filter tube. The illumination was five conditions. One is a whitish illumination (*W1*). Two different saturated level of red (*R1* and *R2*) and green (*G1* and *G2*) illumination were selected. Some objects such as a Macbeth Color Checker Chart and a doll were put into this box to provide the information about the illumination to the visual system. A 10°x10° replaceable Munsell paper was pasted on the front panel, treated as a local surround (*S*). Four kinds of the Munsell paper; which are neutral (*Sn*), green (*Sg*), blue (*Sb*), and red (*Sr*); were selected. Note, the colors of local surround only referred to

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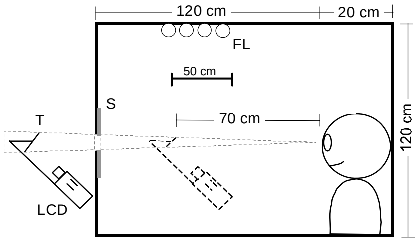

Figure 1 Schematic of the apparatus. LCD, The LCD projector: solid line shows the position of the LCD in the Wall condition; dashed line shows the position of the LCD in the Midair condition.

the color of Munsell paper. The properties of the illumination and the local surrounds under each illumination were shown in Table 1.

A test (*T*) was a Munsell *N4.5* paper hung on a stand attached to the LCD projector (*LCD*) holder. The test is tilted at 45° angle from vertical plane facing downward to minimize the light from *FL* light. The chromaticity and luminance of the test was controlled by projecting light from *LCD*. There were two conditions for the test position; where the test was presented on same plane of the local surround ("*Wall*" condition) and presented on the different plane in front of the local surround ("*Midair*" condition).

In the *Wall* condition, the set of test stimulus was placed behind the box. A 1.5°x1.5° hole was made at the center of the surround. A Subject saw the test through the hole with binocular viewing. The *N4.5* Munsell paper was large enough so that the subject could not see the edge of the *N4.5* patch. Therefore, the subject's retinal image between the left and right eye were identical. No binocular disparity resulted in an appearance of the test pasted on the same plane of the local surround.

In the *Midair* condition, the depth separation between the test and the local surround was employed. The set of test stimulus was placed inside the box (shown by the dashed line in Figure 1). The test was presented at 50 cm in front of the center of the local surround. Due to the binocular disparity, the subject perceived the different depth between the test and the local surround. The test size was kept constant at 1.5°x1.5° so that the subject's retinal image is the same as that in the *Wall* condition. The set of stimulus was carefully calibrated at each condition with a Minolta *CS-100* Chroma Meter.

Two male subjects with normal color vision participated in this experiment. Each session began with two minutes adaptation in the experimental room. After two minute adaptation, the stimulus was presented. The starting chromaticity of the test was randomly selected. Subject's task is to observe the test and to adjust

Table 1 Properties of illuminations and local surrounds.

Illumination	Surround	*CIE u'*	*CIE v'*
W1		0.188	0.480
	Sn	0.198	0.476
	Sg	0.141	0.512
	Sb	0.156	0.422
	Sr	0.253	0.470
G1		0.165	0.499
	Sn	0.167	0.504
	Sg	0.117	0.534
	Sb	0.128	0.473
	Sr	0.217	0.492
G2		0.140	0.518
	Sn	0.141	0.521
	Sg	0.109	0.542
	Sb	0.117	0.494
	Sr	0.189	0.505
R1		0.260	0.493
	Sn	0.244	0.489
	Sg	0.167	0.513
	Sb	0.183	0.440
	Sr	0.320	0.485
R2		0.333	0.507
	Sn	0.304	0.498
	Sg	0.206	0.515
	Sb	0.224	0.453
	Sr	0.386	0.501

the appearance of the test with a trackball until the test appears achromatic. During each setting, the luminance of the test was kept constant at the same luminance of the local surround (isoluminance). The isoluminance level setting was selected because the maximum local effect was observed around this level in the previous work.[3,4] The subject was instructed to look around in the experimental room and not to fix their eyes at the test. There was no time limit for each setting. When the subject achieved satisfactory adjustment, chromaticity of the test was measured at the subject's position using the Minolta *CS-100* Chroma Meter. After recording the measured data, the next stimulus was presented. Within each session, the illumination and the test's position were fixed but four local surround (*Sn*, *Sg*, *Sb*, and *Sr*) were randomly presented. Each local surround was presented 3 times making a total 12 settings per session. Each subject had done three sessions per experimental condition. The experimental conditions were composed of the combination of five illuminations (*W1*, *G1*, *G2*, *R1*, and *R2*) and two test's positions (*Wall* and *Midair*). Each subject made total 360 settings in this experiment.

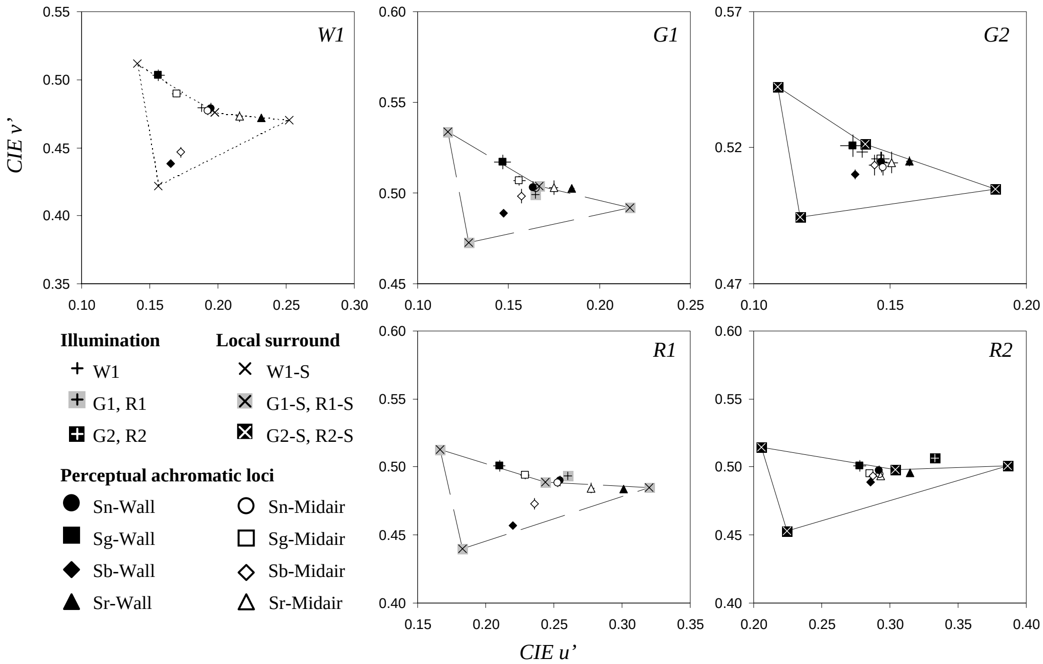

Figure 2 *PALs* of Subject KR plotted in *CIE u'v'* chromaticity diagram. Error bars show SD.

3 RESULTS AND DISCUSSIONS

Figure 2 shows the results of subject KR. Plus and cross symbols represent the chromaticity of the illumination and the local surrounds under that illumination. Circle, square, diamond and triangle symbols represent the chromaticity of the perceptual achromatic loci (*PALs*) setting on the *Sn*, *Sg*, *Sb*, and *Sr* respectively. Solid and open symbol represent the result from the *Wall* and the *Midair* condition.

We assume that the perceptual achromatic setting on the neutral surround (*Sn*) could be a reference condition because the neutral surround does not cause a chromatic induction. The appearance of the test in chromatic domain should entirely determine by the recognized illuminant so that there should not be significant difference between the *PALs* obtained from the *Wall* and the *Midair* condition. The results from every condition agree with our assumption. *Sn-Wall* and *Sn-Midair* almost coincide with each other and follow the chromaticity of physical illumination. However, both *Sn-Wall* and *Sn-Midair* do not always coincide with the chromaticity of physical illumination. The deviation of both *Sn-Wall* and *Sn-Midair* from the chromaticity of physical illumination indicates the incomplete color constancy phenomenon which is more obvious under the high saturated color illumination as shown in panel *G2* and *R2*. This supports the idea that color appearance is not determined by the physical illumination. *Sn-Wall* and *Sn-Midair* then are more suitable to be reference loci in each illumination condition than the chromaticity of illumination. Since there is not significant difference between *Sn-Wall* and *Sn-Midair*, We select only *Sn-Wall* as the reference loci in the later discussion.

When the *PALs* setting on neutral surround and chromatic surround are compared, all *Sg-Wall*, *Sb-Wall*, and *Sr-Wall* do not coincide with *Sn-Wall* (reference loci), but shift toward the chromaticities of their corresponding local surround. The result agrees with some previous work. Delahunt and Brainard[1] have shown that the local area show a significant influence on the perceptual achromatic setting. Under the invalid cue where the local area around the test does not match with color of illumination, *PALs* were always shifted toward the chromaticity of the local surround in all illumination.

When the depth separation is employed to the test, all *Sg-Midair*, *Sb-Midair*, and *Sr-midair* do not coincide with *PALs* in the *Wall* condition. The shift of *PALs* from the reference loci in the *Midair* condition was clearly smaller than that in the *Wall* condition. Based on the idea from previous work,[5] the amount of local effect can be calculated in term of background index (*BI*) by the following equation.

$$BI = \frac{\Delta E_{u'v'}(PAL_{Sn} - PAL_{Sc})}{\Delta E_{u'v'}(C_{Sn} - C_{Sc})} \quad (1)$$

Where PAL_{Sn} and $PALS_{c}$ are *CIE u'v'* chromaticities of the *PALs* setting on *Sn* and chromatic surround respectively; C_{Sn} and C_{Sc} are *CIE u'v'* chromaticities of *Sn* and chromatic surround respectively. The interpretation of *BI* is: 1 represents the strongest local effect dues to the chromatic local surround, whereas 0 indicates no local effect.

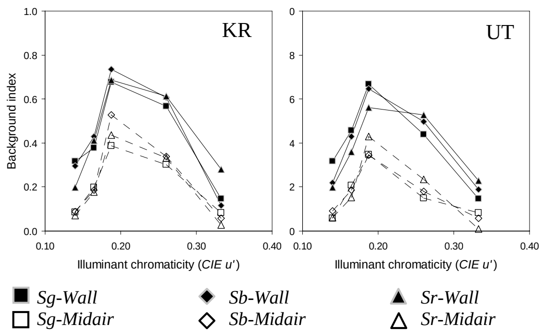

Figure 3 The magnitude of the local effect in term of background index (*BI*). Square, circle and triangle represent *BI* of the *Sg*, *Sb*, and Sr condition respectively. Solid and open symbols represent *BI* from the *Wall* and the *Midair* conditions.

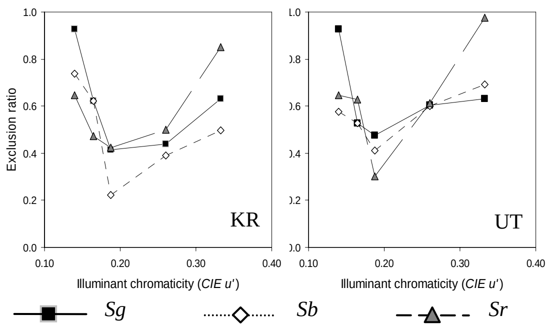

Figure 4 The effectiveness of depth separation, in term of Exclusion ratio (R_E). Square, diamond and triangle represent R_E on the *Sg*, *Sb*, and *Sr* local surround respectively.

From Figure 3, *BI* from the *Midair* condition are smaller than *BI* from the *Wall* condition. This indicates that depth separation is effective for excluding the local effect under not only whitish illumination but also the chromatic illumination. *BI* for the *R2* and *G2* condition, which is the most saturated color illumination in this experiment, is around 0.1. Note that the amount of the local effect is highest at *W1* which is the whitish illumination condition. When the chromaticity of illumination is more saturated, the amount of local effect tends to decrease. This tendency agrees with the previous study that the effect of local surround on the achromatic loci was small under the color illumination.[5]

To compare the effectiveness of the depth separation on the exclusion of the local effect under various illuminations, the Exclusion ratio (R_E) is calculated by the following equation.

$$R_E = 1 - \frac{BI_{Midair}}{BI_{Wall}} \qquad (2)$$

Where BI_{Wall} *and* BI_{Midair} are *BIs* from the Wall and the Midair condition, respectively. If $R_E = 1$, it represents the complete exclusion of the local effect and $R_E = 0$ represents no exclusion.

Figure 4 shows the effectiveness of depth separation under various illuminations. There is a tendency that R_E is lowest under the whitish illumination. R_E increases when the saturation of chromatic illumination increases. This tendency indicates that depth separation is more effective to exclude the local effect under the chromatic illumination. There is one point should be noted here. When the color of local surround and illumination are matched (*e.g.*, green local surround under vivid green illumination), R_E is higher than R_E of the unmatched condition (*e.g.*, red local surround under vivid green illumination). All R_E of matched condition is in range of 0.85-0.96 which can be claimed that the local effect is almost completely excluded.

4 CONCLUSIONS

Based on our work, we conclude that the method for assessing the recognized illuminant should be modified. The perceptual achromatic setting with original configuration which the test is pasted on the wall or the same plane of its immediate area might give more immediate area dependent result. We present based on the concept of belongingness destruction that depth separation between the test and its immediate area is a more suitable configuration in the perceptual achromatic setting. With the depth separation configuration, the local effect is excluded and shows less influence on the perceptual achromatic setting. Even though there is some condition that the depth separation is less effective, we believe that our method can be a basic idea for improving the method for assessing the recognized illuminant.

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A Study of the Teaching Materials with the Method to Judge the Color with the Visual Colorimetry: In the Case of an Experiment about Washing

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ABSTRACT

The subject of the washing for soil removal of the fabrics is studied in the junior high school. Students can do learning based on scientific grounds about the mechanism of washing. The fabrics which we used for the experiment are colored cotton with grape juice. We judged the detergency in this experiment by two kinds of methods. We considered that the colored cotton fabrics should be used as a testing material of the experiment. The first method we choose is the visual colorimetry about the efficiency of the washing. We made the original scale for the judgment of this method. The second method is the physical colorimetry about the efficiency of the washing; the quantity of the soil was measured for this purpose. We measured the reflectance of the colored cotton fabrics' surface with grape juice before and after the washing and calculated the efficiency of the washing. And then, the consistency of these two methods was examined. High correlation about the efficiency of the washing was recognized between the visual colorimetry and the physical colorimetry. In junior high school as for the materials of the teaching, we recommend the method that is simple and easy about the efficiency of the washing. That is the visual colorimetry.

Keywords: Teaching Materials, Washing, Visual colorimetry, Judge the Color, Detergency

1 INTRODUCTION

The construction of the learning system based on the experience is one of the important problems in the school education. We should offer the teaching materials promoting the activity of the students, and it is necessary to raise their will for the learning. In this study, we suggested the teaching materials about the washing.

We think that a study of the teaching materials contains three important matters. In the first place there are the time factor and the economic factor not to burden when a teacher prepares an experiment. In the second place, the teaching materials of the experiment should be simple and easy for the students. And we have to consider the environment when we experiment. Third it is necessary to be held a standard definitely so that the students can consider about the result of the experiment scientifically. In this study, we suggested the teaching materials about the washing that satisfied these three matters.

2 METHOD

2.1 The preparation of the solored fabrics

In this study we used cotton fabrics which were colored with grape juice. Table 1 shows the summary of the test fabrics which we used for experiments. As for one piece of fabrics size; the width is 10cm at 5cm length.

Table 1 The cotton fabrics for experiments

Fabrics	Munsell notation		
	H	V	C
Original white fabric	N	8.0	-
Colored fabric with grape juice	3.0RP	6.2	4.7
Colored fabric after alkali mordanting	6.7PB	6.7	2.1

We measured the colored fabrics with the spectrophotometer. The measuring instrument is SZ-Σ90 which is made in Nippon Denshoku Industries Co., Ltd. of Japan. We analyzed the colors with the color management software that was attached to the spectrophotometer. The name of the software is Color Mate 5. We chose 2 degrees in the field of vision angle as a measurement condition in the C source of light. Because the condition of this field of vision angle is necessary so that measurement data can be converted into Munsell notation.

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2.2 How to wash

The washing examination was done by using the synthetic detergent (Table 2). The ratio of the detergent solution is 1:100 (about 30ml). We washed the cotton fabrics which were colored in the way of repeating the going and returning movement of 100 ± 2 times in 1 minute by using incubator. The conditions about the concentration of detergent solution are 0%, 0.05%, 0.075%, 0.1%, 0.125% and 0.15%. The conditions about temperature in washing are 10℃, 30℃, 40℃, 50℃ and 60℃. And the conditions about the washing time are 5min., 10min, 15min., 20 min. and 30 min. We rinsed out all examined fabrics with ion-exchange water (about 30ml) after having washed.

Table 2 The composition of the detergent

Type	Heavy-duty detergent
Use	Cotton, linen, Synthetic fiber
Detergent solution	Weak alkaline
Component	Surfactant (25%, Linear alkyl-benzene sulfonate, Polyoxyethylene alkyl ether), Aluminosilicate, Sodium carbonate, Sodium sulfate, Fluorescent bleaching agent, enzyme etc.

2.3 The preparation of the scale for the visual colorimetry

We made an original scale for the judgment of the visual colorimetry. We took JIS L0804 (2004) grey scale for assessing change in color into account and made the scale for the judgment (Figure 1, Table 3)[1].

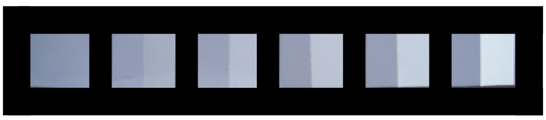

Figure 1 The scale for the visual colorimetry

Table 3 Attribute of the original color scale

Level	L*	a*	b*	H	V	C
1	62.0	3.1	-6.5	10.0PB	6.1	2.0
2	66.6	2.2	-4.6	0.4P	6.6	1.5
3	71.5	2.7	-5.9	0.2P	7.1	2.0
4	76.1	1.9	-4.1	0.2P	7.5	1.5
5	81.2	1.2	-2.5	0.4P	8.1	1.0
6	92.9	0.7	-0.5	8.1P	9.3	0.4

3 RESULTS

3.1 The properties of the colored fabrics

The characteristic of the color of the fabric which was colored in the solution of 100% of the grapes fruit juice is shown in the Figure 2. The principal ingredient of the pigment of the grapes fruit juice is anthocyanin[2].

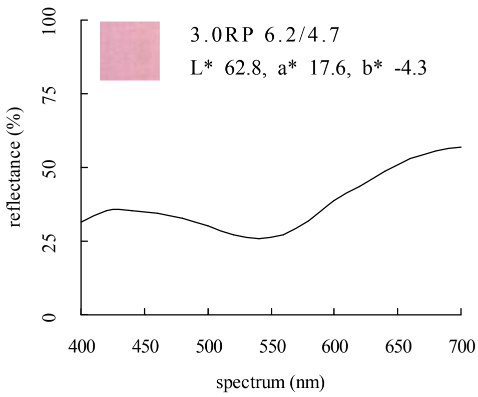

Figure 2 Refractance of colored fabric (anthocyanin)

Anthocyanin takes on red in the acidity, and takes on dark red from red in the case of the neutrality. Then, that pigment takes on red purple-dark indigo blue in the alkalinity (Table 1).

The hue changes when the fabrics colored in grape juice are washed by using heavy-duty detergent. Therefore we did treat the fabrics in Na_2CO_3 of 0.05% which was not washed with weak alkaline detergent, so that the hue of with alkaline detergent washed fabrics became similar to the hue of the not with alkaline detergent washed fabrics (Figure 3).

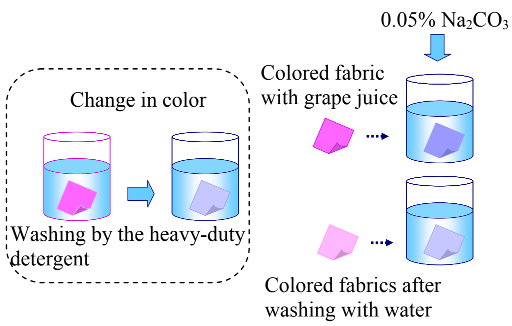

Figure 3 Adjustment of the hue of colored fabrics

3.2 Efficiency of detergency of the colored fabrics

We measured the reflection of the fabrics after washing, and got "degree of soiling", that is, D.S. with the following equation.

$$D.S. = (Rw-Rs) / (Ro-Rs) * 100$$

In this equation, *Ro* is original white fabric. *Rs* is colored fabric with grape juice. *Rw* is colored fabrics after washing.

Figure 4 shows relations between the detergency and the detergent concentration. As for the concentration of a detergent for washing, it was found out that 0.075% was effective.

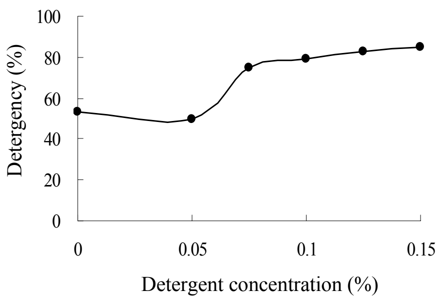

Figure 4 The influence of the detergent concentration in washing: Washing temperature is 30℃, Washing time is 10minutes

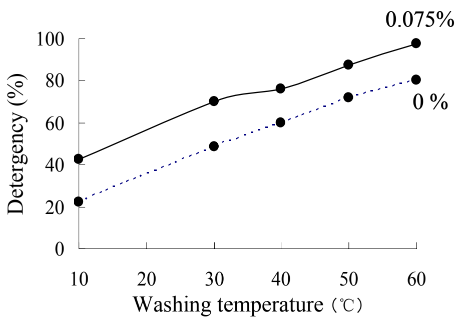

Figure 5 The influence of the washing temperature: Washing time is 10minutes

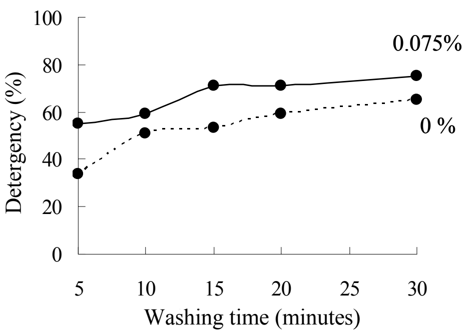

Figure 6 The influence of the washing time: Washing temperature is 30℃

Figure 5 shows relations between the detergency and washing temperature. The detergency of the washing with the detergent was higher in comparison with the detergency of the simple washing 0 with water. The effect on the detergency rises when the temperature of the washing solution becomes high. Figure 6 shows relations between the detergency and the washing time. The detergency rises until 15 minutes after the start of the experiment, but the further effect on the detergency can not be found out after 15 minutes.

3.3 Correlation of the visual colorimetry and the physical colorimetry

We consider the detergency in two methods of the visual colorymetry and the physical colorymetry. Figure 7 shows relations between the visual colorymetry and the detergency about the concentration (p: 0.01). We recognized the coefficient of determination of 0.5 in the visual colorymetry and the physical colorymetry. Figure 8 shows relations between the visual colorymetry and the detergency about the washing temperature. We recognized the coefficient of determination of 0.73 in the visual colorymetry and the physical colorymetry.

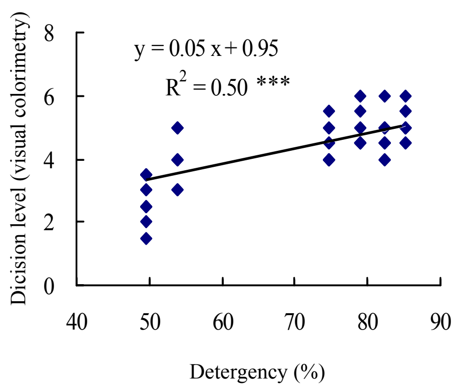

Figure 7 Evaluation about the influence of the detergent concentration

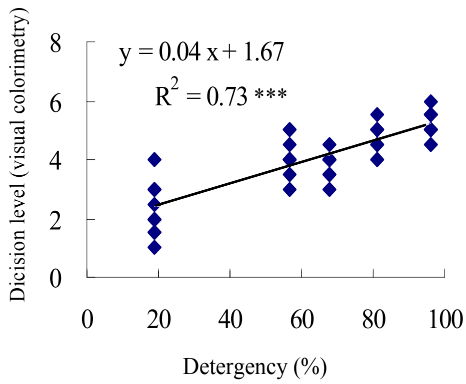

Figure 8 Evaluation about the influence of the washing temperature

Figure 9 shows relations between the visual colorymetry and the detergency about the washing time. We recognized the coefficient of determination of 0.26 in the visual colorymetry and the physical colorymetry. And the correlation was recognized in the visual colorymetry and the physical colorymetry in the washing experiment of the cotton fabrics colored with grape juice. Especially, as for the washing temperature, it was recognized that the correlation was of the visual colorymetry with the physical colorymetry was very high.

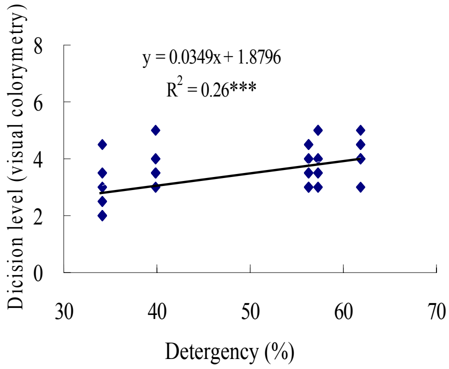

Figure 9 Evaluation about the influence of the washing time

4 CONCLUSIONS

In this study, we suggested the teaching materials about the washing.

The subject of the washing for soil removal of the fabrics is studied in the junior high school.

The fabrics which we used for the experiment are colored cotton with grape juice. We judged the detergency in this experiment by two kinds of methods. We made an original scale for the judgment of the visual colorimetry. And we measured then the reflection of the fabrics after washing, and got "degree of soiling".

We consider the detergency in two methods of the visual colorymetry and the physical colorymetry. The correlation was recognized in the visual colorymetry and the physical colorymetry in the washing experiment of the cotton fabrics colored with grape juice. Especially, as for the washing temperature, it was recognized that the correlation of the visual colorymetry with the physical colorymetry was very high. As for the materials of the teaching in the junior high school, we recommend the method that is simple and easy about the efficiency of the washing. That is the visual colorimetry. Students can do learning based on scientific grounds about the mechanism of washing.

Thanks to Ms. Tae Yonei for the cooperation in the experiment.

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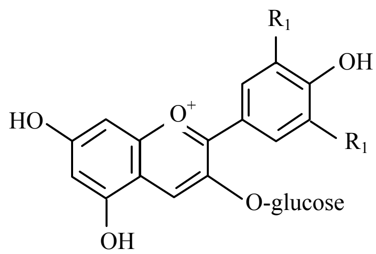

	R_1	R_2
malvidin	OCH_3	OCH_3
Petunidin	OCH_3	OH
Delphinidin	OH	OH
Cyanidin	OH	H
Peonidin	OCH_3	H

Chemical structural formula of anthocyanin

Performance of CIEDE2000 color difference models for the RIT-DuPont dataset

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ABSTRACT

It has been found that one of the four experimental datasets employed for the development of the CIEDE2000 color difference formula, the RIT-DuPont dataset, was not properly used. We analyze the performance of the CIEDE2000 formula for the revised RIT-DuPont dataset, and for the combined (COM) weighted dataset employed in the development of CIEDE2000. This work complements our previous research on the relative significance of the terms in the CIEDE2000 and CIE94 color-difference formulas. For the revised RIT-DuPont dataset, CIEDE2000 is not significantly better than CIE94 (95% confidence level), and only the chroma and hue corrections of CIEDE2000 are statistically significant. However, for the COM weighted dataset which includes the revised RIT-Dupont dataset, CIEDE2000 improves CIE94 with statistical significance at a 95% confidence level, and each one of the 5 corrections introduced by CIEDE2000 are statistically significant at this confidence level. These results call for a comparative study of the four datasets employed at CIEDE2000 development.

Keywords: Color differences, color-difference formulas, CIE94, CIEDE2000, RIT-DuPont dataset.

1 INTRODUCTION

In the development of CIEDE2000[1,2] an anomalous RIT-DuPont dataset was considered with 156 color pairs having a very short range of color differences (0.97-1.03 CIELAB units) and visual differences in a relatively wide range (0.21-1.20 units). The true RIT-DuPont dataset[3] provides tolerances (with their corresponding upper and lower fiducial limits) along 156 vector directions, allowing the formation of 302 color pairs (that is, two sets of colorimetric coordinates about each vector's color center) with a constant visual difference (the fixed anchor pair with 1.02 CIELAB units) and color differences in the range 0.77-4.42 CIELAB units.

Given that the range of CIELAB color differences in the anomalous RIT-Dupont dataset was approximately constant (like the visual color differences in the true RIT-DuPont dataset), it might be thought that the problem was that ΔV and ΔE^*_{ab} (with a constant scale factor) were approximately exchanged in the anomalous RIT-Dupont dataset. In this case, the performance of CIEDE2000 assessed by the *PF/3* index[4] for the anomalous and true RIT-Dupont dataset should be nearly identical. Unfortunately, this is not the situation, as shown in Figure 1, where the visual differences in the anomalous RIT-Dupont have been plotted against the CIELAB color differences in the true RIT-DuPont dataset, resulting a nonlinear relationship.

Therefore we must conclude that the RIT-DuPont data employed in the development of CIEDE2000 were different from the true data. Consequently, it would be useful to test the performance of CIEDE2000 for both a revised (true) RIT-Dupont dataset, as well as for a revised combined dataset (COM). This revised COM dataset is analogous to the one employed for the development of CIEDE2000,[2] but including the revised RIT-DuPont data. These are the main goals of the current paper.

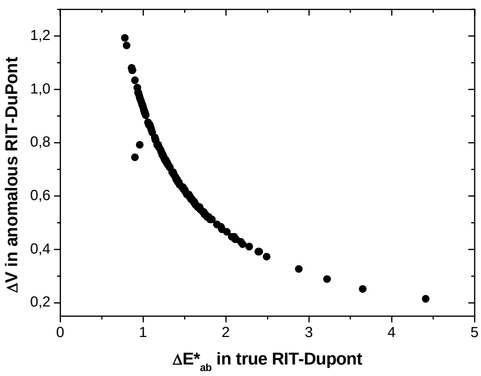

Figure 1. Visual differences in anomalous RIT-Dupont dataset against CIELAB color differences in true RIT-Dupont dataset. Note that the relationship is not linear.

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2 METHODS

In addition to CIEDE2000, we have extended this work to the two previous CIE-recommended color-difference formulas: CIE94[5] and CIELAB. As we did in a previous paper[6], for CIE94 we tested two reduced models (designated as CIE94-Chroma and CIE94-Hue), which are the CIE94 formula modified with S_c=1 and S_h=1, respectively; and for CIEDE2000, we tested five reduced models (designated as CIEDE2000-Lightness, Chroma, Hue, Rot.Term, and Gray), which correspond to the cancellation of each one of the five corrections to CIELAB introduced by CIEDE2000. The *PF/3* and *STRESS* indices have been used here to test the performance of complete and reduced color-difference formulas. The *STRESS* index, which was not employed in the former work, comes from Multidimensional Scaling (MDS) techniques,[7] and is defined by the expression:

$$STRESS = \left(\frac{\sum \left(\Delta E_i - F_1 \Delta V_i \right)^2}{\sum F_1^2 \Delta V_i^2} \right)^{1/2}, \qquad (1)$$

with

$$F_1 = \frac{\sum \Delta E_i^{\,2}}{\sum \Delta E_i \Delta V_i}, \qquad (2)$$

where ΔE_i and ΔV_i are the visual and computed color differences for the i=1,…,N color pairs, respectively . The summations refer to the color pairs, and F_1 is a factor adjusting the scales of ΔE_i and ΔV_i which minimizes *STRESS*.

For perfect agreement between computed and perceived differences, both *PF/3* and *STRESS* must be zero. Greater values of these indices signify worse agreement between computed and visual data. In particular, there is an upper limit of 1 for *STRESS* (but not for *PF/3*). In this paper, *STRESS* values will be given as percentages—that is, we will use the values found from Eq. (1) multiplied by 100. As analyzed in a previous paper[8], the main advantage of *STRESS* with respect to *PF/3* is that it allows statistical *F*-tests on the significance of the differences between two given formulas, from the ratio of the two squared *STRESS* values.

3 RESULTS AND DISCUSSION

Tables 1 and 2 show the results found for the revised RIT-DuPont and COM weighted datasets, respectively. The second column in these tables shows the wrong *PF/3* values reported by us in a previous paper,[6] for comparison with the current ones (third column).

Important differences between the results found from the anomalous and revised RIT-DuPont datasets may be noticed. For example, note the *PF/3* values found for the CIELAB or CIEDE2000 color-difference formulas in Table 1. From comparison of the squared *STRESS* ratios with the critical values of the *F*-distribution,[7] the three most interesting conclusions from Table 1 are that for the revised RIT-DuPont dataset, at a 95% confidence level: 1) CIEDE2000 is not statistically better than CIE94 (but CIELAB is significantly worse than both CIE94 or CIEDE2000); 2) the hue correction in CIE94 is not statistically significant; 3) considering the five corrections proposed by CIEDE2000, only the chroma and hue corrections are statistically significant.

From Table 1 it is also worth noting that for the revised RIT-Dupont dataset the removal of two of the corrections proposed by CIEDE2000 (the Lightness and Gray corrections, both relevant for a relatively high number of color pairs in this dataset) leads to an improvement (decrease of *STRESS* values) of the formula, although these improvements are not statistically significant. The chroma correction is the most important in both CIE94 and CIEDE2000, as we have reported previously.[6]

Table 1. *PF/3* and *STRESS* for the anomalous and revised RIT-Dupont datasets, using CIELAB, CIE94 (with its two reduced versions) and CIEDE2000 (with five reduced versions).

	Anomalous RIT-DuPont[6]	Revised RIT-DuPont	
	PF/3	*PF/3*	*STRESS*
CIELAB	**30.6**	**33.8**	**33.42**
CIE94	**20.1**	**21.0**	**20.31**
CIE94-Chroma	31.7	35.8	35.77
CIE94-Hue	22.4	23.2	22.41
CIEDE2000	**23.4**	**19.6**	**19.48**
CIEDE2000-Lightness	23.1	19.1	18.93
CIEDE2000-Chroma	35.7	37.3	36.84
CIEDE2000-Hue	26.7	24.1	23.06
CIEDE2000-Rot.Term	20.6	21.0	20.56
CIEDE2000-Gray	21.3	17.8	17.75

However, for the revised weighted COM dataset (analogous to the original COM dataset[2] but with replacement of the anomalous RIT-Dupont by the revised one), Table 2 shows that new computed *PF/3* values are slightly lower than the previous ones[6] for all the formulas and corrections studied. The reported *STRESS* values in Table 2 indicate that, at a 95% confidence level: 1) the improvement of CIEDE2000 upon CIE94 is statistically significant; 2) the two corrections introduced by CIE94 are statistically significant; 3) each one of the five corrections introduced in CIEDE200 is statistically significant. Fortunately these three conclusions are the same as those previously reported by us.[6]

Table 2. *PF/3* and *STRESS* for the anomalous weighted COM dataset (which includes the anomalous RIT-Dupont dataset), and the revised weighted COM dataset (which includes the revised RIT-Dupont dataset) using CIELAB, CIE94 (with its two reduced versions) and CIEDE2000 (with five reduced versions).

	Anomalous Weighted COM[6]	Revised Weighted COM	
	PF/3	*PF/3*	*STRESS*
CIELAB	**56.1**	**55.7**	**43.93**
CIE94	**38.3**	**37.7**	**32.07**
CIE94-Chroma	58.1	57.7	46.14
CIE94-Hue	42.5	41.9	35.80
CIEDE2000	**33.7**	**32.1**	**27.49**
CIEDE2000-Lightness	35.4	33.6	29.19
CIEDE2000-Chroma	56.3	56.0	45.18
CIEDE2000-Hue	40.3	38.9	33.86
CIEDE2000-Rot.Term	35.4	35.0	29.54
CIEDE2000-Gray	35.1	33.1	28.69

4 CONCLUSIONS

Given that the RIT-DuPont dataset has a high accuracy, it seems worthwhile to know the performance of the last CIE-recommended color-difference formula CIEDE2000 with respect to this particular dataset. It would be useful to complement our current results for the revised RIT-DuPont dataset considering the different accuracy (upper and lower fiducial limits) reported for each color pair in the original RIT-DuPont dataset[3]. Also, it appears that consideration of the dataset provided by Qiao et al[9]. as an extension of the RIT-DuPont dataset may also be helpful as a complement to the current results.

In addition, using *STRESS* we have also found that some of the corrections proposed by CIE94 or CIEDE2000 are not statistically significant at a 95% confidence level for some of the datasets comprising the COM dataset[2]; specifically, we found that the Hue correction in CIE94 was not statistically significant for the Leeds dataset, and the Gray correction in CIEDE2000 was not statistically significant for the Witt dataset. Bearing in mind also the lack of significance found for the revised RIT-DuPont dataset in this paper, we feel that a comparative analysis of the four datasets involved in COM (BFD-P, Leeds, RIT-DuPont, and Witt) may be useful for future advances.

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Ellipse Comparison between Color Discrimination Threshold and Small Suprathreshold Color Difference Using CRT Colors

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ABSTRACT

The ellipses of color discrimination threshold and small suprathreshold color difference at the nine CIE color centers were obtained using the interleaved staircase method and the method of constant stimuli in the a^*b^*, a^*L^*, and b^*L^* planes, respectively. The differences between the threshold and small suprathreshold color difference ellipses were evaluated with respect to their shapes and sizes in terms of *PF/3* values. The results indicated that both the shape and size were influenced by their corresponding color regions in the CIELAB color space.

Keywords: color and vision, color discrimination threshold ellipse, small suprathreshold color-difference ellipse, CIELAB color space.

1 INTRODUCTION

With the development of the color industry, the importance of small suprathreshold color difference and color discrimination threshold in the industrial color-difference applications becomes more obvious. The color discrimination threshold is thought to depend on the fundamental cone excitations, while the suprathreshold color difference on the opponent visual system[1]. In this study, the color discrimination thresholds were obtained using the interleaved staircase method in the a^*b^*, a^*L^*, and b^*L^* planes, respectively, and the suprathreshold color differences in these three planes were acquired by the method of constant stimuli.

For the stability and convenience of CRT displays in the color vision experiments, which have been demonstrated in several studies[2,3], these two experiments were carried out on a CRT display. The aim of this study was to investigate systemically and quantitatively the correlation between the color discrimination threshold and small suprathreshold color-difference ellipses in the CIELAB color space, in order to provide a new dataset for the modification to the visual uniformity of the color spaces and color difference formulae.

2 EXPERIMENTAL

According to the guidelines of the CIE[4,5] and considering the color gamut of the CRT display used, nine CIE color centers were chosen, the CIELAB values of which are listed in Table 1. A color stimulus pattern was presented on the CRT display of Neso FD570A with a viewing distance of 500mm from the subject. The color stimulus patterns for the threshold experiment and the suprathreshold experiment are shown in Figures 1 and 2, respectively. A panel of 6 subjects with normal color vision participated in these two experiments, most of whom had little experience for such observations. The CRT display was characterized using the 3-1D LUT model[6], and the characterization accuracy was about 0.6 ΔE^*_{ab} units. The stimuli to be observed were evenly distributed from the test color centers along 12 directions every 30° in the a^*b^* plane and along 8 directions every 45° in the a^*L^* and b^*L^* planes, respectively. For the suprathreshold color difference experiment, the standard color difference was about 3.0 ΔE^*_{ab} units, composed of two achromatic gray colors only with lightness difference, which are also listed as the "Reference pair" in Table 1. The task of the subject in the threshold experiment was to judge which of the four arrays was different from the other three, while in the suprathreshold experiment the task was to judge whether the color difference of the test pair was larger or smaller than that of the reference pair.

3 RESULTS AND DISCUSSION

The color discrimination thresholds and suprathreshold color differences were calculated by averaging all the results obtained in the same direction, respectively. The color discrimination

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Table 1 The CIELAB values of the test color centers with the standard deviations in brackets.

Color center	L^*	a^*	b^*	C^*	$h°$
Gray	61.57 (0.15)	-0.04 (0.28)	-0.17 (0.28)	0.17	257
Red	44.37 (0.16)	36.84 (0.29)	23.37 (0.4)	43.63	32
Orange	62.96 (0.11)	13.11 (0.24)	20.88 (0.34)	24.65	58
Yellow	86.61 (0.13)	-6.66 (0.29)	47.05 (0.44)	47.52	98
Yellow-green	64.95 (0.32)	-9.88 (0.27)	13.08 (0.36)	16.39	127
Green	56.04 (0.15)	-32.20 (0.28)	0.38 (0.14)	32.20	179
Blue-green	50.06 (0.15)	-16.09 (0.15)	-11.01 (0.17)	19.50	214
Blue	35.46 (0.28)	4.76 (0.39)	-30.23 (0.29)	30.60	279
Purple	45.95 (0.38)	11.76 (0.20)	-12.81 (0.36)	17.39	313
Reference pair	61.50 (0.15)	-0.05 (0.24)	0.02 (0.27)	0.05	158
	64.60 (0.19)	0.07 (0.28)	-0.26 (0.31)	0.27	285
Background	50.05 (0.20)	0.02 (0.34)	0.08 (0.29)	0.08	76

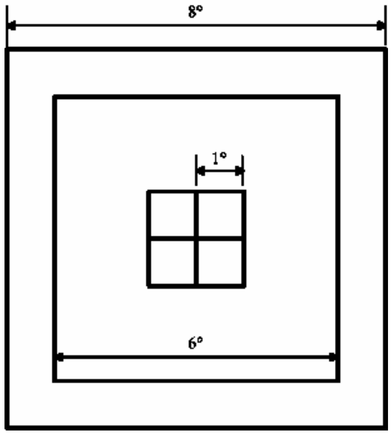

Figure 1 The color stimulus pattern of the threshold experiment.

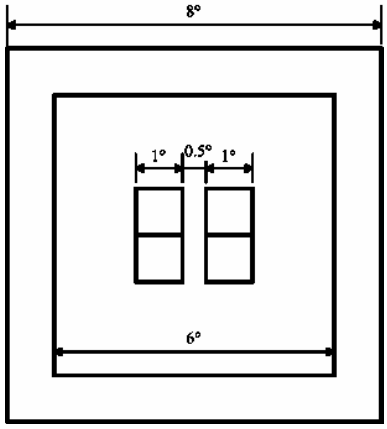

Figure 2 The color stimulus pattern of the suprathreshold experiment.

threshold ellipses and suprathreshold color-difference ellipses were fitted using the least-square technique for every color center in the a^*b^*, a^*L^*, and b^*L^* planes. The fitting accuracy was depicted by *PF/3* factor[7], which was first devised by Luo and Rigg, and modified by Guan and Luo later, as shown in Equation (1).

$$PF/3 = 100\left[(\gamma - 1) + V_{AB} + \frac{CV}{100}\right]/3 \qquad (1)$$

where

$$\begin{cases} CV = \dfrac{\sqrt{\dfrac{1}{N}\sum (X_i - fY_i)^2}}{\overline{X}} \\ f = \dfrac{\sum X_i Y_i}{\sum Y_i^2} \end{cases}$$

$$\lg \gamma = \sqrt{\frac{1}{N}\left[\log_{10}\left(\frac{X_i}{Y_i}\right) - \overline{\log_{10}\left(\frac{X_i}{Y_i}\right)}\right]^2}$$

$$\begin{cases} V_{AB} = \sqrt{\dfrac{1}{N}\sum \dfrac{(X_i - FY_i)^2}{X_i F Y_i}} \\ F = \sqrt{\sum \dfrac{X_i}{Y_i} \Big/ \sum \dfrac{Y_i}{X_i}} \end{cases}$$

where N is the number of compared pairs, and X_i and Y_i are values of the ith pair. A higher *PF/3* value implies worse agreement between the compared datasets.

The mean fitting accuracy was 19, 32, and 24 *PF/3* units for the color discrimination threshold ellipses, and 8, 7, and 6 *PF/3* units for the suprathreshold color-difference ellipses in the a^*b^*, a^*L^*, and b^*L^* planes, respectively.

The shape difference between threshold and suprathreshold ellipse at each test color center was also expressed by *PF/3* factor. The size of the threshold ellipses were scaled to the same as that of the suprathreshold ellipses for individual color centers, and the compared data were 360 points evenly distributed in the ellipse contour with the interval of 1°. The detailed shape comparison results are listed in Table 2. For the ellipses in the a^*b^* plane, the mean shape difference was 20 *PF/3* units, and the largest differences were 40 and 41 for the red and blue-green centers, respectively. The mean difference for the ellipses in the a^*L^* plane was 16 *PF/3* units, with the largest difference of 31 in the red center. In the b^*L^* plane, the mean difference between threshold and suprathreshold ellipses was 15 *PF/3* units, and the largest difference was 25 in the blue-green center. The results indicated that the average shape difference between threshold and suprathreshold ellipses was not significant, but for the red and blue-green centers their differences were quite large.

Table 2 The shape differences between threshold and suprathreshold ellipses in terms of *PF/3* values.

Color center	a^*b^* plane	a^*L^* plane	b^*L^* plane	Mean
Gray	9	4	14	9
Red	40	31	14	28
Orange	24	12	9	15
Yellow	4	2	22	9
Yellow-green	13	17	3	11
Green	25	23	22	23
Blue-green	41	20	26	29
Blue	16	20	14	17
Purple	6	14	15	12
Mean	20	16	15	17

Table 3 The area ratios of the suprathreshold ellipses to the threshold ellipses.

Color center	a^*b^* plane	a^*L^* plane	b^*L^* plane	Mean
Gray	3.92	5.05	5.61	4.86
Red	4.70	4.97	4.32	4.66
Orange	4.37	4.89	4.76	4.67
Yellow	4.27	3.46	5.31	4.35
Yellow-green	4.70	5.54	4.77	5.00
Green	5.02	7.45	6.71	6.39
Blue-green	4.84	5.57	6.98	5.80
Blue	7.36	8.88	9.49	8.58
Purple	7.33	7.75	6.62	7.23
Mean	5.17	5.95	6.06	5.73

Table 3 illustrates the area ratios of the suprathreshold ellipses to threshold ellipses in these three planes. For these ellipses, the mean area ratio in all the three planes was 5.73 *PF/3* units. In all the three planes, the area ratios at the green, blue-green, blue, and purple centers were much larger than those at the others. For these four centers in the a^*b^* plane, the ratios were ranging from 4.84 to 7.47 *PF/3* units, while 3.92 to 4.70 at the others. The ratios in the a^*L^* plane for these four centers were between 5.57 and 8.88, and the others ranged from 3.46 to 5.54. In the b^*L^* plane, the ratios at these four centers were 6.62 to 9.49, but for the others were 4.32 to 5.61. The quantitative analysis showed that in the regions with the hue angles located in the third and fourth quadrants of the a^*b^* plane, the area ratios of the suprathreshold to threshold ellipses were much larger than those in the other regions, which suggested the nonuniformity of the metric scales in the CIELAB color space.

4 CONCLUSION

The differences were compared in this study between the color discrimination threshold ellipses and small suprathreshold color-difference ellipses derived by the psychophysical methods of the interleaved staircase and constant stimuli using CRT colors, respectively. The detailed analysis indicated that both the shape and size of the ellipses were influenced by the color regions in the CIELAB color space. For the shape differences for the red and blue-green color centers were quit large, while negligible at the other color centers. The area ratios of the suprathreshold to threshold ellipses for the color centers in the third and fourth quadrants of the a^*b^* plane were much greater than those in the other regions, which suggested the visual nonuniformity of the metrics in CIELAB color space.

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Comparative study of evaluation structures to the interior color coordination between elderly persons and young persons

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ABSTRACT

In this paper, I show the difference of the evaluation structures to the interior color coordination between elderly persons and young persons. At first, desirable color combinations were examined by the scale evaluation method. Next, the evaluation grid method was used to clarify the evaluation structures to the interior color coordination of elderly persons and young persons.

The image of a desirable space of young persons resembles that of elderly persons. But, young persons feel that the union feeling of the overall color is desirable while elderly persons are paying attention to the color of a part (especially, sofa).

"A calm feeling" and "a feeling of warmth" are strongly related for young persons. On the other hand, "a calm feeling" is strongly related to "a feeling of brightness" for elderly persons.

Keywords: Evaluation structure, Interior color coordination, Elderly persons

1. INTRODUCTION

Super-aged society will come soon in Japan. In 2005, the population of the senior citizen exceeded 20% of the all population. It is forecast that it will exceed 25% in 2013.

In Japan, spatial planning by universal design is needed now. The design that considers not only the hardware side but also a psychological side is necessary. And, it will become more necessary to think for a barrier-free color in the future.

Therefore, at first I researched the color discrimination properties and, compared the color image of elderly persons and young persons. The used method was the semantic differential (SD) method. As a result、the color images of elderly persons were different from young persons'. Especially, elderly persons and young persons differed in the image of an achromatic color. It was suggested that they did not differ in the images of chromatic colors with high values and condition of color discrimination influenced the evaluations of colors.

But the difference of the evaluation doesn't appear remarkably for elderly persons in the impression evaluation of the space by the SD method. Therefore, in this study the evaluation grid method was used to evaluate a space.

Basing the above-mentioned result, this paper aims to compare the evaluation structures to the interior color coordination between elderly persons and young persons.

2. METHOD

2.1 Preliminary experiment

One hundred ninety two color combinations of 8 colors for the sofa and 4 colors for the floor and 6 colors for the wall, were used to the preliminary experiment.

A perspective drawing of a room for the evaluation was made with AutoCAD made in Autodesk. I changed the color combination by Adobe Photoshop, and the card that was used for experiments was printed on A4 size.

Subjects divided the desirability of 192 objects into five stages in the experiment.

Table 1 The colors of the sofa

N2	N9
10YR7/8	2.5PB7/8
10YR4/6	2.5PB4/6
7.5YR4/14	(5Y8/14)

Table 2 The colors of the floor

5YR7/6	5PB7/6
7.5YR4/6	5PB4/6

Table 3 The colors of the wall

10YR8/2	10B8/2
2.5Y8/4	10B8/4
2.5Y6/4	10B6/4

Fig. 1 Used perspective drawing

The subjects were 4 elderly persons and 5 young persons. Average age of young persons was 20.6 years old, and that of elderly persons was 77 years old.

After this experiment objects for experiment 2 were selected.

2.2 Experiment 2

The used method was the evaluation grid method. At first 33 color combinations of the floor and the wall were used by experiment 2-1.

The illuminance on the desk was 150lx. This is average brightness at night of the living room in the house in Japan. The source of light is a white fluorescent lamp whose color temperature is 4200K.

Subjects were 20 elderly persons (11 males and 9 females) and 10 young persons (5 males and 5 females). The average age of elderly persons was 73 years old.

In addition, the supporting experiment that a color combination of the floor and the wall was a main evaluation object was done.

The used objects were 32.

3. RESULTS

3.1 Desirable color coordination

Evaluation to color coordination of young persons is controlled by the value and the hue. The tendency that is controlled than the hue by the value is seen in evaluation of elderly persons.

A red sofa got high evaluation in desirability in both elderly persons and young persons. In addition, on the case of a red sofa, it was clarified that a difference of age or sex influences evaluation greatly.

Therefore, I considered that important elements as an evaluation object are the hue and the value, squeezed objects as follows.

Whether there was a difference of the value of the wall or the floor and whether the hue of the wall and the floor was B or YR, and whether a combination of the hues became equal each were standards to select objects. I chose each four or five pattern among presence of a difference of an evaluation average mark of elderly persons and young persons per one color of sofa as objects of experiment 2.

3.2 Analysis by evaluation structural drawing

3.2.1 The case of elderly persons

There are a lot of answers that a part of the interior is “calm” or “bright”. The tendency to compare the rooms partially is seen.

In addition, three following characteristics were seen in evaluation structure. The wall with high value and YR is related to “calm”. “It becomes clear”, “beautiful” is related to “bright”. Red that is warm color / YR is related to “warm”.

The value affects “a feeling of brightness” and “a calm feeling” greatly. A color with high value is desired generally.

When there is little difference of the hue, subjects judge “a feeling of brightness” and “a calm feeling” by the hue and the value and the chroma generally, though subjects apt to judge it by the value. As a result, “it is calm if it is warm”; “if it is bright, it is calm”, and words are connected.

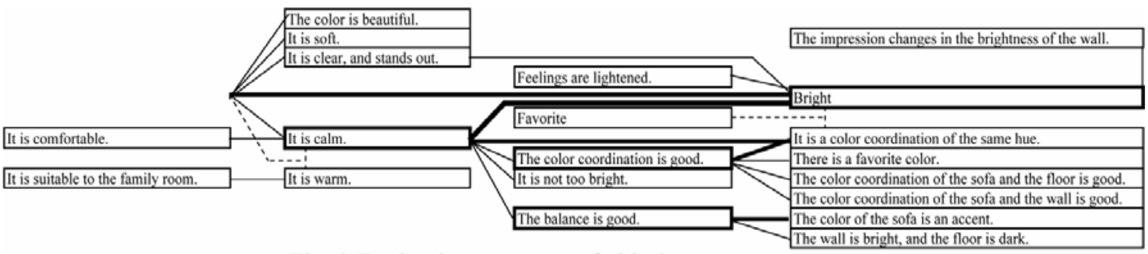

Fig. 2 Evaluation structure of elderly persons

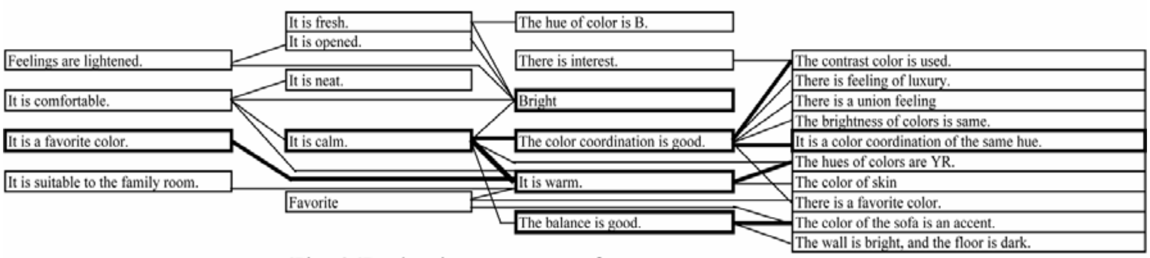

Fig. 3 Evaluation structure of young persons

Table 5 Evaluation order of each color combination(Exp.2-1)

Color combination			Young persons		Elderly persons	
Sofa	Wall	Floor	male	female	male	female
2.5PB4/6	10YR8/2	5YR7/6	1			
2.5PB4/6	10YR8/2	7.5YR4/6	2	1		
10YR4/6	10YR8/2	7.5YR4/6		2		2
10YR4/6	10B8/2	5YR7/6			1	
2.5PB4/6	10B8/2	5PB7/6			2	2
10YR4/6	10YR8/2	5PB7/6			3	1
2.5PB4/6	10B8/2	5PB7/6	3			2
10YR4/6	10YR8/2	5PB7/6	3	3		
10YR4/6	10YR8/2	5YR7/6	3			5
2.5PB4/6	10YR8/2	5PB7/6	3			
2.5PB4/6	10YR8/4	5PB7/6		3		
2.5PB4/6	10B8/2	7.5YR4/6			4	

Table 6 Evaluation order of each color combination(Exp.2-2)

Color combination			Young persons		Elderly persons	
Sofa	Wall	Floor	male	female	male	female
10YR7/8	2.5Y8/4	7.5YR4/6	1	2	1	4
7.5R4/14	10YR8/2	7.5YR4/6		1		1
N9	10YR8/2	5PB7/6			1	
10YR4/6	10YR8/2	5YR7/6	2			
2.5PB4/6	2.5Y8/4	7.5YR4/6	3	4		
2.5PB7/8	10B8/2	5PB4/6				2
7.5R4/14	2.5Y8/4	5YR7/6		3		3
2.5PB7/8	10B8/4	5PB7/6			3	
N2	10B8/2	7.5YR4/6	4			
N9	10B8/4	5YR7/6			4	
10YR7/8	10B8/2	5YR7/6				4
10YR7/8	10B8/4	5PB7/6				4
7.5R4/14	10YR8/2	5YR7/6				4

3.2.2 The case of young persons

"There is a union feeling" and "there is feeling of luxury" and "the balance is good" and so on were answered. In these, there are a lot of answers to the entire atmosphere, the balance, and the arrangement of color. But, there is individual difference about preference.

YR colors affect "a feeling of brightness" and "a feeling of warmth" and also "a calm feeling" generally.

There is much evaluation that appointed the hue; "it is unified in brown", "I like a color combination a white sofa and a blue floor and a blue wall", "a color combination of a black sofa and a blue floor and blue wall is good". The hue much affects evaluation of a color combination for young persons.

"The interior that a color of a wall is YR and middle value" is related to "calm". "A color is brown (YR)" is related to "warm". The hue influences both "a feeling of warmth" and "a calm feeling". When the hue is YR, 2 elements ("it is warm" and "it is calm") are strongly joined together.

3.3 Analysis of desirable color coordination

The standards of judgment of elderly persons for desirability are "the color combination is good", "it is warm" and so on. These are not difference from the standards of young persons. However, the favorite color combination differs between elderly persons and young persons.

Elderly persons desire space for which bright colors are used, and as for young persons, atmosphere and the balance of the entire room are valued, and they desire objects and they desire objects with the floor of low value and with the warm-colored wall and floor. And, elderly persons desire a space colored by cool colors comparatively. Moreover, the space with a black sofa is being comparatively desired by young persons while it is not desired by the elderly persons. However, the evaluation point of the warm-colored space with the sofa of 10YR7/8, the wall of 2.5Y8/4 and the floor of 7.5YR4/6 is high for both generations' persons.

A difference of preference by sex is seen, and females like space with the red (7.5R4/14) sofa.

Even if the desirable image for the space was the same, a color combination to obtain the image is different between young persons and elderly persons.

4. CONCLUSIONS

The image of young persons and elderly persons' desirable spaces is resembled.

"The color is desirable", "the color coordination is good", "it is calm", and "the balance is good" are important points of the favor of the interior color coordination.

However, it is felt that the union feeling of the overall color for young persons is desirable while elderly persons are paying attention to the color of a concrete part (especially, sofa).

"A calm feeling" and "a feeling of warmth" are strongly related for young persons. On the other hand, "a calm feeling" is strongly related to "a feeling of brightness" for elderly persons.

The favorite color coordination differs between elderly persons and young persons comparatively.

Even if the desirable image for a space was the almost same, as for a certain color, the same image may not be provided for young persons and elderly persons.

Therefore, we have to examine more about relations of an image of a space and a color combination.

ACKNOWLEDGMENTS

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I would like to thank cooperation of many people through this research.

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Intergenerational Study on Image of Color concerning Interior Elements in a Living Space

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ABSTRACT

This study was conducted to evaluate the image of color concerning the elements in a living space intergenerationally. From the result of the experiment presented so far, it is clear that psychological factors extracted are stable but that the semantic structures are not the same among the elements. The semantic structure of the color chip is different from the others. While it is clear that that the semantic structure of the aged group is different from the other generations. This seems to be due to the less color sensibility or decline of interest in color.

Keywords: Interior element, Generation, Semantic structure, Factor analysis

1 INTRODUCTION

In recent times, environment surrounding us has become colorful and colorful. Interior elements in a living space also have become so colorful. It is to be desired that we can use color as our like, while the comfortable visual environment we live in has been keenly required for. Though it is important for the color coordination to grasp the image of color of each element, it has not been studied sufficiently. Relationship between semantic factors and color itself was studied by Oyama et.al[1]. However the semantic image of color of a product is different from color itself. A taste toward colors of a product is thought to vary in each product. The image of color of a building façade[2], an interior spaces[3] and a product[4] used in the human life were studied respectively to a certain extent. I have conducted the comprehensive study on image of color of the products concerning human life[5]. However, it must be believed that image of color has intergenerational gap.

This study was conducted to evaluate the image of color concerning the elements in a living space intergenerationally.

2 EXPERIMENTS

Four elements, a system kitchen, a refrigerator and an air-conditioner, and interior wall were selected for experimental elements. An exterior wall and a color chip painted in a single color were also selected for experimental elements to compare.

Typical pictures of each element were taken into a computer and then digital images for color simulation were made. Table1 shows thirty-three colors adopted in the color simulation that were made up of ten pale tone colors, ten strong tone colors, ten dark greyish colors and three achromatic colors. The images of the elements simulated into each color were printed into 198 photo prints. The semantic differential rating method was applied to evaluate. Twenty semantic differential seven-point rating scales were used.

Three groups of observers, the younger group ranging in age from 20 to 23, the middle aged group ranging in age from 30 to 58 and the aged group ranging in age from 61 to 65, were asked for their appraisals. Each group consisted of twenty women. The subjects were tested having over 0.7 of corrected eyesight and normal color vision.

Table 1 Colors used in the experiment

Chromatic Color in Munsell Color System					
No.	Pale Tone	No.	Strong Tone	No.	Dark Greysh Tone
1	4.3R7.8/4.2	11	4.9R5.5/8.6	21	5.3R6/2.5
2	5YR7.9/4.2	12	5.2YR6.1/8.4	22	5.2YR4.9/2.3
3	5.3Y8.8/4.5	13	6.2Y7.2/8.9	23	4.8Y5/2.2
4	5.9GY8.7/3.8	14	5.4GY7/7.8	24	5.5GY5.1/2.8
5	5.5G8.3/3.6	15	4.8G6/7.4	25	4.1G5/2.9
6	4.8BG8.3/2.9	16	6.1BG5.6/6.6	26	5.4BG6/1.9
7	5.3B7.9/2.9	17	5.6B4.6/6.8	27	5.3B6/1.8
8	6.2PB8.2/3.7	18	6B4.6/8.5	28	6.2PB6/2.9
9	4.2P8.2/3.5	19	4.8P4.5/8.5	29	3.6P6/2.1
10	4.9RP7.9/4.5	20	5RP5.6/8.3	30	4.2RP6.1/2.1
Achromatic Color in Munsell Value Scale					
No.	White	No.	Pale Grey	No.	Middle Grey
31	N9.5	22	N8	33	N6

Further auther information: Send correspondence to (ma_sato@kpu.ac.jp)

3 RESULTS

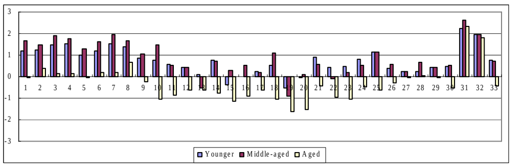
At first all semantic differential rating data were analysed together by factor analysis. Table 2 shows the factor loadings for each scale. Three factors, which describeed the color images of all generations for all products, were clearly extracted. Contributions for the three factors are 44.8%, 22.7% and 18.6% respectively. A cumulated contribution is 86.1%. This means that the color images of the elements can be described by three stable factors. The primary factor named is “comfort”. This is because this factor strongly relates to such scales as 'unnatural-natural’, 'unfriendly-friendly’, ‘boring-interesting’ and 'unpleasant-pleasant’. The secondary factor named is “cheerfulness”. This is because this factor relates strongly to such scales as 'dull-sharp', 'dark-bright’ and 'heavy-light'. The third factor named is “warmness”. This is because this factor relates strongly to such scales as 'cold-warm', 'womanly-manly' and 'soft-hard'.

Table 2 Factor loading of each factor for all data

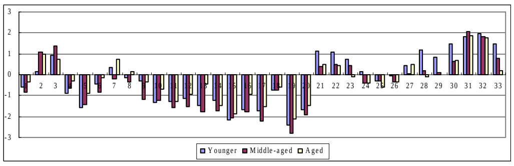
Factor loadings	Comfort	Cheerfulness	Warmness
unnatural - natural	0.949	-0.070	0.127
boring - interesting	0.946	-0.119	-0.009
unfamiliar - familiar	0.934	0.040	0.251
unpleasant - pleasant	0.920	0.220	0.221
unstable - stable	0.918	-0.053	0.166
unfavorable - favorable	0.898	0.191	0.240
dense - clear	0.825	0.426	0.062
disturbing - calm	0.823	-0.386	-0.304
unrefined - refined	0.785	0.493	0.072
simple - complicated	-0.678	-0.362	-0.134
ugly - beautiful	0.642	0.612	0.291
weak - strong	-0.620	-0.102	-0.297
dull - sharp	-0.042	0.916	-0.124
dark - bright	0.206	0.793	0.536
heavy - light	0.347	0.769	0.407
gloomy - cheerful	0.094	0.732	0.628
showy - plain	0.471	-0.709	-0.423
cold - warm	0.079	-0.032	0.928
womanly - manly	-0.201	-0.386	-0.817
soft - hard	-0.357	-0.321	-0.808
Eigenvalue	*8.96*	*4.55*	*3.73*
Contribution (%)	*44.8*	*22.7*	*18.6*
Cumulative contribution (%)	*44.8*	*67.5*	*86.1*

Figure 1 shows the factor scores for “comfort” concerning each element. Each generation is shown in each graph respectively. Scores of the color chip have different tendency from the other elements. Patterns of achromatic colors, white and pale grey, obtain high scores for all elements and all generations. Strong tone colors for all elements except for the color chip are unacceptable for all generations.

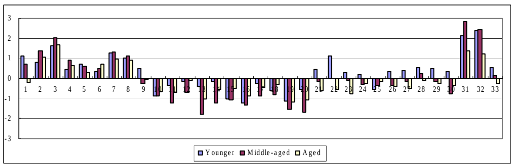
Figure 2 shows the factor scores for “cheerfulness” concerning each element. Small differences between the color chip and the other elements are observed. All elements of the pale color obtain high scores for all generations, while all elements of the dark color obtain negative sores. Scores for all elements of the warm color are lower.



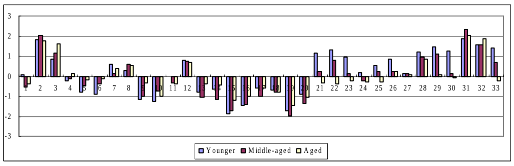
Color Chip



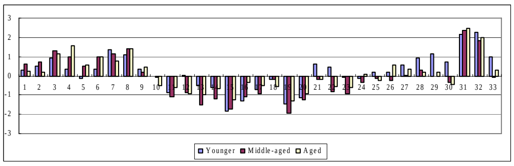
Exterior wall



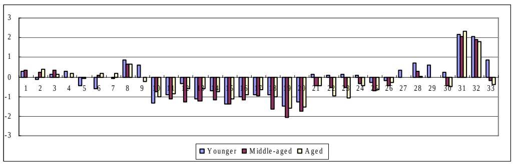
Interior Wall



System kitchen



Refrigerator



Air conditioner

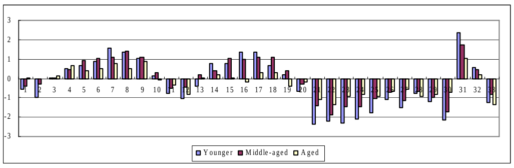
Figure 1 Factor score for “comfort”

Figure 3 shows the factor scores for “warmness” concerning each element. Small differences between the color chip and the other elements are observed. All elements of the warm color obtain high scores for all generations, while all elements of the cool color obtain negative sores. Scores for all elements of the achromatic color are lower. As for the dark color scores for the aged group are the lowest. This means that the aged persons are hard to distinguish the dark tone colors. Range of fluctuation of scores also becomes smaller according with the age. This means that the feeling of color have become less sensible according with the age.

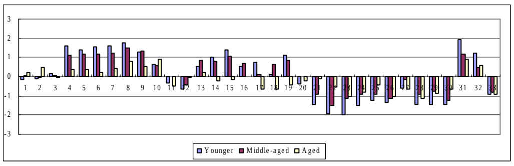
Table 3 shows the factors extracted for each element. The number of the factors extracted for each element was three. Contributions for the primary factors, for the secondary factors and for the third factors varied ranging from 33.6% to 48.4%, from 22.1% to 28.3% and from 16.1% to 24.0% respectively. Cumulated contributions for each product varied ranging from 85.7% to 89.4%. This also means that the color images of the elements can be described by three stable factors.

As for the primary factors, "comfort" is extracted for all elements except for the color chip. The primary factor of the color chip is "sophistication". As for the secondary factors, "lightness" is extracted for the exterior wall and for the system kitchen, while "cheerfulness" is extracted for the interior wall, for the refrigerator and for the air conditioner. "Comfort" is extracted for the color chip as a secondary factor. "Lightness" and "cheerfulness" have almost the same meanings. As for the third factors, "warmness" was extracted for all elements.

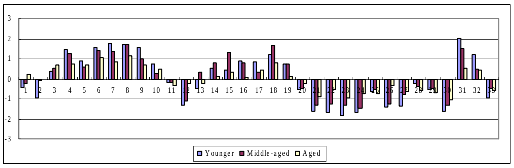
The results stated above indicate that the semantic structure of the color chip is different from the other elements. This seems to be due to the character of the color chip having no shape.



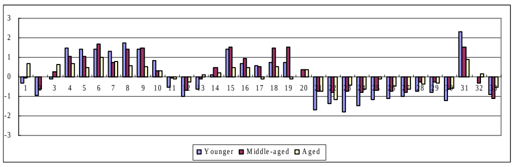
Color Chip



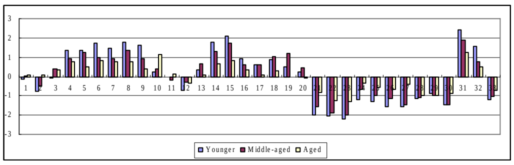
Exterior wall



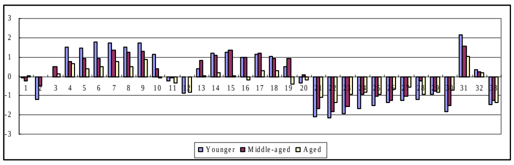
Interior Wall



System kitchen

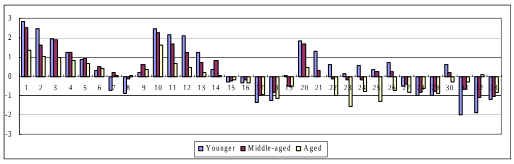


Refrigerator

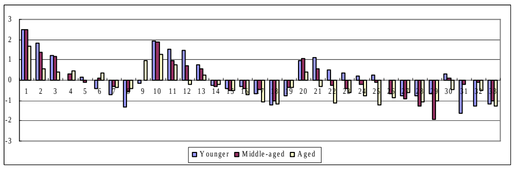


Air conditioner

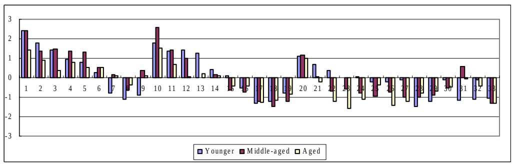
Figure 2 Factor score for "cheerfulness"



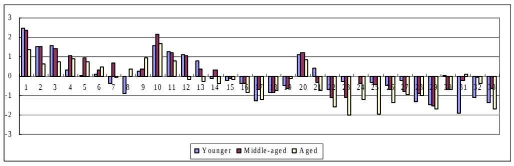
Color Chip



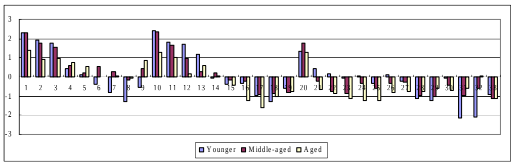
Exterior wall



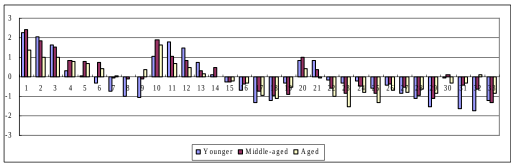
Interior Wall



System kitchen



Refrigerator



Air conditioner

Figure 3 Factor score for "warmness"

Table 4 shows the factors extracted for each generation. The number of the factors extracted for the younger group, the middle-aged group and the aged group are three, three and two respectively. Contributions for the primary factors, for the secondary factors and for the third factors varied ranging from 41.4% to 48.1%, from 23.4% to 37.9% and from 17.7% to 18.1% respectively. Cumulated contributions varied ranging from 81.5% to 89.2%. This also means that the color images of the elements can be described by two or three stable factors.

As for the primary factors and the secondary factors, "comfort" and "cheerfulness" are extracted respectively for all generations. As for the third factors, "warmness" is extracted for the the younger group and the middle-aged group. The third factor was not extracted for the aged group.

Table 3 Factors extracted for each element

Product	Primary		Secondary		Third		Total contribution (%)
	Factor	Contribution (%)	Factor	Contribution (%)	Factor	Contribution (%)	
Color chip	Sophistication	33.6	Comfort	28.3	Warmness	24.0	85.9
Extrior wall	Comfort	48.4	Lightness	22.8	Warmness	16.1	87.3
Interior wall	Comfort	47.4	Cheerfulness	22.1	Warmness	19.9	89.4
System kitchen	Comfort	43.0	Lightness	23.5	Warmness	19.2	85.7
Refrigerator	Comfort	44.6	Cheerfulness	25.9	Warmness	18.4	88.9
Air conditoner	Comfort	42.0	Cheerfulness	27.7	Warmness	16.8	86.5

Table 4 Factors extracted for each generation

Product	Primary		Secondary		Third		Total contribution (%)
	Factor	Contribution (%)	Factor	Contribution (%)	Factor	Contribution (%)	
Young	Comfort	41.4	Cheerfulness	27.4	Warmness	18.1	86.9
Middle	Comfort	48.1	Cheerfulness	23.4	Warmness	17.7	89.2
Aged	Comfort	43.6	Cheerfulness	37.9			81.5

The results stated above indicate that the semantic structure of the aged group is different from the other generations. This seems to be due to the less color sensibility or decline of interest in color concerning the elements.

4 CONCLUSIONS

From the result of the experiment presented so far, it is clear that psychological factors extracted from the observers' appraisal for the image of color are stable but that the semantic structures are not the same among the elements. The semantic structure of the color chip is different from the other elements. This seems to be due to the character of the color chip having no shape. While it is clear that the semantic structure of the aged group is different from the others. This seems to be due to the less color sensibility or decline of interest in color concerning the elements.

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Discussion of Color Planning in Product Design

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ABSTRACT

The color planning can provide a new method of thought to modern design. The article below discussed its scientific significance in technique designing—convenient, accurate and compact; its strategic function in business expanding and market occupying; and its cultural value in reflecting the connotation and grade of the product.

Keywords: product design, color planning, science, strategy, culture

An Italian designer once mentioned, "The days which seeking for form have been outdated and now the colors will be in the rule place in designing." It seems to go to extremes but actually there's some truth in it. In 21st century, great changes in the judgment of product design have taken place, that is the function and the form are no longer the simple criteria in "Homogeneity Age" and the colors become more and more important in product design. As for cultural and mental function, the colors work as the reflection of people's mind and feelings and go deep into our daily life by and by. So making rational use of colors (especially color design) becomes designers' essential capability, it's also used as the enterprise's strategy in marketing.

The color planning is a kind of ordonnance program based on chromatology and provides a new method of thought to modern design.

When we design a product, after its function and form being worked out, color planning then takes on a very important role. Castelli, an expert in chromatology, thinks that although colors, like sense of touch, temperature, sound, etc. belong to immateriality, they are elements in designing. Product designers should, with certain emotions, design the elements directly caused by people's sensation. This kind of design is also called "soft design". Because these elements which consist of colors, sense of touch, temperature, etc. can be said "soft" materially and possess great flexibility, while designing the form is quite different, it is a kind of hard substance. As for the form of the product, people accept it through their understanding, so it belongs to the rational thinking, while the color choosing totally comes from instinctive intuition, so it belongs to sensibility. Colors are important visual language. It is approved by scientific experiment: 80% of the outer world information is caught by our eyes. In the normal state, people's first visual reflection is the colors. Among a good many elements in product design, the colors have the brilliant charm.

All of the colors we can percept have three properties which are hue, lightness and purity. They are the most basic elements to build up colors. Color elements are basic substances of a product's color planning. The correlations among these elements and a series of effect caused by them contain theories about color science and color art. It is very important to grasp the color theory for a designer, just like a musician who must first grasp the theory of how to composing music. Only with abundant theories, can we make a good color planning like "flowery melody".

Hue is the appearance of colors which shows its outer nature. It is both the shinning skin and the spirit of the colors. Lightness is a color's level of light and shade. It is the concealed skeleton. Purity is a color's level of bright and dingy which shows the color's inner quality. With the changes of the purity, color can appear its supreme richness. In a color kingdom, it is really difficult to try to accurately describe the character of each color by words. The development of modern color science, however, provides a set of whole color denotation system with which the designers can study out some color planning accurately and effectively.

The color's denotation system has two species, one is mix-color system, and the other is vision system. The mix-color system is a color summary system mixed on the basis of tricolor lights. The vision system is a set of denotation system which is made for their color marks and signs according to color's tri-elements—hue, lightness, purity which are shown by tri-dimensional space so as to form a solid, it is called color solid, such as Munsell's Color Solid and Ostwald's Color Solid.

The color solid models and color solid books which are made according to color system can show the logical relations of colors themselves and arrange so abundant colors together to have a fine compare. The color denotation system means a color dictionary for designers to help them to analyze the character of color, demarcate color's sort and enlighten their association with colors, it is a theory basis and also a tool to make color planning.

Color planning has changed our used color using habit which was with random order or blindness in product design. Because of the plan's scientificalness, we can effectively control and manage hue, lightness and purity by using a rational and precise fix quantity in a product design and process. Color planning is a technical process virtually, and is to put the color planning studied out into practice under the control of strict technique measures and finally embody design's intention in the products accurately. Color planning is an important part in the traditional project of product design, it requests designers to consider our consciousness and mental demands for colors and bring colors into their uttermost play not only in space but also in their variability of quality and quantity by the means of scientific analysis. The planning combined with color rules and sculpt principles has scientific significance such as convenient operating in techniques and accurate and precise in design practice.

Angel Hawkins, a famous expert of chromatology, said, "Colors can influence our thought and psychological activity, they're vital to products and the process and sale." Colors are the most attractive and appealing things among a good many elements in product design. With the same form and function, the proper color arrangement will affect products' sale—sell well or not. Most designers only emphasized on usage in form and function for the early product design because of the restriction of lacking materials and craft skills comparatively, and overlooked the study on color planning. The colors of products then were mainly black and grey such as in hardwires, domestic appliances and vehicles, etc. Dull colors also presented the material conditions and design ideas at that time. But it is different nowadays from the past; the cool and dull products in old days were replaced by the colorful and bright design.

In 1987, American congressmen disputed over and over again about how to strive for motor selling. All the important points in appearance seemed to count for little because the breakthrough point to resolve the problem lay in the colors of motors, it was the underlying factor. At that time, American had quite powerful car throughput. Cars made by Germany and Japan, however, once took place of American's position in international market and even entered into America's mainland like a great flood. Confronting such disadvantage situation, they disputed and suggested to make some rules to limit the import cars. The congressmen didn't make clear what was the main reason that the youth liked cars made by Germany and Japan. The survey result was that the youth liked not only those cars' body shapes but also the colors. Indeed, Germany and Japan paid much attention to the cars' body shapes as well as the ever-changing fashion colors in design. It catered to the youth's flavor to fashion colors and personalities. Although the Congress possessed decision-making power, the administrative intervention couldn't rule people's aesthetic consciousness. The colors, then, were not merely a design issue and had been up to be the political significance which could affect the existence of the enterprises and even the whole national economy. Since then, the motor companies such as Fort took steps to adjust the product's color planning and finally regained the market.

The science and technology's progress in the present society brings the research and development of new materials, new arts and crafts and especially new colorant into a new area in which it provides much more choices for the product's color planning. The rich and flowery colors make fashion colors more prevailing. And products with fashion colors have been the first choice for customers. It can be said that fashion colors sensibly reflect people's mind and social value's alteration like a mirror.

Fashion colors are determined by an era's tides, social environment and people's psychology. At a certain extent, they come into being with two psychologies, they're self-consciousness and imitating. When some color declines to be common, people will feel to be lack of exciting and charming and will seek for another different visual characteristics, soon such characteristics will be imitated and be prevailing quickly. Colors' popularity brings not only the living and vigorous energy to the products but also much more benefit to the enterprises.

Nowadays, there is a pretty new idea—"eyeball economy". It means the economic phenomenon caused by the buying desire through people's "eyeball" impression. The colors, as one kind of the material expression, give people the most deeply impression, and different colors have different symbolic meanings, so it is no doubt that colors can be one of the most impressive fashion elements which can reflect people's psychology. The colors of a product can catch people's mind only in seven second, so colors have surprising effect of low cost and high benefit to the product. Businessmen are "designing" colors while customers are "consuming" colors. The colors tie the products with customers. It is no doubt that the best selling means for businessmen is to arrange colors in their right orders so as to make perfect connection between selling and buying. Color planning can express the meanings and convey the feelings in product design, so it deepens the product's connotation and brings more vigorous competitive force. It has strategic significance in enterprise's exploitation and market occupying.

"Sun rises over the river and red flowers are redder than fire, spring comes into the river and the water becomes greener even as blue." The colors contrast between fire-like red and bluish green reflects not only the natural beauty but also the poet's romantic feelings. At this point, colors have been transformed from objective reality into cultural reality. Product design is an index of an era's culture and economy as well as a kind of materialization of art and science and technology. The brand of any age shows the harmony and coherence with the times, so does the product. Color design is also a cultural creation as well as our lifestyle's concrete reflection. Under the specific cultural background, people's life seeking and dream can be found in a certain culture value system, so products with color planning can change people's dull life to be interesting and attractive.

In general, people have much more interests in colors. It is the colors that decorate the world colorful and beautiful, that balance our feelings and that act on our choices. If we change the colors of the product on which its form being unchanged, then it will have some symbolic meaning and distinct personality. While many designers make color planning for the product, they also give these colors very elegant names, such as, "Purple Crystal" which has elegant and mysterious nature, and "Blue Charm" which shows the sea spirit and confliction sparkles between sense and sensibility. The colors, holding in designers' hands, are just like a magic cube. Let's look at "Black Knight"—it fully exhibits the male's resolute nature and their mature life quality; while "Silvery Moonlight" is up-dated and much more like a piece of electronic music full of fascination; as for "Red Zeal", it brings users the warm sense and the joyful emotions. People's aesthetic sense is not isolated but influenced by psychology and ethics, and at the same time also restricted by the whole era's aesthetic consciousness.

Distilling increasingly of color emotion can give voice to idea and belief, which is the color's symbol meaning. Different nations and different ranks have different products in all corners of world nowadays. Some products' colors have a symbolic in one place and are favored but not in another place. Symbolic color language has both the general and specific character. Designers should match colors not by personal prefer but first of all find out the symbolic in various specific conditions and then use the symbolic sense to work out ideal color planning for products.

Modern science and technology widened our cognition about colors. It comes to a sensible consumption age, consumers hope that products, besides physical demands, could also satisfy their spiritual expectation. Requiring product's individuation is evolving into a competing hotspot as important as technique index. Individualized allocation in color planning makes us feel easy and joyful in our mind. Colors can be called worldwide language. Colors have to carry with some sensibility and sincerity when colors are soaked into many emotions in our life such as exciting, sad, happy, peaceful, etc. and the gate of exploring color will be opened. Pretty colors are favored by most of consumers. All mobile phone producers in the world swept a cyclone of colors after Motorola produced color shells, color mobile phones hit a hot right off, and especially color-shell mobile phones which could change their shells as we please were more attractive in vision. All of us know color shell design for Apple' computer had caused a sensation, the computers succeeded in their unusual and colorful product's color planning. Computers had been emphasizing on their inner quality's improving but worn the same "dress" for many years. Apple computers changed the used "original look" and had many new color appearances such as strawberry red, orange yellow, sandalwood green and grape, etc. Semitransparent materials and individuation colors built up a supreme fascination and had set up a distinctive image in the same industry. The color planning, as a milestone, enlightens many designers and enterprisers. High-tech products bring us warmhearted and humanism care so as to make our world varied and colorful. The indifference and "colorlessness" world in the past has gone away forever.

Color planning in the product design lays stress on color's aesthetic value and character of its own, so it has changed the colors' subsidiary status which was limited in functions and appearances before. Color planning with humanism care has some culture value which reflects connotation and taste of products.

In product design, color planning is combined with product's appearance and quality closely so as to build up a harmonious product. It is the colors that successfully completed the main task of improving people's life quality. It is not difficult to imagine that, in present society, how the world could be like if there're no colors or color planning at all—the world would lose energy and vigor; the products would be lack of style, charm and tastes.

Textured textiles and advanced visual research

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ABSTRACT

The quantification of the appearance of coloured textiles is a task of the second order vision, since these test objects are generally textured and involve the conjunction of various stimulus features. In the experiments here described we use a second order response, the visual balance. Operationally, we vary the relative areas, and the features contrasts of the two samples juxtaposed within the display, the Test and the Reference. We discuss its relation with another response, the Golden Section or Divine Proportion, traditionally defined as a combination of samples pleasing to the eye, based on purely geometrical factors.

Keywords: textiles, visual appearance, colour combinations

1. AIM OF THE WORK

The experiments described in the present paper are in line with the recent descriptions of the visual process "from simple to complex, from local to global", statements widely utilized by models of computational vision[1-2]. Briefly, the extraction of the stimulus features from the retinal image feeds the various feature maps, and the subsequent interactions and competitions culminating the saliency map, as an ingredient of the task dependent internal representations. The basic conceptual step relies upon the distinction between first order and second order vision. Each order involves:

a)- its features which for the first order are colour, luminance and orientation for the second order are chromatic, achromatic and, generally, feature contrast, texture, patterning, etc.

b)- its responses to complex objects and scenes which, mainly in the second order multidimensional vision, range from bilateral symmetry, harmony, visual balance, comfort, preference, pleasure, emotion, mindsight, abstract vision. etc.

As far as we know, various responses are not yet arranged along a hyerarchical scale, probably because their mutual interdependencies, if any, are not yet sufficiently known. In this framework, as a first step, we aim at investigating the relation between the visual balance3-6 and the Golden Section7. The former is a component of visual harmony, and is assessed as a match of the appearances of two compared samples, in the wider sense of the word: visual weights, saliences, information contents, etc. The latter , which consists of a slight deviation from the bilateral symmetry, is known to be "pleasing to the eye", somehow related to the aspect ratio, to the preference or to the personal selection, and similar, but, in its traditional definition, no reference is made to the spatial structure of the involved surfaces.

2. MATERIALS AND METHOD

The display (Figure 1), consisting of a two sample combination, is placed on a desk, on a black paper, and is illuminated by an incandescent lamp fitted in the ceiling, over it. The observation geometry is 0°/45°. The two juxtaposed samples are named, respectively, Test and Reference.

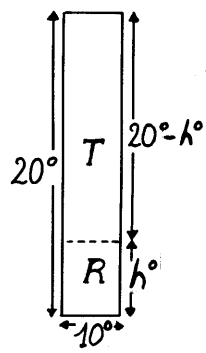

Figure 1 The display. T, for Test object, R, for Reference sample.

In the Experiments 1 to 3, the Reference is a spatially uniform grey cardboard, of luminance Lref =8 cd / sq.m. The Test is textured, knitted with the Garter stitch, by generally using together two identical threads of the same wool. In this way a sort of line grating is obtained, where the lines are regularly modulated in amplitude. In Experiment 4 , however, a more complex sample is used as a reference, where two threads of different colours are knitted together, so that their appearance is a "quasi random" two colour combination.

The Michelson luminance contrast, within the display is C = (L test – L ref) / (L test + L ref).

The NCS notations of the colours of the wools used by us are displayed below:

S 05 00 - N; S 10 00 – N; S 15 00 –N ; s 25 OO – N; S 40 00 – N; S 75 00 –N; S 80 00 – N: S 15 80 – Y90R;

S 05 40 – Y 70R: S 05 20 – Y40R; S 05 20 – Y50R; S 40 50 – Y90R; S 05 80 – Y; S 10 55 – B90G;

S 05 30 – B70G; S 40 35 – R90B; S 20 65 – R90B; S 15 60 – R90B; - S 05 40 – R90B; S 10 70 – R20B;

S 10 40 – R 50B

Operationally, we vary the relative areas of the paired samples, by shifting their dividing line. Various settings are randomized, and the constant stimuli method is applied (ten responses per point). Three highly skilled observers took part in the experiment. Their responses were averaged.

The first Experiment aims at assessing the “preferred” ratio of the areas of the two samples within the display, having in mind the “like/dislike” differential semantic scale , but by assigning to every setting a score, according to a ten point subjective (internal) scaling. We refer the responses to the so called Golden Section7, concerning the relation between the areas of the two paired samples, or to the ratio of their heights, being the width of the display constantly of 10°, and its total height S° = 20°. Briefly, the said proportion is “Divine” when the height of the Reference (h ref) is 12°.24 deg and that of the Test (h test) is 20°-12°.24 = 7°.76 so that the corresponding area ratio, denoted by Re/Te, is 1.58 or its reciprocal , 0.63, respectively. Similarly, the ratio R to the larger area in the display to its total area is 0.612.

In the second and third Experiments the response index is the visual balance, while the material and method are the same as above. While reading the results, now, let us recall that “the small areas of high chroma do balance larger areas of low chroma”, as established by Munsell rule3. Let us recall that in the traditional experiments based on visual balance, where spatially uniform samples were used, the cojoined stimulus features are the Area, the Value and the Chroma. Dealing with complex text objects, we added the feature “texture”, like knitted samples are (6;8) . In the present experiments we try to determine the (first order stimulus) uniform achromatic cardboard equivalent (from the stand point of appearance) to a complex pattern, where colour and texture are cojoined.

In Experiment 4, to put into evidence the pure effect of cojoined colour and patterning, we compare directly knitted grating like samples to a “quasi random“ bi-coloured Reference, the texture being the same (Garter stitch).

3. RESULTS

The responses recorded in the first Experiment are shown in Figure 2, where the normalized scores of the response “preferred” are plotted versus the height of the grey Reference cardboard. Note hat the bell-shaped plots shown in the left column exhibit a single bump, for red (top), green (middle) and pink (bottom) test objects. On the other hand, the plots shown in the right column are bi-peaked. The peaks are of the same amplitude for the white test objects (in the middle), but the relative amplitudes of the two bumps are different for the clear colours (orange, yellow, celestial and light grey) than for the darker ones (blue, violet, brown and dark grey). The Golden Section, indicated by the vertical broken lines, is more-or less close to the above said peaks. It is as if this response to a purely geometrical relation would be somehow perturbed by the response to the variously cojoined features.

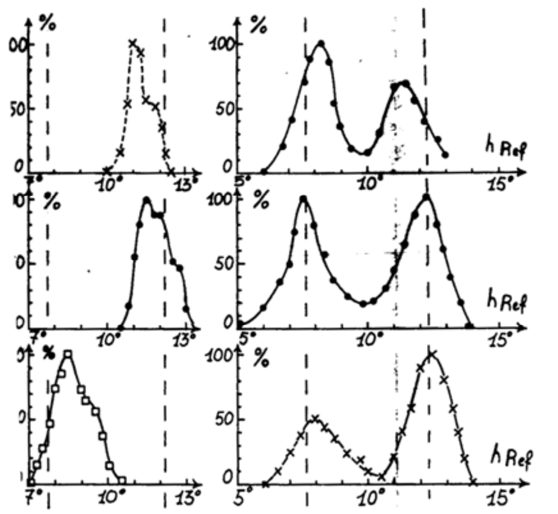

Figure 2 Abscissae: the height of the Reference sample. Ordinates: the percent frequency of occurrence of the response “preferred”. Various plots refer to various colours of the Test.

The data recorded in the second Experiment concern the visual balance. Three response categories are allowed: Yes balance, No balance, Doubtful (the frequency of occurrence of this latter category being halved and added to those of both the Yes and No categories). The colour assigned to the Test is picked up from the list of basic categories: red, green yellow, blue, black, white and grey(s). The Reference is a uniform grey cardboard (L ref = 8 cd/sq.m). As above, te total size of te dislay is of 20°.The psychometric functions are sigmoid-like. For instance, Figure 3 refers to four blue samples, the saturation of wich increases when passing from the left to the right plots. In Figure 4, the ratio (Re/Te) of the areas of the intra-display samples, at the balance, is plotted versus the intra-pair Michelson luminance contrast, C = (L test – 8) / (L test + 8). Note that the data for the achromatic knits coincide with those for the coloured ones, when the luminance contrast is large. On the other hand, at intermediate contrasts, the coloured samples require, at the balance, less contrast than the corresponding (knitted) grey ones. We are faced with the (expected) competition of chromatic and achromatic contrasts. At last, note that our data include the range of ordinate values 1.58 to 0.63, representing the two versions of the Golden Section.

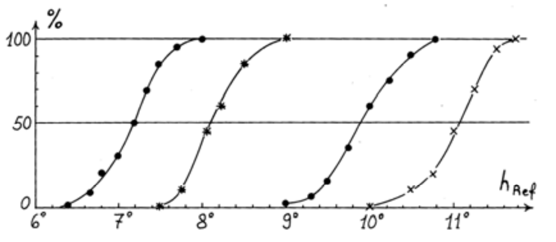

Figure 3 Psychometric curves obtained with blue Tests (knits) decreasing in saturation from left to right. The normalized frequency of occurrence of the responses "Yes balance" is plotted versus the height of the reference sample (grey uniform cardboard, Lref = 8 cd/sq.m)

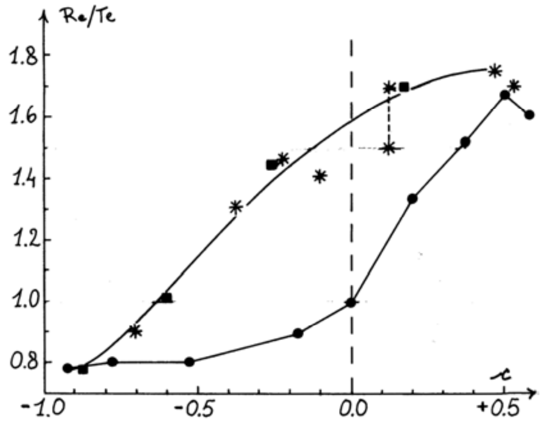

Figure 4 Ratio of the area of the Reference (grey cardboard) to that of the Test (coloured knit) versus the intrapair luminance contrast. Full dots: the Test objects are grey wools knits, of various spectral reflectances. Asterisks and squares: Tests are coloured wool knits (basic monolexemic categories)

In the third Experiment, the total height of the display is not longer kept constant at S° = 20°, as in he previous two Experiments, but, every other thing being equal, S° is varied in discrete steps from 4° to 30°. The plot of R (the ratio of the area of the larger sample to the total area of the display, at the balance) is found to be bell-shaped, but complicated by various ripples. For instance, Figure 5 refers to a black and white incongruent pattern drawn with China ink on a white paper, its average luminance being of 17 cd/sq.m, like that of the uniform grey Reference. A peculiarly favourable situation occurs at those points where the balance meets the Golden Section. Similar, but not identical results are also obtained when using as test objects grey cardboards with different reflectance factors and photographic reproductions of square waves, line gratings, as well as when photographs of some complex real test objects, like multicoloured fabrics for clothing, and even some well known ancient carpets. However, by extending the investigation to numerous different complex real test objects, we find that we cannot generalize. Briefly, the plots like that shown in Figure 5 contain a description of the characteristics of the tested sample which is yet far from being deciphered. A limiting case is shown in Figure 6, which refers to a real test a carpet (clear Kirman). Its fine spatial multicolored structure and the low feature contrasts probably favour a sort of spatial integration, at the site of the unit processing the balance, so that the data are close to the condition of bilateral symmetry, within the display. But other informations still remain hidden.

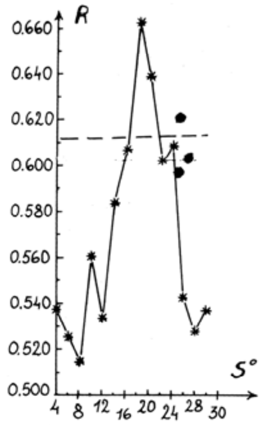

Figure 5 Dependence of the ratio (R) of the greater sample area within the display, at the balance, versus the corresponding total area assigned to the display The asterisks refer to a black-and-white incoherent pattern. The full dots refer to multi-coloured textiles used for clothings

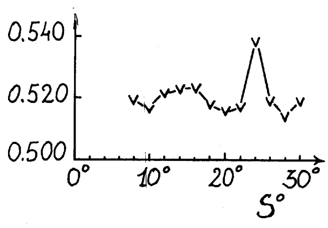

Figure 6 As for Figure 5, but now the Test is an ancient carpet (clear, with low features constrasts)

The above difficulty led us to change our experimental procedure. Instead of dealing with the global response to a spatially complex test object, we started (as in ref.9) from the elementary spatial structures, by complicating them gradually. The

Test consists of a knitted line grating where red stripes are alternated with stripes of a different colour (we used the focal basic monolexemic categories). The period the grating varies from 1° to 4°.6. The Reference now consists in a quasi-random pattern (see Section 2), where a single red thread and a differently coloured thread are knitted together. The percent deviation of the size of the reference from the bilateral symmetry condition is displayed versus the intra-grating luminance contrast .

Note that both Test and Reference have the same texture. being knitted with the Garter stitch, so that we are recording how a sample structured by using gratings, balances a quasi-random spatial situation.

The main result is that by increasing the period of the grating , its weight increases, since the size of the reference needed to balance it also increases It seems of interest the fact that this increase is accompanied by a change in colour appearance: the intra-grating assimilation occurs and the percent deviation from intra-pair bilateral symmetry, at the baance, is less than 10% when the grating period ranges from 1° to 2°; on the other hand, when the stripes of the grating are large (period 4°.6) the intra-grating simultaneous contrast effect occur, and the above said deviation, at te balance, attains even 50%t. This is the first step of our research program now in course.

4. CONCLUSION

In the history of visual science there are various situations where the attempt has been made to propose a perceptual – cognitive space after having assessed the characteristics object in the physical space. This is, for instance, the case of texture in general and of the texture of textiles8. Our experiment might be regarded as an attempt to consider the space of visual appearance of complex images, like the textiles are, based on the recent trends of visual science, where the visual process us being described in terms of computational vision. In other words, we are simply trying to extend the early proposal of Kobayashi10 concerning the images scales for textiles, fashion, clothing colour trends, etc.

We considered two responses of the second order vision, the Golden Section and the visual balance and their interaction, by making use of two "robust" second order factors like the luminance contrast and the area relations. That is, we have been dealing with global responses at the site of feature interactions and competitions. Further data are now being gathered, to obtain a database.

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Twenty Years in the Lives of Twenty People

— The Aesthetic Changes in the Color of Clothing during China's Transitional Period

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ABSTRACT

The past two decades spanning the 80s of the twentieth century until today have been of great significance to the Chinese people. From the exploratory and experimental inception of China's reform and opening-up policy to its steady, rapid economic development today, the lives of Chinese people have undergone tremendous change in terms of clothing, food, housing and transportation. The most direct and vivid reflection of this social transformation has been in the progression of change in color expression in clothing. This article conducts a summary of this progression based on an image compilation of clothing from twenty Chinese people over the past two decades. In addition, this article analyzes the progression of change in color expression in clothing from a broad perspective of social development as well as the origins and the cultural backgrounds which triggered the changes in their aesthetic orientation.

This article is based on old photographs. Although the temperament and appearance of a person is decided by various factors, we can still appreciate the tremendous changes that clothing and personal adornment has brought people. The emphasis of this article is to compile changing rules and changes in the color of clothing and color schemes in different periods and discuss the general rules and changes experienced by the public at large without regard to the aesthetic differences among different social strata. The two decades from approximately 1983 and 1984 until around 2004 witnessed tremendous change in China's society. The writer of this article divides this time span into three stages: the first stage is the undetermined stage; the second stage is the free stage; the third stage is individualistic stage.

1 UNDETERMINED STAGE OF CLOTHING COLOR

1.1 Clothing Features

From 1983 to 1988, when the closed door was first opened in the 1980s, the undefined society received undetermined hope. People began to carefully pursue desires of their own. These pursuits first demonstrated themselves attire and personal adornment. When people decided whether or not to buy new clothes, their primary concern was the whether clothing was of the latest style, even though many people were wearing it. This trend was noted in the photographs of few of my female friends. For example, a red one-piece dress, red sweater, red ski jacket, bat-wing sleeve sweater of red and white stripes; blue, grey western-style clothes or suits; geometric patterned skirt; etc. The Sun Yat Sen suit was still popular everywhere among men, while western-style suits had just begun to win their affection. Complicated seams were employed in the design, emphasis was placed on the decoration of collars, sleeves and edges; multi-colored geometric patterns were popular, etc. In this way, clothing contemporary to this time period displayed that it had been well designed.

1.2 The Rules of the Clothing Color

Although the clothing and color coordination displayed in the pictures may seem a bit odd, it generally gives people a practical and amiable feeling. The general color features of the clothes are as follows: simple colors were mainly used, added with a little bright color. The simple color planes include warm grays and cold grays, for example, gray, blue gray, dark blue, light camel, khaki, etc. These were generally used in designing men's clothing and women's western-style suits. Red and blue were used more frequently as bright colors, and the red was mainly a warm red, including bright red, vermeil, dark red, etc. The blue seemed brighter.

The beautiful red and blue colors brought about many romances and beauties to that time. Looking from the color collocation of some clothes, the high contrast between the two colors of the broad stripe on the sweater is an important color feature. The colors of these geometric stripes, including some adventurous geometric color planes, are simple and explicit. It indicated that people had begun to pay attention to colors, although a majority of people tended to hide the colors inside their coat instead of displaying them.

2 FREE STAGE OF THE CLOTHING COLOR

2.1 Clothing Feature

Time Frame: late 1980s - early 1990s. Between 1989 and 1997, people developed a stronger sense of fashion coordination. For example, different types of suits became popular including western-style suits, sweater suits, etc; jeans were matched with coats, and shirts were matched with sleeveless dresses; the clothing was coordinated with accessories such as hats and scarves. Belts were increasingly utilized as a type of adornment. The boldness of women in their selection of clothes was manifest in the following articles of clothing: large color patterned skirts and coats, plaid shorts and plaid pants, a plaid short overcoat, different colors of leggings and stir-up pants, silk shirts, hip-length knitting coats, short dust coats, rabato and double-breasted overcoats with padded shoulders. Influenced by the way that foreigners wore underclothes and fashionable dress, waistcoats and sweaters became popular as outerwear. After the 1990s, the emphasis on the clothes had a tendency of moving down to the pants from the coat. Costume belts became more and more elaborate. For example, broad belts were fastened around high-waist pants and around the waist of the one-piece dresses and skirts.

Men's clothes started becoming more colorful, particularly in summer clothing such as T-shirts and in winter clothing, such as sweaters. The abandoned western-style suit regained popularity and became an instant fashion for men. The women at this time were clean-cut, agile, capable and open-minded, whereas, the men became more charming than before.

2.2 The Rules of the Clothing Color

In this stage, the use of color in men and women's clothing became more flexible than during the previous stage. There was a greater variety and pattern to the colors. A suit possessed a main color scheme, perfectly matched with decorative colors. Clothing began to use more smooth colors, such as grey, light camel, coffee, light blue, etc. Other colors besides red and blue began to be employed and included secondary colors such as orange and green. High color contrast appeared on the outerwear. The color planes of red and white, blue and white, red and black, white and black, were increasingly used in clothes. The space of color contrast was expanded. Women's skirts made of colorful materials, large colored sweaters and sweater coats added flavor to the fashions of this time period.

The beautiful colors the men chose varied according to different seasons and occasions. This was reflected in the T-shirt they chose in the summer, the clothes they chose for traveling and the sweaters they wore in the winter. Moreover the color schemes included yellow, red, blue, and green. The clothing in this stage obviously presented a great variety of colors, and the degree of color contrast was also being strengthened.

3 INDIVIDUALISTIC STAGE OF THE CLOTHING COLOR

3.1 Clothing Features

From 1998 to 2003 or 2004 in the late 1990s to the beginning of the 21 century, fashionable styles were explicitly dictated by magazines as well shopping malls. Interestingly, people's attire as shown in the collection of photographs looked even more omnifarious. Clothing during this period had four clear features: The first one is a sense of leisure, which is directly related to the increasing rate of travel and the promotion of the physical exercise campaign for the entire civilian population. Typical clothing included jeans, T-shirts, sport shoes, shorts, vests and various types of jackets. The second feature was a sense of elegance. This category referred to the dress of the white collar professionals who had routine lifestyles. Clothing representative of this demographic included: refined suits, formal attire, high-end leather shoes and suitcase. The third feature is ethnic flare, which was due in part to the attention placed on and communication between the cultures of different ethnic groups aroused by travel fever. The representative clothes included Russian skirts and wax painted materials. The fourth feature is the gradual reduction of a sense of seasonal clothing, while individualized clothing was gradually emphasized.

People's lifestyles also underwent change. People went to work, traveled, attended gatherings, went to concerts, bars, played ball, went to beauty parlors, and visited their parents. People began to select clothing according to what they were going to do. The clothes people chose varied according to work and off-work activities, which also varied depending on whether the activity was traveling, shopping or going out for dinner with friends. Even for traveling, the clothing selection also depended on whether one was going skiing or climbing a mountain. People during this time period were not content with simply dressing properly. More importantly; they sought to dress well and emphasized individuality.

3.2 The Rules of the Clothing Color

During the third stage, men and women could finally stand on the same stretch. The color of clothing in this stage had the following features: **One:** colors became simpler, continuously reducing the element of color coordination. The color coordination of a set of clothes tended to be simple; for example, cream went well with coffee, or black matched with white and grey. **Two:** selection of the bright leisure clothes such as red jackets, a orange feather overcoat, yellow T-shirts, a blue skirt. Green seemed to be a popular color at the time. **Three:** Full-bodied ethnic flavor, such as the Chinese traditional color black, red, and brown, the blue and yellow in Thai skirts, etc. **Four:** Red and blue remained people's favorites among the application of all kinds of colors.

Generally, the colors adopted in this stage gave people a more comfortable and natural feeling than in the previous two stages. People are searching for or have already found their own orientation in clothing selection. The concept of color coordination is enriched with more content than was available previously.

4 THE COMPARISON AND ANALYSIS IN CLOTHING COLOR

4.1 A Tendency Towards Warm Colors

By taking a survey of all the pictures over the course of the three stages, most of the colors employed in both men and women's clothing tend to be warm in color. Ranging from vermeil, bright red, date red and dark red, all shades of red are warm colors, with the exception of rosy red, which is rarely used. The warm yellow tones that were frequently used included light yellow, dust yellow and yellow brown. Shades of orange included pure orange, pink orange, orange brown. Shades of green include grass green, olive green, dark green. However the middle and low brightness blue, such as purplish blue, blue black, still release a sense of warmness. Warm grays accounts for a relatively large portion of all types of gray clothing, such as beige, khaki, medium camel, coffee and warm grey. All in all, warm colors have positive visual effect. Warm colors express gentleness and a sense of humanity, which is compatible with Chinese people's warm-heartedness and hospitality.

4.2 Red, White, Blue

4.2.1 Red Culture

Of all the warm colors employed in fashion, red plays an important role. It not only occurs in great frequently, but also occurs in many different types of clothing. Red has special meaning to the Chinese people. Firstly, it is the traditional national color. China red will continue its great popularity with the approaching Olympic Games. Secondly, the affinity for red is born of sentiment cherishing bygone years. In 2000, the movie *Colorful Times* drew the world's attention to Chinese clothing. In the 2001 Shanghai APEC meeting, 20 leaders from different countries gathered together and made their attendance in bright red or sapphire blue Chinese double-breasted Tang Dynasty costume. This image immediately spread all over the globe through TV, and suddenly made Tang dress popular. All of a sudden, the red cheong-sam, Tang Dynasty costume, or other red Chinese style clothes can be found everywhere.

There was a movie called *The Popular Red Skirt* in the 1980s. It is a story describing the life and studies of female textile workers. They had ideals, anxiety, as well as the pursuit of beauty. The "red skirt" in the movie is an expression of beauty and a symbol of the women's emancipation of the mind, as well as a symbol of their pursuit of beauty. The selection of the red by the scriptwriter shows that he has really given much thought to the matter. In addition, Chinese people think "red skirt" sounds comfortable and positive. Chinese people believe that red stands for auspiciousness.

4.2.2 Blue Asia

The color blue presented in the photographs includes light blue, lake blue, sapphire blue, purplish blue, blue black and blue grey. The color blue is a favorite color amongst Asians and quite popular in China. "From the Yindanshilin (dark blue) and bamboo cloth color (light blue) student uniform during the period of the Republic of China during the last century to the representative purplish blue Chinese tunic during the Cultural Revolution; from formal attire to leisure suits to children's school uniform, the color blue has played a very important role in the color of clothing in China's modern history. The color blue embodies a simple, reserved and harmonious character, which is in tune with Chinese people's gentle and moderate characteristics. Blue is also well suited to our people's yellow skin tone. "

The blue clothing in these photographs were divided into two big directions: high light blue and low light blue, especially high light blue is more beautiful than blue liked by the Chinese in tradition and is full of activity.

4.2.3 Harmonious White

White clothes and white color tones frequently appeared during the three stages. The white clothes are "just as undefined as the color 'neutral color', and seems to go well with everything. It easily works well for men and women, young and old, in winter or spring, for formal or leisure attire, underclothes or outerwear as well as for apparel or accessories. In the questionnaire concerning the color of clothing conducted by the China Fashion Color Association in 2005, white ranked number one as people's favorite clothing color. White is elegant, clean, and easily coordinated with. People's love for this color in apparel shows that the features of this color have been rooted in people's hearts.

4.3 Clothing Color and Gender

Looking at the photographs across the three stages, the differences between the men's dress and the women's dress is apparent in the first and the second stages. It is especially so in the first stage, where the color difference between men's ware and the women's ware is obvious. Bright colors were mainly employed in women's apparel, whereas, the men's apparel tended to be drab or simple. The second stage was a transitional period where many colors were still used in the women's clothing. The situation greatly changed during the third stage. Men and the women were equal in terms of the colors used in their attire. The emphasis of color was placed on the category of clothes rather then on distinguishing gender. The colors used in the professional attire and leisure clothes varied accordingly. Yet the colors used in men's and women's clothing of the same type were quite similar.

4.4 Temporal Characteristics and Individuality

The occupations of the people presented in the selected photographs of this article include university teacher, bookstore employee, company manager, architect, accountant, and university logistics worker. They originate from different regions and cities (currently living in Beijing) including Henan, An'hui, Shan''xi, and Beijing, and had different family background including teachers, workers and businessmen. Having these different types of people gathered together at the same time creates an interesting image. Particularly during the first stage, the style and color of their clothing, their hair styles and even their facial expressions and postures are quite similar. This phenomenon makes us think that "fashion", in the past, was more widely spread and influential than fashion in the present. Some individual images of personality were always flooded by the great social mark even today we reviewed and studied these matters far from the present and in having phenomenon .The personality in this time were only a weakly dim memory towards the whole era.

4.5 Changes in Concepts of Taste

4.5.1 Stage 1: The Beauty of Clothing Equals the Beauty of People

The fashionista concerned with personal beauty in Stage 1 were bold. At the beginning of the 1980s, the notion that the people's dress should be connected with politics gradually began to die away. During those years, of those around 20 years of age, some were entering university and some were just entering the work force. They were in their golden years. Suddenly faced with the new concepts in fashion, they seemed a bit overwhelmed. However, through careful observation they began to little by little, differentiate, appreciate, and imitate, paying the most attention to whatever was the newest; the newest textures, the newest colors and the newest patterns, regardless of whether or not it suited them; if other people had it, I wanted it too. If Beijing didn't have it, go to Shanghai or Guang Zhou to buy it. If the item was out stock or they couldn't afford it, they made it themselves. That kind of initiative could be compared with struggling to be a model student or model worker. During that time, when most people bought clothes, they didn't need to try it on. They bought it as long as it looked good. The beauty of clothing was incidental to the beauty of people. As long as your cloths were new, you were sure to be noticed.

4.5.2 Stage 2: The Beauty of Clothing Vies With the Beauty of People

During stage two, women began to have ideas and a sense of self and gender consciousness began to arouse. They paid attention to the way they dressed, their appearance; this is clearly apparent from the hairstyles of that time, with the poofing of bangs, the prevalent use of styling products and adornments. At this time, it could be said that China's fashion market was developing quickly and steadily Its active market, foreign or domestic, high-end or low-end, stimulated all consumers; from among people of means to people without means, all could achieve transformation.

The decade encompassing the 1990s witnessed the fastest development of China's clothing market. Faced with a blossoming world, we could choose foreign style clothing or combine foreign brands with local brands. For a time, whatever fashions were possible were out there. Additionally, many of the clothes purchased or obtained at this time were single articles of clothing; the ensemble people wore served as a test of their level of style. Naturally, while aesthetic standards were still at an elementary level, fashion coordination sometimes ended up botched. There was definitely a period of tumult. During that time, whatever they saw, they bought. Whatever was around they bought. When wearing clothes, people also wore whatever they could get their hands on. On top of that, hairdressing was on the rise. The result was often overdone with a lack of emphasis. Money had to be spent publicly. Image and dress must embody the role. This was a public decade.

4.5.3 Stage 3: The Beauty of Clothing Sets off the Beauty of People

The fashion market has become hotter and hotter; however, people's consumer attitudes are more and more placid. As we mature, the wholesale attitude of looking out for number one is beginning to change in terms of fashion tastes and judgment. The color of clothing must reflect its style and composition. The color of clothing must also harmonize with the individual's personality and temperament. Even after a person has selected the clothes, the clothes continue to serve as an expression of that person.

The clothing of this time period is not indicative of a person's economic or social standing, but rather a symbol of a person's cultural standing. The everyday fashion consciousness of Chinese people is undergoing a silent revolution. The attention they paid to price and design for the many years until now, has transformed in to brand consciousness, placing emphasis on personal requirements. Of course, the primary concern of these brand names does not necessarily lie in price, but rather brand spirit. Selecting the right brand, in as sense, is also a correct selection of style and color, as well as select for people the permissive circle and position of society. At the beginning of the 21st century, the highest ambition that Chinese people had for fashion appeal requirements was to wear their individuality.

5 CONCLUSION

Compared with the past, Chinese fashion has, in the past 20 years, followed the fast pace of economic development as if striding through a whole century. Such change is sudden and violent. The photographs collected for this article have been separated into three stages: The first stage refers to the undetermined stage of clothing color. Such colors used simple shades of gray and dark blue as a primary base, adding small portions of bright colors. The second stage was a period where the color of clothing was freely expressed, an outfit of clothing already had the primary shades of color; for example shades of camel, shades of blue, etc.; the spectrum of colors began to display secondary colors. Tops and bottoms, outerwear and underwear, all displayed strong color contrast relationships. The proportions of white clothing increased and multicolored skirts proliferated. The third stage served as a period of freedom and individuality for color in apparel, representing an increased harmony of integrated coordination; for example dark blue and Cambridge blue or cream and brown. Some latent clothing colors become even brighter, beautiful greens and purples constitute fashionable colors and often occur. There are some full bodied traditional colors find expressions; for example China's traditional black and red, palm, etc. In addition, the different shades of red and blue still remain people's favorite clothing color.

20 years in the course of clothing development has caused us to once again rush into imitate, parallel, step out of line, excessively accessorize, exaggerate, change, unify, work up to the end, self-determine, harmonize and contrast coexistence of our grasp of color in clothing. In the presence of this great era, individuality is sometimes submerged.

The body of colors in the clothing in the photographs has an overtone of warm colors. Different types of red and warm grays serve an important function within these photos; within all kinds of photographs there is a freshness and vitality given by the warm colors.

In the photographs, the colors red, white and blue occurred the most frequently. Red is the traditional color of China. Red clothing is associated with luck and celebration. The nature of the color white is elegance. Clothing that gives you a clean, settled feeling, tends to be matched with this color. Blue is simple and subdued. Blue clothing is very well suited to the mild and moderate nature of Chinese people.

The gender differentiation in the color of men and women's clothing during the first stage was obvious; men wore dark colors, women began to wear bright colors. During the second stage, there was a slight change in the situation. However, many colors were still mostly expressed in women's apparel. During the third stage, men's and women's clothing the usage of colors in men and women's clothing showed no obvious differentiation. The differentiation was not primarily gender related, rather, reflected differences in clothing types.

During the three stages of fashion development, people's concepts of taste have also undergone change. The first stage is The Beauty of Clothing Equals the Beauty of People; the second stage is The Beauty of Clothing Vies With the Beauty of People; The third stage is The Beauty of Clothing Sets off the Beauty of People.

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An study on color management of HI-FI artwork reproduction

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ABSTRACT

This paper analyzed the color's subjective property and impersonality property of artwork, introduced a lot of factor of color management technology which applied in the printing industry, discussed some special questions of color management about HI-FI artwork reproduction, and studied the method how to improve the copying quality of HI-FI artwork that applied color management technology.

Keywords: HI-FI, artwork, color management, ICC profile

1 INTRODUCTION

Now, HI-FI artwork reproduction market is more and more abroad. It is satisfied with the demand of art fans to copy artwork with printing method, speeds up the transmission of human spirit culture, and promotes the development of art.

Color is an important carrier to transfer artwork information. The artists always choose the special color to reflect the signification of artwork, so it has an important meaning to copy the artwork color. So color management is the important approach to solve the problem that copying and controlling artwork color exactly.

2 THE ANALYSIS OF ARTWORK COLOR

2.1 The Analysis of Artwork Color's Subjective Property

The color is the necessary and important substantial basis of artwork. The people always perceive the color from the following several aspects when they appreciated artwork.

2.1.1 The color's vision property

Sometimes different color will give the people different feeling, such as the colorful light tricolor, the artists think that, the red color would give people the warmly and excited feeling, the green color would give people the cool and stability feeling, the blue color would give people the melancholy and sad feeling. Certainly, from the different angle of view and different psychology experience, the people would feel the same color with different aesthetic attribute.

2.1.2 The color's emotional property

The people's feeling of color usually has a big subjective randomness, but for national psychology, culture foundation and traditional custom formed in the long-term history, people usually has some intercommunity of the color feeling. The activity color, such as the yellow color can bring to people an activity attitude, and the blue color can bring to the people an uneasiness attitude.

2.1.3 The color's symbolize property

In people's tradition custom, some special color always is relative to some special content. But for the symbolize effect of color, it is different because of the influence of the difference social factors in every country, Such as the green color respective the peace, but the France dislike it because the jasper color is ever the cloth's color of Nazi.

2.2 The Analysis of Artwork Color's Impersonality Property

Every kind of art form is attention on the combination, construction and composing of colors. The artists always use color to model the form, performance space and texture. The effect of artwork color is decided by whether the color composing is reasonable and has the expressive force. The uncertainty of artwork color composing form, sometimes can determine the content or style of artwork. Therefore, color is

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one of the forms of artwork, and has already become the main component of artwork.

Artwork (painting) mainly includes Chinese painting, oil painting, print, water color, fresco, sketch etc. The characteristics of Chinese painting are mainly made use of lines and ink color to perform objects, not emphasize the tone, and have high expressive force. The characteristics of oil painting emphasize to pile up the pigments, and have a strong color contrast. From the brushwork we can observe daedal and colorful color. The shade is deep but not black; the light tone is bright but not thin. The color of watercolor painting is bright and special, and makes use of water to express the shade and transparency of tone.

While copying an artwork, its color should be copied accurately and based on the above property of artwork's color, which can lead the audience to hold the thought of artists and the meaning of artworks. But because of the color sensitivity of artworks, its color range is big than the printing color range, so it should carry though a special color management when copying an artwork.

3 THE COLOR MANAGEMENT OF ARTWORK COPYING

3.1 Color Management

Color management is based on the standard color space which is independent of equipments, standardize the color description, and make all equipments descriptions can be shared and converted. To carry out the open color management, it needs a virtual PCS (Profile Connection Space) which is independent of the equipments and can include every color space to build up equipment profile.

To carry through color management include the following basic contents. First, it need to define and control the color profile of the input, display and output equipment; Second, it need to define a work flat which can connect all the color profile; Third, it based on the data of input and output equipments of different color space to carry out the color space conversion.

In general, color gamut of input equipment is bigger than it of output equipment, and we can be association color gamut of input and output equipments with color management system. The main composing of color management system software include a data format that can support different equipments color profile, an algorithm that can covert a equipment color data to another equipment color space, the color profile data, and an algorithm that can bring the color gamut of input, display and output equipments into accord.

The principle of color management system is based on the color light additive process or the pigment subtractive process, uses color matching method, matches up to the origin color and reproduction color.

3.2 The Common Problem in the Color Management of Artwork Copying

3.2.1 Scanning input

For the different kind of artwork, or the same kind but different dominant tone artwork, it must use different scanning process. Various artworks, such as Chinese painting, watercolor painting and oil painting etc., their major idea is different, so it needs to accord as the origin characters, sum up their rule and process key point in the scanning and copying course, aim at the different origins to build up scanning curves and raise the scanning quality.

3.2.2 Color and tone adjusting

Using the printing method can duplicate thousands of colors, because it used pigment subtractive process in printing course, the color's brightness is losing, and some artwork which includes vivid color is hard to copy by printing method. On the other hand, the screen use colorful light additive process to represent color, its color range is more abundant than the presswork. This caused to that it can't duplicate the beautiful color on the screen, and the screen color is different with the presswork color.

The above-mentioned problem can be solved by compressed color gamut and contrast. It is through impress artwork's color gamut and contrast on the screen to be fit for the printing process, which can lead to What You See Is What You Get.

There are three main methods to compress color gamut. First, it needs to keep the color in color gamut changeless. The color out of color gamut is replaced of the latest color. Second, it needs to keep the color in color gamut changeless. The color out of color gamut is replaced of the color with the possible highest saturation, even it is departed an angle. Third, the color out of color gamut is projected to the edge of color gamut. The other color is projected to the edge of color gamut, keep the color angle changeless and reduce the saturation.

There are two main methods to compress the contrast. One is to accurately reproduce the color brightness in color gamut, the brightness out of color gamut should be increased or reduced, until it falls to color gamut. It would lose the color's contrast in the highlight or dark tone part. The other is the most brightness overlap each other in the two color space, the other degree brightness would be adjusted activity, so that it can put up an equably compress.

While compressing color gamut and contrast, there is one method or several kinds of methods be used together. It is according to the kinds and character of artwork.

In addition, because different equipments has different color management standard, sometimes it need to use some software such as Photoshop etc. to adjust the color of artwork, setup and adjust the parameter of gray balance, contrast, definition etc. from the technique direction. It also deals with the relation of color's accordatura, saturation, space distance, tone change etc. rightly from the art direction, thereby to realize truly reproduced the color of artwork as possible.

It needs that the preprinting designer not only have the necessary printing knowledge and can be proficient in controlling the whole printing technological process, but also have certain art accomplishment, art culture and perception, and master the basic principle and skill of color, painting etc. After re-handling the artwork, it can be fit for the printing demand, and have the "artwork" witchery. For example, replicating the oil painting, the character of oil painting is that it applies the color's tone and cool or warm color to model the object's art visualizes, to performance the object's solid texture. It pays attention to the variety result of the color light; the color performance is vivid; the color is smooth and not dry. If not carrying through artificial processing image, the image is dry after replicated, whereas after carrying through artificial processing image, it can obtain the perfect printing image. This requires that the preprinting designer should reprocess artwork during the copying process, but the reprocessing must be fit for the condition of printing process.

3.2.3 Color management in printing process

It is very complicated to create the ICC profile of printer. The color reappearance of printing dots is influenced by the related process parameter of numerous stimulant and digital process. During the copying process, the dinky parameter difference will influence the color of presswork, such as preprinting process (producing film and plate), printing material (paper and ink), and printing process (the balance of water and ink) etc. It is indispensable to standardize these different parameters with applying the color management in the printing technological process.

So it needs using the test plate to obtain the correlative data which can make sure the color and contrast of the image copied rightly, and the plate copying and printing course should be in the relative changeless condition. The main composing of test plate include the image with plenty of color and contrast, the gray balance test picture, reflected and transmissive neutral tone ladder ruler, the color measurement table etc. This test must mark clearly the name and type of paper and ink.

Only after obtain the correlative data which can make sure to copy the color and contrast of image correctively in the printing process via above approach, it can control the technological conditions strictly, obtain the data of every working procedure, and form the standard and criterion. It is the basic of color management to standardize the printing process. It needs to standardize the whole printing course, and forms the best printing state. The ICC profile produced on this foundation can reflect the replicated color ability of printer accurately. It must keep the stability of printing material quality, and the condition must keep constantly, such as press pressure, the balance of water and ink etc.

After putting up a strict control to each process, let the IT8 standard color index provided by international standard to be the origin to put up color separation, plate copying, and printing. After testing the L*a*b* chromatic value of the 928 color lump on the presswork with spectrophotometer, it will build the ICC profile of printer, and protract the color space of printer.

In addition, for the replication of artwork, some color characteristics of artwork should be considered, sometimes should choose some special paper and ink, or improve the composition of the paper and ink, so that it can obtain some fresh and pure color through printing.

For the artwork replication, it is not only similar in shape and color, but also be alike in spirit. Moreover for some sensitive color, just like the green and jasper, it must copy accurately, so can performance and express the meaning of the artwork adequately and accurately.

4 CONCLUSION

To carry on a perfect HI-FI artwork reproduction, it must combine with the two means, art and printing. For the art respect, it must hold the meaning of artwork and the thought of artists; for the printing aspect, it must apply the most advanced printing technique. Color management technology is satisfied to the demand of HI-FI artwork reproduction, and provides the technical foundation for HI-FI artwork reproduction.

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Research on the Application of CIEDE2000 Color Difference Formula in Chinese Printing Industry

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ABSTRACT

This paper researched the application of CIEDE2000 Color Difference Formula in Chinese printing industry. Visual color difference ΔV was gotten by visual experiment adopted to evaluation of color pairs collected in printing industry. When K_L, K_H and K_C of CIEDE2000 formula are 1.05, 0.98, and 1.01 respectively, the variance between ΔV and ΔE_{00} is minimum. Considering the complex applied instance in Chinese printing industry, the parameter K_L, K_H and K_C CIEDE2000 color-difference formula of should be set to 1.05, 0.98 and 1.01 respectively.

Keywords: CIEDE2000, color difference, Chinese printing industry

1 INTRODUCTION

In Chinese National Standards and Light Industry Standard CIELAB color difference formula is still used to evaluate color difference[1]. The study on the CIELAB color space has shown that it has a bad agreement with the visual result for small color difference and also can't predict the results of the deep blue colors correctly[2]. In Chinese textile and building industries, CMC(l:c) color difference formula is adopted[3,4] for small color difference. Some Printing Enterprises wake up to the limitation of CIELAB color difference formula and began to adopt CMC(l:c) as their company standards.

2 CIEDE2000 COLOR DIFFERENCE FORMULA

A new color difference formula, CIEDE2000, was recommended by CIE in 2001[5]. Developed by members of CIE Technical Committee 1-47 (*Hue and Lightness Dependent Correction to Industrial Colour Difference Evaluation*), the formula provides an improved procedure for the computation of industrial color differences. In the present study, it is the best color difference formula that can give a best agreement with experimental results than other published formulae[6]. In this paper the application of CIEDE2000 color difference formula in Chinese printing industry will be studied.

3 COMPARISON BETWEEN CIELAB AND CIEDE2000

CIELAB color difference is still the standard in Chinese Printing Industry. In order to prove the CIEDE2000 color difference formula to be used in the industry, its performance was tested in this industry.

In order to evaluate the color difference formula CIEDE2000 a printing proof is designed, which has a series of colors that have different saturation, different value, different hue. Some color patches were from IT8.7/3 target. Figure 1 shows the proof. Some other information is included in this proof to accomplish other tests.

This was printed by offset printing with the printing condition changing. After printing the color patches are cut separately. 15 observers who have worked for a long time in printing industry and have normal vision and abundant experience to justify colors are chosen to assess colors. Illuminant D65 and 10^o visual filed are adopted. The specimens are placed in direct edge contact and illuminated at 1000 lx and viewed in object mode against a uniform grey background of L^*=50.

The observers are requested to select some colors and arrange them to have the same visual difference using gray scale assessment. The visual difference is named ΔV. The accurate data of ΔV cannot be gotten directly by visual sense, so the statistic method was employed. Then the color

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differences are calculated using CIELAB color difference, named $\Delta E^*_{ab,i}$ (i=1,2,……). Again the color differences are calculated using CIEDE2000 ($K_L=K_H=K_C=1$), $\Delta E_{00,i}$, (i=1,2,……). Therefore the PF/3 value[7] can be got, respectively. PF/3 value of ΔE^*_{ab} is 35.27, while that of ΔE_{00} is 32.14. The results shows that the PF/3 value of CIEDE2000 is less than that of CIELAB, that is to say, the performance of CIEDE2000 is better than that of CIELAB under these samples.

Figure 1 The print proof.

4 OPTIMIZATION OF CIEDE2000

In industrial application the view conditions are different from these above to some extent, and the print products will be used by ordinary customers finally. So another 15 college students with no previous color experience in industrial color matching and who have normal visual sense were employed. When the printing proof was printed in different conditions, the same patch has different colors. So the color pairs which have the same position in the proof but not be printed at same print were picked.

In different viewing conditions, the participants were asked to view the printing samples and the visual color difference ΔV' was obtained by estimation. Changing the parameters K_L, K_H and K_C the ΔE_{00} can be calculated and the then the PF/3 values were obtained in different K_L, K_H and K_C values. This was done using Matlab 7.0 software. When the PF/3 value is least, K_L, K_H and K_C are 1.05, 0.98, and 1.01, respectively. Consequently under industrial conditions when K_L=1.05, K_H=0.98 and K_C=1.01, the performance of CIEDE2000 is best.

5 CONCLUSION

In this study the visual color difference is not very accurate. In the second visual experiment only college students were employed. And in printing industry many factors will affect the printing colors, for example mode of printing, printing stock, and so on. The experiment condition in this research has some limitation. The performance of CIEDE2000 color difference formula is better than CIELAB, so the CIEDE2000 should be recommended in Chinese Printing Industry, and I recommend the parameter K_L, K_H and K_C should be set to 1.05, 0.98 and 1.01 respectively.

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A case study of projection display on the patterned screen

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ABSTRACT

Projection display becomes more and more prevalent in the business applications and even our daily life with the cheap, cabinet, and bright projectors available recently. However, the great dependence upon the high quality screens for the traditional projection display systems constraints their application range greatly, and it is believed that relaxing the rigid requirement will make them more convenient and useful. A novel and more "intelligent" projection display system, by attaching a camera to the projector, has been developed. This paper presents a case study of projection display on the patterned screen based on the structure of projector-camera (ProCam) system, in which a new compensation algorithm was proposed, together with the obtained experimental results.

Keywords: projection display, patterned screen, projector-camera (ProCam) system, color modulator, compensation algorithm.

1 INTRODUCTION

Recently the projectors have become very compact and especially inexpensive on account of the technique innovation of their manufacture. The availability of cheap, cabinet, and bright projectors makes the projection display to be used widely in the official and business applications, such as presentations and advertising, and even our daily life for the so-called "family cinema" with large field of view. However, the great dependence of traditional projection display systems upon the high quality screens undermines their potential portabilities and bottlenecks their application range. Herewith, to relax the rigid requirement of traditional projection display systems and to make them more convenient and useful, a novel and more "intelligent" projection display system, by attaching a camera to the projector, has been developed. Upon the new notion of the projection display system, a wide range of potential applications of projection display emerges in the last decade[1-6], such as large-area seamless display, colored and textured screen compensation, neutralizing or controlling the appearance of a painting or 3D objects.

In this paper, a new radiometric model of the patterned screen was constructed and a novel algorithm of its radiometric compensation was developed.

2 SYSTEM SETUP

The ProCam system of this case study is shown in Fig. 1. A VGA NEC LT 30+ projector with a native resolution of 1024 x 768 pixels and a HITACHI HV-D30 camera with a resolution of 768 x 576 pixels were adopted here. The images were projected onto the screen via a RADEON R9200SE display card, and those images from the camera were captured by an 8-bit Matrox Meteor II/Multi-channel frame-grabber. The program involving our developed algorithms ran in the Microsoft Windows (XP) environment on a personal computer (PC) with a Celeron 2.13 GHz processor and 256 MB memory. A white wall (or a white board) and a standard screen were used to calibrate the system or to test our algorithms.

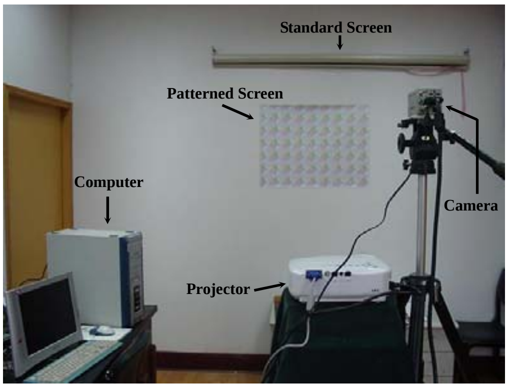

Figure 1 The ProCam system used in this study.

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A simplified dataflow pipeline for this ProCam system is shown in Fig. 2.

The present study is concentrated on the screen's radiometric compensation without considering the environmental lighting, and it is supposed that the pixel mapping has been completed between the image plane of the display system and that of the imaging system.

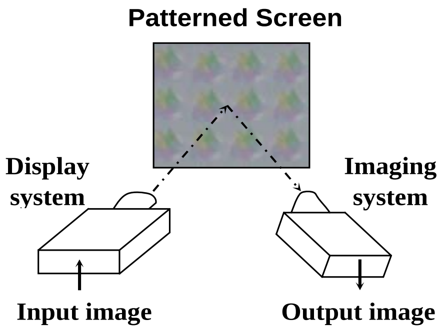

Figure 2 Simplified dataflow pipeline for this ProCam system.

3 RADIOMETRIC MODEL

3.1 General Radiometric Model

Similar to the published model[2,9], a universal radiometric model was developed for the ProCam system of this study.

An input image $\mathbf{I}_{in}$ is processed by the display system and its resulted image $\mathbf{I}_p$ will be projected onto the screen. The radiometric characteristics of the display system can be abstracted as a monotonic and non-linear response function (P) as

$$\mathbf{I}_p = \mathrm{P}\ (\mathbf{I}_{in}). \tag{1}$$

Then, the image $\mathbf{I}_p$ is reflected by the screen and will be captured as image $\mathbf{I}_c$ by the camera of the imaging system. For one point of the screen, its spectral characteristics can be represented as a monotonic spectral response function (S) as

$$\mathbf{I}_c = \mathrm{S}\ (\mathbf{I}_p). \tag{2}$$

Finally, the image $\mathbf{I}_c$ is digitalized by the imaging system so that an output image $\mathbf{I}_{out}$ is obtained. The output response of the capture system can also be described as a monotonic, nonlinear function (M) as

$$\mathbf{I}_{out} = \mathrm{M}\ (\mathbf{I}_c). \tag{3}$$

Both of the projector and the camera have three color channels (R, G, B), so $\mathbf{I}_{in}$, $\mathbf{I}_p$, $\mathbf{I}_c$, and $\mathbf{I}_{out}$ can be concretely represented as the digital vectors of each pixel in the input, projected, reflected, and output images, respectively.

3.2 Optimized Radiometric Model

In the general radiometric model of the ProCam system, only the function **S** depends on the radiometric characteristics at each point of the screen and will be varied with the change of different screens, while the functions P and M are the same for every point in their image plane and will be relatively fixed during one time of the system's operation, though actually they will tinily fluctuate with the environmental condition and the system's life-span. Hereby, in order to achieve the purpose of screen compensation, the function **S**, representing the screen's effect on the input image, should be obtained in a real time mode. However, owing to the nonlinearity, it is hard and inconvenient to determine the functions of P and M.

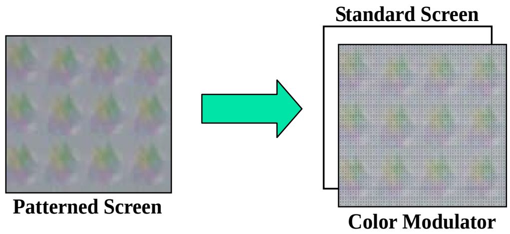

Figure 3 Patterned screen model.

Considering the exact difference between the standard screen and the patterned one, the patterned screen can be treated as the superposition of a standard screen and a color modulator of the same size, as illustrated in Fig. 3. Generally, the spectral characteristics of the standard screen can be regarded as being independent on the wavelength in the visible spectral range and basically uniform on the whole area of the screen. On the other hand, upon the fact that the reflectance characteristics of many ordinary screens are independent of the channel response of the camera[7], the dataflow pipeline for the ProCam system can be slightly modified as Fig. 4.

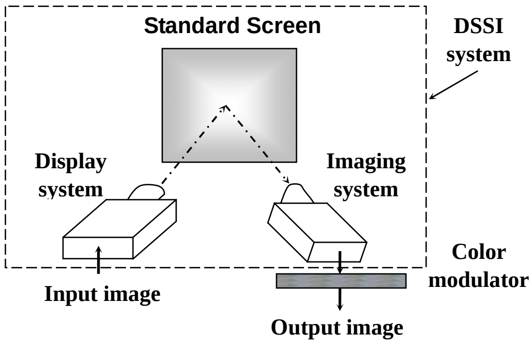

Figure 4 Modified dataflow pipeline for this ProCam system.

Herein an input image $\mathbf{I}_{in}$ is processed by the suppositional Display-Standard-Screen-Imaging (DSSI) system and the resulted image $\mathbf{I}_S$ is output. The forward and reverse response of the DSSI system can be described as two monotonic and nonlinear functions f_o and f_r, respectively, as

$$\mathbf{I}_S = f_o(\mathbf{I}_{in}) \quad (4)$$

and

$$\mathbf{I}_{in} = f_r(\mathbf{I}_S) \quad (5)$$

Then the image $\mathbf{I}_S$ is modulated by the color modulator to output the image $\mathbf{I}_{out}$. For many ordinary screens, the transmission of the color modulator keeps constant within each of the color channels[8] and so can be described as a linear function as

$$\mathbf{I}_{out} = \mathbf{K} \cdot \mathbf{I}_S + \mathbf{b} \quad (6)$$

where $\mathbf{K}$ is a diagonal transmission matrix and $\mathbf{b}$ is a constant compensation vector for the specular reflectance component of the standard screen, they are both the model parameters of the color modulator. $\mathbf{I}_S$ is concretely represented as the digital vector of each pixel in the output image of the DSSI system.

3.3 Parameter Recovery

The model functions f_o and f_r, depending on the standard screen, could be determined off-line in advance by projecting some colored patch images onto the screen, fitting them with polynomial mode, and being calculated using least square technique. However, the images projected on the standard screen showed significant spatial variations in lightness due to the substantial geometric distortion between the projector and the screen, so all the output images should be lightness-corrected before being sampled.

Based on the function f_o, the output image of the DSSI system could be predicted and also the model coefficients $\mathbf{K}$ and $\mathbf{b}$ at each point of the color modulator could be efficiently calculated by projecting several flat-gray images with different gray values onto the patterned screen. If these parameters need to be computed with higher accuracy, more flat-gray images with different gray values would be necessary and then their estimations could be performed by the least square technique.

4 COMPENSATION ALGORITHM

According to the optimized radiometric model and the derived parameters, a novel radiometric compensation algorithm of the patterned screen was proposed as

$$\mathbf{I}_{com} = f_r\,(((f_o\,(\mathbf{I}_{in}) - \mathbf{background}) - \mathbf{b}) / \mathbf{K}) \quad (7)$$

where, **background** is the output background image corresponding to the flat-black input image, and $\mathbf{I}_{com}$ is the compensated image corresponding to the original input image of the ProCam system for the patterned screen. It would be worth emphasized that the images displayed on the standard screen are supposed as the desired images in this study. Noting that the present algorithm is independent of the camera of this ProCam system and the compensated image was derived straightway, so it could be used for the on-line screen compensation.

5 EXPERIMENTAL RESULTS

The proposed compensation algorithm was tested on the patterned screen in Fig. 1, and the experimental results are shown in Fig. 5.

Output on the standard screen

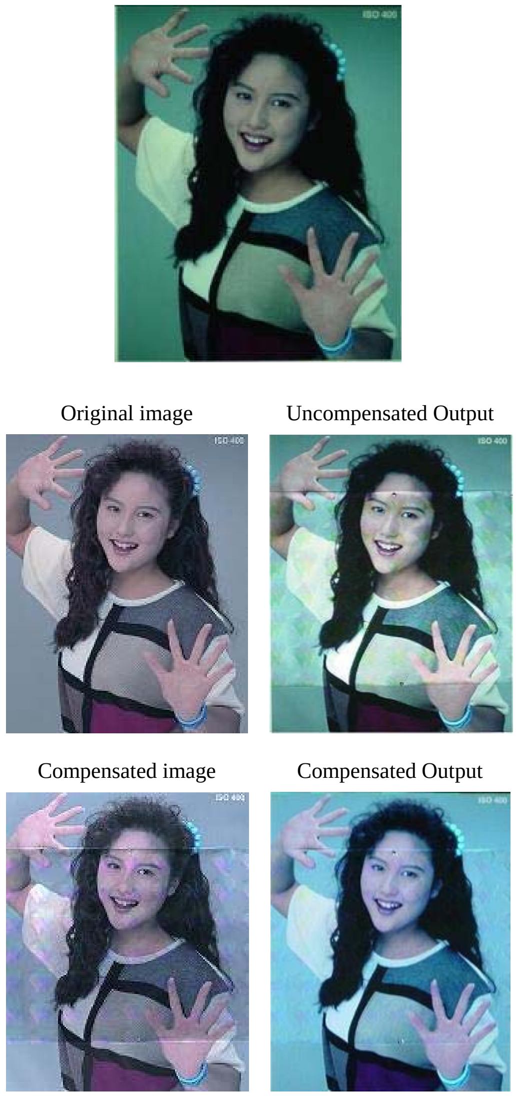

Figure 5 Experimental results of the proposed radiometric compensation algorithm.

All the output images in Fig. 5 were captured by the camera on the same state. Obviously, the pattern of the screen was satisfactorily compensated and the appearance of the original image was reproduced truthfully. However, there is still some evident difference between the compensated output image and the output image on the standard screen as the goal of this study, which needs great effort in the future study.

6 CONCLUSIONS

An optimized radiometric model for the ProCam system was constructed and a novel algorithm of the radiometric compensation for the patterned screen was proposed in this paper. All the parameters of the algorithm can be obtained conveniently and efficiently in advance by the way of off-line calibration without the necessary to know the projector's and the camera's response functions. The experimental results indicated that the original input images were effectively compensated with the algorithm proposed in this study, and the corresponding output images with little perceptual artifacts were expectantly obtained on a patterned screen. In the future study, the radiometric model and compensation algorithm are to be further tested and improved, especially considering the influence of the environmental lighting.

ACKNOWLEDGMENTS

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The Role of Practical Application of Colour in Industrial Production

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ABSTRACT

For the issues covered by this Conference entitled "Colour and Industry", I believe that it might be particularly relevant to illustrate and make some considerations about the topics of an international meeting I organised in Genoa entitled "Colour and Design". Indeed, by discussing the relationship between colour and industry, through an in-depth interdisciplinary approach, the role of practical colour application was pointed out, by analysing items and products of our daily life, from cars to fashion items. Colour in this case does not mean an "outside skin", but rather a deeply rooted value in design and product manufacturing. In particular, today, colour application studies cannot be neglected when talking about design quality, quite the contrary, they make up its very quality. In this field too, a knowledgeable and aware use of colour is an attractive dynamic and innovative element of our human and social space.

Keywords: color design.

1 INTRODUCTION

Contemporary design, today in particular, tends to prompt sensory and creative perceptions, and is deeply focused on transmitting expressive contents, as an alternative to mass production standardization. A sophisticated, or even simplified, use of new materials is also resorted to, by keeping in mind sensory, chromatic, and tactile properties. In particular, quality design today cannot ignore color application studies which are often the expression of the very quality of design. In this field too, a knowledgeable and aware use of colour is an attractive dynamic and innovative element of our human and social space[1].

Conceptual thinking about color in design is still today almost a novelty, although this issue was already tackled by the Bauhaus and Ulm schools, with the contribution of great artists who set the course, like Klee Kandinsky, Albers, Itten etc. (Bauhaus) and Max Bill (Ulm) [2, 3].

As an issue linked to contemporaneity, the study of color with reference to manufactured products is also related to elements of sensitivity and creativity, no longer to essential color with a limited range, and coded by production, but rather worked out and almost proposed from pictorial research. No longer as an "outside skin", but intrinsic design value.

All this has led to a thorough interdisciplinary analysis, which has focused on the practical application of color in industrial production in our daily life, from cars to fashion.

On this topic, a Conference was organized (the Minutes of which will shortly be published) with the title "Color and Design, between Production and Communication". Several experts in this field have analyzed the various production areas where chromatic colors are involved in design.

I think it is useful to briefly present their papers, as a contribution to the overall issue that is going to be dealt with in this conference.

2 EXAMINED RESEARCH AREAS

The following topics were dealt with:

a. Color and Communication
b. Color in car design
c. Color in glass
d. Communication graphic. The importance of color
e. Fashion and color consumption
f. Color education and creative pathways in design

2.1 Color and Communication

It was not by chance that the first speaker was Tom Porter, former Lecturer at Oxford Polytechnic and the author of several works from

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architecture, to educational issues, and environmental color.

In his paper entitled "Color as Communication", he offered an overview of the multiple, even psychological aspects in visual communication, on the color/society relationship, also with regard to individual choices and interpretations, and as expression of our modern times[4]. Mr. Porter then illustrated the culture of color in the UK, the features of the Design Museum in London, where also works by Ron Arad are on display, who is an ever more important designer for his works that are very close to chromatic structures within the environment.

We are all so much concerned about symbols and color associations and, even more so, about fashion colors that are used to give more value and idealize our daily life objects. The more color is investigated in all its communication forms, the more it becomes a kind of language which is used to represent not only ourselves, but also our contemporary *Zeitgeist*[5].

2.2 Color in car design

"Color in car design" was the topic dealt with by Rodolfo Gaffino Rossi, Director of the Car Museum in Turin, the only national museum on this topic and one of the most important ones in the world. He illustrated the evolution over time of the car industry, with particular focus on technology and design. Over time, even color has changed from monochromatic to multiple hues, also obtained through chemistry innovation. Color today plays a very important aesthetic role, accompanying plastic and "streamlined" forms of the most recent models.

You can talk about cars from many different points of view, but today its aesthetics is the most important one, which involves an interdependence of tastes and costume: the car has become one of the most important expressions of industrial culture and, as already mentioned above, it has turned into a "popular" work of art and become an object of cult[6].

2.3 Color in glass

Glass, one of the most ancient materials, when associated with color, becomes a transparent suggestion. This was the topic presented in the paper entitled "The Color of Glass" by Pietro Zennaro (Lecturer of Construction System Design, IUAV University, Venice, School of Architecture), which also referred to Venetian tradition. Prof. Zennaro gave a new and expert reading of this topic, with an overview of the history (the mystic expression of tainted glass windows), up to its contemporary use, and with projections into the future, like in new architecture and design items.

He then concluded by saying that glass and its colors, through its fascinating and long history, is still today one of the most emblematic materials of contemporary expression[7, 8].

2.4 Communication graphics. The importance of color

"Notes on Graphics for Communication" was the topic covered by Maria Linda Falcidieno (Lecturer of Graphics for the Publishing and Advertising Industries, University Course in Industrial Design, School of Architecture of Genoa).

Prof. Falcidieno pointed out that visual perception plays an important role in the design of communication graphics, or in graphics for the publishing or the information industry. Color, in particular, which is a characterising feature of each message, in most recent research and also in the area of Web communication, is more and more selected in its monochromatic hues. The outcome is elegant and sophisticated, drawing attention as a "single outstanding element in a colourful world".

In particular, with reference to IT, an initial phase of web site design, characterized by some sort of "intoxication" with the practically endless opportunities of introducing ever new colors in terms of quantity and composition, was followed by a return to the use of *one* characterising chromatic element. Design and research has since followed this direction[9].

2.5 Fashion and color consumption

Renata Pompas (International Color Design Study Group /Color Consultant Milan) showed how important chromatic trends are in the fashion world, with reference made to history and society, through the relationship of "Fashion and color consumption: which approach?". She also highlighted the fact that color is a product key success factor. Statistics on color preferences were presented to confirm this. Even in the color/fashion relation, the latest trends use highly innovative techniques and new materials, thus creating ever more sophisticated products, for example "optic fiber fabrics".

At the end of her presentation she wondered: "And what about today?. Once all color declinations have already been proposed, there is new focus on surface textures, which, through special technical processing, can offer brand-new aesthetic suggestions."

Color consumption proposals are both emotional and technical, reflecting our modern times and the full involvement of the senses[10].

2.6 Color education and creative pathways in design

Even color education got a fair share of attention during the Conference.

With the paper entitled “Color Education for Future Designers”, Luisa Cogorno (Lecturer of Design and responsible for the Design Lab, University Course in Industrial Design, School of Architecture of Genoa) and Silvia Rizzo (International Color Design Study Group/AIC and professor at N. Barabino Art High School, Genoa) presented the activities of the Workshop on Color which was held during the academic year 2003/2004 for 1st year students of the Degree Course in Industrial Design (Fig,1, 2, and 3). The experience was enriching and creative, and covered several theoretical and application components, through the testing of color in different industrial materials, thus helping student to build the necessary expertise for future design opportunities.

For example, when discussing the visual aspects of industrial products, a chromatic analysis was made of packaging, with quantification of the various percentages of dominating colors. This analytical study, with reference to “persuasive color”, raised much interest among students.

Particularly complex and colorful textures were also produced in industrial materials (on rubber, metal, plastic, and fabric substrata) all of them found and selected by the students. Texture also became an expression of “color synesthesia”, thus prompting tactile feelings and spurring other perceptions.

The course also made it clear that to learn about the role of colour also from a conceptual point of view, with its aesthetic-perceptive dynamics, is an added value in design and in product manufacturing[11].

3 CONCLUSIONS

In general, all the papers have analyzed the persuasive potential of color, which can influence not only our perceptions, but even consumer buying behavior and attitudes. From a technical point of view, marketing color is used for product recognition and to strengthen brand identity.

Through a reversed design and color relation, color, through design, enters our daily life, from function to form. In doing so, it revitalizes our reality and enriches our perceptions in our communication with the environment.[12]

However, our environment is under the constant influence of new stylistic tensions and formal research. The culture of project follows all these processes, no longer through the study of a simple product shape, but through the exploration of new fantastic territories.

This search for new perceptive sensitivities enters the real, virtual, and synesthesic space.

Therefore, color quality takes up the role of an important aesthetic component, which becomes an essential communication carrier within a comprehensive sensory imagination[13].

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Figure 1 Students during the color design workshop, Genoa.

Figure 2 Synesthesia, Color and Fabric, work by students.

Figure 3 Patterns for Color Design Lessons.

The effect of the scattering light on the visual acuity in simulated cataracts

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ABSTRACT

Cataract, as well as presbyopia, is one of the most typical age-related diseases in vision. As the cataract progresses, the crystalline lens becomes hazy and the visual acuity (VA) deteriorates. Since the scattering light causes the loss of VA, a brighter environment is expected to impair VA further. In this study, the VA was measured as a function of the Haze factor of lens and the intensity of scattering light. We propose a novel method for assessing the degree of cataract using the obtained functions of VA.

Keywords: cataract, contrast sensitivity

1 INTRODUCTION

Cataract is one of the most typical age-related diseases in vision. As the cataract progresses, the crystalline lens becomes cloudy.

Since the opaque lens has a lower transmittance, higher intensity of illumination in the environment has been recommended for elderly to maintain the retinal illuminance. The opaque lens, however, increases scattering light. Consequently, the brighter illumination outside the eye increases the intraocular scattering light and makes the retinal image blur. This blurred retinal image raises two problems in vision. One is the deterioration of visual acuity. The other is the desaturated color appearance caused by the superimposition of scattering light on the retina.

Degree of lens haziness is not determined by age only. Rather, the individual difference is very large. To know the degree of cataract, person by person, is essential for the practical care of the elderly vision. If you want to know the degree of cataract, you must take a time-consuming medical workup in the hospital. The objective of the study is to propose a novel and easy method for assessing the haziness of crystalline lens by the measurement of the visual acuity.

2 EXPERIMENTAL FUNDAMENTAL

When an observer with a clear crystalline lens sees a stimulus, there is no intraocular scattering light in his/her eyes. The light goes straight down to the fovea and forms a clear retinal image. On the other hand, when an observer with a hazy crystalline lens sees the stimulus, his/her hazy lens brings about the scattering light in the eye. Then, the scattering light superimposes on the retina and the retinal image becomes blur. This is why the cataract patients have the loss of visual acuity. As the lens becomes hazier and the scattering light is increased, the decline of visual ability becomes larger.

Our basic idea is to estimate the haziness of crystalline lens by measuring the relationship between intensity of the scattering light and the visual acuity. Two methods were employed in the study: the measurement of the visual acuity deterioration with the increasing the scattering light and the measurement of the intensity of the disability scattering light.

3 EXPERIMENTAL

3.1 Measurement of acuity deterioration by scattering light

First, the visual acuity (VA) was measured with a method of limit: a subject judged the direction of Landolt-C, starting from the largest C then proceeding to smaller size of C, until he/she misjudged. A printout of a series of Landolt-C with a hundred percent of negative contrast was illuminated by fluorescent lamps. Background luminance of Landolt-C were set at one of the three levels (26.5, 53, 106 cd/m^2) by modulating the lamp intensity.

The scattering light was provided laterally by a ring-shaped LED array with an integrating hemisphere placed in front of the subject's eye (Figure1). The stimulus was observed through an aperture on the hemisphere so that the luminance

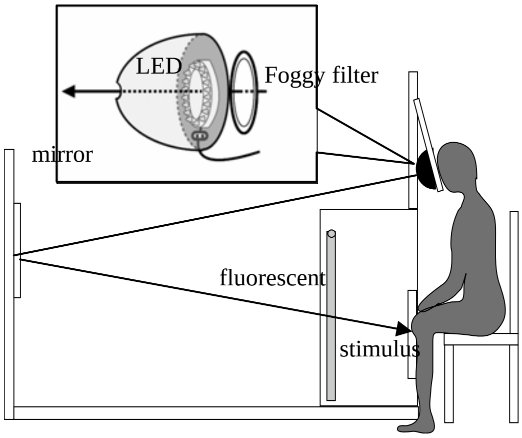

Figure 1 Experimental setup.

of the stimulus was kept constant regardless of the intensity of the LED. Illuminance of scattering light (Es) were 0, 88.6, 443, 1477 lx. Subjects were three young people. To simulate the cataract patient, foggy filters (0, 4.6, 10.5, 14.8, 18.9 % Haze factor) were inserted between the LED and the subject's eye. Before each session, the subjects spent 15 minutes wearing a filter to adapt.

3.2 Measurement of the minimum intensity of disability scattering light

Second, the upper limit of scattering light for visibility was measured with a method of adjustment. A subject adjusted illuminance of scattering light, Es, until he/she could see Landolt-C barely. The experimental setup was the same as the first experiment. We obtained upper limit illuminance for five sizes of Landolt-C (2.0, 3.3, 10, 16.7, 33.3 min) with five levels of Foggy filter. Background luminance of Landolt-C was set to 26.5 cd/m^2. Five young subjects participated in the experiment.

3.3 Haze factor estimation

We examined whether Haze factor can be estimated by measuring minimum intensity of disability scattering light with a certain size of Landolt-C. Two sizes of Landolt-C (6.7, 33.3 min) were used and its background luminance was 26.5cd/m^2. Four levels of Foggy filter (4.6, 10.5, 14.8, 18.9 % Haze factor) were tested. The subject's task was adjusting illuminance of scattering light, Es, until he/she could see Landolt-C barely.

4 RESULTS

4.1 Measurement of acuity deterioration by scattering light

Figure 2 shows the VA as a function of the intensity of scattering light for the stimulus of 26.5cd/m^2 measured with method of limit. Horizontal axis indicates Es and vertical axis threshold gap size. Symbols stand for different Haze factors of filter. As shown in the figure, the lower VA was obtained with higher intensity of scattering light. The slope became steeper for the higher Haze factor. The relationship between VA and the *E*s was approximated by the formula below.

$$Gap\ size = slope \times E_s + \mathrm{A} \quad (1)$$

The *slope* calculated against each Haze factors and the background luminances were shown in Figure3. Horizontal axis indicates Haze factor and vertical axis *slope* obtained from formula (1). Diamonds indicate background luminance of

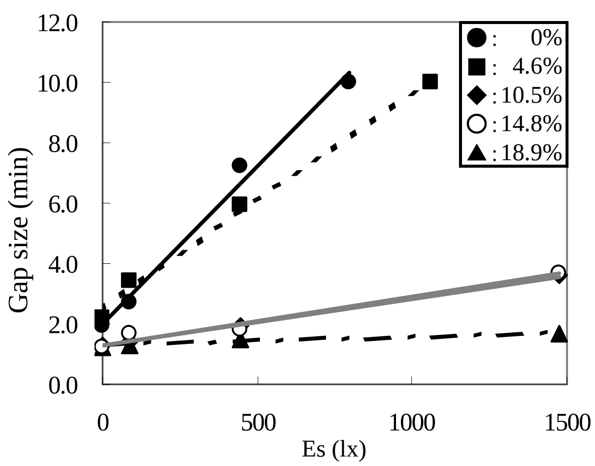

Figure 2 Visual acuity in logMAR scale as a function of the intensity of scattering light. Subject KW.

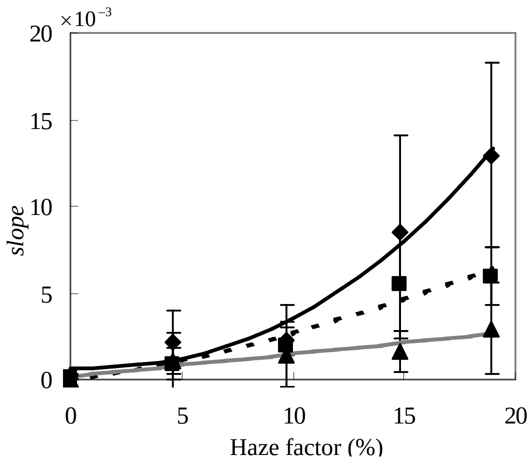

Figure 3 The slope from Figure.2 as a function of the Haze factor. Data points show the averages across all subjects. Error bars represent standard deviations.

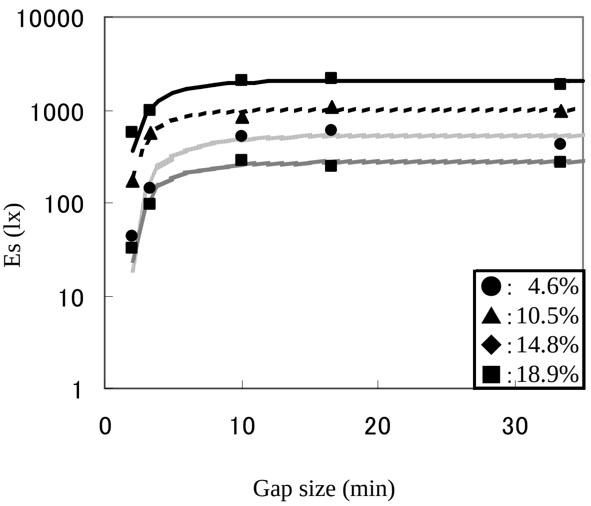

Figure 4 The maximum intensity of scattering light for the visibility as functions of the gap size (min).

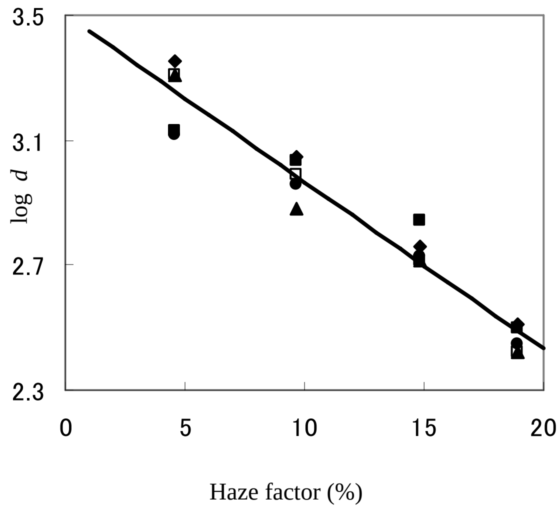

Figure 5 The asymptotic illuminance level from Figure4 as a function of the Haze factor. Symbols indicate different subjects.

26.5cd/m^2, squares 53cd/m^2, triangles 106cd/m^2, respectively. As expected, the slope becomes higher as the haze of lens increases in all subjects and all luminance levels. These trends were fitted with exponential functions in Figure 3. The regression lines are the formula shown below.

$$slope = \alpha \times (Haze\ \ factor)^{\beta} + \gamma \qquad (2)$$

We can estimate unknown degree of haziness by using this formula. First the VA is measured under two or more levels of scattering light intensity and then the slope is calculated from the measured VA. Finally by putting the obtained *slope* into the inverse function of the formula (2), the Haze factor for lens is estimated.

4.2 Measurement of the minimum intensity of disability scattering light

Figure 4 shows the intensity of scattering light as a function of gap size measured with method of adjustment. Horizontal axis indicates gap size of stimulus and vertical axis *E*s. Symbols stand for different Haze factors of filter. Since the upper limit with Haze factor of 0% could not be measured, it is not shown in the figure. We confirmed that the illuminance of visible limit increased with size of stimulus (2.0, 3.3, 10 min), and then this illuminance reached an asymptotic level when the size of stimulus is large enough (16.7, 33.3 min). The measuring values are fitted by the formula below.

$$Es = -a \times b^{(-Gap\,size)} + d \quad (3)$$

The asymptotic illuminance level, *d* in formula (3), became lower for the higher Haze factor. The asymptotic illuminance levels calculated against each Haze factors were shown in Figure 5. Each symbol corresponds to each subject. The relationship between logarithm of *d* and Haze

Table 1 The values of "log *d*" are measured by method of adjustment measuring minimum intensity of disability scattering light. And the values of "Haze factor" are calculated by formula (4). Parenthetic numbers indicate standard deviation

log *d*		Haze factor[%]	
3.219	(0.952)	5.439	(0.050)
2.982	(0.893)	9.943	(0.027)
2.768	(0.432)	13.996	(0.047)
2.441	(1.014)	20.194	(0.079)

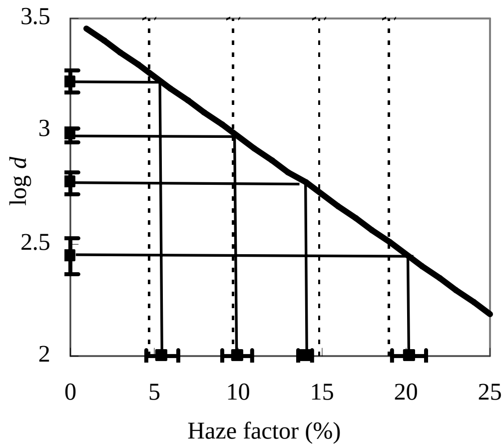

Figure 6 The values of Table.1 are plotted. Error bars indicate standard deviations. Dashed lines stand for Haze factors of the foggy filters used in the experiment. The approximate line is the same as in Figure.5

factor can be estimated by a linear function as shown in Figure5 and fitted by this formula.

$$\log d = \mathrm{B} \times Haze\ \ factor + C \quad (4)$$

Using this function, degree of haze can be estimated without complicated tests. First, the illuminance of visible limit is measured for several Landolt-Cs whose gap sizes are 10min or larger and then the asymptotic illuminance level is calculated from the measured illuminance of visible limit. And by putting the obtained asymptotic point into the inverse function of formula (4), the Haze factor of lens can be estimated.

4.3 Haze factor estimation

In table 1, values of the first column represent the logarithm of *d* obtained from the method of adjustment. The parameter *d* is the average of the maximum illuminance *E*s for visibility measured with Landolt-C of two sizes. Parenthetic numbers indicate standard deviations. These values are plotted on the vertical axis in figure 6. In figure6, the function described by formula (4) is drawn. Now, we can get the estimated value of Haze factor by assigning logarithm of *d* into formula (4). Estimated values of Haze factor are plotted on the horizontal axis in figure 6 and shown in the third column of table 1. Dashed line in the figure means actual Haze factor of Foggy filter used in the experiment. The estimated Haze factors almost coincide with actual values. From here onwards, we can estimate Haze factor with high accuracy by measuring minimum intensity of disability scattering light using stimuli of large sizes.

5 CONCLUSIONS

We here proposed two methods for assessing the haziness of the lens. Unknown Haze factor of patient's lens can be estimated as follows. In the first method, first the VA is measured under two or more levels of scattering light intensity and then the slope are calculated from the measured VA. Finally by putting the obtained slope into the inverse function of formula (2), the Haze factor for lens can be estimated. In the second method, the illuminance of visible limit is measured for several Landolt-Cs whose gap sizes are 10min or larger and then the asymptotic illuminance level is calculated from the measured illuminance of visible limit. Finally the Haze factor for lens can be estimated by putting the obtained asymptotic point into the inverse function of formula (4). By the combination of these two methods, high accurate Haze factor can be obtained.

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Evaluation of light sources based on colour appearance and colour preference assessments

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ABSTRACT

Some issues[1] have been identified for the current CIE colour rendering index (CRI), especially for evaluating white light emitting diode (LED) sources. Recently, the colour quality scale (CQS) has been proposed by NIST[2]. One of its major features is the 'saturation factor', for which a specimen under the test lamp is only penalised for decreasing chroma relative to that under the reference source. Psychophysical experiments were conducted to clarify this effect by evaluating the quality of two light sources. The results showed that an increase in object's colourfulness was not preferred by observers. Finally, the CRI and CQS methods were modified based on CAM02-UCS[3].

Keywords: Colour rendering, Colour Quality Scale, CIECAM02, Colour preference

1 INTRODUCTION

Colour rendering is defined as "Effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant".[4] The current CRI was recommended by CIE in 1974, and has been widely used to test the quality of light sources. However, this method could be outdated and problematic. First of all, CIE 1964 U*V*W* uniform colour space used to calculate colour differences is obsolete and can not give accurate prediction of colour differences. Secondly, the von Kries chromatic adaptation transform used in the CRI performs poorer than other more accurate transforms, such as CAT02 included in the CIE 2002 colour appearance model, CIECAM02[5]. Furthermore, none of the eight reflective samples used in CRI are highly saturated. This could be problematic, because the actual colour rendering of a source could be poor for saturated colours although the CRI value is very high. This is typically marked for the peaked spectra of white LED sources.

Recently, another colour rendering method, Colour Quality Scale (CQS) was proposed by NIST. One of the major features is that the CQS includes a 'saturation factor'. It assumes that an increase in chroma of a test specimen yields better visual clarity and enhances perceived brightness. These are positive effects and are generally preferred by observers. Hence, in CQS, lamps are not penalised for increasing object chroma relative to the reference source. This is a way to take colour preference into account in the CQS.[2] The colour difference calculation in CQS is given in Equation (1).

$$\Delta E = \begin{cases} \sqrt{\Delta L^2 + \Delta H^2}, & \text{if Chroma}_{test} \geq \text{Chroma}_{reference} \\ \sqrt{\Delta L^2 + \Delta C^2 + \Delta H^2}, & \text{if Chroma}_{test} < \text{Chroma}_{reference} \end{cases} \quad (1)$$

In order to clarify the above assumption, two psychophysical experiments were conducted in which observers were asked to estimate the colour appearance and colour preference of test specimens under two light sources: a filtered tungsten lamp (GretagMecbeth (GM) Spectral light II) and a fluorescent lamp (Philips (PH) F20T12/D). The CRI are 97 and 75 for GM and PH respectively, as shown in Table 1.

Table 1 Characteristics of two test illuminants.

	Luminance (cd/m2)	CCT	(x,y)	CRI	CQS
GM	340	6481	(0.3129,0.3304)	97	97
PH	338	6183	(0.3171,0.3463)	75	75

2 VISUAL EXPERIMENTS AND RESULTS

Ten normal colour vision observers, who were PhD students at the Department of Colour Science, University of Leeds, participated in both experiments. Each sample subtended about a 10^o viewing field, and was scaled by the observers in a viewing cabinet located in a dark room.

2.1 Colour Appearance Experiment

The magnitude estimation method was employed to assess the colour appearance of test samples under each light source. Thirty-nine textile samples were used and each observer estimated a test colour in terms of lightness, colourfulness and hue.

Most of the samples were highly colour inconstant[6], i.e. a large change of colour appearance between GM and PH sources. Figure 1 shows the colour appearance shift from GM to PH source in CAM02-UCS a'b' plane. If samples are colour constant, each vector in Figure 1 should be a point. It can be seen that most of non-colour constant samples are located in two ends of *a'* (redness-greenness) scale.

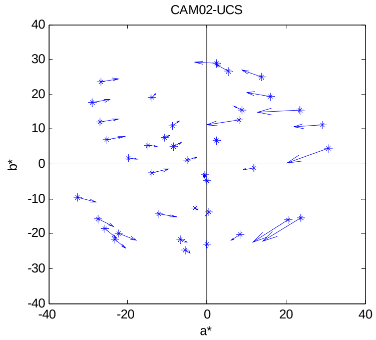

Figure 1 Colour appearance changes between GM (asterisk) and PH (arrow end) sources.

Coefficient of Variation (CV) given in equation (2) was used to indicate the agreement between the two datasets compared. A CV of 30 roughly means a 30% variation between two datasets and a CV of zero means a perfect agreement. A lower CV value represents a better agreement between two datasets.

$$CV = \frac{100\sqrt{\sum (x_i - f \times y_i)^2 / n}}{\overline{x_i}} \qquad f = \frac{\sum x_i \times y_i}{\sum y_i^2} \qquad (2)$$

where x_i and y_i are two sets of data, $\overline{x_i}$ is the mean for set x_i; f is a scaling factor and n is the number of samples.

The first data analysis was conducted to investigate 'observer accuracy'. CV values were calculated between each individual observer's result and mean result. The average CV values for all observers under GM and PH were 18, 24, 8 and 17, 24, 8 in terms of lightness, colourfulness and hue respectively. This implies that observers gave similar degree of accuracy under two sources.

CIECAM02 was tested using the new data in terms of CV. The results are shown in Table 2.

Table 2 Comparison between visual results and CIECAM02 predictions based on the spd of test sources and CIE D65 illuminant.

CV	CIECAM02 predictions based on spd of sources			CIECAM02 predictions based on spd of CIE D65 illuminant		
	Light-ness	Coloufu-lness	Hue	Light-ness	Coloufu-lness	Hue
GM	23	25	7	23	25	7
PH	21	25	8	20	25	8

In Figure 2, it can be seen that the CV values between visual assessments and CIECAM02 predictions using the spectral power distribution (SPD) of the real test sources and of D65 illuminant are almost the same. Besides, when comparing the visual results and predictions under D65, there is not much difference in CV values for the two light sources tested. However, the CRI for GM is much better than that of PH. This implies that although our visual results indicating a similar colour rendering property under two light sources, both CRI and CQS (see Table 1) gave poor performance for PH source. Furthermore, these finding confirms the author's previous study[7], in which the other 3 light sources were investigated.

2.2 Colour Preference Experiment

The 39 textile samples used in colour appearance experiment were again used in the colour preference experiment. The categorical judgment method was used and observers were asked to judge the samples by using a 9-point like-dislike (preference) scale, for which 1 means extremely dislike while 9 means extremely like. The mean visual results between two light sources are plotted in Figure 2.

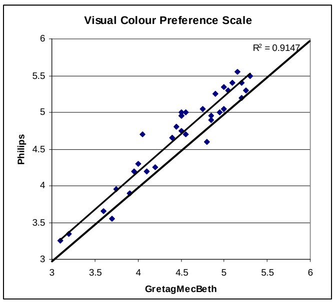

Figure 2 Visual colour preference results under PH source plotted against those under GM source

It can be seen that the visual colour preference results for two test sources agree well with each other (R^2=0.9147). Also, the colour preference results under PH are all higher than those under GM.

Figure 3 shows the differences of colour preference results between the two test sources plotted against those of visual colourfulness results from the last experiment. Both differences were calculated by subtracting the PH visual results by GM visual results.

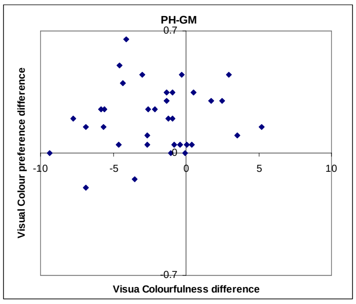

Figure 3 Visual colourfulness differences plotted against visual preference differences between the two sources tested.

If the present results support the assumption of saturation factor, there should be a positive correlation between chroma differences and colour preference differences, i.e. an increase of chroma with an increase of preference. Figure 3 shows that most colours appear to have higher colourfulness under GM source, however, observers did not give a higher preference value. Instead, higher preference values were given under PH, which implies that an increase in colourfulness does not reflect a higher preference. This disagrees with the assumption of CQS.

2.3 Index Based on CAM02-UCS

According to the results from the above colour appearance and colour preference experiments, the results from PH and GM sources were more or less agreed with each other. However, both CRI and CQS predict a much poorer colour rendering property for PH source than for GM.

Table 3 Results of different colour rendering calculation methods.

	CCT	CRI	CRI: CAM02-UCS	CQS	CQS: CAM02-UCS
GM	6481	97	98	97	98
PH	6183	75	85	75	83

The authors' previous study [7] found that a large improvement of CRI and CQS can be achieved by adopting CAM02-UCS to perform chromatic transformation and to calculate colour difference. Their results are also given in Table 3. They are named CRI:CAM02-UCS and CQS:CAM02-UCS, respectively. It can be seen that the modified CRI and CQS methods based on CAM02-UCS gave similar performance as the original formulae for GM source and predicted much higher colour rendering values for PH source than those predicted by the conventional methods. This implies that the new methods based on CAM02-UCS agree better with the current visual results than both CRI and CQS.

3 CONCLUSION

Two psychophysical experiments including colour appearance and colour preference were conducted under two light sources to clarify the saturation factor proposed in CQS.

The findings are summarised below:

- Not much difference was found for both two experimental results carried out between the PH and GM sources studied.
- The present CRI and CQS greatly underestimated the colour rendering performance under PH source.
- The colour preference results based on single colour under two sources do not support the saturation factor concept.
- The CAM02-UCS provides a solid foundation for the existing CRI and CQS.

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Influence of noise in recovering spectral data from natural scenes with an RGB digital camera

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ABSTRACT

In a previous work [*Color Res. Appl.*, **32** (2007, in press)] we found that a noise-free RGB camera coupled with color filters provided significantly better recovery of radiance and reflectance in natural scenes than an RGB camera alone. The recovery of spectral radiances and reflectances was derived using a direct pseudo-inverse algorithm instead of a linear-model approach. The advantages of this direct-mapping method are its simplicity and low computational cost in terms of its performance. In this work, we have tested the method with noisy data. The results suggest that the addition of a color filter when using an RGB digital camera affected by high noise level does not improve the spectral and colorimetric quality of spectral recoveries out of the training set. The results also indicate that a preprocessing of color images is needed before direct pseudo-inverse algorithm is implemented to recover adequately spectral data from noisy signals.

Keywords: reflectance, multispectral imaging systems, illuminants, natural scenes

1 INTRODUCTION

Spectral imaging combines the strength of conventional imaging with that of spectroscopy to accomplish tasks that each cannot perform separately. These spectral image devices capture spectral radiance at any image point and allow an optimal store of the spectral information for each image pixel.[1,2] The product of a spectral imaging system is a stack of images of the same object or scene, each at a different spectral narrow band. These devices offer numerous advantages compared to traditional spectroradiometric devices which have been used for this purpose with limited portability, low spatial resolution and high cost.

In a previous work[3] we found that a noise-free RGB camera coupled with color filters provided significantly better recovery of natural scenes than an RGB camera alone. The recovery of spectral radiances and reflectances was derived using a direct pseudo-inverse algorithm instead of a linear-model approach. The recovered signals had a goodness-of-fit coefficient better than 99.0% and a CIELAB color difference less than 0.27 when the spectral and colorimetric qualities were analyzed and no noise was included in the analysis. In addition, it was found that recovery was better for rural scenes with just rural scenes as the training set, and for urban scenes with just urban scenes as the training set. The advantages of the direct-mapping method are its simplicity and low computational cost in terms of its performance.[4]

The aim of the present work was to estimate the quality of spectral recovery of natural reflectances based on a recovery transformation that incorporates the influence of camera noise. The natural spectra were obtained by hyperspectral imaging[5] of natural scenes. The recovery matrix was estimated using the simulated responses of a conventional RGB digital camera coupled to several combinations of colored filters.

2 METHODS

When a CCD digital color camera is pointed at a surface with spectral reflectance function r^x, the response of the kth sensor for pixel x can be modeled linearly by

$$\rho_k^x = \sum_{\lambda=400}^{700} E^x(\lambda) r^x(\lambda) Q_k(\lambda)\, \Delta\lambda \qquad (1)$$

where $Q_k(\lambda)$ is the spectral sensitivity of the kth sensor and $E^x(\lambda)$ is the SPD of the illuminant impinging on the surface, both functions sampled at 5-nm intervals in the visible range of 400-700

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nm. As we showed in a previous study[3], given a set of training spectra **S** (which can be spectral radiances or reflectances associated with a certain sample of pixels in the scene) and the corresponding set of camera responses, a recovery transformation matrix **D** is defined by

$$\mathbf{D} = \mathbf{S}\boldsymbol{\rho}^{+} \qquad (2)$$

where $\boldsymbol{\rho}^{+}$ is the pseudoinverse of $\boldsymbol{\rho}$. An estimate of a set of test spectra $\hat{\mathbf{S}}_1$ may then be obtained from the corresponding set of camera responses $\boldsymbol{\rho}_1$ by applying the transformation **D**, that is,

$$\begin{aligned}\hat{\mathbf{S}}_1 &= \mathbf{D}\boldsymbol{\rho}_1 = \\ &= \left[\mathbf{S}\left(\boldsymbol{\rho}^{T}\boldsymbol{\rho}\right)^{-1}\boldsymbol{\rho}^{T}\right]\boldsymbol{\rho}_1\end{aligned} \qquad (3)$$

The direct-mapping method has been applied successfully to art imaging[1-2] and to illuminant estimation[4,6], and even for radiance where the illumination is uncontrolled[3].

But any real spectral device is affected by image noise, which can degrade both its spectral and colorimetric performance.[7,8] There are five noise sources which include fixed pattern noise, dark current noise, shot noise, amplifier noise and quantization noise.[9] Assuming a linear response for the CCD camera sensor outputs, the noisy sensor responses $\boldsymbol{\rho}_{\text{noise}}$ can be represented as a function of the noise-free sensor responses $\boldsymbol{\rho}$ as

$$\boldsymbol{\rho}_{noise} = \boldsymbol{\rho} + \mathbf{N} \qquad (4)$$

where **N** is a row vector of uncorrelated components that affects each sensor separately.

To illustrate the influence of noise in the quality of spectral recovery of natural radiances and reflectances, we used equation (4) to calculate a set of simulated noisy camera responses, which we introduced in eq. (2) and (3) to apply the direct-pseudo inverse algorithm[3,4] to recover a set of natural spectra from hyperspectral images of natural scenes.

2.1 Camera spectral sensitivities and colored filters

We first simulated digital counts using the spectral sensitivities of a Retiga 1300 digital CCD color camera (QImaging Corp., Canada) with 12 bits intensity resolution per channel. Camera responses $\boldsymbol{\rho}$ in Eq. (1) are based on a set of camera sensitivities but are only used to generate a set of noise-free fictitious data. The RGB camera outputs are modified to use a 3- 6-band spectral camera when no colored filter (k = 3) or one successive colored filter (k = 6 with an orange filter) was used.

2.2 Hyperspectral data and computations

Hyperspectral data from thirty natural scenes, fifteen of rural environments and fifteen of urban environments, were drawn from a high-spatial-resolution database.[5] For each scene, 33 images were captured at 10-nm intervals over 400–720 nm, with 12-bit intensity resolution at each pixel. Additional details of the scenes, the hyperspectral imaging system and calibration procedure can be found in Ref. [5].

Different sets of scene fragments were used for the training and testing sets. We used two sets for testing: test set 1 (a subset of the training set) and test set 2 (reflectances out of the training set). The recovery matrix was estimated using the noisy simulated responses of a conventional RGB digital camera coupled to several combinations of colored filters; we simulated thermal and shot noise with standard deviations of 1% and 5% (that correspond to signal-to-noise ratios of 40dB and 26dB, respectively).

3 RESULTS

Figure 1 shows the spectral performance of the direct pseudo-inverse algorithm for the unfiltered

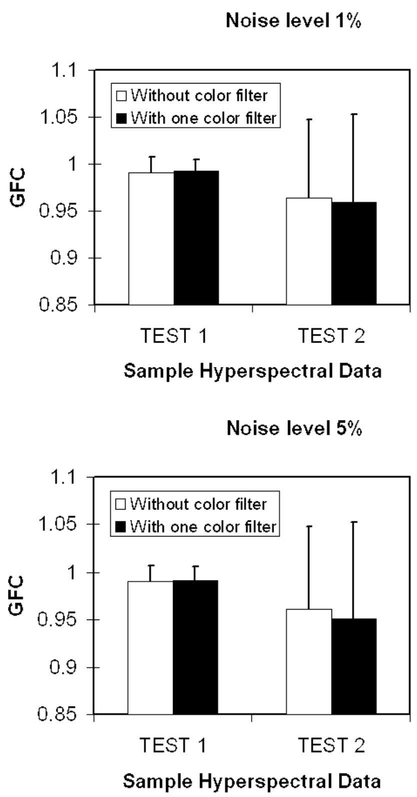

Figure 1 Spectral quality of reflectance recoveries for different levels of noise. Test 1 and Test 2 stands for the *training* and *test* data sets, respectively.

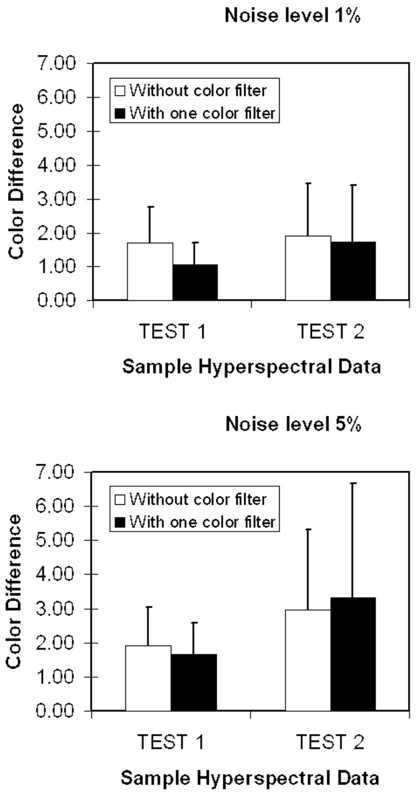

Figure 2 Colorimetric quality of reflectance recoveries for different levels of noise. Test 1 and Test 2 stands for the *training* and *test* data sets, respectively.

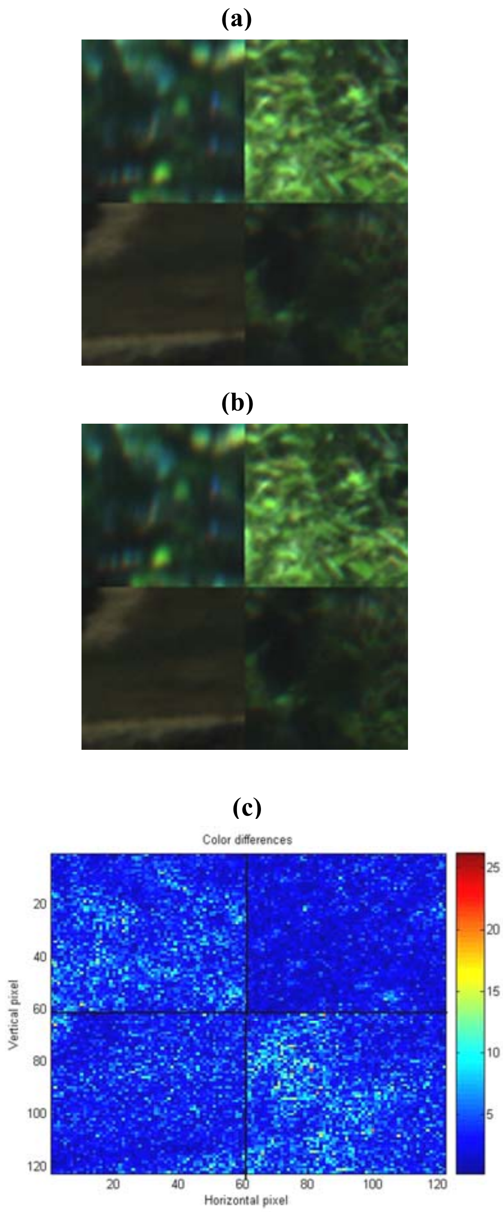

Figure 3 Visualized images of (a) original scene fragments and (b) fragments recovered with the 6-band camera for 5% noise level. The color difference maps is also shown in (c) for each image fragment.

RGB (k= 3 sensors) and for the best color filter (k= 6 sensors) for the two test sets. In what concerns to the influence of noise, the spectral quality of recoveries hardly changes but the colorimetric performance worsens for a noise of 5% standard deviation, as we can see in Figure 2. As expected, the use of the different set of training and test set of surfaces influences the quality of recoveries, so both the spectral and colorimetric quality of recovery for data out of the training set (test set 2) is worse than recovery for data in the training set (test set 1). We can also see bigger spread of quality indexes for test set 2 data.

Figure 3 shows visualized images of a fragment of scene spectra and its recovery with the 6-band camera for 5% noise level. The visualization was based on the calculated camera response values. The figure 3(c) shows that colorimetric accuracy is worst for images which contain dark regions and a great variety of spatial patterns of objects.

4 CONCLUSIONS

A combination of the direct-mapping estimation algorithm and an RGB digital camera with a limited number of colored filters can provide acceptably accurate estimates. The present work supports the related work on recovering spectral radiance and reflectances in natural scenes.[3]

The results suggest that the addition of a color filter when using cameras affected by high noise level do not improve the spectral and colorimetric performance of the algorithm for recovering spectral data out of the training set. The preliminary experimental results confirm this point and suggest that both a preprocessing of the color images and noise estimation procedure are needed before a direct pseudo-inverse algorithm is used to recover spectral data from noisy signals.

ACKNOWLEDGMENTS

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Comparing Research on the Colour Temperature and Colour Rendering of the Gallery Surface Material's Reflected Light

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ABSTRACT

As to fine art museum that exhibits big wall works primarily, it is usually difficult to distinguish between gallery lighting and exhibit lighting. The surface material's spectrum information taken by reflected light will influence the artwork's colour perception. This article takes this as cut-in, uses spectrophotometer to measure material's spectral reflectance and calculates the reflected light spectrum according to measured data. The author does the comparation analysis between reflected light's colour temperature and colour rendering of gallery's regular surface materials eg. 56 kinds of stone, 10 kinds of wood and 4 kinds of fiberglas fabric. The conclusions reached by this article have the guidance meaning to the choice of the gallery's surface materials.

Keywords: Surface materials' reflected light, Artwork's light perceptions of colour, Colour temperature and colour rendering of reflected light

1 INTRODUCTION

There is a link between illuminating factor and non-illuminating factor that affects artwork's colour perception, that is environment reflected light. There is rare research on environment reflected light in fine art museum. In the fine art museum that shows small exhibits, the spotlight implements primary lighting function. The environment in the exhibit hall is usually in dark condition. Because there is few ray enters into the space, the environment reflected light has little influence. As the fine art museum that exhibits big wall works, the gallery lighting and exhibit lighting are usually conbined into one unit. There is much ray enters into the space. The surface material's spectrum information taken by reflected light will influence the artwork's colour perceptions. We use spectrophotometer to measure material's spectral reflectance and calculates the reflected light's spectrum according to measured data.

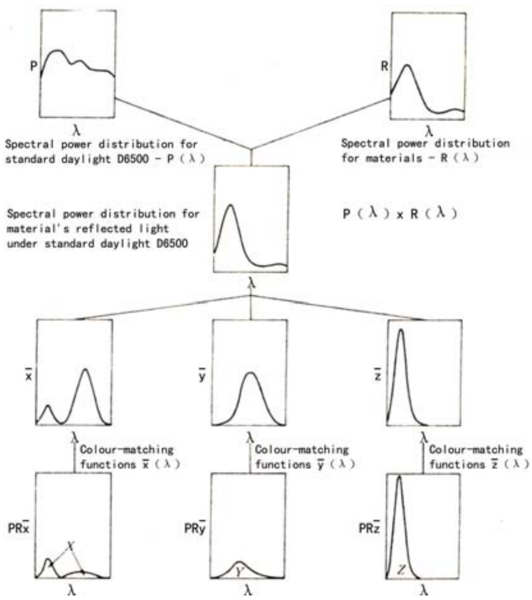

Figure 1 method of calculating the reflex's colour (Billmeyer, jr. and Saltzman, 1981).

2 THE THEORETIC BASEGROUND OF COMPARING RESEARCH ON THE COLOUR TEMPERATURE AND COLOUR RENDERING OF THE SURFACE MATERIAL'S REFLECTED LIGHT

Figure1 shows the method of calculating the reflex's colour temperature and colour rendering. The results only denote that the surface material has the tendency to change the spectrum entering into the space. The changing degree is affected by many factors such as the space material's geometric relation and primary ray direction. There are only two methods of calculating the color rendering capability they are CIE method* and NPL-Crawford method. The first step of NPL-Crawford method is to time multiply the spectrum of incidence luminaire and the spectrum of the reflecting materials in each band. Then we get second luminaire's color coordinate according

* CIE. Method of measuring and specifying colour rendering properties of light sources. Publication No. 13.29, 1974

to CIE1931, then get the second luminaire's color temperature. Crawford carves up the visible light into 6 bands.The deviding line is 400 nm, 455 nm, 510 nm, 540 nm, 590 nm, 620 nm and 760nm.By calculating the difference between each band and reference luminaire's spretum, we evaluate the second luminaire's color rendering.

What should draw our attention is that the same reflecting object has the different reflection capacity because of different source of incidence. The changing degree of color tempeture and color rendering is different. The calculation of light's color tempeture and color rendering reflected by the surface materials has more important meaning to fine art museum's exhibit hall.

1. It is prevalent phenomenon to use indirect light to lighten the wall artworks.Whatever it is natural light or artificial light, it irradiates the artworks' surface by complicated process. In this sense, traditional metheods taking luminaire's color temperature and color rendering as design and evaluation standards is ex parte.

2. As to the exhibit hall takes direct light, the reflex's color tempeture and color rendering have the same important meanings. The author has done experiments to test the same time's contrast and visual invariablenes' influence to the hall color perception. Besides exhibits much material in exhibit hall including visitors are influenced by reflected light to different degree. In the visual feelings about bottom space such as foot and pillar, the floor reflex has some effect. In the visual feelings about visitor's face, the reflex of walls and artworks has some effect. In the visual feelings about walls and artworks, the reflex of other walls and cellings has some effect.

Although the intension of the ray weakened once by once reflection and reflection of different surface makes the lighting environment more complicated. It is difficult to analyze the direct light and surface reflex by analytical manner. But by analyzing the surface material's proterty, we can at least grasp the tendency that selected material changes the ray's color temperature and color rendering as to known luminaires. So we can choose those surface materials that don't reduce the specific ray's color rendering and those surface materials that render the final space color temperature to match the architect's design, original intention of fine art museum and artworks' characters.

3 COMPARING RESEARCH ON COLOR TEMPERATURE AND COLOR RENDERING OF WOODEN FLOOR'S REFLEX

The wooden floor is the most familiar material in fine art museum. According to stat. that 53.6% fine art museums use wooden floor. The floor's spectrum is decided by the wood's character and surface handling manner. We choose D65 and standard A source as incidence luminaires. So each sample has two groups color temperature and color rendering index calculation results, they correspond to practical 6500K skylight and halogen spotlight respectively. The conclusions of testing the 10 warm color wooden floor come to the following.

1. After reflected by all warm color wooden floor, the color temperature of ray sent by D65 and A source reduces and the color temperature of D65 source reflex reduces more distinctly.

2. The color rendering capacity of floor's reflex is low at large among which the color rendering of D65 source reduces more distinctly.

3. There is no relationship between color temperature, color rendering index and reflectance of floor.

4 WALL MATERIALS— COMPARING RESEARCH ON COLOR TEMPERATURE AND COLOR RENDERING OF FIBERGLAS FABRIC'S REFLEX

Most materials of walls in China National Museum of Fine Arts are white fiberglas fabric. In 2004 Oct. the neutral gray, green gray and blue gray fiberglas fabric are added to the hall for French Impressionism Painting Exhibiton. The testing conclusions of four fiberglas fabric samples come to the following:

1. The white, green gray and neutral gray fiberglas fabric increase the color temperature of A source reflex and reduce the color temperatureof D65 source reflex. The blue gray fiberglas fabric increase the color temperature of both reflex. The extent of changing the color temperature is low. The index is far better than that of the wooden floor.

2. The color rendering capacity of three other fiberglas fabric reflex is good, except that the color rendering of green gray fiberglas fabric reflex is on the low side.

3. There is no corresponding relationship between reflex's color temperature and color rendering and reflectance of fiberglas fabric's.

5 COMPARING RESEARCH ON COLOR TEMPERATURE AND COLOR RENDERING OF STONE'S REFLEX

Natural architecture stone can be classified into granite and marble according to the basic character. They form various design and color because of the different producing area and different mineral content. The testing conclusions of 56 stone samples come to the following:

1. The color rendering of gray white, gray and black stone's reflex is preferable. Among the stones that have color tendency in vision, the 2 kins of dark white-yellow marble used in China National Museum of Fine Arts have good color rendering. The other stones such as blue, purple, red, and brown stone have bad color rendering.

2. There is no corresponding relationship among reflex's color temperature, color rendering capacity and material reflectance.

6 CONCLUSION

Although comparing researches on reflex's color temperature and color rendering of wooden floor, fiberglas fabric and stone are based on quantitative analysis and they can be ranked, the choice of hall's surface material can't be decided just according to this. Because this research is based on material's reflex and the material's reflex is the transition factor between illuminating factor and non-illuminating factor. It belongs to illuminating factor substantially but has close relationship with non-illuminating factor i.e. surface spetrum. As to the visual problem of color perception, the visual relationship between space surface and art works is more important. The color temperature and color rendering of surface's reflex are just one of influence factors and it can only be seen as one of the criterion of surface material.

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A new digital illuminance-meter with a special luminance-tubeadapter for universal applications in lighting engineering

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ABSTRACT

A new digital illuminance-meter "MINILUX" with a special luminance-tubeadapter is developed by the University of Applied Sciences Berlin in cooperation with the Technical University of Zhejiang China for universal applications in lighting engineering.

1 INTRODUCTION

Compared with the total turnover of electrical engineering, the extent of lighting technics is constantly rising. Therefore, the exact measurement of light technical quantities such as illuminance, luminance, luminous intensity and luminous flux gains more and more importance. The following article presents a new, reasonable, universally usable and portable digital illuminance-meter for accurate illuminance and luminance measurements.

The measuring of luminous flux, luminous intensity and luminance is based on the measuring of illuminance by means of the photometric fundamental law. That is, why this quantity has got a special significance. A state-of-the-art illuminance-meter should have the following conditions.

2 TECHNICAL REQUIREMENTS ON A STATE-OF-THE-ART ILLUMINANCE-METER

- Fine approximation to the spectral luminous efficiency curve V(λ) of the human eye
- Photometer-head with cosine-correction
- Linear relation between illuminance and photocurrent
- Low temperature influence, ageing and fatigue of the lightsensor
- Correct light- measurement of AC-powered discharged lamps (linear mean of wavy light in accordance with the Talbot-Plateau law)
- Wide measure range, so that the following measurements are possible with just one instrument:
- measuring of indoor lighting up to 2000 lx
- measuring of daylight up to 200000 lx
- measuring of low illuminances, e.g. street lighting up to 20 lx
- Emergency-lighting up to 2 lx
- Correct reading of the measuring results by a digital display

3 FUNCTIONS OF THE DIGITAL LUXMETER

Based on the mentioned conditions, the digital illuminance-meter „Minilux" was developed at the University of Applied Sciences, Berlin in cooperation with the Technical University of Zhejiang, China. Concrete, it is a newly developed, portable illuminance-meter for universal applications concerning the whole lighting technic (Fig. 1).

Figure 1 The MINILUX- device with photosensor (silicon-cell with V(λ)- and cosine-correction in accordance to DIN 5032, class B).

Fig. 2 shows the block diagram of „Minilux". Two amplifiers with an extremely low bias-current are used for protection against overload, when for example high pressure sodium-xenon lamps with pulsed current supply and a high luminous flux crest-factor are measured (Fig. 3). The first amplifier OPA 1 serves the range, the second OPA 2 works as a mean-forming active low-pass-filter.

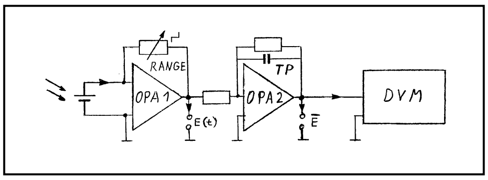

Figure 2 Block circuit of the Minilux illuminance-photometer. Measurement capacity: 0.001 lx…..199.9 klx (6 ranges), luminance capacity: 0.1 cd/m2…..19.99 Mcd/m2 (6 ranges).

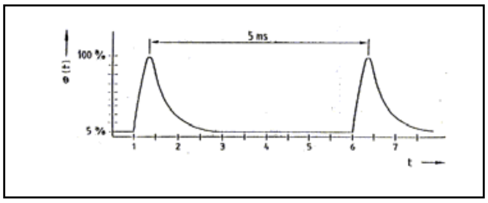

Figure 3 Time dependence of the luminous flux of a sodium-xenon HID-lamp supplied by pulsed high-frequency current.

Accurate photometry of high-pressure discharge lamps with pulsed current supply calls for a special photocurrent amplifier, which in accordance with the Talbot-Plateau-law, reliably estimate the linear mean value of luminous flux.

Ordinary luxmeters are generally not designed to measure high pulsating light sources. Therefore, to avoid errors, the staff of photometric laboratories should heed this recommendation before measuring such light sources. Critical evaluation and investigation of the suitability of the photometer for measurements of pulsating light is required. The new measuring instrument avoids these disadvantages and thereby closes a gap in the market.

4 IMPORTANT TECHNICAL DATA

- Silicon photosensor with V(λ)- and cos-correction (Fig. 4, Fig.5)
- Diameter of the sensitive light area D = 11mm
- 6 lux-ranges
- Total measure range: 1 mlx to 199900 lx
- Resolution: 1 mlx
- Class B in accordance with DIN 5032, section 6
- Crestfactor: about 15
- Dual-slope-digitalvoltmeter with auto-zero
- 7-segment LC-display
- Automatic low-battery-indicator, if U bat < 7V
- Supply-current: only about 2 mA
- 9-V-lithium-blockbattery with 1,2 Ah (working time of the Minilux with this high-performance battery approximately 600 hours !)
- Analog output 1: to measure the waveform of illuminance E(t) with an oscilloscope
- Analog output 2: 0 ... 199.9 mV DC for recorder, plotter, PC etc
- 4-seconds-delay timer with indication-hold-function inclusive of display-light and display-functioning test (e.g. suitable for shadingfree measurings)
- Dimensions: 157 mm x 84 mm x 30 mm
- Weight: 300g
- Price: from 495,00 € (EURO)

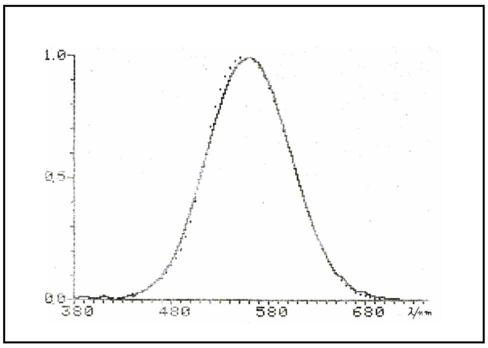

Figure 4 V(λ)- approximation of the silicon-photosensor in accordance to DIN 5032, class B.

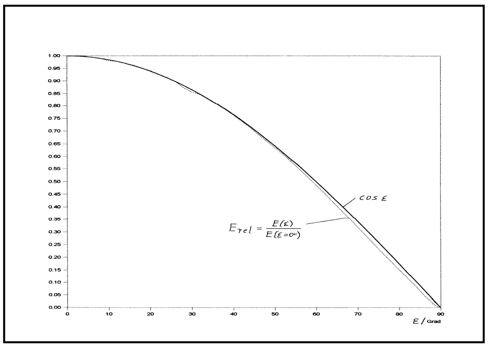

Figure 5 Cosine-correction of the silicon-photosensor.

The instrument measures lux-values from: 1 mlx (resolution) to 199900 lx.

(Note: 1 fc = 10.764 lx // 1 lx = 0.0929 fc)

Range	**Typical application**
0.000 …1.999 lx	Emergency measurements
00.00…19.99 lx	Street lighting measurements
000.0…199.9 lx	Interior lighting measurements
0.000…1.999 klx	Interior lighting measurements
00.00…19.99 klx	Daylight measurements
000.0…199.9 klx	Daylight measurements

The special luminance-tubeadapter has a measuring angle of α = 13°. The tube-geometry is so calculated, that the relation between luminance and illuminance is very simple**:**

L = 100 • E **E in lx, L in cd/ m²**

The procedure of luminance-measurement is as follows:

Put the luminance-tubeadapter on the photocell and hold the tube in the direction, in which you want to measure the luminance of a surface. Read the lux-value from the minilux-display and multiply this lux-value with the constant factor 100. The result is the actual average luminance.

Luminance-capability: 0.1 cd/m²....19.99 cd/m² (6 ranges)

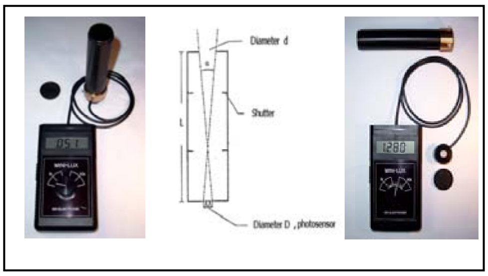

Figure 6 Minilux-photometer with Luminance-tubeadapter.

Procedure for reflection-measurements of a diffuse surface: First measure the illuminance on the surface. Then measure the luminance of the surface at the same area. Calculate the reflection-value with the following formula:

$$\rho = \frac{\pi \cdot L}{E}$$ E in lx, L in cd/ m²

5 FIELDS OF APPLICATION

The instrument is suitable for

- The measuring of illuminance, luminance and reflection
- The measuring of luminous intensity by means of the photometrical law:

  I [cd] = E [lx] • (R [m])²
- Luminous flux measurements in accordance with Φ [lm] = E [lx] • A [m²]

Further applications are possible, e.g. for:

- Luminous flux measurements in conjunction with the Ulbricht sphere
- Control of the turning on and off of street luminaires
- Brightness control for roadway tunnels
- Measurements of building materials used in lighting technology (e.g. for measurement of reflection, transmission, absorption, extinction etc.)
- Measurements for solar facilities
- Light measurements for applications in physics, optoelectronics, meteorology, botany, biology and medicine
- Measurement of the light-pollution, caused by exterior luminaires

6 RESULT

The new lux-meter provides a metrological basis for innovative, energy-efficient and consequently environmentally benign lighting systems. It supports systems based on the use of natural daylight in conjunction with supplementary artificial illuminance which is controlled in accordance with user demand, and which is equipped with dimmable high-frequency electronic ballast devices, which enables power savings of up to 70 %. The presented digital luxmeter contributes to the achievement of this aim.

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Inter-Instrument Agreement: Software to the Rescue?

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ABSTRACT

To be useful, spectrophotometers must agree in their measurements. Software is now available to characterize a spectrophotometer parametrically and correct it to measure like a reference instrument. When should such software be used as a diagnostic tool and when can we trust it as a correction tool? Comparison of two manufacturers' hardware and software shows that correction is most trustworthy when the software and instruments are from the same manufacturer, and the measured test specimens are similar to the BCRA tiles used to perform the correction.

Keywords: spectrophotometer, calibration, correction, color, measurement

1 INTRODUCTION

The exchange of reflectance data among retail and branded apparel companies with their suppliers has increased substantially over the past five years. These electronic color programs are creating a "flatter color space" by connecting tiers of suppliers across continents via a common color language and protocol. Unlike text, digital music, and images, the reliability of reflectance data is often challenged and the variables associated with this process have been previously reported. The instrument, or spectrophotometer, in most cases provides the baseline upon which all other factors are built. In this paper, we will review sources of error in reflectance measurement, especially as it pertains to textiles. We will also discuss the process of spectrophotometer correlation (profile-based correction)---whereby a spectrophotometer is characterized parametrically and corrected to measure like a standard instrument by software and a series of reflectance standards.

The content of the present paper is based on two earlier presentations to the Inter-Society Color Council[1] and to the American Association of Textile Chemists and Colorists[2].

2 PROFILE-BASED CORRECTION

To profile a color-measuring or color-producing device means to quantify its input-output relationships. In spectrophotometry, profiling is used to effect instrument correction---whereby a spectrophotometer is characterized parametrically and corrected to measure like a reference instrument by software and a series of reflectance standards. Such profile-based correction (PBC) has been discussed for a long time.[3,4,5] It is time to look at the question of when instruments *should* be profiled for correction.

Profile-based correction typically starts from a model equation such as the following:

$$R_{ci} = A + B\,R_{mi} + C\,R'_{mi} + D\,R''_{mi}. + E\,R_{mi}\,(100 - R_{mi}). \qquad (1)$$

Here, R_{mi} is the i'th measured reflectance, R_{ci} is the i'th corrected reflectance, all variables implicitly depend on wavelength, and ' and " refer to the first and second derivatives of R mi with respect to wavelength. The corrections in Eq. 1 are offset (A), gain change (B), wavelength-scale change (C), bandwidth change (D), and some nonlinearities (E). The particular nonlinearity in Eq. (1) is taken from Berns and Petersen,2 but other expressions have been used as well. Equation (1) is used twice in profile-based correction: once with known specimens such as the BCRA tiles with parameters A-E (at each wavelength) in the solve state, and again with measured reflectances, now-known A-E, and R_{ci} in the solve state.

3 LIMITATIONS OF PBC METHOD

Profile-based correction has limitations. First and foremost, it can correct only consistent instrument error, not other errors such as user error, sample conditioning dependence, and random errors affecting measurement repeatability. These errors are apportioned approximately as in Figure 1, and are explained in Ref. [6], Clearly, one cannot expect user errors or repeatability (random) errors

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to be corrected by software. The same is true of conditioning errors, if the software is made to depend on the instrument with no knowledge of the samples. Conditioning error refers to failure to control the temperature and humidity in the sample environment: For textiles, ASTM Standard Practice D1776-98 specifies a temperature of 21 +/- 1° C and 65 +/- 2% relative humidity (RH). Substantial deviations from these numbers create the conditioning errors in spectrophotometry.

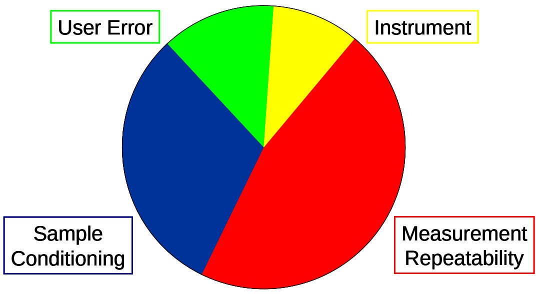

Figure 1 Kinds of error in spectrophotometry.

Given a consistent instrument error, PBC can sometimes come to the rescue. It can compensate instrument malfunction due to changes in wavelength scale, bandwidth, or gain. However, it will not fix optical alignment or bad pixels. Also, it cannot correct, e.g., the numerical noise due to wavelength error (from mismatch between the sample and reference signals.) Also, PBC cannot fix the following typical symptoms of aging spectrophotometers: dirty/dusty optics; stained/hazy filters and lenses; degraded spheres and specular ports; light-source degradation; and imprecise sample mounting. Finally, a corrected spectrophotometer may lose traceability if its native data are unavailable, especially if the reference instrument is un-traceable. Despite the fact that all of color management is based on the philosophy implicit in PBC, the tolerances of industrial spectrophotometry are much tighter than in such worlds as ICC---too tight to permit digital vagaries.

Profiling a spectrophotometer may be useful in diagnosis, and such diagnosis entails a threefold decision: Do nothing (if the performance is good), service the instrument (if its performance is bad), or perform software correction using PBC. That decision should depend not only on the mean ΔE error, but also on the specimens for which the error occurs. Chromatic colors with ΔE > 0.5 can still support PBC, but neutral colors that are off by as little as 0.1 ΔE in the presence of much lower error on the white tile indicate un-fixable errors (e.g. stray light, sample-to-reference cross-talk, gloss/sphere problems, sample-mounting/ aperture-size problems and translucency problems.) Because of the above risks, it is important not to perform PBC on instruments that are performing too well or too poorly. To inform customers of when PBC is appropriate, a test of the candidate algorithm (in conjunction with its implied reference instrument) is needed now that PBC has become more popular than ever.

4 FIELD TEST OF PBC METHOD

Given this need, a test was performed to determine the quality improvement to be expected from PBC, across several kinds of reflecting specimens, across spectrophotometers of the same model and manufacturer, and across spectrophotometers of different models and manufacturers. A total of 42 test specimens were examined: 22 textile and 20 non-textile. Eight units each of d/8 (sphere) spectrophotometers from two manufacturers (A and B) were tested. Three sets of measurements were performed: "as is" (without PBC), profiled using software from manufacturer A, and profiled using software from manufacturer B. Quantities ΔE_{cmc} and ΔE_{cielab} were evaluated for comparison with the arithmetic mean L*a*b* of instruments split by manufacturer, of all 16 instruments together, and of various specimen subsets (BCRA tiles, textiles, and all specimens). Also, quantities ΔE_{cmc} and ΔE_{cielab} were evaluated for comparison with specific instruments (A7 and B7) for various specimen subsets (BCRA tiles, textiles, and all specimens). We examined in each case how many samples "got better", "got worse", or did not change when profiling was brought to bear.

4.1 ΔE_{cielab} from Mean of Devices

As an example of the results obtained, Table 1 shows that both profiling programs were able to improve the inter-instrument agreement with the mean on BCRA tiles, but with consistency only for instruments of the same manufacturer. (Note: Here, OEM means each instrument was corrected by software from its own manufacturer.)

Table 1 ΔE_{cielab} comparison with mean of all 16 instruments, over BCRA tiles.

		Software		
	As Is	A	B	OEM
Instrument A	0.25	0.12	0.35	-
Instrument B	0.19	0.07	0.10	-
All Instruments	0.28	0.12	0.28	0.21

In contrast, it is clear from Table 2 that improvements in agreement with the mean are insignificant when all 16 instruments are corrected to their mean. As borne out by both Table 1 and Table 2, the values improve when the instruments are corrected to the mean of eight from the same manufacturer.

Table 2 ΔE_{cielab} comparison with mean of all 16 instruments, over all samples.

		Software		
	As Is	A	B	OEM
Instrument A	0.28	0.23	0.38	-
Instrument B	0.31	0.23	0.25	-
All Instruments	0.35	0.28	0.36	0.31

4.2 ΔE_{cmc} from a Real Instrument

The above analysis might fail to convince because day-to-day textile processes use a metric of ΔE_{cmc} rather than ΔE_{cielab}, and also that inter-instrument agreement is measured with respect to a particular spectrophotometer unit (not the master unit, but one in the supply chain) and not with respect to an average of units. Therefore, the following results were obtained by computing the ΔE_{cmc} error from fielded instruments A7 and B7, which are units from manufacturers A and B respectively.

The results for BCRA tiles, analogous to Table 1, are shown in Table 3. Again it can be seen that there are mixed results when non-native software is used, but results are always good with native software. These results are the same as those compared with the mean instrument and using ΔE_{cielab}.

Table 3 ΔE_{cmc} comparison with instruments A7 and B7, over BCRA tiles.

		Software		
	As Is	A	B	OEM
Instrument A7	0.26	0.11	0.28	0.18
Instrument B7	0.31	0.14	0.28	0.19

The results for all samples, analogous to Table 2, are shown in Table 4. As in Table 2, the results were mixed, but did not achieve the improvement predicted with BCRA tiles. Use of non-native software again seemed to degrade the inter-instrument agreement.

Table 4 ΔE_{cmc} comparison with instruments A7 and B7, over all samples.

		Software		
	As Is	A	B	OEM
Instrument A7	0.28	0.21	0.34	0.22
Instrument B7	0.32	0.24	0.30	0.27

4.3 How Many Samples Improved?

For the ΔE_{cmc} metric and specific comparison instrument used in Section 4.2, we then asked what percentage of samples did PBC improve by at least 0.05, how many were made worse by at least 0.05, and how many were unchanged (by more than 0.05 ΔE_{cmc} units). The results appear in Figure 2.

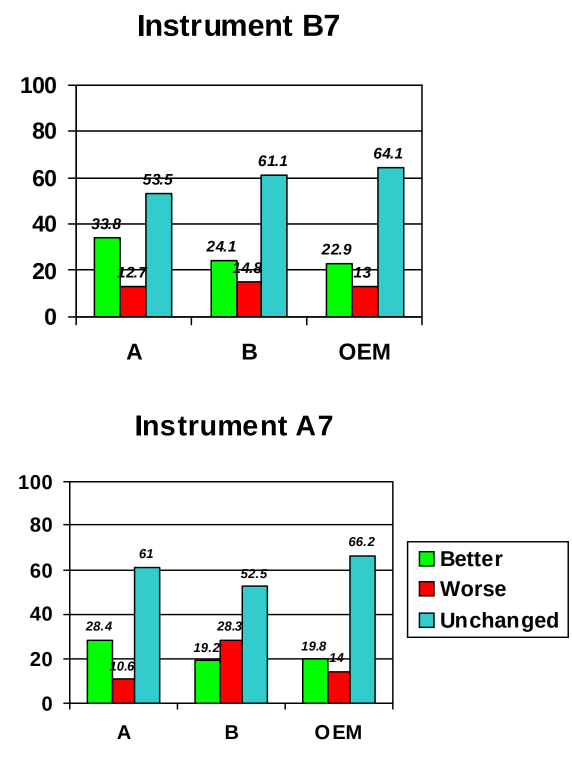

Figure 2 How the samples fared.

There were more improved samples than worsened ones only when each instrument was profiled by software from its own manufacturer. In each case, most of the samples were not changed significantly.

Our data analysis generally indicated that the textile samples did not improve significantly with PBC. The number of textile samples that improved was only slightly greater than the number that got worse after profiling. Not all the news was bad: In cases where the BCRA values improved by more than 0.15 CIELAB unit, textile performance improved significantly though to a lesser degree.

4.4 Diagnostic Tests

It was found that diagnostic tests on non-native instruments failed to identify or falsely identified problems with these instruments. Consequently, instrument diagnostic tests and PBC should generally be performed by the manufacturer's own software. As with PBC tests, one should also expect diagnostic performance on real-world samples to be worse than those obtained from the samples that were used for profiling (BCRA tiles).

5 CONCLUSION

In conclusion, it is good to keep in mind that improvements in inter-instrument agreement gained through PBC of a properly functioning spectrophotometer will be insignificant compared to the error induced by poor measurement, variation in sample conditioning, and operator error. Furthermore, although diagnostic profiling and PBC with your instrument manufacturer's profiling program is a critical part of a total measurement program, it is not a substitute for attention to detail in the measurement.

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A Simple Algorithm for Absolute Fluorescence Colorimetry Measurement

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ABSTRACT

Absolute fluorescence colorimetry measurement is a time-consuming test based on the two-monochromator method. A new method which is named basic-spectrum algorithm is pointed out in this article. It can be used to not only measure absolute fluorescence colorimetry in short time but also provide a new way to solve coincide problems in fluorescence measurement.

Keywords: basic-spectrum, coincide, interpolated

1 INTRODUCTION

For the difference between standard illuminant and all kinds of sources used in practice, colorimetry in the measurement of fluorescent materials by the two-monochromator method was introduced in 1950s. It has been studied systemly by several groups such as Donaldson, and it has got lots of progresses.

The principle of the two-monochromator method is easy to understand. For instance, colorimetry under standard illuminant CIE D_{65} is that: firstly, the fluorescence emission intensity can be measured independently under different excitation wavelengths; secondly, these different excitation wavelengths should be combined as standard illuminant CIE D_{65}, the fluorescence emission intensity under certain excitation wavelength can also be combined in the same way as the total fluorescence emission intensity under CIE D_{65}.

Currently, the two-monochromator method is considered as the most precise method for measuring fluorescence colorimetry. In order to get a higher precision by this method, it has to have more excitation wavelengths used for combination. If the excitation wavelength is between 250 to 500nm for a certain sample, scan interval should be set to 10nm commonly. And then, we need to measure as high as 26 fluorescent spectrum curves to complete the basic colorimetry measurement for a sample. So it is a time-consuming procedure.

2 BASIC-SPECTRUM ALGORITHM

Theoretically, the emission wavelength position is determined by energy level of molecule or atom which is immovably for certain material. The emission light intensity depends on the excitation light intensity and absorption of material. In other words, the excitation light wavelength could not change the emission wavelength position.

In our study on fluorescence spectrum, the shape of fluorescent spectrums under different excitation wavelength is very similar (See figure 1).

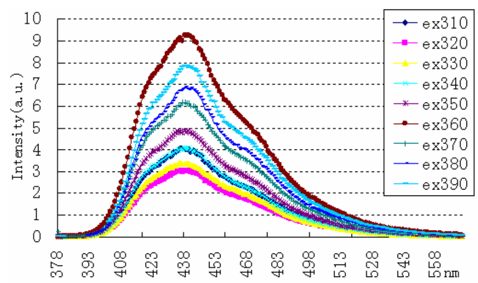

Figure 1 Emission spectrum under different excitation wavelength, "ex310" means excitation light wavelength is at 310nm.

To simplify the measurement of fluorescent colorimetry, we can select one of these spectrums as fluorescence emission basic-spectrum for template. Only emission intensity under a selected wavelength should be measured for other excitation wavelength. The emission intensity under other wavelengths can be ignored.

Curves in figure 1 show that we can apply fluorescence emission spectrum under excitation

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wavelength at 310nm, which can be used as fluorescence emission basic-spectrum, for calculating fluorescent colorimetry. Only one point in 378nm－558nm must be measured(we consume its wavelength as W1 ,intensity value as INT1) when we use 320nm light to excite fluorescent material. Then a constant should be multiplied to fluorescence emission basic-spectrum to make the value at W1 and INT1 equal. The new fluorescence emission basic-spectrum can be used as fluorescence emission spectrum under excitation wavelength at 320nm.That is to say, measuring a point instead of a curve, lots of time can be saved.

It is better to choose these spectrums having higher fluorescence intensity and no coincide between reflection and fluorescence curve for selection of fluorescence emission basic-spectrum.

3 BASIC-SPECTRUM INTERSECTION FOR SOLVING COINCIDE

Figure 2 shows relation between excitation light and fluorescence emission light. Excitation light and fluorescence emission light is separate in spectrum when excite light is in ultraviolet band. Coincide will appear in emission spectrum while excitation wavelength moves to visible band for fluorescence emission spectrum positions are relatively steadily.

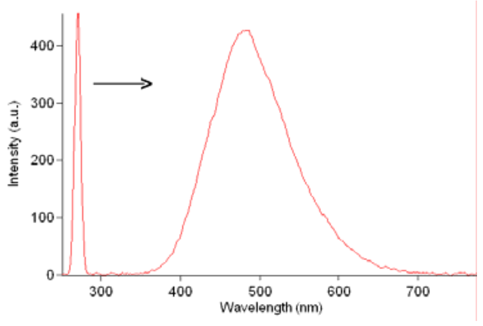

Figure 2 Reflection peak (280nm) and fluorescence peak(400nm-650nm).

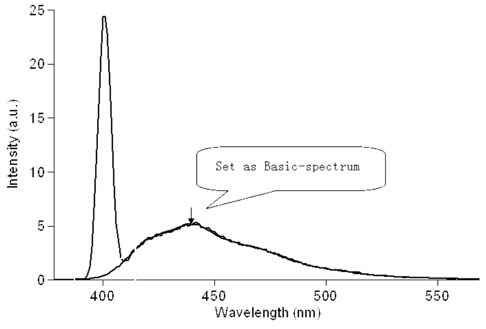

Figure 3 The clearness of coincide by basic-spectrum.

In figure 3, the solid and tint line shows fluorescence spectrum excited by light at 320nm and the solid and dark line shows fluorescence spectrum excited by light at 400nm. Apparently, the peak at 400nm is not caused by fluorescence but by reflection. These data in the spectrum should be deleted instead.

In ASTM, it recommends using a cubic spline to interpolate deleted data. However , it would bring in surges sometimes determined by data. Under extremeness situation, it can cause errors illogicality. On the assumption that when there is a edge fluorescence peak at 400nm, according to ASTM, the peak will be deleted while excitation wavelength is also at 400nm, and a line which is far away from practice will be replaced.

Fluorescence emission basic-spectrum may be effective for solving this problem. If spectrum R contains coincides, then procedure can be made as below:

① Select a certain wavelength λ_1 which is far away from reflection and with a higher fluorescence intensity (such as 450nm in figure 3).

② Turn fluorescence emission basic-spectrum over to 1 at λ_1 , set result curve as new basic-spectrum.

③ Multiply all points of new basic-spectrum with value, R (λ_1).

④ Distill all points of new curve in reflection band as interpolated data.

Advantage of this method not only avoids interpolating data surgeing but also makes result reasonable and the procedure simplify.

4 CONCLUSION

Basic-spectrum algorithm pointed out in this paper can save lots of measurement time. Based on basic-spectrum interpolated method can makes result reasonable and the procedure simplify. However, these methods only can be used on a premise: fluorescence emission spectrum will not be red-shift or blue-shift while excitation wavelength moves from ultraviolet to visible band. The premise suits well for most of mineral materials. And, more experiment should be done for macromolecule fluorescence materials.

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Cross-cultural color difference between European and Japanese streetscapes
- In the case of Great Britain, Italy, Austria and Japan -

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ABSTRACT

The importance of color comfort in streetscapes has been recognized. A comparative study on international differences in streetscape colors is awaited for effective color planning. This study aims to show the basic data for color planning by such a comparative study. Investigations of streetscape colors were conducted in Europe and Japan. The wall and signboard colors were measured in the main streets of each city according to the Mansell book of color. In Great Britain, Italy, Austria and Japan, the color attributes of each city were extracted and identified.

Keywords: Streetscape color, Comparative method of color, Color planning

1 INTRODUCTION

There have been a number of publications on streetscape colors. However, only a few have referred to the in cross-cultural differences in streetscapes. Recently, the color control in streetscapes has been attached greater importance for color planning and conservation of streetscapes.

The aim of this study is to show the theoretical frameworks and the basic data for color planning. In so doing, the comparative study on streetscape colors were carried out in Great Britain, Italy, Austria and Japan.

2 INVESTIGATION

Color investigations were performed in six cities in Great Britain, 12 cities in Japan, three cities in Austrian and two cities in Italy. In each city, the wall colors were measured in accordance with the Mansell book of color.

In the main street of each city, the wall colors were measured at around 70 points with reference to the Mansell book of color. The measured data comprised Munsell hue, value and chroma. Hue refers to the quality of a colour that distinguishes red, blue, green and etcetera. Value is the lightness of a colour. Chroma is the purity or intensity of a color.

The investigated streets were chosen because they are central and prosperous. As to the measurement of the wall colors, colors that covered the largest area on each wall were regarded as representative.

3 RESULTS

The measured color attributes are shown in Tables 1, 2, 3, and 4.

3.1 The color attributes in Great Britain

Table 1 shows the color attributes of the six cities in Great Britain. About 70 points in each city were selected for the measurement. The values of northern cities like Edinburgh and York were found to be smaller than those of southern cities.

Table 1 Color attributes of each city in Great Britain.

city	Wall	colors	
	value mean	chroma mean	ratio of achromatic (%)
Edinburgh	6.7	1.8	1
York	7	2.9	22
Liverpool	8.1	1.1	36
manchester	7.2	2.9	12
London	8	1.8	2
Brighton	8.5	2	6

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3.2 The color attributes in Italy

Table 2 presents the color attributes of the two cities in Italy. 210 points were chosen in Venice while 60 points were used for the measurement in Florence. In comparison with other countries, the chromas of Italian cities were higher.

Table2 Color attributes of each city in Italy.

city	Wall color		
	value mean	chroma mean	ratio of achromatic (%)
Venice			
Grand canal	7	5.3	0.5
Fondamena nuove	7.2	5.8	0
Riva degli Schiavoni	7.7	5.1	0
Burano	6.5	5.4	0
Florence	9.2	3.4	1

3.3 The color attributes in Austria

The color attributes of the three cities in Austria are illustrated in Table 3. In each city, about 70 points were selected .The color differences between northern cities and southern cities were discussed here. The values of Salzburg and Rattenberg were revealed to be bigger than those of Insbruck and Villach. In addition, the chromas of Salzburg and Rattenberg were smaller than those of Insbruck and Villach.

Table 3 Color of attributes of each city in Austria.

city	Wall color		
	Value mean	Chroma mean	ratio of achromatic (%)
Salzburg	8	2.1	0.5
Rattenberg	8.3	1.9	0
Insbruck	7.9	4	0.5
Villach	7.6	4.3	0

3.4 The color attributes in Japan

Table 4 illustrates the color attributes of the 12 cities in Japan. The wall colors of about 70 points were measured in each city. In the north-east of Japan, the values of cities, such as Akita and Sakata, which faces the Sea of Japan were smaller than the values of cities facing the Pacific Ocean. In the north-east of Japan, the chromas of cities like Hirosaki, Akita and Sakata, which faces the Sea of Japan, were found to be larger than the chromas of cities facing the Pacific Ocean.

Table 4 Color of attributes of each city in Japan.

Region	city	Wall color		
		value mean	chroma mean	ratio of achromatic (%)
North-east Japan	Aomori	7.7	2.1	17
	Hirosaki	7.8	2.4	15
	Hachinohe	8	1.8	23
	Nosiro	7.8	1.8	19
	Akita	7.3	2.4	12
	Morioka	8.2	1.5	25
	Miyako	8.4	1.2	24
	Omagari	8	1.8	18
	Hanamaki	8.6	1.6	26
	Kamaishi	8.6	1.4	24
	Ichinoseki	8.6	1.2	31
	Sakata	7.7	2.4	25
South-east Japan	Tottori	8.1	2.5	42
	Kurayosi	7.9	2	48
	Yonago	6.8	3	16
	Matue	8	1.6	38
	Tuyama	7.6	1.3	26
	Niimi	8.1	1.1	53
	Okayama	7.9	2	25
	Fukuyama	8.1	1.2	38
	Takamatu	7.6	1.8	33
	Kochi	8	1.7	35

4 DISCUSSION

In the previous section, the color attributes of cities in the four countries are outlined. In this section, more detailed data are presented and discussed within macro and micro theoretical frameworks.

4.1 The relationships between the color attributes and climatic elements in Great Britain and Japan

In Tables 1 and 4, the wall colors in Great Britain were characterized by low values and high chromas in comparison with those of Japan. For further understanding of these differences, correlation analyses were made between the color attributes and climatic elements of these two countries. Table 5 shows the correlation coefficients between color attributes and climatic elements of Great Britain and Japan.

The ratio of sunshine duration was found to be correlated highly with the wall color values (R=0.47) and wall color chromas (R=-0.42). The global solar radiation shows a certain correlation with the wall color values (R=0.39) and with wall color ratios of achromatic (R=0.54). Average perception per year appeared to correlate to the wall color ratios of achromatic (R=0.44).

On account of these findings, the cross-cultural differences in color attributes are argued to be explained, at least to some extent, in light of climatic elements.

Table 5 Correlation coefficience matrix.

	ratio of sun-shine dura-tion (%)	global solor Radia-tion (MJ/m^2)	tempe-rature (℃)	perci-ption (mm)
value	0.47**	0.39*	0.02	0.14
chroma	-0.42**	-0.23	-0.01	0.02
ratio of achro-matic	0.4	0.54**	0.57**	0.44**
ratio of Yellow hue	-0.21	-0.46**	-0.6**	-0.41**
*p<0.5, **p<0.1				

4.2 The relationships between the color attributes and snowy climate of northern Honshu in Japan

Color investigations were conducted in the main street of 12 cities in the north-east of Japan (see Table 4). In each city, the wall colors were measured at around 120 points according to the Munsell book. It is known that the regional climates vary from location to location. In Japan also, the climates vary across the country, and the weather are often quite changeable even in a small area. The nature of Japanese climate is characterized by the monsoon and mountain ranges that divide the island arc into the Omote Nippon facing the Pacific Ocean and Ura Nippon facing the Sea of Japan. The winter monsoon creates prevailing northwesterly winds, and those winds regularly bring snowfall and cloudy weather to Ura Nippon.

Correlation analyses were conducted between the climatic elements and wall color attributes. The rates of (B)/(A) were highly correlated with the wall color values (R=0.87) and chromas (R=-0.86)[A: sunshine duration in hours per year, B: sunshine duration in hours during Dec.-Mar.]. The numbers of days when each city was covered with snow showed some correlation with the wall colour values (R=-0.52) and with the chromas (R=0.48).

4.3 The relationships between the stone colors and streetscape colors

It is said that streetscape colors are affected by building materials. Especially in cities where stone materials are predominant, streetscape colors are expected to be determined by the nature of the stones. In this section, the relationships between stone colors and streetscape colors are discussed with reference to a case study in Ghent in Belgium.

Color investigations were carried out in three blocks (Graslei, Krannlei and Veldstaat) and at symbolic buildings according to the Munsell book of color. Table 6 shows the wall color attributes of the symbolic buildings. Belfort consists of slate (A type) while Lankenhalle is made of sand stone (B type).

Table 6 Color of symbolic building in Ghent.

building	stone type	stone name	color
Belfort	A type	slate	5PB5/4-5Pb8/1
Lankenhalle	B type	sand stone	5Y9/1-5Y8/3
St.baafskathedraal	B type	sandstone	5Y9/1-5Y3/1

Table 7 presents the utilization of the stones of each block. In Graslei and Korenlei, sandstones (B type) and bricks without painting are predominant. It is also pointed out that the different utilization of stones and various patterns of painting on blocks are identified. However, Table 8 illustrates the similarities in colors among blocks, irrespective of the different utilization of stones and various patterns of painting. It is suggested that the locals utilize a limited range of painting colors (R,YR Y hue), and that, as a result, the colors of the streetscape may be harmonious with slight varieties in colors on the whole. It may be argued that the social consciousness of color environments and painting traditions may influence actual colors in the streetscapes of Ghent.

Table7 Stone attributes of each block.

block	No. of buil-ding	Rate of sand-stone (B)	Rate of slate (A)	Rate of brick	Rate of paint-ing
Graslei and Korenlei	24	21%	5%	50%	25%
Krannlei	27	15%	0%	26%	60%
Veldstaat (upper floor)	29	3%	0%	7%	79%

Table 8 Base color attributes of each block.

block	No. of buil-ding	Rate of R, YR, Rhue	Rate of except for R, YR, Y	Rate of achro-matic
Graslei and Korenlei	24	83%	4%	13%
Krannlei	27	74%	11%	15%
Veldstaat (upper floor)	29	93%	4%	4%

5 CONCLUSION

(1) The color attributes in Great Britain, Italy, Austria and Japan have been identified.

(2) The theoretical frameworks that can explain color attributes of streetscapes have been discussed and suggested.

(a) The relationships between color attributes and climatic elements have been discussed with reference to the cases of Great Britain and Japan (Macro).

(b) The relationships between color attributes and snowy climatic elements within northern Honshu in Japan have been discussed (Micro).

(c) The relationships between stone colors and streetscape colors in Ghent in Belgium have been discussed (micro).

(3) The basic data for color planning within the theoretical frameworks have been obtained.

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Spectrophotometric analysis of the interiors of seventeenth century churches in Arbanassi

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ABSTRACT

This paper presents the use of a new method of assessment and comparison of the appearance of colour in an art historical context, using some seventeenth century churches in Bulgaria as a case-study. The method also allows initial identification of the main colour agent of the pigments used. It contains the results of the identification of the colour red. This research provides a possible basis for further investigation into the use of colour in seventeenth century Bulgaria, in a way that overcomes the limitations of colour reproduction in print. In addition, a faithful and unambiguous record of the existing colours will make it possible to create the non-metameric subtractive mixtures that are needed for the restoration of the frescoes.

Keywords: Arbanassi, art history, spectrophotometry, colour appearance, pigment identification.

1 INTRODUCTION

The town of Arbanassi, situated in the middle of Bulgaria, contains seven churches built in the seventeenth century. The interiors of four of these are completely covered with frescoes which were executed between 1612 and 1681 and have been proved by scholars to be preserved in their original state [1]. During the late 1970s and the 1980s the frescoes of all of the examined churches were cleaned.

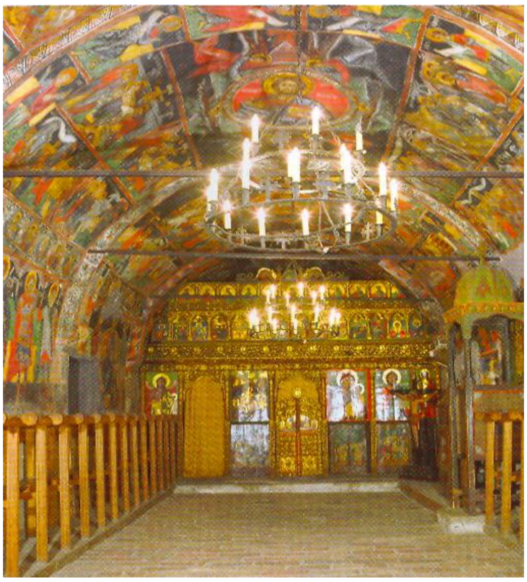

Illustration 1 Church of the Nativity of Christ, Arbanassi, Bulgaria: Nave.

The aim of this research was to record and compare the colours used in these four churches and to perform an initial comparison of the dominant colorants used. The research was prompted by the significance of colour in the construction not only of the decorative system employed in the churches of Arbanassi, but also in the construction of any decorative composition. Colour also has an impact on the way an interior space as a whole is experienced.

Previous research on the site has been limited to the traditional and meticulous (but subjective) assessment and verbal description of the colours used in the church interiors [2-3]. However, this methodology has significant limitations due to the complexity of the processes by which the intricate interaction between light, the eye and the brain result in the experience and recognition of colour [4-5]. The mechanism of recognition does not permit colour to be identified, assessed and communicated with great precision because each observer may see and interpret colour somewhat differently. Moreover, very often the descriptions sought to assess the psychological effect of particular colours on the basis of the meanings which the writer supposed that the investigated composition had been intended to convey. Even though such an approach acknowledges the importance of colour, it still leaves the actual appearance of colour as a peripheral issue. By contrast, the use of analytical methods can provide an unambiguous description which makes it possible to identify, record and then compare the use of colour. One such method is

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spectrophotometry which is non-invasive and does not cause damage to the painted layer of the examined surfaces.

2 EXPERIMENTAL

In this research a hand-held Minolta CM-2600d spectrophotometer was employed, using target mask CM-A146 (8mm measurement area). All data were processed in the Konica-Minolta colour imaging laboratory at the University of Leeds. The instrument is easy to use, precise and highly portable making it possible to obtain comprehensible reference data in the simplest way. One of the types of data which the instrument can provide is spectral reflectance factors. The reflectance factors were obtained (at intervals of 10 nm in the visible spectrum) from averages of 16 measurements for each colour. These results were then converted to CIELAB values (using the 1964 CIE 10º observer and for the D65 illuminant). Before commencing the measurements, the spectrophotometer was calibrated using the white calibration plate CM-A145.

The fact that all the frescoes in the churches were painted at about the same time and were then subjected to much the same exposure to smoke from candles and from the burning of incense for about the same number of years and finally underwent the same cleaning procedure at about the same time, makes the churches suitable sites for the conduct of this research. In a comparative study such as this, the changes which have taken place over time can be ignored because the investigation is concerned not with changes in the appearance of colours since they were first applied, but with the differences between the appearances of the same hue as used in different churches.

Frescoes with a similar theme and composition from each of the churches were identified in order to create a further base for comparison of colour in the different churches. The surfaces of the frescoes have a comparatively smooth and even finish, which allows the instrument to lie flat over the point of measurement (thus preventing any external light from interfering with the reading of the instrument). Furthermore the measurements were taken from comparable points on the figures or pictorial compositions initially chosen. The areas chosen for examination were prepared prior to the measurements being taken. For this purpose a soft brush was used to remove dust and loose matter from the surface followed by the use of pair of very small bellows. This was done to avoid inaccuracies which might occur because of the presence of small particles when the measurements are performed.

3 RESULTS AND CONCLUSIONS

The dominant colours in the frescoes of the churches in Arbanassi are: red, blue, green, ochre, white, black or deep navy blue and gold (gold leaf). Because of the concise format of this paper we will limit our examination to the colour red.

Illustration 2 Church of the Nativity of Christ, Arbanassi, Bulgaria. Depiction of Christ Pantocrator on the ceiling above the altar. Above his head is the image of the Mother of God and he is surrounded by angels.

The choice of the hue was governed by the relatively high frequency of the use of reds in the iconographic tradition of the Eastern Church from very early days up to the seventeenth century [6-8]. According to some authors the colour red has particular symbolic meaning within a conventionally accepted visual code. Red is mainly associated with the Messiah, the Archangel Michael, royal figures, some martyrs and the Last Judgment. Most of the presumed symbolic associations of reds derive primarily from the theological link between blood and redemption which makes it a popular choice in the artistic palette of the iconographers [6, 8].

In the initial examination it appears that in every church the appearance of the colour red, at least in any particular chamber, is more or less constant, which could be explained by the way the frescoes were executed and the way paints were prepared [8-9]. This involved painting a large area – sometimes the entire chamber – in one day. Although there were several artists working at the same time, paints were mixed by the artist who headed that particular studio [9-10]. Assessed subjectively, the appearance of the reds seems to be divided between bright red in the churches of the Archangels Michael and Gabriel (brightest) and St Atanass and deep red in the churches of the Nativity of Christ (darkest) and St Dimitr. Initial examination of the images revealed negligible differences between the bright reds, but a very considerable perceived difference between the dark reds. Furthermore there seems to be a sharp difference between the lightest and the darkest red. Given the impossibility of retaining a memory of the sensory experience of a colour, any valid comparison of the appearance of the colour red used in the four churches must be made by external, objective means. Such a comparison is needed for the study of the use of colour. The CIE data, presented in Tables 1 and 2 make that comparison possible.

Table 1 CIELAB values for red in four church samples.

Church	L*	a*	b*
Nativity of Christ	18.38	11.74	14.14
St Dimitr	17.22	14.12	9.86
Archangels M&G	31.59	26.83	16.67
St Atanass	32.44	27.05	17.91

Table 2 CIE chroma and hue angle values for four church samples.

Church	C^*_{ab}	h_{ab}
Nativity of Christ	18.38	50.30
St Dimitr	17.22	30.93
Archangels M&G	31.59	31.85
St Atanass	32.44	33.51

However, the CIE data relate to the sensory experience of the observer and do not give an indication of the way in which that colour effect has been achieved, namely about the colorant used to impart colour to the artistic material.

Figure 1 shows the original reflectance spectra of the four church samples. These curves can provide important clues about pigment identification. The reflectance spectra obtained from each of the churches were compared with spectra measured from samples of a range of pigments obtained from suppliers. These particular pigments were chosen because analytical chemical research done on samples from fresco fragments collected from various churches in Bulgaria at different stages of their restoration has already demonstrated their use. Research also shows that the main range of pigments did not change until the beginning of the eighteenth century and, even then, did not increase significantly before the beginning of the nineteenth century. All of them can be categorised chemically as inorganic [11-12]. Issues such as paint thickness, pigment loading, and, of course, light fading all make a direct comparison of the spectral data difficult. It is useful, therefore, to compare the spectral data in terms of the ratio of Kubelka-Munk absorption and scattering coefficients (K/S) which can be obtained – for opaque samples – from the reflectance P using the expression $K/S = (1-P)^2/2P$ [13]. Figure 2 shows the K/S plot for the four church samples and pigment standards.

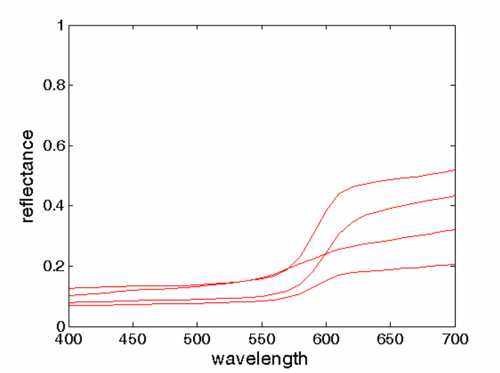

Figure 1 Reflectance spectra for four church samples.

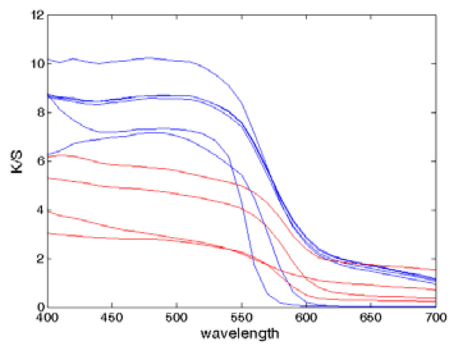

Figure 2 K/S plots for church samples (red lines) and pigment standards (blue lines).

The advantage of the K/S representation is that the shape of the K/S spectral curve is relatively invariant to pigment concentration since K/S can be considered to be approximately linearly related to concentration.

Table 3 The possible dominant pigment for four church samples.

Church	Possible pigment
Nativity of Christ	Fe_2O_3 + 1% MgO_2
St Dimitr	Fe_2O_3 + 1% MgO_2
Archangels M&G	Fe_2O_3 + small quantity of Al/Mg/Si
St Atanass	Fe_2O_3 + small quantity of Al/Mg/Si

The standard pigments with which the measured samples were compared were: Pb_3O_4; HgS; Fe_2O_3; Fe_2O_3 + small quantity of Al/Mg/Si; Fe_2O_3 + 15-20% MgO_2; Fe_2O_3 + 1% MgO_2. A Nelder-Mead simplex optimization was used to find the best match (independent of pigment concentration) for each sample K/S curve with the standard pigment curves [14]. This analysis revealed the possible identification of pigments as shown in Table 3.

The differences between the composition of the pigment samples appear to be constant and in all probability can be explained by differences in the initial sources of the particular sample. Such a finding is of value to further research attempting to identify the geographical origins of the pigments. That in turn may help answer the long-standing question: where did the artists who painted the Arbanassi churches come from? Some scholars have argued that they might have been local artists, trained at Mount Athos. Others have suggested that they came from the mainland Greek province of the Ottoman Empire. A third group of scholars have argued that the artists of Arbanassi were based on Mount Athos.

This research provides a possible basis for further investigation into the use of colour in seventeenth century Bulgaria, in a way that overcomes the limitations of colour reproduction in print. In addition, a faithful and unambiguous record of the existing colours will make it possible to create the non-metameric subtractive mixtures that are needed for the restoration of the frescoes.

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Study on the Evaluation Structure of Street Furniture in City Streets

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ABSTRACT

This study is aimed at developing an evaluation structure to systematically analyze how pedestrians evaluate street furniture from which view. This study mainly used the evaluation grid method, an advanced psychological evaluation method that was developed to examine the exact cognitive construct of individuals about a certain objective by the interview survey. By using this method, the cognitive construct between images that evaluators see from street furniture, and physical elements that form the images can be systematically drawn into a network diagram.

The study is conducted by the following procedures.

1) Street furniture are classified into specific types and the target type of street furniture for the study is determined. 2) On the basis of the evaluation grid method, interview is conducted to identify the cognitive construct of the environmental evaluation on a street landscape. The correlation between the observer's psychological evaluation and the physical elements of the street environment is drawn into a network diagram in a systematic way. 3) In the analysis step, the network diagram is analyzed to identify the physical elements that affect the evaluation on environmental furniture and to find out how much the individual elements affect the evaluation.

Keywords: Street furniture, Arrangement, Shape, Color, Material

1 INTRODUCTION

A street landscape in the city environment is an essential element to express the unique and attractive atmosphere and cultural history of a city. However, Korean cities were designed focusing on quantity without considering a city landscape, especially a street landscape. Therefore, the effort to improve and develop the street environment of a city is much required. The components of the street environment of a city include buildings, landscape gardening, roads and street furniture. This study will focus on street furniture.

This study is aimed at developing an evaluation structure to systematically analyze how pedestrians evaluate street furniture from which view. This study mainly used the evaluation grid method, an advanced psychological evaluation method that was developed to examine the exact cognitive construct of individuals about a certain objective by the interview survey. By using this method, the cognitive construct between images that evaluators see from street furniture, and physical elements that form the images can be systematically drawn into a network diagram.

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2 STREET FACILITY TYPES

2.1 Street Facility Types

Table 1. Street Facility Classification Table.

Type		Details
Rest		Chairs, benches, shelters, outdoor tables
Sanitation		Trash bins, ashtrays, restroom, washroom, beverage facilities
Stand	Food	Manned stands, vending machines
	Commodities	Manned kiosks, vending machines
Information	Sign	Information sign, induction sign, identification sign, regulation sign
	Communication	Telephones, postbox
	Information	Electronic light board, event information board
Light	Functional light	Light for all uses, road light
	Decorating light	Street light, switch light
Transportation	Transfer	Bus stop, taxi stop, bicycle drop-off
	Traffic	Overpass, pedestrian deck, shelters for arcade
Event		Temporary outdoor facilities, banners, flagpole, lantern
Play ground		Swing, slide, sand playground
Utilities		Telegraph pole, fire hydrant, power distribution box, manhole, speaker
The disabled		Slope, slope way, handrail
Landscape gardening		Food materials, water, environmental sculpture, graphic design
Pavement		Road paving materials

2.2 Target Street Facilities for Experiment

This study was conducted focusing on four facilities such as trash bins in the sanitation type, public telephone boxes in the information type, street lights in the light type and bus shelters in the transportation type.

3 EVALUATION GRID METHOD

In this study, the evaluation grid method was used to determine the evaluation structure on street furniture in a street space. The details are as follows.

3.1 Theory

The repertory grid method developed by G.A.Kelly, a clinical psychologist, in 1955 was an interview method to identify a cognitive construct system of an individual based on the personal cognitive construct theory.

The method has been developed into the repertory grid development method by Sanui Junichiro to effectively establish the network of the environment evaluation structure to show the correlation between images related to environment and environment components.

3.2 Experiment overview

1) Selection of elements

In this study, an interview survey based on the evaluation grid method was conducted in terms of the street environment.

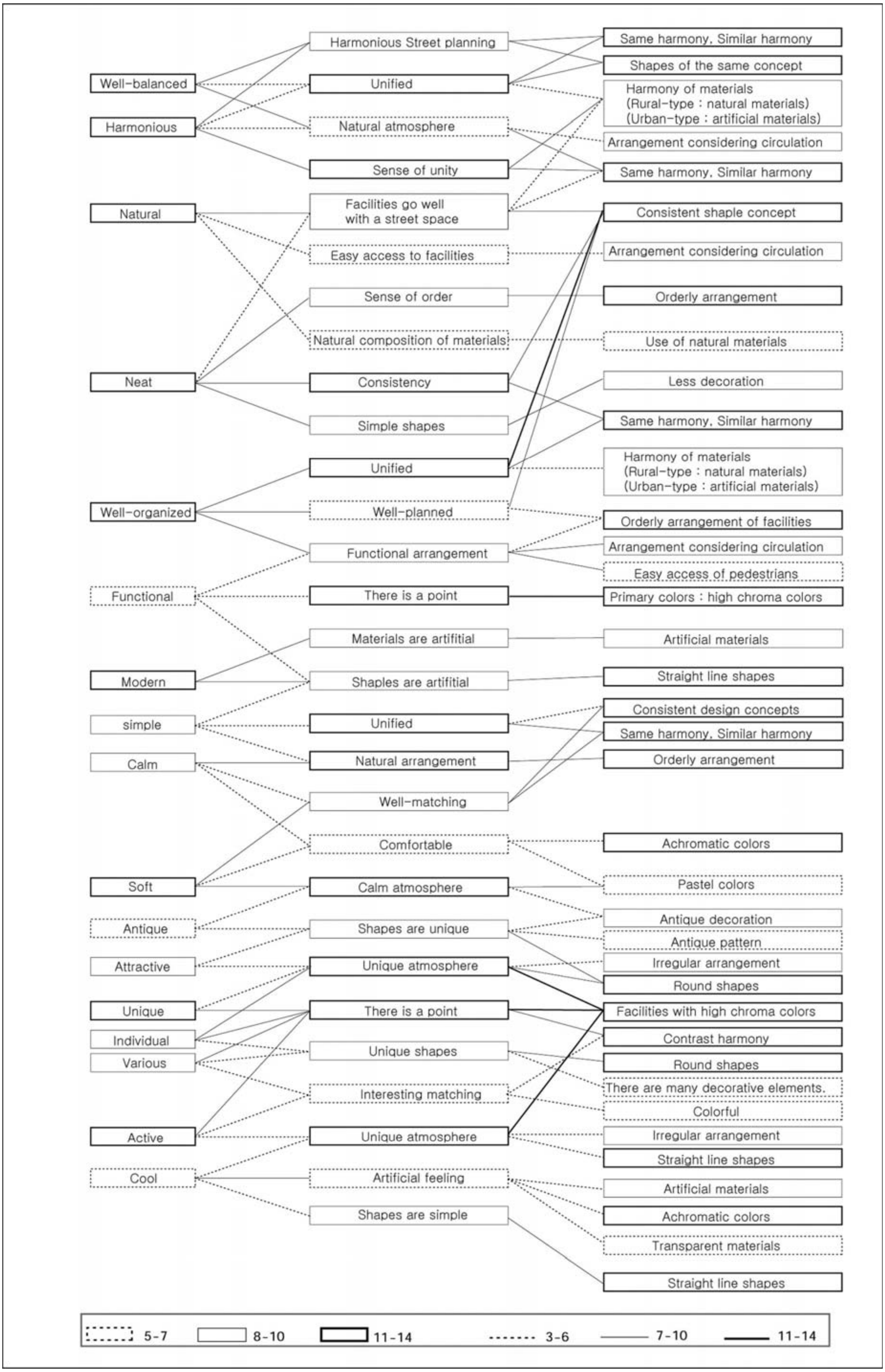
Color photographs of the street environment were selected as the elements, considering the two reasons : 1) Comparison between elements is relatively easy when evaluation items are determined. 2) A variety of elements in number and scope can be prepared. According to previous experimental result that there were no big differences between photo experiments (evaluation on environment by seeing photos) and field experiments (evaluation on environment by visiting the places). In this sense, it was determined that color photographs had no problem to become the elements for this study.

Photographs of the street environment was classified based on the types of street furniture. Then, thirty four photos, that clearly showed street furniture in a street environment, were selected as the experiment elements,

Figure 1 An example of the photos used for this experiment.

2) Selection of Subjects

Postgraduates and undergraduates majoring in architecture were selected as the subjects because they are considered to have the ability to evaluate the street environment.



Well-balanced
Harmonious
Natural
Neat
Well-organized
Functional
Modern
simple
Calm
Soft
Antique
Attractive
Unique
Individual
Various
Active
Cool
Harmonious Street planning
Unified
Natural atmosphere
Sense of unity
Facilities go well with a street space
Easy access to facilities
Sense of order
Natural composition of materials
Consistency
Simple shapes
Unified
Well-planned
Functional arrangement
There is a point
Materials are artifitial
Shaples are artifitial
Unified
Natural arrangement
Well-matching
Comfortable
Calm atmosphere
Shapes are unique
Unique atmosphere
There is a point
Unique shapes
Interesting matching
Unique atmosphere
Artificial feeling
Shapes are simple
Same harmony, Similar harmony
Shapes of the same concept
Harmony of materials (Rural-type : natural materials) (Urban-type : artificial materials)
Arrangement considering circulation
Same harmony, Similar harmony
Consistent shaple concept
Arrangement considering circulation
Orderly arrangement
Use of natural materials
Less decoration
Same harmony, Similar harmony
Harmony of materials (Rural-type : natural materials) (Urban-type : artificial materials)
Orderly arrangement of facilities
Arrangement considering circulation
Easy access of pedestrians
Primary colors : high chroma colors
Artificial materials
Straight line shapes
Consistent design concepts
Same harmony, Similar harmony
Orderly arrangement
Achromatic colors
Pastel colors
Antique decoration
Antique pattern
Irregular arrangement
Round shapes
Facilities with high chroma colors
Contrast harmony
Round shapes
There are many decorative elements.
Colorful
Irregular arrangement
Straight line shapes
Artificial materials
Achromatic colors
Transparent materials
Straight line shapes
5-7
8-10
11-14
3-6
7-10
11-14

Table 2 Subject composition.

Gender	Male : 8 , Female : 6
Degree	Postgraduate : 6, Undergraduate : 8
Total	14

3) Interview Survey Method

The interview survey was conducted in three steps based on the evaluation grid method. The first step was to select elements for the experiment. Photos that clearly shows street furniture in the street environment were selected as the elements. In the second step, subjects made the voluntary evaluation points. The elements selected in the fist step were presented to each subject. The subjects classified the elements into five groups based on the standard of 'good street environment'.

Each subject was asked to compare the classified results with each other and to record the reason why he/she thought that one group is better than other group in terms of the street environment with his/her own expressions. The points that they made were recorded as evaluation points. The third step was the laddering step. Laddering is a method to identify the cognitive structure in hierarchical way. By using this method, the causal relations between evaluation points can be clearly uncovered and an evaluation mechanism can be systematically established. In short, on the basis of the voluntary evaluation points, the evaluation structure of superior evaluation points and inferior points can be comprehensibly organized.

3.3 Analysis

The qualitative data from the all twenty subjects alone can be enough to understand the evaluation structure in terms of the office interior color environment. However, the following analysis was conducted to secure more objective and efficient data by organizing the data.

First of all, all evaluation points made by subjects in their own expressions were comprehensively analyzed and classified into groups of the same points although there was a little different expression. As a result, 124 points were classified into 17 points.

Then, evaluation points of each subject were replaced with the classified points. During the laddering process, a frequency matrix to show the causal relations of all evaluation points was developed after collecting the number of subjects who mentioned the casual relation.

Fig. 2 is the evaluation structure model of the street environment made of the data of all subjects. The points with over six frequency were selected from this matrix, then organized by a network diagram. Points in the left side of the diagram are the most superior points (ladder up) and points in the right side of the diagram are the most inferior points (ladder down). The layout was made manually in the principle of minimizing the line crossing that shows the causal relations.

The relations between the superior and inferior points in the diagram can be summarized as follows:

1) 'Well-balanced', 'Harmonious', 'Comfortable', 'Unified', 'Well-organized' and 'Neat' were mainly affected by the arrangement of street furniture.

2) 'Sophisticated', 'Modern', 'Antique', 'Simple', 'Practical' and 'Fun' were mainly affected by the shape of street furniture.

3) 'Luxurious', 'Calm', 'Attractive', 'Active', 'Warm' and 'Cool' are affected by the colors and materials of street furniture.

4 CONCLUSION

The evaluation showed the following result based on the analysis of the relations between the superior points and inferior points.

1) 'Well-balanced', 'Harmonious', 'Comfortable', 'Unified', 'Well-organized' and 'Neat' were mainly affected by the arrangement of street furniture.

2) 'Sophisticated', 'Modern', 'Antique', 'Simple', 'Practical' and 'Fun' were mainly affected by the shape of street furniture.

3) 'Luxurious', 'Calm', 'Attractive', 'Active', 'Warm' and 'Cool' are affected by the colors and materials of street furniture.

This study analyzed the characteristics resulted from the emotional evaluation on environmental furniture in a city street. The result will be used as the basic data of the selection of evaluation variables and expressions, when it comes to the follow-up evaluation experiment.

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Determination of the main colors for the landscape of a new administrative city

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ABSTRACT

The absence of systemic color plan to express the structure and system of the city, have produced monotonous and uniform image on the city landscape in most area of Korea including big cities. In addition, urban landscape to represent unique characteristic of the district has not been built by using appropriate colors, and even color planning to consider the structural features, function, and shape of the building has not been performed. Sejong, a new administrative city, will be constructed by 2030, with a construction plan to consider the city environment color as a critical aspect of city landscape from the beginning of construction. Therefore, the purpose of this study is to build a systemic and consistent landscape to establish city own identity by establishing the fundamental plan for the application of landscape color.

The procedures of the study were as follows.

1) Determination of the basic frame of the color plan suitable for spatial structure of the city by analyzing the development plan for the city construction. 2) Analysis of the color pattern and its distribution of natural environment elements with an observer view by a survey of the color of the natural environment of a new city. 3) Development of the color guidelines depending on the residential types according to the land using plan of the city development plan by identifying the main color of the city.

Keywords: Main color, Hue, Value, Chroma, City construction, Residential area

1 INTRODUCTION

The absence of a systematic color plan to express the structure and system of a certain city, has produced monotonous and uniform images on the city landscape in most big cities in Korea. In addition, an urban landscape to represent the unique characteristics of the district has not been built by using appropriate colors, and even color planning to consider the structural features, function, and shape of buildings has not been performed.

Sejong city, a new administrative city, will be constructed by 2030, with a construction plan to consider the city environment color as a critical aspect of city landscape from the beginning of construction.

This study is aimed at providing fundamental guidelines on a color plan to build a systematic, consistent city landscape that shows the identity of a new administrative city.

The procedures of the study were as follows:

1) Determination of the basic frame of the color plan suitable for spatial structure of the city by analyzing the development plan for the city construction. 2) Analysis of the color pattern and distribution of natural environment elements from an observer's view by a survey of the color of the natural environment of the new city. 3) Development of the color guidelines for each residential type according to the land using plan in the city development plan by identifying the main color of the city.

2 ANALYSIS OF THE CITY CONSTRUCTION AND DEVELOPMENT PLAN

2.1 City Construction and Development Plan

1) The Basic Direction of the Landscape Plan

The city landscape will be developed in harmony with a natural landscape by securing a view corridor at a view point to have a view on rivers

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and streams, and by establishing building skyline harmonizing with natural hills in a central open space. The unique and lively streetscape will be developed by creating the central image of the city with major buildings positioned in a visual way and designing specialized streets in major functional districts. Rivers and streams will be categorized into preservation, recovery and water-friendly spaces and a creative water landscape combined urban and rural style landscapes will be developed to provide a dramatic landscape that people can enjoy.

2) Establishment of Landscape Districts and the Landscape Theme for Each Functional District

The landscape districts were determined based on visibility and geographical characteristics. A large landscape district is being formed centering on the Jangnam plain. A landscape district in highlands in the Northwest district and the Northeast district was formed visually separated from outside area due to geographical characteristics. The Bonggi district and the Walsan district were classified as independent landscape districts. Although the Deapyung and Songwan districts could have been classified as a large landscape district like the Jangnam plain in a visual aspect, the two districts were divided into different districts because they are separated by Geumgang and the 1st national highway.

The landscape district is developed by comprehensively considering city functions and geographical characteristics to realize the ring-shaped city structure and the decentralization concept. The themes for each landscape district were specified by reviewing and comparing functions, major activities and environmental and geographical characteristics.

3) Residential Area Development Plan

Residential areas were classified into four types such as low density, low and medium density, medium density and city types.

① Low Density Residential Area

This area is planned to be adjacent to green parks and be located in surrounding area of city circular highways in order to secure a good natural landscape.

Field-type and block-type detached houses and terraced houses are planned to be built in order to create a rural-type housing site and a low density residential area.

② Low and Medium Density Residential Area

This area is planned to be built in order to secure a daily life zone where multi-community facilities for basic life are deployed and to secure view corridors and wind ways linking central districts in a city.

Block-type townhouse, which is easy to form a space for courtyards, and roadside-type town house and terraced house considering the natural environment are planned to be built.

③ Medium Density Residential Area

This area will be developed around arterial roads to secure a landscape of the central part of the basic life zone.

Neighborhood-type mixed-use housing and patio-type, roadside-type and block housing are planned to be built, considering the streetscape consistence and city amenities.

④ High Density(City-type) Residential Area

City-type mixed use housing is planned to be built in areas around stations in order to prevent city hollowness and vitalize city at night time.

High-rise and tower-type housing with commercial use of low floors is planned to be built.

3 ESTABLISHMENT OF THE BASIC DIRECTION OF CITY ENVIRONMENT COLOR DESIGN

3.1 Objectives of City Environment Color Design

On the basis of the analysis of the basic frame of a landscape in city construction, basic objectives of a color plan were established as follows:

① Formation of a color landscape as an environment-friendly eco-city to harmonize with nature and maximize the potential of land,

② Formation of a dynamic color landscape to express a variety of city functions as a complex city,

③ Formation of a consistent color landscape of flow and connection that reflect non-central characteristics of spatial structure of the city,

④ Creation of a color landscape that describes identity and symbol of an administration-centered complex city

⑤ Formation of a color landscape where people want to walk and see.

⑥ Establishment of the step-by step color application concept to respond to social changes according to city development phases.

3.2 The Basic Structure of City Environment Color Design

The basic structure of city environment color design is as follows:

1) Application of City Main Colors

Main color of a city is determined to harmonize with natural environment color and match with the city images. The main colors are applied according to annular composition centering on the whole residential complex of a development region.

2) Selection of Districts for Use of Color and Establishment of Identity

Seven districts are selected based on main functions of a city and two or five daily life zones are selected. Identities of seven districts are established by applying colors that can give identity for each district.(Applying identity colors for each district facility that represent main functions of a city)

3) Establishment of Identities for Each Life Zone

The color concept, that emphasizes cohesion of each life zone, is applied to community facilities in the central part of each life zone, forming identities for each life zone.

4 SELECTION OF CITY MAIN COLORS AND APPLICATION METHOD

4.1 Analysis of Natural Environment Colors

The natural environment color distribution of a prospective area was measured and analyzed before the city main colors are selected. Color measurement of a prospective area was classified into three steps on a basis of long distance, medium distance, and near distance.

Table 1 Object for measurement.

Near Distance	Grass, Trees(Needle-leaf tree, road-leaved tree), soil
Medium Distance	Grass, Mountain, Soil, Water
Long Distance	Mountain, Sky, Water

4.2 Determination of City Main Colors

For main colors of a city, a color range that can be harmonized with soil color was selected from over 7 brightness of YR, Y series, below 2 chroma or over 8 brightness of R, RP series, color of below 1 chroma, and achromatic brightness of over 7.

4.3 Application of City Main Colors

The selected main colors are arranged for residential area according to the annular city composition. Based on location characteristics, including visual corridor, highland, an area adjacent to a park, visual order was formed by imposing the color hierarchy.

Plans for color application for each residential type are as follows:

1) Colors that go with the surrounding natural environments (highland ·green zone of a park) were applied for low-density residential areas.

2) Low to medium-density housing area is expected to be built mainly in a form of block-type town house and roadside-type town house and be served as a visual path to the surrounding natural landscape. So more quiet colors were applied to the area in order to establish images.

3) The order system integrated by shapes, materials, and colors on a basis of block units, was applied to medium-density life zone creating unified landscape images.

4) The upper and middle parts of urban high-density residential areas followed the order of main colors of the city. But secondary colors and accent colors were applied to the lower part according to characteristics of construction materials and features of each district and each function.

5 CONCLUSION

This study was aimed at providing the guidelines for landscape color application of a new administrative city to form a systematic and consistent city landscape and establish the identity of a city. This study determined the range of main colors for a city and presented the color application plan for each residential area type.

This study can be summarized as follows:

1) On the basis of the analysis of the basic directions of city landscape in the city construction, the basic directions of the color plan were established as follows:

① Formation of a dynamic color landscape to express a variety of city functions as a compex city

② Formation of a consistent color landscape of flow and connection that reflect non-central characteristics of spatial structure of the city

③ Creation of color landscape that describes identity and symbol of an administration-centered complex city

④ Formation of color landscape where people want to walk and see.

In addition, residential areas, that take up 70% of the total prospective land, were classified into four types such as low density, medium to low density, medium density and city type. Different color plans were applied to each area.

2) The color measurement of prospective area for a new administrative city was classified into three steps on a basis of long distance, medium distance, and near distance. The color distribution of soil, trees and grass, and sky was surveyed.

3) For main colors of a city, a color range that can be harmonized with soil color was selected from over 7 brightness of YR, Y series, below 2 chroma or over 8 brightness of R, RP series, color of below 1 chroma, and achromatic brightness of over 7.

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④ The upper and middle parts of urban high-density residential areas followed the order of main colors of the city. But secondary colors and accent colors were applied to the lower part according to characteristics of construction materials and features of each district and each function.

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Decision on Urban Environment Color

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ABSTRACT

Under the instruction of a comprehensive theory, this article elaborates some elements in decision on urban environment color such as the systematic nature, its purpose, coordination and economic consideration so as to prove the importance of such decision as a core on the basis of some disputable cases.

Keywords: city, environment, color, decision, system, and coordination

In 1988, China Association for Science and Technology held a leading edge academic forum participated by hundreds of academic fields and experts, and my lecture titled Environment Color Management attracted much attention thereon.

In compliance with "systematic theory and basic principle of environment color management" set up by color academic field, the color management is applied in different areas and by various industries, and achievements are made subsequently. In 2004, the campaign "Color China" was sponsored for the first time with 8 awards for color application, of which "urban color" leads the top. This move encourages the application and innovation of color, and helps to promote the rapid growth of color industry and enable the color to play a positive role in economic and social development.

With the entry into 21st century, in particular Beijing winning the right to host Olympic Games, the medias of China show great concern over the urban city and also pose many questions about "urban color pollution", and "color Olympics" or so. People have realized that urban color needs to be planned and regulated, but how to do so is a hard nut to crack. The first is to establish a guidance for color application, however, would it be set up according to the objective information or chromatics, or on the basis of comprehensive theory (modern science and its methods) or the art design? Without a convincible basis or proper technical support for the foresaid decision, this will inevitably lead to dilemmas in the decision of urban environment color. I explained my views in terms of principles.

1 SYSTEMATIC NATURE

The systematology, information theory and cybernetics, born in the end of 1940s, comprise a new and comprehensive fundamental theory. This is a great scientific achievement.

A systematic concept concerns with the classification of the objectives. But why? Generally, we advocate, while studying the problem of urban color, solving the problem of urban color from the whole view. That is to say that if an architect, an industrial designer or an advertising designer only care about the color of their objectives, focusing on an individual color show, how could a city be colored in such a misplanned way. As a regime without law must be corrupt, an urban environment color without order is dangerous as well.

The urban color directly shows the environment of a city. The environment is composed of roads, bridges, buildings, public facilities, mountains, water, animals and plants. A city is, catering to the living, working and production need of people, formed by exploitation, reconstruction and development based on natural environment. The urban color is a system, undoubtedly composed of people, garments and vehicles. Someone holds that the urban system refers to the building and the connection with its facilities and infrastructures. This is a unilateral view. The building is only a subsystem under the urban system. The urban system also contains other subsystems, including vehicle, garments, plants and other animals.

From the principle of systematic nature, we need to determine the position and role of various subsystems. A case in point is that the determination of a building color is required to take the feature of natural scenes into consideration. As Frank Lloyd Wright said that architecture should be organic in nature and insisted that the buildings "grow" naturally from their surrounding. The buildings are rooted in them just as a plant is in the soil in which it is planted, otherwise they will lose their value of existence. In contrast, people are movable and their dresses are easily changed. In light of the change of sunshine in urban environment, the animals and plants change their colors in different seasons. In these subsystems, the building is comparatively unchangeable. As a result, the color of a building plays important role in urban landscape.

It is a disputable problem for a long time to design a building emphasizing its style or engineering. We advocate that the color of building group should be rich and stable, while considering to complement with colors for the regional or seasonal defects. This is because the large volume of building could stabilize the color of buildings, and thereby dominate the environment color. This becomes the background and stage of people, other animals and plants, vehicles and advertisements showing their changeful colors. A style design for individual building is acceptable, and highlighted in the building group. But the number of such buildings must be controlled. It is noted that the color of these buildings will become a label in geological color and a name card for urban color. The Forbidden City of Beijing, White House of Washington and Red Square of Moscow are good examples.

2 PURPOSE NATURE

The purpose for the decision on urban environment color is to show people a legible, orderly, safe and stable color environment. We assume that if there is no traffic lights and double yellow line on the road, how could a pedestrian's safety be guaranteed; if there is no red line around the public building to forbid parking, how could fire truck enter the accident site without any barriers, not to mention rescuing people's life and property. Also, how could people's rest be guaranteed even in the night, they are embraced by so dazzling light in the residential area. People's life, study or work will get in chaos. While judging the urban color from the point of art, we hope the function of color would be preferred. In the process of determining the use of color, the government should consider more about people's psychological and physiological aspects, and an overall planning of the environment.

A case in point is the color of taxi in Beijing, which is called "yellow worms". Moreover, according to the "Theory of Five-Color" set up in the philosophy of Ancient China, it proposed the central yellow as a basic color, which is surrounded by 8 colors to be used for mixing with it to form other colors. The taxi of Beijing has itself a unique image. For the one comes to Beijing from other place and wants a taxi, the color of Beijing taxi will give him/her first impression. So in my opinion, it is ok to leave people a deep impression of the "yellow taxi" in Beijing, either as a former royal place or a capital of New China. That's why we choose this uniform color for taxi, a distinct difference with the taxi in other place. The simpler the color is, the deeper impression the one has. There are also other good examples in New York, the yellow taxi, and in London and Paris, where is famous for the black taxi. All of them choose the simple and legible color for taxi.

This kind of distinct identification is also generally used in the fire truck and ambulance with red and white color respectively so as to guarantee the security. Both of them are entitled to drive beyond the restriction of traffic signal. The orderly color identification could prove the importance of people's life and property in a best way.

In order to regulate the urban color, we must take first step to the color of buildings. In addition, the buses should be differently identified with color according to their routes, which is generally identical with the color marked on map. The public service and their vocational suits adopt uniform colors. The urban color is mainly composed of these colors, so if we could regulate them, it means we have controlled the urban landscape color. In a meanwhile, the color of people's garment and private cars belong to the open color beyond control.

To the date, the application of advertisement color in building and vehicle body arouses much concern. Someone calls it "a beautiful scene", but others call it "source of urban color pollution". We could get a mutual understanding that the advertisement on buses should be limited in terms of the posting part of vehicle, size, color and light effect, otherwise, the color of a city will lose control.

3 COORDINATION NATURE

Every open system is supported by external resources and energy, and in fact, they are inter-related and mutual influenced. The position, role and development of subsystem are therefore determined by such kind of mutual reference. The coordination refers to two conditions, one is the horizontal coordination among subsystems and the other is the vertical coordination with time factor.

In accordance with different sunshine energy in various cities, we could take the measures of sunshine absorption and reflection in architectural design respectively. In tropic zone, the wall of building is white coated with few holes on it, highlighting the ventilation effect. In contrast, the cold zone building is designed to open a large window in the south and small one in the north with dark wall coating, emphasizing heat preservation. In hot summer, people are generally dress white or other light colors, but wear clothes with dark or warm color in the winter. In an open urban environment, people will adopt corresponding measures owing to the input of external energy.

Nowadays, human has made much headway in architectural technology. The building design and construction are thoroughly changed with emergency of different materials such as high effective heat-insulating material, insulating glass and low-e glass, invention of mechanical ventilation facilities and air-conditioner, especially the extending of railway, increasing of marine routes, available materials, technology exchange, development of dying technology, progress of coating technology, and the abundant colors. The fashionable dyestuff is renewing the traditional one. The color of buildings, vehicles and garments are developed in a coordinated way with the development of human. This makes it possible to decrease the difference between regions and nations. People are trying to design the building with regional or national style, however, the color of modern artificial stone has replaced the color of natural stone, wood and sintered materials. With the less use of natural stones, decrease of farmland, and the higher of buildings, the change determined by the resources and technology is inevitable.

The urban color is changeable with the time passed. While the popular color of vehicle, garment and industrial product are renewed year by year, even the comparatively stable color like building will be affected as well, on which the popular color will be partly coated. Of course, the period of such color in building won't be as short as in others. The reference of colors in building, vehicle, garment and industrial products will make it convinced in this environment. A coordinated development and the balance in a new stage under the system are thereby decided.

The coordination under the system is changeable with the development of system. I had proposed to define the resource, energy resources, material, weather, temperature, politics, economy, culture, science & technology, mental factors as the control variable; also define the lightness, color phase and chroma of color as the state variable in 1992. When the control variable is stable or under change, the state variable will keep pace with it. In compliance with the regular movement of subsystem caused by the every change of control variable, we create the theory of season, geology, sunspot, politics, religious and culture, psychology, physiology, technology, material and experts. However, they all ignore an important problem, the coordination and competition between the control variables. That's why they always feel disappointed to the predication of popular color and the determination of urban color management. The properness of a decision is subject to the scientific and democratic aspects. The so-called democratic aspect refers to the coordination of control variable, and the scientific aspect means the competition of control variable. Finally, the result of decision is only the result of competition of control variable.

4 ECONOMY NATURE

As to the color of materials putting into use, it may be affected by the light, oxygen, heat, dust, static, freeze thawing and its own chemical change, people have to invest in color renewal. If a color of material needs to be supported as a popular color all the time, you have to invest more to constantly change the carrier material of the popular color.

In ancient building protection cases, it is improper to apply the colored coating on wood and tiled brick of ancient building. This kind of measure fails to recognize the economic value of materials and is unfavorable for the protection of urban architectural culture. The material and color constitute an important component of the history of a city.

The color of business is shown by the color of advertisement and represents the popular color. It is a color obviously financial supported. The color of business is rich and constantly changeful because the business owner expects to win market share partly through the advertisement with fresh colors. They hope these fresh colors could arouse people's impetus and desire of shopping. However, in the business color strategy, someone may adhere to their traditional color without change, including the yellow products of Kodak, and green products of Fuji Film. The color of their shops is a kind of advertisement as well.

The decision of urban color embodies the level of civilization and economic development, and quality of citizens. On the other hand, it plays a functional role and facilitates the citizens in their life, working and learning, to increase the practicability and efficiency. It could also produce environment profits, that is to say that a successful urban color could help improve the image and brand of itself and promote the investment, production, tourism and business profits of the city, as well as the development of its relevant industries. As a result, people are interested to take the filed of color as an industry and drive the development of society by the additional value of color economy. With the study of successful and failed color cases around the world, we could make a proper decision on color that is in harmony with our situation and beautify the city we are living in.

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Urban Color Planning for Changnan Region of Nanchang City

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ABSTRACT

By introdcing the working methods and techniques for urban colo planning for Changnan Region in Nanchang City and delineating the details of color planning, this article purports to investigate into the new way of thinking, management strategy and implementation methods concerning urban color planning and suitable for China's actual situation.

Keywords: Urban color Planning, Nanchang, Color preference, Measurement.

1 RESEARCH BACKGROUND AND SIGNIFICANCE

In the 21st century with rapid domestic economic growth, ever-flourishing culture, increasing exchange with the outside world, and ever-improving living standard, people have shown an ever-increasing trend for higher requirements for the quality of the objective world in addition to personal existence. Lack of special planning and management system for color planning in China in the past has resulted in increasingly chaotic urban color environment, leading to both physically and mentally negative effect.

The "color sickness" in Changnan Region (Fig. 1) is mainly reflected by its poor color harmony, lack of regional characteristics and poor application of colors of the natural materials. Some planning work concerning city image for the Honggutan area in Nanchang was carried out in 2004, including urban color planning, which has certain influence to the subsequent construction, but barriers still exist in actual implementation, mainly in lack of executive power, which, therefore, has become the main concern for the color planning this time. In fact, the existing status of environment colors in Changnan region is far from satisfaction. Therefore, it is imperative to carry out urban color planning for Changnan region under such situations.

Fig. 1 Disorderly Urban Colors.

2 WORKING METHODS AND TECHNIQUES FOR CHANGNAN URBAN COLOR PLANNING

2.1 Survey for users' color preference

First, we will investigate into the primary purpose and significance of color planning and the main existing problems and management status in colors in present Nanchang from the managerial level via personal interviews and identify the important objects aimed and strategies adopted in this color planning through communication with the management, ensuring the planning more feasible and pertinent. Secondly, to reflect the color impression of the majority people, we have prepared Nanchang representative color questionnaire and released it on http://www.lighting-vision.com/poll/index.html, through which the people can choose their respective representative colors of Nanchang City. At present, the web page has been linked with the website of Nanchang City Government and publicized in local papers, attracting extensive voting by the Nanchang citizens.

2.2 Objective measuring means

In addition to subjective appraisal, we have also adopted such objective means as image collection, color chart comparison and instrument measuring. Image collection is to take photos of the areas by digital camera. Color chart comparison is to compare the city colors by Munsell color charts and take records of calibrated Munsell values of the colors. Instrument measuring is to ensure precise digital measuring and data records by using CM-2300d spectro color photometer and Japan TOPCON BM-7 portable color luminance meter. The investigation is mainly to extract and consolidate the chromatogram of the main urban color elements such as buildings, road pavement, greening and advertisements and therefore the color inclination of Nanchang City is identified, as well as the various problems exited with Changnan urban color.

2.3 Extraction, Analysis and Application of Colors

We have made digital treatment to the colors collected through our investigation and transfer the colors into pixels, making the color more straightforward. Based on the advantages and disadvantages of the various color systems, we finally choose Munsell color system as our system for research and then we transform all color data collected into the values in Munsell system, thus making the colors uniform and comparable. We then use EXCEL for statistics and analysis. After the data analysis, we are very clear of the color inclination of certain zone or street, thus helpful for our evaluation and judgment of the colors in these zones and laying foundation for future color planning.

3 DETAILS OF URBAN COLOR PLANNING FOR CHANGNAN REGION

3.1 Concept of Master Planning

Nanchang City has experienced different architectural evolution into current scale. However, the development in different zones is imbalanced and the functional zoning is not definite. We have found that it is hard to endow the city with only one dominant color for a city having rich history and culture and enjoying fast modern development. What is more feasible and reasonable is to divide the city into reasonable zones and to coordinate among and control the zone color design and application via zone-specific color planning. Finally we come to some color planning ideas showing strong regional features and cultural connotations: by virtue of the regional, historical, cultural and folk characteristics of Nanchang.

3.2 Principles for Planning

3.2.1 Principle of Integrated Regional and Time Characteristics in Urban Color Planning

According to Master Plan for Nanchang City (2003-2020), Nanchang, while remaining its position as modern regional economic center and a suitable living city, will remain its position as famous historical and cultural city. Therefore, the urban color design shall take into the following into consideration: both remaining it history and popularizing its local cultures, and reflecting the time-specific momentum of the flourishing city.

3.2.2 Principle of Integrated Sightseeing, Comfort and Convenience in Urban Color Planning

The sightseeing property of the color landscape shall be considered in urban color planning, while providing living comfort and convenience for the daily life. While satisfying with people’s aesthetic requirements, color planning shall also consider people’s requirements for visual comfort, facilitate their recognition and identification to the environment, and organically integrate the functionality of colors with the artistic property of the colors.

3.2.3 Principle of Uniform but Diversified Style in Urban Color Planning

As for overall style of urban colors, first it must be uniformly orderly, thus preventing loose and chaotic color landscape. In addition, it is also inevitable for diversified urban colors. The urban environment shall have different features based on overall uniformity to form colorful urban space.

3.2.4 Principle of Systematic and Hierarchical Control in Urban Color Planning

Control to urban color planning shall be a clear-cut systematic process and system. Different control hierarchies shall be identified according to different objects and the respective functions and locations of the actual objects while mutual harmony is paid attention to, thus forming uniform, rich and orderly urban landscape color system.

3.2.5 Principle of Standardized, Pertinent and Operable Management in Urban Color Planning

To make out scientific and effective urban color management system is the fundamental in safeguarding favorable urban images. Management of urban colors shall have standardized management mechanism, effective and concrete management rules and shall be pertinent and operable to facilitate the implementation by the management department and to ensure better implementation of urban color planning.

3.3 Zone-Specific Orientation for Color Styles

According to the Master Plan for Nanchang City (2003-2020), the downtown area of Changnan region is divided into five zones: downtown area, Zhaoyang zone, east city zone, south city zone and Yaohu zone, for the purpose of further optimizing the urban spatial layout. Different historical and cultural background, geographical conditions and layout, functions and development orientation of the land use are fully taken into consideration in the zone-specific color planning, which are guided from the angle of overall color, coloring methods and recommended chromatogram for the purpose of forming individually characteristic and uniformly harmonious urban color environment (Fig. 2).

Name of Zone	Orientation of Style	Orientation of Planning	Principle for Landscape	Concept for Color Planning
Downtown area of old city	Fashionable Humanistic	This area is the business, financial, trade, office, entertainment, cultural, and scientific information center of the whole city.	Keep balance between traditional culture with modern business area, to realize harmonious downtown color landscape in densely populated downtown area	Protect original color style with color systems harmonious with the original color system for new buildings. Relatively bright and luxurious colors can be chosen for business streets.
Zhaoyang zone	Natural Warm	Adjacent to Gan River, Hu River, Xiang Lake, to form a new urban area integrated with residence, culture, entertainment and recreation and tourism.	Keep original water system and green land intact, to form harmonious urban landscape with natural scenes.	Use natural colors or color systems close to local materials with highly bright and low-chroma colors as the dominant colors.
East city zone	Vigorous Light	with state-level hi-tech economic development zone, university cluster and Qingshan Lake and Aixi Lake, the zone is planned to be new urban area.	Remain the modern and highly efficient landscape features of the hi-tech zone	Remain existing urban color features, use highly bright or medium high bright chroma as the dominant color for buildings to create flourishing and light color environment
South city zone	Elegant Bright	The south industrial zone of Nanchang, to develop it into some complex area integrated with industry, logistics, warehouse and residence	Form unique urban landscape integrated with leisurely living place and vigorous industrial zone	Take small-area medium high chroma for industrial zone and low-chroma dominant color for living place, to form elegant and bright urban color environment
Yaohu zone	Fresh Graceful	Form university park, and well-developed hi-tech zone centered on export-oriented economy and export processing trade	While remaining original natural landscape, create pleasant city landscape	Colors with medium high brightness and chroma is applied to create fresh and graceful urban color environment

3.4 Hierarchical Control of Environment Colors

The areas in Changnan region controlled for color landscape include riverside color landscape strip along the Gan River, urban main road color landscape strip, traffic landscape nodes, natural scenic river landscape, historical and cultural protection zones, urban core area and sub-civic center (Fig. 3). We take the buildings as the example to illustrate. The control of building colors in Changnan region consists of five hierarchies and each hierarchy has different requirement for color control, thus facilitating future restructuring and implementation of new building. Hierarchy 1: the fundamental color of buildings shall strictly observe to the recommended chromatogram by this color planning and the color design for building plan shall go through strict examination by management authorities and the design plan shall be carried out strictly. Hierarchy 2: the fundamental colors and auxiliary colors of buildings shall conform to the dominant colors of the urban environment. Hierarchy 3: the fundamental color of buildings shall conform to the dominant color of urban environment and the auxiliary colors may be somewhat flexible. Hierarchy 4: Fundamental colors and auxiliary colors of building may be somewhat flexible in selection and try to be harmonious and natural. Hierarchy 5: building colors can be flexible in selection, but with special application for such special color design, which shall be strictly examined and approved by relevant authorities to try to create choice buildings under the prerequisite of not damaging the overall environment style.

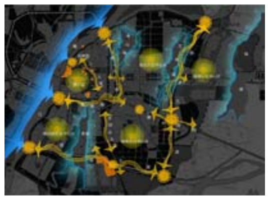

Fig. 2 (left) Specific Orientation of Color Styles.

Fig. 3 (right) Control of Landscape Colors.

4 CONCLUSIONS

We have laid emphasis to preliminary investigation for this color planning and have entered into in-depth study in the existing problems and have found out the reasons of problems by using scientific color systems. In the planning emphasis is laid to the contents of the study, trying to apply the latest scientific research achievements, both foreign and domestic, into the project. Research planning is the feature for the university to undertake planning work and is also our advantages in launching this work. Based on the mature foreign and domestic color theories, and using scientific color instrument, we have conducted data collection and analysis. Not like the print colors and object colors, urban environment colors will be subject to great influence by the building dimension and features. Therefore, it is a new subject in urban color design and the planning process is certainly a process of study. To eliminate the past weakness of lacking detailed instruction in planning documents, we have laid special emphasis to the practicability and operability of the planning results and explained the complex theories, technical standards and planning design by expressions understandable to both managerial personnel and designers, and worked out directives, examination forms and instructions, and color application software based on the actual demand for working process and management, thus ensuring favorable instructions to the architects in selecting colors. This planning has won Color China 2006 China Environment Color Nomination Award and also won the first prize in 2006 Shanghai outstanding scientific research achievements and has thus great directive significance in promoting the urban color planning in Changnan region of Nanchang City.

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