Colour accuracy in digitally-printed textiles: what you see is not (always) what you get

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One problem faced when digitally printing textiles is ensuring that the colours of the final printed output are a satisfactory match to those of the design on a computer monitor or the original artwork. In other words, that there is a close enough match for the designer to feel that their intended outcomes have not been compromised. Anecdotal evidence from colleges and universities with digital print facilities suggests that they regularly encounter problems in this area of colour matching. This paper discusses the initial stages of an investigation into colour accuracy in digitally-printed textiles in the higher education environment.

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Introduction

The impetus for this project emerged from the authors' experience when creating and printing designs digitally onto textiles (Figure 1) and from observations made while working with BSc Textile Design and Design Management students. The difficulties encountered when colour matching between screen and digital textile print are, more often than not, an issue. The aim of this research project is to look at what is currently being done with regard to colour matching between media in higher education (HE) and to develop a resource that can be used to raise students' awareness of all aspects of colour in the digital textile print process, and therefore better equip them to work productively with digital textile printing.

Figure 1: Examples of digital textile design by Aileen Collis.

There is a raft of information readily available (from industry journals, company websites and specialist trade fairs) relating to commercial digital textile printing. Innovations and developments, such as the latest printers and the newest colorants and colour management systems, are widely documented. However, although textile digital printing is becoming widely available in HE establishments there is a scarcity of information about how digital textile printing is being used in undergraduate textile degree programmes and how staff and students deal with colour accuracy issues. This research aims to investigate digital textile printing and related colour accuracy issues within the HE environment, essentially looking at how colour in digital textile printing is understood and managed in order to optimise teaching of this important developing technology.

This current paper explores and compares approaches to achieving colour accuracy in digital textile printing in industry and HE environments, determining the importance of colour accuracy in both environments.

It is not unusual to find a digital textile printer in HE institutions offering textile degree programmes. To have access to a digital textile printer is undoubtedly an asset for students. Having a working knowledge of a range of textile printing processes and their associated applications, restrictions and potential, will be beneficial in their future careers. Students on textile degree programmes may gain experience of various software programmes (for example, Adobe Photoshop, Lectra Kaledo Print, AVA CAD/CAM) for creating their textile designs, giving them transferable skills they can take forward into the workplace.

These transferable skills should also include a fundamental understanding of the intricacies of colour management. In terms of colour matching, digital textile printing comes with its own restrictions and requirements. A colour viewed on screen cannot be accurately reproduced if it is not within the achievable colour range (or gamut) of the particular digital textile printer and colorants being used (Figure 2); a colour that is viewed on screen may also not be an accurate representation as it may not be within the monitor's gamut, and will appear differently depending on the actual monitor used for viewing. To complicate matters further, each individual monitor or printer will have its own achievable gamut; so a colour viewed or printed on one device may appear different when viewed or printed on another device (Figure 3). From experience, students are often disappointed when colours in a design they have created on computer do not match the same design when it is digitally printed onto fabric. With no prior knowledge of the technicalities of colour matching, it is not unreasonable to have an expectation that there will be an exact match from screen to textile (Figure 4). To have an understanding of colour matching and colour management issues for digital textile printing would undoubtedly be an asset in the colour-sensitive world of textiles. Ujiie suggests that, '...an effective textile education should encourage problem solving in digital inkjet fabric printing and cutting edge design concepts' [1].

Figure 2: Selected colours from digital textile design by Aileen Collis; when viewed in AVA CAD/CAM software, the individual colour chips display warning triangles when a colour is not within the gamut of the printer and/or monitor (screen shots courtesy of AVA CAD/CAM; copyright AVA CAD/CAM Group Ltd).

Figure 3: Digital design (left) which has been digitally printed onto a variety of paper substrates via two separate ink-jet printers (right).

Figure 4: Digital textile design (left) which has been digitally printed onto cotton (right).

Defining the function of digital textile printing in a HE environment is an important stage in understanding the related colour accuracy issues. Having access to this design tool gives students the opportunity to experience digital printing technology alongside more traditional methods (for example, screen printing). It gives an extra dimension to their creative practice allowing them to bring their computer-aided design (CAD) work to life and into real-world applications, such as furnishing or apparel fabrics; otherwise this work would only exist on screen or on paper. The digital textile printer can be utilised on a number of levels, with different aspects of the machine and its function giving students different experiences: it is a design tool; it is a machine for the coloration of textiles; it offers a more environmentally friendly alternative to traditional methods; it provides an insight into colour matching and finishing issues; it is an adaptable and flexible medium for exploring technical textile applications. In all of these cases a basic knowledge of how the machine works, the different colorants that are used, the requirements for the substrates and the applications, plus fundamental aspects of colour management will give students grounding for a whole range of future roles including those of designer, technologist, buyer and merchandiser.

Compared to more traditional textile printing processes, such as block printing, digital textile printing is still in its infancy. Students are in a position to explore and develop this as a medium. A core function of digital design is to create representations of things that do not (yet) physically exist. Having a machine that allows the realisation of these designs blurs boundaries: the digital textile printer is a device for printing onto cloth, but it is also a relatively new medium with its full potential as yet undiscovered. As Ujiie comments, 'Throughout history, textile designs have been tailored to the production methods in use, and each technological innovation has led to a change in the visual vocabulary' [2].

Digital textile printing enables rapid response to changes in fashion, is more environmentally friendly than other methods such as screen printing (using less water and creating less waste) and lends itself to innovative technical textile applications. In a changing market where the production of printed textiles is moving away from long print runs, digital textile printing is coming to the fore. As Holme comments, 'Within Europe, the average production run is now only 500 metres or less' [3]. Knowledge of the issues relating to colour accuracy and how these can be dealt with will enhance students' employability.

Experimental and methodology

The methodology used in this study includes:

- an overview of the history of textile printing, in order to place digital textile printing in context;
- the history of digital textile printing and colour matching issues, in order to understand its development from a carpet and paper printing process;
- the current status of digital textile printing in industry, to gain awareness of what innovations have been made and how these relate specifically to colour accuracy issues and provide comparisons with findings from HE; and
- how digital textile printing is being used in HE.

An overview of basic colour theory and how colour is communicated is also included, in order to understand what colour actually is and how this relates to colour matching in digital textile printing.

Primary research commenced with a review of textile degree programmes. A preliminary course search was carried out via the Universities and Colleges Admissions Service (UCAS) website to determine which HE institutions provided undergraduate textile design degree programmes. Each of the identified institutions' individual websites was then searched to establish whether digital textile printing was included in their programmes, and to find staff contact information.

From this research, a contact list for appropriate institutions was drawn up. A short questionnaire was designed after consulting relevant guidelines [4]. Specific information was sought as to what equipment was being used, what issues relating to colour accuracy were being encountered and how these were dealt with. The type of questions used were a combination of 'closed format' (when the respondent is required to chose an answer from a given list) and 'open format' (when the respondent replies to a question in their own words). A 'differential scale' was used when asking about attitudes to colour accuracy, with respondents asked to rate how important this issue was. Each one of the respondents stated that colour accuracy was 'very important' to them (the highest value on the differential scale) and they all had issues with achieving accurate colour reproduction. Responses to the questionnaire were followed up by visits to four HE institutions to discuss their digital print facilities in more detail.

Visits to the HE institutions revealed differences in the ranges of equipment used for digital textile printing and how it is delivered to students:

- printers used range in age and model;
- different types of colorants are used (both reactive and pigment);
- colorants are supplied via bulk feed systems, manufacturers sealed cartridges or refillable cartridges;
- a variety of colours are used, for example, magenta may be used in addition to, or instead of, red;
- there are a variety of software packages used to run the printers, for example, AVA or Smartprint;
- digitally-printed fabrics are finished in different ways, for example, fabrics may be steamed but not washed, or steamed and washed; and
- some fabrics are washed in a domestic washing machine while others are washed using industrial equipment.

The methods for delivering digital textile printing and colour matching issues to students also varied:

- some students are given a demonstration of the textile printer alongside lectures and projects specifically designed to emphasise colour management issues;
- others are instructed to print small samples of designs and to keep detailed notes on colour adjustments made at the design stage; and
- varying the length of time fabrics were steamed is another method used to try and control colour.

Contextual review synopsis: history of printed textiles

The practice of decorating the surface of textiles (generally referred to as 'textile printing') has been carried out for thousands of years [5]. In the history of textile printing, digital (or ink-jet) printing is an emerging technology. A timeline detailing some of the key dates from the history of printed textiles up to the advent of wide format digital textile printing is shown in Figure 5 [5–10].

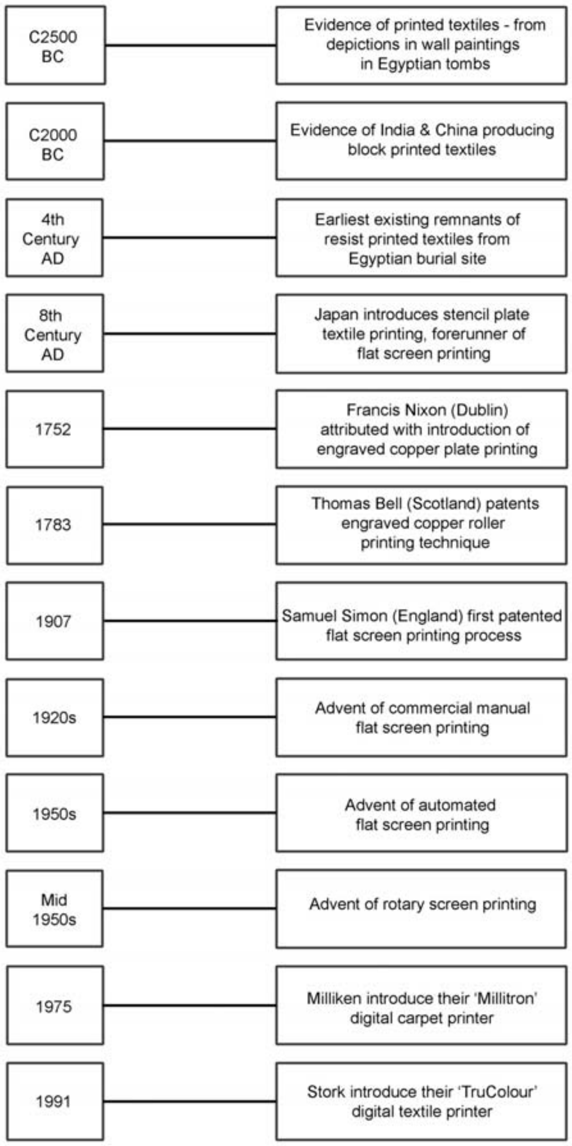

Figure 5: Timeline of some key dates in the history of printed textiles, up to the introduction of wide format digital textile printing.

Advances in technology do not necessarily signal the cessation of earlier techniques, for example, as Storey [5] points out, block printing continues to the present day, 'as a means of producing exclusive fabrics for a specialised market'. Many factors influence the choice of printing method: the end application; the desired effect; the substrate; cultural and economical criteria.

Contextual review synopsis: digital textile printing

Digital textile printing is a comparatively new development in the history of printed textiles. As Moser states, 'The first true inkjet printer for fabric was exhibited by Stork in 1991' [7]. Although ink-jet technologies existed prior to this point in the graphic and carpet printing industries, adapting the process for direct printing onto a range of textiles required a great deal of modification. However, traditional methods are still used to pre-treat and finish digitally-printed fabrics.

Adapting existing ink-jet printing technology

Ink-jet printing has been defined as, '[a] non-impact dot-matrix printing technology in which droplets of ink are jetted from a small aperture directly onto a specified position on a media to create an image' [11].

Existing ink-jet printing technologies from the graphic industry and carpet manufacturing industry were adapted to extend their applications to textiles: the Milliken designed Millitron ink-jet printer for carpet, launched in 1975, was the first of its kind; wide-format ink-jet printers were in use in the graphic industry for signage and banners [11]. The processes used for carpets and banners then had to be modified to make them suitable for direct printing onto a variety of textile substrates; print heads were adapted from carpet printing, where control and continuity of ink droplets was not a requirement. However, in order to reproduce finer, detailed designs directly onto textiles, control and continuity of discharged ink is essential [12].

To date, digital printing for the textile industry has proved to be most useful for sampling designs prior to full production, as the process removes the need for producing numerous screens for each sample, which is costly. However, digital textile printing is an area of growth and innovation and is becoming a more viable option for industrial production as machines become faster. At the Federation of European Screen Printers Association's (FESPA) Digital Textile Conference in 2008, Patti Williams (from the American consultancy IT Strategies) predicted that the share of the market for digitally-printed textiles for fashion and home would grow, 'from $890 million in 2005, to $1.6 billion in 2010' [13]. It is, therefore, becoming more pertinent for students on textile degree programmes to develop a working knowledge of digital textile print.

The most up-to-date industrial digital textile printers are capable of longer print runs as their performance improves; for example, the Osiris digital textile printer (from Xennia Technology Limited) has the potential to produce 30m/min [14]; and the Heracle (from the Korean company d-gen) is advertised as having a daily production rate of 900 m^2 [15]. Digital textile printing has the potential to push what is currently possible in textile design rapidly forwards. It has a place in industry alongside established and traditional printing methods, not in competition with them. As Tyler points out, '...digital printing should not be seen as competing with rotary screen printing or other mass production techniques...the main market opportunities for digital printing are likely to be in areas of innovative designs and customised products' [16].

Technical textiles is an area of exciting developments in digital textile printing. Karen Pooley (FESPA's Group Marketing Manager), reporting from the Digital Textile Conference in 2008, noted that current research includes, '...chromic materials (which change colour under specific conditions); materials that delivered controlled release of substances such as pharmaceuticals; and antibacterial and anti-static finishes' [13].

In addition, research is also being carried out into the possibility of using ink-jet technology to produce printed electronic circuitry within garments, with a view to creating 'wearable electronics' [3].

Contextual review synopsis: colour

In order to understand the difficulties implicit in achieving accurate colour in digital textile printing, it is necessary to gain a basic understanding of what colour actually is, and how it is perceived in human vision.

Colour is a sensation produced by the viewing of light wavelengths in various environments. Billmeyer and Saltzman describe colour as a result of 'interaction of a light source, an object, and the eye and brain, or a visual system' [17 p1-30]. Colour can be 'additive' or 'subtractive' depending on whether it is created by mixing light wavelengths (additive), or by mixing physical colorants together (subtractive). For the purpose of this research, both additive and subtractive colour are being considered – additive colour when viewing a design on a computer screen, and subtractive colour when viewing the same design printed onto fabric.

Additive colour and RGB colour space

Colour generated by the mixing of several sources of illumination, where the light sources combine together to produce white light, is said to be additive. RGB (red, green, blue) colour space (one of several specific ordering systems for colour) is so called because it is a combination of red plus green plus blue wavelengths that combine to create white light. RGB colour space is typically used for monitors and scanners, i.e. devices that produce colour electronically. There are several RGB colour space variants as different standards apply for different applications: for example, sRGB, ISO RGB, Adobe RGB 98. As Süsstrunk, Buckley and Swen explain, 'There is no one size fits all approach, no one RGB colour space that is ideal for the archiving, communicating, compressing, and viewing of colour images. The correct colour space, be it RGB or not, depends on the application' [18].

Having some knowledge of the different colour spaces used when designing and printing digitally onto textiles and, most importantly, knowing that each individual device (i.e. laptop, monitor, digital textile printer, etc.) will have its own distinct colour gamut (range of achievable colours that can be viewed and/or printed) will go a long way in demystifying some of the issues students have concerning colour in digital textile printing.

Subtractive colour and CMYK colour space

Another colour space, CMY (cyan, magenta, yellow), is created when red, green and blue colorants are blended together in different permutations. Different types of surfaces absorb different wavelengths of light. The unabsorbed light is reflected from the surface into the eye to create the sensation of a particular colour. Colour generated in this way is said to be subtractive colour, as certain colours are absorbed by a surface, leaving a remainder that reflects as a specific shade via the eye. While additive colour produces white light, the starting point for subtractive colour is understood to be the white of paper. CMYK (cyan, magenta, yellow, black) is the colour space historically associated with graphic design and ink-jet printing on to paper, which in turn is the model which has been adapted for use in digital textile printing.

Whereas in additive colour mixing, white is achieved by combining red, green and blue wavelengths, the opposite is not true for subtractive colour mixing; the addition of a separate black component represented by the letter 'K' was necessary to achieve a satisfactory depth of black; for digital textile printing, the basic CMYK format did not yield a sufficiently wide range of colours. This was addressed by including additional colours such as blue and grey [19]. As with RGB, there are several variations of CMYK, for example, CcMmYyKk, where there is an additional, lighter version of each colour [20].

Difficulties arise when trying to recreate colours produced by additive mixing (i.e. with light wavelengths) by subtractive mixing with physical colorants (e.g. reactive dye onto cotton). Because of the inherent differences between additive and subtractive colour mixing it is not easy to recreate the range and depth of colours from a design on computer screen to a digitally-printed textile [12]. This creates a problem that is constantly being addressed by industry, in the quest to achieve the closest colour matching possible. In their online resource, Wasatch Computer Technology (an American company with 25 years' experience in colour management) describes the printing process, 'The real challenge of printing ... colour images accurately is that we are attempting to approximate the colours of the real world using devices or technologies that are not capable of reproducing anywhere near all the colours in the visible spectrum' [21].

Textile students often build the colour palettes for their designs using different sources: colour libraries in software packages; decorators' colour charts; scanned in original artwork. There is then an expectation that their colour palettes will look exactly the same when their designs are digitally printed onto fabric. This is not an unreasonable expectation to have without some basic knowledge of the many variables affecting colour in digital textile printing.

Colour perception

The human eye's limitations restrict the range of what is visible in the light spectrum to an approximate range with a wavelength of maximum absorption (λ) between 380 and 750 nm [17]. Within this range, the eye can discern the colours of the rainbow from violet through to red. Typically, this translates as the average person being able to 'distinguish about 2.3 million colours' [19]. Computer monitors are capable of reproducing millions of colours, 'far more than the eye can see' as Treadaway points out [22]. The perception of colour is different for each individual, as the information received visually has to be interpreted by the brain and human beings are non-standard. As Taylor comments, 'The eye is only a conductor. It does not analyse or determine the character of what we observe, but only passes the message on to the brain. In other words it is the brain which determines the colours seen, and no two human brains discern or comprehend in like manner' [23].

When evaluating whether or not an acceptable colour match has been achieved on a digitally-printed textile, the colour vision and colour perception of the person making the evaluation, the viewing environment (lighting, background colours etc.) and the method of assessment, all have an impact. An evaluation of the colour reproduction is made by examining the printed textile output against the required standard. In this scenario, the light source has a direct effect on the appearance of the print; whether the print is assessed by a human or a mechanical process will also affect the interpretation. If there is a difference between input and output, it is then necessary to describe the difference in a meaningful way, and then make a decision as to whether the difference is acceptable or unacceptable [17 p107-130,24].

Colour management in digital textile printing

Colour management in digital printing attempts to minimise all the variables involved when printing colour images by using specific colour modes or spaces. In terms of printing digitally onto textiles, colour management could be said to 'facilitate the achievement of acceptable colour fidelity' [25] in that an evaluation is made between the on screen colours and colours on the digitally-printed textile. Using the same colour space throughout the process of printing a colour image, from monitor screen to printed media, is intended to ensure colour accuracy. According to Boris Oicherman, previously a colour management specialist at the University of Leeds, when the concept of digital colour management was first introduced in the 1980s it was intended to, '[maintain] the correct colour across the printing production chain. The correct colour, being a philosophical, rather than technical term, could not be delivered, simply because no one knew what it was. Thus, it was gradually replaced by consistent colour - which was at least technically definable, though not really achievable. This was due to colour gamut limitations inherent to different imaging devices. The scanner can capture colours which are not reproducible by the printer, who in turn can generate colours that are not reproducible by the monitor - meaning that the colour can be maintained consistent only within some fairly narrow limits' [26].

Colour management between different colour spaces

The CIE (International Commission on Illumination) was founded in 1931 [27] and has a broad remit covering all aspects of light and lighting, including colour vision and image reproduction. Technical and scientific data are shared and discussed across the member countries. The standards and models produced as a result of this dialogue are commonly used across the world. The Commission is divided into seven sections, with the first of these devoted to research into the study of colour vision and reproduction. A key example of the work carried out by the CIE is their development of the $L^*a^*b^*$ colour space, a depiction of colours in a mathematical map format.

Because it is not device dependent, CIE $L^*a^*b^*$ space can be used to provide a bridge between RGB and CMYK colour spaces. In CIE $L^*a^*b^*$ space, colours are referred to in terms of their position on axes within a three-dimensional model: where L is the value between black and white, i.e. the lightness of a colour; a is a colour's position on the red to green axis; and b is a colour's position on the blue to yellow axis. These values are constant and remain unchanged regardless of what application is used, i.e. computer, scanner or printer. But despite the values remaining constant, there will still be variations in appearance dependent upon the type of media being viewed – screen, paper, textile etc.

Colour profiles

The International Colour Consortium (ICC) comprises companies from around the world who have a vested interest in the business of colour reproduction. The founding companies included Adobe Systems Inc., Agfa-Gevaert NV, Apple Inc., Eastman Kodak Company and Microsoft Corporation [28]. A colour profile may be an 'input' or an 'output' profile; output encompasses all the variables involved in producing a colour print, e.g. what media is being used and what the capabilities are of the printer being used; and input refers to the specifications of the computer, scanner and specific colour space being used. An ICC colour profile takes the numerical information for a particular colour in a particular colour space (e.g. RGB), then expresses the same colour in another colour space (e.g. CMYK). Both sets of information are then combined to produce a third set of figures in $L^*a^*b^*$ colour, which facilitates the correct transfer of information from input to output.

The difficulties of standardising colour and creating a universal language with which to describe it are well documented. At every point in the process of describing and reproducing colour there are a vast number of variables at work waiting to undermine the outcome. Colour management is the phrase used for systems and parameters that attempt to corral colour; yet colour persists in being unmanageable to a great extent. In Taylor's opinion, 'It may well be that the rationalistic view of matter will be found to be quite untenable, and that as regards colour no object will be considered to have an intrinsic colour in the sense of human vision, but only a specific electromagnetic wave vibration which every human being may resolve differently' [23].

The final variable in the equation is the human interpretation of colour; by definition an element that will continue to remain impossible to standardise.

Conclusions and future work

There is scope to examine each of the elements involved in the delivery of digital textile printing in a more detailed in-depth study: the technical elements used to create a digitally-printed fabric; the human element with regard to evaluating a digitally-printed fabric; and how these elements interact to manage colour throughout the process. The next step of this study will focus on digital textile printing at the University of Manchester, with staff and students to be interviewed to elicit their thoughts and experiences of the digital textile print component of the degree programme. Input from industry will be obtained via questionnaires and interviews. This will provide a valuable insight into what industry professionals consider to be essential knowledge regarding colour in digital textile printing and will help to build a picture of what expectations there are for textile graduates. Once the results have been analysed it is hoped that a model for the delivery of digital textile print on textile degree programmes will emerge: a definition of best practice. Further work could include the development of a student resource in the form of a handbook or e-learning facility, to raise awareness and better equip students for their professional careers.

References

1. Ujiie H (2002), Textile design education in digital inkjet fabric printing, *Proceedings of the IS&T's NIP18: International Conference on Digital Printing Technologies*, 254–257, San Diego, USA.
2. Ujiie H (2006), *Design Life Now: National Design Triennial 2006*, Cooper-Hewitt National Design Museum, New York, USA. [http://archive.cooperhewitt.org/design-life-now/triennial.cooperhewitt.org/designers/hitoshi-ujiie.html – last accessed 17th September 2012]
3. Holme I (2006), Digital printing of texiles, *Colourage*, **54** (4), 103-109.
4. Leung W-C (2001), How to design a questionnaire, *Student BMJ*, 171–216. [http://student.bmj.com/student/view-article.html?id=sbmj0106187 – last accessed 17th September 2012]
5. Storey J (1992), *Thames and Hudson Manual of Textile Printing*, London: Thames and Hudson, 11–24, 31.
6. Society of Dyers and Colourists Colour Experience (2012), private communication.
7. Hann MA (2005), *Patterns of Culture - Techniques of Decoration and Coloration*, Leeds: University of Leeds, 9.
8. Moser LS (2003), ITMA 2003 review: Textile printing, *Journal of Textile and Apparel Technology and Management*, **3** (3), 1-15.
9. Robinson S (1969), *A history of printed textiles: block, roller, screen, design, dyes, fibres, discharge, resist, further sources for research*, London: Studio Vista, 42.
10. Cahill V (2006), The evolution and progression of digital printing of textiles, in *Digital Printing of Textiles*, Ujiie H (ed), Cambridge: Woodhead Publishing Ltd., 1-15.

11. Le HP (1998), Progress and trends in ink-jet printing technology, *Journal of Imaging Science and Technology*, **42** (1), 49–62.
12. Dawson TL and Ellis H (1994), Will inkjets ever replace screens for textile printing?, *Journal of the Society of Dyers and Colourists*, **110**, 331-337.
13. Federation of European Screen Printers Association (FESPA).
[http://www.fespa.com/ – last accessed 17th September 2012]
14. Xennia Technology Limited.
[http://www.xennia.com/Xennia/uploads/Xennia%20**Osiris**.pdf – last accessed 20th September 2012]
15. Image Reports (2008), Multi-plot presents new machines at Viscom, *Image Reports Magazine website*.
[http://www.imagereportsmag.co.uk/component/content/article/3-technology/133-multi-plot-presents-new-machines-at-viscom.html – last accessed 17th September 2012]
16. Tyler DJ (2005), Textile digital printing technologies, *Textile Progress*, **37** (4), 1–65.
17. Berns RS (2000), *Billmeyer and Saltzman's Principles of Color Technology*, 3rd edition, New York: John Wiley & Sons.
18. Süsstrunk S, Buckley R and Swen S (1999), Standard RGB color spaces, *Proceedings of the IS&T/SID's Seventh Color Imaging Conference*, 127-134, Scottsdale, USA.
19. Dawson TL (2000), Ink-jet printing of textiles under the microscope, *Coloration Technology*, **116** (2), 52–59.
20. Campbell JR (2006), Controlling digital colour printing on textiles, in *Total Colour Management in Textiles*, Xin JH (ed.), Cambridge: Woodhead Publishing Ltd., 160–190.
21. Wasatch (1999), Color Management: Basic Color Theory, *Wasatch Computer Technology website*.
[http://www.wasatch.com/colortheory.html – last accessed 17th September 2012]
22. Treadaway C (2004), Digital imagination: the impact of digital imaging on printed textiles, *Textile: The Journal of Cloth and Culture*, **2** (3), 256-273.
23. Taylor FA (1962), *Colour Technology*, London: Oxford University Press, 43.
24. Butts K (2006), A practical guide to visual evaluation of textile samples, in *Total Colour Management in Textiles*, Xin JH (ed.), Cambridge: Woodhead Publishing Ltd., 76–93.
25. Berns RS (1999), Challenges for colour science in multimedia imaging systems, in *Colour Imaging, Vision and Technology*, MacDonald LW and Luo MR (eds.), Chichester: John Wiley & Sons, 99–127.
26. Oicherman B (2007), Keeping colour under control, *Digital Print Centre of Industrial Collaboration website*.
[http://www.digitalprintcic.com/content/view/12/7 – last accessed 17th September 2012]
27. International Commission on Illumination (CIE)
[http://www.cie.co.at – last accessed 17th September 2012]
28. International Colour Consortium (ICC)
[http://www.color.org – last accessed 17th September 2012]

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