Virtual Fabrics or Multispectral Imaging in B2B

Patrick G. Herzog
Color AIXperts GmbH
Aachen, Germany

Abstract

Recently, digital Imaging has evolved rapidly, leading to an intensified use of the Internet as a communication channel. Many causes are leading to colour renditions being far less faithful than one would expect. A solution to most of the problems is provided by entirely multispectral imaging systems. Though only the image capture part of such a system is currently availably to the market, this enables already a great improvement in many applications. The paper focusses on the integration of a multispectral image capture system with current display and printing technology into a complete colour image communication framework, also including synthetic image generation (e. g. by weaving CAD software) as well as image modification and further processing in order to create new images from multispectral ones (e. g. 3D draping software). A very important matter is the control of defined viewing conditions which can currently only be achieved in the professional field. Here, the faithful communication of colour images between business partners is achievable today, raising colour communication to a new level of colour quality which enables considerable savings of time and material. Though there are still many limitations to colour reproduction, most of them will be eliminated as multispectral research proceeds.

Introduction

Digital Imaging has evolved rapidly during the last decades. Particularly the advent of digital cameras promised to revolutionise the market. Moreover, the rapidly growing Internet and the evolution of very powerful computers have dramatically changed the communication infrastructure. In fact, the migration from traditional photography on analog film to digital capture devices has been much slower than initially expected, both in the amateur and in the professional domain. Professionals from other industry branches such as the textile and clothing industry have tried to make use of the new imaging technology, but due to a lack of knowledge in handling colour, they got disappointed of the reachable color fidelity and often gave up. On the other hand, time constraints in the fashion domain are such severe that digital imaging is being used anyway, partly with, partly without any colour management, resulting in tedious sessions of trying to match colours on prints iteratively to a fashion designer's imagination.

Even if colour management ist available, the trial to digitise a piece of fabric by using a flatbed scanner or digital camera generally fails due to the metameric behaviour of the reflective material and the scanner or digital camera. The reason for the failure of digital imaging systems is twofold: the "machine" (scanner or camera) "sees" colour differently than a human, and a three-channel imaging system is not able to reproduce the colour changing behaviour, depending on the used illuminant, which means that the built-in lamps of a scanner produces different colours than e. g. daylight on the same object. Robert Hunt summarised all the "factors affecting color" on monitors used to display web contents for shopping, and he concluded that it would be best to confine oneself to goods where colour is not important.[1]

This leads us to the fact that a digital imaging system that intends to faithfully reproduce arbitrary originals needs to record more information than traditional three-channel systems, and the solution is provided by *Multispectral imaging*.[2–6] Multispectral imaging means that the complete reflectance spectrum is captured for every pixel in order to reproduce the image on a multispectral printer or on a multispectral display. For the latter case, an arbitrary light source is chosen for which the image is to be rendered.

It can be said that multispectral image capture systems combine spectral measurement technology with imaging, meaning that such systems can also be used to take spectral measurements.[2]

Neither multispectral printers nor multispectral displays are commercially available, so this paper deals with what is reachable using current technology. In the textile and clothing industry, colour plays a key role as it is the most important property of a textile, besides its structure and feeling. This industry branch has been globalised for many decades already, so global communication is just as important. Using the textile and clothing industry as an example, a comprehensive network will be sketched that helps the industry improving digital colour communication quality and hence saving time and money.

Figure 1: *SpAIXscan: Multispectral scanning system.*

Multispectral Imaging System

Multispectral Image Capture

Figure 1 shows a realised multispectral image capture system. The device is based on illuminating an object with a spectrally known light source, and imaging the object consecutively through 16 different optical filters with a digital camera (3000x2000 pixels, cooled sensor, 12bit digitisation). The spatial non-uniformity of the illumination is channel-wise corrected by a white calibration. The complete process of multispectral image capture takes ca. 30 to 120 s, depending on the actual resolution. Result is a multispectral reflectance image which can be rendered on a display using a selectable light source.

Displaying Multispectral Images

To reproduce a multispectral image on a soft copy screen, one would need a multispectral display. Such systems are currently under investigation,[3,7,8] but not yet available to the market. The only practical solution is to make use of current technology such as a CRT or LCD monitors. However, these devices only have three channels, with strong peaks in power spectrum of the red phosphor, hence spectral reproduction is not possible.

Since a soft copy display is self-luminous, on a spectral display, spectral colour stimuli are reproduced rather than reflectance spectra. This means that the spectral reflectance image needs to be rendered for a certain illuminant. Likewise, on a three-channel display, the choice of a a certain illuminant is necessary to calculate a tristimulus image that can be displayed on the screen. Provided that either display is watched by a standard observer (according to CIE), there is no basic advantage of a multispectral display over a three-channel system.

Advantages of the multispectral display come into play when the colour rendition reaches an accuracy that makes inter-observer differences of spectral colour vision visible. A further advantage of a multispectral display is usually the larger colour gamut.

A very important aspect is that a computer display is a rather different medium than a reflective print or an original object. A monitor is self-luminous, usually viewed under a dim surround, and usually standing upright while a print is often laid flat on a table. It is known that colour appearance of a monitor is different from that of a paper print with the same colours in terms of tristimulus values. Colour appearance models are under development, in order to resemble the differences of colour vision resulting from the different viewing condition. However, it is often difficult to correctly set all the parameters of these models so that a good model performance can be achieved. For many of the parameters, only recommendations are given, or the users have to estimate them by themselves.

For industrial applications, an end user does not have the ability to make such adjustments. Furthermore, the viewing conditions are generally very hard to control if "designers like to watch trees move in the wind on nice sunny afternoons" in order to keep their creativity active and vivid. Therefore, and due to the fact that colour appearance models are still experimental, a different solution was chosen.

The first thing was to define a viewing situation that is reproducible under various circumstances. The second aspect is to assimilate the viewing conditions of monitor display and reflective prints/originals, so that the use of colour appearance models is not necessary. Figure 2 shows the realised viewing workstation which was given the name "SpAIXview". On the left hand side, the system contains an area for placing hardcopy material, while onthe right hand side, a CRT monitor in integrated in the

Figure 2: *SpAIXview: Multispectral viewing workstation.*

same plane. By software, the same background like on the hardcopy area is displayed. For the hard copy, three standard illuminants (D65, F11, A) are available, of which the spectral power disptributions are individually measured spectrally and made available to the software, so that the multispectral image can be rendered for the correct light source.

The monitor is characterised colorimetrically, and a colour management system is used that allows to mark all colours that cannot be displayed accurately on the monitor (gamut warning). So, the user can recognise, that in most cases gamut limitations are the cause for colour discrepancies between original and soft copy. On the other hand, even if some of the colours are out of gamut, in most cases the deviations are not disturbing.

Note that the SpAIXview assessment workstation provides the same defined viewing conditions at arbitrary locations. It is equipped with a curtain that allows users the "make viewing conditions controlled" when it is necessary; they are not forced to work in a dark room. Due to the assimilation of the viewing condions, the system is optimised for the comparison of hard copy and soft copy. Since a monitor is self-luminous and hardcopy objects need external illumination, without such a system, it is very difficult to accurately compare originals or prints with monitor images, even if a light booth is used.

Printing Multispectral Images

Paper prints of multispectral images have the advantage that the viewing conditons of original and reproduction are inherently the same, so that no colour appearance modelling is required. On the other hand, at the time of printing, the light source under which the prints will be viewed, is essentially unknown. Since numerous different types of light sources exist, and the spectral behaviour of printing inks is normally quite different from those of originals such as fabrics, plastics, etc., metameric problems occur more often than with monitor displays. These problems can only be solved by spectral printing.

Spectral printing systems are currently under research.[9] Still unsolved problems are the enormous amount of data for characterisation of the print process, the kind of spectral approximation, and the desired accuracy. Moreover, the reproduction of unprintable colours (gamut mapping), which is comparatively well understood for three- or four-colorant processes, is yet to be solved with spectral printing processes.

Since none of them is currently available on the market, one needs to make use of current four-colorant printing technology. Even though paper prints are usually viewed under different (and mostly unknown) light sources, the reproduction can only be made for one light source. In ICC workflow,[10] D50 is mandatory. While D50 may be a good compromise between daylight (D65) and tungsten light, in many applications such as in the textile industry, D50 is none of the required or recommended

Figure 3: Sample fabric simulation of a weaving CAD software (Dobby type).

Figure 4: Sample fabric simulation of a weaving CAD software (Jacquard type).

light sources. Consequently, the print does not show the correct behaviour under any of the available illuminants.

Thus, once again, spectral printing is worthwhile. Until its availability, one could only make different prints for the different light sources, or accept the "D50 compromise". At least, multispectral imaging still has the advantage that the *captured* image is free of systematic colour errors, so that errors only stem from the rendering of the image.

Applications

Besides the archiving or reproduction of art, the digital communication of faithful colour images is probably one

Figure 5: Sample textile (printed on white fabric), multispectrally captured.

of the most important applications of multispectral imaging. A scenario is given in the following.

A network of colour communication

Imagine a fabric manufacturer who is about to ship several batches of fabric to the production plant of a garment maker. Before the stock leaves the factory, multispectral images are taken of each batch and sent to the garment maker's headquarters, so the product management is able to check against the order without having any original piece of fabric available.

But this is not the first time, digital images of fabrics are exchanged between the manufacturer and their customer. The fabric manufacturer uses CAD software to design fabrics out of single yarns, the colors of which have been measured spectrophotometrically. Two examples are shown in Figures 3 and 4. Hence, the CAD software is able to produce realistic simulations of the fabric which can be printed locally on paper, and transmitted electronically to customers in order to provide a basis for reliable colour communication at a stage where no physical counterparts exists.

The garment maker can use the virtual fabrics to create virtual garments using CAD and design (so-called 'draping') software; here realistic models can be virtually dressed with these garments. Figure 5 shows a sample fabric which has been used to simulate a 3D garment in Figure 6.

The respective images are sent to the retail trade in order to jointly set the fashion for the upcoming season. Naturally, there is some interaction between the business partners, but the communication can be finished within a few days instead of weeks. Figure 7 shows a sketch of such a communication network.

Figure 6: 3D simulation created from a flat sample file by "draping" on a 3D figure.

Other workflows

This was just an example for the workflow of fabric designs. Other fabric manufacturers are designing textiles differently. Some of them do not have a yarn database, they are designing fabrics by picking colours freely on a monitor. They get the simulation of the fabric again from a CAD software, but in this case, yarns or fabrics are dyed after the decision about the final fashion was made. For this purpose, colour values and/or print-outs of the designs are sent to the dye house, where digital values or even a print on paper serve as a reference for dyeing.

Another textile manufacturer produces coloured textiles by printing on white fabric (cotton etc.) using rotary printing machines. Here, designers are working with a colouring software which is based on dye recipes. The user inputs recipes based on an ordered structure, and the software provides the user with calculated colours which are displayed on the monitor (and can be printed on paper) through a colour management system. Hence, by the simulations, the manufacturer saves enormous amounts of money by avoiding the need to make trial prints on textile.

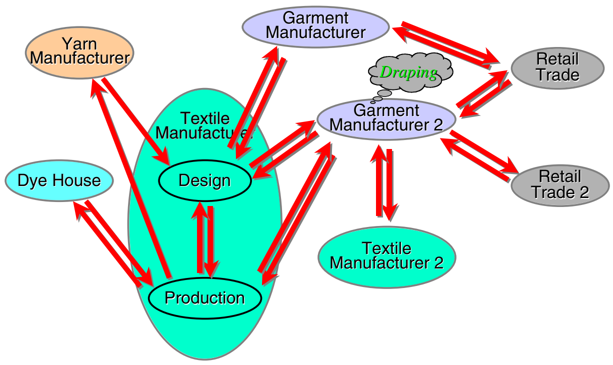

Figure 7: Communication network between the partners of the textile chain.

Business-to-bussiness communication

It is very important to see the multispectral technology in the consensus of a colour communication network. While a complete multispectral imaging system, comprising of multispectral image capture, multispectral image processing and transport, and multispectral image reproduction would solve most of the colour problems of reproducing existing objects, a great deal of the images are created synthetically, where no spectral information is available or used.

Besides image capture, the most important aspect is controlling the viewing conditions when colours need to be reliably judged. Hence, we argue that it is currently not possible to provide a 'normal end user' with reliable colour information. However, in the communication between business partners, it is possible to define identical viewing conditions at arbitrary locations. Hence, multispectral imaging elevates colour communication technology to a level that suffices to accelerate many partial processes such as design and production cycles and time to market. This has an enormous value e. g. for the textile industry, taking into account that the time period from the first fabric design to the production of the garments currently often takes as much as 18 months.

Conclusions

In this paper, multispectral imaging is seen in the context of colour communication. A focus is put on the question what is realisable with current technology. For real colour faithfulness under all circumstances, an entirely multispectral imaging system would be worthwhile. While we recognise, that the state of the art currently allows only the capture process to be "multispectral", this is already a big milestone forward. It enables the faithful reproduction under controlled viewing conditions.

Having this requirement in mind, this high level of colour fidelity is only available in the professional domain, where investments break even after a short period of time due to the improvements of colour communications and the short-cuts of design and production cycles.

Here, multispectral imaging is able to provide the spine of an extensive colour communication framework, including faithful image capture, display, reproduction as well as the interface for simulation software on the input side (weaving CAD, colouring, etc.), processing side (recolouration), and on the output side (3D draping).

Still many weaknesses have to be accepted, but as research moves forward and the market acceptance is increasing, they will be eliminated step by step.

References

1. R. W. G. Hunt, "How to shop on the web without seeing red," in *Proceedings of the 8th Color Imaging Conference: Color Science and Engineering Systems, Technologies, Applications*, pp. 2–7, IS&T/SID, (Scottsdale, AZ, USA), 2000.
2. P. G. Herzog and F. König, "A spectral scanner in the quality control of textiles," in *Proc. SPIE*, vol. 4300, (San Jose, CA), Jan. 2001.
3. B. Hill, "Optimization of multispectral imaging systems," in *Proc. 9th Congress of the AIC, Color 01*, (Rochester, NY, USA), June 2001.
4. F. König and W. Praefcke, "A multispectral scanner," in *Procs. of Colour Imaging in Multimedia*, pp. 63–73, (Derby), Mar. 1998.
5. M. Hauta-Kasari, J. Lehtonen, J. Parkkinen, and T. Jaaskelainen, "Spectral image compression for data communications," in *Proc. SPIE*, vol. 4300, pp. 42–49, 2001.
6. J. Y. Hardeberg, F. Schmitt, and H. Brettel, "Multispectral image capture using a tunable filter," in *Proc. SPIE*, vol. 3963, pp. 77–88, 2000.
7. F. König, K. Ohsawa, M. Yamaguchi, N. Ohyama, and B. Hill, "A multiprimary display," in *Proc. 9th Congress of the AIC, Color 01*, (Rochester, NY, USA), June 2001.
8. T. Ajito, T. Obi, M. Yamaguchi, and N.Ohyama, "Six-primary color projection display for expanded color gamut reproduction," in *Proc. Int. Symp. on Multispectral Imaging*, pp. 135–138, (Chiba University, Japan), 1999.
9. L. A. Taplin and R. S. Berns, "Spectral color reproduction based on a six-color inkjet output system," in *Proceedings of the 9th Color Imaging Conference: Color Science and Engineering: Systems, Technologies, Applications*, pp. 209–213, IS&T/SID, (Scottsdale, AZ, USA), 2001.
10. "Specification ICC.1:1998-09 – file format for color profiles." International Color Consortium, 1998.

Biography

Patrick Herzog received his diploma degree in Electrical Engineering in 1992 from the Aachen University of Technology (RWTH). Since then, he has been engaged in the field of color reproduction, device characterization and gamut mapping, and received his PhD degree in 1997. Dr. Herzog is currently with the Technical Electronics Institute at RWTH, where he is responsible for research and industry projects in multispectral imaging, new sensor technologies, color management and faithful color displays. Since spring 2000 he serves as managing director of the newly founded Color AIXperts GmbH.