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# Proceedings from Gjøvik Color Imaging Symposium 2003

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## Introduction

Gjøvik Color Imaging Symposium was held at Gjøvik University College November 24–25 2003. The first day was devoted to color and quality in digital film and video. Lillehammer University College and Gjøvik University College has been running a joint two year project related to this topic. The project has been funded by Morgenlandet AS over the PROKOM programme. The main idea of the symposium's first day was to bring this project to an end, and to discuss the results of this and related projects.

The second day of the symposium was devoted to multispectral color imaging. Recently, Gjøvik University College received funding from the Norwegian Research Council for a major project in this field. The symposium was planned to serve as a kickoff for that project. The symposium was funded over the two mentioned projects.

Researchers from different locations in Europe contributed to the symposium. All of the presentations were invited, and the authors were encouraged, but not obliged, to contribute with an abstract and the foils used for the presentation for inclusion in these proceedings.

# Program

## Day 1 (24.11): Color and Quality in Digital Film and Video

**Room K102 – A Building**

*1000–1030:* **Managing colors in the production and presentation of digtal video**, Gudmund Stjernvang, Lecturer, Lillehammer University College

*1030–1100:* **Film scanning and color adjustment: A colorist's perspective**, Egil Ljøstad, Colorist, Norwegian Broadcasting Corporation

*1100–1130:* **Color adjustment by color space warping**, Jon Y. Hardeberg, Associate Professor, Gjøvik University College

*1130–1230:* Lunch on your own

**Room Eureka 1/3 – E Building**

*1230–1300:* **Practical consequences of the Digital Intermediate (DI) process in feature film and restoration**, John Chr. Rosenlund, Director of Photography, Norway

*1300–1320:* **Digital cinema commercials – is the quality good enough?** Ivar Farup, Associate Professor, Gjøvik University College

*1320–1340:* Coffee break

*1340–1410:* **Monitor calibration and viewing conditions**, Kjell Kolstad, Senior Engineer, Norwegian Broadcasting Corporation/European Broadcasting Union

*1410–1450:* **ICC color management in the motion picture industry**, Andreas Kraushaar, Researcher, Fogra, Germany

*1450–1500:* Break

*1500–1530:* **Media technology education and industry: convergence or divergence?** Jens-Uwe Korten, Dean, Lillehammer University College, and Rune Hjelsvold, Professor, Department head, Gjøvik University College

## Day 2 (25.11): Multispectral Color Imaging

**Room K105 – A Building**

*0830–0845:* **The Department of Computer Science and Media Technology at Gjøvik University College**, Rune Hjelsvold, Professor, Department Head, Gjøvik University College

*0845–0915:* **The Norwegian Color Research Laboratory**, Jon Y. Hardeberg, Associate Professor, Gjøvik University College

*0915–1015:* **Introduction to multispectral color imaging: motivation, spectral dimensionality, and existing systems**, Jon Y. Hardeberg, Associate Professor, Gjøvik University College

*1015–1045:* Coffee break

*1045–1130:* **Spectral camera calibration**, Ali Alsam, PhD, University of East Anglia, England

*1130–1230:* Lunch on your own

*1230–1250:* **Creating light with arbitrary spectral power distribution**, Ivar Farup, Associate Professor, Gjøvik University College

*1250–1330:* **Multispectral imaging: acquisition and processing**, Pierre Gouton, Professor, University of Burgundy, France

*1330–1350:* Coffee break

*1350–1430:* **Spectral image reproduction using print technology**, Andreas Kraushaar, Researcher, FOGRA, Germany

# Managing Colors in the Production and Presentation of Digital Video

**Gudmund Stjernvang**

Ever since the beginning of the color film era, color adjustment has been a permanent area of difficulties in the production of moving pictures. When the captured shots are edited together, the colors must be harmonized, and this color corrections was done by use of color filters and laboratory chemicals.

The introduction of video technologies changed the methods of work, but color corrections remained a tedious process, requiring expensive equipment for use in profesional environments. The transition from analog to digital video now opens the possibilities for developing methods of video color management, by applying principles similar to those already in use for digital image reproduction on various media. Digital video color management can potentially be implemented using common computer platforms, and equipment which cost a fraction of todays dedicated video editing and color correction equipment. At the same time, the processes can be simplified and made less time-consuming.

In a collaborative research project involving researchers from the neighboring institutions Gjøvik University College(GUC) and Lillehammer University College (LUC), it was decided to investigate further into this interdisciplinary area of research and development. The research project was funded by Morgenlandet AS, a regionally based company which aims for restructuring and innovation, and has a duration of two years (2002-2003). It brings together two scientific communities color science and color management mainly for graphic arts applications at GUC, and video, television, and film production at LUC.

We have identified four different research topics of particular interest

1. Color management in the acquisition of digital video.
2. Color control for editing of digital video.
3. Color characterization of monitors used in the production.
4. Color quality of projective displays used for presentation of digital video.

# Film Scanning and Color Adjustment: A Colorist's Perspective

**Egil Ljøstad**

I think my presentation is done best visually and therefore I will show examples on typical colour correcting work and explain how my approach to get the final result is done.

Colour-correcting experiences from different tape-formats with creative work and rescue operations.

Ways of working in telecine productions. Maybe talk a little about video-to-film productions I have been working on and what to consider for that kind of productions.

Talk about experiences with transfer of archive film-material.

Show examples of ways of making video look like film.

# Color Adjustment by Color Space Warping

**Jon Y. Hardeberg**

Matching the colors of digital pictures that are to be used together is an important problem for many applications, such as image stitching, comparative image analysis, and editing of digital film and video. In particular, for the production of moving pictures, the use of several cameras simultaneously or at different times and under varying lighting conditions results in varying color rendering in the different captured shots. When these shots are edited together, the colors must be harmonized, and this currently requires substantial manual adjustments by skilled professionals.

This paper presents an innovative method for color correction using a technique we call color space warping. The problem definition originated from considering the tasks typically performed by a colorist adjusting colors of video sequences in order to obtain certain effects/moods, and also to match the colors of other sequences. The proposed method could also be applied to other applications such as image stitching and color correction and cast removal of digital still photographs.

While the more commonly known image warping algorithm is based on a set of source/destination pixel locations in the image plane, our color warping algorithm is based on a set of source/destination points in a given color space. This set of color pairs define the warping of the color space, according to the following properties:

- The source color is directly mapped to the destination color.
- Colors close to a given source color end up close to the corresponding destination color.
- Colors that have the same distance to two source colors are influenced equally by the two source/destination pairs.
- Colors are influenced more by closer source colors than by more distant ones.

Promising results have been obtained by a method in which corresponding colors are selected from the two shots to be harmonized. This is done using a color picker tool, either interactively directly in the captured scene, or using a color test target, which have been introduced in the (physical) scene.

# Practical Consequences of the Digital Intermediate (DI) Process in Feature Film and Restoration

**John Chr. Rosenlund**

Digital post-production in feature film represent a paradigm shift from the over 100-year-old analogue lab process to digital colour correction of the film on a computer. In 2001 3 films went through this process, in 2003 the number increased to 60, and in 2007 I expect this number to be 2000 films.

The first film scanner meeting the demand in terms of speed and quality is available at a competitive price 2003/04. This is a turning point for the market enabling economical digital processing of feature films. At IBC 2003 strong signals leads towards a total change in the market of postproduction in feature films from analogue to digital.

The film-production is today where the typewriter was in the late 70´s. when the computer became personal and available for everybody.

The DI process confronts some importance questions regarding technical and artistically quality.

Image and color fidelity

In the computer it is a question of pixels and BIT. To be able to work in the computer with the colour-space and resolution with in the original medium we need to define colour and pixels for the DI process.

Film is analogue and has an enormous amount of information. A healthy exposed negative is close to 6K in pixel resolution and 16Bit colour dept.

The problem is to maintain the image and color fidelity from acquisition to final screening.

We need to calibrate the digital process to the analogue to be able to "WYSIWYG" (What you see is what you get).

Who do we define the "accepted technical image parameters" to be able to say film=film in a Di process.

Digital capture has been part of the world of television and video for more than a decade. The lower spatial, temporal and color resolution of analog video equipment paved the road for a much earlier and easier digital transition. The same has not proved to be the case for film, which is capable of capturing far more detail than current digital camera technologies. Today film can resolve far more detail in terms of spatial resolution, light intensity and temporal changes (high speed photography). Digital video formats such as Digital Betacam, D2, D3, HDCAM and D5, while adequate for TV image reproduction, have too limited a dynamic range or are too reliant on compression to be effective as a high-end replacement for film. They cannot capture image information at high resolution without aggressively compressing the data, which limits their suitability as a high quality digital film master.

# Digital Cinema Commercials – is the quality good enough?

**Ivar Farup**

We describe the partial results of a collaborative research project conducted by researchers at Gjøvik University College and Lillehammer University College. The goal of the project is to develop methods and tools to improve the control of color information in the production and presentation of digital video. The project represents a unique attempt to bring together two scientific communities graphic arts and television/video production on a theme of common interest, namely color. We have investigated the color quality achieved by a system for digital distribution and presentation of cinema commercials. Our results show that the quality bottleneck is the digital projector. Especially in large theaters, the business-type projector does not yield sufficient image quality.

# Monitor Calibration and Vieweing Conditions

**Kjell Kolstad**

The human vision has certain properties when perceiving images. Images are received from real life situations or as reproduced images or a combination of both. There are facts to be understood in how we perceive images and mechanisms to be aware of when the human vision is subjectively used for producing images.

Image control requires knowledge on the reproduction technique in question and the understanding of human image perception. There are several issues to be discussed in watching images on a screen. Issues that effect the image variables and the appearance of a scene, a sequence of scenes or a sequence of programs.

# ICC Color Management in the Motion Picture Industry

**Andreas Kraushaar**


## Abstract

This paper discusses the implementation of a Colour Management workflow within the post production scenario in the motion picture industry. Beside other image quality aspects like contrast ratio and sharpness the colour reproduction plays a very important role. The main aim is to improve the predictability (reproduceability) and to softproof the cinema screen on class 1 HDTV studio monitors or appropriate projectors. For this purpose, the ICC Colour Management has been implemented in the motion picture environment. Within a labarotory setup display (HDTV and projector) and printer profiles were created. The main purpose is a absolute colorimetrical match between a HDTV-monitor and a projected silde located side by side. While the average delta Es were decreased significantly by the ICC colour management, improvements are still required for dark and yellow colour regions.


## Introduction

This paper discusses the implementation of a ICC colour Management workflow within a special part of the post production scenario in the motion picture industry. This industry is driven primarily by high picture quality. Beside other image quality aspects like contrast ratio and sharpness, all kinds of colour decisions are an extremely important component of the post production workflow shown in figure 1.

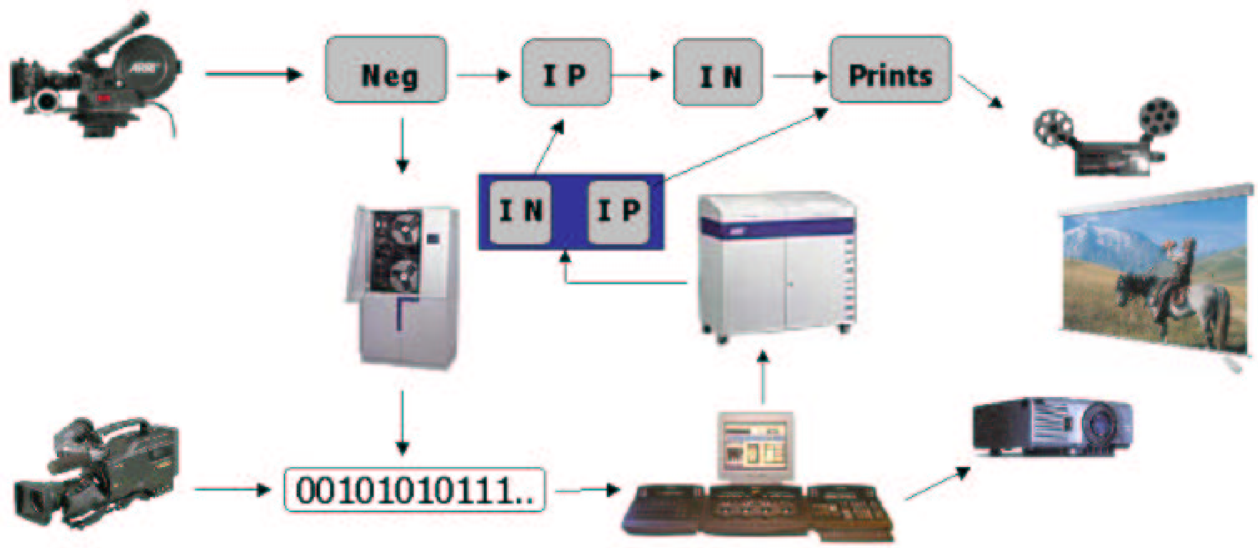


Figure 1: Digital film production workflow.

The field of digital colour reproduction is a playground of several much older industries coming together. Each of these industries has their individual aspects of colour reproduction that have been evolved within the constraints of their particular production workflows. The motion picture industry includes generally the high definition broadcast television, motion pictures as well as computer graphics. There is a great need for appropriate methods of representing, controlling and communicating colour. This paper illustrates how the colour management system was implemented to make the monitor in the post-production simulate the print film projected in the theatre. Fur this purpose the ICC (International Colour Consortium) framework within the latest specification was evaluated. In the past and present a variety of processes were necessary in order to obtain an acceptable colour

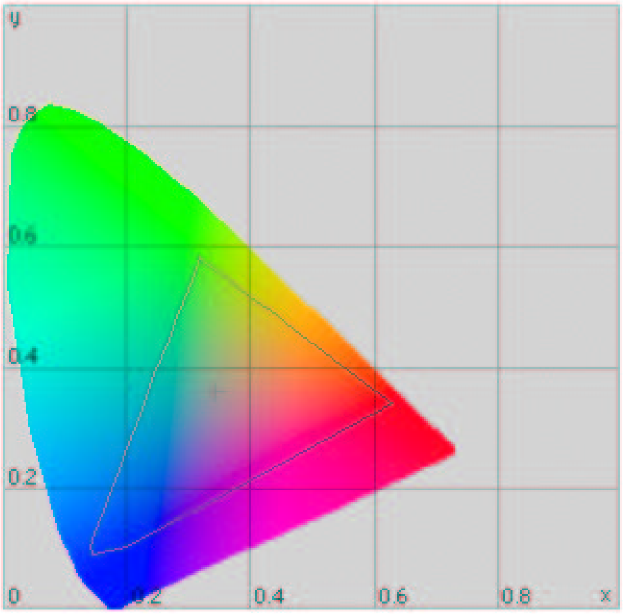


Figure 2: Typical colour chromaticity diagram of a CRT.

match between monitor and film. In everyday work it is very common to apply one dimensional LUT (Look Up Table) iteratively until it looks right. It is very time consuming and costly to output all the images handled and viewed in post production, in order to know what will happen at the end of the chain. The main aim here is to improve the predictability (reproducibility) and to softproof the conventional cinema screen on class one HDTV video studio monitors. In addition, new projectors (DLP) do have a similar imaging performance with respect to colour gamut and contrast ratio. The artist, the producer, as well as the director have to rely on the images displayed on the monitor. They demand a side by side preview nevertheless the later images in the theatre are shown later on.

Theoretically, the colour reproduction system of CRT monitors is a 3-primary (RGB) additive system. Within the assumption of a linear channel behavior and no cross talk, there are several mathematical models (Bodrogi, 2000). These models describe the relationship between the digital frame buffer values driving the colour channel and the phosphor emission of that channel, often in a colorimetrically manner. Due to the specified primaries, e.g. in SMPTE 295, a typical colour chromaticity for CRT displays is easy obtainable and shown in figure 2.

On the other hand, the colour reproduction system of film is a subtractive method with Cyan, Magenta and Yellow dyes. Practically the colour reproduction of the film is more complex because of the non-additive relationship and several other aspects that would exceed the scope of this paper. Hence the computation of a typical print film gamut is more complicated.

## Methods

In this work the widely used intermediate stock (Eastman Kodak 5242) and the print stock (Eastman Kodak 2383, Daily Vision film stock) were used. The ARRI Laser film recorder is set up with the system LUT that is designed using the relationship between the 10 Bit code values and status M densities given by the manufacturer. Here several grey patches with neutral 10 Bit code values of R=G=B is interpreted as the status M density provided by Kodak for this material. The reproducibility of the print film is maintained by reaching the appropriate status A densities for the vision film stock. Before illustrating the gamut of the used print film the measurement conditions have to be explained. In contrast to the general measurements in the graphical industry (45/0 or 0/45 for

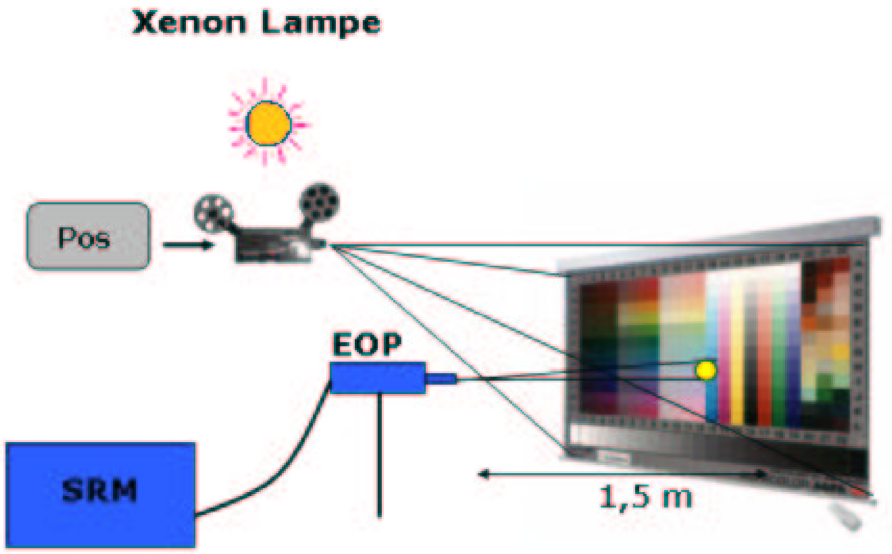


Figure 3: Measurement conditions for cinema colorimetry.

reflective media) here the spectral data was obtained by direct measurement of the stimulus reaching the observer. This is similar with the colorimetric characterization of a CRT monitor with a tele-spectrometer (PhotoResearch). In this work the projected scene was assumed to be a self-luminating display, a totally new (original) scene.

For laboratory work a mobile film projector (ARRI LocPro) was colorimetrically characterized. This had the advantage of a film transport frame by frame without destroying the film base as well as using a common Xenon lamp . Peak luminance of the film has to be gathered from the digital code value of R=G=B=1024. Note that this code value is about 800 after applying the recorder LUT. Figure 4 illustrates the resulting colour gamut and figure 5 shows both gamuts simultaneously.

These two different kinds of display have 3 dimensional gamuts which exceed film in some areas and fail to match it in others.

In principle, the XYZ tristimulus space should be able to represent any colour stimulus presented on a theatrical projection screen unambiguously (Giorgianni, 1998). CIELAB was designed furthermore as a uniform colour space for average-surround reflection colorimetry at a stable adaptation condition. Unsurprisingly, it does not model human visual performance well in dark-surround theatre conditions. The absence of a white reference in natural scenes greatly complicates the application of colour science to the production of motion pictures. It is necessary to devise a method for determining an adopted white luminance and chromaticity. Some authors obtain the white point by taking the brightest colour (Yaguschi, 1984). However most cinematic presentations occur at an average luminous scene level between 5 and 15 cd/m$^2$. During the viewing process the luminous discrepancy depends on the viewing angle on the retina and the time history of the darkest and brightest colours presented on the screen. In post production, the colour shift shown in figure 4 has been known as a nature of film recording. Thus, in colour matching process of CRT to film the following factors become more important than anything else: Handle gamut mapping (white point drift), Minimal change to the workflow, No introduction of artifacts trough computation Introduction of a quality control system.

As Bartleson says: The object of a colour television cannot be simply to reproduce the colorimetric values of objects (Bartleson, 1968). The main aspect in this work is to match the appearance between the monitor and the theatre!

As a first step, display profiles were built and tested out by the use of the above mentioned

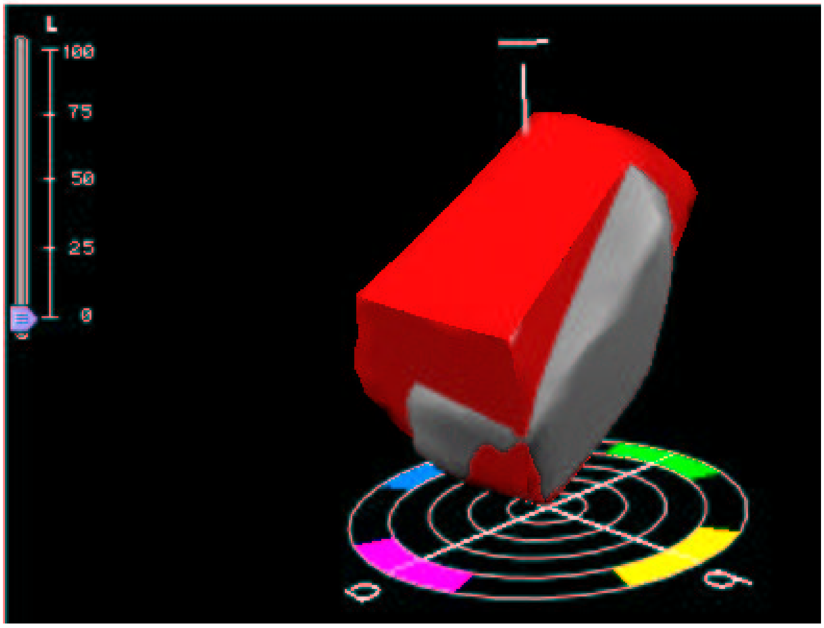


Figure 4: Both, LocPro and monitor colour gamut.

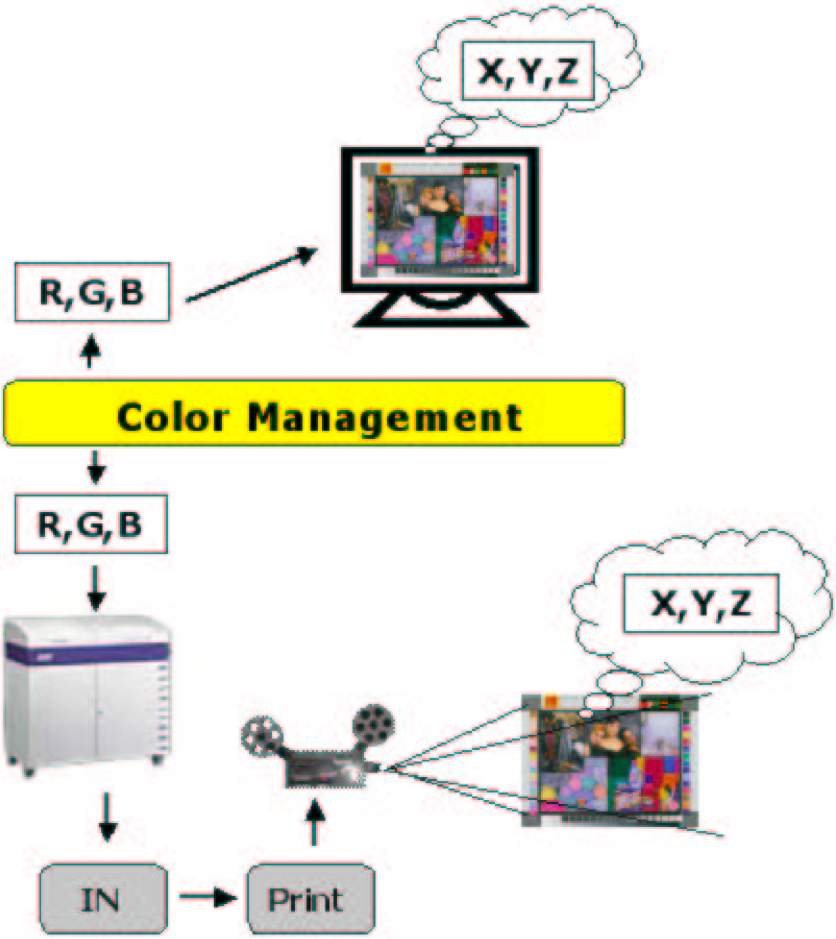


Figure 5: Colour management scenario.

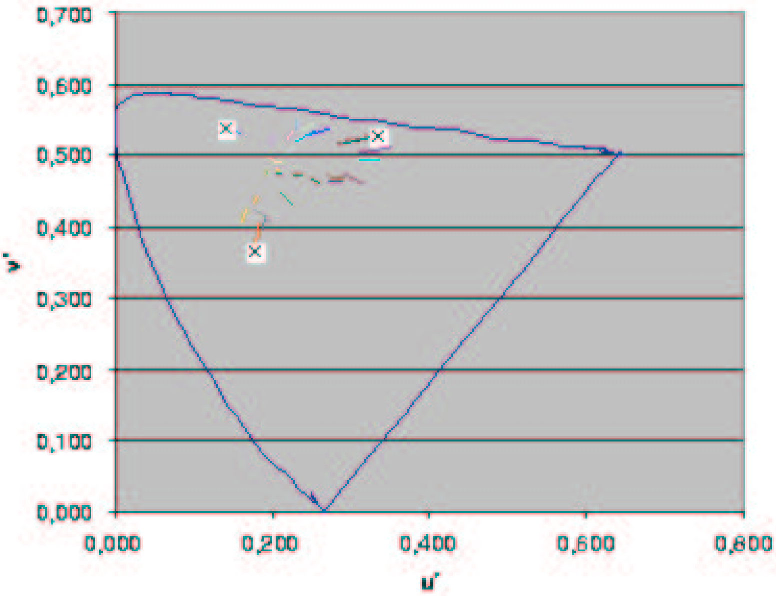


Figure 6: Differences between the monitor and the projection.

telespectrometer. Beyond this, cinema profiles were established by the means of RGB printer profiles. Here the basICColour tools (print3c) have to be tested. In this evaluation step the ARRI LocPro was used to emulate the cinema screen. This mobile film projector is very popular for the purpose of fast observing film material. With this setup, theatre screen and monitor were arranged in the following manner: The monitor was placed one meter beside the cinema screen in a darkened room. For a first (absolute colorimtric) comparison the aspect ratio and the absolute luminance (about 80 cd/m$^2$) were quite similar. Now a surround light was placed behind this construction because several years of usage has led to a universal acceptance by production and technical personnel. It serves as a helping point for adapting colour temperature. The luminance level of the neutral surround at about 2 cd/m$^2$ is similar to practical situations. In contrast, monitor is set up with a colour temperature of 6500 K regarding the SMPTE specification and LocPro projection was set up with a colour temperature of about 5300K. This laboratory scenario hardly attains comparable viewing conditions but lets the artist valuate the image picture by picture or scene by scene. Afterwards profile modification were done by means of changing the gradation, the white scaling and the gamut mapping strategies were tested. During this trial and error process subjective judgments were conducted to compare both images. Results This environment suitably ensures that important colour appearance effects (Abney effect, Bezold-Brueke shift, Hunt effect, Bartleson-Brenamann effect, rod intrusion) have mainly to be neglected. Cinema projection (35mm release prints) readily span a whiteto-black ratio of 1900:1 (at ARRI cinema Munich, 1999). In contrast, ARRI LocPro involves a whiteto-black ratio of 500:1 and the SONY HDTV monitor of about 250:1 (ANSI), respectively. So, there were only a few discrepancies for the laboratory construction. The colour management tools for cinema projection must encompass an accurate and controllable work over the entire tone scale, including the deep shadows and some yellow regions. Thereupon subjective judgments were carried out in a non-professional way so only colorimetric values are available. Figure 6 shows the differences between the monitor and the projection in the u,v diagram, while table 1 illustrates several results of some colour difference formulas.

**Conclusion**

In conclusion, it has been shown that the average delta Es were decreased significantly by the ICC colour management, improvements are still required for images containing gradients in the higlight region. Beyond this, it was recognized that colour management for cinema hardly assures a absolute colorimetrical match because of differences in the pertinent color gamuts and different gamut mapping strategies. Furthermore, a method was established to judge a monitor display and the cinema projection side by side. An important issue is the time between colour timing the scenes in front of the monitor and the viewing (later) in the theatre. It is well known that human vision is very restricted when matching two colours successively. For this purpose a relative colorimetrical transformation has to be prefered but the artist, the producer, as well as the director want a simultaneously demonstration, where an absolute colorimetric transformation is necessary. In spite of all the quantitative data presented on the quality of the profiles and transformations, it is mandatory that the colour match, or lack thereof, is verified visually. Unfortunately, the results from this test cannot be quantified, but it is suffice to say that the colour timers were suitably impressed. Additional work has to be done in future in the field of gamut mapping from the monitor gamut (D65) to the film gamut (5300 K) as well as the adopting for new electronic cinema display devices.

**Literature**

Bartleson, C.J. (1968): Colour perception and colour television, *SMPTE* Vol. 77, pp. 1-12

Bodrogi, P. (2000): *Accurate colorimetric calibration of CRT monitors*

Giorgianni, E. (1998): *Digital Color Management*, Massachusetts, Addison Wesley

Yaguschi H., Ikeda M. (1984): Mesopic luminous-efficiency functions for various adapting levels, *JOSA A* V1 pp. 120-123

# Introduction to Multispectral Color Imaging: Motivation, Spectral Dimensionality, and Existing Systems

**Jon Y. Hardeberg**

Conventional color imaging science and technology is based on the paradigm that three variables are sufficient to characterize a color. However, in particular, due to the effect of metamerism, three color channels are often insufficient for high quality imaging e.g., for museums and digital archives. In this course the general requirements for digital image capture and reproduction are addressed. We start with an introduction to 3-color imaging and limitations to the current systems. Metamerism in image capture and reproduction systems are explained. Current digital color image capture systems are then described in terms of the achievable tolerances of several important system characteristics. Several practical systems for multispectral image capture and delivery will then be described, along with their strengths and weaknesses.

Attendees of the tutorial will be able to:

- Understand the basics of color science.
- Realize the limitations of conventional color imaging, and how increasing the number of color channels to more than three can resolve these limitations.
- Decide between 3-color and multispectral approaches.
- Understand the issues and tradeoffs involved in the design and practical realization of a color image acquisition system.
- Learn methods to evaluate the performance of multispectral acquisition systems.
- Know where to find more information about this subject, equipment, and tools.

# Creating Light with Arbitrary Spectral Power Distribution

**Ivar Farup**

The spectral integrator at the University of Oslo consists of a lamp whose light is dispersed into a spectrum by means of a prism. Using a transmissive LCD display controlled by a computer, certain fractions of the light in different parts of the spectrum is masked out. The remaining spectrum is integrated and the resulting colored light projected onto a dispersing plate. Attached to the computer is also a spectroradiometer measuring the projected light, thereby making the spectral integrator a closed-loop system. One main challenge is the generation of stimuli of arbitrary given spectral power distributions. We have solved this by means of a computational calibration routine: Vertical lines of pixels within the spectral window of the LCD display are opened successively and the resulting spectral power distribution on the dispersing plate measured. A similar procedure for the horizontal lines gives, under certain assumptions, the contribution from each opened pixel. Hereby, light of any spectral power distribution can be generated by means of a fast iterative heuristic search algorithm. The apparatus is convenient for research within the fields of color vision, color appearance modeling, multispectral color imaging, and spectral characterization of devices ranging from digital cameras to solar cell panels.

## Multispectral Imaging: Acquisition and Processing

**Pierre Gouton**

A Multispectral imaging system acquires images of the same scene simultaneously in many contiguous spectral bands over a given spectral range. By adding wavelength to the image as a third dimension, the spectrum of any pixel in the scene can be calculated [1].

### I – Multispectral system with Rotating wheel fitted with optical filters

The first multispectral camera system we use is a low cost device. It is designed to be flexible and portable (figure 7). It is composed of a single monochrome IR CCD camera: Jai CVM50 IR, a standard photographic lens, a set of nine interference filters and a personal computer. The filters wavelength varies from 400 to 1100 nm to cover all the range of the camera sensor. The average Full-Width-at-Half-Maximum (FWHM) bandwidth is approximately 65 nm, each one overlapping the immediate neighbors. A wheel fitted with nine holes houses the nine filters (numbered 1 to 9). The wheel is located in front of the camera/lens system. It is motorized to rotate and all is piloted by software. Multispectral images are captured during each revolution and transferred to the computer. The image acquisition in this system is completely computer controlled. We can choose the number of spectral bands (1-9), the number of multispectral data sets to acquire, the time between each dataset and for extending the dynamic range of the camera, we also control the exposure time for each spectral band according to each filter transmittance under a fixed gain and aperture. A multi-spectral image is thus acquired by positioning successively each of the nine filters in front of the camera; this image is composed of nine shots. Each of them can be considered as a narrow-band image having a wavelength band equal to that one of the filter. Our optical system is composed of a standard lens and a set of nine interference filters, all with the same thickness. Interference filters combine many thin-film layers of dielectric materials having different refractive indices to produce constructive and destructive interference in the transmitted light. In this way, filters are designed to transmit only in a specific waveband, function of the filter bandpass. This system is working [2], and we test it actually for different spectral reflectance reconstruction methods. Also we test it for agriculture of precision in separating onions from weeds.

### II – Multispectral system with Liquid Crystal Tunable Filter

A second Multispectral imaging system is actually under developing (figure 8). It is based on The VariSpec liquid crystal tunable filter. The VariSpec LCTF uses electronically-controlled liquid crystal elements to select a transmitted wavelength range, while blocking all others. the colour of the light it transmits is electronically-controllable through an RS-232 interface enabling the filter to respond to signals and synchronization pulses generated by computers. This filter is combined with a large band camera: Jai CV-M2. which is a digital monochrome camera using 1600x1200 CCD. It features frame delay readout and single or dual video output of either 10 bit and the wavelength range of the CCD is from 300nm to 900nm. All functions of this camera are also controlled via RS232C. In simple terms, an LCTF is something like a filter wheel. But being electronic; therefore, it is ideal for automation and acquisition requiring fastness. Being continuously tunable, a wider range of colours is tus available.

## References

[1] J. Y. Hardeberg, F. Schmitt, H. Brettel, J. P. Crettez, and H. Maitre, Multispectral image acquisition and simulation of illuminant changes, MacDonald and Luo, ed, *Colour Imaging: Vision and Technology*, John Wiley & Sons, Chichester, England, 145-164, 1999.

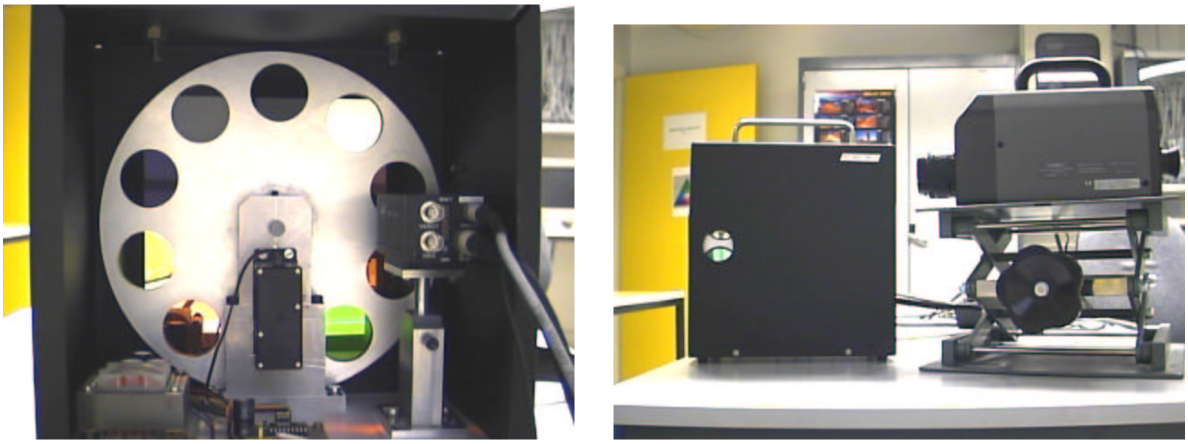

Figure 7: Multispectral camera based on rotating wheel with optical filters.

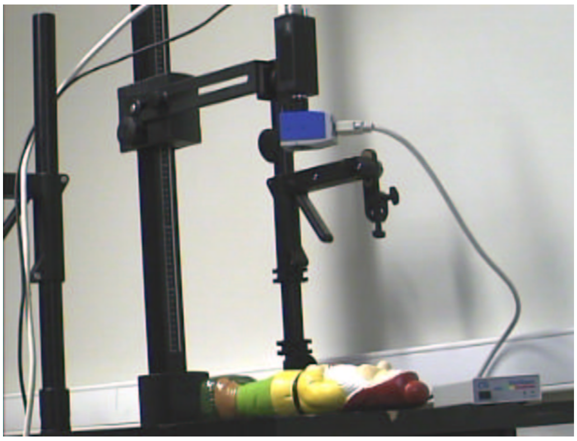

Figure 8: Multispectral camera based on Liquid Crystal Tunable Filter.

[2] A. Mansouri, J Y. Hardeberg, F. S. Marzani, P. Gouton, Optical calibration by deblurring channel images in a multispectral imaging system, In *Proceedings of VIIP2003*, Benalmadena, Spain, (1) 210-215, 2003.

## Appendix: Foils from selected presentations

1. Gudmund Sternvang: Managing colors in the production and presentation of digital video
2. Jon Y. Hardeberg: Color adjustment by color space warping
3. Ivar Farup: Digital cinema commercials – is the quality good enough?
4. Andreas Kraushaar: ICC color management in the motion picture industry
5. Jon Y. Hardeberg: Introduction to multispectral color imaging: motivation, spectral dimensionality, and existing systems
6. Ali Alsam: Spectral camera calibration
7. Ivar Farup: Creating light with arbitrary spectral power distribution
8. Pierre Gouton: Multispectral imaging: acquisition and processing
9. Andreas Kraushaar: Spectral image reproduction using print technology