ICC Color Management in the Motion Picture Industry

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Abstract

This paper discusses the implementation of a ICC Color Management workflow within the post production scenario in the motion picture industry. Beside other image quality aspects like contrast ratio and sharpness the color reproduction plays a very important role. The main aim is to preview the cinema screen on class 1 video studio monitors. For this purpose, the ICC Color Management has been implemented in the motion picture environment. Within a labarotory setup, scanner, display and printer profiles were created. Furthermore, methods were established to accommodate the differences between the ICC specifications and the motion picture workflow. In addition, new white scaling algorithms were selected and tested. While the average delta E's were decreased significantly by the ICC color management, improvements are still required for some special color regions.

Introduction

This paper discusses the implementation of a ICC Color Management workflow within a special part of the post production scenario in the motion picture industry. Beside other image quality aspects like contrast ratio and sharpness, all kinds of color decisions are an extremely important component of the post production workflow shown in figure 1. At the beginning a film camera captures the scene on a camera negative film stock (NEG). On this point you can go the conventional way through the film lab: Interpositive (IP) -> Internegative -> to the Dailies (Prints). Hence the creative part nowadays plays in the digital post production. For this purpose the film has to be scanned. A Color Management workflow should provide that color transforms could be carried out in a repeatable and visually convincing fashion.

The field of digital color reproduction is a playground of several much older industries coming together. Each of these industries has their individual aspects of color reproduction that have 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 color. This paper illustrates how the color management system was implemented to make the monitor in the postproduction emulate the print film projected in the theater and vice versa. Fur this purpose the ICC (International Color Consortium) framework within the latest specification 1:2001-12 was evaluated.

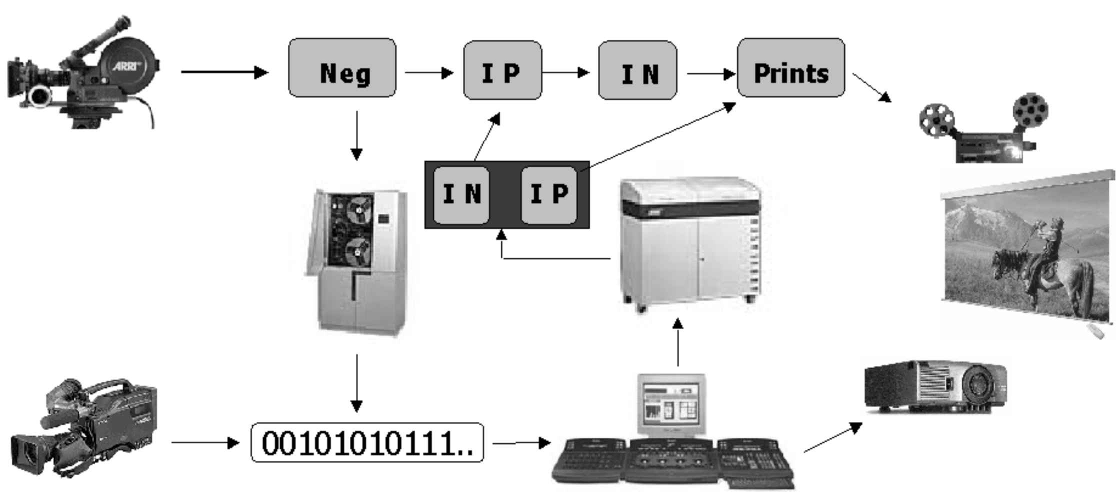

Figure 1. Digital film production workflow

In the past and present a variety of processes were necessary in order to obtain an acceptable color match between monitor and film. In everyday work it is very common to apply one dimensional LUT's (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. The artist, the producer, as well as the director have to rely on the images displayed on the monitor.

Theoretically, the color 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.[1] These models describe the relationship between the digital frame buffer values driving the color 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 color chromaticity for CRT displays is easy obtainable and shown in figure 2.

On the other hand, the color reproduction system of film is a subtractive method with Cyan, Magenta and Yellow dyes. Practically the color 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.

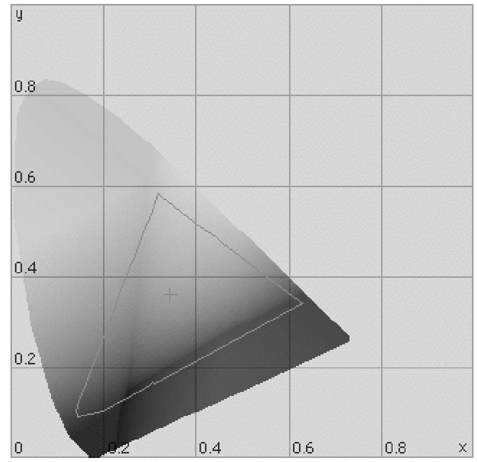

Figure 2. Typical color chromaticity diagram of a CRT

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 a grey patch with neutral 10 Bit code values of R=G=B=445 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.

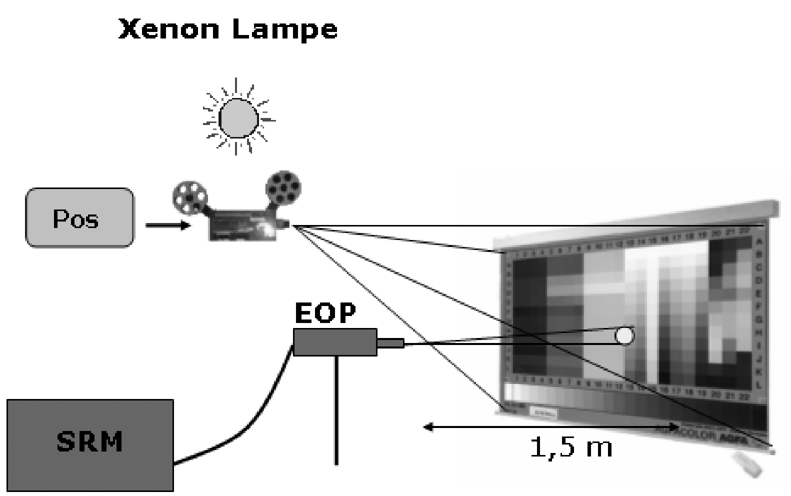

Figure 3. Measurement conditions for cinema colorimetry

In contrast to the general measurements in the graphical industry (45/0 or 0/45 for 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. In this work the projected scene was assumed to be a self-luminating display, a totally new (original) scene.

For this purpose the incoming light is transported through fiber optic cables to the array spectrometer. Practically, each color patch consists of 50 pictures (two seconds while projecting in real time). The spectral measurement of all the 512 color patches was conducted with an integration time of approximately 1.5 seconds. For laboratory work a mobile film projector (ARRI LocPro) was colorimetrically characterized too. This had the advantage of a film transport frame by frame without destroying the film base because of the used HTI lamp instead of a xenon lamp. From July 2002 a LocPro with a Xenon lamp is available. 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 color 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.

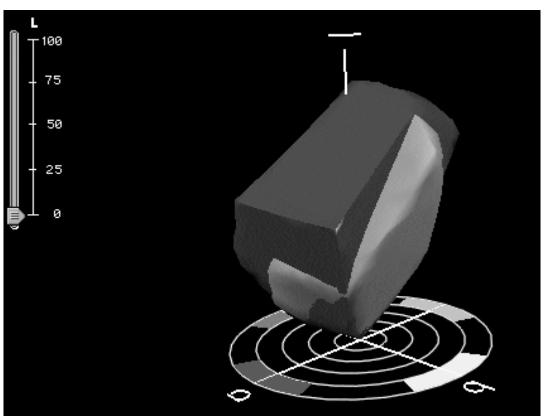

Figure 4. Both, LocPro and monitor color gamut

In principle, the XYZ tristimulus space should be able to represent any color stimulus presented on a theatrical projection screen unambiguously.[2] CIELAB was designed furthermore as a uniform color space for average-surround reflection colorimetry at a stable adaptation condition. Unsurprisingly, it does not model human visual performance well in dark-surround theater conditions. The absence of a white reference in natural scenes greatly complicates the application of color 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 color.[3] However most cinematic presentations occur at an average luminous scene level between 5 and 15 cd/m*m. During the viewing process the luminous discrepancy depends on the viewing angle on the retina and the time history of the darkest and brightest colors presented on the screen. In this work, a compromise was made by taking 2/3 of the brightest area (film base) for determining the white point.

In post production, the color shift shown in figure 4 has been known as a nature of film recording. Thus, in color matching process of CRT to film the following factors become more important than anything else:

- Optionally handle gamut mapping,
- Minimal change to the workflow,
- Computation should not introduce artifacts and
- Introduction of a quality control system.

As Bartleson says: “the object of a color television cannot be simply to reproduce the colorimetric values of objects”[4] the main aspect in this work is to match the appearance between the monitor and the theater!

As a first step, display profiles were built and tested out by the use of the above mentioned array spectrometer and several profile creating tools. Beyond this, “cinema profiles” were established by the means of RGB printer profiles. Here the basICColor 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, theater screen and monitor were arranged in the following manner:

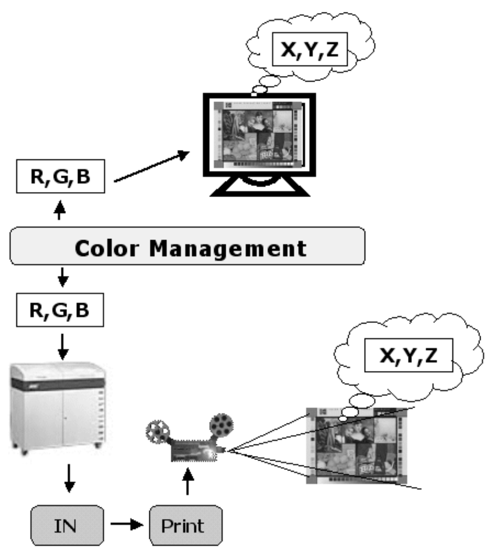

Figure 5. Color management scenario

The monitor was placed one meter beside the cinema screen in a darkened room. For a first comparison the aspect ratio and the absolute luminance (about 80 cd/m*m) 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 color temperature. The luminance level of the neutral surround at about 2 cd/m*m is similar to practical situations. Both, monitor and LocPro projection were set up with a color temperature of about 5300K. This laboratory scenario attains comparable viewing conditions and lets the artist valuate the image picture by picture or scene by scene. After then profile modification (profile maker from Gretag Macbeth) and profile creation were tested by means of changing the gradation, the white scaling or gamut mapping strategies. During this "trial and error" process subjective judgments were conducted to reach a better match.

Results

The comparison between the colorimetry of the "laboratory construction" and the practical theater situation has led to similar results except of some regions in the shadows. This environment suitably ensures that important color appearance effects (Abney effect, Bezold-Brueke shift, Hunt effect, Bartleson-Brenamann effect, rod intrusion) have to be neglected. Cinema projection (35mm release prints) readily span a white–to-black ratio of 1900:1 (at ARRI cinema munich, 1999). In contrast, ARRI LocPro involves a white–to-black ratio of 500:1 and the SONY HDTV monitor of about 250:1, respectively. So, there were only a few discrepancies for the laboratory construction. The color management tools for cinema projection must encompass a accurately and controllably work over the entire tone scale, including the deep shadows. Thereupon subjective judgments was 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 color difference formulas.

Conclusion

In conclusion, it has been shown that the average delta E's were decreased significantly by the ICC color management, improvements are still required for some special color regions. Beyond this, it was recognized that color management for cinema does not have to match exactly the absolute luminance of the image specified by international standards. Furthermore, a method was established to judge a monitor display and the cinema projection side by side. An important issue is the time between color timing the scenes in front of the monitor and the viewing (later) in the theater. It is well known that human vision is very restricted when matching two colors successively. The demonstration here was presented simultaneously. In spite of all the quantitative data presented on the quality of the profiles and transformations, it is mandatory that the color match, or lack thereof, is verified visually. Unfortunately, the results from this test cannot be quantified, but suffice to say that the color timers were suitably impressed. Additional work has to be done in future in the field of appearance modeling from the laboratory environment to the cinema as well as the adopting for knew electronic cinema display devices.

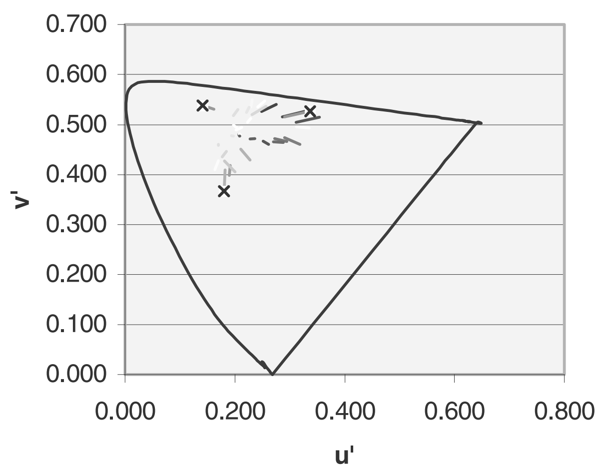

Figure 6. Differences between the monitor and the projection

Table 1. Results for a Number of Color Difference Formulas

Color difference formula	ICC- color management	No color management
delta-xy mean	0.022	0.034
delta-uv mean	0.015	0.022
delta-ab mean	7.51	10.69
‚delta-E_{ab}‘ max	26.9	44.8
‚delta-E_{ab}‘ mean	9.85	14.46
‚delta-E_{ab}‘ std. dev.	4.93	6.57
‚delta-E_{uv}‘ max	32.3	40
‚delta-E_{uv}‘ mean	10.1	15.7
‚delta-E_{uv}‘ std. dev.	4.31	24
‚delta-$E_{CIE-2000}$‘ max	11.6	23.1
‚delta-$E_{CIE-2000}$‘ mean	5.94	8.2
‚delta-$E_{CIE-2000}$‘ std. dev.	1.74	5.8

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Biography

Andreas Kraushaar was born in Kreuzebra, Germany, in 1976. In 2001 he received a master degree in media technology from the Technical University Ilmenau, Germany. His thesis work was centered on color management in motion picture production at ARRI, Munich. His main interests are color imaging and color vision. Presently he is a researcher in the prepress devision at FOGRA, Munich, Germany.