Color Quality Analysis of a System for Digital Distribution and Projection of Cinema Commercials

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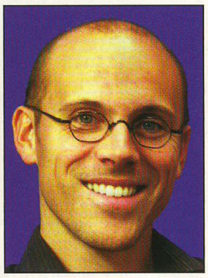

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The partial results of a collaborative research project conducted by researchers at Gjøvik University College and Lillehammer University College are described in this paper. The goal of the project is to develop methods and tools for improving the 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. The color quality achieved by a system for digital distribution and presentation of cinema commercials has been investigated. Results show that the "quality bottleneck" is the digital projector. The "business-type" projector does not yield sufficient image quality, especially in large theaters.

Since the beginning of the color film era, color adjustment has been a permanent area of difficulty in the production of moving pictures.[1] The use of several cameras simultaneously or at different times and under varying lighting conditions results in varying color rendering in different captured shots. When these shots are edited together, the colors must be harmonized, and this requires substantial manual adjustments. The fact that shots are often taken under lighting conditions that are different from those desired to tell the story has also led to extensive color corrections 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 professional 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.[2] Digital video color management can potentially be implemented using common computer platforms and equipment that cost a fraction of today's dedicated video editing and color correction equipment. At the same time, the processes can be simplified and made less time-consuming. Such solutions will have the potential of strengthening smaller production environments with limited resources and increasing the possibility for distributed production of video material.

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 project brought together two scientific communities—color science and color management, mainly for graphic arts applications at GUC, and video, television, and film production at LUC.

In a recent interview, Garrett Smith of Paramount Pictures, when discussing the problems with varying aspect ratio in digital television, stated: "Please be careful before you trespass on the visual integrity of these motion pictures".[3] This quote can serve as a motivation for the current study. Whether the filmmaker's goal is to convey realism—a sense of "being there"—to invoke certain emotions, or to use the diverse symbolic meanings of color; color is a very important part of the visual integrity of motion pictures.[4] The overall goal here is to make sure that the creative use of color in the production of all types of moving pictures is not compromised because of technological limitations. Obviously, a large part of what it would take to achieve this lies completely out of reach, so the decision was made to limit the scope to digital video. This is due, partly, to the obvious flexibility inherent in digital video processing using today's powerful computers, and also because digital video technology is now quickly replacing traditional film technology for many applications. This is particularly true for amateur video production and digital broadcast television, but also the concept of digital cinema is now being introduced.[5,6]

Four different research topics of particular interest have been identified:[7]

(1) Color management in the acquisition of digital video. This topic includes problems such as automatic white balance, colorimetric characterization of cameras, and the use of color targets in the acquisition process.

(2) Color control for editing digital video. Here, specific attention is given to 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.[8]

(3) Color characterization of monitors used in the production of digital video. How color management principles, typically ICC-based, can be applied to a video production environment in which several different monitors are used simultaneously, is investigated.

(4) Color quality of projective displays used for presentation of digital video. The use of digital projective displays for the presentation of moving pictures is growing rapidly, both in the home theater environment and in public movie theaters. However, very little scientific work has been published on the colorimetric characterization of such displays and on the resulting color quality.

Does the quality match conventional cinema technology? Do the presented colors appear the way the producer intended them? These questions are addressed both through visual assessments and by using advanced measurement instruments such as a spectroradiometer.[9,10]

In sum, the overall approach here to color management in digital video is to strive for consistent, repeatable, and automatic processing of color information in all parts of the production and presentation chain, except in the editing phase where creativity is desired.

The results of the fourth research topic above are presented in this paper. First, a new system for digital distribution and presentation of cinema commercials is described. An analysis of the quality of the images produced by this system is then presented, before concluding.

Digital Video in Cinema Theaters

Introduction

In the beginning of 2002, a system for digital distribution and presentation of cinema commercials was introduced in Norway, and by now, almost all movie theaters use this system.[11] Although the introduction of digital cinema commercials has not created much public attention in Norway, concerns have been voiced about the image/video quality produced by the system.

Norway is probably the first country to introduce digital technology into movie theaters at this scale. It is possible that this may be a first step toward using digital technology for feature-length movies also. This definitively increases the relevance and interest of examining the digital cinema commercials system in a D-Cinema context.[5]

The System

The digital cinema commercials system is managed by a Norwegian private company that, through association with other companies, controls both the technical and commercial aspects of the distribution and projection of commercials, and, to a certain extent, also their production. There are no longer alternatives for traditional distribution and projection of analog 35mm cinema commercials.

In the system, commercials are first digitized using telecine equipment, if they are produced on traditional 35mm film. However, more and more commercials are now produced digitally. The change toward digital production has been accelerated, probably because the two main channels where the commercials are shown, television and cinema, now both make extensive use of digital technology for distribution and presentation.

The digital footage, typically either in DigiBeta or DV format, is then compressed to 15 Mbits/sec using the MPEG-2 scheme and distributed to the movie theaters by satellite. In the theaters, the commercials are stored and managed on dedicated computer systems.

Finally, typically just before the feature movie presentation, preprogrammed sequences of commercials, so-called "playlists," are presented using digital projectors.

One interesting feature of the system is that the selection of commercials can easily be targeted toward the audience of particular movies.

Two main types of projectors are used in the system: high-resolution digital cinema projectors using 3-chip Digital Light Processing (DLP) technology, and conventional business-type projectors using Liquid Crystal Display (LCD) technology. The differences in cost, spatial resolution, and brightness are indeed non-negligible.

Quality Analysis

This new system will be examined within the framework of a collaborative research project focusing on color issues in the production and presentation of dig-

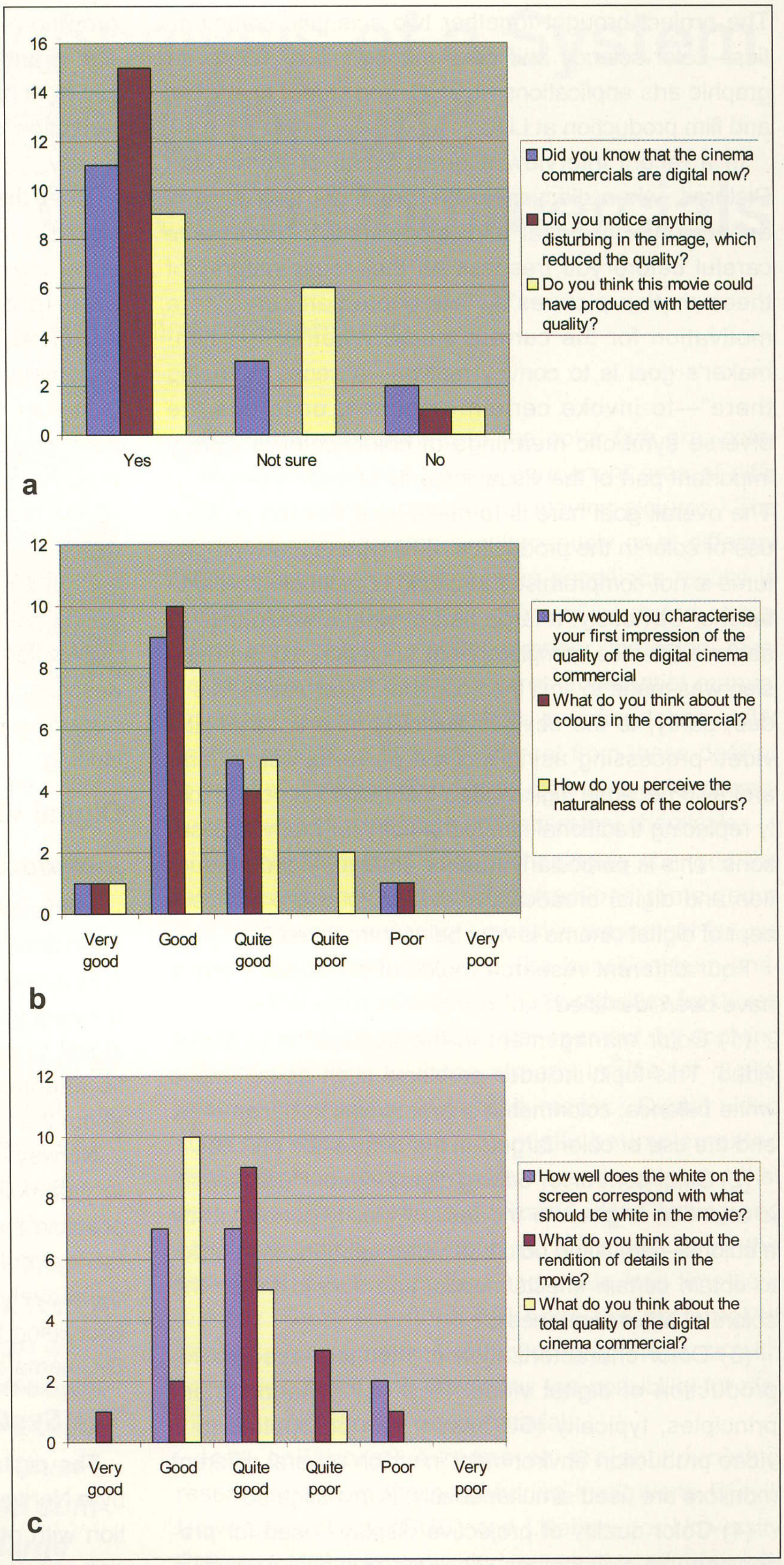

Figure 1. Results of the questionnaires concerning the quality of digital cinema.

Figure 2. Split-screen arrangement for pair comparison blind test. The scene shown is taken from Norsk Tipping's commercial "Taxi Driver."

ital video, particularly addressing its color image quality. The main goal of the project was to carry out qualitative and quantitative measurements and evaluations of different parts of the system for distribution and projection of digital cinema commercials, in particular, with regard to color and visual quality.[12] The project has been carried out partially by students in media technology and graphic arts engineering.[13]

Ideally, comparing the quality of the traditional 35mm film with the digital system would have been preferred, but unfortunately it was not possible to collect test material on traditional film. This is partly because the commercials are now mostly produced digitally. It was therefore decided to focus on whether the digital medium was used to its full potential, that is, if different parts of the system induced quality reductions as compared to high-quality digital video. The compression and projection stages were analyzed, in particular. Important tools that were used in the project included interviews and questionnaires, "blind tests" with a panel of observers, and spectroradiometric measurements in which color changes due to compression were evaluated.

Visual Tests

In order to evaluate the quality of the system, a test movie containing elements from real movie commercials was created, as well as test sequences prepared by the Norwegian Broadcasting Corp. This test movie, originally in DV format, was compressed using the actual system, and also an MPEG-2 encoder with varying degrees of compression. Three different versions of the movie were selected for further tests: the original DV version (25 Mbits/sec), the version compressed by the system (15 Mbits/sec), and a version compressed to 2 Mbits/sec.

First, the original DV version and the cinema commercial system version were shown to a panel of 16 observers in a movie theater, using the business-type projector. The panel was asked to answer nine questions by selecting the most appropriate answer (Fig. 1). When asked about their first impression of the quality of digital cinema commercials, only one person (6%) in the panel gave a negative answer. However, when asked if they noticed artifacts that reduced the quality, 15 people (94%) answered yes.

Second, a quality evaluation experiment ("blind test") was carried out. The three versions of the test movie were shown simultaneously side by side, with one side mirrored, as illustrated in Fig. 2. The identities, that is, compression technology, of the movies were not identified to the panel. For each of the six possible combinations, the panel was asked to identify which side they considered to have the best quality. This corresponds to the quality evaluation protocol known as pair comparison, which is based on Thurstone's law of comparative judgment.[14] There was no significant difference in quality between the uncompressed DV version and the one compressed by the system. In fact, an equal amount of people preferred one over the other. The version compressed to 2 Mbits/sec was consistently judged to be of inferior quality.

Measurement-Based Tests

Spectroradiometric measurements were done of a standard test image shown on a reference video monitor, in order to evaluate unwanted color changes due to the video compression used in the system (Fig. 3). The differences were relatively large—the average color difference over 12 test colors was 7.9 Eab units, while a maximum difference of 16.6 Eab units occurred for blue. Generally, the colors were desaturated by the compression. It is remarkable that despite this difference, the test panel did not find the compressed version to be of lower quality.

Interviews and Overall Analysis

Interviews with the management of several movie theaters revealed that those who had invested in the high-end digital cinema projectors were generally satisfied with the image quality, while those who were using the business projector were more concerned. However, most of them were very positive about the new system, because of its simplicity and flexibility.

From visual judgments, varying degrees of artifacts such as whiteouts and excessive contrast in the business projectors were noticed, while with the high-end digital cinema projectors, the overall quality was judged to be very good. This, together with the experimental results presented above (i.e., that no visual quality reduction was introduced by the compression), leads to the conclusion that the most crucial quality factor in the system is the digital projector.

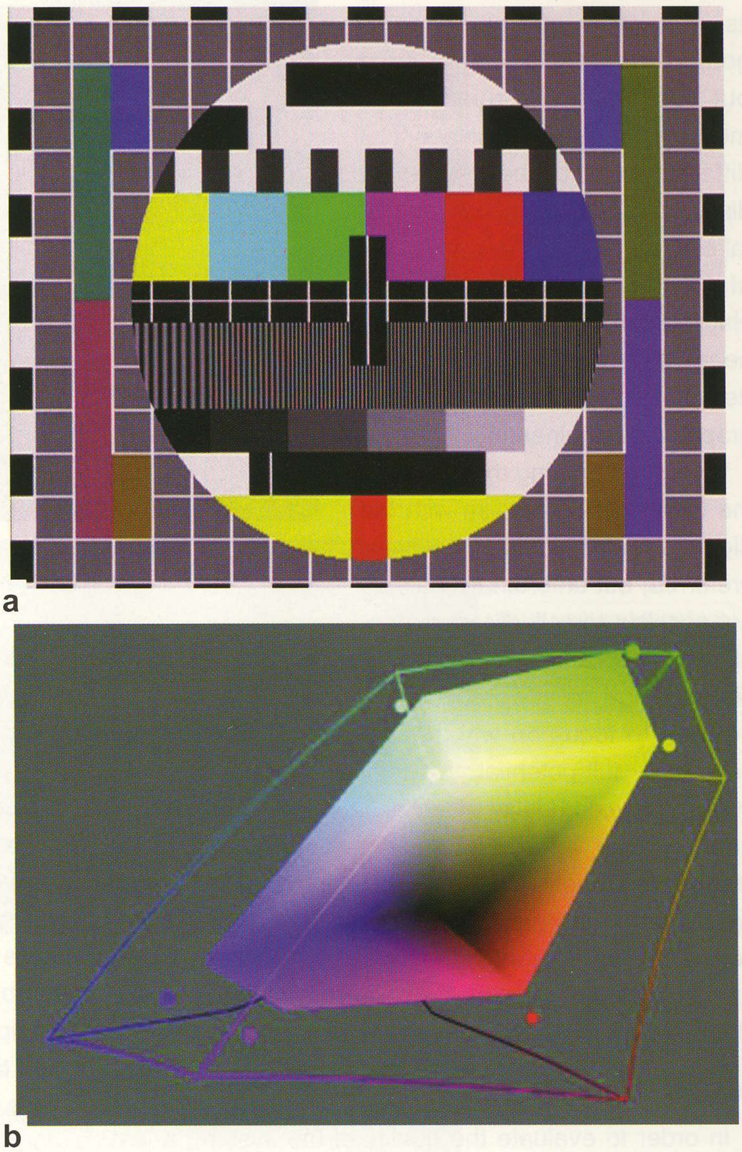

Figure 3. The standard test target used for color measurements (a), and an illustration of the resulting color desaturation introduced by the compression algorithm (b). The dots represent the original colors in the CIELAB color space, and the vertices of the solid object represent the colors of the compressed video.

Conclusion

The current study has shown that the "quality bottleneck" of the new Norwegian system for distribution and presentation of cinema commercials is the digital projector. Especially in large theaters, "business-type" projectors do not yield sufficient image quality. The MPEG-2 video compression used in the system does not introduce visible quality degradations, although color differences can be measured.

Acknowledgments

The financial support of Morgenlandet AS, through the Prokom program, is greatly appreciated. We acknowledge the support from the other members of the project group, Sigmund Andresen, Sven Erik Skarsbø, and Jens-Uwe Korten, as well as the significant contribution made by our students, Henning Døvre, Rune Hofslundsengen, John Inge Førland, and Robert Czari. We are also very grateful to the Norwegian Broadcasting Corp. and Norsk Tipping AS for providing video material, and to Gjøvik Cinema for allowing the use of their theaters for our tests.

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A contribution received September 2004.

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