Improving the Quality of Film to Digital Transfers for Digital Cinema

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Abstract

High quality on screen picture performance is the ultimate technical goal of Digital Cinema. Tests have been performed projecting movies from standard and High Definition (HD) telecine transfers that were intended for home video and HD broadcast applications. The results of these have fallen short of the image quality needed for large screen theatrical projection.

This paper reports on work that has been undertaken to improve the image quality by altering the source characteristics through adjustments the telecine transfer process. The work is based on using a display with identical characteristics to the ultimate theatrical projector to perform the transfers. This has resulted in transfer images with a different quality to the "standard" transfers using CRT monitors as the transfer target.

The image was improved by concentrating on the treatment of the following: gamma, black and white crushing and clipping, colorimetry and digital enhancement. The results have been remarkable, as will be demonstrated in the presentation following this paper.

Background

There has been a long-standing desire to achieve theatrical images from electronic projection devices. This has resulted in development of high performance, high brightness projection technologies. Coupled with these advances in projection technology is the need to produce digitized film material that is suitable to show the projector at its best.

Texas Instruments' DMD™ device has given rise to a new generation of image quality and stability not available previously. In the early stages of projector development based on this technology, Digital Projection International, (formerly Rank Brimar Limited) of Manchester, UK, accessed high quality D-1 clones of film based materials, and reviewed the resulting image quality.

The pictures from these tests were adequate, but not ***great***, and adequate wasn't good enough. The projected images were lacking depth, the colors were not always true, and the images often had a video-like appearance, with enhanced edges.

How could these images be improved? Clearly, some improvements could be (and were) made in the capabilities of the projector, but the theatrical image quality was still not there.

In 1995, a series of transfers was performed using the projector as the transfer target. The projector was brought into the post production facility, and connected to the output of the telecine. This created a situation where the colorist could make his decisions in real time, based on the look and feel of the image as it would ultimately be viewed. This material was transferred in 625 lines to D-1, to be displayed on a 800 x 600 resolution DMD projector.

Subsequently, the process has been refined through tests performed by Texas Instruments, Digital Projection International and Entertainment Technology Consultants. This work has been performed in 1125 line HD formats, using HD telecines and recording the data on HDD-1000 and D-5 recorders. Many hours of demonstration and test material have been produced, with very good results.

This paper reports on the development of the process for achieving telecine transfers with optimum image quality for these devices.

Theatrical Exhibition and Home Video – Different Display Characteristics

One of the primary current uses for Telecine machines is to create video masters of theatrical releases for use in home video, airlines, hotels, and network broadcasts. The intended display is a television or TV projector.

Television display environment (the living room hotel room or airline) is a dramatically different viewing environment from the movie theatre. There are differences in image size, clarity, resolution, and brightness of the surrounding environment. The expectations and intentions of the audience are also different.

The differences between CRT based direct view and theatrical projection occur on a variety of dimensions, and are discussed below. The display parameters that affect the viewing are also discussed.

Image Size and Field of View

The first and most noticeable difference is the viewing distance. Home video is usually viewed at greater than 7x picture height, and High definition television was developed to be viewed at 3x picture height. Theatrical viewing distances range from 1.5 times to 4 times picture height.

This drives the obvious difference in how image detail is viewed. Details such as ringing on enhanced edges grain, and other noise that is not visible on the HD monitor will be clear on the big screen. Decisions in the transfer process regarding image enhancement and noise reduction will be different on the big screen.

Field of view of the image is another perceptual factor independent of detail. A wider field of view gives a greater sense of immersion, and reduces the necessity of increased color saturation and brightness to give impact to the image.

Display Colorimetry

Standard Hi-DEF transfers are performed using monitors that conform to the standard SMPTE 240M color primaries. This color space was developed based on the availability of practical phosphors for direct view CRT application. Projectors that modulate an external light source (DMD and light valve projectors) have the capability of a broader color gamut, thus may display colors not available on CRT monitors.

In practice, the color space used in these projectors is slightly broader than SMPTE 240M. If material produced for the 240M color space is shown in a broader space, there will be color differences in the displayed images, - in particular, the orange and yellow colors are very sensitive to this difference, and dramatic differences in fleshtones can occur with only small changes in color primaries.

Contrast Ratio and Black Level

CRT's have very good black level capability. In fact it is possible to achieve a perfectly black screen on a properly adjusted CRT – making contrast ratios infinite. Analysis of the transfer function of the CRT in lab conditions will yield contrast ratios of greater than 200,000:1 – or black levels of .0005% of peak white.

On the other hand, projectors that modulate lamps (such as electronic and film projectors) have a finite contrast ratio. Black levels achievable are in the range of 0.1% of peak white for electronic projectors and around .05% for film. The difference in black level between the CRT and projectors creates a situation where a black in a dark scene on the CRT may appear as gray on the projector.

It is important to note that the richness of theatrical film presentation is due to the treatment of black levels. The effect of a 0.1% black "floor" is to add 0.1% of peak white to the entire image. In bright scenes this is not particularly relevant, but in night scenes where the peak white might be 5% of maximum, this 0.1% level can have a significant effect on the depth and richness of the picture.

On transfers using CRT's, this effect is negligible, and minimal optimization is required to compensate for finite black levels.

Dynamic Range

This issue is related to black level. As we have seen above, CRT's offer a dynamic range in excess of 5 orders of magnitude, while projectors are around 3 orders. Release print film is between 3 and 4 orders of magnitude.

The low end of the dynamic range requires management – dark information visible on a CRT is lost at the bottom end of the projector's range and not available.

Image Brightness

Human perception of color changes with brightness. At an average brightness above about 1 ft.L, the eye is experiencing pure photoptic vision. With photoptic vision, the cones are active in the eye and yield maximum color and visual acuity. Below this brightness, to about 0.01 ft.L, the eye is in transition between photoptic and sctotpic vision – called Mesopic vision. During this transition the rods and cones are both active, and the visual effect is a mixture between the two. As the average image becomes darker, the visual effect will be to reduce the perceived saturation of color, and to shift the eye's sensitivity peak color toward blue, giving an overall blue tint to the scene.

Typical monitor set-up for 525 line transfers is 32 ft.L, and HD monitors are set at around 22 ft.L. Feature films, on the other hand are shown with an open gate luminance of 16 ft.L – resulting in peak whites of about 12 ft.L on the screen. If the image is exercising the entire 1000:1 dynamic range, then differences in color saturation and blue shift in the darker areas will be perceptible.

Resolution and MTF

The specific display device has a different pixel profile which will contribute to the detail that is visible in the image. CRT based images have a gaussian spot profile, DMD projectors have square closely packed pixels with a very sharp profile on the edges.

These different profiles create different "looks" to the image displayed. The effect of this is to have a softer look on the CRT display, and a sharper look on the DMD display.

Transfer Function – Gamma

The transfer function is the relationship between voltage input and light output. SMPTE has defined this for HD and STV, and these are the curves assumed in standard HD and 525 line monitors in telecine suites.

The transfer functions used in projectors are usually a little different from the SMPTE defined standards, because the projector has a residual black level to manage. It has been noticed that even a small difference in the transfer function will change the perception of color and the overall luminance of the image. These small differences can be the difference between a deep rich filmic image and a flat one.

Temporal Effects

Film is captured at 24 and displayed at 48 fps. In the telecine process for American television, the frame rate is increased from 24 fps to 30 fps through a process of adding a duplicate field of information every 4^{th} field. This has the effect of giving motion a non-uniform speed across the screen – creating an effect known as "judder"

Projectors intended for theatrical exhibition will have different methods of managing the frame rate, from constructing new intermediate frames to displaying the image at 24 FPS.

Managing the Display Differences - Transfer Process

Within these image display dimensions, there are significant differences in how the display device handles the image. Compensation can be made for many of these differences by the colorist in the telecine process, and a "pre-corrected" master can be created.

To achieve this, a projector was brought into the telecine to act as the transfer target. The intention was to have the colorist make his decisions based on the images projected in the transfer suite.

This provides a "wysiwyg" (what you see is what you get) environment, giving direct and immediate feedback on the expected image quality for the final display.

Within this new environment, the colorist interacts with the projected display and manages the image from his control panel to optimize it for theatrical projection. The management of the picture as it relates to each of the display dimensions is discussed below.

Image Size and Field of View

The screen size is dictated by practical considerations and has in practice been from 6' wide to 14' wide. It is located in front of the colorist so that he is sitting about 1.5 to 3 screen heights back from it, giving the colorist the actual projected image to work with. This screen provides him with a wider field of view and greater visible detail than on the monitor, because each pixel subtends a larger angle.

The effect of the bigger image is greater visual impact. This allows the impact to be taken into account when making color and luminance adjustments. The bigger image also shows the effects of noise, grain, and aperture correction / edge enhancement. Electronic processing and enhancements can be seen as they appear. In general, with the larger image, less aperture correction and digital noise reduction is used than in a standard video transfer.

The process is not complete without a review on a full size projection screen of 30 to 50 feet. Details and effects are seen on the theatrical screen that aren't apparent on the telecine screen. Usually some minor trimming results from the review on the bigger screen.

Display Colorimetry

Since the target projector has the same properties as the ultimate display, its colors will be representative of the final images. The decisions of the colorist can be made based on direct visual feedback. As with the CRT monitor, the color gamut is different from film, and certain colors are not available.

Contrast Ratio and Black Level

Compensating for a finite black level is one of the biggest issues. The effect of residual luminance in the black is to take the "punch" or "depth" out of the image, or lose detail in the dark areas. The dark areas of the image may appear muddy or milky. The task of the colorist is to restore the image depth without destroying the artistic integrity of the image.

Depth is restored by striking a compromise between suppressing detail in the blacks, and raising the lower and midrange luminance levels. The actual approach is highly dependent on scene content. In addition, the muddiness has the effect of desaturating the low luminance colors. This is difficult to correct, and usually must be compensated for by increasing luminance.

Dynamic Range

Digitally driven projectors will exhibit quantization, which may be visible in the darkest areas of the image. This quantization will appear as luminance bands and as subtle color steps. They are an artifact of limited bit depth in the recording or projection system, and the colorist can only make small adjustments in black level or gamma to minimize the effects.

Image Brightness

Because human color perception mechanisms are highly dependent on image brightness, the luminance must be set to match the ultimate viewing conditions. For theatrical projection, this usually means setting the projector in the telecine to a luminance of between 10 and 15 ft.L. This is accomplished by reducing lamp power and when necessary, inserting neutral density filters in the light path.

Transfer Function and Gamma

These are set to be identical to the system used for the theatrical projection.

Tests and Results

During the last 3 years, a number of transfers have been performed to test and develop the process described above. The projection targets have been DLP™ projectors - a Texas Instruments DLP™ Cinema projector prototype, and several different models of Digital Projection POWER displays.

A wide variety of film material was used in developing and testing the telecine processes.

- Clips were licensed from 7 studios for transfer
- More than 50 clips from over 35 titles were transferred
- The process has been used at 8 different post-production houses in the US.

Each transfer test has provided an opportunity to: increase the knowledge in the specific transfer process; to feed-back image related information to the projector manufacturer; and to feed-back telecine operational issues to the post production facility. With each iteration came better images, because of a better process, more knowledgeable operation of the telecine and better performance from projection devices.

The results have been a work in progress. Where the initial transfer processes were very involved with many variables tested, experience with the process is achieving better results more easily. The current state of the transfer process, coupled with the current state of the art DLP projectors is very close to achieving the goal of images that are viable for theatrical exhibition.

Conclusions

Results of the tests show that much better images can be achieved if a projector with the same characteristics as the ultimate display device is used as the transfer target. The development of this process over the past three years has resulted in continuously improving images. These images are now very close to achieving a look that is viable for theatrical exhibition. Pictures are moving from ***Adequate*** to ***Great***.

Acknowledgements

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