
Color Grading a Feature Film for Digital Cinema



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ABSTRACT

The craft of the colorist is a fascinating craft. The purpose of this thesis was to describe the grading process for a documentary feature film *Autolla Nepaliin*. The film was a charity project initiated by a handful of young entrepreneurs, who decided to drive from Finland to Nepal in order to raise money for a Nepalese women's shelter and an outcaste school. On the journey they posted frequent video blog updates and afterwards they decided to compile the film based on the experience.

The main objective for the thesis was to go entirely through the color grading workflow for digital cinema distribution. Which includes detailed preparation in order to ensure color accuracy, the enormous grading process in itself and the mastering process to comply with the present digital cinema standards. While the thesis was focused on the grading process, in practice the research expands important knowledge about color accuracy and digital cinema workflow to ensure the best grading outcome for the big white screen. The main research method was a collection of e-books regarding the color grading process supplemented by web research and expert interviews to confirm additional details.

The thesis was based on the practical color grading project and thus it has a hands on approach. The thesis demonstrates how invaluable it is for the colorist to understand every aspect of the grading process. The process that helps the colorist to achieve color accuracy while making sure that the picture complies with digital cinema standards. As the final conclusion it is fair to say that the thesis is good for those who desire to learn about the big picture of the grading process.

Keywords Color grading, feature film, digital cinema

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TIIVISTELMÄ

Opinnäytetyön tarkoituksena oli kuvailla dokumenttielokuvan Autolla Nepaliin värimäärittelyprosessia kokonaisuudessaan. Elokuva oli hyväntekeväisyysprojektin huipennus jonka muutama nuori Suomalainen yrittäjä laittoivat alulle. Heidän tavoitteenaan oli ajaa autolla Nepaliin kerätäkseen rahaa paikalliselle naisten turvakodille ja kastittomien koululle. Matkalta he tekivät säännöllistä videoblogia ja matkan jälkeen he päättivät koota kokemuksiin perustuvan elokuvan.

Päätavoitteena opinnäytetyölle oli käydä lävitse värimäärittelyn työnkulku digitaalista teatterilevitystä varten. Se käsittää yksityiskohtaisen valmistelun väritarkkuuden takaamiseksi, suuren värimäärittelyprosessin itsessään ja viimeistelyn digitaalisen teatterilevityksen standardeihin. Vaikka opinnäytetyö on keskittynyt käytännöllisesti värimäärittelyyn niin tutkimustyö lisää tietoutta väritarkkuudesta ja digitaalisen teatterilevityksen työkulusta parhaan lopputuloksen saamiseksi elokuvateatteriin. Tutkimustyössä lähteenä oli värimäärittelyn e-kirjallisuus, jota tukivat digitaalinen tiedonhaku ja ammattilaisten haastattelut.

Opinnäytetyö perustuu käytännönläheiseen raportointiin värimäärittelyprojektista. Se havainnollistaa kuinka tärkeää värimäärittelijälle on ymmärtää värimäärittelyprosessi kokonaisuudessaan. Prosessin osaaminen auttaa värimäärittelijää tekemään tarkkoja värikorjauksia ymmärtäen digitaalisen teatterilevityksen standardit. Lopputuloksena tämä opinnäytetyö on hyvä niille jotka haluavat lisä tietoutta värimäärittelyn kokonaiskuvasta.

Avainsanat Värimäärittely, elokuva, digitaalinen teatteri

Sivut 38 s.

GLOSSARY

Academy flat (1.85:1) Common digital cinema aspect ratio.

ARRIRAW Raw codec of the ARRI ALEXA motion picture camera.

Bit depth Describes the number of values between the black point and the white point of a picture.

Black point The darkest part of a picture.

Bleach bypass Contrasty and desaturated look that originates from skipping the bleaching part of a color film development process.

Boolean operations Mathematical calculations that are used to unite, intersect, complement and invert mattes.

BT.709 (see Rec. 709)

CinemaDNG Open film format raw codec of various cameras including Blackmagic Cinema Camera.

Cinemascope (2.39:1) Common digital cinema aspect ratio. May also be used when referring to other wider aspect ratios in general.

Chroma channel Color information of the video signal.

Chroma subsampling Compression technique that reduces resolution in chroma channel.

Chromaticity coordinates Coordinates defining the usable chroma range of any color space within the CIE 1931 chromaticity space.

Color management Controlled conversion and compatibility of color representation between various devices.

Color model Describes how the colors can be created by an abstract mathematical model.

Color rendering index (CRI) Measurement unit for color faithfulness of a light bulb.

Color space Specification that describes predefined selection of colors used by a particular standard.

DCI-P3 Color space used in digital cinema that is specified by the DCI specification document.

Debayering Color reconstruction process required for any raw format to become human readable.

Deliverable The final distribution ready version of the film.

Denoise Process of reducing the visible noise in a picture or a matte.

Digital cinema Motion picture distribution and playback system that uses digital technology instead of motion picture film.

Digital cinema distribution master (DCDM) DCI specified standard for the uncompressed master files.

Digital Cinema Initiative (DCI) Joint collaboration of major motion picture studios that works towards a standardised digital cinema system.

Digital Cinema Package (DCP) Container that includes the entire motion picture content for transport, storage and playback.

Digital intermediate (DI) Motion picture finishing process.

Digital Picture Exchange (DPX) File format containing single frame of a motion picture and is commonly used in DI or VFX work.

Display-referred The color management type of color grading describing that the color fidelity of an image is judged based on the appearance on a monitor.

DNxHD (Digital Nonlinear Extensible High Definition) Lossy mastering codec developed by Avid Technology, Inc.

H.264 Highly compressed codec used by the most consumer cameras.

Gamma Power function that refers to a nonlinear representation of luminance of a monitor. It is used to code and decode luminance values of any digital imaging system.

Gamut Range of colors that a monitor or any other device is capable to produce.

Graticule Overlaid measuring scale.

HDR Hero display The color accurate main display of a grading suite or a theatre.

Histogram Supporting tool to evaluate luma and chroma levels of a picture. Can also be used in RGB mode.

HSL qualifier Qualifying method that creates a key based on hue, saturation and luma channel difference.

ITU-R Recommendation Collection of various digital imaging standards including the Rec. 709 by International Telecommunication Unions Radiocommunication sector.

IRE (Institute of Radio Engineers) Measurement unit for video signal.

JPEG 2000 Picture codec used in DCP packaging.

Lookup table (LUT) Mathematical tables used to save image processing operations that emulate a color space, normalise a log-encoded media or serve as a creative starting point for a look.

Luma channel Monochrome information of the video signal.

LUM qualifier (or Luma Key) Qualifying method creates a key based on luma channel difference.

Master offset Primary control to manipulate the entire image tonality.

MXF (Material eXchange format) Container used in DCP packaging.

Normalising Color grading process that makes a log-encoded picture look right to the eye. Fundamentally increases contrast and saturation of the picture.

OLPF comp (Optical Low Pass Filter or Anti-Aliasing Filter) Image processing operation that makes a picture less sharp in order to reduce moiré.

Power windows Color grading tool that creates a key based on custom trackable shapes.

Qualifier Color grading tool that creates a key based on HSL, RGB or LUM qualification.


Quicktime ProRes Lossy mastering codec developed by Apple, Inc.

Rec. 709 ITU-R Recommendation for HDTV production. Specifies the standard color space and gamma for broadcast.

REDCODE RAW (R3D) Raw codec of the Red Epic motion picture camera.

REDcolor Color preset used with R3D format.

REDgamma Gamma curve preset used with R3D format to debayer the linear sensor data to a normalised Rec. 709 picture.



REDlog FILM Gamma curve preset used with R3D format to debayer the linear sensor data to a log-encoded picture.

RGB qualifier Qualifying method that creates a key based on RGB channel difference.

S-curve Curves control that increases contrast. Used to normalise a picture.

Scopes Set of supporting tools used to evaluate luma and chroma levels of a picture.

Sony RAW Raw codec of the motion picture cameras manufactured by Sony.

Spatial noise reduction Noise reduction type that attempts to preserve detail by smoothing out areas of high-frequency noise.

sRGB Color space and gamma standard for consumer displays and web distribution.

Temporal noise reduction Noise reduction type that analyses multiple sequential frames to isolate noise from the detail.

TIFF (Tagged image file format) File format containing a single frame of a film and is used to create the DCDM of the film.

Tonality Range of tones in a picture.

Tonal range Selected range of tones for an adjustment.

UHD (Ultra-high-definition television) Standard for 4K and 8K broadcast.

Vectorscope Supporting tool to evaluate chroma level of a picture.

Waveform Audio File Format (WAV) Uncompressed audio file format used for audio mastering.

Waveform monitor Supporting tool to evaluate luma and chroma levels of a picture. Can be used either in monochrome, RGB or RGB parade mode.

White point The brightest part of a picture.

2K DCI (2048x1080) Standardised aspect ratio for digital projection.

2K DCI Cinemascope (2048x858) Standardised aspect ratio for digital projection.

4K DCI (4096x2160) Standardised aspect ratio for digital projection.

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1. INTRODUCTION

Color grading is a vital part of any video or motion picture production. A colorist can correct the picture to look right, balance sequences to make shots look perfect together, add specific styles and depth upon request and monitor quality of the final product, essentially improving production value (Hurkman 2014, loc 277–310). Color grading is a storytelling tool that is absolutely necessary for any digital cinema workflow.

This thesis is a practical report of a digital cinema grading project for a feature film: *Autolla Nepaliin*. The film is put together by a handful of young entrepreneurs, who decided to drive from Finland to Nepal in order to raise money for a Nepalese women's shelter and an outcaste school. On the journey they posted frequent video blog updates attempting to elevate awareness for the issue. After successful return they decided to compile a film based on the experience.

The creators of the film had seen some of my previous work and for this reason they asked me to participate in the project. I am a self-taught colorist and I've been interested in grading for quite a long time. Prior to this project, I have been grading anything from wedding videos and short films to TV series and other multicamera productions. Hence, I did not hesitate when I got this opportunity as now I could get a good insight to a feature length grading production.

The foremost goal for the thesis is to go entirely through the color grading workflow for digital cinema distribution. I will go through the essential theory although the practicality is the primary focus. That includes thorough preparation in order to ensure color accuracy, the enormous grading process in itself and the mastering process to comply with the present digital cinema standards. To start with I will review the role of a colorist. Then I will observe the grading project from the very beginning discussing all the things that matter before the grade, while preparing for the grade, during the grading process and when the film is prepared for digital cinema distribution.

2. THE CRAFT OF THE COLORIST

A colorist is an artist who within an editorial department of a film crew alters and corrects the film in order to make sure that color and light are continuous through the film. As an artist the colorist is capable of creating stylistic looks for the film collaborating with the director and the cinematographer. (IMDB n.d.)

Alexis Van Hurkman describes in his book *The Color Correction Handbook* the six major exercises that define the craft of the colorist: correcting errors of color and exposure, making key elements look right, balancing shots in a scene to match, creating style, creating depth and adhering to

quality control standards (Hurkman 2014, loc 277–310). This chapter takes a fresh look at the aforesaid exercises.

The footage is hardly ever distribution ready straight out of the camera. It may be exposed way off the mark, the color balance may be inaccurate or the digital noise may be too evident in the blacks. For this reason as the first step the colorist has to make sure that every shot looks as correct as possible.

Every frame of the film has a key element that is supposed to draw the attention of the audience. On many occasions it is the people or an advertised product, and the viewers have certain color preferences for them by memory. (Hurkman 2014, loc 288.) For example they presume that a can of coke has a certain red color and skin tones look as natural as possible. It is expected from the colorist to study these memory colors so that the audience wouldn't get distracted.

To make the film feel continuous the colorist must make sure that all the shots within a scene match. Inconsistency between the shots will stand out and as a consequence the audience will lose its grasp of the film. By carefully balancing all the shots that are originally shot in various locations and on dissimilar conditions the scene will look as it was shot in one continuous take (Hurkman 2014, loc 288–299).

The color grading process can also be a dramatic tool to take the story forth. The colorist is an artist that has a capability to design creative looks that affect the mood and the feel of a scene. The colorist can make the scene appear threatening, upbeat, downhearted, calming or anything else only by changing its color balance. The colorist can also make the scene look as if it was shot at dawn, at midday or at night. The colorist works together with the director to realise the dramatic goals of the film.

The colorist works together with a cinematographer to create depth. While it is for the cinematographer to create depth on the set to begin with, the colorist can enhance the effect by making secondary corrections. (Hurkman 2014, loc 303–312.) The colorist can separate and emphasise specific parts of a shot to help the cinematographer during the finishing stage. (Hurkman 2014, loc 303–312.)

The colorist is one of the final chains of the filmmaking process. Therefore the colorist is the one who must make sure that the film is within the legal limits if it is required (Hurkman 2014, loc 311). For example a broadcast station may have strict guidelines for black, white and chroma limits. The colorist is responsible that all these standards are adhered in preparation for the final deliverable.

3. BEFORE THE FILM: TECHNICAL BASELINE

The vast majority of the footage for the *Autolla Nepaliin* film was recorded with the video blog in mind. It was recorded in a documentary style with ranging equipment and therefore the quality of the footage varies throughout the film. In addition to the main adventure segment, supplementary scenes were recorded specifically for the film with higher quality equipment. Recording conditions changed drastically as other parts of the film were shot on the go and other well lit scenes were added afterwards. This set some uncontrollable challenges and this chapter is about getting to know all the variables that the colorist needs to know about the footage.

3.1 Recording format

The video blog segment of the film was recorded with Nikon D800, Sony NEX-7, Canon 5D Mark II and GoPro Hero 2 cameras with a selection of lenses. Supplementary scenes were shot with a Canon 5D Mark III DSLR and a Red Epic digital cinema camera.

As the colorist it is important to know certain things about recording format such as general compression, chroma subsampling and bit depth as well as basics of linear and logarithmic encoding. All of these have tremendous impact on what the colorist is able to do during the color grading process. As a rule of thumb it is fair to say the more data you have, the more latitude you have for a certain color grading processes. Table 1 lists all the relevant specifications of the cameras used in the project (Derugin n.d.; Red n.d.; Sony n.d.)

Table 1 - Camera specifications.

	Nikon D800	Sony NEX-7	GoPro Hero 2	Canon 5D Mark II	Canon 5D Mark III	Red Epic
Codec	H.264	H.264	H.264	H.264	H.264	REDCODE RAW
Chroma subsampling	4:2:0	4:2:0	4:2:0	4:2:0	4:2:0	4:4:4
Bit depth	8-bit	8-bit	8-bit	8-bit	8-bit	16-bit

3.1.1 Compression

Compression reduces storage space and transmission bandwidth drain for data by changing its format (Compression n.d.). There are a few attributes such as codec, container and bit rate that have an effect on picture quality. Codec is a portmanteau of compressor-decompressor (Codec n.d.) and is basically the instruction for how the data is compressed and played back. There are various codecs but the most common are raw formats such as REDCODE RAW or ARRIRAW, mastering quality formats QuickTime ProRes and DNxHD and highly compressed formats such as H.264. Con-

tainer contains the codec and is displayed as the type of file such as MOV or MP4. Bit rate is about how much data the codec uses. (Kong 2014.)

While raw format captures all the data that the sensor sees and hence is recommended for the most latitude, it is heavy to process and requires large storage space (Hurkman 2014, loc 585–601). This is where mastering quality codecs simplify the workflow while maintaining the high quality standard. In regards to heavily compressed codecs such as H.264, there is only as much you can do. Different attributes do play their part in the equation but the adjustment latitude is still limited.

3.1.2 Chroma subsampling

The video signal can be split to separate luma and chroma channels that stand for lightness and color. The human eye is less sensitive to changes in chroma than in luma and therefore it is possible to compress the resolution of the chroma channel without significant total perceived quality loss. (Red 101 2013a.) Chroma subsampling reduces the file size in exchange to reduced color information.

The most common chroma subsampling ratios are 4:4:4, 4:2:2 and 4:2:0. 4:4:4 stands for full chroma data, 4:2:2 has half of the color data and 4:2:0 has a quarter of the original chroma data (Kong 2014). These ratios are the specified horizontal rates at which luma and chroma values are scanned. For example if each horizontal scanline had 2 chroma values for every 4 luma values the chroma subsampling ratio would be 4:2:2. (Red 101 2013a.) This is illustrated in image 1.

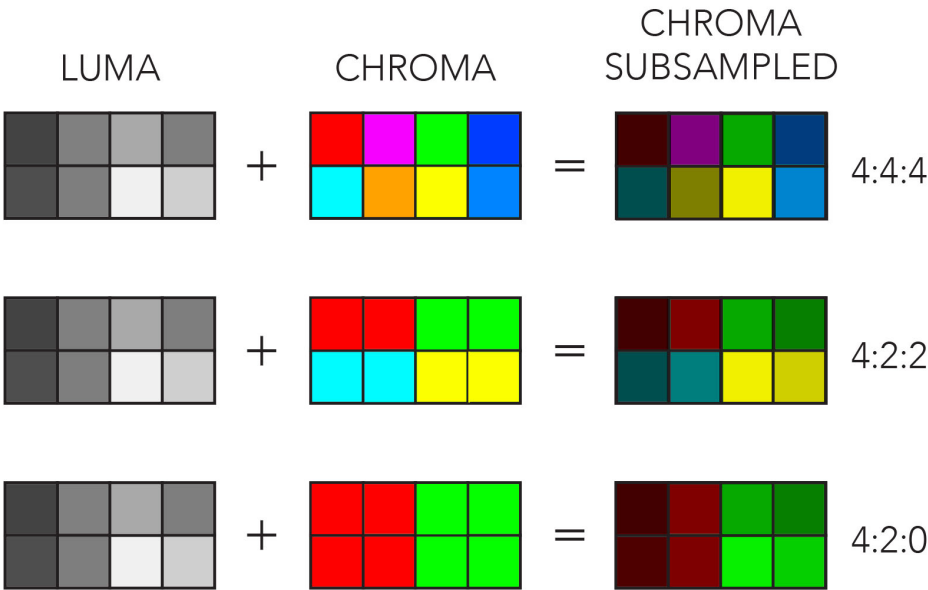


Image 1 - Chroma subsampling ratio illustrated.

For the colorist chroma subsampling can become an issue when latitude is required for exposure correction. Increased chroma subsampling will result in compression artifacts and noise when demanding exposure adjustments are applied (Hurkman 2014, loc 658–678). Another notable inadequacy of chroma subsampling is that creating a chroma key becomes more complicated as every sharp edge will have color transitions that would not otherwise exist. Therefore it is fair to say that using chroma subsampling affects to the whole post-production crew.

3.1.3 Bit depth

Bit depth is a key determinant of a picture's fidelity (Oran & Roth 2012, 21). Bit depth describes the number of values between the black point and the white point. For example an 8-bit picture has $2^8=256$ shades of gray for each color channel and therefore the fidelity of the picture is over 16 million colors. Similarly for a 10-bit picture there are 1024 shades of each color and that counts for over a billion colors. (Hullfish 2008, loc 848.) Only with infinite bit depth the information is a perfectly smooth curve, identical to the original analog equivalent (Most 2011b).

Today, the majority of the consumer video cameras and home entertainment systems use 8-bit imagery (Hurkman 2014, loc 1307). However it is good to note that those 16 million colors of an 8-bit picture may not always be enough. Banding may occur within smoothing gradients when there are not enough shades to grade with. The banding defect is clearly visible in the background of the ungraded image 2.



Image 2 - The banding defect in the leftmost and rightmost parts of the shot (Autolla Nepaliin 2014).

Much the same as with the compression and the chroma subsampling, highly compressed 8-bit format is less preferable when compared to less compressed 10-bit or higher bit depth pictures. However, while any data that was discarded by compression is lost forever, grading applications will promote any picture to 32-bit floating point within the image processing pipeline. Therefore to preserve the higher quality image processing

made by the colorist, it is recommended to export the final corrected output to a higher bit depth format. (Hurkman 2014, loc 695–708.)

3.1.4 Linear or logarithmic encoding

Human perception of visual imagery is logarithmic and we do not perceive detail in very bright or dark areas. Digital cameras measure light linearly and as high end digital cameras are able to create 16-bit imagery we're able to present most of the critical data in a 10-bit or 12-bit container by logarithmically encoding the picture. The essence of log-encoding is to “weigh” fewer values to dark and bright areas, and more values to the more critical midtones. (Most 2011b.) This is illustrated in the image 3 where the linear and the logarithmic light are compared.

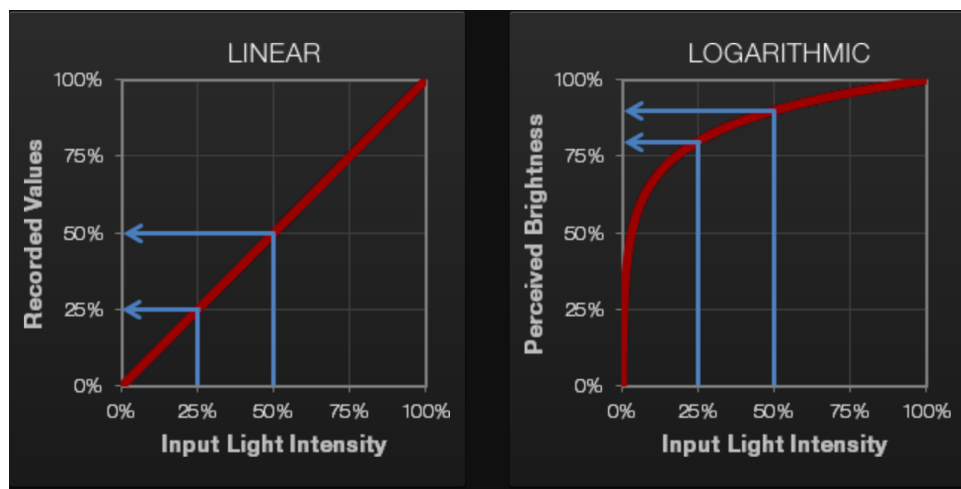


Image 3 - Linear and logarithmic light compared (Red 101 2013b).

Alexis Van Hurkman describes log-encoding: “Log-encoded media compresses the contrast of the image capture by the sensor in order to preserve the greatest amount of latitude for adjustment within the available bit-depth of these formats” (Hurkman 2014, loc 618). This gives a far greater amount of latitude for the colorist to make use of than the normalised rec. 709 format.

If the footage is shot log-encoded, it has to be normalised before the grading can begin. The effect of the log curve can be normalised by using an “s-curve” (Most 2011a). The s-curve has a slight bend at the shadows and highlights to increase contrast. By increasing contrast the representation of the picture will look right to the eye. Image 4 compares a log-encoded picture to its normalised version.



Image 4 - Comparison of a log-encoded picture to its normalised version (Autolla Nepali-in 2014).

3.1.5 Resolution

While not quite a compression method, the resolution affects the overall sharpness of the video. The scaling filters smoother, sharper or bilinear have an effect on overall sharpness by handling the scaling process differently.

There are a few common resolutions available for recording and playback. A DCI specification document is created by the largest film studios to standardise digital cinema technologies (Digital Cinema Initiatives, LLC 2012, 13). The DCI specification defines the standard digital cinema resolutions 2K DCI and 4K DCI and they have also variations in 1.85 academy flat and 2.39 cinemascope aspect ratios (Hurkman 2014, loc 1484). When the editing timeline contains various source resolutions, differences in image clarity are unavoidable without making any compromises in quality. Image 5 is a comparison of all the common resolutions.

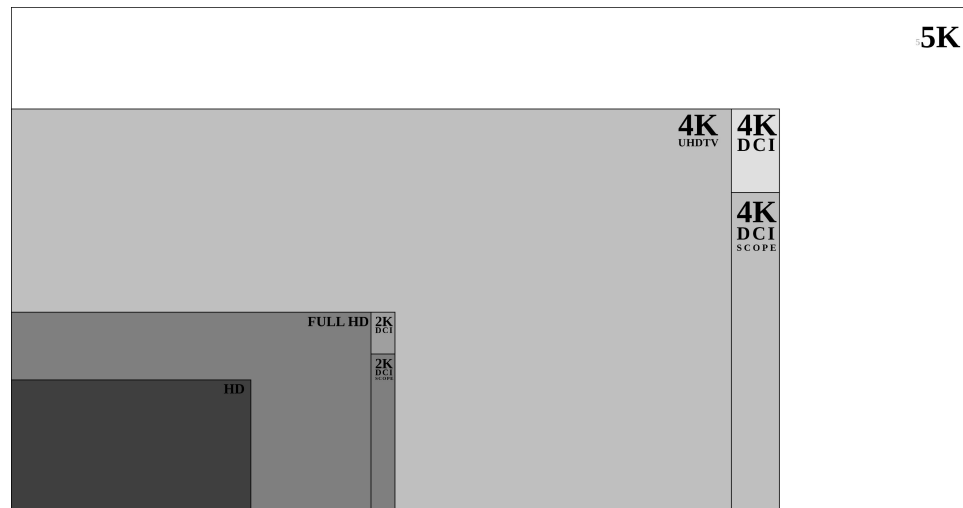


Image 5 - Resolution comparison.

3.2 Recording conditions

Recording format is not the only variable when it comes to the entire picture quality. The way the footage is shot has a tremendous effect on the quality. A well exposed H.264 shot can actually be quite suitable for correction but a poorly exposed H.264 shot will be a colorist's nightmare. Flaws that originate from the set such as over- and underexposure, digital noise, lens flare and the out of focus shots have an effect on the quality. Some of the detail destroyed by the aforesaid issues may be fixable but more often it may be beyond repair.

Overexposure occurs when the sensor sees too much light and cannot capture all the data. An overexposed area will render out as a uniform pool of white and is beyond repair. (Hurkman 2014, loc 3766–3783.) The overexposed area does not contain any image data and is destroyed forever.

As might be expected the reason for underexposure is contrary to overexposure and it occurs when there is not enough light for the sensor to capture any data. That being the case the shadows are clipped and the darkest parts of the picture do not contain any other data than random image sensor noise. This causes many problems when contrast adjustments are applied such as excessive noise and inadequate shadow detail. (Hurkman 2014, loc 3594–3667.)

Noise is a visual indication of a lower signal-to-noise ratio (Resnick 2011). The digital noise is recognised as a flaw and should be limited. It is similar to film grain but when it comes to the aesthetics of the pattern, the real film grain is a clear winner. Especially color grading adjustments that raise the shadows exaggerate the noisiness of a picture. This limits the available grading repertoire and is an unavoidable defect when shooting to a format with higher compression. Nevertheless it is fair to say that there are some great noise reduction software that can limit the visible noise.

The lens flare originates from a strong light source that emits light through the camera lens that refracts the light rays off many surfaces finally hitting the sensor (Wright 2010, loc 4605). While the lens flare is a natural phenomenon it can cause some issues for the colorist such as localised contrast reduction, a veiling glare and colored tints. The nature of the lens flare will vary depending on the lens used.

While merely a human error (unless the lens is severely damaged) an out of focus shot can be another nuisance for the colorist. This affects the image sharpness and unfortunately it is unrepairable and cannot be fixed by the colorist. However a minor sharpening filter can be applied to ease the pain.

4. PREPARING FOR THE FILM: SETTING UP A GRADING SUITE

Grading a film for digital cinema distribution requires a properly set up environment and hardware to provide color accuracy. The most accurate color interpretation is achieved when both technology and environment work seamlessly together. Alexis Van Hurkman describes today's display-referred color management: "Display-referred means that color fidelity is judged based on the appearance of the image on the display" (Hurkman 2014, loc 1072). Hence it is necessary to understand how the human eye perceives the picture depending on the surroundings and how it is actually rendered out on a monitor.

While it is vital to have color accurate systems when grading a film to cinema distribution, it is good to know that not everyone has their systems calibrated. When grading a film it is good to know your audience. Whether the final delivery is for high quality cinema, standardised broadcast or color mess web distribution it has an effect on the grading suite.

Grading suites and theatres are both built for their own distinct purposes. If the final deliverable is for the big white screen, the projector will be more accurate for color critical evaluation while for broadcast the monitor will do its job. This is due to the fact that monitors are backlit whereas the projector projects the picture to the screen and has its own peculiar taste. That being said building the grading theatre will stretch the budget and that is not always an option. That is why we focus on building a grading suite.

4.1 Grading environment

4.1.1 Environment

The environment of the grading suite has an impact on how the eye perceives the picture. Therefore it is important to examine details such as wall and furniture color to get the most color accurate workflow as possible.

The wall around the hero display is called the surround wall. It should be around 18 percent neutral gray for two reasons. Firstly color neutrality helps the eye to evaluate colors without an outside stimulus and secondly the brightness of the wall directly correlates to the perceived contrast. (Hurkman 2014, loc 1944–1959.)

The furniture and other decorations may also impact the picture. A subdued, desaturated and generally dark environment reduces the amount of light bouncing in the room. That kind of environment won't give the eye any incorrect stimulus of how the colors should be perceived, hence keeping the eye "neutrally calibrated". In addition all unnecessary bright colors and lights should be avoided. (Hurkman 2014, loc 2068–2094.)

4.1.2 Lighting

Surround lighting should adhere to certain standards such as luminance, color temperature, color accuracy and illumination standards depending on the final deliverable.

The Bartleston-Breneman effect states how an increase in the surround luminance increases the perceived contrast of an image (Nezamabadi 2008, 21). Therefore surround lighting should be matched to the reference luma and gamma settings. General preference for the luminance is around 80-120cd/m² with accompanying gamma setting of 2.2-2.4 (Hurkman 2014, loc 1984).

There is also a standard for surround lighting color temperature and color rendering index (CRI). For most European and American countries the surround lighting color temperature is standardised as D65 (6500K) while in some Asian countries the standard is D93 (9300K). CRI stands for the faithfulness of color and to gain high color faithfulness fixtures that have CRI of 90 or greater are recommended. (Hurkman 2014, 1973–2016.) If these standards are complied, the human eye is adjusted to the correct white balance and that greatly improves accurate color balancing.

Lighting fixtures should be set up so that the illumination is indirect. Any unwanted ambient lighting that directly hits the display may cause a veiling reflection that lowers perceived contrast and obscures the image on the display. (Hurkman 2014, loc 2027.) For grading suite it is preferable to have surround lighting installed behind the desk.

Lighting intensity and amount depends on the room size and final distribution channel. While it is necessary for the colorist and the client to see their workspace, the lighting should be kept to such an amount that it is just enough to see controls and notes. (Hurkman 2014, loc 2029–2070.) It is also important to consider the average viewing environment of the audience and then adjust the lights as required. For example a darkened cine-

ma requires full blackout while for web distribution it is acceptable to have lighting appropriate for a living room.

4.2 Grading hardware

While grading environment is a significant luxury for grading accuracy, having proper grading hardware is an absolute necessity. Grading can be a very demanding task for any system and therefore knowledge about making a system that is fast enough while making sure that color accuracy is fulfilled is extremely valuable.

Similarly to the grading environment, the hardware can be adjusted to the need. Whether the system is for Full HD or 4K workflow it has a great impact on hardware requirements. In all its simplicity the professional grading suite requires the following units: a computer fit for grading, a media storage, a video interface, a monitor and other accessories such as a control surface.

4.2.1 Hardware configuration

The hardware configuration has a significant impact on the performance. For Full HD web distribution a lower performance system is enough while for 2K or 4K cinema distribution this is not the case. Compressed 4K footage causes an enormous drain for the system and requires powerful components for real-time processing. (Blackmagicdesign 2014b, 3.)

The image processing within the grading pipeline is very GPU intensive. Most of the professional color grading applications use 32-bit floating point processing to provide the highest quality possible. Furthermore for UHD and 4K DCI workflows the data is usually compressed and therefore it has to be decompressed to the full RGB per pixel depth and it requires over four times more processing power than the Full HD image. For this reason the fastest GPUs with the most GPU RAM are recommended. In addition other bottlenecks may occur as other computer specifications such as codec, CPU, system RAM, motherboard slot speed, file system and media storage speed, etc. do have their role in realtime playback. (Blackmagicdesign 2014b, 3–6.)

For this film we had a chance to build a grading suite from scratch to an OS X platform. Our hardware was configured to a 2K DCI workflow as follows: Late 2013 Mac Pro with 2,7 GHz 12-Core Intel Xeon E5 CPU, AMD FirePro D700 6144 MB GPUs, 64 GB 1866 MHz DDR3 EEC RAM, Internal 1TB SSD storage and external thunderbolt 2 8TB RAID 5 storage. While this system had some bugs like any new system would, it was very effective for real time playback.

4.2.2 Monitor

When looking for the professional grade monitor it is important to find one that has an accurate and stable color with 10-bit channel support and is calibratable and adjustable to the color temperature, setup, gamut and gamma standards while being able to produce resolution, contrast and black level necessary for the color critical workflow. (Hurkman 2014, loc 1260–1557.)

One of the most important factors for the color critical workflow is that the monitor should be capable to reproduce the exact gamut and gamma of the final delivery format. (Hurkman 2014, loc 1274.) By making sure that gamut and gamma standards are complied, the colorist can be sure that he sees the picture the way it should be seen.

A color model, a color space and the gamut are terms to describe how the color is rendered out. The color model describes how the colors can be created by an abstract mathematical model. The gamut is a range of colors that a monitor or any other device is capable to produce. The color space is a specification that defines predefined selection of colors used by a particular standard. (Workwithcolor n.d.)

Gamma is a power function that refers to a nonlinear representation of luminance of a monitor (Hurkman 2014, loc 1371). It resembles how we perceive the luminance nonlinearly with our eyes. Gamma is used to transfer the linear sensor data to a nonlinear gamma corrected output. This is due to the fact that the monitor gamma is the opposite of the gamma correction and it has to compensate the effect. (Wright 2010, loc 5554–5708.) Gamma is a major factor in how the picture is rendered out on a display. With an incorrect gamma setting the picture may look either too dark or too bright. That is why there are various gamma settings for different uses. Gamma 2.6 is used for digital cinema, 2.4 is a standard for rec. 709 footage, 2.2 is a common standard for consumer televisions and sRGB 2.2 gamma is the standard for the web (Hurkman 2014, loc 1395).

There are a few common standards for color and gamma settings. The following lists review the most important ones for web, broadcast and digital cinema distribution. Image 6 is a comparison of Rec. 709 and DCI-P3 standards.

- ITU-R Recommendation BT.709 or Rec. 709 is the standard color space and gamma specification for HDTV production with the specified primary chromaticity coordinates and the gamma of 2.4. (Image Engineering 2014)
- DCI-P3 is the DCI specification for the color space used in digital cinemas. Main purpose of it is to standardise digital projection equipment so that every film would look the same in any cinema. (Technicolor

n.d.) At this point DCI-P3 technology is quite expensive and in Finland it is common to grade in Rec. 709 instead.

- sRGB is almost the same as the Rec. 709 standard as chromaticity coordinates of its primaries are identical. However sRGB gamma is very close to, but not identical to Rec. 709. It is considered that sRGB has a gamma of 2.2 because the linear part of the function is very close to it. However the exponent of sRGB transfer function is actually 2.4. (Image Engineering 2014) For consumer monitors and web distribution sRGB is a common standard.

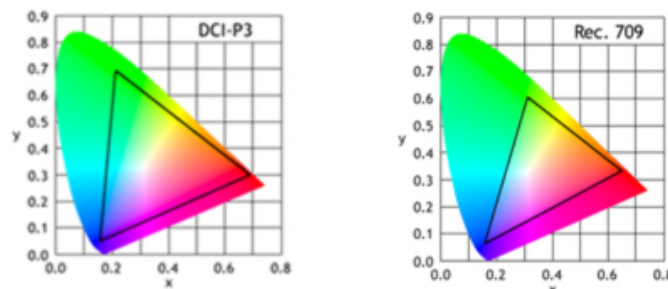


Image 6 - Chromaticity coordinates of DCI-P3 and Rec. 709 compared (Technicolor n.d.).

Similarly to the lighting in the grading suite the monitor has to be matched to the standard color temperature. Only by doing so the whites are as white as they should be and they do not have tints to one side or another. For a digital cinema reference projector the DCI specification standard is 6300K while the standard for SD and HD broadcast video in Europe and America is D65 (6500K). In case that the final deliverable is for the Asian market the broadcast standard temperature is D93 (9300K). (Hurkman 2014, loc 1309–1332.)

Other essential features worth mentioning are the light output, setup level, contrast ratio, resolution and adjustability. The light output of a monitor should be adjustable to luminance recommendations of 80-100 cd/m² for a darkened environment and 120 cd/m² for an environment with display surround lighting. IRE is a video signal measurement unit and all digital signals have a black level of 0 IRE. Hence the monitor should be used with a setup of 0 IRE. The contrast ratio should be capable of producing acceptable level blacks. The monitor should also be capable of matching the final resolution of the film. Lastly the monitor should have an option for additional grading feature such as monochrome only mode. (Hurkman 2014, loc 1341–1468.)

For the film we decided to go with a budget solution and to get a HP Dreamcolor Z27x monitor. Its price to value ratio is impressive and it has most of the important monitor features straight out of the package. It is capable to produce Rec. 709 color space and it has adjustable color temperature and light output. However, it is not entirely a grading monitor and

therefore it lacks some necessary inputs and has an average contrast ratio. Nevertheless after a test screening in a cinema, we noticed that there was hardly any difference when compared to the monitor output.

4.2.3 Video interface

Even with the high quality color calibrated monitor it is important to make sure that the picture is actually as high quality as possible. SDI video I/O interface is required for this reason. Interfaces are used for video ingest and playback and offer various connections to get the best out of any monitor. (Blackmagicdesign 2014b, 7.) The main reason for the interface is to output 4:4:4 and 10-bit picture to the monitor via an SDI connection. As a result the quality of the picture is guaranteed for critical color grading workflows.

As our monitor of choice was HP Dreamcolor Z27x our only way to input the footage was to use a HDMI 1.4 port. Therefore we had to convert the 6G-SDI connection of the I/O interface with a SDI to HDMI 4K converter to a proper HDMI 1.4 connection. Our system schematic turned out to be very similar to the Blackmagicdesign configuration guide schematic in picture 7 only with the exception of having the converter between the I/O interface and the monitor. Our Mac Pro was connected to a control surface via an ethernet cable and to the storage system and ultrastudio 4K I/O interface via a thunderbolt 2 connection.

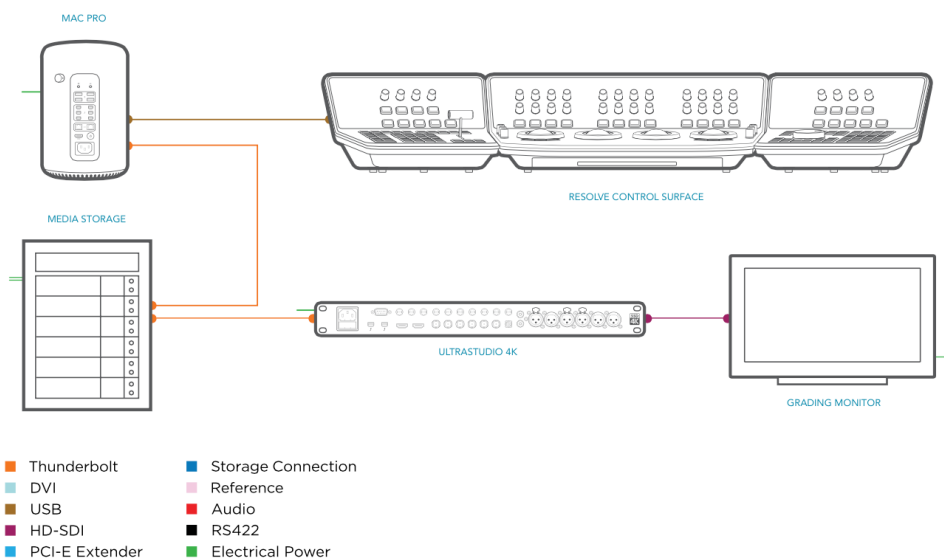


Image 7 - System Schematic (Blackmagicdesign 2014b, 12).

4.2.4 Accessories

A colorist may want to accessorise his working place with other equipment to make workflow more effortless. The control surface is a character-

istic tool for the grading suite and is extremely useful for the colorist. A graphic tablet is also very handy to the color grading process.

The control surface usually consists of three trackballs, three contrast rings and a variety of other knobs and buttons to streamline control of the color grading software. Trackballs respond to the black, midtone and white adjustments, contrast rings to lift or black point, gamma or midtone and gain or white point adjustments and knobs and buttons respond to variety of other adjustments such as contrast and hue adjustments. (Hurkman 2014, loc 2353.) Using the control surface makes the work of the colorist much easier and is recommended. When doing primary color wheel adjustments, the possibility of real-time compensation is invaluable.

The graphic tablet however is not necessarily a grading tool yet it is handy when creating secondary corrections. A pen-like control is a pleasure to use when drawing masks over and over again (Hurkman 2014, 2381–2339).

5. GRADING THE FILM: GRADING TOOLS

5.1 Scopes

Scopes are supporting tools for the colorist to use when evaluating luma and chroma levels. A histogram and a waveform monitor are great to judge image contrast while a vectorscope, a RGB parade scope and a RGB histogram are useful for color evaluation.

The histogram is a graphical representation of a picture where every pixel is plotted against a horizontal scale. The scale ranges from the black point to the white point while the midtones fall somewhere in between. The histogram is useful for analysing the contrast ratio of a picture. (Hurkman 2014, loc 2600–2613.) Image 8 displays an alternative RGB version of the histogram. It is similar to the histogram but it presents individual histograms for each RGB channel separately. (Hurkman 2014, loc 4506–4515.)

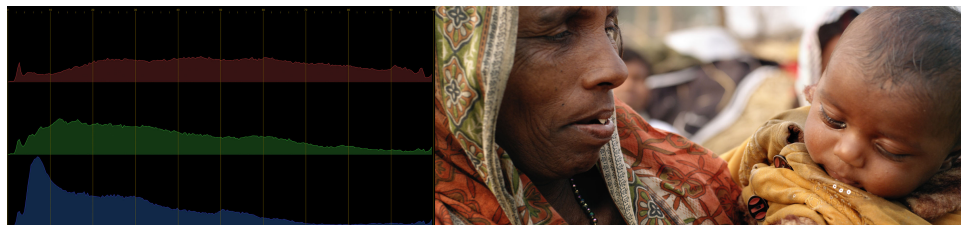


Image 8 - The RGB histogram with a sample picture (Autolla Nepaliin 2014).

The waveform monitor is a vertical graph where the black point of the picture is at the bottom and the white point is at the top. In image 9 the x-axis of the graph presents the picture from left to right and corresponding luma

values of the picture are plotted to the graph vertically where the top is the whites and the bottom represent the blacks. The midtones of the picture can be discerned as the spread at the middle of the graph. The waveform monitor is useful when luma values of specific areas have to be evaluated. (Hurkman 2014, loc 2628–2674.) The waveform monitor usually has an optional RGB parade mode. As illustrated in image 10 the RGB parade is similar to the waveform monitor but displays the RGB channels separately. (Hurkman 2014, loc 4424–4496.)

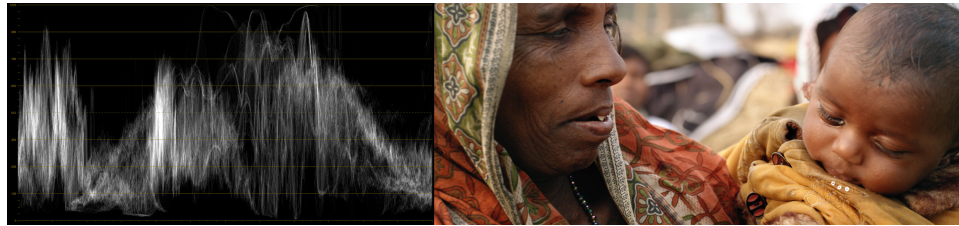


Image 9 - The waveform monitor with a sample picture (Autolla Nepaliin 2014).

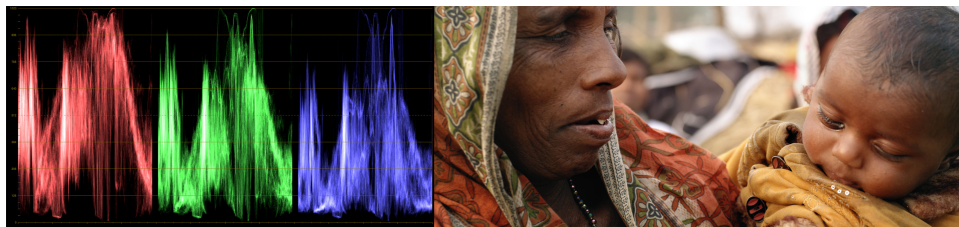


Image 10 - The RGB parade with a sample picture (Autolla Nepaliin 2014).

The vectorscope is used to measure the overall saturation and hue of a picture. A graticule is a reference crosshair that includes diagonal I and Q bars and color targets for red, magenta, blue, cyan, green and yellow. Simply put the angle around the crosshair center measures hue and the distance represents saturation. The center of the crosshair is the reference point for the monochrome picture. (Hurkman 2014, loc 4340–4425.) The vectorscope is a convenient tool when judging the color balance and saturation of the picture. Image 11 is an example of the vectorscope in a DaVinci Resolve.



Image 11 - The vectorscope with a sample picture (Autolla Nepaliin 2014).

5.2 Primary controls

The primary controls empower the colorist to manipulate the entire picture's tonality. The controls can control luma and chroma components of

the picture separately or in unison. The luma controls adjust the monochrome portion of the picture that determines image lightness (Hurkman 2014, loc 2435). The chroma component has two characteristics: hue and saturation (Hurkman 2014, loc 4114–4137). The primary controls can manipulate hue and saturation separately. Similarly to the vectorscope hue can be manipulated by turning the angle around the color wheel while the distance adjusts the saturation. Image 12 is an example of a color wheel in a DaVinci Resolve color grading software.



Image 12 - The color wheel in DaVinci Resolve.

5.2.1 Color balance controls

The most distinguishable tool of the colorist is the color balance wheels. To manipulate the picture's tonality the tonal range is divided to three ranges: lift, gamma and gain (Blackmagicdesign 2014a, 504–505). For each range is its own individual color wheel as seen in image 12. Lift adjusts the black point, gain the white point and gamma the other tones in between. The tonal range for each individual control is illustrated in image 13. For each control there is a wheel to control chroma and a slider to control the luma component of the picture. Additionally the overall signal can be adjusted with the master offset control. Primaries palette is an alternative slider view to the color wheels. It is introduced in image 14.



Image 12 - The primary color wheels palette in DaVinci Resolve.

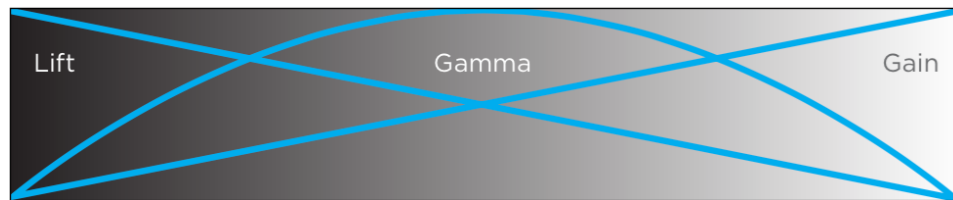


Image 13 - Tonal ranges of the lift, gamma and gain controls (Blackmagicdesign 2014a, 506).

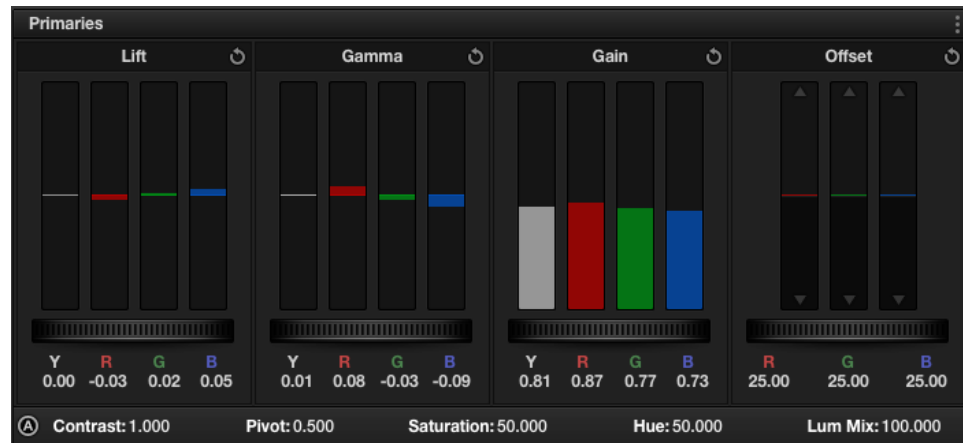


Image 14 - Alternative slider view of primaries palette in DaVinci Resolve.

In addition, the primaries palette usually contains contrast, contrast pivot, saturation and hue controls. These controls also have an effect on the entire picture tonality by manipulating its luma or chroma channel. The contrast control increases or decreases the distribution of tones and the contrast pivot adjusts the center point of the adjustment. Saturation controls the colourfulness of the picture and hue the wavelength of the color (Hurkman 2014, loc 4128).

5.2.2 Log wheels

The log wheels is an alternative mode for the color balance wheels. The shadow, midtone, and highlight controls of image 15 have adjustable tonal ranges that are controlled by pivot points (Blackmagicdesign 2014a, 510). The pivot point adjusts the transition point between the controlled ranges. The effect of the pivot point manipulation is described in image 16. Similarly to the color balance controls, the log mode has an offset wheel to manipulate the entire image tonality. Log wheels were designed to control a log-encoded picture but can also be used to create creative adjustments to a normalised picture (Blackmagicdesign 2014a, 508).



Image 15 - The log wheels palette in DaVinci Resolve.

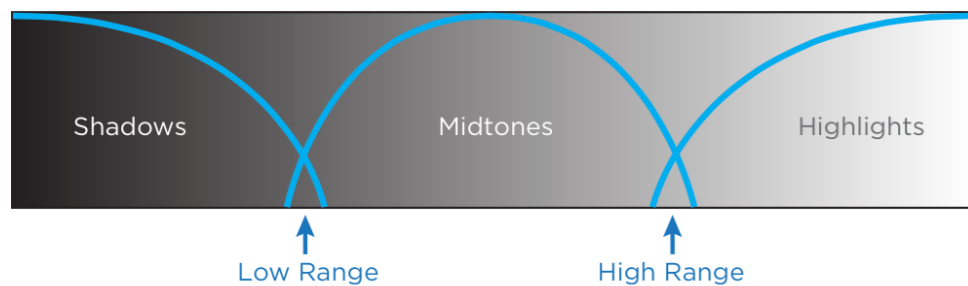


Image 16 - Tonal ranges of the shadow, midtone and highlight controls (Blackmagicdesign 2014a, 514)

5.2.3 RGB mixer

The RGB mixer is a tool used to mix image data from one RGB channel to another (Blackmagicdesign 2014a, 521). The RGB mixer as seen in image 17 can be used for many creative purposes such as adding color from a single color channel to a monochrome image or just to remix color channels. For example a portion of the blue channel values could be added to the red output resulting in a red tint to the blue areas of the picture.



Image 17 - The RGB mixer in DaVinci Resolve.

5.2.4 Curves

Curves is a mathematical graph that represents the entire tonal range of a picture (Adobe n.d.). Curves can be used to manipulate the entire picture very specifically either as ganged curves or as separate channels. The original picture values are plotted to the x-axis of the graph and output values are plotted to the y-axis. Image 18 is an example of the s-curve adjustment.

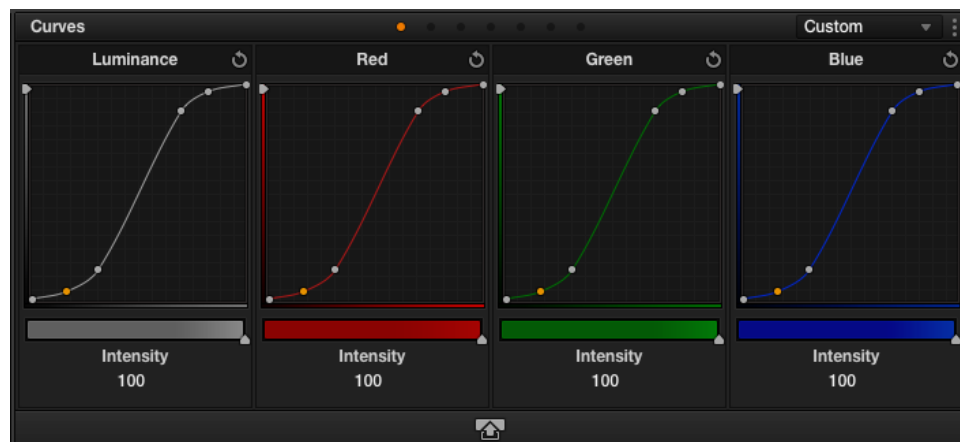


Image 18 - S-curve in the curves tool of DaVinci Resolve.

The curves palette usually includes special curves such as hue, luma and saturation curves. These tools are used to manipulate either the hue, saturation or luma of the picture in relation to one another. (Blackmagicdesign 2014a, 547.) While these curves can be considered as secondary corrections due to the nature of selective correction, I would consider them as an alternate approach to the curves tool. DaVinci Resolve has a following selection of special curves: hue vs. hue, hue vs. saturation, hue vs. luminance, luminance vs. saturation and saturation vs. saturation. The original values of the picture are plotted horizontally in the middle of the graph and, depending on the curve type selected, the output values are mapped according to the vertical divergence. These curves are very useful tools when the colorist wants to emphasise either the hue, saturation or luminance within a certain tonal range. Image 19 is an example of a hue vs. saturation correction where saturation of reds is lowered, greens is raised and blues is kept at the original values.

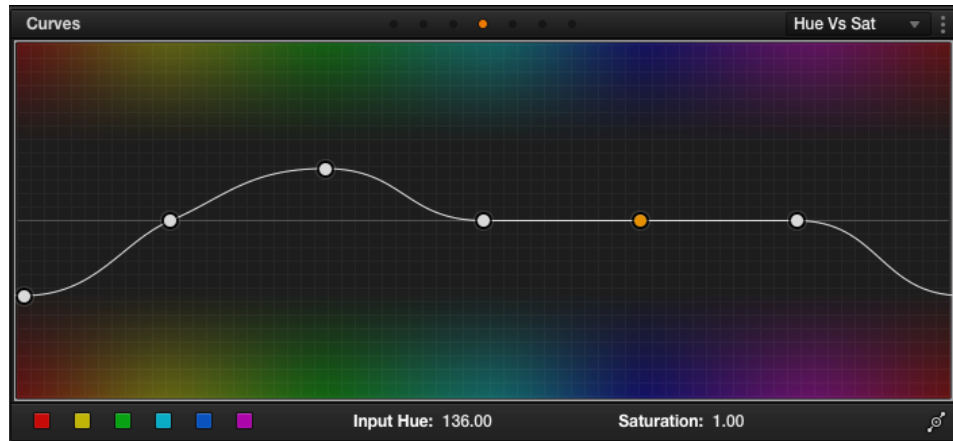


Image 19 - Hue vs. saturation correction in DaVinci Resolve.

5.2.5 Primary controls for image detail

Professional color grading software have additional tools like blur and sharpening, noise reduction and motion blur to control picture detail. They can be used when original footage is unsatisfactory and has to be repaired or as a creative tool to create a style for the film.

Blur and sharpening can be thought as contrasting adjustments. When blur is applied, the picture loses some of the sharp details and vice versa. Neither blur or sharpening are considered as color corrections but are useful tools to make stylistic grades or to fix image detail. (Blackmagicdesign 2014a, 627.) Sharpening can be adjusted as a first-aid to an out of focus shot but even so it may be beyond repair. While the picture can be blurred afterwards, it has only as much detail as it had when it was shot.

The video signal has always more or less noise. For this reason noise reduction is required to reduce unnecessary noise especially with underexposed clips. There are two widely used ways to apply noise reduction: temporal and spatial noise reduction. By analysing multiple sequential frames, temporal noise reduction isolates the noise from the detail. Alternatively the spatial noise attempts to preserve detail by smoothing out areas of high-frequency noise. (Blackmagicdesign 2014a, 523–524). Noise reduction can be applied to repair noise and banding resulted by highly compressed format. Sometimes it is advisable to apply real film grain to improve the quality of resulting grade.

Appearance of the motion blur depends of the shutter angle of the camera. The amount of motion blur increases when the shutter angle widens. (Red 101 2012.) While it is impossible to reduce motion blur, the motion blur can be applied artificially in the post-production by using optical-flow based estimation (Blackmagicdesign 2014a, 530). The motion blur tool does miracles when the playback appears sluggish and is missing the motion blur effect.

5.3 Secondary controls

While primary controls are used to control the entire picture tonality, the secondary controls are used to adjust a specific object or an area within the picture. Secondary controls such as qualifiers and power windows are the primary way to pull a chroma or luma key to isolate primary correction to the desired area for the correction. The resulting matte can then be tracked or keyframed so that it follows the movement within the picture. Lastly the matte can be managed with various parameters and combined with other keys with boolean operations to get the best outcome.

The qualification method is used to pull a key when the subject is shaped irregularly and has a distinct range of color or lightness (Blackmagicdesign 2014a, 570). The key can be pulled from the initial color and lightness values by using either HSL, RGB or LUM qualifiers. HSL qualifier pulls the key based on the difference between hue, saturation and luma components. RGB qualifier samples the difference in RGB channels and is used on rare occasions when the HSL qualifier can't discern the component difference. A LUM qualifier is used to pull the key using only the monochrome luma component of the picture. Image 20 is an example of a qualifier palette that has been used to pull a skin tone key from image 2. The qualifier palette has also additional tools like denoise, black and white clip, blur radius and I/O ratio to refine the key.

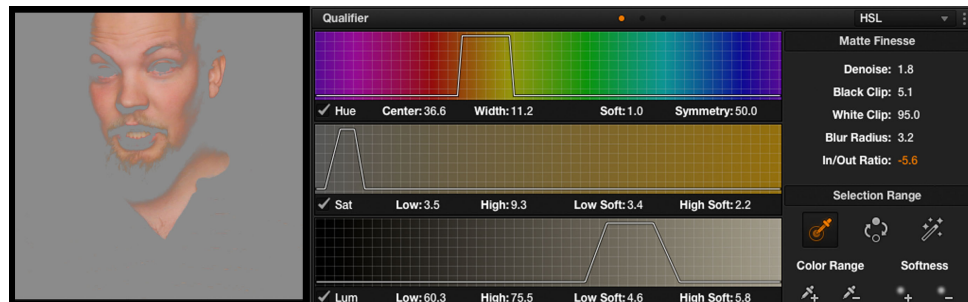


Image 20 - The qualifier palette and a matte in DaVinci Resolve (Autolla Nepaliin 2014).

Power windows are shapes that can be transformed, stretched and combined to create a key. The shapes can be oval, rectangular, polygonal, or custom curved shapes and they can be used to isolate geometrical regions with ease (Blackmagicdesign 2014a, 585). Image 21 shows a matte created from Image 4.

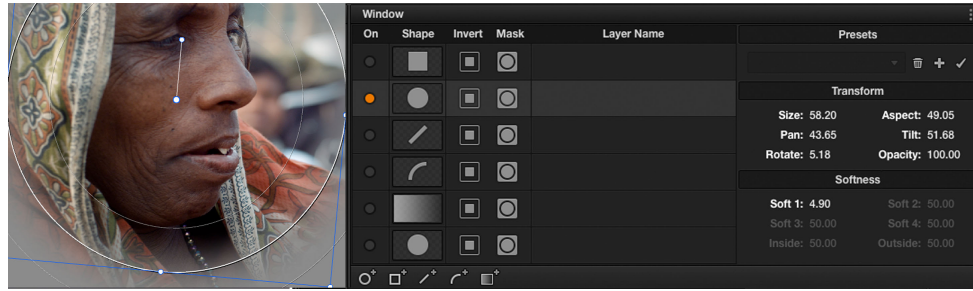


Image 21 - The power window palette and a matte in DaVinci resolve (Autolla Nepaliin 2014).

While qualifiers and power windows utilise dissimilar methods to key a particular area, the resulting matte is the same. The matte can be adjusted and transformed in the key palette. Additionally by using node tree connections as a boolean operation canvas several mattes can be united, intersected, complemented and inverted. However in contrary to the qualifiers the power windows usually have to be tracked to stick with the moving picture. Trackers create a moving pivot point by analysing a cloud of tracking points following the vectors of every trackable group of pixels (Blackmagicdesign 2014a, 602). The resulting location data is used to move the matte in relation to the picture movement. The tracker palette shown in image 22 can also be used to stabilise the shot.

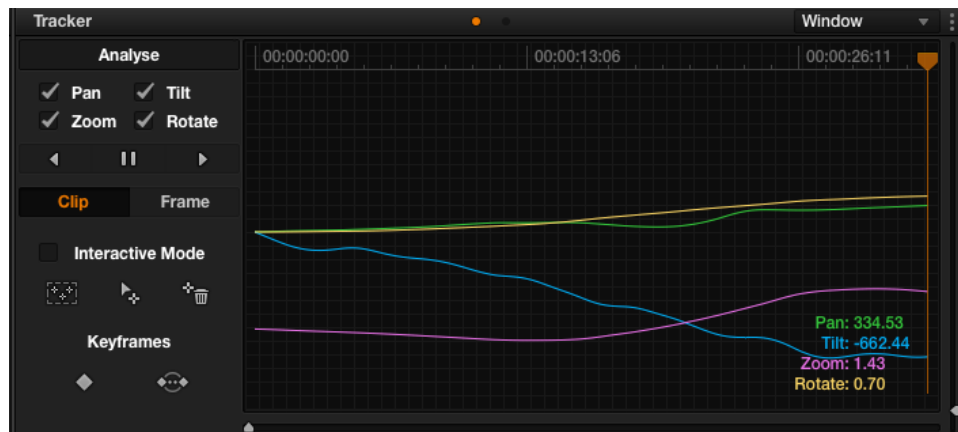


Image 22 - The tracker palette in DaVinci Resolve.

Keyframing is a secondary option to move the key or adjust the timing for primary correction. Keyframing is a manual operation where movement or parameter correction can be applied frame by frame or by using dynamic transition. Image 23 shows a keyframe palette that has been used to push some additional warm color to the picture over time.

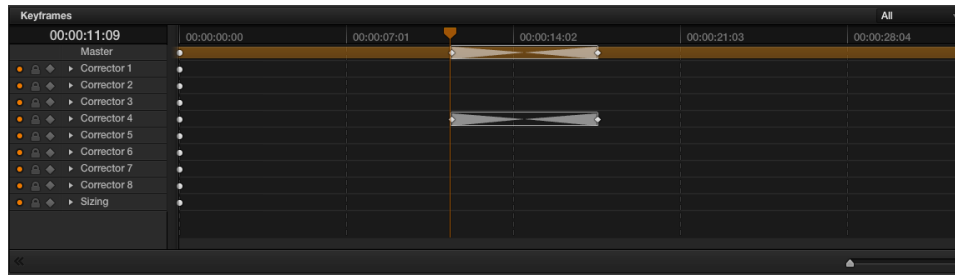


Image 23 - The keyframing palette in DaVinci Resolve

5.4 Nodal workflow

The node based workflow is a very efficient way to work when doing complicated grades. Both the most advanced compositing and grading software take advantage of its adaptability. The nodal workflow is based on individual correction nodes that are combined together in multiple ways to create multi-correction node trees (Blackmagicdesign 2014a, 31). When combined together the nodes containing separate corrections create a grade for the shot.

The node tree displayed in image 24 begins from a source bar and ends to an output bar. An additional source bar can be added when grading RED HDR media and alpha output bar when alpha output is required for VFX work (Blackmagicdesign 2014a, 664). In between is the correction node tree. Individual nodes can be connected to pass either image data or key information.

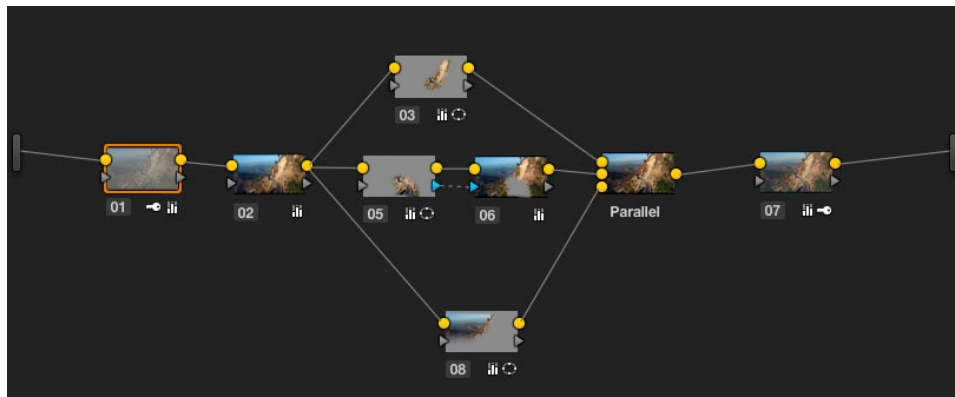


Image 24 - The node tree in DaVinci Resolve

There are multiple kinds of nodes available so that the colorist can have precise control over the grade. A serial node contains a correction that can be either primary or secondary correction. A parallel node is used to combine serial nodes to make simultaneous corrections in a single stage. Likewise a key mixer is used to blend previously created keys together at the same stage. Similarly to the parallel node, a layer mixer blends serial nodes but with the exception of using composite modes. A splitter/combiner combo is used to split the node tree to separate RGB component corrections.

5.5 Camera raw

Professional color grading software have a specialised control palette for the cameras recording in the raw format. The raw data has to be debayered in order for it to become human readable. The camera raw palette shown in image 25 has an adjustable parameter for all the adjustable camera metadata and it is the very first step of the image processing pipeline. (Blackmagicdesign 2014a, 169.)

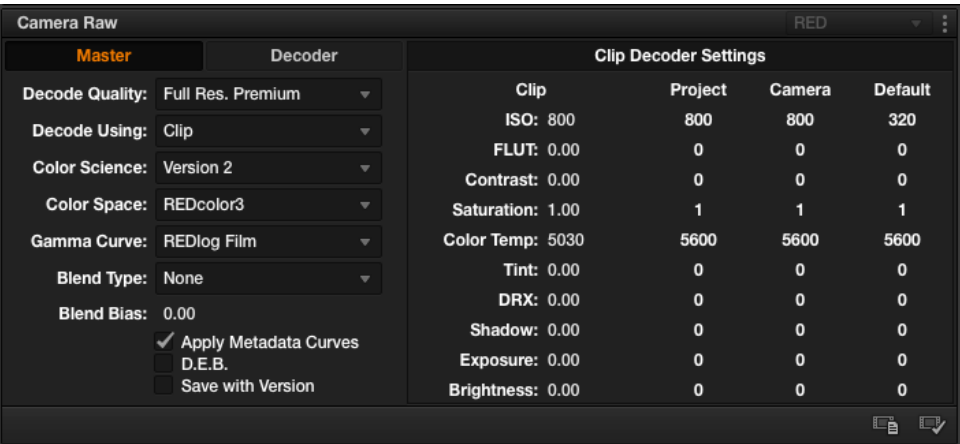


Image 25 - Camera RAW panel for REDCODE RAW in DaVinci Resolve

The raw panel has a personalised set of controls for every supported camera raw format, including but not limited to ARRIRAW, REDCODE RAW, Sony RAW and CinemaDNG. Depending on the selected raw format the panel may have controls for decode and play quality, bit depth, timecode, color science, color space, gamma and HDR setup, as well as clip settings for typical camera settings such as ISO, color temperature and exposure just to mention a few. Additionally some cameras may have additional decoder settings just like REDCODE RAW has settings for de-noise, OLPF comp and image detail.

5.6 Lookup tables

Lookup tables (LUTs) are mathematical tables that can be considered as saved image processing operations. Based on the calculation, a LUT maps a new RGB value to each RGB value that is put in. (Hurkman 2014, loc 1754.) Primarily LUTs are used to preview destination color space, as a normalising tool or as a starting point for a creative grade.

LUTs are great for transforming a signal to how it should look on an ideal monitor (Hurkman 2014, loc 1745). If the monitor is not natively capable of producing a desired color space, a LUT can be used to compensate. It will transform a picture to look as it should with correct color balance and gamma settings.

LUTs can also be used to normalise a log-encoded picture. Applying a LUT that contains previously created normalising correction as a single

node does not only make a picture look as it is supposed to but it also makes the workflow much faster. After the node is applied the colorist can continue the grading process from a solid starting point. LUTs are also very mobile if the colorist still has to fix certain things from the original log-encoded picture, another correction node can be applied ahead of the LUT node.

It is also common to use previously created LUTs as a starting point for a creative grade. LUTs may contain film stock emulations or other creative grades such as bleach bypass looks. Therefore LUTs can serve as creative baseline for the color grading process.

6. PROCESSING THE FILM: GRADING WORKFLOW

6.1 The big picture

The grading process for a feature film length film is enormous. Every single frame of the film has to be examined before and after the adjustments have been applied, not forgetting the time consuming grading process in itself. Grading a feature film would not be possible within a modest time-frame without an efficient workflow. The color grading process is one of the last steps of the filmmaking process and for this reason the colorist has to work efficiently.

As a result colorists have developed a workflow technique that brings efficiency, speed and organisation to the grading process. The order of operations workflow has three stages: correction stage, looks building and secondary corrections (Riddle 2013). This technique maximises the time usage and makes the big picture a lot easier to approach.

While it can be argued whether the order of operations workflow is the standard because every colorist certainly has their own ways to operate, it is a good starting point for a colorist to begin with. Later it is for the colorist himself to evaluate the best way to work. The order of operations workflow can be followed quite strictly or it can be adjusted to fit within any other workflow.

The order of operations workflow is closely related to the six exercises of the colorist mentioned at the very beginning. On that account the correction stage is to correct errors of color and exposure while making sure that all the shots in a scene are perfectly matched to each other (Hurkman 2014, loc 277–310). It is certain that the footage given for the colorist to grade will have dissimilarities of color and exposure. It is the duty of the colorist to make sure that all the shots are perfectly balanced. During this stage the colorist goes through the footage shot by shot and makes sure that they are perfectly balanced.

After the desirable balance has been achieved, the colorist will move on to the looks building. The creative style for the film is created in this stage and it can be applied on top of the previously balanced shots individually or uniformly. The colorist can alter the time of the day, mood of the scene and contextual characteristics of the shot while crafting creative and stylised looks for the film (Riddle 2013).

The very last step of the process is to focus the perception of the audience to the important details, enhance the picture and clean-up errors originating from previous stages by doing secondary corrections (Riddle 2013). When set side by side with the six exercises of the colorist this step is to create depth, to make key elements look right and to make sure that the film adheres to the quality control standards (Hurkman 2014, loc 277–310). This step can make a lot of difference to the shot. By making digital flags and vignettes the point of interest inside the frame can be controlled. Additionally the colorist can manipulate a specific area within the frame such as making grass look more appealing to the audience.

6.2 The *Autolla Nepaliin* project

The *Autolla Nepaliin* project was a huge challenge. The footage given to me was unbelievably diverse so I knew from the very beginning that the grading process would not be easy. I was given footage from various unlike sources, locations and conditions that ranged from underexposed 8-bit, 4:2:2 and H.264 shots to perfectly lit 16-bit, 4:4:4 and REDCODE RAW shots.

That being so I also had a lot of creative freedom. Both the producer and the director of the film were open to the ideas that I passed on to them. I had a chance to experiment and then present my ideas to the team. Together we decided to make the film look very natural while making it as cinematic as possible.

Hence the overarching theme for the film was to use colors to intensify the mood of the scene. This can be noticed in image 26 where we compare a selection of shots from various scenes to each other. When the mood was joyous the colors were bright, warm and saturated. Contrary when the mood was mellow the colors were muted and cold. If the scene was neutral such as an interview, the colors were as natural as possible.



Image 26 - Collection of shots from the film (Autolla Nepaliin 2014).

I moved on to the grading process with this decision as the starting point for the grade. The following section contains case studies of a few actual grades from the film. Hence it is good to note that the colors won't print out properly and so the following images will have differences when compared to the actual film on a calibrated monitor or projector.

6.3 Case studies

6.3.1 Case study A: Grading a close-up shot

As the first case study, we will grade a shot from the intro sequence of the film displayed in image 27. The shot covers faces of a mother and her child and therefore it is an exemplary shot of how to direct the perception of audience to the subject. The first thing to look at is the recording format. By looking at the inspector we can learn that it is shot as 16-bit REDCODE RAW with camera metadata set to ISO 800, color temperature of 5600K, REDcolor3 color space and REDgamma3 gamma curve.

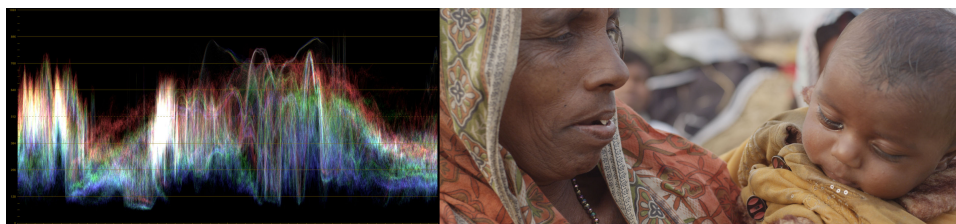


Image 27 - The original shot with a corresponding RGB overlay waveform (Autolla Nepaliin 2014).

A few adjustments need to be applied to the debayer before the grading process can begin. The shot may be an inch off the neutral color temperature and hence the color temperature should be dropped to the neutral daylight color temperature of 5400K. Furthermore to preserve the greatest amount of latitude for correction the gamma curve should be set to the REDlog Film. This will make the clip log-encoded and so the debayer does not apply the normalising REDgamma3 in advance. The effect of the

log-encoded gamma curve can be perceived from the RGB parade scope in image 28.

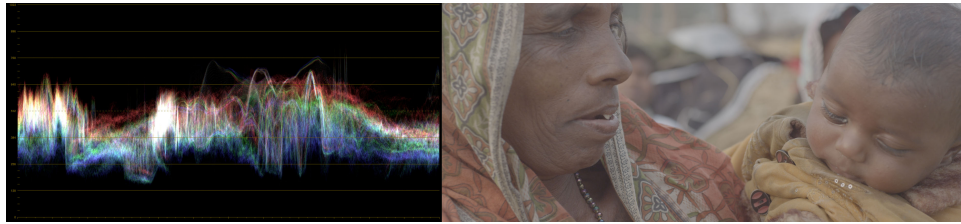


Image 28 - The shot with adjusted debayer settings (Autolla Nepaliin 2014).

Now that the shot is debayered as it is supposed to, the shot has to be normalised. The effect of the log-encoding can be compensated by an s-curve correction. As a result of increased contrast the shot will look as any standard rec. 709 picture. However, instead of using the curves tool we will use a normalising LUT combined with a primary color wheel luma correction to normalise the shot. The primary correction pushes the shadows and the midtones down while it is compensated by raising the highlights. The result seen in image 29 is very similar to the s-curve correction but is more efficient for the workflow. It is also evident in the RGB overlay waveform how the normalising affects the picture tonality.

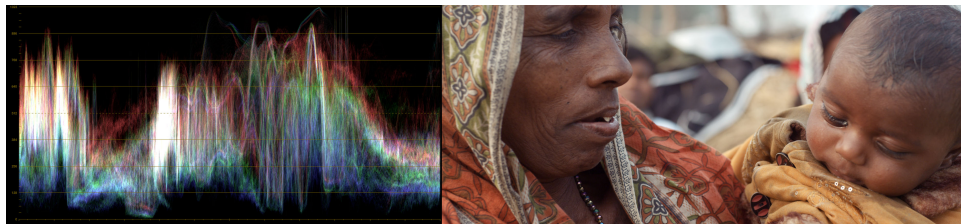


Image 29 - The normalised shot (Autolla Nepaliin 2014).

The creative decision for the film was to make Nepal appear warm and colourful every time it appears in the film. For this reason the intro sequence was graded to look warm and sunset like. As most of the shots were not shot during a sunset we needed to apply a creative style for the sequence. The style is created with a basic color wheel correction by adding warmth to the midtones and highlights while pushing the shadows towards blue to compensate. A stylised warm look can be recognised in image 30 from the increased red distribution in the RGB overlay waveform.

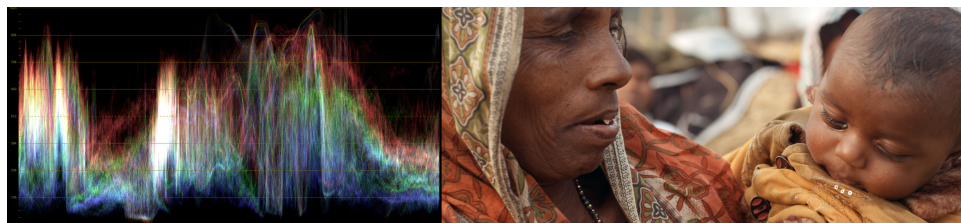


Image 30 - The shot after applying the look (Autolla Nepaliin 2014).

Lastly to draw attention to the subject of the scene, a secondary correction is required. Power windows is a great tool to create a key around their faces. Then we can use the key to push the gamma up a bit to lighten their faces. Moreover the key mixer combines previously created keys so that it can be inverted in order to create a combined outside matte. Because of that we can easily make the people stand out by pushing the gamma of the surroundings down. Due to the resulting contrast difference, the audience will direct their eyes towards the brighter parts of the shot. Additionally an inch of blue tones should be applied to the outside matte as color contrast is another way of increasing depth and separation from the background. The final shot is displayed in image 31 with the final node tree.

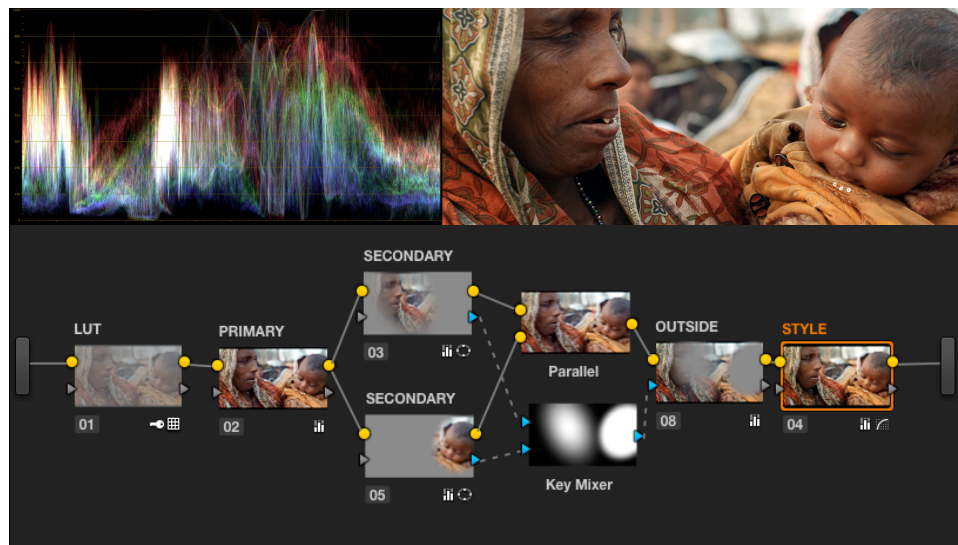


Image 31 - The final result with the final node tree. (Autolla Nepaliin 2014).

6.3.2 Case study B: Grading an establishing shot and balancing a scene

After making the first grade, we have to make sure that it is matched to the other clips in the scene. At this case study we will match the previous shot to two successive aerial establishing shots displayed in image 32. All the aerial shots were shot originally as REDCODE RAW but because the aerial shots required stabilisation they were debayered first to a stabilising software and then exported out in a log-encoded QuickTime ProRes 4444 format.

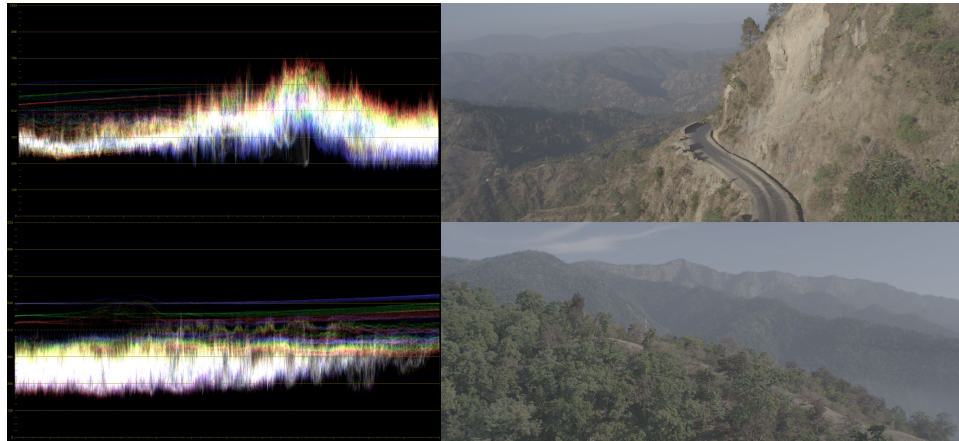


Image 32 - The log-encoded establishing shots (Autolla Nepaliin 2014).

As our goal is to match these shots to appear sequential with image 31, our first step is to normalise the shots. The first step is very important as the primary balancing happens at this stage. Similarly to the first shot we'll begin with the same LUT followed by a primary correction node. On the primary correction node, we make sure that luma and color balance between the clips is correct by examining the scopes and comparing the shots by eye. By looking at the RGB parade scope in image 33 we see that the black point and color balance is quite right between these pictures. Only the cliff on the first establishing shot is clipping and it will be addressed later.

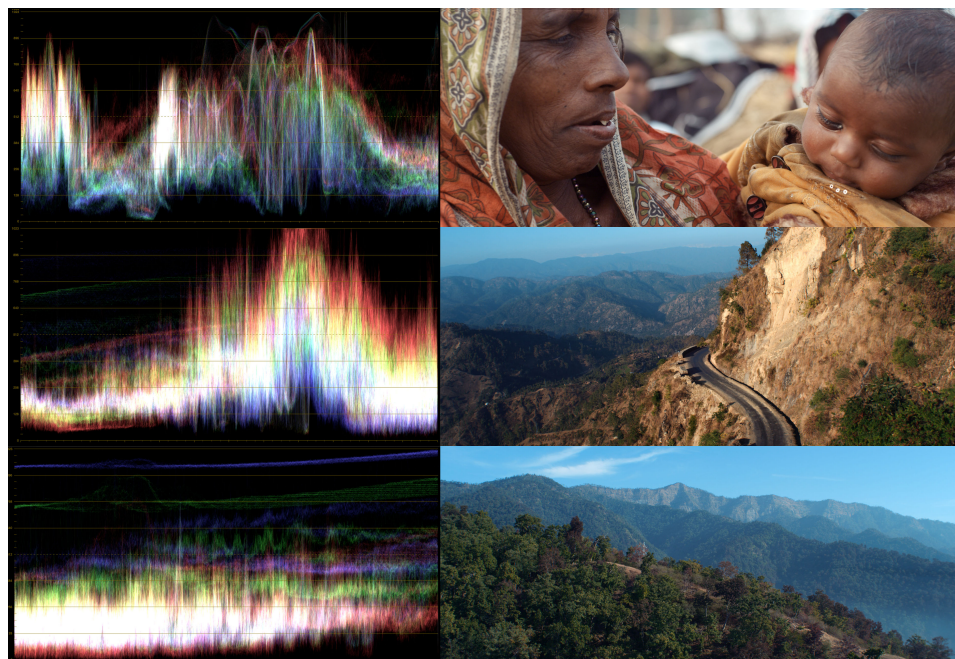


Image 33 - The balanced sequence (Autolla Nepaliin 2014).

Regardless of the initial balancing we may notice that the sequence still looks quite dissimilar. This is due to the fact that the shots are shot in different locations and include completely different subjects. The close-up shot of the mother and her child has completely different tones than the picture with a mountain range. However it is a good starting point for our

next step where we apply a look. The look created while making the base grade can be pasted on top of the the sequence. Nonetheless the correction still needs to be adjusted to a specific clip. For example we need to push highlights of the mountain range shot further to the reds than we had to with the other shots. The effect of it can be recognised in image 34.

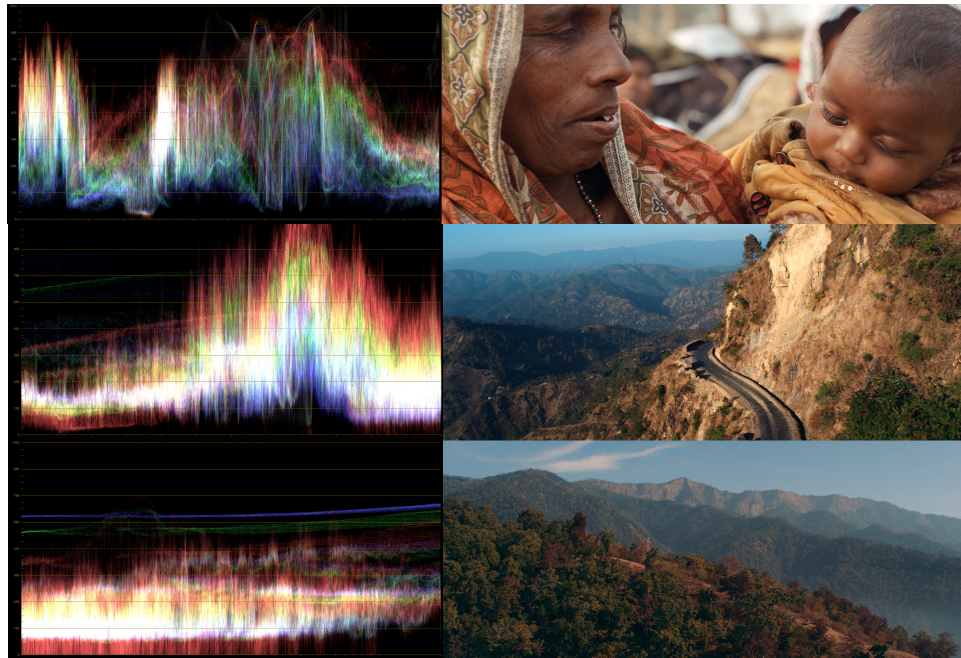


Image 34 - The sequence after the warm look has been applied (Autolla Nepaliin 2014).

To make the mountains and road pop out we need to use secondary corrections. The mountain range will look more stunning if we push green tones back to the shadows and the road will stand out better if the midtones and highlights of the cliff and the valley are pushed back. Image 35 shows the final balanced sequence and image 36 the corresponding node tree.

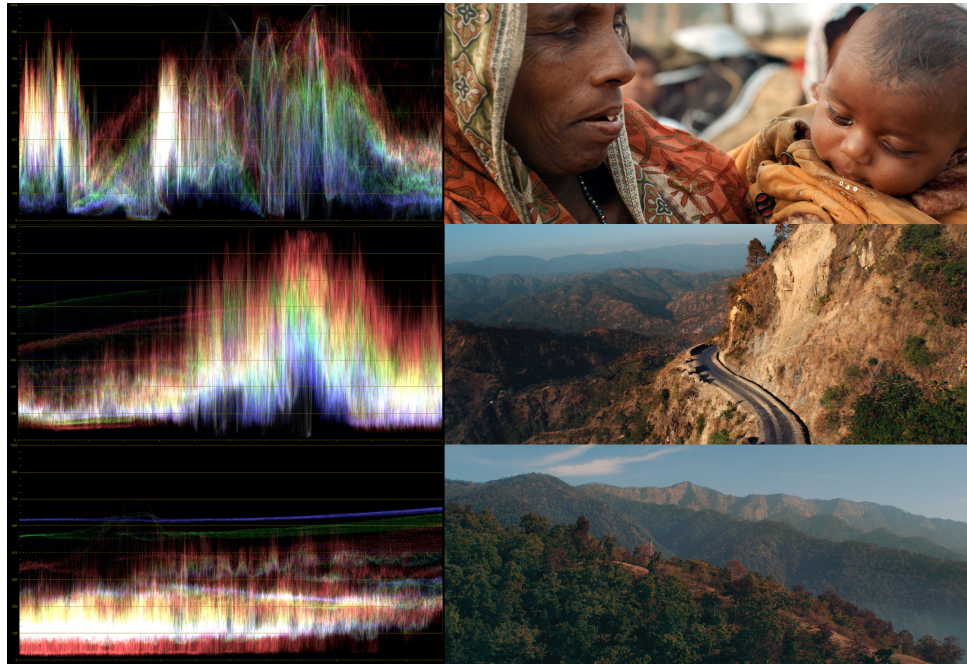


Image 35 - The finished sequence. (Autolla Nepaliin 2014).

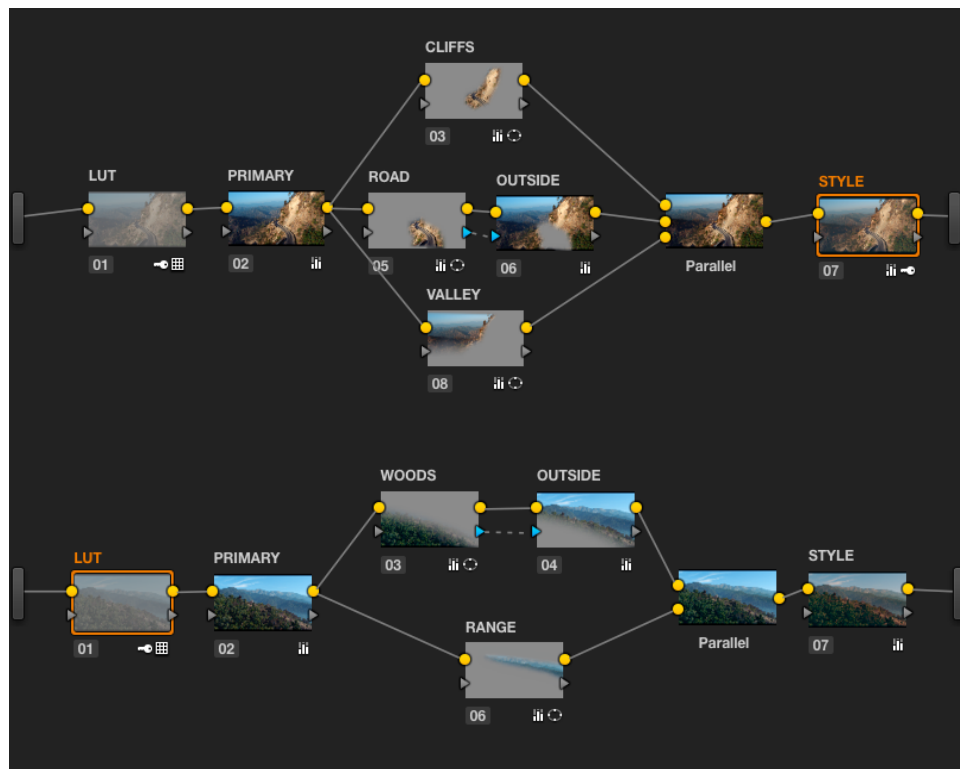


Image 36 - The final node tree (Autolla Nepaliin 2014).

6.3.3 Case study C: Grading a shot with extensive grain

Not every shot is log-encoded REDCODE RAW that has an extensive dynamic range to work with. Especially this film had a great deal of shots that were shot with lower quality cameras shooting 4:2:2 H.264 footage in

challenging lighting conditions. While there is only so much to do, there are also powerful tools to make the picture more usable.

The disadvantage of a H.264 shot is evident even in the well lit image 2. The challenges of a highly compressed format can be clearly seen when the picture is zoomed in. Image 37 shows how the H.264 compressed footage introduces compression artifacts and noise in both the luma and the chroma channel. In addition the 8-bit encoding results strong banding that is visible in the leftmost and rightmost parts of the picture.



Image 37 - The studio shot with zoomed in noise print (Autolla Nepaliin 2014).

Applying noise reduction is the first step of the H.264 grading process. To get rid of extensive compression artifacts, noise and banding, we use a Neatvideo noise reduction plugin. The plugin analyses the noise profile of the picture and then reduces noise based on that noise profile. The noise reduction can be more aggressive in the chroma component but with the luma component we have to be more careful not to lose too much detail. The effect of noise reduction is evident in image 38. While the shot appears to be softer it is due to the fact that the noise is missing.

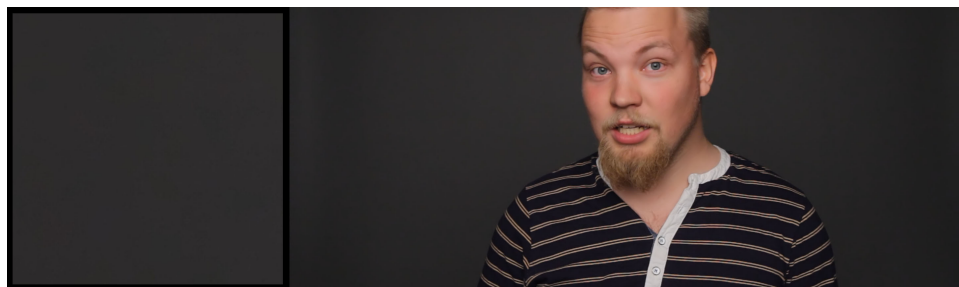


Image 38 - The noise reduction applied (Autolla Nepaliin 2014).

When the noise is reduced we can begin to grade. Similarly to the previous grade, we will first balance the shot, then apply the look and add a secondary correction to separate the subject from the background. But because it is a very similar process to the previous case studies we will continue from the point visible in image 39 where the secondary correction is finished.



Image 39 - The balanced, stylised and secondary corrected shot (Autolla Nepaliin 2014).

As we perceived the noise reduction may cause a loss of picture detail and the picture will appear soft. This is where a minor sharpening adjustment can improve the perceived image quality. Image 40 shows the difference in detail after we apply the sharpening adjustment.



Image 40 - The image after sharpening adjustment (Autolla Nepaliin 2014).

The optional final step to the noise reduction process is to add some film grain back to the picture. It is not necessary but I prefer the aesthetic of the film grain over the completely clear picture. Besides the film grain will bring back some perceived detail to the final picture and the noise print will look uniform like in image 41. The grain can be created in a compositing software or by overlaying scanned grain print over the original footage. The grain print can be overlaid over the picture by using an exterior matte with a layer mixer node as seen in image 42. It is recommended to set the composite mode of the layer mixer to overlay and reduce the strength of the grain to not more than 20%.

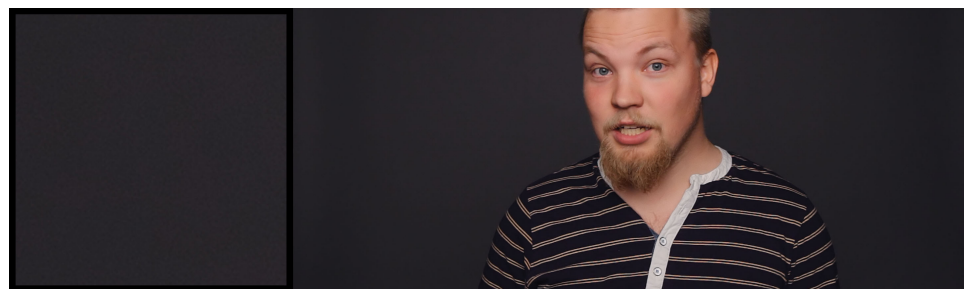


Image 41 - The final image with film grain overlay (Autolla Nepaliin 2014).

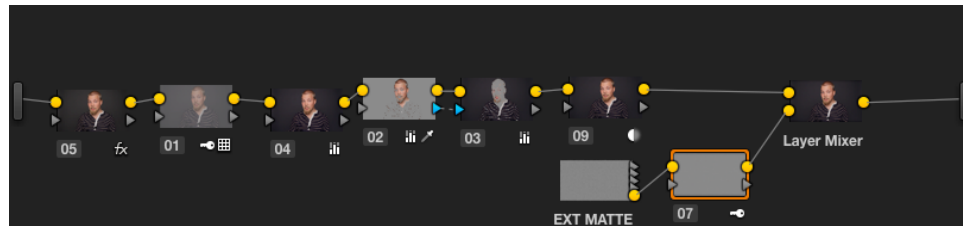


Image 42 - The final node tree (Autolla Nepaliin 2014).

7. FINISHING THE FILM: CINEMA MASTERING

Theatres worldwide have standardised their systems to comply with the DCI specification. The Digital Cinema Initiatives is a joint collaboration of the largest film studios. Specifications for mastering, distribution and digital cinema playback are all described in the DCI Digital System Specification document. This ensures compatibility with digital cinema systems throughout the globe. (Digital Cinema Initiatives, LLC 2012, 13.)

Specifications for the final master files are entitled as the DCDM which stands for Digital Cinema Distribution Master (Digital Cinema Initiatives, LLC 2012, 13.) The DCDM requires the use of common file formats, frame rates and synchronisation. The DCDM-picture recommendation is to use properly synchronised 16-bit TIFF files that contain all the necessary metadata. (Digital Cinema Initiatives, LLC 2012, 24–26). However, the use of 16-bit TIFF files is not always necessary as while being future-proof they may overshoot in the file size. If this is the case, a 12-bit DPX sequence or QuickTime ProRes 4444 file is enough. The DCDM-audio standard is an appropriately synchronised 16 channel 24-bit WAV file (Digital Cinema Initiatives, LLC 2012, 26–27). In addition the DCDM must include standardised subtitles if required.

The DCDM is then prepared for the theatrical playback by compressing, packaging and optionally encrypting it to the Digital Cinema Package (Digital Cinema Initiatives, LLC 2012, 20). The DCP can be considered as a digital equivalent for a film print as it is a container for the entire digital motion picture content including picture, audio, metadata and subtitles (Indie DCP. n.d.). As the first step the DCDM-picture is compressed to a 2K or 4K JPEG 2000, 24 fps (or alternatively 48 fps for 2K), 12-bit X'Y'Z' color space format. The DCDM-audio and -subtitles remain as they were. (Digital Cinema Initiatives, LLC 2012, 21). Packaging organises all the data into a suitable package for storage, transmission and unwrapping for the playback. The compressed files are encrypted inside a MXF container. At this point the package is called the DCP and it is ready to be handed out to distribution. (Digital Cinema Initiatives, LLC 2012, 35).

The DCP is only a container for the transport and storage. At the theatre the DCP is unwrapped, decompressed and decrypted (if it was encrypted) for the playback (Digital Cinema Initiatives, LLC 2012, 21). There are

many other underlying standards accompanying the DCP creation, transport, storage and projection. Nevertheless, it is good to know that by having the DCI standard and complying to it, we can be sure that the film is played back as supposed.

8. DISCUSSION AND CONCLUSION

The main objective for this thesis was to figure out the color grading workflow for digital cinema and then put it into action. Thus three major segments can be identified from the work. First was the preparation to the digital cinema color grading process in order to ensure color accuracy. The second was the actual color grading task. And the third was to observe shortly the mastering process for digital cinema.

It is fair to say that good preparation ensures the best outcome and education is nothing without application. The time I spent researching the digital cinema workflow and preparing for the grading process was crucial for the final outcome to be what it was. I explored techniques, technologies and systems with a clear goal in my mind. I wanted to guarantee that I could create color accurate grades so that the picture that I see with my grading monitor resembles what we see in the cinema. There are so many variables that vary from mathematical curves to room environment that influence the final perception of the image. By carefully analysing each variable that affects perception, I was able to bring grades into being that looked just as they were supposed to. Having said that, the outcome was not that good solely because of the research but also because of what the trial and error caused by the hands on work taught me.

It is also great to notice that something new can always be learned out of something that is very familiar. Color grading was not a new concept for me. It is actually something that has been part of me for five years now. Before this thesis I knew by heart all the fancy tips and tricks of how to balance a shot, fix errors of colors and exposure or create style. Nonetheless the massive hours spent on research and in the actual color grading process gave me a lesson: experience is an invaluable tutor for any kind of craft. Studying through color theory, eye perception, color grading tools and techniques yet again and then putting them straight into action gave me a great deal of new understanding of the grading process.

However, none of the above is valid without being able to bring the project to a conclusion. While I only scratched the surface of the digital cinema mastering process, it is still very essential theory for the colorist to know. It is noteworthy that major film studios in Hollywood have realised the need of digital cinema standardisation by creating the DCI specification document. Consequently I realised that it can be used as an advantage not only to create high quality grades but also to make the grading workflow more efficient.

The craft of the colorist is very beneficial to master as every film requires a colorist. None of the films would look as good if there wasn't a colorist watching over the picture quality. It was a really great experience to be aboard the *Autolla Nepaliin* project and help them to reach their vision. The knowledge that I gained while making this thesis is invaluable and will be useful for years to come. As a final conclusion it is fair to say that this project prepared me to work as a colorist in any grading project that may come to me.

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