Simulation of film media in motion picture production using a digital still camera

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ABSTRACT

The introduction of digital intermediate workflow in movie production has made visualization of the final image on the film set increasingly important. Images that have been color corrected on the set can also serve as a basis for color grading in the laboratory. In this paper we suggest and evaluate an approach that has been used to simulate the appearance of different film stocks. The GretagMacbeth Digital ColorChecker was captured using both a Canon EOS 20D camera as well as an analog film camera. The film was scanned using an Arri film scanner. The images of the color chart were then used to perform a colorimetric characterization of these devices using models based on polynomial regression. By using the reverse model of the digital camera and the forward model of the analog film chain, the output of the film scanner was simulated. We also constructed a direct transformation using regression on the RGB values of the two devices. A different color chart was then used as a test set to evaluate the accuracy of the transformations, where the indirect model was found to provide the required performance for our purpose without compromising the flexibility of having an independent profile for each device.

1. INTRODUCTION AND BACKGROUND

The post-production work on a movie is typically carried out on digital representations of the movie frames. The use of digital technology has brought unique possibilities in all aspects of the post-production of a movie (editing, color grading, visual effects) to the creative community of filmmakers. However, in many cases the preferred medium to capture a scene is analog film stock. This is due to the dynamic range one can capture with film. The latitude of film stock gives this media an advantage over digital forms of acquisition. The cinematographers have also become familiar with the properties of film as a medium, which also slows down the acceptance of digital film cameras.

These factors have led to the digital intermediate (DI) workflow, where the scene is captured on film which is later digitized using a film scanner or a telecine machine. The post-production work is done on the digital data, before the images are printed back to film. A possible solution to the color management for such a process has previously been proposed by Ishii.[1] While the film production is moving towards digital aquisition and delivery, this remains the dominant workflow for the time being. The DI process gives the colorists at the laboratory the possibility to make drastic corrections to the material. However, there is a need to convey the intent of the artistic decisions on the set to the colorists.

New tools and applications[2] are being developed to ease the communication between the set and the laboratory. The possibility of using still images captured on the set and color corrected to represent the intended look is desired by film photographers, who want more control of the work done at the laboratories. This requires that the viewing devices at the laboratory and on the set are characterized, and that viewing conditions are carefully controlled. Currently available applications typically have very limited support for device profiles, and any characterization done is limited to attributes like chroma and lightness.

There are also additional possibilities if the images from the digital still camera on the set are colorimetrically similar to the images obtained in the laboratory. This will give the previsualization on the set the same starting point as the color grading in the laboratory, and color corrections can be communicated to the laboratory as lookup tables or metadata. Goldstone[3] mentions some problems regarding the use of ICC profiles[4] in movie productions. An additional reason why we do not use ICC profiles to solve this problem is that camera profiles generated using ProfileMaker Pro and several other tools do not contain the information necessary to convert from the Profile Connection Space (PCS) to the camera RGB space.

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2. METHOD AND EXPERIMENTAL SETUP

We will consentrate on the task of simulating the scanned images from various film stocks. In our case, the telecine machine was calibrated to give an image that was as close to the film scanner output as possible. We therefore consentrated on using the images from the digital still camera to simulate the film scanner, making the metadata and color corrected images more relevant for the final color grading of the film. The viewing conditions on the set were made as similar to the laboratory as possible.

ICC profiles generated for the devices at the two locations were used to construct a 3D lookup table, allowing the on set color correction to be performed using the RGB of the laboratory monitor as the working color space. This workflow does not require any support for profiles at the laboratory, nor does it necessitate any changes in the procedures for calibration at the laboratory. By making a single transform based on the two profiles, the RGB to RGB transform can be applied to the graded images quickly using graphic cards available in standard laptop and desktop computers.

Table 1. Color differences between digital camera and film scanner before any color transformations are applied, average and standard deviation

Film stock	ΔE_{ab}	ΔE_{00}
Kodak Vision II 200 Tungsten	20.77 (11.38)	12.47 (6.70)
Fuji Eterna 400 Tungsten	20.51 (12.40)	13.92 (9.50)
Kodak 250 Daylight	19.95 (6.37)	13.82 (4.36)

Goldstone[3] elaborates on the problems associated with using ICC profiles for film production purposes. Several solutions have later been suggested to improve on this solution. Since the laboratory in our experiment works in a Rec. 709 color space, we avoid some of the difficulties reported by users working with media having a very non-linear characteristics.

We have used a digital still camera (Canon EOS 20D) and several types of film stocks. The GretagMacbeth Digital ColorChecker and a custom made color chart were carefully positioned in a scene to make the illumination as consistent as possible. The digitally captured images were stored in a RAW file format. We have then used the free RAW converter DCRAW * to convert these images to RGB TIFF files, ensuring the repeatability of this transformation. The analog images were captured using a film camera, and later processed and scanned at the Chimney Pot post-production facility in Norway using an Arri film scanner. At the time of the experiment their laboratory equipment was calibrated according to the ITU-R Recommendation BT.709 (Rec. 709) standard. The DPX files from the film scanner were then paired with the corresponding TIFF files according to their attributes (e.g. film speed, ASA setting, spectral sensitivity).

In order to verify the calibration of the systems, we developed a custom color chart (Figure 1)that was later filmed at each movie location. By analyzing the resulting images, the telecine operator can detect problems with the camera setup, as well as issues with the development of the film stock. We considered using existing color charts made for the print industry, but decided that these were not optimal for the movie production field. The telecine operators are used to working with tools like waveform monitors and vectorscopes to analyze the data signal, and it is a great advantage if the color chart is designed with this in mind.

By placing grey patches of increasing and decreasing brigtness in a horizontal pattern, they will show up as easily identified elements on the waveform monitor. This allows the operator to quickly identify problems with the dynamic range, and easily compare images captured at different locations filmed on different days. We also included patches with high chromatic content, which can be analyzed using a vectorscope.

We tested and compared two different approaches to do the simulation of the film. Figure 2 illustrates the direct and indirect transformation models. By using a single model and going directly from the RGB values of the digital camera to the RGB produced by the film scanner, one would assume that a better match could be made than by using the two separate models for each device. However, this would require that each time a new

*Dcraw, a tool for decoding raw digital photos. Available at http://www.cybercom.net/~dcoffin/dcraw/

Figure 1. A scanned version of our custom made color chart, optimized for telecine operators

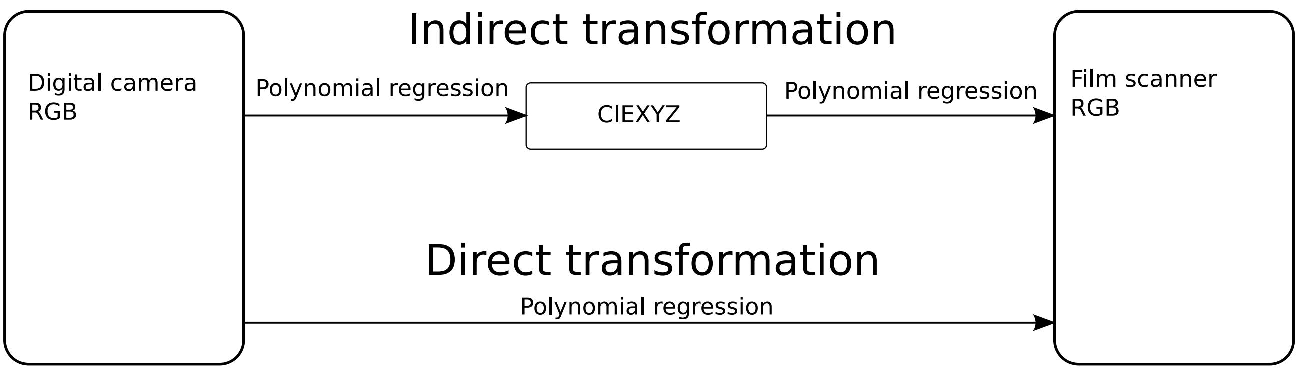

Figure 2. An overview of the direct and indirect transformations

device or film stock is used, a new set of models would have to be computed for each combination of digital camera and fikm stock. In comparison, the indirect approach only requires that a single model is constructed for each medium that is added to the process.

One of the advantages of a regression-based model is that it does not require knowledge of the parameters or the internal working of the devices used. Therefore it can be utilized independently of the calibration at the post-production laboratory, which may change as time passes. As the color correction of the still images on the set should only serve as a guideline for the laboratory, absolute color accuracy is also not required. The ability to quickly compute a new model for a any laboratory using semi-automated tools is considered more important.

The indirect transformation depends on creating regression models suitable for converting digital camera RGB into device-independent CIEXYZ values, as well as CIEXYZ to film scanner RGB. Alternatively, the direct transformation consists of a single regression model which skips the conversion to CIEXYZ and works only with the RGB values of the ColorChecker. In order to create the actual model we used the regression module available for ICC3D,[5] which performs standard least squares polynomial fitting, although at the time of the experiment there were some limitations on the choice of coefficients.

3. RESULTS AND DISCUSSION

Both the direct and the indirect approach result in simulated RGB values that must be compared with the actual RGB values from the film scanner. In accordance with the procedures that the laboratory uses for calibration of their monitors, the RGB values are converted from the Rec. 709 color space to CIELAB via CIEXYZ. We then compare the captured and simulated values by calculating the average CIELAB[6] and CIEDE2000[7] color difference for the transformations, using different orders of polynomials.

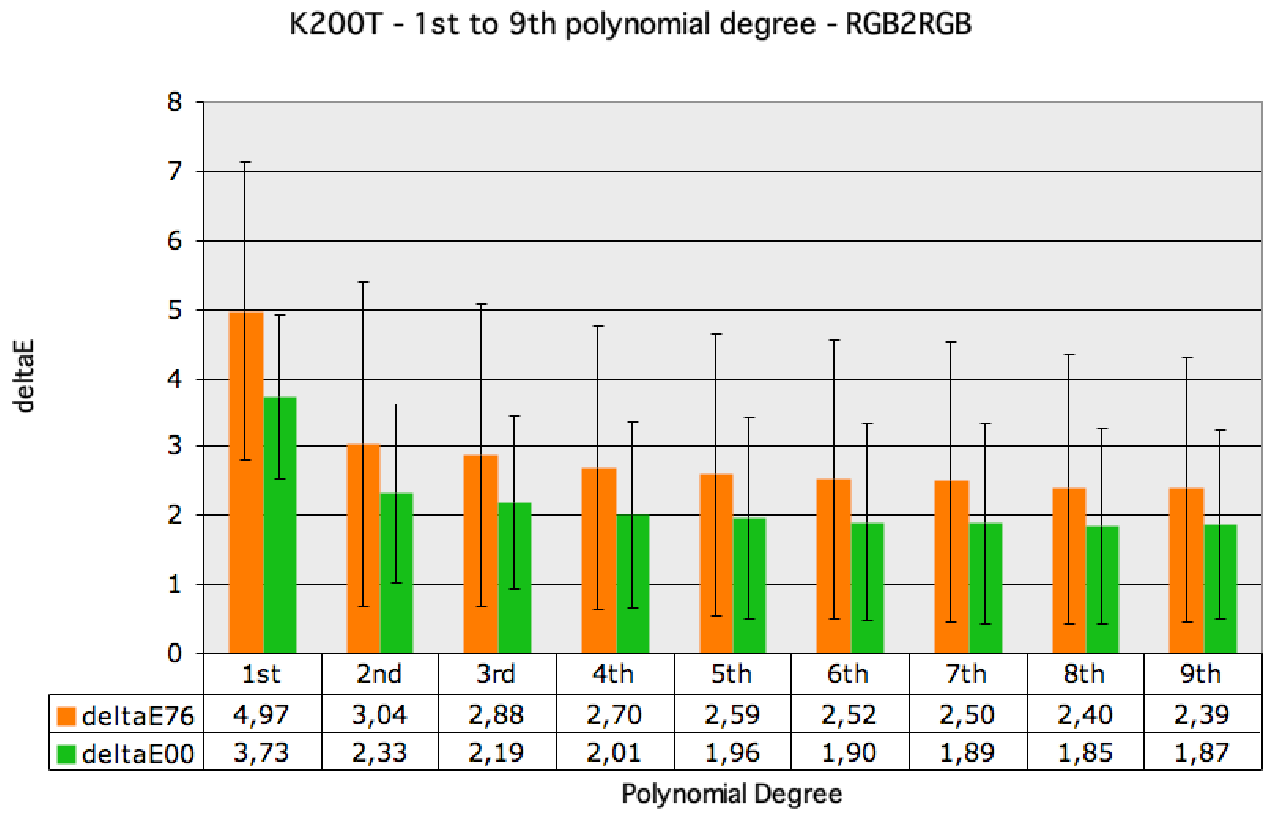

Figure 3. Average performance for direct transformation with varying polynomial order

Table 1 gives an overview of the color differences that we have calculated between the source and the reference images before any transformations were applied to them. Results in the next sections will be given for Kodak Vision II 200 Tungsten stock only. Models created for other film stocks show approximately the same results.

In Figure 3 we have depicted the performance of regression-based models from 1st to 9th polynomial order for the direct approach. While the model based on first order regression (assuming a linear relationship) performs comparatively bad, the quality of models based on higher polynomial orders (third and above) increase only very moderately. The reason for that can be seen in Figure 4. The functions show approximately the same output values in the relevant range of values between 0 and 255. Functions of higher polynomial orders will only tend to fit closer to the noise present in the data. In Figure 5 we present a visual comparison between the reference image from the film scanner and the paired image that was captured with a digital still camera and transformed with a model based on a second order polynomial. While one can still perceive some differences the illustration shows that the simulated image is quite close to what the reference looks like.

Although polynomials of varying order were tested, the results are affected by the choice of polynomial coefficients implemented in the software we used for the calculation and testing of the models. ICC3D did not use the full set of coefficients, which for a ninth order polynomial model would result in a much too complex solution. An improvement has later been made to ICC3D, allowing easier specification of which polynomial terms should be included in a model. Preliminary tests show that a colorimetrically better match should be possible using a model with a better selection of polynomial terms. The general conclusions regarding our results do not change, since the only effect is that all color differences at various polynomial orders are reduced comparatively.

The indirect approach, which basically consists of two separate transformations, leaves a greater freedom of choice for the film photographer to decide both film stock and digital camera. In Figure 6 we compare the two approaches against each other. To keep the number of possible combinations within a certain limit, we choose

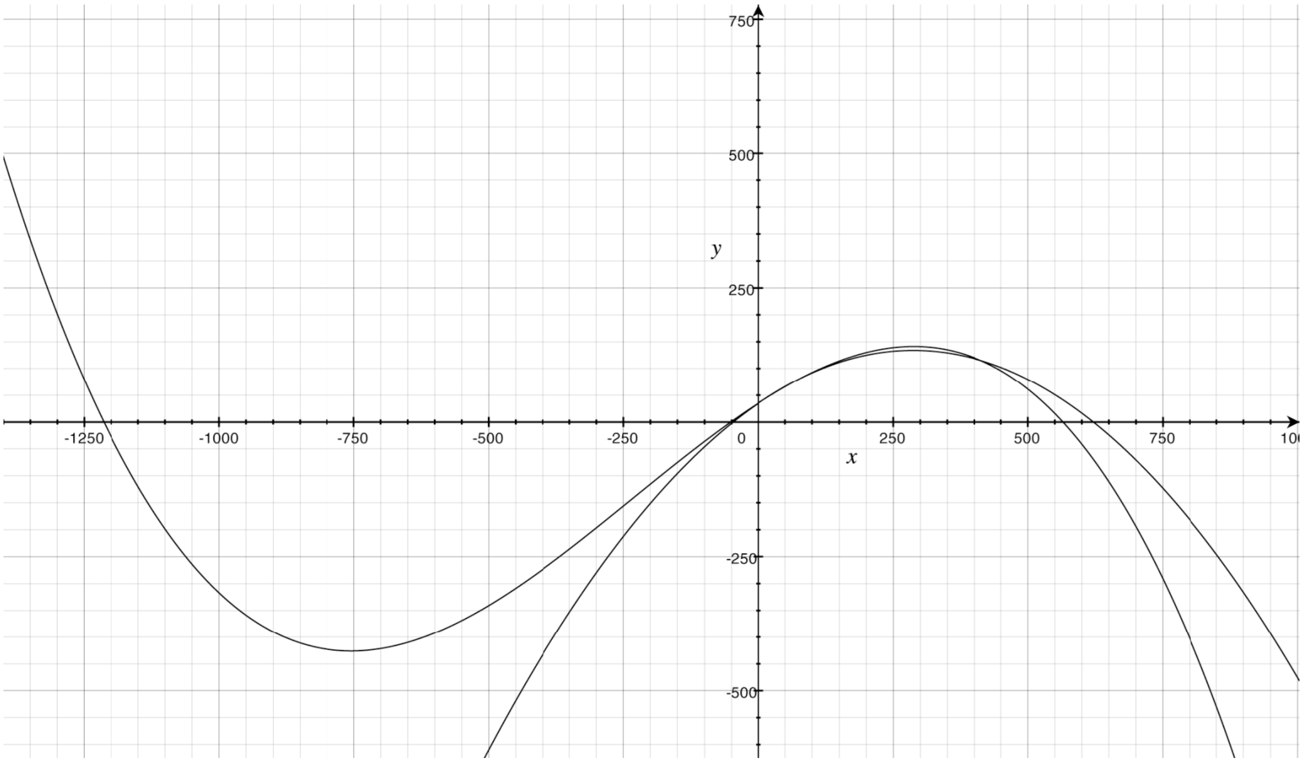

Figure 4. Second and third order polynomials fitted to the data

Figure 5. A reference image from the film scanner (left) and a still image transformed using a second order polynomial model (right)

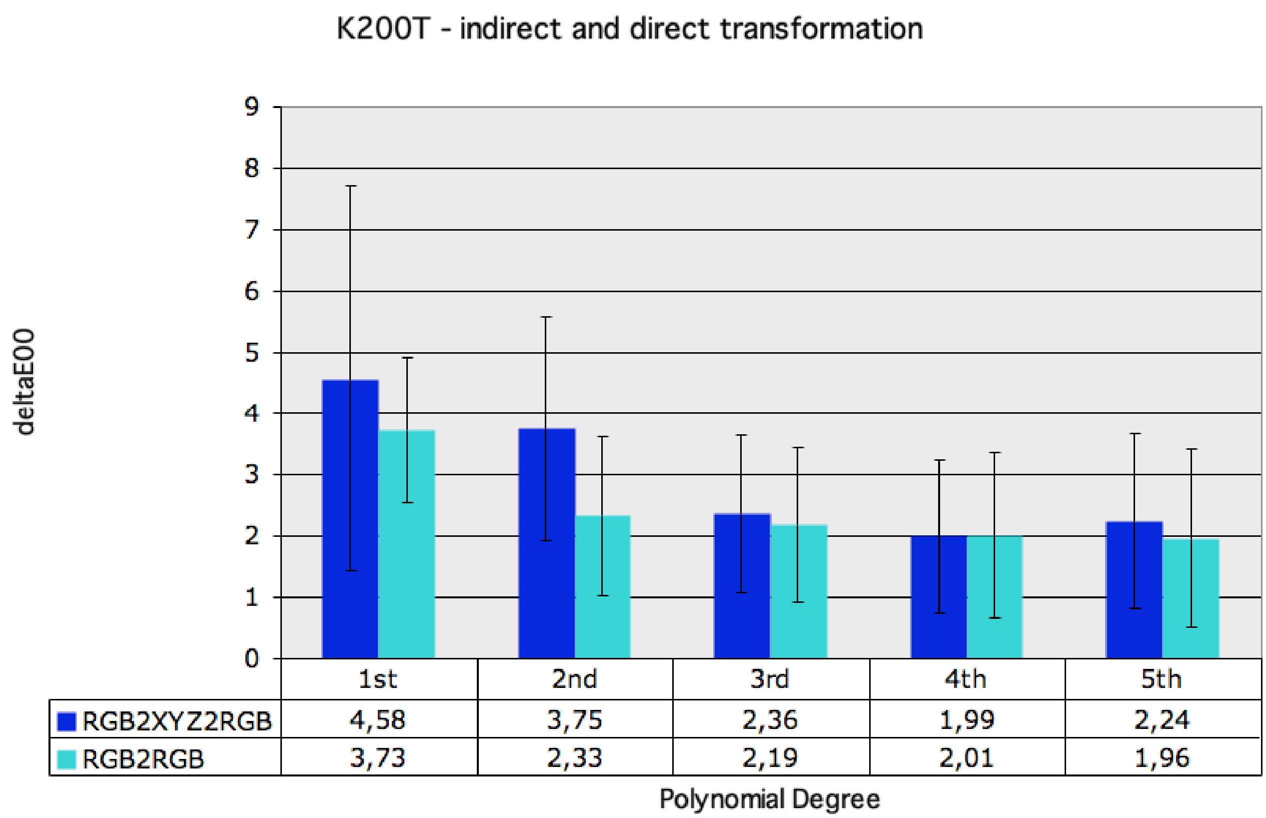

Figure 6. The performance of the direct and the indirect transformations

the same polynomial degree for both the inverse and the forward transformation. A visual comparison for the mentioned transformation is depicted in Figure 7.

The proper reproduction of the black level seems to create some problems (possibly due to non-uniform illumination of the test chart), as well as the reproduction of some of very high values, visible in the upper right corner of the sheet of paper, held by the person in the image. This, however, can be explained with the fact that the patches in the test chart do not accommodate the full range of RGB values. The model is simply not defined for the bright spots in the rest of the image. To sum this up, both approaches were also tested with a test set, showing slightly worst but still acceptable results.

The test set consisted of the patches on our custom-made, printed color chart. While this chart contains color patches covering a large part of the CIELAB color space, it is not particularly suited as a test set for the verification of our models. The color chart contains many grey patches, which should be easily modelled using polynomial regression. However, the rest of the color chart is made up of patches with a very high chromatic content. This represents a great challenge for the dynamic range of the digital still camera, and are among the colors that have the largest deviation using the regression models.

Although the ICC profile generation tools that we tested were unable to create profiles suitable for the entire transformation chain, they can still serve as a basis for comparison of the reverse transformation of the digital still camera. Figure 7 shows the performance of such an ICC profile compared with our regression model. The regression model clearly outperforms the ICC profile, which is another indication that support for camera profiles is less than optimal in standard profiling tools made for graphic arts work.

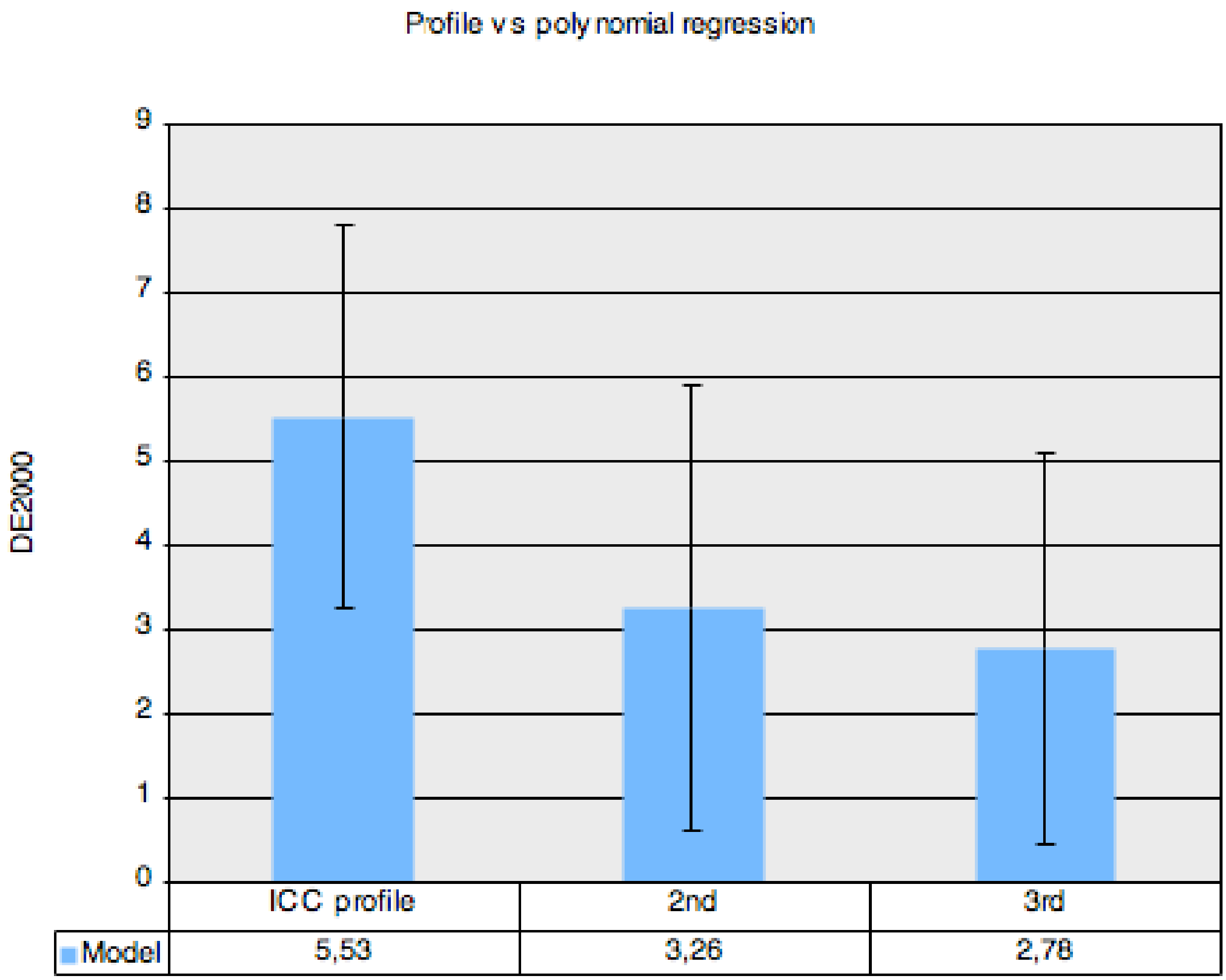

Figure 7. The reverse model of a camera ICC profile compared to a model based on polynomial regression

4. CONCLUSIONS AND FUTURE WORK

We have found that there is no straightforward method to make use of ICC profiles generated by standard print industry tools to carry out the desired transformation into an RGB color space determined by a certain type of film stock. We have tested two approaches using polynomial regression, one which performs a direct transformation similar to a device link profile from the RGB color space of the digital camera to the RGB of the film scanner given the film stock, and another which consists of separate forward and reverse models for each device configuration in the chain. As expected the indirect approach does not perform quite as good as the direct one, but still the differences are not significant enough to justify the added complexity.

The problems associated with simulating very dark and bright colors have later been reduced by adding artificial data points for the digital still camera in these areas of the color space. This leads to a model which performs slightly worse on average, since a minor compression of these high values is added. However, we consider that the advantage of avoiding these unwanted visual artifacts far outweighs the disadvantage of any reduced average model performance.

We recommend that regression-based models of second or third order be used. Alternatively, the use of an ICC profile might be considered to perform the conversion from the color space of the digital camera to CIEXYZ. Two custom profiles – one for scenes lit with tungsten light sources and another one for daylight conditions – might produce acceptable results. Future work should focus on taking advantage of the possibilities introduced by later versions of the ICC specifications, so that ICC profiles suitable for this type of work easily can be generated using standard tools.

We have started the work on a framework spesifically designed to enable the use of ICC profiles in film productions, while having more detailed control of the profile generation. By integrating state of the art gamut mapping algorithms, this should result in profiles that satisfy the need for very high color accuracy in this field. Early work on experimentation with real-time computations on the graphic card show that this might enable spatial gamut mapping[8] to be performed when previewing images on monitors and projectors.

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