EVALUATION OF COLOR GRADING IMPACT IN RESTORATION PROCESS OF ARCHIVE FILMS

FAMU
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INTRODUCTION

The **film restoration methodology** resulting in the **Digitally Restored Authorizate** (DRA)[2, 3] aims to achieve the appearance of the **digitized film** so that the audio and the visual component is as close as possible to the author's **original concept** as presented at its **premiere**.

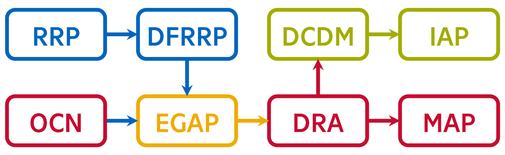


Fig. 1: Simplified diagram of DRA methodology.

Original sources (in red): Original Camera Negative (OCN), Digitally Restored Authorizate (DRA), Master Archive Package (MAP)[1]
Copies (in blue): Reference Release Print (RRP), Digital Facsimile of Reference Release Print (DFRRP)
Digital dissemination masters (in green): Digital Cinema Distribution Master (DCDM), Intermediate Access Package (IAP)[4]
Restoration (in orange): Crucial step of restoration based on estimation of the DRA utilizing the Educated Guess of Answer Print (EGAP)[2, 3]

The most important step is the **color grading** of the scanned **Original Camera Negative** (OCN) lead by the **restorer** and supported by the **group of experts**. The primary goal is to **remove all unwanted color and light tonality drifts** caused by the **aging** of the archive film.

Quantification of perceived color differences in the independent outcomes of color grading is necessary, and there are **two approaches introduced**:

- Methodology for **subjective assessment** of perceived color differences
- Techniques for **objective assessment** of perceived color differences

SUBJECTIVE ASSESSMENT

The **content for the subjective experiment** was obtained using the **DRA procedure** from the actual color movie **"Capricious Summer"**, important work of **Czechoslovak cinematography produced in 1967**.

Fig. 2: Selected test contents from the movie "Capricious Summer" (1967).

The expert group selected nine common key scenes with an average duration of about 90 s and followed by the selection of 20 particular still frames from these scenes. The resolution of these images is 4096 × 3112 pixels (4K Full Aperture "Open Gate"), with the active image area of about 3680 × 2670 pixels, i.e. with the aspect ratio of about 1:1.37.

Evaluation of **perceived color differences** among the **three complex stimuli** was performed within the **subjective experiment** in the scenario where **three outcomes of color grading** process applied to the **same film samples** are available.

(a) DFRRP w/ soundtrack (b) Group 1 (c) Group 2 (d) Group 3

Fig. 3: Comparison of the Digital Facsimile of Reference Release Print (DFRRP) of the selected test content and the three outcomes of color grading process obtained by the three independent expert groups.

Perceived difference between the color appearance of the DFRRP and the outcome of the expert groups is evident, but the differences between the groups are tiny and might be unnoticeable, especially in the printed form.

The methodology used for the subjective experiment was based on the modified **Double Stimulus Impairment Scale** method (DSIS).[13] The **two stimuli for the two selected groups** were projected in a **randomized order time sequence**. The **viewers were asked to evaluate** the **perceived difference** between the two stimuli on the projection screen.[12]

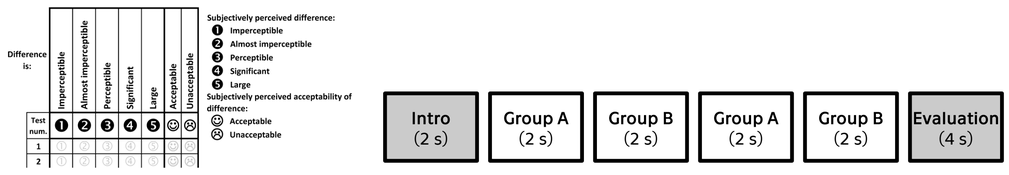
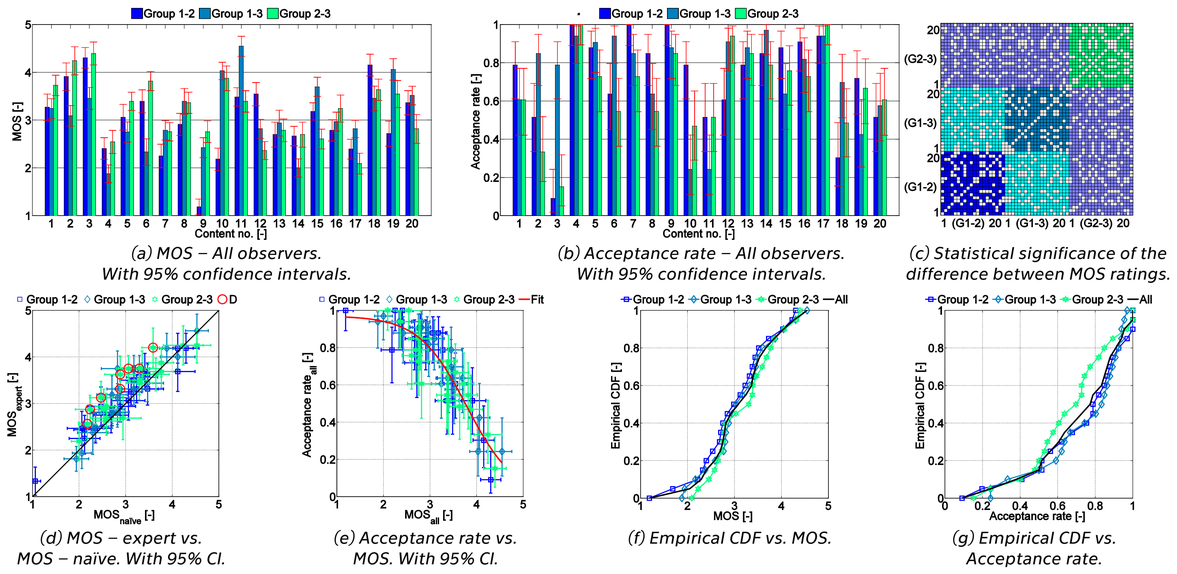


Fig. 3: Subjective experiment. The evaluation form and the phases of presentation.

The digital projector was Barco DP4K-P - digital postproduction projector with the native 4K resolution of 4096 × 2160 pixels. The projector meets the high-performance demands for postproduction, archiving, restoration and 4K color grading and is compliant with SMPTE RP431-2 standard. As the primary characteristic, the luminance in the center of the projection screen should be 48 cd/m² and chromaticity x=0.314, y = 0.351 for the white point.[5]



(a) MOS – All observers. With 95% confidence intervals.
(b) Acceptance rate – All observers. With 95% confidence intervals.
(c) Statistical significance of the difference between MOS ratings.
(d) MOS – expert vs. MOS – naïve. With 95% CI.
(e) Acceptance rate vs. MOS. With 95% CI.
(f) Empirical CDF vs. MOS.
(g) Empirical CDF vs. Acceptance rate.

Fig. 4: Subjective experiment. Selected results of statistical analysis.[13, 14]

OBJECTIVE ASSESSMENT

The **perceived difference** in images projected onto the cinematographic screen can also be assessed **objectively** based on a **computational comparison** of the two projected images with **different color** or **light tonality**.[12]

Three **conceptually different approaches were** used to obtain the **colorimetric data** in order to **assess color differences** between the images:

a) **measurement of color samples** from the projection screen using **spectroradiometer**,
b) **capturing the projected images** using **calibrated digital camera**,[12, 18, 20, 21]
c) **direct evaluation** of **source image files**.

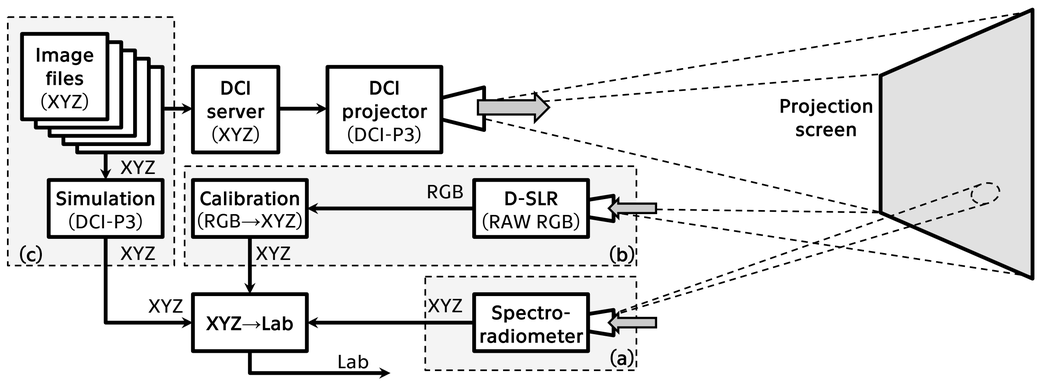


Fig. 5: Block diagram with the three techniques for colorimetric analysis of projected cinematographic images.

System (a) is based on the measurement of CIE XYZ tristimulus values in selected color samples using spectroradiometer (Photo Research SpectraScan PR-740). System (b) captures the 2D distribution of CIE XYZ tristimulus values using calibrated digital single lens reflex camera (Canon EOS 6D). System (c) is based on the calculation of CIE XYZ tristimulus values using a simulation of digital projection.

For all the **three approaches** the primary goal is to obtain **reliable colorimetric measurements** of the picture on the projection screen in device independent color space, preferably as **CIE XYZ tristimulus values**.[19]

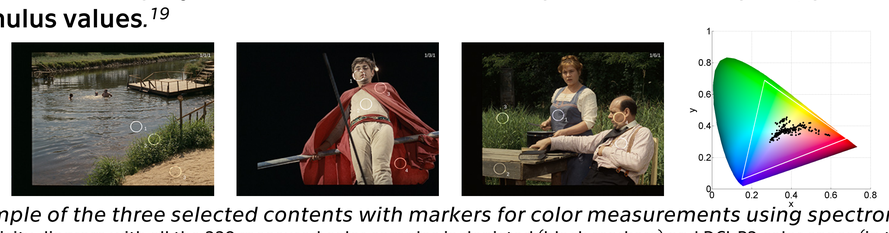
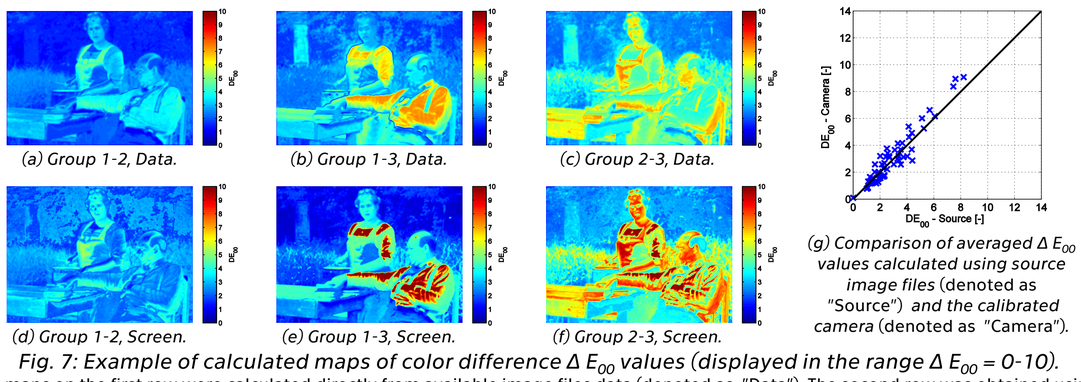


Fig. 6: Example of the three selected contents with markers for color measurements using spectroradiometer.

CIE xy chromaticity diagram with all the 228 measured color samples is depicted (black markers) and DCI-P3 color space (in the white triangle).

Spatial extension of **CIEDE2000 color difference formula**[6, 9, 22] was selected as a good performing measure to assess **perceived color difference** between two projected images. The images or color samples in **CIE XYZ device independent** color space were **transformed to CIE Lab**. Then the **CIEDE2000 color difference formula** was applied to obtain **color difference map** which was averaged to get the **overall Δ E_{00} measure**.

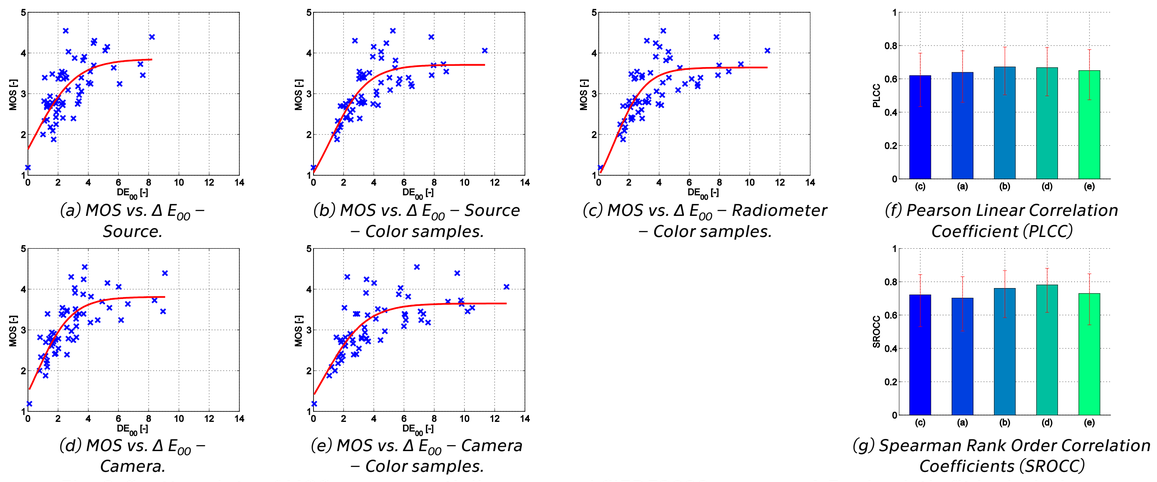


(a) Group 1-2, Data.
(b) Group 1-3, Data.
(c) Group 2-3, Data.
(d) Group 1-2, Screen.
(e) Group 1-3, Screen.
(f) Group 2-3, Screen.
(g) Comparison of averaged Δ E_{00} values calculated using source image files (denoted as "Source") and the calibrated camera (denoted as "Camera").

Fig. 7: Example of calculated maps of color difference Δ E_{00} values (displayed in the range Δ E_{00} = 0-10).

The maps on the first row were calculated directly from available image files data (denoted as "Data"). The second row was obtained using images captured by the calibrated digital camera from the projection screen (denoted as "Screen").

Performance analysis of the **objective assessment** techniques is based on the comparison of the outcome of the **subjective and objective** assessment. For each pair, **CIEDE2000 color difference** formula is used to obtain the overall **Δ E_{00} measure** of perceived color difference. Each of the **60 image pairs** has also **corresponding MOS value assigned**. Comparison of the **MOS values** and **Δ E_{00}** values can be depicted in the **scatter plots**.



(a) MOS vs. Δ E_{00} – Source.
(b) MOS vs. Δ E_{00} – Source – Color samples.
(c) MOS vs. Δ E_{00} – Radiometer – Color samples.
(f) Pearson Linear Correlation Coefficient (PLCC)
(d) MOS vs. Δ E_{00} – Camera.
(e) MOS vs. Δ E_{00} – Camera – Color samples.
(g) Spearman Rank Order Correlation Coefficients (SROCC)

Fig. 8: Scatter plots of MOS versus spatially averaged CIEDE2000 measure Δ E_{00}. Logistic fit included.

Δ E_{00} values were calculated using input data from spectroradiometer "Radiometer", from source image files "Source'", and from the calibrated digital camera "Camera". Pearson Linear Correlation Coefficient (PLCC) and Spearman Rank Order Correlation Coefficient (SROCC) calculated, with confidence intervals included. Bar graphs are denoted using the same letter as the scatter plots (a)-(e).[13, 17]

CONCLUSIONS

Presented techniques for objective assessment of perceived color differences can be used to provide **basic information** on the **visibility or acceptability** of color differences. The **performance** of the three methods by measures of prediction accuracy and monotonicity **is not ideal** and a maximum of the **SROCC** is reached at **0.781**. In our future work we will focus on **further improvement of CIEDE2000** based techniques.

References

[1] "DCI Specification, Version 1.2 with Errata." Digital Cinema Initiatives (2012). **[2]** Jícha, M. and Šofr, J., "Digitální restaurování památek filmového umění. Metoda DRA," Zprávy památkové péče 76(1), 76–90 (2016). (in Czech). **[3]** Jícha, M. et al., "Methodology of Digital Film Restoration Producing Digital Restored Authorizate (DRA)." Czech Society for Quality (2016). (in Czech). **[4]** "ISO/IEC 15444-1:2004/Amd 2:2009 Extended profiles for cinema and video production and archival applications." International Organization for Standardization (2009). **[5]** "SMPTE Standard RP 431-2:2011 D-Cinema Quality - Reference Projector and Environment." The Society of Motion Picture and Television Engineers (2011). **[6]** Ortiz-Jaramillo, B., Kumcu, A., and Philips, W., "Evaluating color difference measures in images," 2016 8th International Conference on Quality of Multimedia Experience, QoMEX 2016 (2016). **[7]** Johnson, G. and Fairchild, M., "A Top Down Description of S-CIELAB and CIEDE2000," Color Research and Application 28(6), 425–435 (2003). **[8]** Wu, H. and Rao, K., [Digital Video Image Quality and Perceptual Coding], Signal Processing and Communications, Taylor & Francis (2005). **[9]** Zhang, X. and Wandell, B., "A spatial extension of CIELAB for digital color-image reproduction," Journal of the Society for Information Display 5(1), 61–63 (1997). **[10]** Yang, Y., Ming, J., and Yu, N., "Color image quality assessment based on CIEDE2000," Advances in Multimedia 2012 (2012). **[11]** Baxter, D., Cao, F., Eliasson, H., and Phillips, J., "Development of the I3A CPIQ spatial metrics," Proc. SPIE 8293, 829302–829302–12 (2012). **[12]** Fliegel, K., Krasula, L., Páta, P., Myslík, J., Pecák, J., and Jícha, M., "System for objective assessment of image differences in digital cinema," Proc. SPIE 9217, 92170I–92170I–14 (2014). **[13]** "Rec. ITU-R BT.500-13 Methodology for the subjective assessment of the quality of television pictures." International Telecommunication Union (2012). **[14]** Brown, L., Cai, T., and DasGupta, A., "Interval estimation for a binomial proportion," Statistical Science 16(2), 101–133 (2001). **[15]** Winkler, S., [Digital Video Quality: Vision Models and Metrics], Wiley (2013). **[16]** Wang, Z. and Bovik, A., [Modern Image Quality Assessment], Synthesis lectures on image, Morgan & Claypool Publishers (2006). **[17]** De Simone, F., Goldmann, L., Baroncini, V., and Ebrahimi, T., "Subjective evaluation of JPEG XR image compression," Proc. SPIE 7443, 74430L–74430L–12 (2009). **[18]** Fliegel, K. and Havlin, J., "Imaging photometer with a non-professional digital camera," Proc. SPIE 7443, 74431Q–74431Q–8 (2009). **[19]** Sharma, G. and Bala, R., [Digital Color Imaging Handbook], Electrical Engineering & Applied Signal Processing Series, Taylor & Francis (2002). **[20]** Barnard, K. and Funt, B., "Camera characterization for color research," Color Research & Application 27(3), 152–163 (2002). **[21]** Akkaynak, D., Treibitz, T., Xiao, B., Guerkan, U. A., Allen, J. J., Demirci, U., and Hanlon, R. T., "Use of commercial off-the-shelf digital cameras for scientific data acquisition and scene-specific color calibration," Journal of the Optical Society of America A: Optics and Image Science, and Vision 31(2), 312–321 (2014). **[22]** Sharma, G., Wu, W., and Daa, E., "The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations," Color Research & Application 30(1), 21–30 (2005). **[23]** Lukac, R., [Single-Sensor Imaging: Methods and Applications for Digital Cameras], Image Processing Series, Taylor & Francis (2008). **[24]** Buil, C., [CCD Astronomy: Construction and Use of an Astronomical CCD Camera], Cognitive Development, Willmann-Bell (1991).

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