A Mixed Perceptual and Physical-chemical Approach for the Restoration of Faded Positive Films

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Abstract

Restoring color of highly degraded movies can be a challenging task. In some cases the color left is almost null. For these cases no image enhancement technique can be appropriate. If the color information is completely disappeared only impainting technique can work, but if small information is left a dye fading model can be of some help. To perform color restoration we have proposed in previous paper a perceptual approach. Since the exact original film gamut is almost impossible, or too expensive, to reproduce within digital domain, the proposed idea is to reproduce the appearance of the frames more than their exact physical properties. This is an interesting kick-off technique able to perform a great percentage of the required correction. However in some cases information left is not sufficient to obtain satisfactory results. The proposed approach prefilter the color information left with a dye fading model before applying the perceptual method. Test and results are presented.

Introduction

Film based media are strongly subject to degradation over time, unless they are stored at low temperatures and the humidity is controlled. Digital restoration methods are growing fast as an alternative solution to classic photochemical restoration methods.

Digital restoration techniques can solve a wide variety of defects: flicker, scratches, etc [1]. This paper focuses exclusively on the restoration of color. Regarding digital color restoration the classic approach is based on physical-chemical model of dye fading. The restoration, following this approach, evaluate the film situation and the amount of dyes fading and applies a color reconstruction starting from the color left.

In previous works we have proposed an alternative approach. Since, due to common wide differences in gamuts among various film support and digital display devices, rendering, the exact original physical color can be practically impossible to obtain, our proposal is to recuperate the visual appearance of the projected images more than their colorimetric values. In order to do this a computational model of human color perception is used. These models can be used as unsupervised image enhancers that modify the image following the perceptual adjustment of our vision system.

The physical-chemical approach is usually fast and reconstructs the color with a good colorimetric approximation. However it can return limited dynamic range and contrast. These problems are typically solved by post-filtering enhancement techniques. In this case perceptual and unsupervised.

This paper aims to present a mixed approach between these two methods, proposing a pipeline in which after a reconstruction of the original color by means of a dye fading model, a perceptual based image enhancer recuperates a wider dynamic and a more balanced contrast.

The model of dye fading we have implemented derives from the studies of Rudolf Gschwind [2]. It assumes a linear combination of the scanned densities in the three chromatic layers with some overlap. After the acquisition of the basic optical densities, an estimation of the fading factors is carried out. On the base of this values the chromatic layers are reconstructed [3].

The restoration pipeline

The digital film restoration process involves five main stages:

• Historical analysis: the historical and technical analysis of a film is the first important step to perform at the beginning of film restoration. It is important that with the help and advice of a curator, to find out as many facts as possible that can help the restorer to be in line with the restoration strategy chosen. For example, the kind of film, the available copies, possible editing incongruence, former restoration tests, storage conditions of the support, etc. This in order to correctly plan the following stages of acquisition and processing.

• Acquisition (Film scanning): the digitization phase by means of telecinema or film scanner, of the image impressed on the film. In this phase critical acquisition parameters are, beside the resolution, the dynamic range and the layer spectral overlap.

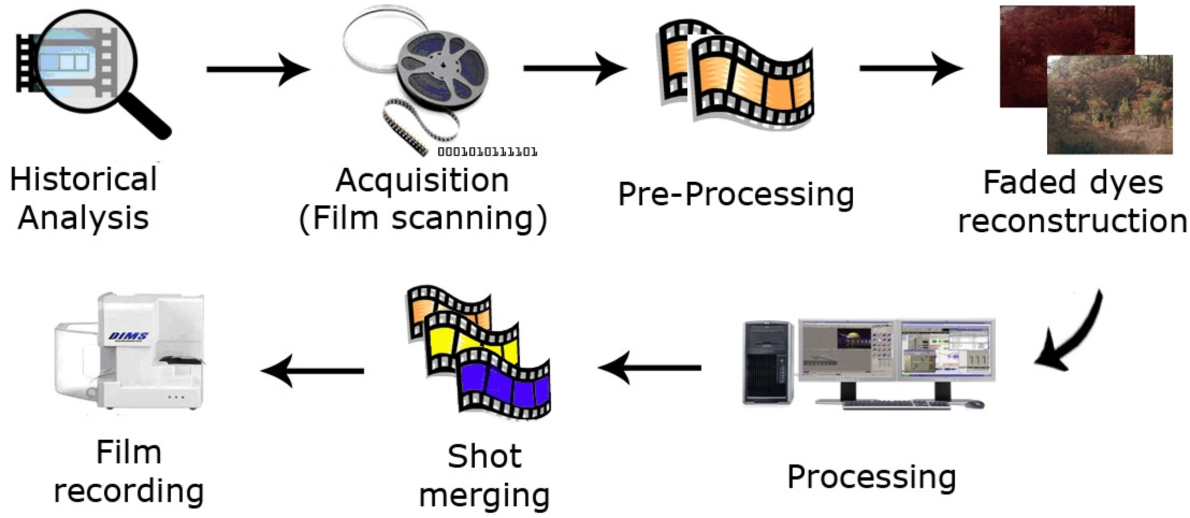
• Pre-processing: this phase removes errors (noise) introduced by the scanning. During this phase, the segmentation of the film in shots and keyframes on the basis of scene analysis is realized. This allows to perform in a simpler way the following steps.

• Faded dyes reconstruction: in this phase the dye fading model is applied to enhance the color information to filter with the perceptual model. In this preliminary proposal no automatic tuning of this phase has been performed. This will be the subject of future research.

• Processing: in this phase, parameters of ACE perceptual model are selected by the curator among a series of tests on the keyframes, and are then applied automatically on the remaining frames of the shot.

• Shot merging: in this phase all the processed shots are recombined following the original sequence, or in some case in a different order, chosen by the curator according to historical reasons. This phase has the goal to verify the smooth visual transition across the shots. If some flickering is detected, one or both shots are filtered again with different parameters.

• Film recording: this final phase records the result on film or digital support.



ACE algorithm

The chosen model of visual color perception is ACE [4,5], an algorithm for unsupervised enhancement of digital images. Inspired by some adjustment mechanisms of the human visual system, ACE, while taking into account the spatial distribution of color information, is able to correct automatically possible color casts and to expand the frame dynamic range.

However this behavior is not always a good restoring solution: there are cases in which the cast has to be maintained (e.g. underwater shots) or the dynamic range has not to be expanded (e.g. sunset or night shots). To this aim, new functions have been added to preserve the natural histogram shape, adding new effects in the restoration process. These are operative parameters that will not be discussed in this paper. For a more detailed discussion please refer to [6-9].

The implementation of ACE follows the scheme as shown in Fig. 2: the first stage, chromatic spatial adaptation is responsible for the local color correction and the second stage, dynamic tone reproduction scaling, configures the output range, and implements an accurate tone mapping. No user supervision, no statistics and no data preparation are required to run the algorithm.

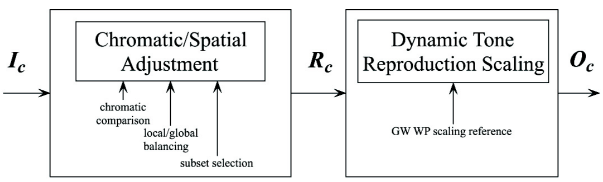


***Figure 2**. ACE basic scheme*

In Fig. 2 I is the input image, R is an intermediate result and O is the output image; subscript c denotes the chromatic channel.

The first stage, the Chromatic/Spatial adaptation, produces an output image R in which every pixel is recomputed according to the image content, approximating the visual appearance of the areas in the image. Each pixel p of the output image R is computed separately for each RGB chromatic channel c as shown in equation (1).

$$R(p) = \frac{\sum_{j \in \mathrm{Im}, j \neq p} \frac{r(I(p) - I(j))}{d(p,j)}}{\sum_{j \in \mathrm{Im}, j \neq p} \frac{Y_{\max}}{d(p,j)}} \qquad (1)$$

The second stage maps the intermediate floating point pixel array R into the final displayable output image O. In this stage, a balance between two normalization principles, gray world and white patch, is added, scaling linearly the values in R_C with the following formula

$$O_c(p) = round\,[127.5 + s_c R_c(p)]$$

where s_c is the slope of the segment $[(m_c,0),(M_c,255)]$, with

$$M_c = \max[R_c(p)]$$

$$m_c = \min[R_c(p)]$$

using M_c as white reference and the zero value in R_c as an estimate for the medium gray reference point to compute the slope s_c. A more detailed description of the algorithm can be found in [4,5].

Test and results

The images quoted in this publication are scans of original films coming from a former work carried out by Balázs Kránicz [3].

In Fig. 3a and 4a the original frames are shown and in Fig. 3b and 4b the frames restored with the dyes fading model. It is visible how the color cast is eliminated, but the frame dynamic and contrast still are unsatisfactory. Fig 3c and 4c show the frames after ACE filtering. The colors remain almost untouched, while contrast and dynamic are strongly equalized.

***Figure 3**. a) original frame, b) restored with dye-fading model, c) restored with dye-fading model + ACE*

***Figure 4**. a) original frame, b) restored with dye-fading model, c) restored with dye-fading model + ACE*

Conclusions

In this paper we have presented an improved pipeline for digital color and dynamic range restoration of faded movies. It uses a dye fading model to correct the color degradation and right after an unsupervised colour equalization algorithm, based on a perceptual approach.

This technique can be used as a complete restoration pipeline or in case of particular requirements as a kick-off procedure followed by a fine manual color correction by experts. In fact in some cases the result of the filtering can not be exactly as desired by the restoration expert, but the amount of work required to reach the final result is greatly reduced by this unsupervised and automatic processing.

The use of the dye fading model prefiltering gives promising results, here briefly reported, but needs deeper investigations and tests and will be a subject for future research.

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Author Biography

Alessandro Rizzi took degree in Computer Science at University of Milano and PhD in Information Engineering at University of Brescia. Now he is assistant professor, and senior research fellow at the Department of Information Technologies at University of Milano. Since 1990 he is researching in the field of digital imaging and vision. His main research topic is color information with particular attention to color perception mechanisms. He is the coordinator of the Italian Color Group

Lorenzo Gatti just graduated in Information Technology at the Università degli Studi di Milano, with a degree thesis “Comparison of spatial color computational algorithm for color film restoration”.

He’s working in the field of digital film restoration since 2006, when he began to study spatial color algorithms like Retinex, ACE and RSR.

Anna Jerry Berolo, was born in London and now lives in Italy, working as a programmer and web-designers and is on track to graduate in Digital Communication at the Università degli Studi di Milano. Her thesis is the "Restoration digital color." Her passion for vintage film has addressed her interest to recovery and restoration of films.

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