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Stéphane Bres
Robert Laurini (Eds.)

Visual Information and Information Systems

8th International Conference, VISUAL 2005
Amsterdam, The Netherlands, July 2005
Revised Selected Papers

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Preface

Visual Information Systems on the Move

Following the success of previous International Conferences of VISual Information Systems held in Melbourne, San Diego, Amsterdam, Lyon, Taiwan, Miami, and San Francisco, the 8th International Conference on VISual Information Systems held in Amsterdam dealt with a variety of aspects, from visual systems of multimedia information, to systems of visual information such as image databases.

Handling of visual information is boosted by the rapid increase of hardware and Internet capabilities. Now, advances in sensors have turned all kinds of information into digital form.

Technology for visual information systems is more urgently needed than ever before. What is needed are new computational methods to index, compress, retrieve and discover pictorial information, new algorithms for the archival of and access to very large amounts of digital images and videos, and new systems with friendly visual interfaces.

Visual information processing, features extraction and aggregation at semantic level and content-based retrieval, and the study of user intention in query processing will continue to be areas of great interest. As digital content becomes widespread, issues of delivery and consumption of multimedia content were also topics of this workshop.

Be on the move...

June 2005

Stéphane Bres
Robert Laurini

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Unsupervised Color Film Restoration Using Adaptive Color Equalization

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Abstract. Chemical processing of celluloid based cinematic film, becomes unstable with time, unless they are stored at low temperatures. Some defects, such as bleaching on color movies, are difficult to solve using photochemical restoration methods. In these cases, a digital restoration tool can be a very convenient solution. Unfortunately, for old movies color and dynamic range digital restoration is usually dependent on the skill of trained technicians who are able to control the parameters through color adjustment, and may be different for a sequence or group of frames. This leads to a long and frustrating restoration process. As an alternative solution, we present in this paper, an innovative technique based on a model of human color perception:, to correct color and dynamic range with no need of user supervision and with a very limited number of parameters. The method is combined with a technique that is able to split the movie into different shots and to select representative frames (key frames) from each shot. By default, key frames are used to set the color correction method parameters that are then applied to the whole shot. Due to the robustness of the color correction method the setting used for the key frame is used successfully for all the frames of the same shot.

1 Introduction

Movie chemical materials are the result of a chemically unstable process, and is subject to fading with time. This fading is irreversible and in several cases photochemical restoration of faded prints is risky and not always possible. In these cases, digital color restoration can solve the problem.

In this paper, we propose a technique for color digital restoration of faded movies based on a perceptual approach, inspired by some adaptation mechanisms of the human visual system (HVS), in particular, lightness constancy and color constancy. The lightness constancy adaptation enables perception of the scene regardless of changes in the mean luminance intensity and the color constancy adaptation enables perception of a scene regardless of changes in color of the illuminant.

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Restoring film fading and/or color bleaching can be seen as a problem of chromatic noise removal, such as color constancy mechanisms [1][2]. Consequently an algorithm is chosen for digital images that performs unsupervised enhancement, called ACE (Automatic Color Equalization) [3][4]. It provides experimental evidence in an automatic correction of the color balance of an image. Although the number of ACE parameters is very small and their tuning not critical, their setting can vary widely according to the image content and to the kind of final rendering chosen by the film director (e.g. low or high key, artistic color distortion, etc..).

2 Towards Unsupervised Restoring Parameters Tuning

To implement a standard tuning procedure, we need to extract a set of still images (key frames) that summarize the video content in a rapid and compact way.

Different methods can be used to select key frames. In general these methods assume that the video has already been segmented into shots by a shot detection algorithm, and extract the key-frames from within each shot detected. One of the possible approaches to key frame selection is to choose the first frame in the shot as the key frame [5]. Ueda et al [6] and Rui et al. [7] use the first and last frames of each shot. Other approaches include time sampling of shots at regular intervals. As an alternative approach [7], the video is time sampled regardless of shot boundaries. In [8][9] the entire shot is compacted into a small number of frames, grouping consecutive frames together, or taking frames from a predefined location within the shot. Other approaches, such as [10][11], compute the differences between consecutive frames in a shot using color histograms, or other visual descriptions, to measure the visual complexity of the shot; the key frames are selected by analyzing the values obtained. In [12][13] the frames are classified in clusters, and the key frames are selected from the larger clusters, or by hierarchical clustering reduction.

The drawbacks to most of these approaches is the number of representative frames must be fixed in some a priori method, for example, depending on the length of the video shots. This cannot guarantee that the selected frames will not be highly correlated. It is also difficult to set a suitable interval of time, or frames: large intervals mean a large number of frames will be chosen, while small intervals may not capture enough representative frames, or those chosen may not be in the right places. We apply here a new algorithm that dynamically selects a variable number of key-frames depending on the shot's visual content and complexity.

After the extraction of key frames, these images are used as a set for the parameter tuning of ACE, the chosen algorithm for color correction. By default the key frames are used to set the color correction method parameters, which are then applied to the whole shot. Due to the robustness of the color correction method the setting used for the key frames is used successfully for all the frames of the same shot.

3 ACE: Automatic Color Equalization

ACE is an algorithm for unsupervised enhancement of digital images. It is based on a computational approach that merges the "Gray World" and "White Patch" equalization mechanisms, while taking into account the spatial distribution of color information. Inspired by some adaptation mechanisms of the human visual system, ACE is able to adapt to widely varying lighting conditions, and to extract visual information from the environment efficiently.

The implementation of ACE follows the scheme as shown in Fig. 1:

first stage: chromatic spatial adaptation (responsible for color correction); and
second stage: dynamic tone reproduction scaling, to configure the output range, and implement accurate tone mapping.

No user supervision, no statistics and no data preparation are required to run the algorithm.

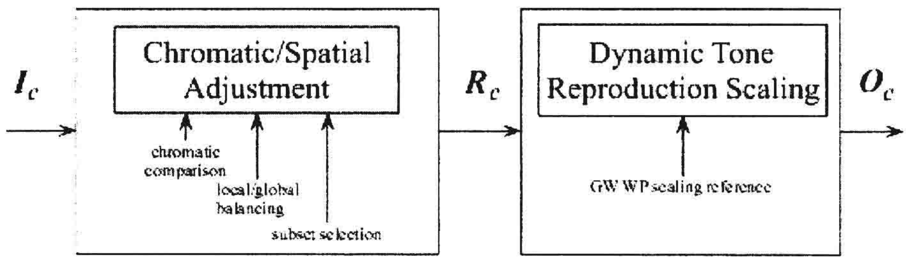

Fig. 1. ACE basic scheme

In Fig. 1 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 image. Each pixel p of the output image R is computed separately for each chromatic channel c as shown in equation (1).

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

Fig. 2 displays the used $r(\,)$ function.

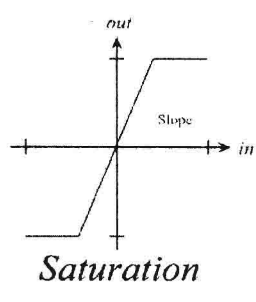

Fig. 2. $r(\,)$ function

The second stage maps the intermediate pixels array R into the final output image O. In this stage, a balance between gray world and white patch is added, scaling linearly the values in R_c with the following formula

$$O_c(p) = round[127.5 + s_c R_c(p)] \quad (2)$$

where s_c is the slope of the segment [(mc,0),(Mc,255)], with

$$M_c = \max_p[R_c(p)]$$
$$m_c = \min_p[R_c(p)] \quad (3)$$

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 [3][4].

The application of ACE for movie restoration, is not a straight forward process; several aspects have been modified or introduced in order to fulfill the technical needs of the film restoration field.

4 Color Frame Restoration

The principal characteristic of ACE is its local data driven color correction; ACE is able to adapt to unknown chromatic dominants, to solve the color constancy problem and to perform an image dynamic data driven stretching. Moreover, ACE algorithm is unsupervised and needs little involvement of the user. These properties make it suitable for film restoration, a problem in which usually there is no reference color to compare the results of the filtering, subjectivity is used to determine the pleasantness and naturalness of the final image.

Faded movie images are dull, have poor saturation and an overall color cast. This is due to the bleaching of one or two chromatic layers of the film. Since it is necessary to deal with lost chromatic information, restoring the color of faded movies is more complex than a simple color balance. The technique, presented here, is not just an application of ACE on movie images, but an enhancement of ACE principles to meet the requirements of digital film restoration practice.

ACE is used to remove possible color casts, to balance colors and to correct contrast of every single frame of the movie. This preliminary tool does not use any inter-frame correlation to improve its performance. This will be a subject for future research.

In this instance, ACE parameters have to be properly tuned and new functions have been added to achieve image naturalness, to preserve the natural histogram shape and to add new functions for the restoration process. These new functions can obtain satisfactory results even though the input frame is excessively corrupted. The new functions are:

- **Keep Original Gray** (KOG)**:** This function is devised to relax the GW mechanism in the second stage. Instead of centering the chromatic channels around the medium gray, "keep original gray" function preserves the original