Video Tonal Stabilization with Automatic Multiple Anchor Frames

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***Abstract*—This paper proposes an algorithm to fix the tone inconsistency in captured video especially by mobile devices such as smartphone and black box cameras. We propose a method to stabilize the inconsistent tone of video frames in which tone is adjusted for each frame with adjustment map using several key anchor frames.**

Keywords*— *video; tone; stabilization; anchor frame

I. INTRODUCTION

In recent years, the development of camera and video capturing technology becomes more portable where user can bring and use the device especially mobile phone and black box in car to record video across different positions and light conditions. However, captured videos usually suffer from inconsistent white balance due to automatic correction from device. This automatic white balance runs when the device adjust different color spectrum due to illumination. For instance, sun and artificial indoor illumination emit light with different color temperature. Sometimes it causes noticeable fluctuations to the exposure and color balance. Therefore, it disturbs temporal coherence of tone within capture videos. Turning off automatic exposure and automatic white balance can be an alternative to solve the problem. However, not all of the video capturing device has a control to turning off auto-exposure and white balance.

Wang and Huang has overcome this problem by using color transfer [1]. However, their basis images are selected manually and limited to only three images. Professional videographers can make consistent color balance and exposure by editing frame by frame. However, this could be a tedious job. The proposed method overcomes the problem of tonal fluctuation by utilizing adjustment map and automatic anchor frames selection. Color balance is applied in order to obtain coherent color across sequential time.

II. PROPOSED ALGORITHMS

In order to produce a tonally stabilized video in recording device, it is needed to consider adjustment of color and luminance between frames so they change coherently. Anchor frames should be selected as references to the other frames how they should be adjusted. Our algorithm is based on the previous work [2] in which they proposed a method to adjust tone based on the manually chosen key frames to create smooth changes between frames. The overview of our algorithm is shown in Fig. 1. Our algorithm is described as follows.

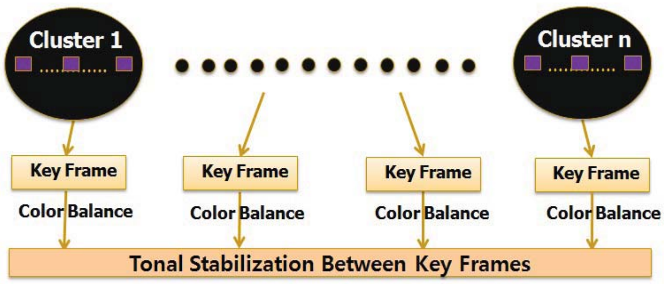

Fig. 1. Overview of the proposed method.

A. *Frames Clustering and Key Frames Extraction*

Video is composed of several frames f_i $(1 \le i \le n)$ with a continuously moving scene. They can be clustered to make several groups with corresponding key frames. Clustering is the initial process of extracting key frames. In our approach, average color of each frame is used as the feature vector of the frame and *K*-means clustering is utilized to group the frames into clusters. The number of cluster *K* is obtained as explained in [3] as follows.

$$K \approx \sqrt{n/2} \tag{1}$$

where n is the total number of frames. Each cluster has its mean color value as μ_i . The key frame F_i of cluster i is selected by finding the frame which has the closest mean color to μ_i . Note that the clustering process should align with the time sequence of the video.

B. *Color Balance*

Each extracted key frame possibly suffers from inconsistent tone. It occurs because automatic white balance and illumination source change in video frames. A color balance algorithm such as grey-world hypothesis [4] can be used to overcome this problem. Grey-world hypothesis assumes the average reflectance of a scene is achromatic. Grey-world color normalization in (2) is invariant to illuminated color variations.

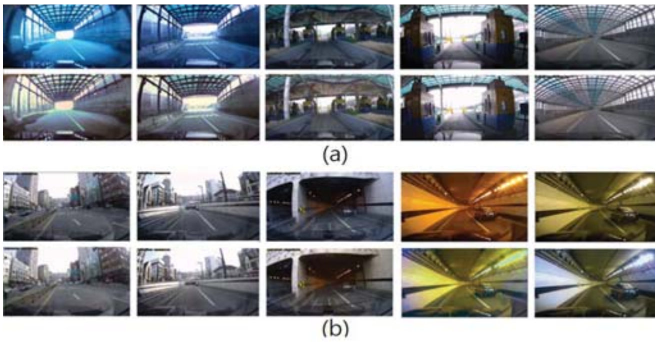

Fig. 2. Result comparison (a) First video. (b) Second video. Top : Original video. Bottom : Result of the proposed method.

$$(R',G',B') = \left(\frac{\sum R}{\sum R + \sum G + \sum B}, \frac{\sum G}{\sum R + \sum G + \sum B}, \frac{\sum B}{\sum R + \sum G + \sum B} \right) \quad (2)$$

C. Tonal Stabilization

The proposed tonal stabilization method is based on Farbman *et al*. [3] in the Lab color space. Firstly, in order to reduce the noise, each frame needs to be smoothed with 5×5 bilateral filter. In their implementation they use adjustment map A_i to gradually change the white balance in (3).

$$A_{i+1}(x) = \begin{cases} A_i(x) + (f(x) - f_{i+1}(x)) & foreach\, x \in R_{i/i+1} \\ 0 & otherwise \end{cases} \quad (3)$$

where,

$$R_{i/i+1} = \{ x \mid (L_i(x) - \overline{L_i}) - (L_{i+1}(x) - \overline{L_{i+1}}) < 0.05 \} \quad (4)$$

$R_{i/i+1}$ in (4) is the set of pixels with small difference between consecutive frames by calculating the difference of luminance L_i from image f_i . $\overline{L_i}$ denotes the mean value of luminance channel of the particular frame. The zero values in the adjustment map A_{i+1} can be interpolated using nonzero neighboring pixels to obtain the interpolated adjustment map A'_{i+1} . Note that χ is zero if A_{i+1} is zero, while χ is one if A_{i+1} is nonzero with the distribution using Gaussian function G .

$$A'_{i+1}(x) = \frac{\sum_{r=0}^{N} G(x, x_r) A_{i+1}(x_r)}{\sum_{r=0}^{N} G(x, x_r) \chi_{A_{i+1}}(x_r)} \quad (5)$$

III. EXPERIMENTAL RESULTS

In our implementation, Itronics ITB-100HD black box is utilized to capture the videos. This device is able to adjust its white balance and dynamic range automatically. Each frame in video has 1920×1080 resolution and adjustment map is processed in four times lower resolution. Using C++ and OpenCV, the processing time for each frame is about 1.4 seconds and only adjustment map processing is processed on GPU. CPU and GPU in our experiment are 3.5 GHz Intel Core i7 processor and NVIDIA GeForce GTX 680, respectively.

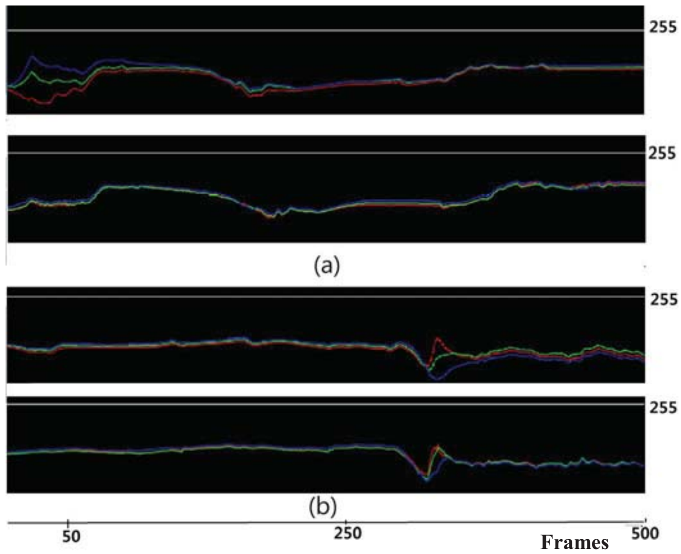

Fig 3. Histogram comparison before and after the tonal stabilization. (a) Histogram over time (first video). (b) Histogram over time (second video). Top : Histogram of original video. Bottom : Histogram of processed video.

In Fig. 2, it is shown that processed frames yield stabilized tone among frames. Fig. 3 shows stabilized average RGB color composition across time sequence in video in the form of the histogram. It is shown that the original video has tone fluctuation while the video processed with the proposed method has stabilized tone.

IV. CONCLUSION

In this paper, we have presented tonal stabilization with automatically choosing key frames as anchor frames. Practical application for black box videos can be applied to stabilize their tonal fluctuations.

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