A NEW IMAGE CORRECTION METHOD FOR MULTIVIEW VIDEO SYSTEM

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ABSTRACT

Because of scene illumination or camera calibration, color appearance of the same object between different viewpoints may be different in multiview video system. Traditional illumination compensation algorithm for image is unable to solve this problem effectively. In this paper, a novel color correction method for multiview video system is proposed based on retinex color constancy theory. To eliminate influence of un-consistent light sources, histogram equalization, retinex processing and color restoration are performed for multiview images to extract reflectance that describes object intrinsic properties. Experimental results show that the proposed image correction method for multiview video system is effective.

1. INTRODUCTION

Multiview image processing will have many applications, such as free viewpoint television because of its arbitrary acquisition of different viewpoint position information of the same scene[1]. Two key tasks of multiview video systems are data compression and viewpoint rendering, and image-based rendering (IBR) is the main technique to realize multiview video system[2-4]. The rendering operation is based on the common hypothesis that the scene is static, and rendering is just to change the viewpoint position or direction to scan the scene. IBR method usually uses multiple viewpoint images to render new viewpoint image. Clearly, to obtain perfect intermediate viewpoint rendering, it is necessary for the corresponding multiple viewpoint images to have consistent color appearance.

Color appearance of an object depends not only on the reflectance properties of its surface but also the lighting and the properties of the imaging devices. Even if we do not change the lighting and imaging device (shutter speed and aperture), unnatural variations of the color appearances of the object may also occur between different viewpoint images. These variations perhaps come from the CCD noise, jitter or shutter speed and aperture, or the variation of angle between light source and camera.

The purpose of multiview image correction is to balance the color appearance of different viewpoint images about the same scene or object. For single viewpoint images, luminance compensation has been already used to eliminate brightness variety influence in video coding[5-6]. But for multiview images, the contents of inter-view images will be different (considering occlusion or viewpoint interval), and luminance compensation cannot effectively eliminate the influence of color un-consistence between viewpoint images. In this case, research on effective color correction is necessary to be paid attention to.

In this paper, a novel multiview image correction method is proposed based on retinex color constancy theory. We first recover the illumination information from an image of a scene, and then reproduce an illuminant invariant image, in which the color distortion, caused by inhomogeneous illumination, is corrected. Experimental results show that the corrected images, obtained by the proposed method, not only have high color contrast, but also have consistent color appearance with reference image.

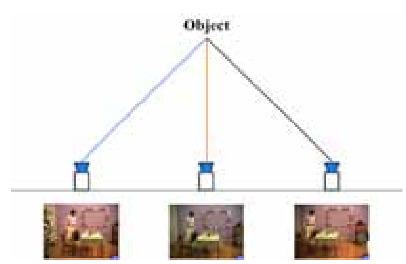


Fig.1 An example of multiview image capture with three viewpoints.

2. MULTIVIEW IMAGE CORRECTION METHOD

Fig.1 depicts an example of multiview images capture with three viewpoints, provided by KDDI Corp.[10]. Due to non-consistent lighting or imaging device, the color of the middle view is different from the others. Therefore, a color correction process is necessary before viewpoint interpolation is performed for rendering.

A color correction algorithm for multiview images is proposed as shown in Fig.2. It is composed of three main steps, histogram equalization, retinex processing and color restoration. Histogram equalization is first performed for multiview images, followed by bright and dark retinex processing for equalization images, respectively. Finally, color restoration is carried out to achieve the color correction.

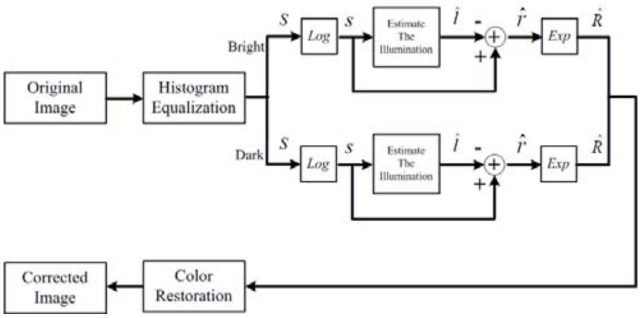


Fig.2 The proposed multiview image correction algorithm.

Sometimes rare colors in an image occupy a relatively large portion of the color space, while the more frequent colors in a smaller portion of the color space. Histogram equalization is a color transformation that creates an image with a uniform histogram to eliminate the nonuniformity. Histogram transformation is described as $H_E(g)=\sum_{i=0}^{g}h(i)$, $h(i)$ is histogram of image, $H_E(g)$ is called the accumulated histogram of the image.

Human vision system can adapt to the change of light source, and eliminate uneven lighting effect and only reserve corresponding information describing intrinsic properties of object, such as surface reflectance. Then, these intrinsic properties deliver to human brain cortex, through complex information processing, and finally form human vision. The human's ability is called as color constancy[7]. Here, color constancy theory is used to separate light source and surface reflectance from color information. Thus, color image can be described as

$$\rho_k(x,y)=\int E(x,y,\lambda)S(x,y,\lambda)R_k(\lambda)\mathrm{d}\lambda \quad (k=1,2,3) \quad (1)$$

where $E(x,y,\lambda)$ denotes the power spectral distribution of the viewing illumination, $S(x,y,\lambda)$ denotes the surface spectral reflectance of the object, and $R_k(\lambda)$ is the spectral sensitivity of k^{th} color channel of camera sensors. From formula (1), it is clear that changing either the surface reflectance function or the power spectral distribution of the illumination will change the value recorded by the imaging device.

A number of algorithms have been proposed for the purpose of color constancy. Land first proposed retinex theory attempting to develop a computational model for color constancy[8]. The goal of retinex is to decompose a given color image S into a reflectance image R and an illumination image L, thus, at each point (x,y) in the image domain, $S(x,y)=R(x,y)\cdot L(x,y)$. The illumination image L determines the maximum dynamic of an image and the reflectance image R determines intrinsic properties of color image. By transforming the image to the logarithm domain, we get $s=\log S$, $l=\log L$, and $r=\log R$, and thereby $s=l+r$. In this paper, we adopt Kimmel retinex algorithm[9], a compensation functional $F(l)$ is based on the below assumptions

Minimize:

$$F(l)=\int_{\Omega}(|\nabla l|^2+\alpha(l-s)^2+\beta|\nabla(l-s)|^2)dxdy$$

Subject to: $l \geq s$, and $\nabla l \cdot \vec{n}=0$ on $\partial\Omega$

where Ω is the support of the image, $\partial\Omega$ is boundary, and $\vec{n}$ is the normal to the boundary. α and β are free non-negative real parameters. In the functional $F(l)$, the first penalty term $|\nabla l|^2$ gets spatial smoothness on the illumination image. This choice of smoothness penalty is natural, if we keep in mind that minimizing $\int(\nabla l)^2dxdy$ translates into the Euler-Lagrange equation $\nabla l=0$. The second penalty term $(l-s)^2$ denotes a proximity between l and s. This term is weighted by the free parameter α. The main objective of this term is a regularization of the problem that makes it better conditioned. The third term represents a Bayesian penalty expression. It forces the reflectance image r to be a visually pleasing image. This term weighted by the free parameter β penalizes gradients in r and forces it to be spatially smooth.

The retinex process is used over the image and its inverse, to produce the bright retinex image and the dark retinex image, which should be combined together. We have tried a lot of combination schemes, and the scheme, with the ratio of 0.35 bright retinex image to 65% dark retinex image, will achieve better visual result.

After the above bright and dark retinex processing, dynamic ranges of the processed images will be restrained, thus, a color restoration needs to be performed, which is a non-linear processing. Traditional color restoration only takes the original image of the current viewpoint as reference information. But for multiview image, because of the large color difference between different viewpoint images, inter-view information must be used. Here, we regard one viewpoint image as a reference viewpoint image, and restore other viewpoint images to get consistent color appearance with the reference.

For the reference viewpoint image, color restoration is described by

$$R'_k=R_k\cdot\log\left(D+CI_k/\sum_{i=1}^{3}I_i\right) \quad (k=1,2,3) \quad (2)$$

For other viewpoint images, color restoration can be described by

$$R'_k=R_k\cdot\log\left(D+CI_k/\sum_{i=1}^{3}I_i\right)\cdot\lambda_k \quad (k=1,2,3) \quad (3)$$

Here, I_k is the k^{th} color channel of the original image, R_k is the k^{th} color channel of the retinex processing image, D and C are constants, and D=1, C=3 in this paper. λ_k is defined as inter-view color variation factor, $\lambda_k = Mean_k^{\text{ref}} / Mean_k^{\text{curr}}$, where, $Mean_k^{\text{ref}}$ and $Mean_k^{\text{curr}}$ are the k^{th} channel means of the original reference viewpoint image and the original current viewpoint image, respectively.

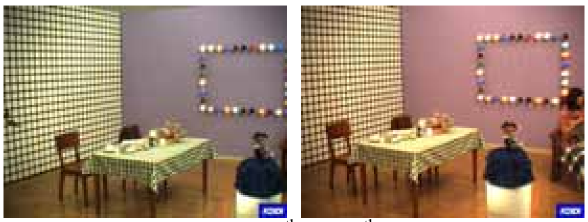


Fig.3(a) Original images of 1th and 3th viewpoints in object3

Fig.3(b) Corrected images of 1th and 3th viewpoints in object3

Fig.4(a) Original images of 1th and 3th viewpoints in flamenco1

Fig.4(b) Corrected images of 1th and 3th viewpoints in flamenco1

3. EXPERIMENTAL RESTULTS

In the experiments, multiview video sequences, 'objects3', 'flamenco1', 'race1' and 'golf1', provided by KDDI Corp[10], are used as test sets, the size of which is 320×240. The multiview images were taken by a horizontal parallel camera configuration with eight viewpoints and 200mm camera interval. Figs.3-6 show the original images and the corrected images of the 1th and 3th viewpoints in objects3, flamenco1, race1 and golf1 test multiview images, respectively. Here, we consider the 1th viewpoint image as the reference viewpoint image, and correct the 3th viewpoint images so as to obtain consistent color appearance with the reference. Clearly, the corrected images in the figures have almost consistent color appearance.

Fig.5(a) Original images of 1th and 3th viewpoints in race1

Fig.5(b) Corrected images of 1th and 3th viewpoints in race1

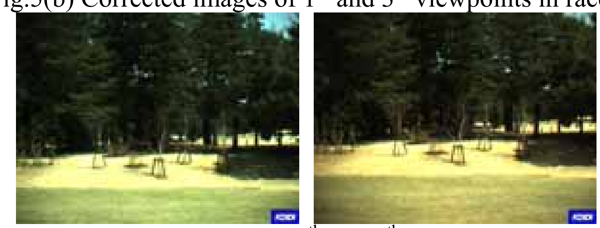


Fig.6(a) Original images of 1th and 3th viewpoints in golf1

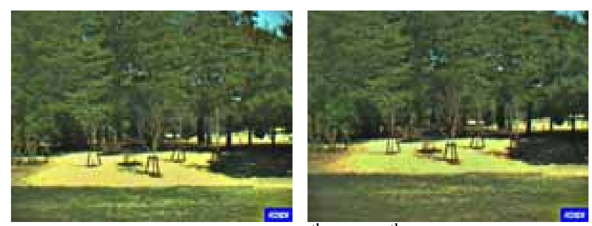


Fig.6(b) Corrected images of 1th and 3th viewpoints in golf1

In order to objectively evaluate color correction effect, we define Euler distance, between reference image and other viewpoint image, as an evaluation function. Firstly, we transform RGB color space to normalized rg space, then get Euler distance $D_{1,2}$ as follows

$$r = R/(R+G+B) \tag{4}$$

$$g = G/(R+G+B) \tag{5}$$

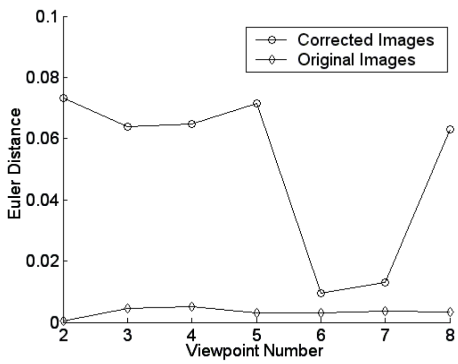
$$D_{1,2} = \sqrt{(\overline{r}_1 - \overline{r}_2)^2 + (\overline{g}_1 - \overline{g}_2)^2} \tag{6}$$

where $\overline{r}_1$, $\overline{g}_1$ and $\overline{r}_2$, $\overline{g}_2$ are the mean of r and g with respect to reference image and other viewpoint image before or after correction.

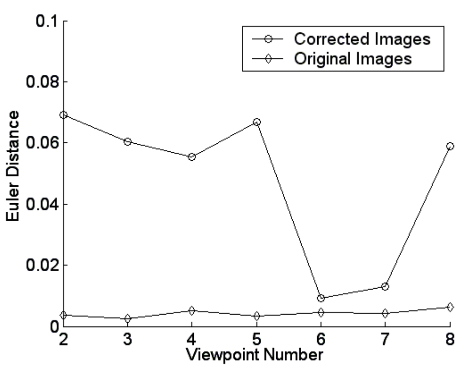
In Fig.7, Euler distances of original images and Euler distances of the corrected images compared with reference image are given. Obviously, the Euler distances of the corrected images are much smaller than those of original images, and Euler distances of the 6th and 7th viewpoint images with respect to the corrected images and original images are very close because the original 6^{th} and 7^{th} viewpoint images have consistent color with the reference image. It also shows that the proposed color correction algorithm is quite effective.

4. CONCLUSIONS

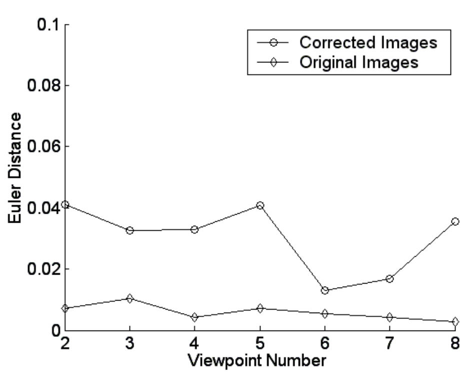
Color non-consistence between views is the main problem in multiview video system. In this paper, we have proposed a correction method of balancing the color appearance of multiview images based on the retinex theory. The experimental results show the effective of our method. The farther work may focus on more effective color space and objective evaluation methods of image quality.



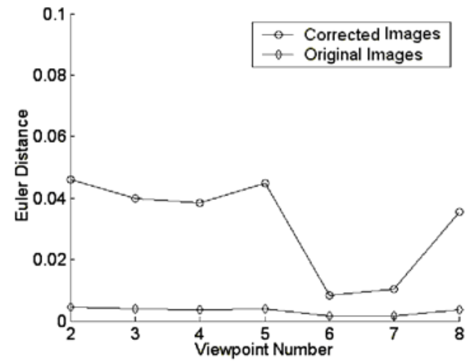
(a) Euler distance of object3



(b) Euler distance of flamenco1



(c) Euler distance of race1



(d) Euler distance of golf1

Fig.7 Comparison of Euler distances of the original images and Euler distances of corrected images.

ACKNOWLEDGEMENT

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