Color Correction Using 3D Multiview Geometry

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ABSTRACT

Recently, many 3D contents production tools using multiview system has been introduced: e.g., depth estimation, 3D reconstruction and so forth. However, there is color mismatch problem in multiview system and it can cause big differences for the final result. In this paper we propose a color correction method using 3D multi-view geometry. The propose method finds correspondences between source and target viewpoint and calculates a translation matrix by using a polynomial regression technique. An experiment is performed in CIELab color space which is designed to approximate an human visual system and proposed method properly corrected the color compare to conventional methods. Moreover, we applied the proposed color correction method to 3D object reconstruction and we acquired a consistent 3D model in terms of color.

Keywords: color correction, correspondence matching, 3D warping, polynomial regression

1. INTRODUCTION

Recently, interests on three-dimensional (3D) image is increasing day by day. 3D image gives some feeling that real objects are seemed to exist in our view through the sense of the depth. It extends its active areas into education, advertisement, movie and medical. For practical example, in the education field, education materials promotes understanding and in the film industry, a lot of 3D movies are produced by using 3D contents production tools so that it increases interests for 3D movie. Moreover, in the Brazil World Cup 2014, a goal line detector was used to determine whether a ball goes over the goal line or not so that referees can make a decision rapidly[1].

Multiview camera system is employed in various specific field for 3D image processing. For example, it can be used for a depth estimation technique. Usually, the depth estimation is divided into two main parts: active and passive sensor based method. The passive sensor based method, especially stereo matching, employs the multiview color images for the depth estimation. Stereo matching is to acquire depth information by using texture comparison as a block unit from a pair of color images. However, color images obtained from the multiview system include illuminance variation and noise resulting from image sensors. Since the relationship of the color among color images affects the performance of the stereo matching, to obtain accurate disparity is very hard when color images have a quite different color relation. Moreover, we can perform 3D reconstruction which represents real objects into a virtual space by using color and depth images from a multiview. If color differences from each viewpoint influences the 3D reconstruction, then we may get the object which shows an unnatural color consistency.

In order to solve the color mismatch problem in multiview color images, many kinds of methods have been proposed. As a well-known color correction method, there are histogram matching and global color transfer methods. A histogram matching method acquires the histograms from each viewpoint and adjusts the histogram distribution of the target viewpoint along with that of the source viewpoint. Global color transfer method proposed by X. Xiao is also one of the color correction method. It considers pixel values in a target viewpoint as 3D statistic variables and sets image as a sample space. Then it obtains a correlation among three color component (RGB) by using a covariance. After acquiring a translation matrix by using singular value decomposition (SVD), we can adjust a target image by applying this translation matrix on it[2].

In this paper, we employ 3D multiview geometry to solve the color correction problem. First, we obtain color and depth images from source and target viewpoint as an offline process. Next, we find correspondences between source and target viewpoint by using 3D warping. After eliminating the outliers resulting from occlusion and disocclusion, we can get mathematical relationship between correspondences by using a polynomial regression technique. Through the proposed method, we can find translation matrices which can correct color values excluded in correspondences. Finally, we can correct the color consistency for all pixels in target viewpoint by using this translation matrix.

2. PROPOSED COLOR CORRECTION METHOD

Proposed method adjusts color images in multiview camera system by using 3D geometric structure. Figure 1 shows the flowchart of the proposed method.

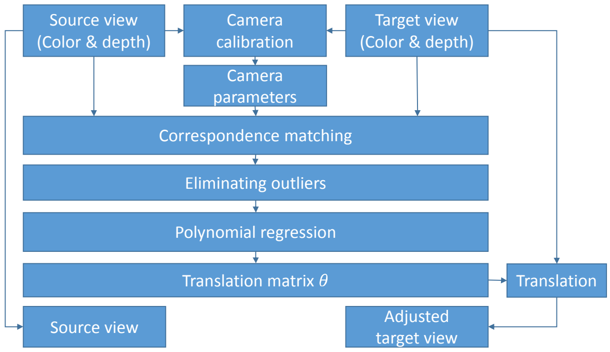

Figure 1. Flowchart of the proposed method

First, we perform a camera calibration step for multiview images as an offline process. The camera calibration means acquisition process for intrinsic and extrinsic parameters. After capturing the multiview color images for planar chessboard pattern from each viewpoint, then we acquire the parameters by using Matlab calibration toolbox .

Next, we obtain color and depth images from each camera at target and source viewpoints. After that, we can employ 3D image warping translating depth information from source to target image viewpoint to find correspondences between two images. After eliminating outliers generated from the occlusion in the correspondences, the translation matrix θ can be acquired by polynomial regression technique. Finally, we can get color corrected images by applying this translation matrix to all pixels in a target viewpoint image.

3. CORRESPONDENCE MATCHING

Correspondence matching is to find same point in both source and target viewpoint images. We employ 3D image warping as a correspondence matching method. 3D image warping is to forward depth information in a source viewpoint to a target viewpoint which we want to observe via the world coordinate. Through this technique, we can find correspondences between two viewpoints. Before the 3D image warping process, we need to acquire intrinsic and extrinsic parameters by employing the camera calibration step. In this paper, we captured calibration sequences by using a planar chessboard pattern and obtained the parameters by Matlab calibration toolbox[3]. Figure 2 illustrates the 3D warping[4].

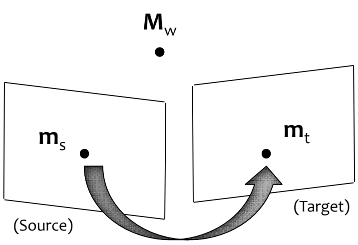

Figure 2. 3D image warping

First, we operate Eq. (1) to forward a pixel m_s in a source 2D viewpoint to 3D world coordinate.

$$\mathbf{M_W} = \mathbf{R_s^{-1} A_s^{-1} \tilde{m}_s} - \mathbf{R_s^{-1} t_s} \tag{1}$$

In this equation, the matrix **A** represents an intrinsic parameter. The matrix **R** and **t** represent a rotation and translation matrix in an extrinsic matrix respectively. The subscript **s** and **t** means source and target viewpoints respectively. Lastly, $\mathbf{\tilde{m}}$ represents a position at 2D plane as a homogeneous coordinate by using the corresponding depth value. Then we can know what is the corresponding point to $\mathbf{m_s}$ in 3D world coordinates.

Next, we operate Eq. (2) to send a pixel moved to 3D coordinates to a target viewpoint.

$$\mathbf{\tilde{m}_t} = \mathbf{A_t R_t M_W} + \mathbf{A_t t_t} \tag{2}$$

By using Eq. (1) and Eq. (2), we can construct Eq. (3) that obtains a pixel position at a target viewpoint corresponding to that of a source viewpoint.

$$\mathbf{\tilde{m}_t} = \mathbf{A_t R_t R_s^{-1} A_s^{-1} \tilde{m}_s} - \mathbf{A_t R_t R_s^{-1} t_s} + \mathbf{A_t t_t} \tag{3}$$

Finally, we can find correspondences to calculate a mathematical relationship for color.

4. POLYNOMIAL REGRESSION

The regression analysis, usually used in statistics, is a method that calculating a relation between dependent and independent variables from an observation. Especially, the polynomial regression represents those relation as a polynomial equation. Hence, it shows the relation naturally even though they are non-linearly related.

In this study, we construct a relation for r (red), g (blue) and b (blue) values between source and target viewpoints. First, we make a vector $\mathbf{X_r}$ and $\mathbf{Y_r}$ like Eq. (4) to employ the polynomial regression for the red value in a target viewpoint[5].

$$\mathbf{X_r} = \begin{bmatrix} 1 & r_{s1} & r_{s1}^2 & r_{s1}^3 & r_{s1}^4 & r_{s1}^5 \\ 1 & r_{s2} & r_{s2}^2 & r_{s2}^3 & r_{s2}^4 & r_{s2}^5 \\ & & & \vdots & & \\ 1 & r_{sn} & r_{sn}^2 & r_{sn}^3 & r_{sn}^4 & r_{sn}^5 \end{bmatrix}, \ \mathbf{Y_r} = \begin{bmatrix} r_{t1} \\ r_{t2} \\ \vdots \\ r_{tn} \end{bmatrix} \tag{4}$$

Where r means a red value for a pixel in a source viewpoint and a subscript *sn* means a pixel in a source viewpoint as n-th correspondence. Likewise, a subscript *tn* means a pixel in a target viewpoint. And then, we can find a translation matrix $\boldsymbol{\theta}_\mathbf{r}$ for the red value by using a normal equation method like Eq. (5).

$$\boldsymbol{\theta}_{\mathbf{r}} = \left(\mathbf{X}_{\mathbf{r}}^{\mathbf{T}}\mathbf{X}_{\mathbf{r}}\right)^{-1}\mathbf{X}_{\mathbf{r}}^{\mathbf{T}}\mathbf{Y}_{\mathbf{r}} \tag{5}$$

Finally, getting translation matrix $\boldsymbol{\theta}_{\mathbf{r}}$, we can adjust color values for all pixels even it was not include in correspondences. Therefore, when we apply this process to green and blue values, we can acquire translation matrices $\boldsymbol{\theta}_{\mathbf{g}}$, $\boldsymbol{\theta}_{\mathbf{b}}$.

5. EXPERIMENTAL RESULTS

The experimental environment is as follows. For getting color and depth images at each view, we employed triple Kinect cameras. We arranged it in front of the scene as a convergence form. The size of color and depth image is 640×480. We captured Munsell color chart from X-Rite to compare the color differences among images[6]. Table 1 shows a comparison among original, conventional and proposed images.

Table 1. Image sequences for color correction methods

	Target viewpoint 1	Source viewpoint	Target viewpoint 2
Original images			
Global color transfer			
Histogram matching			
Proposed method			

When we compare original images, the target images show a darker result than the source image. We compare it with results of the conventional methods such as global color transfer and histogram matching. The result of each method shows brightened colors according to a source viewpoint. However, it is hard to determine which method shows a better result. Therefore, we perform a qualitative evaluation on it and Figure 3 shows the flowchart of the proposed evaluation.

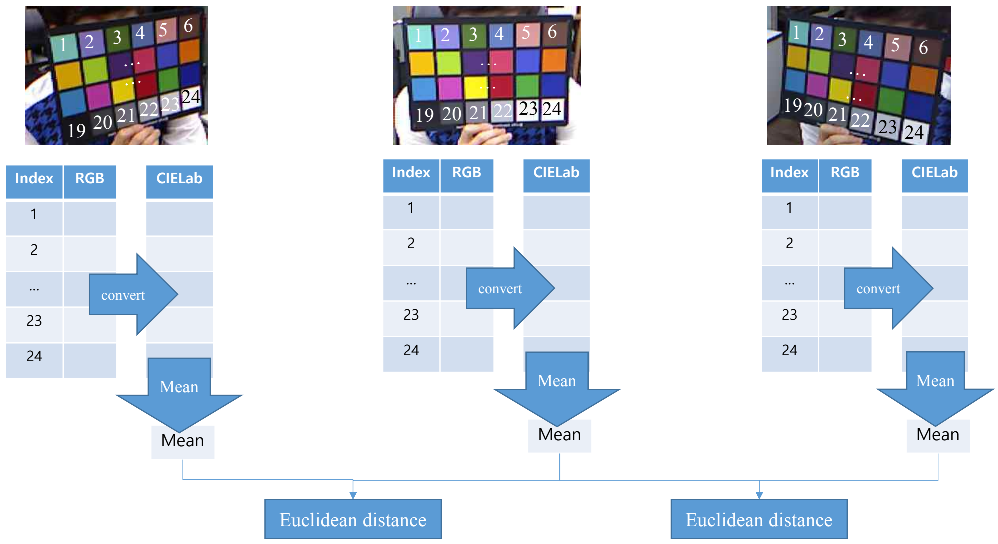

Figure 3. Flowchart of the proposed evaluation

Table 2 represents the result of the qualitative evaluation. We converted images from RGB to CIELab color space and calculated average values of Euclidean distance for 24 colors in the color chart between source and target viewpoint images. CIELab color space is designed to approximate a human color system. Hence, it is employed to represent the color difference which human percepts. Figure 4 shows Table 2 visually[7].

Table 2. Euclidean distance in CIELab color space

	Target 1	Target 2
Original images	13.0488	10.2544
Global Color Transfer	12.1945	15.0885
Histogram Matching	10.6297	16.6104
Proposed method	8.0320	6.4672

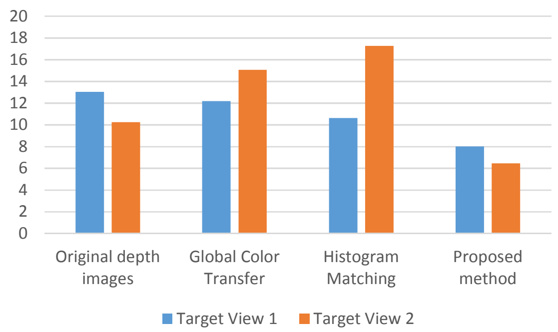

Figure 4. Bar graph for the comparison result

In Fig. 3, the global color transfer and histogram matching method well corrected the color for the target viewpoint 1 but show bad results for the target viewpoint 2. However, the proposed method shows the closest distances for both target viewpoint 1 and 2. Through this result, the proposed method achieves the most consistent result among above results.

As an application for the proposed method, we applied it to 3D object reconstruction. Figure 5 shows the result of 3D object reconstruction using triple Kinect cameras[8].

(a) Before color correction (b) After color correction

Figure 5. Result of 3D reconstruction

Before the color correction, we can find distinct color differences caused by the disparity of the viewpoints. However, after the proposed color correction, we can see a more natural 3D model than the original one.

6. CONCLUSION

In this paper, we proposed the color correction method using 3D geometry to solve the color mismatch problem in multiview system. First, we acquire correspondences between source and target viewpoint by using 3D image warping and eliminate outliers generated from occlusions. And then, we obtain color translation matrix $\boldsymbol{\theta}$ by using the polynomial regression. Experimental results show better result than the conventional method and we found that the proposed method show a natural 3D model in terms of the color.

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