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Correction Vectors for Dynamic Color Images under Multiple Luminance Conditions

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Abstract – **A color restoration algorithm for dynamic images under multiple luminance conditions is proposed by using correction vectors, defined for sub regions that the original target is divided into and calculated from color information given in well-illuminated regions. These vectors restore chromatic information of the restored image obtained by the color restoration algorithm in a low luminance condition. Under the condition that the size of dynamic color images in multiple luminance conditions is** 320×240**, experimental results show that the restored image by the proposed algorithm decreases the color-difference about 30% than that of the restoration algorithm with color change vectors in a low luminance condition. The proposed algorithm aims to construct the surveillance system with a low cost CCD camera in the real world.**

I. INTRODUCTION

The color images of video cameras for surveillance systems are used to monitor scenes and to identify a person in the scene. The images, however, are often degraded and blurred due to the uncontrollable lighting conditions and limited camera positions. Thus the algorithm that restores color information is essentially necessary to construct security systems in the real world. In the case of the images taken under low illumination, a manual restoration of the color information has been widely used. But the manual restoration has disadvantages against the automatic restoration in terms of the processing time as well as the image quality (i.e., the resultant image highly depends on the operator's skill). Moreover, the manual operation simply enhances the image taken under low illumination by uniformly increasing luminance in all pixels of the original image. The simple operation as uniformly increasing luminance yields unnecessary correction to some regions in the image.

To solve the above-mentioned problems, the algorithm that automatically restores the color information of the still image taken under low illumination has been proposed [1]-[3]. In [1], color change vectors are defined for all color information of the color scheme card [4] in a L*a*b* color metric space. These vectors restore color information of target image in the piece-wise manner. In [1]-[3], it has been confirmed that the restored image quality is enough for a surveillance system.

This paper focuses on dynamic color images with multiple luminance conditions (i.e., low illumination and standard illumination). In the setting of the L*a*b* color metric space that is in harmonize with [1]-[3], the restoration algorithm for dynamic color images under the multiple luminance conditions is proposed. In the proposed method, the target region is divided into sub regions, then correction vectors are constructed using the color information of target at a well-illuminated region. These vectors restore color information of the processed image obtained by [1].

In a color restoration experiment for dynamic color images under multiple luminance conditions, the proposed algorithm is compared with the conventional one in terms of color-difference.

In Sec. 2, an algorithm to generate the correction vectors and the restoration process using these vectors for dynamic images are proposed. Section 3 shows the experimental results.

II. COLOR RESTORATION ALGORITHM WITH CORRECTION VECTORS

Figure 1 shows an overview of the proposed algorithm for dynamic color images restoration. The correction vectors for divided target regions are constructed with color information at a well-illuminated region. The frame processed by the color change vectors is restored using correction vectors. The target region in the input image is determined using the difference between the input image and the "background" image taken in advance.

A. Generation of Correction vectors

Color information of the target at a well-illuminated region in the frame is used for the restoration. The color information provides the correction vectors that restore color information of the processed image using color change vectors [1]. Due to the target region in the input frame including different segments, e.g. skin and clothes, false correction vectors are obtained by using the color information in all pixels of a target region. In order to get the appropriate correction vectors, target region is divided

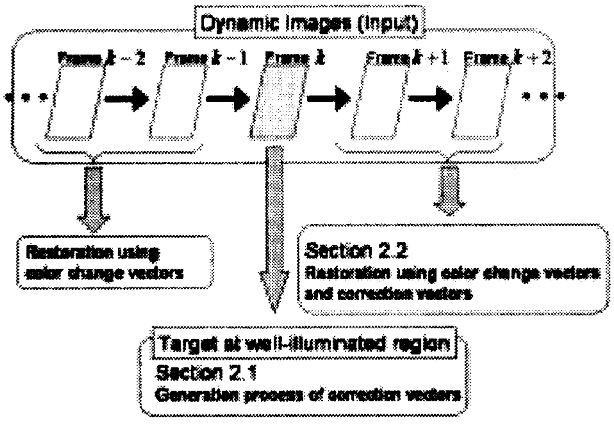

Fig.1 Restoration process of dynamic images

Fig.2 Divided target regions in the well-illuminated region in the frame

into sub regions as shown in Fig. 2 (There are 12 regions in the experiments mentioned in Sec. 3).

The correction vectors are calculated as follows (cf. Fig.3). The pixel in a frame with size $X \times Y$ is denoted by

$$\mathrm{Frame}_{x,y} \ (x = 1,2,...,X,\ y = 1,2,...,Y), \qquad (1)$$

where the frame is indicated simply "Frame" ($\mathrm{Frame}_{x,y} \in \mathrm{Frame}$). The target region in the input frame is denoted by

$$\mathrm{TR}\ (\subset \mathrm{Frame}), \mathrm{TR}_{x,y} \in \mathrm{TR}. \qquad (2)$$

Color information at $\mathrm{Frame}_{x,y}$ in terms of L*a*b* color metric space is denoted by

$$CI_{\mathrm{Frame}_{x,y}} = \{L^*_{\mathrm{Frame}_{x,y}}, a^*_{\mathrm{Frame}_{x,y}}, b^*_{\mathrm{Frame}_{x,y}}\},$$
$$0 \le L^*_{\mathrm{Frame}_{x,y}} \le 100, -100 \le a^*_{\mathrm{Frame}_{x,y}} \le 100,$$
$$-100 \le b^*_{\mathrm{Frame}_{x,y}} \le 100. \qquad (3)$$

Step1 (Dividing target region)

The well-illuminated target region TR in the frame is divided into sub regions $\{\mathrm{TR}^n\}$

$$\mathrm{TR}^n\ (n \in 1,2,...,N),\ \mathrm{TR}^n_{x,y} \in \mathrm{TR}^n (\subset \mathrm{TR}), \qquad (4)$$

$$\mathrm{TR}^i \cup \mathrm{TR}^j = \varnothing\ (i \ne j),\ \bigcup_{n=1}^{N} \mathrm{TR}^n = \mathrm{TR},$$

where $\mathrm{TR}^n_{x,y}$ indicates the pixel of the sub region TR^n (e.g. in Fig.2, N=12).

Step2 (Acquisition of color information in the target regions)

Color information $CI_{\mathrm{TR}^n_{x,y}}$ at $\mathrm{TR}^n_{x,y}$ is obtained in step1. The set of color information in TR^n is indicated by

$$\mathbf{TCI}^n = \{CI_{\mathrm{TR}^n_{x,y}} \mid CI_{\mathrm{TR}^n_{x,y}} : \text{color information of } \mathrm{TR}^n_{x,y}\}. \qquad (5)$$

The distribution of color information is calculated. The number of pixels with $CI_{\mathrm{TR}^n_{x,y}}$ is written by

$$\# CI_{\mathrm{TR}^n_{x,y}}. \qquad (6)$$

Step3 (Calculation of correction vectors)

Correction vectors ($\overrightarrow{CV^n_{CI}}$) in TR^n for arbitrary color information (CI) are calculated using neighborhood

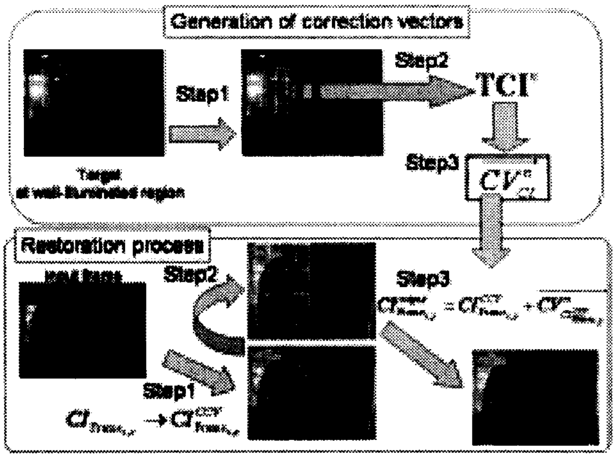

Fig.3 Generation of correction vectors and restoration process

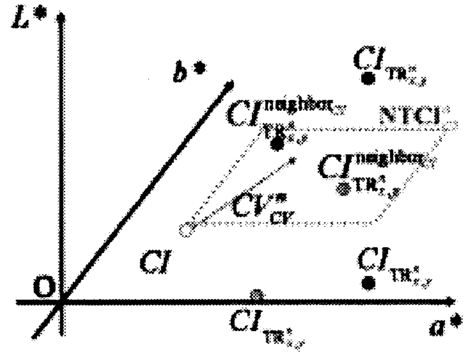

Fig.4 Calculation of correction vectors (CV^n_{CI})

$CI_{\mathrm{TR}^n_{x,y}}^{\mathrm{neighbor}_{CI}}$ of CI in the L*a*b* color metric space (Fig.4).

The calculation of $\overrightarrow{CV^n_{CI}}$ is defined by

$$\overrightarrow{CV^n_{CI}} = \{\Delta L^{*n}_{CI}, \Delta a^{*n}_{CI}, \Delta b^{*n}_{CI}\} = \overrightarrow{ave^n_{CI}} - \overrightarrow{CI},$$

$$ave^n_{CI} = \sum (CI_{\mathrm{TR}^n_{x,y}}^{\mathrm{neighbor}_{CI}} \times \# CI_{\mathrm{TR}^n_{x,y}}^{\mathrm{neighbor}_{CI}}) / \sum \# CI_{\mathrm{TR}^n_{x,y}}^{\mathrm{neighbor}_{CI}} \quad (7)$$

the average color information of $CI_{\mathrm{TR}^n_{x,y}}^{\mathrm{neighbor}_{CI}}$ is ave^n_{CI}. The set of $CI_{\mathrm{TR}^n_{x,y}}^{\mathrm{neighbor}_{CI}}$, denoted by $\mathbf{NTCI}^n_{CI}$, stands for

$$\mathbf{NTCI}^n_{CI} = \{CI_{\mathrm{TR}^n_{x,y}}^{\mathrm{neighbor}_{CI}} \mid L^{*\mathrm{neighbor}_{CI}}_{\mathrm{TR}^n_{x,y}} - L^* < 10,$$
$$, |a^{*\mathrm{neighbor}_{CI}}_{\mathrm{TR}^n_{x,y}}| - |a^*| < 10, a^{*\mathrm{neighbor}_{CI}}_{\mathrm{TR}^n_{x,y}} \times a^* > 0,$$
$$|b^{*\mathrm{neighbor}_{CI}}_{\mathrm{TR}^n_{x,y}}| - |b^*| < 10, b^{*\mathrm{neighbor}_{CI}}_{\mathrm{TR}^n_{x,y}} \times b^* > 0\}, \quad (8)$$

$\mathbf{NTCI}^n_{CI} \subset \mathbf{TCI}^n, CI = \{L^*, a^*, b^*\}$, respectively.

B. Color restoration process with correction vectors

Input frames are restored using color change vectors [1]. The processed frames are restored by adding correction vectors of target regions. The restoration process with the correction vectors is summarized as follows (cf. Fig. 3).

Step1 (Restoration with color change vectors)

Input frames are restored with color change vectors [1]. Color information of the restored frame is denoted by

$$CI^{CCV}_{\mathrm{Frame}_{x,y}}. \quad (9)$$

Step2 (Dividing target region)

The target region, RTR , in the restored frame is determined with the difference between restored "background" image and the restored frame. This target region is divided into sub regions, denoted by

$$\mathrm{RTR}^n (n \in 1, 2, \cdots, N),$$

$$(\mathrm{RTR}^n \subset \mathrm{RTR} \subset \mathrm{Frame}, \mathrm{RTR}^n_{x,y} \in \mathrm{RTR}^n). \quad (10)$$

Step3 (Restoration with correction vectors)

Color information of $\mathrm{RTR}^n_{x,y}$ ($CI^{CCV}_{\mathrm{RTR}^n_{x,y}}$) is restored by adding $\overrightarrow{CV^n_{CI^{CCV}_{\mathrm{RTR}^n_{x,y}}}}$.

III. EXPERIMENTS ON COLOR INFORMATION RESTORATION

The dynamic images taken by a CCD camera (OLYMPUS CAMEDIA C-2020Z) under multiple luminance conditions are used as input images, and the outputs are the images restored by the proposed algorithm. The pixel size of dynamic images is 320×240 /frame. Experimental conditions are:

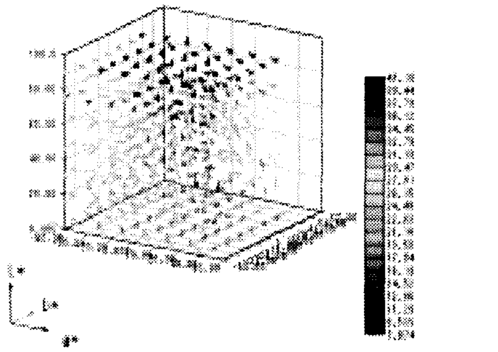

Fig.5 Color change vectors in restoration process

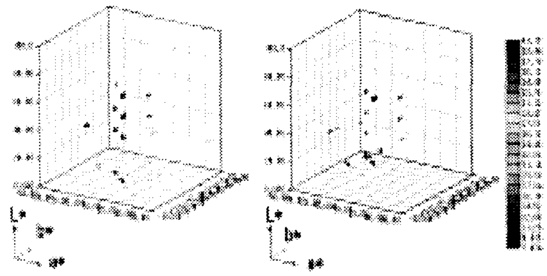

Fig.6 Correction vectors in divided target region
(Left is in middle region and right is in top region)

Fig.7 The images of an input frame and a goal frame
(Left: Input frame for Fig. 8 and Fig. 9, Right: the image where target is taken under standard illumination)

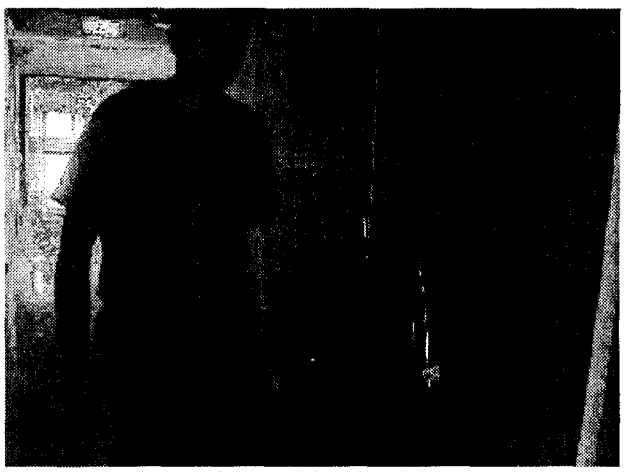

Fig.8 Restored frame with color change vectors
(Conventional algorithm [1])

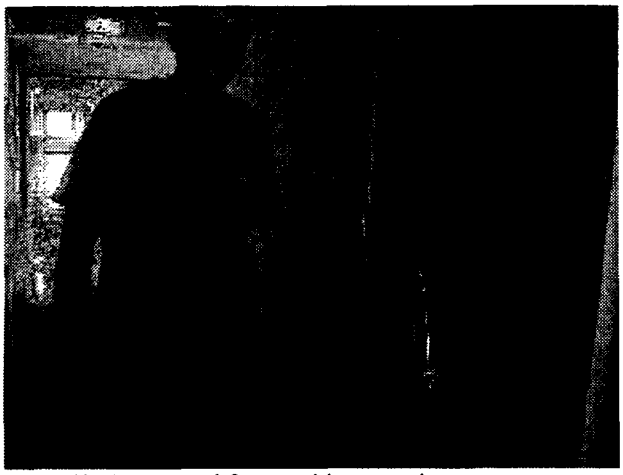

Fig.9 Restored frame with correction vectors (obtained by the proposed algorithm)

	Color-difference
Color change vectors (Conventional algorithm)	8.1
Color change vectors + Correction vectors (Proposed algorithm)	5.4

Table 1 Color-difference between an image under standard illumination and that of the restored frame in the target region (in full scale $4{,}000{,}000 = 100\times200\times200$)

- The number of target in the images is one.
- An image is taken under the low illumination, where the contours of subjects should be visible.

Figure 5 shows color change vectors for input images (The left image of Fig. 7 is a frame of input dynamic images). Figure 3 is the image that has the target region at well-illuminated region. Figure 6 are correction vectors from Fig. 2, respectively (Left image is in middle region and right image is in top region).

Figure 8 is the image restored with color change vectors (Fig. 5). Figure 9 is the restoration result of Fig. 8 using correction vectors (Fig. 6). Right of Fig. 7 shows the target taken under standard illumination.

The target color of Fig. 9 is deeper than that of Fig. 8. Low luminance condition reduces chromatic information more than intensity information. Figure 9 shows that correction vectors restore chromatic information of the restored image with color change vectors.

The color-difference between the target region of an image under standard illumination and that of the restored frame is shown in Table1. The color-difference of target regions between an image under standard illumination and a restored image with correction vectors is 5.4 (where the full scale is $4{,}000{,}000 = 100\times200\times200$) in the average of 90 frames, and the restored image by the proposed algorithm decreases the color-difference about 30% than that of the restoration algorithm with color change vectors (The color-difference in target regions is 8.1). Thus, the proposed algorithm is considered to restore images under multiple luminance conditions.

IV. CONCLUSION

A problem of color restoration in dynamic images under multiple luminance conditions is mentioned, and a color restoration algorithm in the problem is proposed. The algorithm enhances the image quality using correction vectors that are constructed with color information of target in the well-illuminated region.

To confirm the effectiveness of the proposed algorithm, an experiment is done using general real world dynamic images inside rooms. The experiment shows that the restored image by the proposed algorithm decreases the color-difference about 30% than that of the restoration algorithm with color change vectors and that the correction vectors restore chromatic information of the restored image with color change vectors.

The conventional manual operation has several problems in the automatic processing for the color restoration problem such as time-consuming and highly depending on individual skills. The proposed algorithm restores the dynamic images under multiple luminance conditions automatically and can be applied to track a person using color information in dynamic images. The proposed algorithm gives the foundation of the security system to identify a person with a low cost CCD camera.

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