Color Restoration Algorithm in concert with Region Detection

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Abstract — A color restoration algorithm under low luminance conditions in concert with region detection is proposed. Restoration algorithms using physics-based model are difficult to implement in the real world surveillance because of noise, assumption of inputs and processing time, therefore the proposed algorithm is a color instance-based method. First, the proposed algorithm gives similarity of target color in a point wise manner. Next, the input image is restored with color instances which are calculated using color values of color charts in consideration of the similarity. Experimental results show that the shade region in restored image by the proposed algorithm decreases the color-difference about 30% lower than that of the restoration algorithm with color change vectors (existing color restoration algorithm). The proposed algorithm aims to construct the surveillance system with a low cost CCD camera for real-world applications.

I. Introduction

Video color images for surveillance systems are used to monitor events and to identify persons in the scene. In real situations, sufficient illumination for surveillance, however, is not always assumed, e.g., in the office at night. This low illumination problem has not been studied enough. Although color constancy [1-3], and color invariance [4] address color restoration under varying illumination, these algorithms are likely to fail in color restoration in the poorly-illuminated scene due to insufficient illumination in calculating surface reflectance, i.e., low illumination leads to loss of the physical properties. This fact makes it difficult to restore the color of low-illuminated objects using physics-based models.

To solve the above-mentioned problem, an algorithm that automatically restores color information of still images taken under low illumination [5], [6] has been proposed. In the algorithm [7], color change vectors are defined at each sample point in the L*a*b* color metric space by measuring a color chart whose color scheme card [8] is used. These vectors restore color information of a given target image in a point wise manner. In the algorithm [5-7], it is confirmed that the restored image quality is good enough for a surveillance system. But the restoration results for shade region are not good because color information of shade region is lost.

One of applications with the algorithms [5-7] is detection method. Many segmentation and extraction algorithms [8-13] have already been proposed in the literatures. The input images of these algorithms are assumed to be taken under standard luminance condition, because an operator can hardly obtain colors and contours of images taken under low illumination. Detection algorithm with the color instances (color change vectors) [14] has been proposed using color values in low luminance conditions. The subset of shade region is correctly detected as target region in [14]. Therefore, shade region is correctly restored by emphasizing the detected shade region.

Color restoration algorithm using result of detection algorithm is proposed. The purpose of the proposed algorithm is to generate the image which is easy to use for the real surveillance by manual operation or computer (e.g. tracking and identification.) The proposed algorithm is divided to two processes, detection process and restoration process. Detection process gives similarity for target color in a point wise manner and restores an input image using the color change vectors. Restoration process defines new color instances, emphasizing vectors. The emphasizing vectors are calculated in consideration of the similarity.

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

In Sec. II, an algorithm to generate the emphasizing vectors and the restoration process using these vectors for an image under low illumination are proposed. Section III shows the experimental results.

II. Restoration algorithm using detection method

The proposed algorithm is consists of detection process and restoration process. These processes are performed with color change vectors which are defined using color values of the color scheme cards. The overview of this algorithm is shown in Fig.1.

A. Detection process

The detection process is performed using only color values. The proposed process expresses the target region as a rectangle region with similarity. The overview of this process is shown in Fig.2.

Step 1 (Defining target color value)

Color values of detected target are defined by manual operation in advance. The **C**olor **I**nformation is denoted by

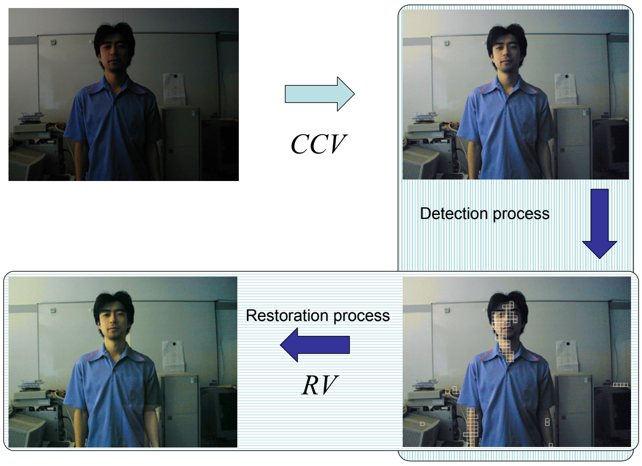

Fig.1 Overview of the proposed algorithm

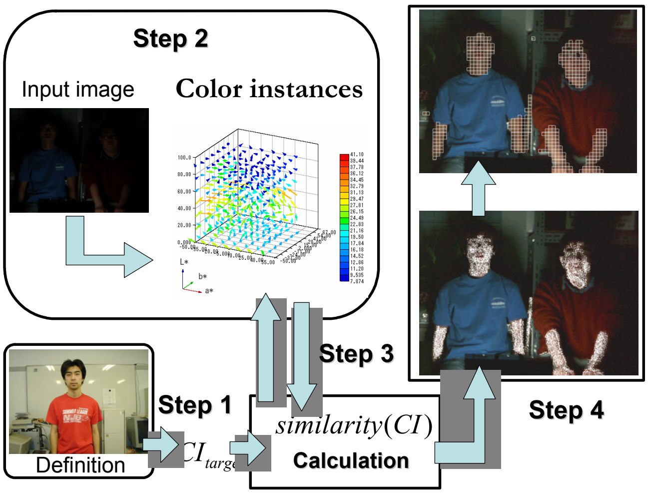

Fig.2 Overview of detection process

$$CI_{target}(\in \mathbf{CI}_{target}),$$
$$CI = \{L^*, a^*, b^*\}. \quad (1)$$

As shown in equation (1), the color information is presented in the L*a*b* color metric space. The color values of targets do not exist at a point in the L*a*b* color metric space, the cardinality of $\mathbf{CI}_{target}$ is more than 1.

Step1 is preprocessing, Next steps are processed after the input image is given.

Step2 (Creating Color Change Vectors)

Calculate the color instances. That is, the **C**olor **C**hange **V**ectors are calculated and modified according to [1]. The ***CCV*** is denoted by

$$CCV(CI^{in}) = CV, \quad (CCV: \text{L*a*b*} \rightarrow \text{L*a*b*})$$
$$CV = (\triangle L^*, \triangle a^*, \triangle b^*). \quad (2)$$

Step 3 (Defining the similarity to skin color)

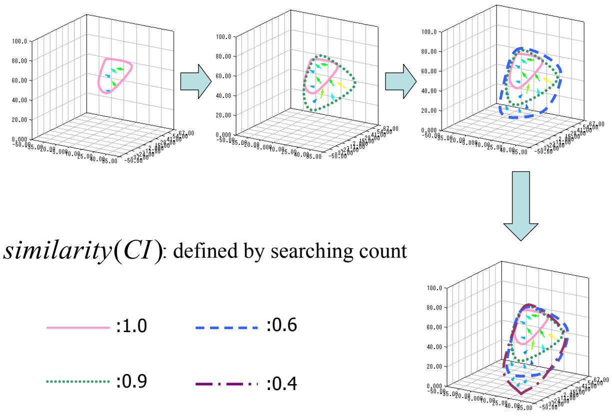

Fig.3 Color instances which is recursively restored to targets colors

Defining similarity of color values in the L*a*b* color metric space to color values of the target regions. First, color values of target regions under standard luminance condition are defined as

$$similarity(CI_{target}) = 1. \quad (3)$$

Second, the proposed algorithm searches the low color values which are directly restored to target color values under standard illumination. These color values are denoted by

$$CI_{direct}(CI_{direct} + CCV(CI_{direct}) \in \mathbf{CI}_{target}). \quad (4)$$

The similarity of the searched colors CI_{direct} is defined by

$$similarity(CI_{target}) = 1. \quad (5)$$

Detection results using (3) and (5) are not good, because color values of an input image under low illumination are lost for capability of CCD. Therefore, the proposed method recursively searches the color values which have possibility to be restored to target color (Fig.3). These color values are defined by

$$\mathbf{CI}^n = \{CI^n \mid CCV(CI^1 + CCV(CI^2 \cdots + CCV(CI^n + CCV(CI^n))\cdots) \in \mathbf{CI}_{target}\}. \quad (6)$$

As evidenced by (6), CI^1 is equal to CI_{direct}. Moreover, neighbor color value of $\mathbf{CI}^n$, $\mathbf{NCI}^n$, is defined in consideration of color noise. The $\mathbf{NCI}^n$ is denoted by

$$\mathbf{NCI}^n = \{CI^n_{neighbor} \mid |L^{*n} - L^{*n}_{neighbor}| < 5, |a^{*n} - a^{*n}_{neighbor}| < 5, |b^{*n} - b^{*n}_{neighbor}| < 5\}. \quad (7)$$

These similarity of CI^n and $CI^n_{neighbor}$ for CI_{target} is defined by

$$similarity(CI^n) = 1 - ((n-1)/10),$$
$$similarity(CI^n_{neighbor}) = 1 - ((n-2)/10). \quad (8)$$

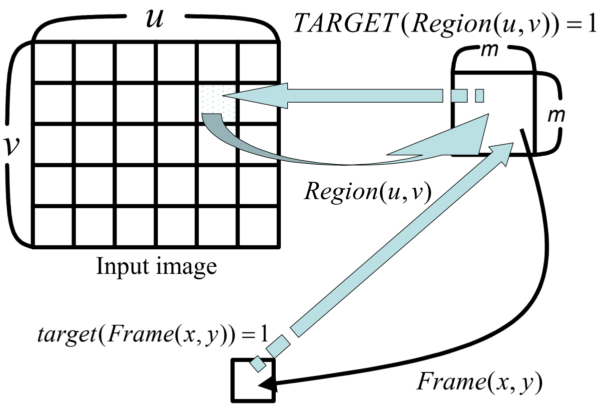

Fig.4 Divided image and target region

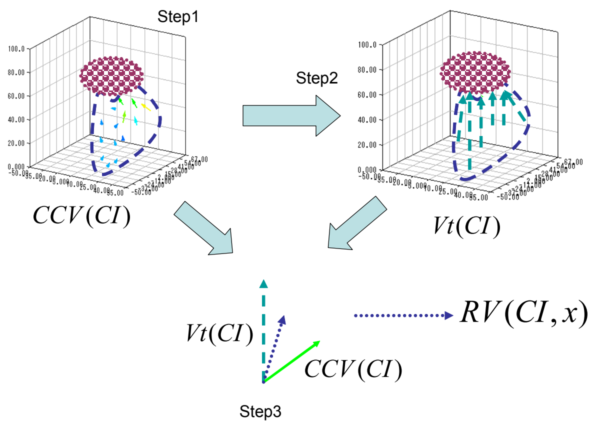

Fig.5 Overview of calculating the emphasizing vectors

Step 4 (Calculating target regions)

Define color of input region as target color values using the similarity. The overview of this step is shown in Fig.4. An input image and pixels are denoted by

$$\mathbf{Frame} = \{Frame(x,y) \mid x = 1,2,\cdots,X,\ y = 1,2,\cdots,Y\}. \quad (9)$$

Decision function for input pixel ($Frame(x,y)$) is defined by

$$target(Frame(x,y)) = \begin{cases} 1 & \left(similarity(CI(Frame(x,y))) \geq threshold_{pixel}\right) \\ 0 & \left(similarity(CI(Frame(x,y))) < threshold_{pixel}\right). \end{cases} \quad (10)$$

The result of the detection process is presented as a rectangle region with similarity. The rectangle region is denoted by

$$\mathbf{Frame} = \{Region(u,v) \mid u = 1,2,\cdots,X/m,\ v = 1,2,\cdots,Y/m\},$$

$$\#Region(u,v) = m \times m,$$

$$Region(u,v) = \{Frame(x,y) \mid x = u \cdot m, u \cdot m + 1, \cdots, u \cdot m + m - 1,\ y = v \cdot m, v \cdot m + 1, \cdots, v \cdot m + m - 1\}. \quad (11)$$

The detection process defines $Region(u,v)$ as a target region using function *TARGET*, defined by

$$TARGET(Region(u,v)) = \begin{cases} 1 & \left(\sum_{Frame(x,y) \in Region(u,v)} similarity(CI(Frame(x,y))) \geq threshold_{region}\right) \\ 0 & \left(\sum_{Frame(x,y) \in Region(u,v)} similarity(CI(Frame(x,y))) < threshold_{region}\right). \end{cases} \quad (12)$$

In $Region(u,v)$, cardinality of *similarity* with x is defined by

$$cardinality(x, Region(u,v)) = n. \quad (13)$$

Similarity in $Region(u,v)$, *SIMILARITY*, is defined by

$$SIMILARITY(Region(u,v)) = similarity(\arg(\max(cardinality(x, Region(u,v))))). \quad (14)$$

The parameters $threshold_{pixel}$ and $threshold_{region}$ in equations (10) and (12) are experimentally defined.

B. Restoration process

Restoration process creates new color instances, emphasizing vectors, using the results of detection process. The image restored by color change vectors is restored using emphasizing vectors. The overview of creating emphasizing vectors is shown in Fig.5.

The emphasizing vectors are defined to change color values at input pixel to target color. The arguments of the emphasizing vectors are *CI* and *SIMILARITY* in (14). The emphasizing vectors are defined for the color values which have possibility to be restored to target color. That is, the proposed algorithm gives color information, whose similarity in (8) is over 0, emphasizing vectors. Therefore, *CI* is necessary for calculating the emphasizing vectors. The low value in *SIMILARITY* is not necessarily means that the $Region(u,v)$ is the target region. Therefore, the emphasizing vectors are defined using *SIMILARITY*. The calculation of the emphasizing vectors for CI_{input} is as follows.

Step1 (Searching the target *CCV*)

As mentioned in A., search $\mathbf{CI}^n$ and $\mathbf{CI}_{target}$.

Step2 (Calculating vectors to the target color values)

Calculate vectors to the distribution of CI_{target}. The vectors is named *Vt(CI)*. The vectors is from CI_{input} to the nearest CI_{target} for CI_{input}. Therefore, *Vt(CI)* is defined by

$$Vt(CI) = (L*_{nearest} - L*, a*_{nearest} - a*, b*_{nearest} - b*),$$
$$CI_{nearest} = (L*_{nearest}, a*_{nearest}, b*_{nearest}),$$
$$CI_{nearest} = \arg(\min(color - difference(CI, \mathbf{CI}_{traget}))) . \quad (15)$$

Step3 (Calculating the emphasizing vectors)

Calculate the emphasizing vectors using *CCV(CI)* and *Vt(CI)*. The emphasizing vectors for CI_{input} and *SIMILARITY*, *x*, is defined by

$$EV(CI, x) = (1 - x) \times CCV(CI) + x \times Vt(CI) . \quad (16)$$

As shown in (16), effect of Vt(CI) is little in case of low value in *SIMILARITY*.

C. Total process

The total process is as follows (cf. Fig.1). The color value of input pixel is presented by $CI(Frame(x, y))$.

Step1 (Restoration using CCV)

As shown in [7], color value is restored using the color change vectors. The color value is denoted by

$$CI_{output}(Frame(x, y)) = CI(Frame(x, y)) + CCV(CI(Frame(x, y)) . \quad (17)$$

Step2 (Detection process)

As shown in A., $Region(u, v)$ where $CI(Frame(x, y))$ exists is determined whether $Region(u, v)$ is the target region. The *SIMILARITY*, *X*, is denoted by

$$X = SIMIRALITY(Region(u, v)),$$
$$Frame(x, y) \in Region(u, v) . \quad (18)$$

Step3 (Restoration using *RV*)

As shown in B., the emphasizing vectors is calculated. The color value at $Frame(x, y)$ is restored using *RV*. The restored color value is denoted by

$$CI_{output}(Frame(x, y)) = CI(Frame(x, y)) + EV(CI(Frame(x, y), X) . \quad (19)$$

III. Experiment on color restoration

The purpose of experiments is to check reflection of the detection results using only color values for the color-difference (that is, a comparison between the proposed algorithm and the conventional algorithm [7]).

An input for the proposed algorithm is a still image under low luminance conditions in the L*a*b* color metric space with a CCD camera (OLYMPUS CAMEDIA C-2020Z.) The low luminance condition of the input image is the same as the conditions in which a human operator can recognize enough colors of the target (person). That is, the contours of a target in the input are visible for a human operator. It is not useful to define the quantitative condition of low luminance condition, because the quantitative conditions (i.e., lux) depend on the performance of the CCD camera and the brightness of the lens.

An output for the proposed algorithm is a restored image by 175 color scheme cards to use in criminal investigation. The purpose of the proposed algorithm is to generate the image which is easy to use for the real surveillance by manual operation or by computer (e.g. tracking and identification.) Tracking and identification require the same color values of a target as that under standard illumination. Therefore, the evaluation of color restoration is done using the color-difference in the L*a*b* color metric space.

The size of input images is 640×480 pixels. The proposed algorithm is implemented with Visual C++ on a Pentium 3 (1 GHz) PC.

The target region in experiments is skin region. The $\mathbf{CI}_{target}$ is defined by

$$\mathbf{CI}_{target} = \{CI_{target} \mid 40 \le L*_{target} \le 60$$
$$10 \le a*_{target} \le 30, 10 \le b*_{target} \le 30\}. \quad (20)$$

Figures 6 – 11 show the results for still images. The image of Fig.6 is input image. Figure 7 shows the restored image using CCV. The detection result displayed as 20×20 region is shown in Fig.8 ($threshold_{pixel} = 0.4$ and $threshold_{region} = 0.2$). Figure 9 shows the restored image using *CCV* and *EV*. Figure 10 shows the restored image using *CCV* and *EV* with the target regions which are skin and cloth region.

The color-difference between the target region of an image under standard illumination and that of the restored frame are shown in Table1. The maximal value of color difference is 300. The target region means person region. Blue, Red and Green in table 1 shows color which person wears shirts. The color-difference is decreased by the proposed algorithm by 10% or more comparing to that of [7]. Moreover, the color-difference of shade region is decreased by the proposed algorithm by 40% or more comparing to that of [7]. Thus, the proposed algorithm restores still images under low luminance conditions to use for the real surveillance.

Fig.6 input image

Fig.7 restoration image using *CCV*

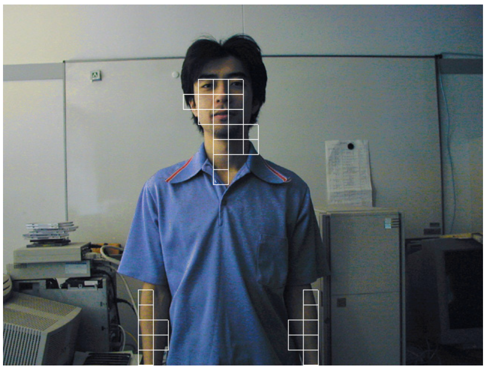

Fig.8 The detection result

Fig.9 restoration image using *EV*
(target region is skin region)

Fig.10 restoration image using *EV*
(target regions are skin and cloth region)

Table1 color-difference between the target region of an image under standard illumination and that of the restored image

	Blue	Red	Yellow	Green
Proposed	13.4	12.7	10.2	15.8
conventional	15.1	17.9	14.5	18.4

IV. Conclusion

A problem of color restoration for still images under low luminance conditions is investigated, and a color restoration algorithm is proposed. The proposed algorithm enhances the image quality using color values of input video image. The emphasizing vectors are constructed using the results of detection process and restore the image restored using the color change vectors.

In order to confirm the performance of the proposed algorithm, experiments are done using general real world still images inside rooms. First, for an input frame, the restored image obtained by the proposed algorithm is compared with that obtained by the existing algorithm [7] in terms of color difference. The experimental results show that shade region of the restored image by the proposed algorithm decreases the color-difference by 30% compared to that of the algorithm [7]. The proposed algorithm is successfully applied to the image where color information is lost. The restored image, in which personal identification is possible, is obtained.

In the restoration of low illuminated still images, the manual operation has disadvantages compared to the automatic processing, because it is time-consuming and it highly depends on individual skills. Moreover, image restoration under low illumination using knowledge is difficult by manual operation in the real-time operation. The proposed algorithm automatically restores the still images under low luminance conditions in real time. And it can be applied to tracking a person using color information in dynamic images. The proposed algorithm aims to establish the foundation for identifying a person for the practical security systems with a low cost CCD camera.

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