Color Restoration Algorithm in Low Luminance Conditions with Color Change Vectors

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Abstract – A color restoration algorithm is proposed to restore the color information of still images in low luminance conditions. The 175 color scheme cards taken under low and standard illumination provide color change vectors. Adding the color vector in a color change vector for an input pixel value restores color information of a pixel in the input image. Under various luminance conditions, color change vectors are changed with considering color information of an input image and color scheme cards. Experimental results show that the restored image by the proposed algorithm is the same as that of the previously proposed algorithm in terms of color-difference (with an uncertainty 10%). A proposed algorithm will be used as a basis of the surveillance camera system.

Index Terms— color information , Restoration.

1. Introduction

The algorithm that restores the color information of images taken under low illumination with a surveillance CCD camera is useful for constructing the real world security systems.

The manual operation for restoring the color information from images taken under low illumination has been widely used. However, the manual operation has disadvantages against the automatic processing in terms of the processing time as well as the image quality (i.e., the resultant image highly depends on the individual capability). Moreover, the manual operation simply enhances the image taken under low illumination by uniformly increasing luminance in value at all pixels. This simple operation causes unnecessary correction to some regions in the image.

To solve the above-mentioned problems, the algorithm [1] that automatically restores the color information of the still image taken under low illumination has been proposed.

This algorithm takes 175 pairs of the color information under low and standard illumination as the instances, based on which the color information of each pixel is restored. The restored image quality is enough for a surveillance system. But this algorithm restores the target image in a fixed lighting condition.

In this paper, the restoration algorithm with color change vectors in various luminance conditions is proposed. The proposed algorithm restores the target image with color change vectors in the L*a*b* color metric space which is created with color information of color scheme card [2]. In this algorithm, the L*a*b* color metric space is employed as the color space to compare with the previously proposed algorithm [1] which employs the L*a*b* color metric space.

A color restoration experiment with the proposed algorithm is performed, based on which the proposed algorithm is compared with the previously proposed algorithm [1] in terms of the color-difference.

In Section 2, the color restoration algorithm for a still image is explained, and Section 3 shows its experimental results.

2. Color restoration algorithm with color change vectors

Color change vectors in the L*a*b* color metric space are constructed with color information of 175 color scheme cards under low illumination (target illumination) and standard illumination. In various luminance conditions, color change vectors are changed considering the average of color information in the input image (target illumination) and color scheme cards (different illumination).

2.1 Color change vector in color metric space

In the instance-based algorithm [1], the input image is restored with 175 color change vectors of color scheme cards from low illumination to standard illumination. Fig.1 shows the color change vectors of color scheme cards in the L*a*b* color metric space. The difference of each color change vectors is large, and a restored image is not smooth.

The proposed algorithm creates the color change vectors of all color information in a color space with that of color scheme cards.

The color change vector of target color information is calculated with neighbor color change vectors of color scheme cards.

$$\mathbf{VCSC} = \{CCV_i\}(i = 1, 2, \cdots 175) \quad (1)$$

$$CCV_i = \{CI_i^l, CV_i\} \quad (2)$$

$$CI_i^l = \{L^*, a^*, b^*\} \quad (3)$$

$$CV_i = \{\triangle L^*, \triangle a^*, \triangle b^*\} \quad (4)$$

The **VCSC** in (1) is a set of color change **v**ectors of 175 **c**olor **s**cheme **c**ards. The CCV_i in (2) is the *i*th color change vector, which consists of low color information (CI^l in (3)) and a color vector from low illumination to standard illumination (CV in (4)) . These parameters are given.

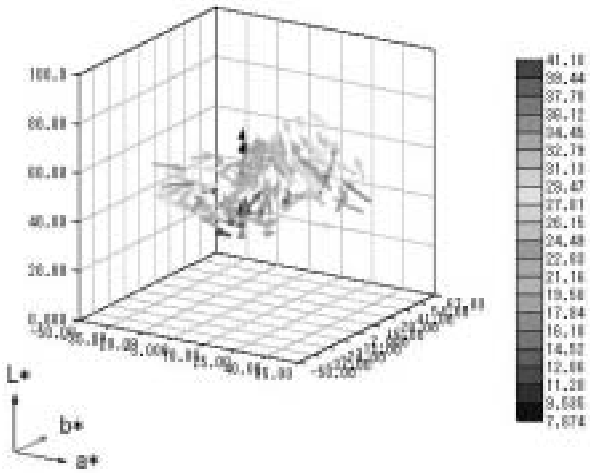

Fig.1 Color change vectors of color scheme cards

$$\mathbf{VCMS} = \{CCV_{L^*,a^*,b^*}\} \quad (5)$$

$$(0 < L^* < 100 \quad -45 < a^*, b^* < 45)$$

$$CCV_{L^*,a^*,b^*} = \{CI^{in}_{L^*,a^*,b^*}, CV_{L^*,a^*,b^*}\}$$

$$CI^{in}_{L^*,a^*,b^*} = \{L^*_{in}, a^*_{in}, b^*_{in}\}$$

The **VCMS** in (5) is a set of color change **v**ectors in a **c**olor **m**etric **s**pace. In the restoration process, this **VCMS** is used. The Calculation of CV_{L^*,a^*,b^*} (Fig.2) is as follows.

<u>Step1 (Acquisition of vectors in color scheme cards)</u>

The Color change vector of color information, which is the same as color information of color scheme cards, is same as the color vector of **VCSC.**

(If $CI_{L^*,a^*b^*} = CI_i^l$, $CV_{L^*,a^*b^*} = CV_i$.)

In other cases, Step1 is done for $N = 1$ in Step 2.

<u>Step2 (Average of CV)</u>

This step is calculation of average (in (6)) of CV in neighbor color information.

$$aveV^N_{L^*,a^*,b^*} =$$

$$\mathbf{NCI}^N_{L_{in}^*,a_{in}^*,b_{in}^*} = \{L^*, a^*, b^*\}$$

$$(|L^* - L^*_{in}|, |a^* - a^*_{in}|, |b^* - b^*_{in}| < N \times wid)$$

: Neighbor color information

$Num^N_{L^*_{in},a^*_{in},b^*_{in}}$: The number of CI_i^l which is in $\mathbf{NCI}^N_{L^*_{in},a^*_{in},b^*_{in}}$

wid : Constant ($wid = 5$ in **3.2**)

If $Num^N_{L_{in}^*,a_{in}^*,b_{in}^*} = 0$, the calculation process goes step4 without calculation of an average in (6).

<u>Step3 (Calculation of color vector)</u>

If $CV_{L^*,a^*,b^*} = \{0,0,0\}$, $CV^N_{L^*,a^*,b^*} = aveV^N_{L^*,a^*,b^*}$. In the other case,

$$CV^N_{L^*,a^*,b^*} = \frac{N \times CV^{N-1}_{L^*,a^*,b^*} + aveV^N_{L^*,a^*,b^*}}{N+1}. \quad (7)$$

<u>Step4 (Termination condition)</u>

If $N < N_{final}$, $N = N + 1$ and the calculation process goes step2.

If $N = N_{final}$, $CV_{L^*,a^*,b^*} = CV^N_{L^*,a^*,b^*}$

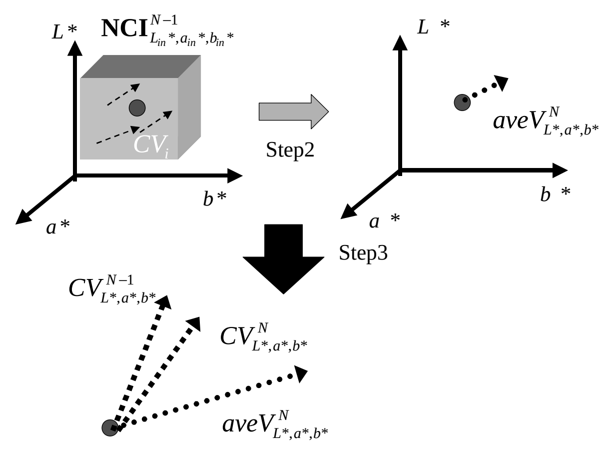

Fig.2 Calculation of color vectors

2.2 Color change vectors in various luminance conditions

In the previously proposed algorithm [1], one of experiment conditions is that an image is taken under the uniform lighting condition. The lighting condition of color change vectors in **2.1** is fixed. The color change vectors are changed to restore the input image in various luminance conditions.

In restoration process, the given data is color information of color scheme cards and an input image. The **VCMS** divides into 5 areas ($L^*, a^* \geq 0, a^* < 0, b^* \geq 0, \quad b^* < 0$) and are changed with considering the given data. The concrete procedure (Fig.3) is as follows.

$$\mathbf{VCMS}^{change} = \{CCV^{change}_{L^*,a^*,b^*}\}$$
$$CCV^{change}_{L^*,a^*,b^*} = \{CI^{in}_{L^*,a^*,b^*}, CV^{change}_{L^*,a^*,b^*}\}$$
$$CV^{change}_{L^*,a^*,b^*} = \{\triangle L^{*change}, \triangle a^{*change}, \triangle b^{*change}\}$$

$$\triangle L^{*change} = \triangle L^* + \Delta ave_{L^*} \times Dis^{L^*_{in}}_{ave^{input}_{L^*},100} \tag{8}$$

$$\Delta a^{*change} = \begin{cases} \Delta a^* + \Delta ave_{a^* \geq 0} \times Dis^{a^*_{in}}_{ave^{input}_{a^* \geq 0},45} (a^*_{in} \geq 0) \\ \Delta a^* + \Delta ave_{a^* < 0} \times Dis^{a^*_{in}}_{ave^{input}_{a^* < 0},-45} (a^*_{in} < 0) \end{cases} \tag{9}$$

$$\Delta b^{*change} = \begin{cases} \Delta b^* + \Delta ave_{b^* \geq 0} \times Dis^{b^*_{in}}_{ave^{input}_{a^* \geq 0},45} (b^*_{in} \geq 0) \\ \Delta b^* + \Delta ave_{b^* < 0} \times Dis^{b^*_{in}}_{ave^{input}_{a^* < 0},-45} (b^*_{in} < 0) \end{cases} \tag{10}$$

$$\Delta ave_{L^*} = ave^{cs}_{L^*} - ave^{input}_{L^*}$$
$$\Delta ave_{a^* \geq 0} = ave^{cs}_{a^* \geq 0} - ave^{input}_{a^* \geq 0}$$
$$\Delta ave_{a^* < 0} = ave^{cs}_{a^* < 0} - ave^{input}_{a^* < 0}$$
$$\Delta ave_{b^* \geq 0} = ave^{cs}_{b^* \geq 0} - ave^{input}_{b^* \geq 0}$$
$$\Delta ave_{b^* < 0} = ave^{cs}_{b^* < 0} - ave^{input}_{b^* < 0}$$

$$Dis^{z}_{x,y} = \begin{cases} \dfrac{z}{x} & (x \geq z) \\ \dfrac{x - z}{y - x} + 1 & (x < z) \end{cases} \tag{11}$$

ave^{Y}_{X} : Average of color information of X in Y

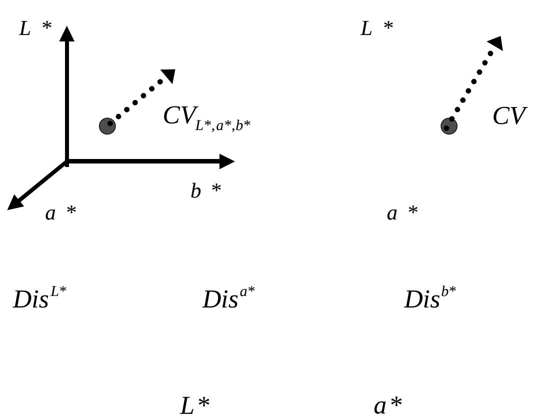

Fig.3 Color change vectors in various luminance conditions

If CV adds by Δave instead of $\Delta ave \times Dis$ in (8), (9), and (10), color information of the restored image is not correct. This result is shown in **3.2**.

2.3 Color restoration process with color change vectors

The input pixel value $Input_{X,Y}$ is restored by adding CV . This calculation is shown in (12).

$$Output_{X,Y} = Input_{X,Y} + CV_{L^*_{X,Y}, a^*_{X,Y}, b^*_{X,Y}} \tag{12}$$

$Input_{X,Y} = \{L^*_{X,Y}, a^*_{X,Y}, b^*_{X,Y}\}$

: Color information of input image

(X, Y : Coordinates of the objective pixel in the input image)

$Input_{X,Y} = CI^{in}_{L^*_{X,Y}, a^*_{X,Y}, b^*_{X,Y}}$

$Output_{X,Y}$: Color information of the restored image

3.Experiments on color information restoration

3.1 Experimental conditions

The images taken with a CCD camera under low illumination are used as the input images, and the outputs are the images restored to the color information under standard illumination with using the proposed algorithm. Experimental conditions are shown below.

- The lighting type (color temperature) is fixed.
- An image is taken under the low illumination, under which the contours of subjects are visible.

3.2 Experimental result

Fig.4 shows **VCMS** constructed with **VCSC** (Fig.1). The left image in Fig.5 is an input image. The luminance condition of this image is the same as that of low illumination in **VCSC** (Fig.1). The right image is taken under standard illumination. The left image in Fig.6 is the restored image with **VCMS** (Fig.4). The right image is the restored image by the previously proposed algorithm [1].

Fig.7 shows $\mathbf{VCMS}^{change}$ in various luminance conditions (Fig.8 left). The images in Fig.8 are input and taken under standard illumination. The left image in Fig.9 is the restored image with $\mathbf{VCMS}^{change}$ of Fig.7.The right image is the restored image with **VCMS** whose luminance condition is the same as the left image in Fig.8. Fig.10 shows the restored image of the left image in Fig.5 with the proposed algorithm whose CV adds by Δave instead $\Delta ave \times Dis$ in (8), (9) and (10).

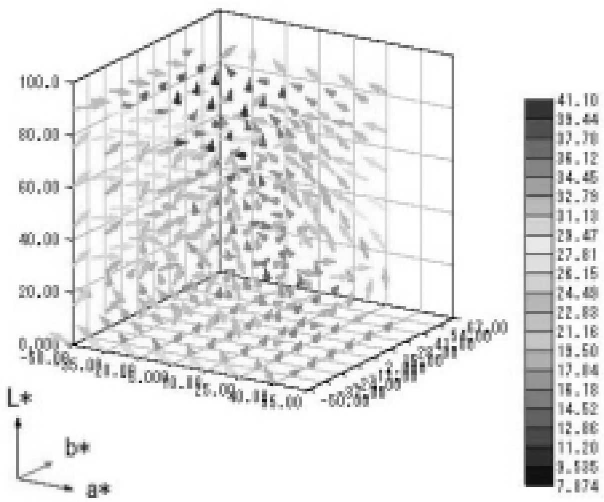

Fig.4 Color Change Vectors calculated by Fig.1

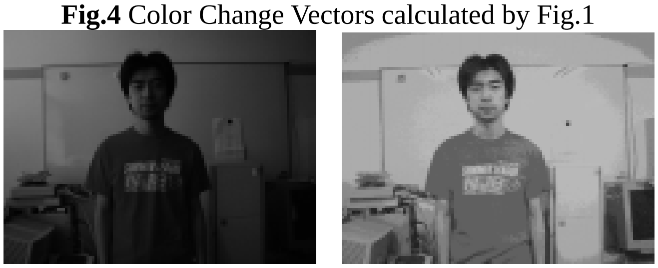

Fig.5 Input image (left) and Image taken under standard illumination (right).

Fig.6 Restored image by proposed algorithm (left) and restored image by previously proposed algorithm (right).

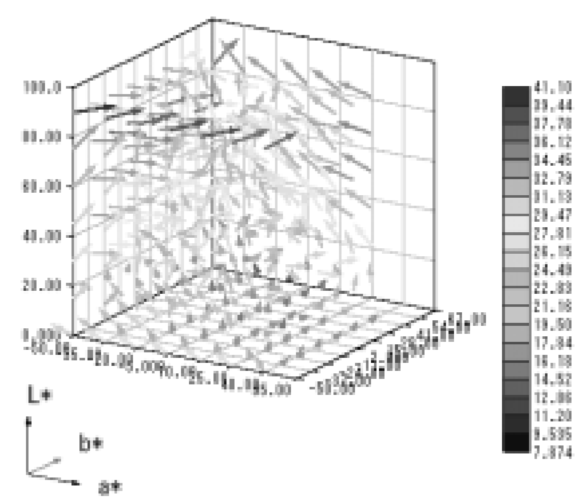

Fig.7 **VCMS**^{change} calculated with Fig.4 (Target luminance is same as Fig.8 left)

Fig.8 Input image (left) and Image taken under standard illumination (right).

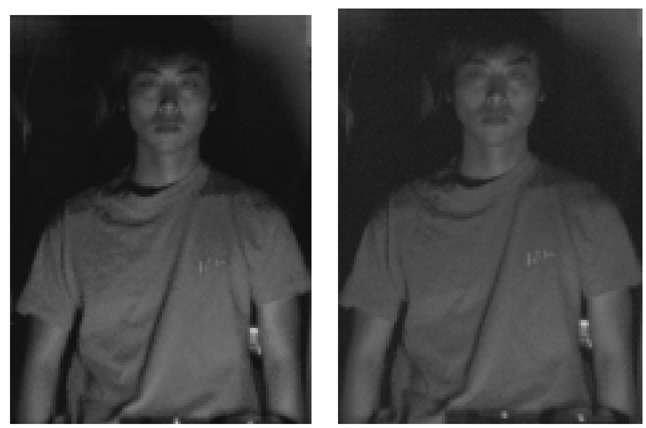

Fig.9 Restored images by proposed algorithm with **VCMS**^{change} of Fig.7 (left) and **VCMS** whose luminance condition is same as left image of Fig.8 (right).

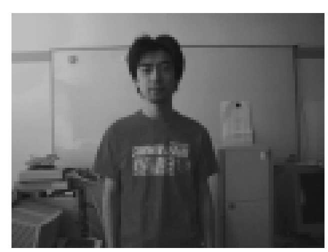

Fig.10 Restored image of the left image in Fig.5 with proposed algorithm (CV adds by Δave instead $\Delta ave \times Dis$ in (8), (9) and (10))

3.2 Comparison experiment with the restoration in a fixed luminance condition

The color-difference between an image under standard illumination and a restored image is shown in table 1,2 and 3.

In table 1, the luminance condition of color scheme cards is same as Fig.5. And the luminance conditions of an input image are the same as the left image of Fig.5. The color-difference of the proposed algorithm is the same as that of the previously proposed algorithm. And the color noise of the restored image with the proposed algorithm is low than the previously proposed algorithm.

In table 2, the luminance condition of color scheme cards in $\mathbf{VCMS}^{change}$ is the same as that in Fig.5. The luminance condition of color scheme cards in **VCMS** is the same as that in Fig.8. And the luminance conditions of an input image are the same as the left the image of Fig.8. The color-difference of $\mathbf{VCMS}^{change}$ is same as that of **VCMS** (with an uncertainty 8%).

In table 3, the luminance condition of color scheme cards in $\mathbf{VCMS}^{change}$ is same as Fig.8. And the luminance conditions of an input image same as the left image of Fig.5. The color-difference of $\mathbf{VCMS}^{change}$ is the same as that of **VCMS** in Fig.4 (with an uncertainty 10%).

The image of Fig.10 is a reddish image. And the color-difference is 31.5. From this result, *Dis* is necessary in (8), (9) and (10).

	Blue	Red (Fig.6)	Yellow	Green
Proposed	19.1	22.1	21.7	16.8
Previous	16.8	20.3	22.2	22.2

Table 1 color-difference between an image under standard illumination and the restored image whose subject has each color shirt (luminance condition is same as Fig.5. **VCMS** is Fig.4)

	Blue	Red (Fig.9)
$\mathbf{VCMS}^{change}$	35.1	26.4
VCMS	34.3	24.0

Table 2 color-difference between an image under standard illumination and the restored image whose subject has each color shirt (luminance condition is same as Fig.8. $\mathbf{VCMS}^{change}$ is calculated with Fig.4)

	Blue	Green	Red	Yellow
$\mathbf{VCMS}^{change}$	20.2	23.4	22.9	19.5

Table 3 color-difference between an image under standard illumination and the restored image whose subject has each color shirt (luminance condition is same as Fig.5.Luminance condition of **VCMS** is same as Fig.8)

From these experimental results, it is conducted that the restored image in various luminance conditions with the proposed algorithm is the same as that of the same luminance in terms of the color-difference.

4. Conclusion

The problem of color restoration in images under various low luminance conditions is addressed, and a color restoration algorithm is proposed. The proposed algorithm enhances the image quality using color change vectors. To evaluate the performance of the proposed algorithm, two experiments are performed using real images. First, for an input image, the restored image obtained by the proposed algorithm is compared with that obtained by the previously proposed algorithm in terms of color difference. The experiment shows small color difference between the two images. Thus, the proposed algorithm is the same as the previously proposed algorithm in terms of color difference in the restored image. Next, the experiment is performed under two luminance conditions, and the restored images are compared in terms of color difference. The experiment shows that the change in lighting conditions does not affect restored results. Thus, the proposed algorithm is considered to work under various luminance conditions.

The proposed algorithm gives the foundation of the security system to identify an invader, in cooperation with the CCD camera of low cost.

Reference

[1] Y.Hatakeyama, Y.Takama, K.Hirota, "Instance-based Color Restoration Algorithm for Still Image under Low Illumination", 2nd International Symposium on Advanced Intelligent Systems (ISIS), pp185-188, 2001

[2] Color scheme card 175b(sinhaisyokukado in Japanese), nihonsikiken, 1989