Projector Camera System Presenting Color Information for Color Vision Deficiency

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Abstract

There are individual differences in color vision. It is difficult for people with defective cones in the retina to recognize the difference of specific colors. We propose a system using a camera and a projecctor to present color information for color vision deficiency. When there are indistinguishable colors in real objects, the system converts the color to a distinguishable color for projection. The system also produces an image with texture and blinking light when multiple color combinations of indistinguishable colors exist. On projecting the image onto the object, the system equalizes an observed color with a target color by color feedback. Effectiveness of the proposed method is verified through experiments.

Keywords – Projector camera system, Color vision deficiency, Image processing

1 Introduction

In recent years, aged people and disabled people are becoming supported by universal design and barrier-free approaches to lead comfortable lives. In regard to color vision, there is an effort to use distinguishable color combinations for any color vision people. However, it is realized in only some route maps, and it has not been commonly used.

To support people with color vision deficiency, there are studies of color conversion methods targeting images on web pages [1, 2], but these methods do not treat real objects. Therefore, we think that it is effective to use a projector camera system which enables color deficient people to distinguish object color patterns by presenting distinguishable color information on the object. The system can be used in many places to present color information with a projector, and it can be applied according to the color vision of individuals.

There is a previous study to present color information by a projector camera system [3]. However, there is a problem that this system cannot support color distinction when multiple combinations of indistinguishable colors exist. Additionally, an observed color is not equal to the target color when projected on the object because it does not take account of the reflective properties and the color of the object.

In this paper, we propose a projector camera system which solves the above problems. To solve the problem of multiple combinations of indistinguishable colors, the system projects texture and blinking light on the object. To equalize an observed color with a target color, the system employs color feedback.

2 System Overview

Figure 1 shows the proposed projector camera system. An object to be recognized by the system is assumed to be a planar one such as a poster.

At first, a user takes an image of an object to observe with a camera, and the system judges whether the acquired image has indistinguishable colors. If there are color combinations that are difficult to distinguish, the system produces an image in which a color is converted to another distinguishable color. If simple color conversion is not enough because of multiple combinations of colors to distinguish, the system produces an image with texture and blinking light.

On projecting the image, the system equalizes the produced image and a target image by color feedback.

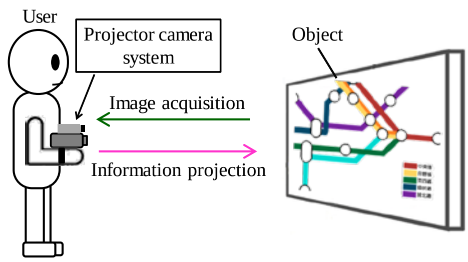


Fig. 1. Proposed projector camera system.

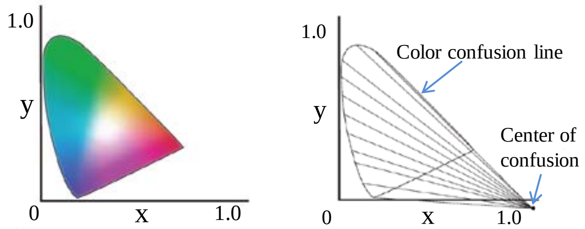
3 Color Information Presentation

3.1 Detection of Colors of Difficult Distinction

In order to examine colors of difficult distinction, color confusion lines are used [4]. A color confusion line is a straight line radiated from the center of confusion (copunctal point) on the CIE1931 x-y chromaticity diagram (Fig.2). The center of confusion is given according to the type of the color vision.

Our method calculates a color confusion line drawn from the center of confusion to a color of a pixel in an acquired image. In addition, lightness and color difference is used in our study.

If both the angle between color confusion lines of two colors and the difference of lightness of two colors are small, the system determines that these two colors are indistinguishable and need to convert to distinguishable color combination. Here, it should be noted that, if color difference of two colors is small, these two colors are regarded as the same ones which are not necessary to distinguish.



(a) CIE1931 color space. (b) Color confusion line.

Fig. 2. CIE1931 x-y chromaticity diagram.

Color difference is given by the following equation.

$$\Delta E_{00}^{*} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}} \quad (1)$$

where $\Delta L'$, $\Delta C'$ and $\Delta H'$ are the lightness difference, the chroma difference, and the hue difference, respectively. R_T is a hue rotation term. k_L, k_C and k_H are weighting parameters for lightness, chroma and hue. S_L, S_C and S_H are the compensation for lightness, chroma and hue, respectively.

3.2 Color Conversion

The acquired image is divided into areas of colors by K-means clustering. Representative colors of the areas are detected, and combinations of color regions are examined whether they are difficult to distinguish. If there are color combinations that are difficult to distinguish, the system produces an image in which the color of the smaller area is converted to a distinguishable color.

Distinguishable color for color deficient people cannot be obtained in a systematic manner if color conversion is made by changing the parameters of the color system such as *XYZ* and *RGB*. Because of necessity of full search, it is not efficient.

Therefore, in this study, color conversion is made by changing the b^* and L^* components of the $L^*a^*b^*$ color system.

First, using Eq. (1), color difference ΔE^*_{00} when changing the value of b^* of the representative color of the area to be converted is calculated. The value of b^* when the color difference exceeds a threshold is determined as a value for conversion. If sufficient color difference cannot be obtained by changing the value of b^*, L^* is changed until color difference exceeds a threshold.

3.3 Texture mapping and blinking

If the system performs only color conversion, it cannot be applied to the case where multiple combinations of indistinguishable colors exist. Therefore in our study, the system projects prepared textures when color distinction is not sufficiently obtained by simple color conversion. However, users cannot distinguish the texture when there is not enough area to project the texture. In such cases, the system projects blinking light. When using blinking light, it is necessary to be careful about blinking cycle, because photosensitive epilepsy might be caused by blinking light. By these methods, the system can be applied to many kinds of object color patterns.

3.4 Projection Image Generation

When the system projects a target image to a projection target, an observed color and a target color are not exactly equal. Therefore, it is necessary to equalize the observed color with the target color by color feedback. Our method of color feedback is based on the method proposed by Amano and Kato [5].

4 Experiment

4.1 Experiment Environment

The experimental system consists of a projector and a camera (Fig. 3(a)). The experiment was performed in a room. Figure 3(b) shows the object to use in the experiment, and the system projects color information on this object.

(a) Experimental equipment. (b) Object in experiment.

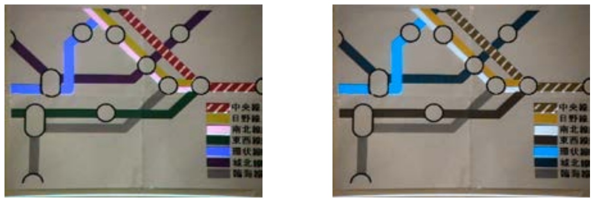
Fig. 3. Experiment environment.

4.2 Experimental Result

Figure 4(a) shows an acquired image before projection. Figure 4(b) shows the results of the deuteranope simulation for Fig. 4(a). The combinations of red and green areas, blue and purple areas, and gray and pink areas in Fig. 4(a) are indistinguishable in Fig. 4(b), respectively. Figure 5(a) shows the result of color information presentation by the proposed method. Figure 5(b) shows the results of the deuteranope simulation for Fig. 5(a). The system converts the color on blue area, projects texture on red area, and projects blinking light on pink area. Thus, it is possible for color deficient people to distinguish those color areas.

(a) Normal color vision. (b) Deuteranopia simulation.

Fig. 4. Acquired image before projection.



(a) Normal color vision. (b) Deuteranopia simulation.

Fig. 5. Result of color information presentation.

5 Conclusion

We proposed a presentation method of color information for people with color vision deficiency with a projector camera system using color feedback. We confirmed the effectiveness of the method by experimental results. In our method, it is possible to project color information by distinguishable color, texture and blinking light. Thus, it can be applied to various color combinations. As future works, the system should treat not only a plane but also 3-D objects. Textures to be projected should be selected automatically depending on the shape of target area.

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