

Color Blind Image Correction

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Abstract—Color blindness or color vision deficiency (CVD) refers to the inability to perceive or distinguish certain colors or shades of colors to some degree. This paper presents different methods of correcting images especially for people suffering from dichromacy: protanopia, deuteranopia and tritanopia. Color transformation, color simulation and colormap approximation are the methods that have been applied in this project for helping color blind people to improve color perception when they see things in this world. Experimental results demonstrate the effectiveness of the proposed methodology. A survey has been conducted to colorblind people to test the proposed methodology. The output of the survey shows very promising results, indicating that the proposed method of image correction using colormap approximation method is capable of relaying information in the picture or image to the color blind people.

Keywords—color blindness; LMS color space; colormap approximation method

I. INTRODUCTION

Color blindness or color vision deficiency (CVD) refers to the inability to perceive or distinguish colors or shades of colors to some degree. According to the statistical data [1], about 8% of males and less than 1% of females are suffered from CVD from birth. The effects of CVD can be characterized by mild, moderate or severe, depending upon the defects. There are three degrees of color blindness: anomalous trichromacydichromacy, and monochromacy [2]. Anomalous trichromacy, a mild color deficiency, is often characterized by the defect of one of the three cones (*Long*, *Medium* and *Short* (LMS) wavelength cones). Dichromacy, a more severe color deficiency, is present when one of the three cones is absent. Monochromacy, the severest but rarest type of color deficiency, is present when all three cones are absent [3]. Image recolorization algorithm for enhancing the representation of colors of the images is a famous method that has been proposed to help the colorblind [3, 4]. The hue component in the HSV color space was re-mapped based on the statistics of local characteristics of the original color image. This will help to enhance the color contrast through generalized histogram equalization. Recently, Jinmi Lee *et al.* [5] presented three computational tools to help color blind people. The correction tool called *DaltonCor* which using digital image processing, is intended to improve the visual quality of the color blind individuals. This tool was divided into three modules: Filter, Fuzzy and Control. The proposed correction seeks to compensate the lack of sensitivity to a particular color with new values for the normal color perception.

This paper focuses on the image correction especially for people who are suffering from dichromacy. There are three categories belong in this type of deficiency: protanopia (absent of *L*-cone), deuteranopia (absent of *M*-cone) and tritanopia (absent of *S*-cone). The purpose of image correction is to improve the interpretability or perception of color information in images for this type of deficiency. Basically, the idea behind this method is still to remap the colors of the original image for accommodating the dichromacy in order to provide a better color representation in the image, similar to the main objective as in [3, 4]. However, in this paper, we used colormap approximation method for image correction. The detail of the approach is discussed later. The paper is organized as follows: In Section II, the method of simulating color blindness image is described. In Section III, image correction method is discussed. In Section IV, results and discussions are presented, and finally in Section V, conclusions of the work are made.

II. SIMULATING COLOR BLINDNESS

The first step is to simulate color deficient vision. The simulation algorithm of color blindness is based on the color model LMS adapted from [6]. In this algorithm, the RGB components of the image are converted into LMS components, where the data corresponding to the cones absent are removed. The conversion is done by the application of a matrix and a linear conversion [4].

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 17.8824 & 43.5161 & 4.11935 \\ 3.45565 & 27.1554 & 3.86714 \\ 0.0299566 & 0.184309 & 1.46709 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

The second step is to adjust the normal domain of colors to the domain of a color blind individual. The linear transformation for protanopia and deuteranopia is expressed in (2) and (3), respectively.

$$\begin{bmatrix} L_P \\ M_P \\ S_P \end{bmatrix} = \begin{bmatrix} 0 & 2.02344 & -2.52581 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} L \\ M \\ S \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} L_D \\ M_D \\ S_D \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0.494207 & 0 & 1.24827 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} L \\ M \\ S \end{bmatrix} \quad (3)$$

The next step is to convert the LMS color space image back to RGB image using (4). This transformation yields the modified image for the CDV.

$$\begin{bmatrix} R_P \\ G_P \\ B_P \end{bmatrix} = \begin{bmatrix} 0.080944 & -0.130504 & 0.116721 \\ -0.0102485 & 0.0540194 & -0.113615 \\ -0.000365294 & -0.00412163 & 0.693513 \end{bmatrix} * \begin{bmatrix} L_P \\ M_P \\ S_P \end{bmatrix} \quad (4)$$

Fig. 1 shows the normal vision image and the simulation images for protanopia, deuteranopia and tritanopia, respectively. The middle column shows the color spectrum image and the right column shows the Ishihara color plates. From Fig. 1, it can be seen that the protans and deutans have difficulties distinguishing certain shades of red and green. As for the tritans, they have a problem in distinguishing between blue and green, while yellow may appear as pale purple.

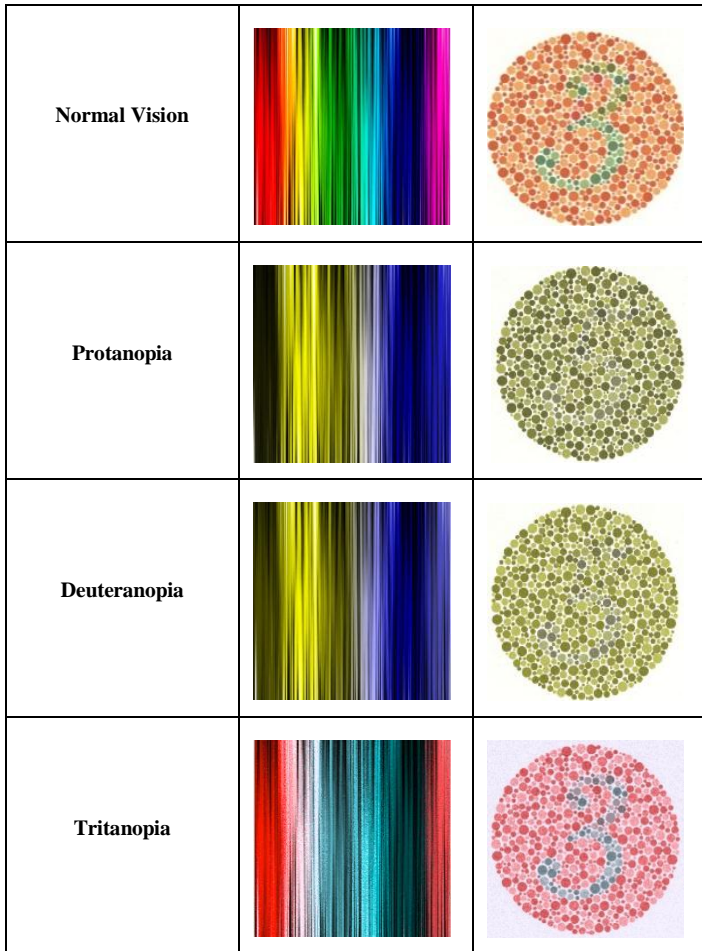


Figure 1. Normal vision image, protanopia, deuteranopia, and tritanopia.

III. IMAGE CORRECTION

Image correction technique that was used in this project is known as Colormap Approximation Method. Here, palettes are used because they form the colormaps of indexed images. In other words, colors of indexed images are assigned to pixels by using a look-up table called a colormap, where the maximum number of entries is 256. The color palettes for normal vision and its RGB values are shown in Fig. 2. In this project, *WhatColor* tool software as shown in Fig. 3 is used to display the RGB values.

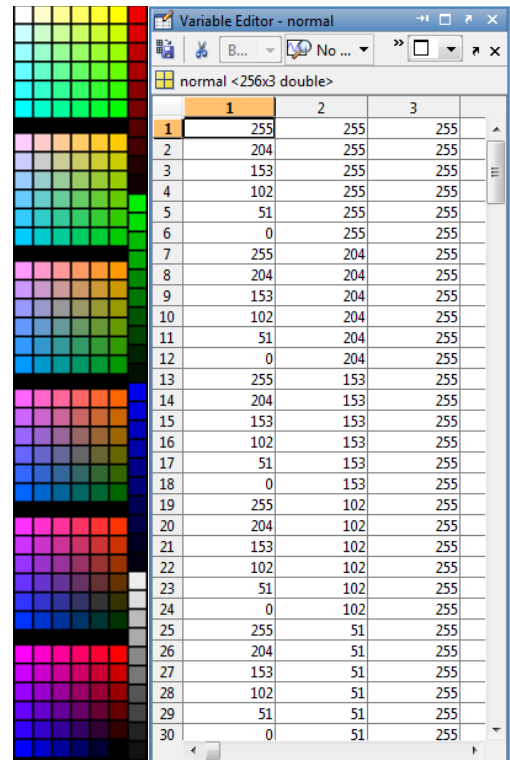


Figure 2. (a) Color palettes (b) Respective RGB values.

The same method was applied in order to display the values of indexed images for CVD viewers. The color palette of the original image is then converted to the respective deficiencies: protanopia, deuteranopia and tritanopia. The color palette for the corrected image of any type of CVD is then being run through Daltonize algorithm [7]. It will then be converted back to RGB image for CVD viewers.

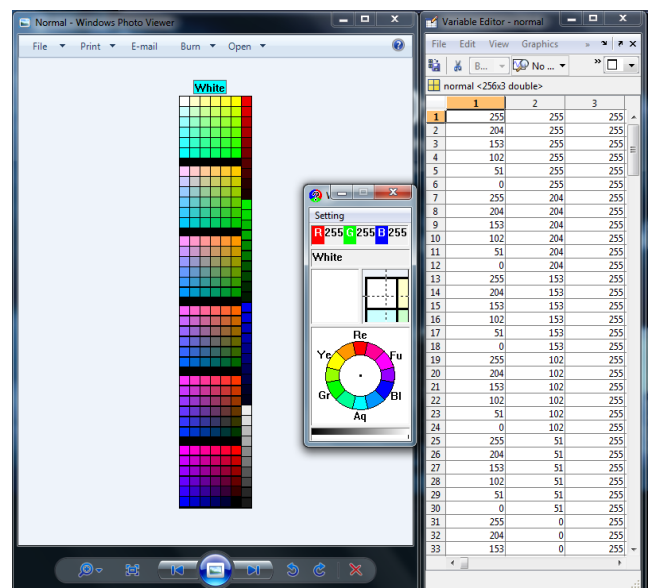


Figure 3. *Whatcolor* tool software.

IV. RESULTS AND DISCUSSIONS

Experiments have been set up using real image and Ishihara color plates to qualitatively evaluate the proposed methodology. The first part of the experiments used the real image of different kinds of fruits, as shown in Fig. 4. The middle column of Fig. 4 shows the simulated fruits images as seen by people with protanopic, deuteranopic and tritanopic color deficiencies, and the right column shows its corresponding simulated corrected images. Normal viewers can see many types of fruits. Someone who suffered with protanopia and deuteranopia have trouble seeing all different fruits as all red color fruits turning into green. The simulated corrected images show that now the protans and deutans for example, can see two different types of fruits available in the center of the image. The circle highlights these differences.



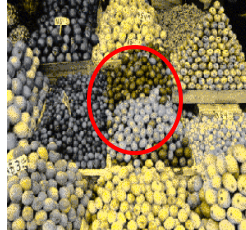

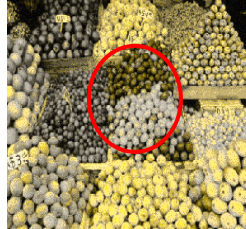


Original Image (Fruits)		
Type of CVD	CVD image	Corrected image
Protanopia		
Deuteranopia		
Tritanopia		

Figure 4. Original fruits image (top) and the simulation for three types of CVD (left column). Simulation of corrected images for each type of CVD are shown in the right column.

The second part of the experiments used the smaller test of Ishihara Color Blindness Test consisting only 17 plates out of 38 plates for a complete full test. Fig. 5, 6 and 7 show example of three Ishihara color plates that were used in this experiment.

Fig. 5 shows that normal viewer is able to see numeral “8” on the plate. Viewer with protanopia may read it as “3” and viewer with deuteranopia may see nothing. For both types, the reds are all gone. Fortunately, viewer with tritanopia is able to identify the numeral on the plate. However, the green in the image has turned to shades of blue and black. After the correction was made, viewers with protanopia and deuteranopia are able to see numeral “8” on the plate.

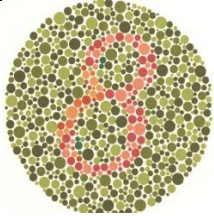
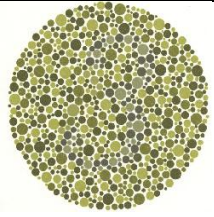
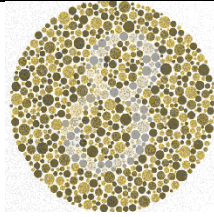
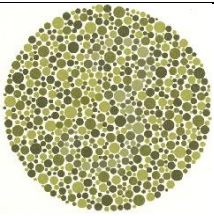
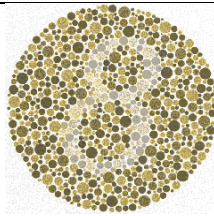
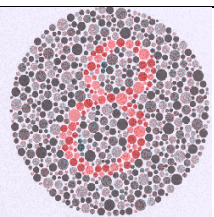
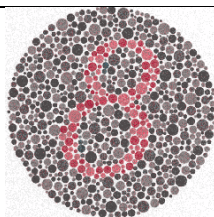
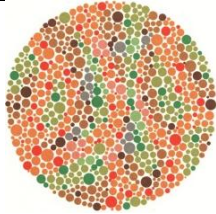
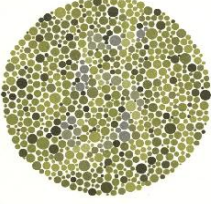
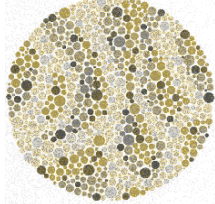
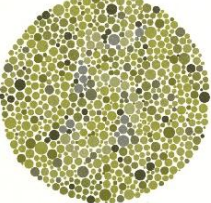
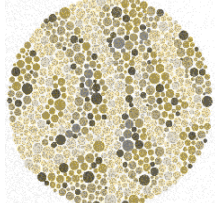
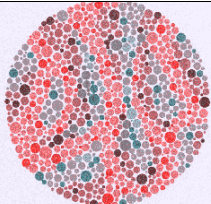
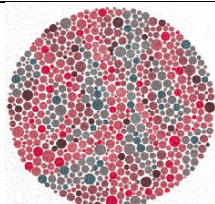
Normal Vision		
Types of CVD	CVD Image	Corrected Image
Protanopia		
Deuteranopia		
Tritanopia		

Figure 5. Normal vision of numeral “8” image (top) and the perceived images by protanopic, deuteranopic and tritanopic viewers (left columns). Simulation of corrected images for each type of CVD are shown in the right columns.

Fig. 6 gives some impression what protanopes, deuteranopes and tritanopes see a red wiggly line on the plate. Those with normal color vision should be able to trace the red wiggly line easily. However, the protanopes and deuteranopes are unable to trace any line because the reds are all gone. After the correction was made, they should be able to trace the correct line. For the tritanopes, the red wiggly line is mostly seeing looks like shades of pink and the green dots have turned to blue. The brightness of simulated corrected image has been increased after the correction was made.

Normal Vision		
Types of CVD	CVD Image	Corrected Image
Protanopia		
Deuteranopia		
Tritanopia		



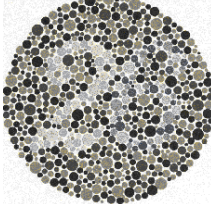
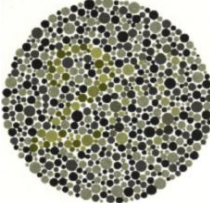
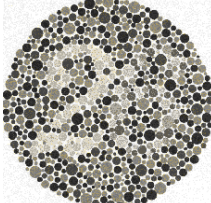
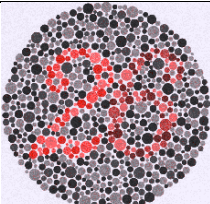
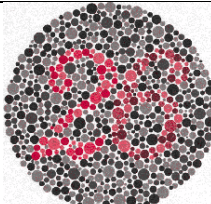
Normal Vision		
Types of CVD	CVD Image	Corrected Image
Protanopia		
Deuteranopia		
Tritanopia		

Figure 6. Normal vision of red wiggly line image (top) and the simulation images for three types of CVD (left columns). Simulation of corrected images for each type of CVD are shown in the right columns.

Figure 7. Normal vision of numeral “26” image (top) and the perceived images by protanopic, deuteranopic and tritanopic viewers (left columns). Simulation of corrected images for each type of CVD are shown in the right columns.

Fig. 7 presents the plate that contains black-gray-red-purple dots to experiment of how the test works on different color combination. The numeral “26” should be clearly visible to normal viewer. Viewer with protanopia may see nothing and viewer with deuteranopia may read it as numeral “2”. For both types, the reds and purples are all gone. After the correction has been made, viewers with protanopia and deuteranopia are able to see numeral “26” on the plate. The correction has changed the red and purple dots that forming numeral “26” into white dots. Now they can identify the number more easily. Viewer with tritanopia is able to identify the numeral on the plate.

The graphical user interface (GUI) of the proposed methodology has been developed as shown in Fig.8. Firstly, the user must upload the original image, and then they select their vision deficiency. The simulated image for specific CVD and its corrected images will appear on the middle and right columns of the interface, respectively, as depicted in Fig. 9. It can be seen that the CVD users (protanopia, in this case) will be able to distinguish different kinds of fruits that available in the image.

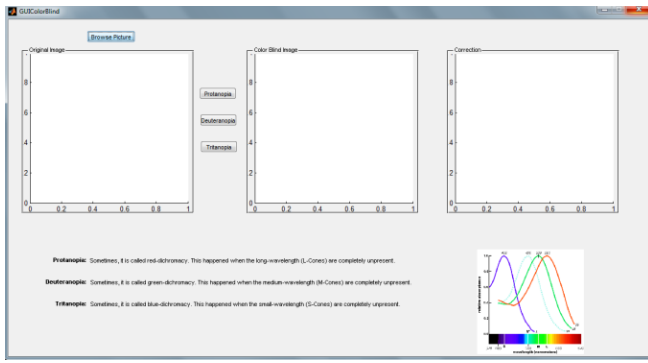


Figure 8. GUI for image correction.

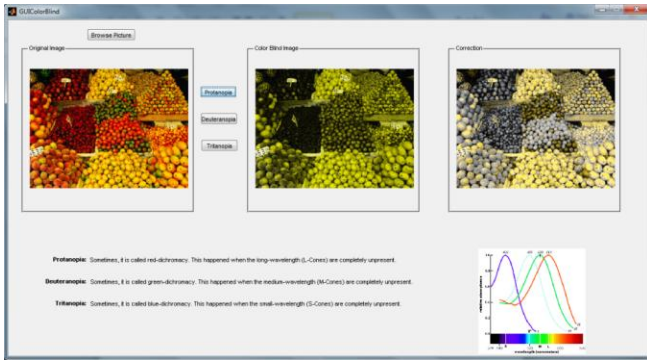


Figure 9. Results of image correction (protanopia).

A survey was conducted with a group of people with color blindness deficiencies to evaluate the proposed methodology on the image correction. Four respondents were evaluated with thirteen Ishihara plates using the proposed methodology. The results from the survey show that all respondents are able to identify the numeral on the Ishihara plates after the correction on the images was made. The results are presented in Table I, where **O** and **C** represent the original and the corrected images, respectively. The “X” symbol represents the error where the respondents were unable to identify the numeral on the plates. The output of the survey shows very promising results, indicating that the proposed method of image correction is able to provide a better color representation on the image.

TABLE I. RESULTS OF THE SURVEY

Numeral on Ishihara Plates	Respondent 1		Respondent 2		Respondent 3		Respondent 4	
	O	C	O	C	O	C	O	C
12	12	12	12	12	12	12	12	12
8	X	8	X	8	3	8	X	8
29	X	29	X	29	29	29	X	29
5	5	5	X	5	5	5	5	5
3	3	3	X	3	5	3	3	3
15	15	15	X	15	17	15	15	15
74	74	74	X	74	21	74	74	74
6	X	6	X	6	X	6	X	6
45	X	45	X	45	X	45	X	45
7	7	7	X	7	X	7	7	7
16	X	16	X	16	X	16	16	16
73	X	73	X	73	X	73	23	73
26	26	26	X	26	26	26	26	26

V. CONCLUSIONS

A survey was conducted using Ishihara plates to a group of people with color deficiencies to evaluate the proposed image correction. The results were very positive and this shows that the proposed methodology of image correction has been successful in helping each individual to identify the numbers on the plates.

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