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Model and Analysis of Optimal Color Vision Deficiency System

A. Ya'akup[*,a] *and F. S. Ismail*[b]

Centre for Artificial Intelligence & Robotics (CAIRO), Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.
[a]*afiqamirul92@yahoo.com*, [b,*]*fatimahs@fke.utm.my*

Abstract – *The inability to recognize color has caused several problems to the patient daily life and in conducting certain color oriented activities. To help the patient cope with problem related to color, a color vision deficiency aided device is designed. This paper focuses on developing a user interface that can detect colors and show it as text on the screen of the device using the concept of augmented reality. The system basically consists of a mini computer, Raspberry PI and its own camera module as well as a LCD screen for display purposes. Raspberry PI is used due to its small and compact size and capability to carry out image processing. Programming using OpenCV library has been developed for optimal color detection, filtering and processing can be carried out easily. Various experiments have been carried out to test for the performance and functionality of the device. The result of the distance test for various benchmark shapes and colors show that the hue element is almost consistent whereas the saturation varies by roughly 49.3% and value by 30.5%. As for the range of detection, the minimum range is about 20 cm where the maximum range is up to 12 meter. The accuracy of the four base colors detection is about 68%.*

Keywords: Color Vision Deficiency, Image Processing, Color Coding, Open Software

1.0 INTRODUCTION

Based on The global statistics from the World Health Organization (WHO) indicate that there are more than 39 million blind and 285 million of visual impairments during year 2012. It is approximately 1 of 12 men (8%) and 1 of 2. The inability to recognize color has caused several problems to the patient daily life and in conducting certain color oriented activities. To help the patient cope with problem related to color, a color vision deficiency aided device is designed. This paper focuses on developing a user interface that can detect colors and show it as text on the screen of the device using the concept of augmented reality.

Currently there is no treatment for inherited color blindness. There is an urgent need to reduce the results of visual disabilities, which represents a high percentage of society and to create innovate solutions to improve their daily life conditions especially children. It is important to detect the problem as early as possible because color vision problems can affect children's growth and learning process. Firstly, human eyes see when light stimulates the photosensitive cells (photoreceptors) in the retina. Photoreceptors consist of rod (sensitive to light) and cone cells (pick-up color). This cones are sensitive to either red (long), green (medium) or blue (short) light. (In wavelength). The eye sees color when these cones sense different amount of

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the basic colours. When one/more of these cone cell is absent/fails to function normally, the eye cannot see colours as normal. [1-2].

Currently there are many color detection device that are sold on market. However, the device only based on voice teller and colour sensor. The device will detect the colour and give the output of the colour by voice output only which tell the colour name. The device also need colour card as input for the colour sensor. The limitations of the device are short range color detection and don't have a text output.

2.0 COLOR RECOGNITION

There are several AI color model algorithm. Firstly, device color characteristics method based on fuzzy control. Based on the fuzziness of description in color by natural language and the basic principle of fuzzy control 8 subsets to divide the three color components of input RGB color space, and 21 fuzzy subsets to divide the output color components. It builds the device color characteristics method of RGB color space by establishing the fuzzy rules and doing the fuzzy reasoning for getting the fuzzy quantity of output parameters which are clear disposal by weighted average method of area (centroid) method.

This method can use less sampling space points to get high model conversion precision. Secondly, the device color characteristics method based on dynamic subspace divided BP neural network identification method is by means of calculating the distance between input spaces point and sample points, to choose a certain amount of sample points which has nearest space distance with input spaces point so as to divide dynamically the input space to innumerable subspace and use those sample points which is in the subspace to train the BP neural network, and output the input spaces point by the trained BP neural network. This method can effectively avoid phenomenon of training speed too slow, or even the network cannot correct regression. Lastly, device color characteristics method based on fuzzy and neural identification method. Device color characteristics method which based on fuzzy and neural identification method adopt in fuzzy control to divide the input space to corresponding subspace and train the BP neural network by sample points which are in the subspace, and output the chromatic value of input space point by the network [3-5].

Color recognition approaches have 2 methods either using real time camera or color sensor. In this project, the real time camera is used because can be functioning on long range color detection. Color recognition mode will run straight after the code is compiled. The application is able to detect 16 base colors as well as their correspond variation based on the HSV value such as dark green and light green. Table 1 shows the range of H value with their corresponded base color whereas the S value and V value determine the saturation level and the brightness respectively as shown in Table 2 and Table 3.

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Table 1: The range of Hue (H) value with correspond color

NO.	Range of H values	Colors
1	170-180 & 0-6	Red
2	7-11	Red-orange
3	12-20	Orange-brown
4	21-25	Orange-yellow
5	26-32	Yellow
6	33-40	Yellow-green
7	41-67	Green
8	68-85	Green-cyan
9	86-100	Cyan
10	101-110	Cyan-blue
11	111-121	Blue
12	122-140	Blue-purple
13	141-160	Purple
14	161-165	Purple-pink
15	166-173	Pink
16	174-177	Pink-red

Table 2: The range of saturation (S) value

Ranges of S value	Saturation Level
0-85	Light
86-170	Medium
171-255	Solid

Table 3: The range of brightness (V) value

Ranges of V value	Brightness Level
0-85	Dark
86-170	Medium
171-255	Bright

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3.0 EXPERIMENTAL VERIFICATION

The system basically consists of a mini computer, Raspberry PI and its own camera module as well as a LCD screen for display purposes. Raspberry PI is used due to its small and compact size and capability to carry out image processing. Programming using OpenCV library has been developed for optimal color detection, filtering and processing can be carried out easily. Various experiments have been carried out to test for the performance and functionality of the device. The result of the distance test for various benchmark shapes and colors show that the hue element is almost consistent whereas the saturation varies by roughly 49.3% and value by 30.5%. As for the range of detection, the minimum range is about 20 cm where the maximum range is up to 12 meter. The accuracy of the four base colors detection is about 68%.

The image can be axtracted from the depth map according to the following approach. Firstly, assuming that the image detection algorithm returns the 2D position and dimension in pixels (w 2D, h 2D) of an image region, its 3D physical dimension in mm (w3D, h3D) can be estimated as follows:

$$w_{3D} = w_{2D}\frac{d}{f_x}, \quad h_{3D} = h_{2D}\frac{d}{f_y} \tag{1}$$

where f_x and f_y are the position of pointer camera focal lengths computed by the calibration algorithm and d is the length between image and color detection device [9].

The HSV stands for the Hue, Saturation and Value, provides the perception representation according with human visual feature. The quantization of the number of colours into several bins is done in order to decrease the number of colours used in image retrieval, J.R. Smith designs the scheme to quantize the color space into 166 colours. Li design the non-uniform scheme to quantize into 72 colours. We propose the scheme to produce 16 non-uniform colours. The formula that transfers from RGB to HSV is defined as [3]

$$H = \cos^{-1}\frac{\frac{1}{2}[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}} \tag{2}$$

$$S = 1-\frac{3}{R+G+B}(\min(R,G,B)) \tag{3}$$

$$V = \frac{1}{3}(R+G+B) \tag{4}$$

The R, G, B represent red, green and blue components respectively with value between 0-255. In order to obtain the value of H from 0o to 360 o, the value of S and V from 0 to 1, we do execute the following formula:

H = ((H/255*360) mod 360 (5)

$$V = V/255 \quad (6)$$

$$S = S/255 \quad (7)$$

4.0 RESULTS AND DISCUSSION

The whole system is setup by connecting the PI camera module to the CSI port on the Raspberry PI board via ribbon cable while the LCD screen is connected to the board via HDMI cable. The wireless keyboard and mouse is connected to the board using wireless USB adapter. This is only needed when manipulation of code is required. The power is supplied to the board by connecting a micro USB to USB cable to a wall socket USB adapter or power bank.

Table 4: The HSV range of lower and upper threshold

Threshold	H value	S value	V value
Low	H - 5	S - 30	V - 30
High	H + 5	S + 30	V + 30

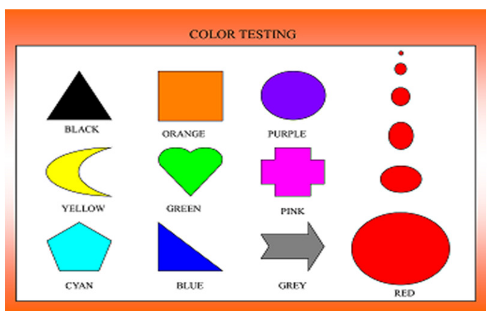

Figure 1: Color and shape benchmarks

The second part of the application is highlighting the regions, which have the same HSV value as the centre of the circle. In coding aspect, two thresholds are used for the filtering process. The low threshold is an array which contains the minimum of the HSV value whereas the high threshold holds the maxima of HSV value. In Table 4, the minimum and maximum of the HSV value are listed. Figure 1 shows the color benchmark, which consists of 10 different colours such as black, yellow, orange, green, purple, pink, cyan, blue, grey and red. It also have different shapes according to the color and have different sizes of sphere for red color.

The prototype color detection assistive device, for experimental purposes only detects 16 base colours and HSV within its range. Besides the HSV range, the result will display unknown or not detected.

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Table 5: Accuracy test

NO.	Colors	Accuracy out of 10 sample	Percentage,%
1	Red	5	50
2	Red-orange	6	60
3	Orange-brown	7	70
4	Orange-yellow	6	60
5	Yellow	8	80
6	Yellow-green	7	70
7	Green	8	80
8	Green-cyan	8	80
9	Cyan	6	60
10	Cyan-blue	5	50
11	Blue	8	80
12	Blue-purple	7	70
13	Purple	8	80
14	Purple-pink	6	60
15	Pink	8	80
16	Pink-red	6	60
	Standard Deviation	6.8	68

A range test is been carried out for each of the color to determine the deviation on the HSV value when the range of object changes. 10 samples of HSV value on the same test object (color paper) was recorded. The accuracy test between 10 centimeters to 12 meter with 10 samples for each color is tabulated in Table 5. The result shows the minimum percentage of color detection is 50 percent where the maximum percentage 80%. The average accuracy of the color recognition is 68%.

Fig. 2-3 present the visual image of the accuracy test. These figures show that a boundary line is created and bounded around the region, which has similar color with the region inside the blue circle. In addition, the color of the boundary line is changed based on the color of the region, which is covered under the circle.

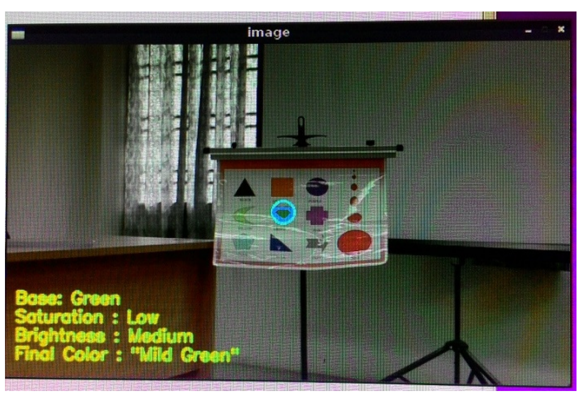

Figure 2: Distance Test (4 meter)

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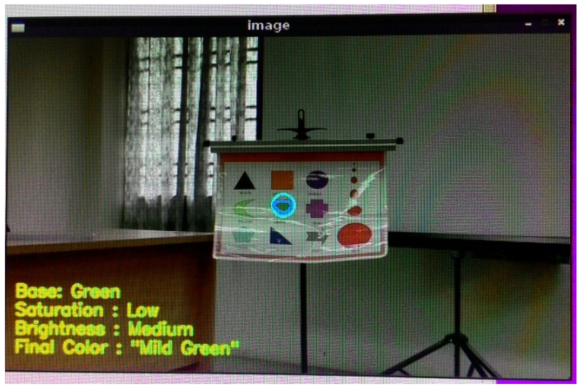

Figure 3: Distance Test (50 centimeter)

5.0 CONCLUSION

The characteristics and type of color blind has been studied and identified as well as the problem faced by individual that is color blind. A real-time optimal color recognizing system using image processing technique is successfully developed and tested. A different experimental test was performed to test the functionality of the developed application. One is the range test while another is the color deviation test. The results of the range test showed that the device could recognize color from a range of 20 cm up to 12 m. For the optimal color deviation test, the results showed the deviation on the HSV value of the tested color was small and within an acceptable range. In conclusion, the developed application is able to recognize up to four type of color that is red, blue, green and yellow as well as their respective variations such as light blue or dark blue. The region with similar HSV value to the designated region is also highlighted. The visual results which is text indicating the object color as well as the boundary line is successfully shown on the LCD monitor.

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