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Development of Color Vision Deficiency Assistive System

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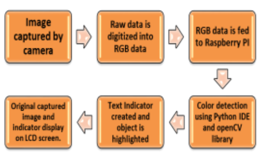
Graphical abstract



Abstract

Color vision deficiency is commonly known as color blind, is a type of vision defect in our eyeball. 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 the problem of recognizing colors, 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. With the help of OpenCV library, color detection, filtering and processing can be carried out easily. Benchmark shape and color of has been designed for experimental purposes to test for the performance and functionality of the system. The result of the distance test shows that the hue (H) element is almost consistent whereas the saturation (S) varies by roughly 49.3% and value (V) by 30.5%. As for the range of detection, the minimum range is 12 cm where the maximum range is up to 15 meter. The accuracy of the 4 base colors detection is about 80%.

Keywords: Color vision deficiency; image processing; color coding; open software

1.0 INTRODUCTION

Color vision deficiency (CVD) is commonly known as color blind is a type of vision defect in our eyeball. It is caused by the defecation in our eyeball, which is either the defects or completely missing of certain photoreceptors. As a result, color with certain spectrum is unable to be detected by the photoreceptors causing the color of the image saw with the eyes is different from the real color. For instance, a red object might appear as yellow for red-green color blind's people [1, 2].

Furthermore, based on global statistics, roughly 1 in 10 men are either fully or partly color blind. In fact, the most common type of color deficiency is protanopia for red-weakness and deuteranopia for green weak. Individuals who suffered from these two types of color deficiency had very hard time to distinguish between red and green color. This cause them a lots of trouble when choosing clothes, differentiating red and green light on a traffic light, acquiring a driving license or even taking some courses in university, etc. As for color blind children, the problem is even worst as most of the time their learning's in school are related to color, like object sorting, puzzle building, color matching and so on [3-5]. Unfortunately, this kind of vision deficiency is normally inherited genetically through parents and so far there is no solution that could solve this defect by any genetic means.
Currently there are plenty of assisting devices on the market that help people to differentiate color. However, most of these devices are color teller that only detect color and then tell it to the user through earphones or speakers. Although these devices are able to detect between 150 colors to 1500 colors depending on the device, they can only speak out the color and could not display the result visually due to the lack of screen.

Thus, the range of detection of these devices is short. Due to this limitations, the user can only use the device on object that is in close range and could not use it to detect distant object such as the banner board, traffic lights, color of roof top, etc. Hence, it is undeniable that a device with an integrated screen that can detect color and show it visually in text form will be helpful to the color blinded individual. For pass few years, various works on implementing image processing techniques for color recognizing have been developed by researchers. These devices are developed to detect the desired color and show it on the screen in text form. However, these devices are still in premature stage and the hardware is big and not able to bring around.

The objective of this project is to study how color vision deficiency (CVD) will affects people especially children in their daily life. Besides that, to design a system in assisting people with color vision deficiency and to develop a software interface using image processing. Hence, for these people there are two solutions they can apply that are by adapting to the defected vision or use some aiding system or device to help them recognize color.

2.0 BASIC THEORIES

2.1 How Color Vision Works

There are two different types of photoreceptors in our eyeballs that allow us to see everything. They are called rods and cones. The rods receptors are very sensitive to low light level but not to color [5-10] while cones are sensitive to colors. There are three types of cones that responsible for color vision: long, medium, short wavelength cones. Each of these cones corresponds to a specific light wavelength, which is red (long wavelength), green (medium) and blue (short). Hence, each of these cones had its own specific color absorption curve that peaked at different points in the color spectrum.

2.2 Types of Colour Vision Deficiency

There are three types of color blindness that are monochromatism, dichromatism and anomalous thricomatism. Monochromatism is either the absence of cones or only one type of them in the eyes. A person with this type of colorblind is very rare and his/her vision is equivalent of a black-and-white movie [11-15]. Dichomatism is also quite rare and is due to missing of one of the cones in the eyes. Anomalous trichromatism is the most common type of color blindness as it is only due to defection in one of the cones which results in a smaller color spectrum. Dichromats and anomalous trichromats can be further differentiated into three categories, which could be referred as blue-, green- or red-weakness respectively as listed in Table 1 [16-18].

Table 1 The different forms of color vision deficiency

Type	Denomination	Prevalence %	
		Men	Women
Monochomacy	Achromatopsia	0.00003	
Dichromacy	Protanopia	1.01	0.02
	Deuteranopia	1.27	0.01
	Tritanopia	0.0001	
Anomalous Trichromacy	Protanomaly	1.08	0.03
	Deuteranomaly	4.63	0.36
	Tritanomaly	0.0002	

2.3 Augmented Reality Concept

Augmented reality (AR) is the integration of synthetic or virtual information into the real environment. It is the projection of virtual objects in two or three dimensions real-time into the three dimensional environment. However, users are not able to sense these virtual objects at any means although they could see them. This is what differentiates AR from VR (virtual reality) as the real environment is not completely suppressed in AR. In VR, human react with a completely synthetic world whereas in AR we still able to react with the real world combined with synthetic supplements. In this booming age of technologies, the application of AR could be seen almost everywhere due to emergence of smart phones, handheld tablets and other high-tech gadgets such as Google glasses [19, 20].

2.4 Python IDE and OpenCV Library

Python is one of the high-level programming languages, which designed by Guido van Rossum and is extensively used for general-purposes. The main different of this language is that it emphasizes on code readability as well as its syntax that allows programmers to develop an application with fewer lines of codes.

Multiple programming paradigms are supported by python. Examples are object-oriented, imperative and functional programming's or procedural styles. Since python is widely used as mentioned, it also features a large and comprehensive library. Python is also frequently used as scripting language just like other dynamic languages. Furthermore, with third-party tools, Python code could even be packaged into an executable program [21, 22].

I n addition, OpenCV (Open Source Computer Vision) library is used along with Python IDE. OpenCV is a library that contains programming functions that deal mostly with real-time computer vision. OpenCV was developed by Intel Russia research center and supported by Willow Garage and Itseez. The library is cross-platform and free for use under the open source BSD license [23-25].

3.0 METHODOLOGY

3.1 Overview of the System Process

Firstly, the real-time image will be captured by the camera module. The camera itself has its own processing unit that automatically digitized the information (captured image) into 8 or 10-bit raw RGB data. This RGB data will then be feed to the Raspberry PI. After that, all the color detection process and filtering will be done by using Python IDE (integrated development environment) with the help of OpenCV library. An indicator will be created using OpenCV codes when the desired color is detected. Then the indicator will be combined with the original captured image and display on the LCD screen. The overall process of the system is shown in Figure 1.

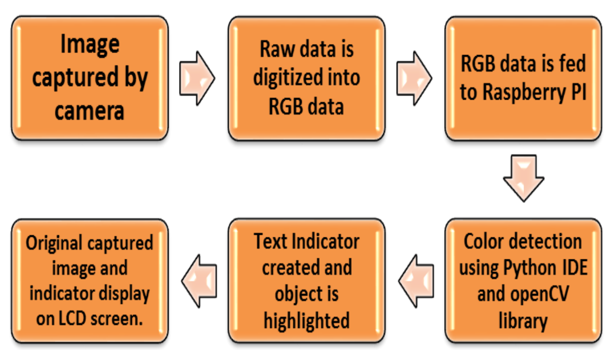


Figure 1 Block diagram of the processes of the system

3.2 Software and Program Development

The software implementation involves a few parts that are the live stream signal, Linux environment and Python IDE. The Raspberry PI board is booted up by installing Raspbian which runs on Linux operating system (OS). In this OS, Python 2.7, which is an integrated development environment (IDE), is used to develop the application along with OpenCV libraries. OpenCV provides large number of function that is specific for image processing.

The program will start with initializing the PI camera. The camera will start up after that and start capturing the image. The image captured is duplicated and relevant filtered in order to reduce noise. After that, the filtered image will be converted into HSV model. HSV color space are consists of 3 matrices, 'hue', 'saturation' and 'value'. In OpenCV, value range for 'hue', 'saturation' and 'value' are respectively 0-180 or 0-255, 0-255 and 0-255. 'Hue' represents the color, 'saturation' represents the amount to which that respective color is mixed with white and 'value' represents the amount to which that respective color is mixed with black. The HSV value of the pixel at the centre of the image is extracted.

The HSV value obtained is then checked with multiple present values. Three different flag (color, saturation, value) is set if the HSV value matches the present value respectively. Otherwise, the system will loop back to previous step which is obtaining the HSV value. After the flags are set, the image in HSV model will be further filter leaving only the region with similar value with the designated value. Then filtered image will be passed to perform edge detection. Once the edge is detected, a boundary line will be drawn around these edges.

After that, the text indicating the color of region is printed on the original image along with the boundary line (highlight). Finally, the processed image will be shown on the LCD screen. The flow chart of the program is showed in Figure 2.

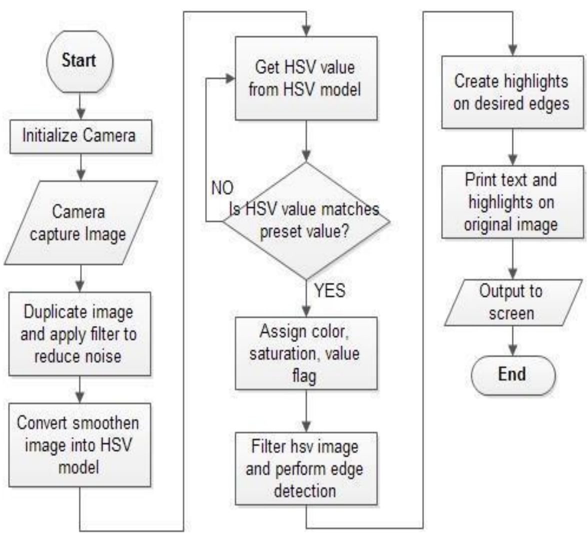


Figure 2 Program flow chart of the system

3.3 Color Recognition

Color recognition mode will run straight after the code is compiled. The application is able to detect four base color which are red, yellow, blue and green as well as their correspond variation based on the HSV value such as dark green and light green. If there not detect HSV value outside the color range, it will display unknown or not detected the color. Table 2 shows the range of H value along with S and V value with their corresponded base color. The S value and V value determine the saturation level and the brightness respectively as shown in Tables 3 and 4 respectively.

Table 2 The range of HSV value with corresponded color

Range of H values	Ranges of S value	Range of V value	Color
0 to 13 or 168 to 255	12 to 255	0 to 255	Red
16 to 31	12 to 255	90 to 255	Yellow
32 to 50	>30	65 to 210	Green
51 to 97	47 to 79	0 to 255	Blue
	>79	0 to 140	Green
98 to 131	12 to 255	0 to 255	Blue

Table 3 The S value with corresponded saturation level and its color level

Ranges of S value	Saturation Level	Color Level
20 to 90	Low	Faint (Close to White)
91 to 194	Medium	Mild
195 to 255	High	Solid

Table 4 The V value and corresponded brightness level

Ranges of V value	Brightness Level
30 to 105	Dark
106 to 181	Medium
182 to 255	Bright

■4.0 RESULTS AND DISCUSSION

4.1 Full Hardware Setup

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 as shown in Figure 3. 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. Figure 4 shows the device with DIY enclosure casing.

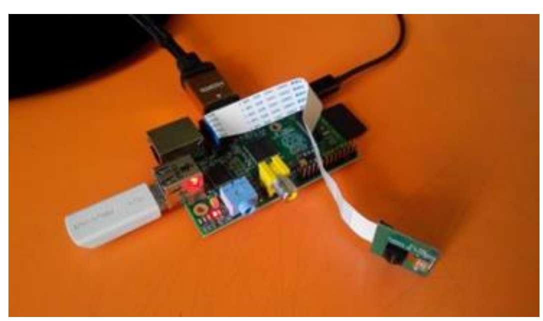


Figure 3 Hardware setup of the color vision deficiency assistive device

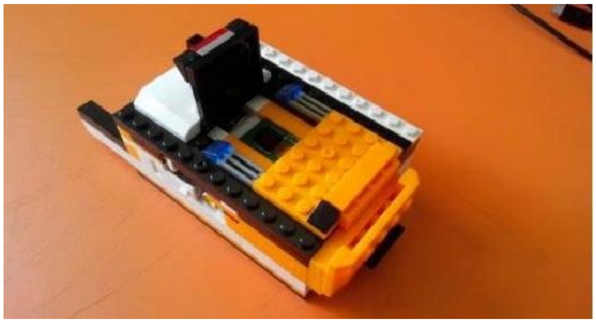


Figure 4 Color vision deficiency assistive device with DIY enclosure

4.2 Object Highlighting

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 5 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 4 base colours and HSV within its range. Besides the HSV range, the result will display unknown or not detected.

Table 5 The HSV range of lower and upper threshold

reshold	value	alue	value
w	5	30	30
gh	+ 5	30	+ 30

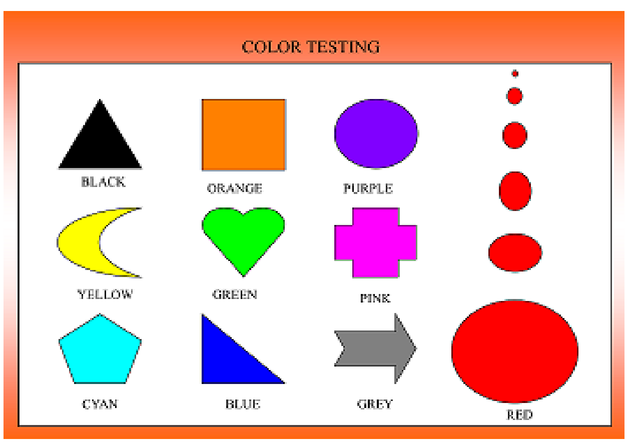


Figure 5 Color and shape benchmarks

4.3 Performance Analysis

A set of range test has been carried out for each color in order to determine the deviation of the HSV value when the range of object changes. 50 samples of HSV's value on the same sample (color paper) were recorded.

The standard deviation of HSV values for red, green, blue and yellow color with the distance of 40 cm, 60 cm and 80 cm are listed in Table 6. For color recognition, the most important element is the H value, which determines the nature of the color. Hence, from the table it is clear that red color and yellow have the least deviation, which is between 0.4 and 0.6. For blue color, when the object is in close range the deviation is slightly higher. The same goes green color, where in close range the H value deviates more compared to longer range.

The system accuracy has been tested between 10 cm to 12 meter with 10 samples for each color are tabulated in Table 7. The results show that the minimum range of color detection is around 20 cm where the maximum range is about 15 meter. The average accuracy of the color recognition is 80%.

Table 6 The standard deviation of HSV value for red, green, blue and yellow color in 40cm, 60cm and 80cm

Distance (cm)	Color	Standard Deviation		
		H	S	V
	Red	0.6274	2.9974	1.97828
	Blue	0.9000	4.3046	2.0824
	Yellow	0.4652	8.2594	1.3948
	Green	1.3416	5.6795	2.6141
	Red	0.5044	3.5721	1.6971
	Blue	0.5657	4.6691	1.5000
	Yellow	0.6779	2.7498	1.7368
	Green	1.1007	4.5212	1.1080
	Red	0.8052	3.7314	1.6401
	Blue	0.4899	4.3406	1.1426
	Yellow	0.5571	2.7917	1.8664
	Green	0.6353	3.2958	0.8102

Figures 6 and 7 present the visual image of the range 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

Table 7 Accuracy of the detection of red, blue, yellow and green color from difference distance

Distance (cm)	Color	Accuracy (out of 10 sample)	Percentage (%)
10	Red	2	20
	Blue	3	30
	Yellow	1	10
	Green	1	10
40	Red	8	80
	Blue	6	60
	Yellow	9	90
	Green	7	70
100	Red	9	90
	Blue	8	80
	Yellow	8	80
	Green	7	70
300	Red	9	90
	Blue	8	80
	Yellow	7	70
	Green	8	80
600	Red	10	100
	Blue	8	80
	Yellow	7	70
	Green	8	80
900	Red	9	90
	Blue	8	80
	Yellow	8	80
	Green	9	90
1200	Red	8	80
	Blue	9	90
	Yellow	6	60
	Green	8	80
Mean		8	80

Figure 6 Distance test (12 meter)

Figure 7 Distance test (1 meter)

■5.0 CONCLUSIONS

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 color recognizing system using image processing technique is successfully developed and tested.

A various experiments were performed to test the functionality of the developed application for color deviation and range tests. For the color deviation test, the results showed the deviation on the HSV value of the tested color was small and within an acceptable ranges. The results of the range test showed that the device could recognize color from a range of 20 cm up to 12 m.

In conclusion, this prototype is able to recognize up to four colours such as 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. The result of the distance test shows that the hue (H) element is almost consistent whereas the saturation (S) varies by roughly 49.3% and value (V) by 30.5%. As for the range of detection, the minimum range is 12 cm where the maximum range is up to 15 meter. The accuracy of the 4 base colors detection is about 80%.

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