Implementing Text Information Display of Detected Color for Partially Color Blinded Person using .NET Platform and EmguCV Library

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***Abstract*— Color blindness is a form of generative deficiency where the patient lost the ability to recognize color, either particular color (partial color blind) or the whole color (total color blind). The disability of the patient to recognize color is potential to cause problems to the patient in daily life or in more specific area. To help the patient cope with problem in recognizing colors, a color blindness helping system is designed. This system is designed for embedded system and Windows Phone 7 using the concept of augmented reality. In this work, we have implemented an integrated color detection module integrated in color blind aid system in the form of application for embedded system and mobile application. Testing result on embedded system shows that the module is able to detect the color samples with the percentage of 69.33% using Hue Saturation Value (HSV) color model, and 90.67% using Hue Lightness Saturation (HLS) color model in a bright and ideal lighting condition. Testing on mobile application shows that the module is able to detect color samples with percentage of 11.33% using Red Green Blue (RGB) color model and 95.33% using HLS color model in a bright and ideal lighting condition.**

***Keywords*— color blindness; augmented reality; embedded system; color detection; HSV; HLS**

I. INTRODUCTION

Color blindness is a deficiency commonly found in the world. There are two kinds of color blindness, total and partial color blindness. Most cases of color blindness is found in males where the percentage reached 7-10%, while in women the number is less than 1% [1]. The deficiency occurs naturally and is usually due to genetic factors. Color blindness occurs due to genetic mutation on X-chromosome.

Color-blind person will likely experience trouble both in everyday life, and within the scope of a more specialized environment. Deficiencies in the form of color blindness would hinder a person in his life. From this problem, we have designed a system to help people with color blindness using the technology of embedded devices and augmented reality concept for providing information in an interactive way.

This paper focused on the design and implementation of color detection module and the addition of color information using the concept of augmented reality. The design and implementation objective is to create an application for an embedded system, and mobile application for Windows Phone 7 platform. Section II provides the basic theories used in developing the system. Section III discuss the design of color detection module, Section IV describes the implementation process of the system. Section V presents the test results and Section VI provides the conclusion of this work.

II. BASIC THEORIES

A. Color Blindness

Color blindness is a genetic mutation that makes the color blinded person's vision sensitivity to particular wavelengths of color is reduced, which occurs naturally in a population [1].

Color blindness can be categorized into two types, total and partial color blindness. Total color blindness or monochromacy causes the color blinded unable to recognize any color, so his vision is limited to black and white color, while the partial color blindness causes a person to have a difficulty in distinguishing red, yellow, or green colors, and distinguish those colors that have low intensity.

B. Augmented Reality Concept

Augmented Reality (AR) is the extension of the Virtual Reality (VR) technology. The concept of VR is to create virtual objects with a computer to represent the real world [2], while the concept of AR is to combine virtual objects created by computer into the real world [3].

C. RGB, HSV and HLS Color Model

Red Green Blue (RGB) is a color model that uses three basic colors of red, green, and blue as the main component to define other colors.

Hue Saturation Value (HSV) is a color model that represents color into three components: hue, saturation, and value. Hue indicates the major components that define a color, saturation indicates the concentration of the color, while the value indicates the brightness of the color. This color model is commonly used in image processing since color processing and calculation will be simpler by using HSV [4].

Hue Lightness Saturation (HLS) or Hue Saturation Lightness (HSL) is a color model in which the concept is

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similar to HSV. However, there are major differences in the definitions of existing components. On HLS, hue shows the main color components. Lightness indicates the darkness and lightness of the existing color. Saturation component defines the gray level of the color.

D. .NET Framework and EmguCV Library

NET Framework is a framework used in application development, both desktop applications and web-based applications. C# programming language based on .NET Framework is used in the system development [5]. .NET Framework uses compilation method the so called managed compilation [6]. Managed compilation allows interoperability among programming languages and portability among operating system.

In addition, EmguCV library is used as a library that provides functions for image processing is also used. EmguCV is a cross-platform .NET wrapper for OpenCV allowing it to be run on different operating systems [7]. Using EmguCV, image processing functions found in OpenCV can be called from NET-compliant programming language. OpenCV itself has been well-known as a complete and robust image processing library to make computer vision related applications [8].

III. Design of Color Detection and Color Information Module

The color-blind aid system consists of hardware and software. Designed hardware is used to simulate head-mounted display device. The software has the following features:

a. Increasing the intensity of a specific color selected by the user to ease the user in recognizing the color.
b. Gives color information in the form of text that appears in the video stream using the concept of augmented reality.
c. Audio color information utilizing text-to-speech technology.

The whole system design and implementation is described in [9].

Color detection module discussed on this paper is used to recognize object color from camera input from the hardware designed. Figure 1 shows flowchart of the color detection module.

IV. Module Implementation and Color Blind Aid System Integration

A. Module Implementation for Embedded System Application

In this phase, the development process is focused on creating a stand-alone module for testing purposes before the function is integrated into the whole system.

Figure 2 shows the working of module. The result of the object which color is selected by user is marked with rectangle and text telling the user the name of the color.

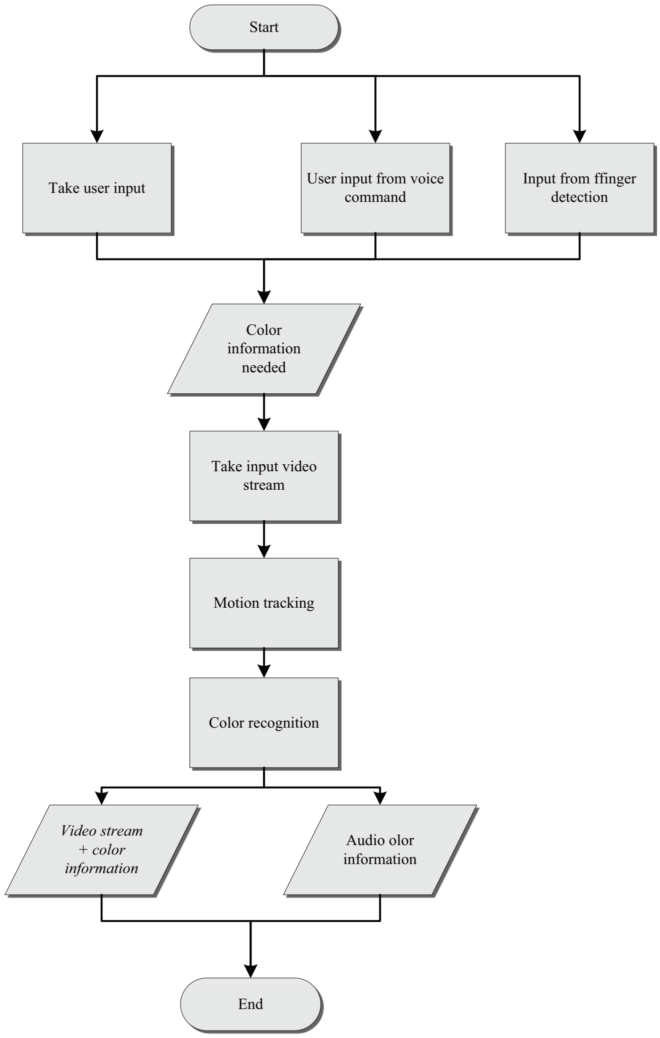

Figure 1. Color detection module flowchart.

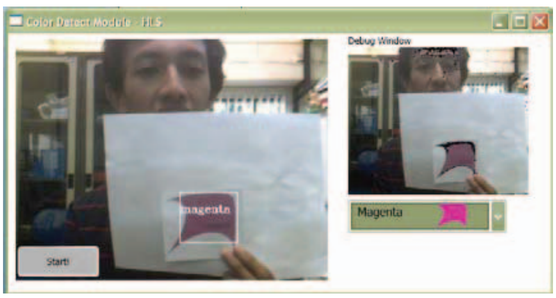

Figure 2. Color detection module.

B. Module Integration on Embedded Application

Color recognition module for embedded systems application is integrated with other modules, finger-pointed object color recognition, color intensity increase and speech recognition module which are explained in [9].

Integrated application is then installed on an embedded system consists of EBox [10] and supporting peripherals. This embedded system uses Windows Embedded Standard 2009 operating system, which supports .NET Framework 3.5. Figure 3 shows the color detection module in the integrated application.

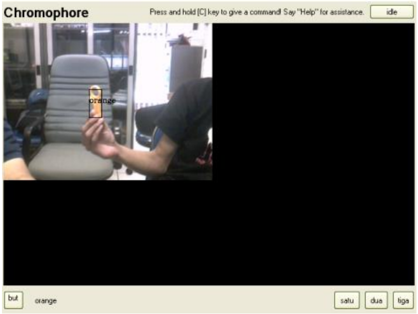

Figure 3. Integrated color detection module.

The system is also implemented as mobile application. The features of the mobile application are color recognition, color blindness test and color intensity increase.

On the initial screen of the program, there is an option for user to choose either to perform color-blind test, or using color detection and color transformation function. If the user chooses the color blindness test option, there will be program interface shown in Figure 4. When the user selects the capture color option, then the user can perform the color detection function. In Figure 5, the object with specified color is marked with text and white box.

Figure 4. Color blindness test module.

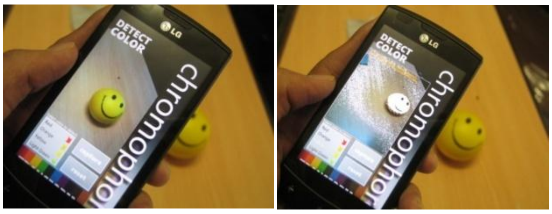

Figure 5. Integrated color detection module.

V. Testing and Analysis

A. Testing Method

Testing is then conducted to the color detection module. The testing includes technical testing and user testing. Technical testing is conducted to observe the percentage of the successful color detection using two color models, HSV and HLS on embedded system and HLS and RGB on mobile application to observe the influence of lighting condition to color detection success rate.

On the test related with color detection, printed color sample paper is used. The color of printed sample paper is set using the values of hue, lightness and saturation used by the program. This is intended to simulate the ideal condition for the program.

The testing is also done in variation of lighting condition to compare the color recognition rate in various lighting condition. Those lighting condition are dark, moderate, and bright. We define bright condition by a room with fluorescent lamp as it source of light. While moderate lighting condition is the slightly shady part on the room and the dark condition is the darker-shady part on the room itself.

The testing process was also influenced by the quality of camera. When testing the module for embedded system application, 1.3 megapixel built-in camera is used. In addition, 5 megapixel camera is used for testing module on mobile application.

In the user testing, each test is done 10 times, then the average value is determined. User testing is conducted by 5 normal vision users and 5 partially color blinded users. There are two kinds of test, color perception test and user experience test, which are conducted simultaneously. The color perception test is intended to know perception of users toward the defined colors and their ranges which are used in the program to define colors to be detected.

User experience test is also conducted to test users opinion on several aspects. On this test, the sample users are guided to use both the embedded system application and the mobile application. A questionnaire is then given to each user to know user’s opinion on several aspects which reflects his/her experience on using the application.

B. Testing Results and Analysis for Embedded System Application

1. Color Detection Success Rate on Lighting Condition Variation Testing Result

This test was conducted to determine the effect of lighting condition on the color detection module for embedded systems. Testing is also done using two-color model, HSV and HLS. Table 1 shows the test results with the HSV color model and Table 2 shows the test result with HLS.

TABLE I
RECOGNITION RATE OF DIFFERENT COLORS ON VARIABLE LIGHTING CONDITIONS USING HSV

Color	Lighting Condition		
	Dark (%)	***Moderate (%)***	***Bright (%)***
Red	0	100	90
Orange	0	100	90
Yellow	60	100	100
Light Green	30	100	100
Green	20	60	70
Tosca	40	10	40
Light Blue	0	10	30
Blue	70	100	90
Purple	10	20	100
Magenta	30	100	80
Dark Green	0	100	80
Dark Orange	10	100	70
Yellow-Green	0	100	0
Dark Gray	0	0	0
Dark Red	0	10	0
Average	18	67.33	69.33

TABLE II
RECOGNITION RATE OF DIFFERENT COLORS ON VARIABLE LIGHTING CONDITIONS USING HLS

Color	Lighting Condition		
	Dark (%)	***Moderate (%)***	***Bright (%)***
Red	10	100	90
Orange	10	100	100
Yellow	20	100	100
Light Green	30	100	100
Green	40	100	80
Tosca	0	100	100
Light Blue	40	90	50
Blue	40	50	90
Purple	40	90	100
Magenta	20	100	100
Dark Green	10	50	80
Dark Orange	10	50	100
Yellow-Green	20	30	90
Dark Gray	0	80	80
Dark Red	10	80	100
Average	20	81.33	90.67

The following are the explanation for the condition found in Table 1 and Table 2. In bright lighting conditions, both color models perform good color detection. Table 3 shows that HSV can produce an average success percentage of 69.33% and 67.33% for bright and moderate lighting. Table 4 shows that the percentages of success for HLS are 90.67% and 81.33% for bright and moderate lighting respectively. The average percentages in both color models are still high in moderate and bright illumination because the camera will read the color samples close to its original condition. It was proved that HLS produce higher percentage of success than the HSV.

In dark lighting conditions, the percentage of success in both color models decreased. HSV produces an average success percentage of 18%, and HLS by 20%. This suggests that the dark lighting conditions gives significant effect. In the HSV color model, dark lighting affect the value of the hue, saturation and value component. However, saturation and value are affected more significantly than hue. The existing modules used only saturation component, so that when the color sample to be detected tend to be dark, the module with the HSV color model cannot perform the detection well.

2. *User Testing Result*

From testing of integrated modules in the embedded system obtained some results and processed by calculating the 95% confidence interval using equation 1:

$$Average \pm \left(\frac{1{,}96 \; x \; Standard \;\; Deviation}{\sqrt{Population}}\right) \qquad (1)$$

Testing result on normal user is shown in Figure 6. On the examination of color perception testing result, average normal testers give the average value of 2.68 to the printed color samples. The color of the printed color samples itself is adjusted according to the reference color used in the embedded application. Incompatibility of color perception may also be caused by slight change of color in the printed color sample paper when printing.

From user experience testing related to color detection, the average users give opinion value of 3.6. This indicates that the module has been good enough in meeting the expectations of a normal user.

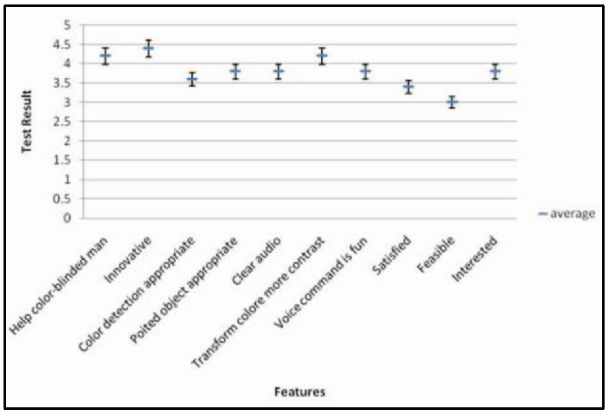

Figure 6. User experience test result on normal user.

Testing result on partial color-blinded user is shown by Figure 7. The average testing result on partial color blinded persons gives the average value of 2.86 for the color samples perception test. A higher percentage for normal users occur due to the absence of a particular color on a user's perception with partial color blindness.

From user experience testing related to color detection module, average users gives opinion value of 3.8. This value indicates that the module has been good enough in meeting partial color-blinded user expectation

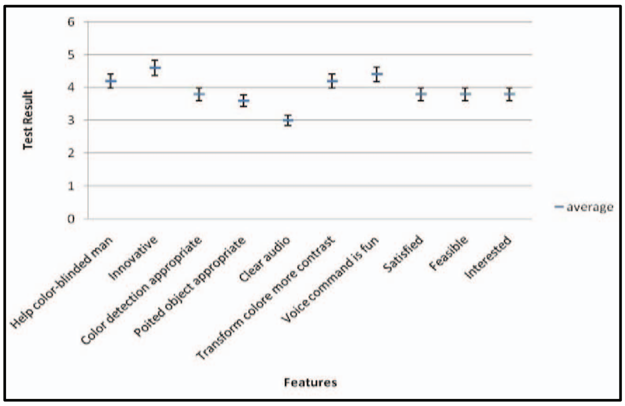

Figure 7. User experience test result on partial color-blinded user.

E. Testing Result and Analysis for Mobile Application

1. Color Detection Success Rate on Lighting Condition Variation Testing Result

This test was conducted to determine the effect of lighting variation on the color detection module for mobile applications. Testing is also done using two-color model, RGB and HLS. Table 3 shows the test results with the RGB color model, and Table 4 shows the test results with HLS.

TABLE III
RECOGNITION RATE OF DIFFERENT COLORS ON VARIABLE LIGHTING CONDITIONS USING RGB

Color	**Lighting Condition**		
	Dark (%)	***Moderate (%)***	***Bright (%)***
Red	0	0	0
Orange	0	0	0
Yellow	0	0	0
Light Green	0	0	0
Green	0	0	0
Tosca	0	0	0
Light Blue	0	0	0
Blue	0	0	0
Purple	0	0	0
Magenta	0	0	0
Dark Green	0	0	50
Dark Orange	0	0	0
Yellow-Green	0	0	0
Dark Gray	0	10	90
Dark Red	0	0	30
Average	0	0.67	11.33

Based on the table of lighting variations testing on module for mobile applications, it can be seen that in all lighting conditions, the module with RGB color model shows that the success rate of color samples detection are low, i.e. 0%, 0.67%, and 11.33% respectively for each lighting condition respectively. With the RGB color model, the color of objects should match the reference value of red, green, and blue components so that it can be detected. However, it seems that a dark green, dark gray and dark red can still be detected in bright lighting. This suggests that in bright lighting, the color read by the camera is not much shifted from the color of references used in the module.

TABLE IV
RECOGNITION RATE OF DIFFERENT COLORS ON VARIABLE LIGHTING CONDITIONS USING HLS

Color	**Lighting Condition**		
	Dark (%)	***Moderate (%)***	***Bright (%)***
Red	20	80	100
Orange	10	90	100
Yellow	10	80	100
Light Green	30	80	100
Green	20	80	90
Tosca	20	90	90
Light Blue	10	70	100
Blue	0	10	100
Purple	20	70	100
Magenta	0	70	100
Dark Green	0	0	100
Dark Orange	0	0	100
Yellow-Green	0	10	90
Dark Gray	0	0	100
Dark Red	0	0	60
Average	9.33	48.67	95.33

Test results on the module with the HLS color model, obtained percentage of success of 95.33%, 48.67%, and 9.33%. In HLS color model dark lighting conditions affect the value of the lightness components of the object to be detected. The module gives a low percentage of detection rates for dark lighting conditions due to the increase of lightness value of the objects.

2. User Testing Result

The user testing result on normal users are shown by Figure 8.

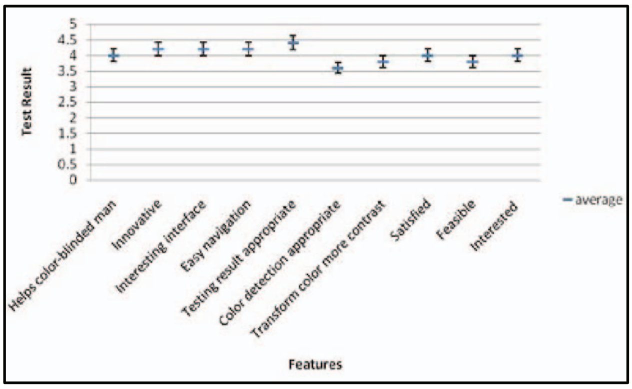

Figure 8. User experience test result on normal users.

On color perception test using color samples, the average value is 2.94. In this mobile application testing, the printed color samples used is different with those used in embedded system testing, since there is a difference on the reference color value range between the two applications. The average value of the test results on color perception of mobile applications is higher than the value of testing on the embedded system modules. This shows that the range of colors used in mobile applications is closer to the perception of a normal user.

On user experience test, related with the color detection module, we obtained an average value of 3.6 ± 0480. This suggests that the color detection module is sufficient to meet normal expectations, although it is done with a simple detection method.

Testing result on partial color-blinded users is shown on Figure 9.

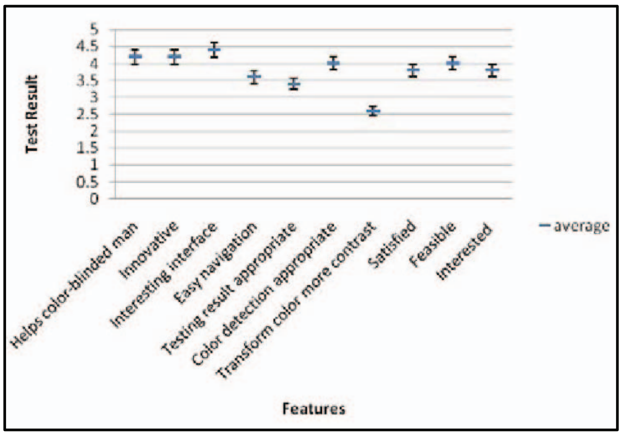

Figure 9. User experience test result on partial color-blinded users.

On the color perception test using color samples, we obtained an average value of 3. As with the testing of applications on embedded systems, color perception test in people with color blindness gives higher scores than the normal user. This is possible because the absence of a specific color perception in people with color blindness.

Testing the user experience on partial color blinded people, related to the color detection module, we obtained average opinion value of 4 ± 1074. This suggests that the detection module testers sample meet expectations with partial color blindness, although it is done with a simple detection method.

VI. CONCLUSIONS

Our work and research conclude that color blindness is a generative deficiency that causes the color blinded people cannot recognize the color. Color blindness itself is divided into the total and partial color blindness. Augmented reality technology can be used as an alternative in providing color information. In our work, EmguCV is used. In .NET Compact Framework as used in Windows 7 Phone, EmguCV cannot be used, so we develop the program using simple algorithm to do the color detection. Based on the testing, the color detection module for embedded systems with HSV color model, we obtained an average rate of 69.33%, whereas in the HLS color the success rate is 90.67% in bright and ideal lighting condition. In the same lighting condition, color detection module for mobile applications, the RGB color model gives detection rate of 11.33%, while the module with the HLS color model gives detection rate of 95.33%. Testing result also suggest that lighting condition gives significant influence on the success on color detection, both on the module or modules for embedded systems in mobile applications. In addition, sample users have different perceptions of color. In the testing, average testers quite satisfied with the system that has been implemented. In the future works, to enhance the user experience on the module that has been implemented on the embedded system, speech recognition feature can be added. In the module for mobile applications, image processing functions can be performed more advance to minimize noise and improve the detection rate. The existing system can also be designed to be implemented on a head-mounted display device in the future.

REFERENCES

[1] S. Poret, R. D. Jony, and S. Gregory, “Image processing for colour blindness correction,” Science and Technology for Humanity, 2009 IEEE Toronto International Conference, Toronto, Canada, 26 – 27 September 2009.

[2] Yoh, Myeung-Sook, “The reality of virtual reality,” Proceedings of the Seventh International Conference on Virtual Systems and Multimedia (VSMM’01), Berkeley, California, USA, October 25 – 27, 2001.

[3] Bimber, Oliver, & Ramesh, Raskar. (2005). *Spatial Augmented Reality*. Massachusetts : A K Peters.

[4] Shuhua Li and Gaizhi Guo, “The application of improved HSV color space model in image processing,” 2nd International Conference on Future Computer and Communication, China, May, 2010.

[5] Harvey M. Deitel and Paul J. Deitel, Visual C# 2008 How To Program. USA, Pearson Education Inc., 2008.

[6] Mayo, Joseph, C# 3.0 Unleashed With the .NET Framework 3.5. USA, Pearson Education, 2008.

[7] EmguCV Main Page. *http://www.emgu.com/wiki/index.php/Main_Page* accessed December 7, 2010.

[8] Gary Bradski and Adrian Kaehler, Learning OpenCV. USA, O’Reilly Media, 2008.

[9] Alfa Sheffildi M, Burhan Adi W., Ruki Harwahyu, and Bayu Sri A., “Color blind aid system with augmented reality, speech, and fingertip interaction,” unpublished.

[10] DM&P eBox Series. *http://www.dmp.com.tw/tech/eBox/* accessed June 28, 2011.