2011 International Conference on Electrical Engineering and Informatics
17-19 July 2011, Bandung, Indonesia

Simulation System of Color Blind Glasses by Image Processing

Ginanjar Fahrul Muttaqin [1], Iping Supriana Suwandi [2]

Informatics Engineering, Bandung Institute of Technology
Ganeca 10 Bandung 40132, Indonesia
[1] If17103@students.if.itb.ac.id
[2] iping@informatika.org

Abstract — **Color vision deficiency people have difficulty to distinguish certain colors, while some other people can distinguish well. Some researches try to help the people that has color vision deficiency problem by manipulating color. In this way, it must be so many different solutions based on the type of color vision deficiency. For this moment, we can personalize glasses with different tinted lenses which can help improve color vision deficiency people to distinguish color. This method has also been developed by several researchers but unfortunately, these researches are still not open to public or only been used on commercial use. Using glasses for color vision deficiency people is interesting to develop so the science and technology of this method will grow well. Simulation or modeling system of color blind glasses is base on reality of human vision and take advantage of human binocular vision. To simulate this real problem, how the glasses work, we need a model. In the end of the research, that model shall be validated by an observed experiment data from reality. On this occasion, we will discuss how to build a model. On way to understand how human vision work may be analogous by image processing. The image acquired is transformed to color blind chromaticity diagram. Then, the system simulates color transformation through lenses, retina, and human vision to achieve goal. The goal of this system is how to find a suitable color of lenses with the approach of normal vision chromaticity. With this model of glasses, we hope that system can bring out both two parameters of this glasses color. The expected result of this simulation is to achieve goal of color filter lenses parameters. With this output, the color vision deficiency people can be helped to distinguish color better than before wearing these glasses.**

Keywords— **color vision deficiency, color space model, modeling and simulation, color transformation, binocular vision**

I. Introduction

The latest technology has been able to create tools to help color vision deficiency people [1]. Dr. Thomas Azman ColorMax® develops a design glasses for people with color vision deficiency since 1975. Hiroshi Ito began in 1996 to develop ColorView® in a different way. Both these studies are still closed and commercial. The principle colored glasses to improve color vision deficiency vision is very simple. Color vision deficiency people use colored lens on his non-dominant eye. This allows both eyes to see different colors and both sides of the brain will work together to get the information from the side that uses colored lens. It can also use different colored lens in each eye. However, this method will not work if the same colored lenses are placed in both eyes. This method works for every type of color vision deficiency and with varying degrees of severity, but it will not work for people who suffer from total color vision deficiency.

Several studies have produced the image of a successful transformation change the image I into I' which can be identified by the color difference people with color blindness. Previous research Vischeck [2] has successfully do it with some shortcomings such as the color fades into distant of the original color image. Other research has managed to transform the color HSV appropriate parameters into the image of the original image can be identified with color vision deficiency [3].

How brain interprets the light into an image is an interesting discussion today. The colors formed from the light waves will be translated into signals the brain that must follow certain rules. It can be simulated by an image processing. Therefore this color vision deficiency glasses were built.

A main idea of simulation which can describe input and output of the system is still simple. The system will get input from image. Suppose the image is the image I. Image I would pass up into two lens with filters each $\alpha 1$ and $\alpha 2$. After that, I will be transformed into $I1$ and $I2$. The system will display the results of merger simulation images $I1$ and $I2$ to $I3$ as the work of human vision system by using binocular vision concepts [4]. A color vision deficiency person will be asked to identify the $I3$ to verify the accuration of model. The $\alpha 1$ and $\alpha 2$ can be set to get the appropriate $I3$. That $\alpha 1$ and $\alpha 2$ is the output color filter glasses in this simulation.

The color transformation issues and color merging into $I3$ is a form of simulation implemented in a computer device. In the reality the glasses using two lens, but the lens was modeled with a color transformation. Transformation of the lens color is not as complicated as the transformation that combines the image of $I1$ and $I2$ to $I3$. Need a specific learning how to understand how the brain combines two images of the left and right eyes, binocular vision, into a single image like the human eye sees. How the brain works needs to be understood before it is simulated by image processing. Until now, the formation of $I3$ transformation process has not been clearly defined and will be part of the modeling analysis on the next stage in this discussion.

II. Analysis

A. Modeling and Simulation

The 2006 National Science Foundation (NSF) Report on “Simulation-based Engineering Science” [5] showed the potential of using simulation technology and methods to revolutionize the engineering science. There are following advantage using modeling and simulation of the system in reality: using simulation is cheaper and safer than building prototype experiment in real thing; simulation allow the free configuration of environment parameter to operate final product in a next stage; simulation can often be conducted faster than reality; simulation allow setting up a synthetic environment that allows for integration of simulated systems in the early analysis.

This color blind glasses system has also a potential way to build in a simulation system. Two parameter $\alpha 1$ and $\alpha 2$ generated from the system will be easier in a simulation system than a reality. Both tinted lens will produce after simulations succeed. Nevertheless, the simulation need validation and evaluation to measure how accurate model if implemented in a real time.

Figure 1 below show a development process minimizing a real system to a model [6]:

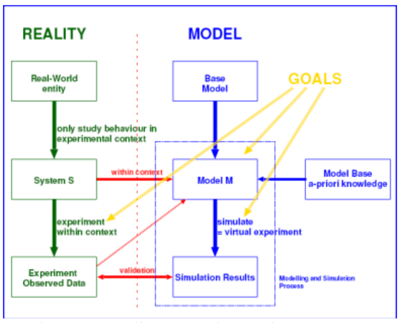


Fig. 1 Modeling and simulation process

There are many steps to get result of this simulation. First, learn a real system and create an abstraction model. Second, build virtual experiment to get a simulation result. Third, use simulation result and create abstraction for experiment results which will be tested to measure the result accuration.

B. Color Blind Glasses Simulation Method

There are three models after abstraction step from reality model on color blind glasses system:

- light absorption by lens model,
- color vision deficiency model,
- binocular vision perception model.

In human vision, light a basic principle to be understood before develop a simulation system. Light has a subtractive color mixing, either: project different superimposed light; spatially juxtapose different colored spot; or temporal addition. Figure 2 below show mixtures of lights. There are also happened if white light pass a tinted lens.

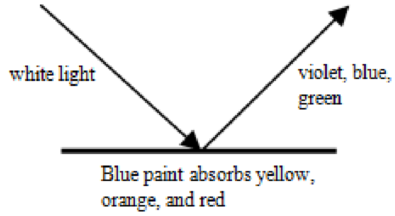


Fig. 1 Color mixture

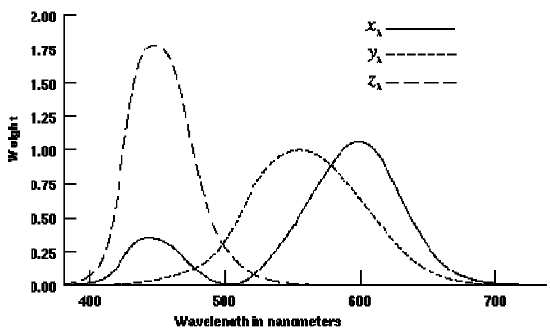
Light intensity subtraction must follow the Beer-Lambert Law:

$$I = I_0 e^{-\propto x}$$

Light as an electromagnetic wave has a wavelength that is proportional to the speed of light and inversely proportional to frequency. In addition, Planck proposed that energy on the electromagnetic wave with a constant (h) multiplied by the frequency of these electromagnetic waves, while the intensity of light is the amount of energy in one particular area. The conclusion is it can be formulated that the reduction in intensity will be inversely proportional to the reduction of the wavelength of light that passes through the media.

An α value means an absorption coefficient. In this simulation the absorption (α) value must be calculated to make a suitable lenses property.

After that we can simulate how eye vision combines the electromagnetic light following this CIE Color Match Diagram [7]:



$$X = \nabla\lambda \sum_{\lambda_{red}}^{\lambda_{violet}} \bar{x}_\lambda P(\lambda), Y = \nabla\lambda \sum_{\lambda_{red}}^{\lambda_{violet}} y_\lambda P(\lambda), Z = \nabla\lambda \sum_{\lambda_{red}}^{\lambda_{violet}} \bar{z}_\lambda P(\lambda)$$

Fig. 2 CIE color match diagram

After understanding CIE 1960 about Uniform Chromaticity Scale, that is a way to simulate how to transform a normal color vision to color blind vision. Meyer has simulate what color vision deficiency’s people see the color [8]. Tests on people with one normal eye and one affected eye have shown that there is an axis for each type of disorder onto which all the colors collapse. For protanopes this joins up 473nm and 574nm on the spectral locus; for deuteranopes the line is very similar, joining 477nm and 579nm. To convert colors from normal vision to a simulated color defective:

- plot normal color chromaticity diagram,

- construct a line from some point to confusion point based on type of color blind,
- find the intersection of this line on step 2 with the appropriate axis line and that is a new chromaticity.

Meyer on 1988 has observed a single confusion point for each type of color blind defective. In a chromaticity diagram the confusion point *(u, v)* of color blind shows in Table 1.

TABLE I
SINGLE CONFUSION POINT

	Protanopes	Deuteranopes	Tritanopes
u	0.61	-4.75	0.26
v	0.51	1.31	0.003

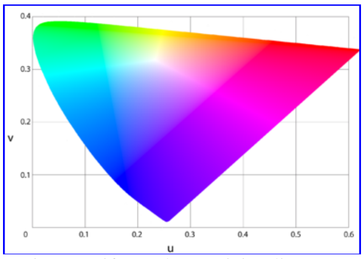


Fig. 1 Uniform chromaticity diagram

The binocular vision of human vision is approached by adding combining an image from left eye and right eye on visual cortex. It can be simulate by mixing colors based on CIE standard of human vision.

C. Method and Result

In the real case, this color blind glasses work as mentioned in introduction section of this paper. Ray light comes over two tinted lens and constructs different color perception in brain. Input of the system is type of color vision deficiency people who can't distinguish color. We hope that a simulation can produce output two parameters of colored lens wearing in glasses. Certainly, the chromaticity must have a same range color space with before wearing glasses but has different chromaticity diagram.

Human vision process can be understood by digitalized it to an image processing. Therefore the simulation system build based on image processing especially color image manipulation. Another fact, human has a binocular vision which can see a vision using both dominant and non-dominant eyes. Two visual perceptions captured by left and right eyes in a same time, but human brain precept it signals to a single vision.

Therefore, different color beams passing through those eyes might be a single color in the brain. This is main idea how to setting up color blind glasses system. Assume that person A has color vision deficiency. He lost *L-cones* in his retina's cone cells. Then, *A* can't see some color in a hue level, for example color *C* so in his perception *A* see color *C'*. When *A* wear tinted lens of the glasses, it may change color *C'* while passing to retina. Left lens change *C'* to *C1* and the other change *C'* to *C2*. In brain, these colors fuzzed to one color *C"*. There are two variable which can produce color *C"* in this system. Left and right lens were responsible in this case.

After we understood the abstraction of real system, including light and vision concepts, we build a virtual experiment to get a simulation result. There are steps producing outputs lens parameter:

- step 1, image preprocessing,
- step 2, simulating color transformation through lens,
- step 3, building colorblind visual simulation,
- step 4, simulating binocular visual perception,
- step 5, find a suitable color of lens which approach normal chromaticity.

In step 1, captured image will be preprocessed to an *RGB* color space easily after image acquisition, sampling, and quantization process well. Assume this image as *L*.

Assume that new *XYZ* color as *I,* in step 2, image *I* transform to *I1* and *I2* by passing a filter lens *α1* and *α2*.

Step 3 is used to simulate color blind vision. We can choose one of protanopes, deuteranopes, or tritanopes single confusion point to convert image to color blind perception. Convert RGB to *CIE XYZ* using this 3*3 simple matrix multiplication below to have the monitor data.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.41 & 0.36 & 0.18 \\ 0.21 & 0.72 & 0.07 \\ 0.02 & 0.12 & 0.95 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Then use this *CIE* 1960 UCS equation below to construct line from *XYZ* point confusion point *(u, v).* So that an intersection of this line with axis line will produce a new *XYZ* color. This step occurs before *I1* and *I2* merged as *I3.*

Step 4, then system displays the result of merger *I1* and *I2* as *I3* in accordance with binocular vision concepts. At last, the parameters of lens filter will be an output of this system. The merger if *I1* and *I2* follow the color mixing equation on CIE chromaticity diagram [9]:

$$x_3 = \frac{Y_1}{Y_1 + Y_2} x_1 + \frac{Y_2}{Y_1 + Y_2} x_2$$
$$y_3 = \frac{Y_1}{Y_1 + Y_2} y_1 + \frac{Y_2}{Y_1 + Y_2} y_2$$

Step 4; analyze image *I3* similarity with image *L* before step 1 using histogram analysis. The nearest similarity of image *I3* and *L* will produce better accuration of *α1* and *α2* outputs. The last step is validation step using real system to test the accuration of this simulation.

III. FUTURE DEVELOPMENTS

This simulation system is not mature yet, and need more experiment to test the accuracy. Important to note, when image *I* transform to *I3,* system must have a same color space range between *I* and *I3.* In this case, we can't use strong from both lens, for example dark blue lens. It will limit the reach color space of *I3.* Further research will handle this case so the outputs of system have simple calculation.

The steps of this system still use a constant confusing point based on Meyer research. The system can be developed better

978-1-4577-0752-0/11/$26.00 ©2011 IEEE

if there is personalization for specific color vision deficiency people. Step 1 will be ignored because system can calculate confusion point from user input test. The system will also have best step 5 while verify the combination output from specific user test.

IV. CONCLUSIONS

There are many ways to help color vision deficiency people to distinguish color. One of them is let them see a color which s/he can't distinguish before. Binocular vision using tinted glasses may possible interpret some color out of color blind chromaticity in human brain. This virtual experiment has simple basic goal. But it may far away the expectation to have best combination of colored lens. So that this model needs validation and verification in a real experiment observed data.

ACKNOWLEDGMENT

Author said thanks to all contributors in this discussion. Thanks to all friends in Graphics and Artificial Intelligent Labs on Bandung Institute of Technology. This simulation is not perfect but author hopes the idea or method in this paper will still discusse till the color vision deficiency people can distinguish color well.

REFERENCES

[1] McDougal, Debra, "Color vision deficiency Glasses Explained. Health & Wellness".
[2] Vischeck, (2007). [Online]. Available: http://www.vischeck.com/
[3] Indrawan, Eri, *Perangkat Lunak Transformasi Warna untuk Penderita Buta Warna*. Institut Teknologi Bandung. 2008.
[4] Bhola, Rahul, *Binocular Vision*. University of Iowa. 2006.
[5] National Science Foundation (NSF) Blue Ribbon Panel. Report on Simulation-Based Engineering Science: Revolutionizing Engineering Science through Simulation. NSF Press, May. 2006.
[6] Vangheluwe, Hans, "*Modelling and Simulation Concepts"*. 2001.
[7] Walker, John, *Colour Rendering of Spectra.* 1996 – 2003.
[8] Meyer, G.W. & Greenberg, D.P, "Color Defective Vision and Computer Graphics Displays". IEEE Computer Graphics and Applications. 1988.
[9] Williamson, S J and Cummins, H Z, Light and Color in Nature and Art, Wiley 1983.