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Color Blind Test Quantification using RGB Primary Color Cluster

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Abstract— **Color Blindness Test Quantification using Primary Color Cluster is a color blindness test that was developed to complement the existing color blindness test nowadays. Color cluster based test aims to classify what colors that can and can not be seen by anyone with more detail. Color blindness test quantification in this thesis aims to cluster human's eyes ability to distinguish primary colors: red, green, and blue from the highest to the lowest intensity. Clustering aims to find out which one of primary colors that can be distinguished more clearly by someone. Tests are conducted using 8-bit color channels of red, green, and blue so each has 255 of maximum intensity and 0 of minimum intensity. Tests are also conducted using computer to facilitate color intensity modification.**

Keywords— **color blindness, color blind, eye, test, cluster, quantification.**

I. INTRODUCTION

Color blindness is an abnormality that occurs in the eye where the eye cannot distinguish one color with another color. Color blindness can be caused by a brain damage or a genetic disorder which is inherited. Color blindness affects approximately 5-8% of the global population in which 0.4% of sufferer were women and 5-8% are men [1]. Color blindness is caused by abnormalities of rod cells and cone cells that located in the eye [2]. Rod cell is used for regulate the light intensity which is released to the eyes. While cone cells are part of the eye that serves to distinguish the color. There are 3 types of cone cell: Red Cone Cell, Blue Cone Cell and Green Cone cell. Color blindness is one of the disabilities that cannot be cured or changed.

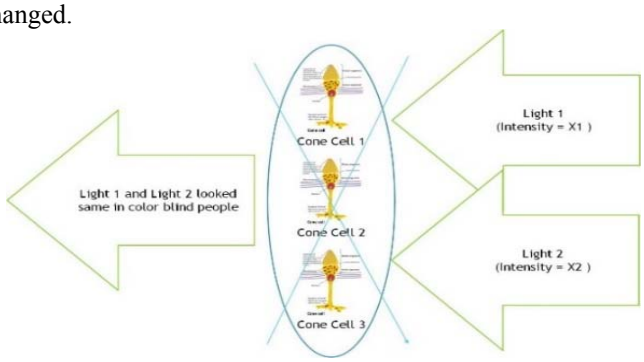

Fig 1. Color blind illustration

Ishihara test is one method to find out whether someone is color blind or not. It is used since 1917 but it still not able to quantify a color blind patient with more detail and perfect. Most partial color blind people are considered equal by the Ishihara test . Ishihara test available today will justify whether people normal or color blind sufferer. Some of partial color blind people get discriminated in some are of job and education even they can see the color needed. Ishihara test which is used today only can give a universal condition of the eye. Therefore, we need a new test that can help the people with color blindness. The new test must give detail and exact number about what color can be seen and what color can not be seen by anyone. The new test can be used for supporting ishihara test.

II. LIGHT AND COLOR

A. Light

Light is an electromagnetic energy which has a certain wavelength. Light also controls what kind of colors human eye can receive. Color in the light correlates to the wavelength of the light. The wavelengths of light which is visible by human eye are between 380 – 750 mm [2]. The light also has intensity to determine the color of the light.

Most computer systems use 3 primary colors. The colors are red, green and blue (RGB) which will represent the data. It was illustrated in the Figure 1. The mixture of the color will produce a new color. This primary color was originally discovered by Young-Helmholtz. In this study, RGB is selected as the primary color because the RGB principal was similar to the human eye's physiology [5] which is sensitive to the visible light. Furthermore, the system is built on a computer that uses the RGB primary color as the representation of the data. The RGB also can map out many colors so it can be used for many areas that are sensitive to the color [6].

Fig 2. Light in RGB Concept

B. Eye

Eye is one of the human body's organ of visual system. Eye works by detecting the presence of light and then convert it to be electro-chemical impulse [2].

Eye works by collecting the light from its environment. The light will be collected by corneal and it will be forwarded to pupil and iris. The light will be going through eye lens and then it will be sent to the retina. In the retina, there are 2 types of cells to determine the color of the light. The cells are rod cell and cone cell. The impulse that has been produced by retina will be received by human brain in the occipital lobe and then will be represented as a color.

The cone cell is a photoreceptor cell which has a cone-shaped in the retina. It handles visual acuity and vision in the medium-wavelength light or long-wavelength light. Cone cell has a cone in the peak of the cell (Figure 3).

Cone cell is divided into 3 types, red-cone cell, green-cone cell and blue-cone cell. Cone cell can be used to respond the light and convert it to be an electrical respond (Figure 3). Red-cone cell handles red light, green-cone cell handles green light and blue-cone cell handles blue light [3]. The light that is collected by human eye will activate the electrical impulse for each cone cell [4].

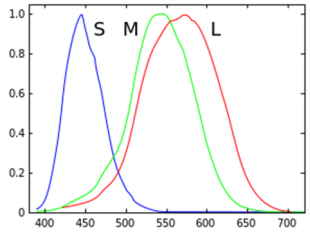

Fig 3. The Cone Cell responds towards the light.

III. SYSTEM

Authors designed a new color blind test which is developed from Ishihara test. The new test can give exact number about the ability of the eye to distinguish the color. Here is a block diagram of the system wake author:

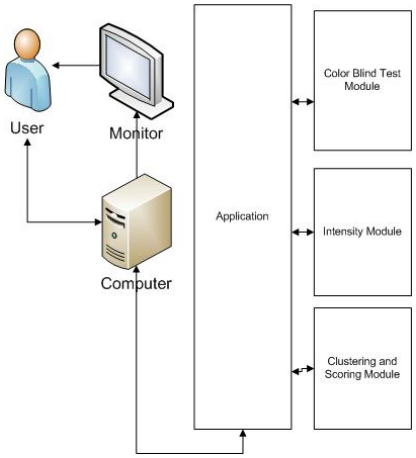

Fig 4. Block Diagram

The system which is developed by the author is used for doing quantification to the color which is can be seen by the people. Consequently Author used computer for make the color quantification and modification process easier. The system consist of Color Blind test module, Intensity Module and clustering and scoring module. Color Blind test module is a place where subject doing the test. This module will show subject the picture and the number. The subject must guess the number which is disguised by the picture. The picture which is use for disguised the number is consist of many circle. The circle will have their own color. The color is controlled by the intensity module.

While doing the test, the subject must guess what number is appeared in the test. After guessing the number, user will input the number to the system. The application will process the user input and check whether the input is right or wrong.

After doing several test, the application will give result which called cluster. The cluster will use for scoring the subject ability to distinguish the color. The Clustering and Scoring module will handle this job.

After knowing the whole system, we will explain in detail how about the testing system. This system aims to cluster human's eyes ability to distinguish primary colors: red, green, and blue from the highest to the lowest intensity. First the color of the disguised picture and the information (number) will be same. The color intensity of the disguised picture will be decreased slowly by the system. If the subject cannot guess the information (number) from the test, the intensity of disguised picture will be decreased again (figure 3). If the subject can guess rightly the information, the system will create a cluster. After that the system will do another test with another color intensity until all basic color intensity tested.

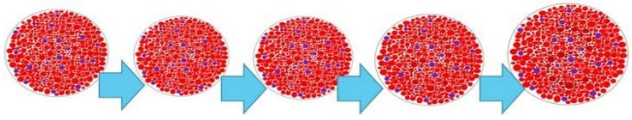
Fig 5. Test Illustration

In This test, we choose RGB color space due to the characteristic of cone cell which is responsible for percepting color in human eye. L cone cell responsible for Red Color, M cone cell responsible for Green Color and S Cone Cell responsible for Blue color. We test human eyes to distinguish Red, Green and Blue color from the highest intensity to lowest intensity in this test to determine the ability of human cone cell.

Fig 6. RGB Test

IV. Cluster and Color Distance

After doing all of the test, the system creates 3 basic cluster (Red Cluster, Green Cluster and Blue Cluster) (figure 4).

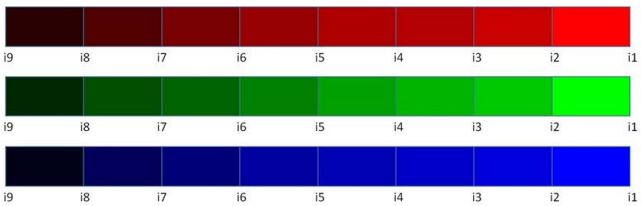

Fig 7. Cluster

Meaning of the clusters formed will describe the eye's ability to distinguish colors. In the same cluster, eye almost cannot differ the color. In the same cluster, subject will see almost same color because cluster boundary is created when the subject can distinguish the information (number) from the test. Cluster will show us about the cone cell ability to distinguish the color. More number of color cluster boundary means greater cone cell ability. Less number of color cluster boundary means worst cone cell ability. From the clusters, we can determine what color can be seen and what color cannot be seen by the subject.

From the cluster, we will give some more detail for forming a formula. We will put upper limit (ba), Median (me) and lower limit (bb) (figure 5).

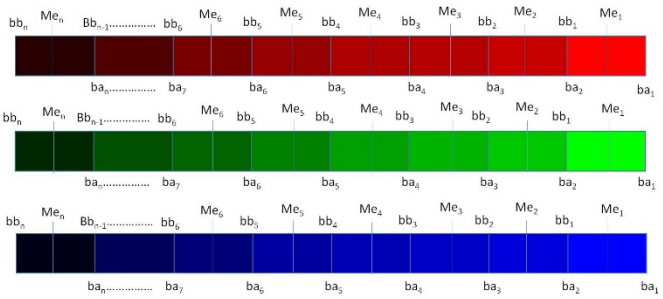

Fig 8. Cluster Detail

In a cluster, upper limit will be given at the beginning of a sub test. Lower limit will be formed while subject can guess rightly the information (number) from the test. We can conclude that upper boundary – lower boundary is a minimum intensity range needed to distinguish the color.

From the notation given above, authors can form a formula. A distance formula between 2 different colors with different intensity:

$$
\begin{aligned}
d(w1,w2) = {} & \left(\left(\frac{i(im1) - i(bbm_i)}{i(bam_i) - i(bbm_i)} \times 100\% \right) + \left(\frac{i(bam_{i+z}) - i(im2)}{i(bam_{i+z}) - i(bbm_{i+z})} \times 100\% \right) + \left((x\text{-}1) \times 100\% \right) \right) \\
& + \left(\left(\frac{i(ih1) - i(bbh_j)}{i(bah_j) - i(bbh_j)} \times 100\% \right) + \left(\frac{i(bah_{j+y}) - i(ih2)}{i(bah_{j+y}) - i(bbh_{j+y})} \times 100\% \right) + \left((y\text{-}1) \times 100\% \right) \right) \\
& + \left(\left(\frac{i(ib1) - i(bbb_k)}{i(bab_k) - i(bbb_k)} \times 100\% \right) + \left(\frac{i(bab_{k+z}) - i(ib2)}{i(bab_{k+z}) - i(bbb_{k+z})} \times 100\% \right) + \left((z\text{-}1) \times 100\% \right) \right)
\end{aligned}
\tag{1}
$$

After doing test with many subjects, authors can conclude that:

- 2 colors with distance greater than 100% can distinguish the color (d (w1, w2) > 100% → Subject definitely can differ w2 and w1 color).
- 2 colors with distance between 50-100 can distinguish the color with a doubt (100% > d (w1, w2) > 50% → w1 and w2 looks vaguely different).
- 2 colors with distance less than 50% absolutely cannot be distinguished by the subject (d (w1, w2) < 50 % → Subject definitely can't differ w2 and w1 color).

V. Test and Result

In this research, testing is used to combine Ishihara test with the new test. Ishihara test is used for diagnose whether subject is people with color blind or not. Whereas the cluster test is used for knowing the cone cell ability to distinguish the color.

Testing also use for finding the cluster pattern of the people with color blindness. By combining Ishihara test and cluster test, we wish we will get a better test with better detailed result and accurate. The test also use for proving the formula which is created before.

In this research, we do the test to 25 peoples where 10 of them are positively people with color blindness. Test is done in a closed well-lighted room. The distance between subject eyes and the monitor is 30 cm. After guessing the information (number), subject need to close the eyes for a while before next guess. This is used for minimizing eyes adaptation to the condition. Every subject will do 7 test. The tests are as follow:

- Ishihara Test
- Red Cluster Test
- Green Cluster Test
- Blue Cluster Test
- Test to distinguish color with color distance greater than 100%.
- Test to distinguish color with color distance less than 100%.
- Test to distinguish color with color distance between 50-100%.

After doing test to all of subjects, we get some results that every person has a unique cluster and person without color blindness also has different cluster compared to normal person. The test also shows that every person is definitely suffering color blind, however every person has different eye ability. There is no color blindness. The only term available is someone with less ability to distinguish the color.

The result also gives us some information that 96% of color blind people have less than 7 clusters for one or more basic color, 100% subjects can distinguish 2 colors with distance greater than 100%, 100% subjects cannot distinguish 2 colors with distance less than 50% and the last is 96% subjects can distinguish 2 colors with a doubt and color distance between 50%-100%.

VI. CONCLUSION

According to the study, it can be concluded that cluster-based test is an alternative way to provide better and more detail result compared to Ishihara test. Cluster-based test is able to provide how many primary colors that can be distinguished by a person, the ability of cone cell to distinguish color, and also the eye defect towards the primary colors. Meanwhile, existing Ishihara Test only provide test result in form of whether a person is color-blind or not.

Cluster-based test can divide colors into some groups which can be distinguished by a person. By using and grouping the existing cluster, cluster-based test can determine whether two colors with a certain intensity can be distinguished by human eye. While Ishihara Test cannot determine which colors can be distinguished by human eye.

Cluster-based test is able to provide cluster which can be distinguished by a person or not so it can obtain more detail and non-discriminative result. In Ishihara Test, the result is relatively equal for everyone. Cluster-based test can affect the probability of color-blind people to get a job and get proper education which considering the ability to distinguish color using a specified threshold.

Everyone was definitely color-blind but the difference is the ability to recognize color. According to the result of this study, some subjects can see colors many more than another subjects. It may indicate that individual's ability to distinguish color was different.

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