INCREASING VISUAL DETAIL FOR TV WATCHERS WITH COLOR VISION DEFICIENCIES BY USING IMAGE PROCESSING METHODS

A Thesis

by

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INCREASING VISUAL DETAIL FOR TV WATCHERS WITH COLOR VISION DEFICIENCIES BY USING IMAGE PROCESSING METHODS

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To my family…

ABSTRACT

There are three types of cone cells in the human retina that respond to different color spectrums. The signals generated by these cone cells are combined and the color information is interpreted. Color blindness, or color vision deficiency is the inability or decreased ability to see color or perceive color differences, under normal lighting conditions. The most common types of color blindness result from the loss or limited function of the red pigment or the green pigment. Such color blindness is commonly referred to the red-green color blindness. This thesis introduces a method to increase the accessibility to image detail of TV viewers with red-green color blindness while not changing the image dramatically for people that have healthy trichromatic vision. In this thesis, $Y'C_bC_r$ signal was used and seven separate color channels were defined according to $Y'C_bC_r$ data. Information from defined channels were used in independent hue control, independent saturation control, independent brightness control and 2-dimensional peaking video blocks while Y component is used in dynamic luminance control block which includes histogram equalization part. For obtaining success rate of proposed method, two separate experiments were applied to seven red-green color vision deficient people and ten people with healthy vision by using a television set. At the first experiment, digital versions of Ishihara test plates that include 38 test plates were applied to seven red-green color vision deficient people and conclusion of tests showed that proposed method increased correct answer rate of color vision deficient people by 49.62% compared to conventional TV. At the second experiment, 103 real images were applied to ten people with healthy vision and conclusion of tests showed that proposed method is the most preferable method among the comparative methods that are released as color vision deficiency display solution.

ÖZET

İnsanın retinasında farklı ışık frekanslarına cevap veren üç tip koni hücresi bulunmaktadır. Renk körlüğü veya renk görme eksikliği, normal ışık koşullarında renkleri görme veya renk farklılıklarını algılama yeteneğini kaybetme durumudur. Renk körlüğünün en yaygın türleri, kırmızı koninin veya yeşil koninin foto pigment kaybı veya sınırlı işlevinden kaynaklanmaktadır ve kırmızı-yeşil renk körlüğü olarak adlandırılmaktadır. Bu tezde, kırmızı-yeşil renk körlüğüne sahip TV izleyicilerinin detay erişilebilirliğini artırmak için, görüntü işleme yöntemleri kullanılarak, renk aralığının ayırt edilebilir bölgeye çekilmesi ve bu değişiklik yapılırken renk görme bozukluğu bulunmayan bireyler için resmin minimum değişimi hedeflenmektedir. Bu metotta, $Y'C_bC_r$ renk uzayı kullanılmış ve $Y'C_bC_r$ verilerine göre yedi ayrı renk kanalı tanımlanmıştır. Bu kanal bilgisi, bağımsız ton, doygunluk, parlaklık kontrolü ve 2 boyutlu keskinlik video bloklarında, Y bileşeni ise dinamik parlaklık kontrol bloğunda kullanılmıştır. Önerilen yöntemin başarı oranını elde etmek için, bir televizyon seti kullanarak, yedi kırmızı-yeşil renk görme eksikliği olan kişiye ve sağlıklı görüşe sahip on kişiye iki ayrı deney uygulanmıştır. İlk deneyde, yedi kırmızı-yeşil renk görme eksikliği olan kişiye 38 test plakası içeren Ishihara test plakalarının dijital versiyonları uygulanmış ve testlerin sonuçları, önerilen yöntemin, renk görme eksikliği olan kişilerin doğru cevap oranını geleneksel yöntemle karşılaştırıldığında % 49.62 oranında artırdığını göstermiştir. İkinci deneyde, sağlıklı görüşe sahip on kişiye 103 adet gerçek görüntü uygulanmış ve yapılan testlerin sonucunda, önerilen yöntemin, renk görme eksikliği teşhisi çözümü olarak ortaya çıkan karşılaştırmalı yöntemler arasında en çok tercih edilen yöntem olduğu görülmüştür.

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CHAPTER I

INTRODUCTION

According to researches, red-green color blindness affects up to 8% of males and 0.5% of females of Northern European descent [1]. Red-green color blindness is the most common form, followed by blue-yellow color blindness and total color blindness. Because of this fact, most of the color blindness tests and removal methods are specific to red-green color blindness.

Red green color blindness has four types known as protanomaly, protanopia, deuteranomaly and deuteranopia. Protanomaly is abnormality of red cone photo-pigment while protanopia means that there are no studying red cone cells. Deuteranomaly is abnormality of green cone photo-pigment while protanopia means that there are no studying green cone cells [2].

Since the most common form of color blindness is red-green color blindness, nearly all of the methods of image correction, simulation and testing for color blindness people are protanomaly and deuteranomaly based in literature.

Previous studies on literature about Red-Green Color Vision Deficiency (CVD) enhancement by image processing methods has generally focused on changing red, green, blue (RGB) color data on confusion bands. In this thesis, for the first time, Y'CbCr signal was used and seven separate color channels were defined according to Y'CbCr data. By this method, image detail is increased for color vision deficient people while not changing the image dramatically for people with normal vision.

In the following sections, previous study, methodology, experimentation setup and results is mentioned respectively. Finally, a conclusion is provided about the achievements of our thesis study.

CHAPTER II

PREVIOUS STUDY

2.1 Color Blindness

The retina of the human eye has three types of cone cells that respond to different ranges of color (light frequencies). It is from the signals generated by these cone cells and the way in which those signals are combined and interpreted that our sensation of color is derived. Another set of cells in the retina, the rods, are adapted for dim light and night vision.

At the top of the diagram that is shown as Figure 1, there are four curves where each one of them shows the sensitivity of a cone (color) or rod (dashed) cell to the spectrum of colors in the white light.

It can be seen that the three cone cells overlap in their range of sensitivity, but that each has a particular range over which it is most sensitive.

Color blindness, or color vision deficiency, is the inability or decreased ability to see color, or perceive color differences, under normal lighting conditions. The most usual cause is a fault in the development of one or more sets of retinal cones that perceive color in light and transmit that information to the optic nerve [3].

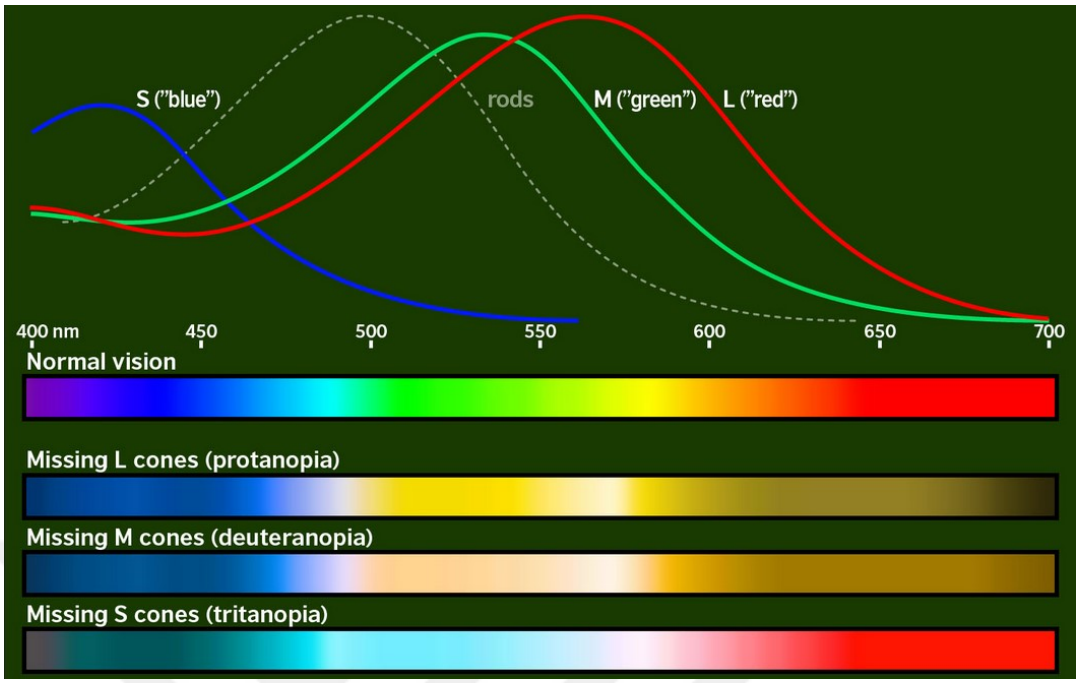

Figure 1: Sensitivity range of cone cells [3]

2.1.1 Red-Green Color Blindness

The most common types of color blindness are due to the loss or limited function of red cone or green cone photo-pigments [2]. This kind of color blindness is commonly referred to as red-green color blindness.

- Protanomaly: People with protanomaly, the red cone photo-pigment is abnormal. Red, orange, and yellow appear greener and colors are not as bright. This condition is mild and doesn't usually interfere with daily living.
- Protanopia: People with protanopia, there are no studying red cone cells. Red appears as black. Certain shades of orange, yellow, and green all appear as yellow.

- Deuteranomaly: People with deuteranomaly, the green cone photo-pigment is abnormal. Yellow and green appear redder and it is difficult to tell violet from blue. This condition is mild and doesn't interfere with daily living. Deuteranomaly is the most common form of color blindness.
- Deuteranopia: People with deuteranopia, there are no studying green cone cells. They tend to see reds as brownish-yellow and greens as beige [2].

2.1.2 Blue-Yellow Color Blindness

Blue-yellow color blindness is rarer than red-green color blindness. Blue-cone (tritan) photo-pigments are either missing or have limited function.

- Tritanomaly: People with tritanomaly have functionally limited blue cone cells. Blue appears greener and it can be difficult to tell yellow and red from pink. Tritanomaly is extremely rare.
- Tritanopia: People with tritanopia, also known as blue-yellow color blindness, lack blue cone cells. Blue appears green and yellow appears violet or light grey. Tritanopia is an extremely rare autosomal recessive disorder affecting males and females equally [2].

The upper figures shows how the color spectrum changes. The shown lines are just meant as guides. Any line which ends in the so-called copunctal point connects the colors of confusion for a certain type of color vision deficiency. More severe color blindness simply results in thicker and longer confusion bands.

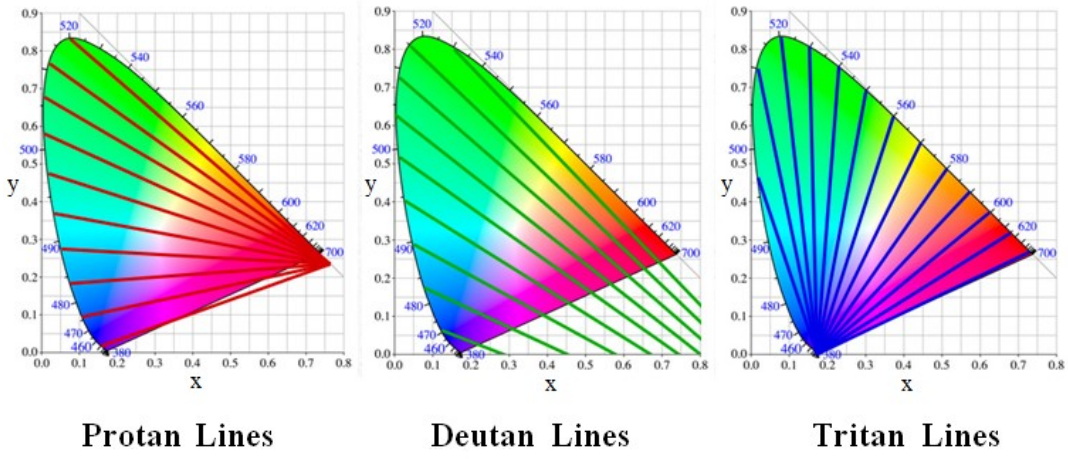

Figure 2: Confusion bands on CIE color space [17]

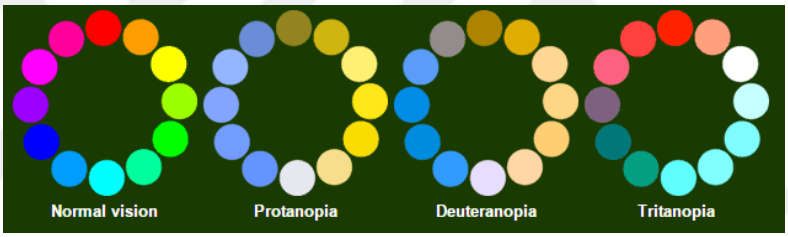

Figure 3: Vision simulation [3]

2.1.3 Complete color blindness

People with complete color blindness (monochromacy) don't experience color at all and the clearness of their vision (visual acuity) may also be affected [2].

Previous studies about color vision deficiency can be summarized in three parts; diagnosis methods, simulation methods and correction methods.

2.2 Diagnosis Methods

Different methods are used for diagnosis of color vision deficiency including; Anomaloscope, arrangement tests, and Pseudoisochromatic plates which are the most popular and easily applicable screening tests [4]. Different test books have significant variations, and the pigment technology, and age of the test could affect the result of the test [5]. Ishihara color test is most often used to screen for congenital and acquired red green deficiencies, and the characteristics of the responses may change with the severity of the defect [6].

The Ishihara test is most successful color perception test for red-green color deficiencies and it is called as pseudo-isochromatic plates (PIP). It was pusblished in 1917 and named by its designer, Dr. Shinobu Ishihara who is a professor at the University of Tokyo.

The test consists of a number of colored plates, called Ishihara plates, each of which contains a circle of dots appearing randomized in color and size. Dots within the pattern form a number or shape clearly visible to those with normal trichromatic color vision and invisible, or difficult to see, to those with a red-green color vision defects. Other plates are intentionally designed to reveal numbers only to those with a red/green color vision deficiency, and be invisible to those with normal color vision [7]. The full test consists of 38 plates.

Computer software programs had been previously used to test different visual functions such as; visual acuity, stereo vision, visual field, and color vision [8].

The study of Marey et al. [9] shows the results of study that was conducted to evaluate the use of digital versions of Ishihara test plates as compared to the results of Ishihara test book.

In the study of Marey et al. [9], all participants were examined using the paper-based test, and the computer-based test with plates presented on LCD monitor. Computer based test gave 100% sensitivity and 98.78% specificity, which makes the use of computer-based test convenient for screening red green color vision deficiency without losing any positive cases, or misdiagnosing negative cases as red green color vision deficiency [9].

Based on this study, digital version of Ishihara test patterns are used in the experimentation section of thesis.

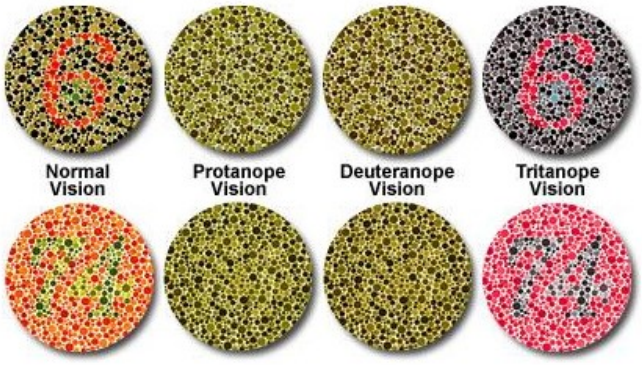

Figure 4: Ishihara Plates

2.3 Simulation Methods

Normal color vision is trichromatic. It is initiated by the absorption of photons in three types of cones, the peak sensitivities that lie in the long-wavelength (L), middle-

wavelength (M), and short-wavelength (S) regions of the spectrum. Therefore any color stimulus can be specified by three numbers, the cone responses; and all colors visible to the color-normal observer are included in a three-dimensional color space.

Reduced forms of color vision arise from the effective absence of one of the retinal photo pigments of the L type in protanope people, the M type in deuteranopes, and the S type in tritanopes. For dichromatic observers any color stimulus initiates only two cone responses, and all colors that they can discriminate are included in a two-dimensional color space. Compared with trichromatic vision, dichromatic vision entails a loss of discrimination and results in a reduced color gamut [10].

A series of papers describe color appearance for dichromate people by measuring between eye color matches measured in unilateral dichromate people: these people are dichromatic in one eye and trichromatic in the other. The between-eye color matching experiments were first reported by Judd in 1948 [11] and subsequently by Graham in 1958 [12] and Alpern in 1983 [13]. Judd reported that equal energy light and two narrow band lights at 475 nm and 575 nm look the same when presented to both eyes of a unilateral protanope and a unilateral deuteranope [11]. Alpern conducted a similar experiment with a unilateral tritanope and reported three eigen-colors: equal energy light, narrow-band light at 485 and 660 [13]. We refer to lights whose color appearance match between the two eyes of a unilateral dichromate as eigen-colors. In 1995, Vienot used the data from these unilateral dichromate people to calculate the equivalent color appearance in a standard color observer [14]. Vienot and later Brettel noted that eigen-colors define an empirical map between two cone coordinates in a dichromatic eye and three cone coordinates in the trichromatic eye [11].

The technique proposed by Brettel is the most referenced of all existing simulation techniques. In this technique, the color gamut of dichromate people is mapped to two semi-planes in the LMS color space, while the authors constrained the direction of confusion lines to be parallel to the direction of the color space axes L, M, or S, depending on whether the dichromacy type is protanopia, deuteranopia, or tritanopia, respectively [10].

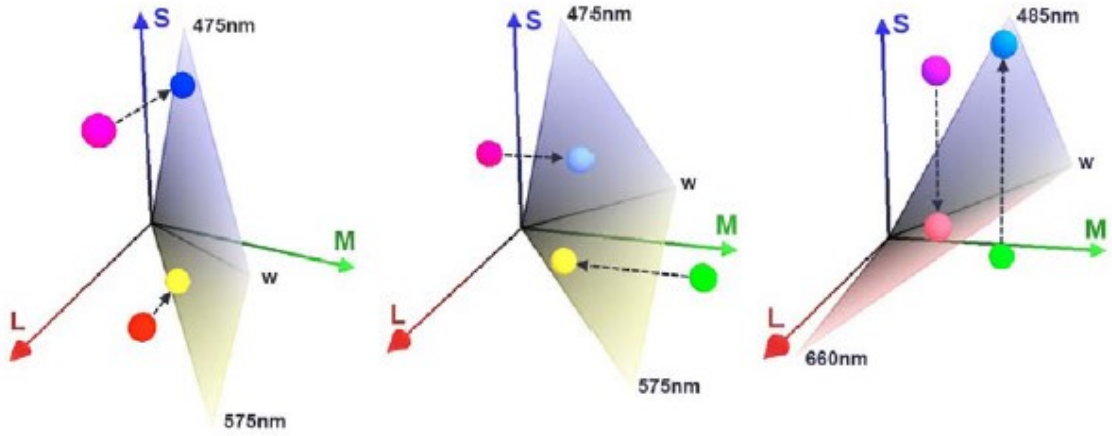

Figure 5: Technique for simulating the perception of individuals with dichromacy - The three graphs illustrate the technique for simulating the perception of individuals with dichromacy proposed by Brettel [10] In the LMS color space, the original colors are orthographically projected to corresponding semi-planes, along the direction defined by the axis representing the affected cone. Illustrations of the technique for simulating protanopia (left), deuteranopia (center), and tritanopia (right).

In 2001, the CVD simulation algorithm is released by Vischeck Company. Vischeck draws on algorithms developed at many different vision laboratories around the world. In particular, this plug-in owes a great deal to a 1997 paper by Brettel, Vienot

and Mollon entitled "Computerized simulation of color appearance for dichromats" [10] and to studies from Vision Imaging Science and Technology Lab group at Stanford. Vischeck Photoshop and Java plugins are freely available for use and distribution and using for academic studies as a simulator [15]. Therefore, in this thesis, Vischeck Java plugin is used as a simulation basis.

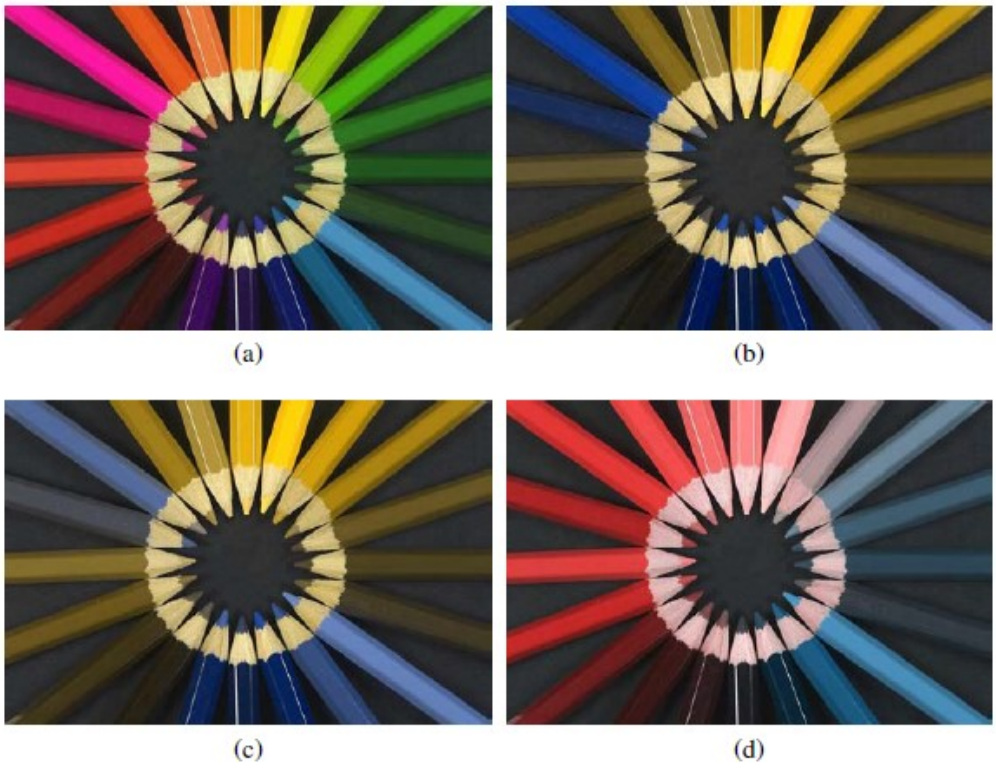

Figure 6: Examples showing the results obtained with Brettel's simulation technique. (a) Reference image showing a set of color pencils. The subsequent images show the simulation of the perception of protanope people (b), deuteranope (c), and tritanope people (d).

2.4 CORRECTION METHODS

Since the most common form of color blindness is red-green color blindness, nearly all of the methods of image correction for color blindness are protanomaly and

deuteranomaly based in literature and most of them apply dramatic change to image for making colors visible to color vision deficient people.

2.4.1 Red-Green Color Blindness (protanomaly and deuteranomaly) Color Translation Algorithm

The two simple translation formulas are simple yet effective. They have only one major flaw: the blue channel is completely thrown out and in both cases replaced by the red channel. One third of the information in the image, all the blue information, is lost and red-green color-blind people gain a lot of information that was previously lost in the red and green channels. This method totally changes all color spectrum. Therefore, this method is not applicable to TVs as a special mode, since it would disturb the perception for people who don't have color vision deficiency [16] [17].

Red-Green to Blue-Yellow Translation

$R \rightarrow B$

$G \rightarrow G$

$G \rightarrow R$

Red-Green to Green-Magenta Translation

$R \rightarrow R$

$G \rightarrow G$

$R \rightarrow B$

2.4.2 Daltonization

Details of the Daltonization algorithm are not published; however, Daltonization procedure is based on histogram stretching of colors appropriate for a given type of dichromacy. There are two steps to make information in pictures available to color blind people.

i) Red-green contrast is increased in the image. Many color blind people have some residual red-green discrimination. Increasing the red-green contrast makes them more likely to see these types of color variations.

ii) The information is conveyed by variations in the red-green direction and converts these into changes in brightness and/or blue-yellow colorization. This allows mapping information from a color dimension that is invisible to dichromate people into those that they can see.

The combination of these two processes is called as 'Daltonization' after John Dalton, the British scientist who was one of the first people to investigate color blindness [15] [18]. The license of Daltonization algorithm is held by Vischeck Company.

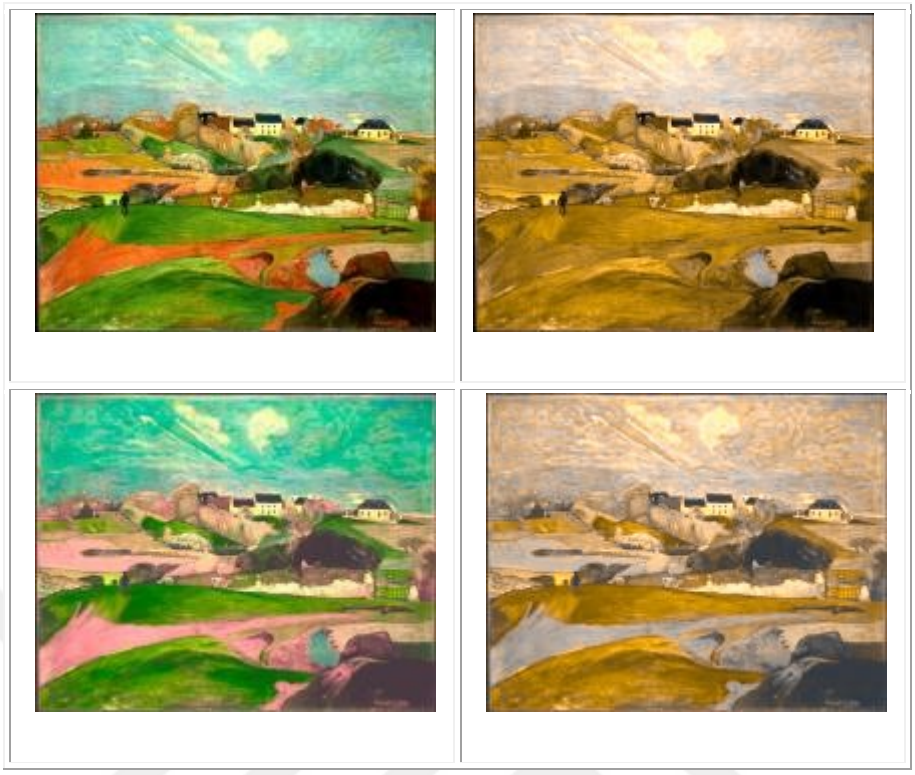

Figure 7: Example of application of Daltonization - Gauguin painting: In each case, the images are numbered 1 to 4 where 1) is the original full-color image, 2) is a simulation of the color-blind view of the full color image, 3) is the Daltonized version of the full color image and 4) is the color blind simulation of the Daltonized image showing improved red/green discrimination. To see how well the Daltonization algorithm studies for someone with color blindness, compare images 2) and 4) [15]

This method totally changes all color spectrum. Therefore, this method is not applicable to TVs as a special mode, since it would disturb the perception for people who don't have color vision deficiency [16] [17].

2.4.3 Gradient Map Method

This is an approach that is able to indicate regions that encounter the accessibility problem for color-blind viewers. The regions contain information that may not be well perceived by color-blind people. This method can be applied in different scenarios, such as checking the accessibility of designed images and to help designers to avoid the accessibility problem by making changes on the image. There are two major steps: inaccessible point detection and in-accessible region localization [19].

- Inaccessible point detection: Inaccessible points are defined as the points around which the patches are not identifiable by color blind people, due to the loss of color information. For this estimation of the information loss as the difference of gradient maps of the original image and its protanope or deuteranope views is calculated [16] [17]. Several points can be obtained that are still able to be recognized by color-blind viewers even if there exists significant information loss. Therefore, full gradient maps of the color-blind views of the image are computed, which is the sum of the gradient maps of channels, and its inaccessible point detection is accomplished.

- Inaccessible region location: It is the region that covers inaccessible points.

This method totally changes all color spectrums. Therefore, this method is not applicable to TVs as a special mode, since it would disturb the perception for people who don't have color vision deficiency [16] [17].

2.4.4 Lookup-Table-Based Gradient Field Reconstruction

This method proposes a solution to artefacts of ordinary gradient map methods. A serious problem with gradient map approach is that the reconstruction step often introduces artefacts (commonly, smoothed and smeared edges) to the recovered image. Artefacts can be diminished but not removed, by using complex to highly complex reintegration techniques. This method presents an algorithm for reconstructing gradient fields, by starting with a multichannel original input and deriving a 1-D gradient field from it. Lookup-table-based map relating the multichannel original is proposed to a reconstructed scalar output image, whose gradient best matches the target gradient field. The idea is that if it is learned how to map the gradients of the multichannel original input onto the desired output gradient, then the lookup table (LUT) constraint can be used and the mapping from the multichannel input to the desired, reintegrated, image output is derived effectively [20][21].

This method is used by Spectral Edge Company. They have the patent of this method and they have a product which is named as Eyeteq Lite. Eyeteq Lite technology is different than other methods of aiding color blindness. Their aim is to ensure the delivery of beautiful-looking images and video [22].

This method does not change the full spectrum of colors. Therefore, if this method is applied to TV as a special mode, the results are also satisfactory for people who have healthy color vision.

Since “Lookup-Table-Based Gradient Field Reconstruction” method is the most successful method in literature that has increased detail on images for color vision

deficient people while not changing image dramatically for people with normal vision. It is used as the comparison basis in the experimentation section.

CHAPTER III

METHODOLOGY

Previous studies on literature about Red-Green Color Vision Deficiency (CVD) enhancement by image processing methods has generally focused on changing red, green, blue (RGB) color data on confusion bands. In this thesis, for the first time, Y'CbCr signal was used and seven separate color regions were defined according to Y'CbCr data for increasing image detail for color vision deficient people while not changing the image dramatically for people that have normal vision.

Y'CbCr color space was developed as part of ITU-R BT.601 during the world-wide digital component video standard and updated by ITU-R BT.709 standard. It is used as a part of the color image and video pipeline in video and digital photography systems. Y' is the luma component and Cb and Cr are the blue component relative to the green component and red component relative to the green component, respectively. Y is defined to have a nominal 8-bit range of 16-235; Cb and Cr are defined to have a nominal range of 16-240.

7 color channels information; red, green, blue, cyan, magenta, yellow and flesh (RGBCMYF) are used in independent hue control, independent saturation control, independent brightness control and 2-dimensional peaking video blocks while Y component is used in dynamic luminance control block which includes histogram equalization part. These blocks are used for enhancing object edges and details which have different colors. By this method, image detail enhancement for red-green color

vision deficient TV users is provided by both color and luma enhancement while image is not changed aggressively for TV users with healthy vision.

For proposed method, images are enhanced on single chip iDTV solution that supports channel decoding, MPEG decoding and media-center functionality enabled by a high performance AV CODEC and CPU. This chip's video blocks are fully programmable by registers. Image data will be processed on Y'CbCr domain on real-time. Image processing path is illustrated in Figure 8.

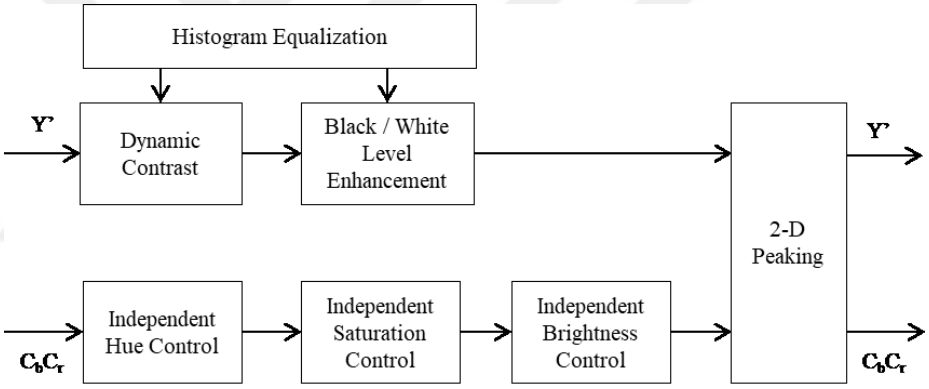

Figure 8: Color Enhancement in Y'CbCr

3.1 RGB to Y'CbCr Conversion:

The first step of this conversion is to define transfer function according to display. The transfer function of most displays produces an intensity that is proportional to some power (referred to as gamma) of the signal amplitude. By gamma correcting the video signals before display, the intensity output of the display becomes roughly linear.

Broadcasting systems assumed a simple transformation at the display with a gamma value of 2.2. Compensation for nonlinear display, 2.2 gamma correction is applied on linear RGB data. Gamma corrected RGB data is notated as R'G'B'.

$$\begin{aligned} R' &= R^{1/2.2} \\ G' &= G^{1/2.2} \\ B' &= B^{1/2.2} \end{aligned} \tag{1}$$

Second step is applying conversion equations on R'G'B' data according to ITU-R BT.709 HDTV standard. The basic equations to convert between 8-bit digital R'G'B' (gamma corrected RGB) data with a 16-235 nominal range and Y'C_bC_r are shown below.

$$\begin{aligned} \mathbf{Y'} &= 0.213\mathbf{R'} + 0.715\mathbf{G'} + 0.072\mathbf{B'} \\ \mathbf{C_b} &= -0.117\mathbf{R'} - 0.349\mathbf{G'} + 0.511\mathbf{B'} + 128 \\ \mathbf{C_r} &= 0.511\mathbf{R'} - 0.464\mathbf{G'} - 0.047\mathbf{B'} + 128 \end{aligned} \tag{2}$$

3.2 Independent Hue, Saturation, Brightness Control

In this method, seven separate color channels were defined according to C_bC_r data. By this method, image detail is increased for color vision deficient people while image is not changed dramatically for people that have healthy vision. This method is patented

on 2009 by the SOC Company that is used in this study and it is used for improving image for color vision deficient people for the first time [23]. First approach of proposed method is changing hue, saturation and brightness on only specific color regions instead of applying them on to the whole image. Second approach is having flexibility to change hue, saturation and brightness in different directions by different coefficients. Therefore, proposed method includes independent hue, saturation and brightness control on specified color regions as a novelty compared to previous studies.

Independent hue and saturation blocks uses two dimensional CbCr plane for rotating hue and changing saturation level. Hue is measured by degrees on C_bC_r plane and saturation is measured radially outward from the center. Defined color regions can be seen on Figure 9. Every pixel on the image is controlled by the processor and is assigned to a specific color channel. Every region is controlled by independent coefficients. By using these coefficients, red and green regions are removed from each other and the details in these regions are prevented from intermingling. While applying changes on hue and saturation, other color regions are affected at minimum level contrary to previous studies. By this method, details on image are increased by changing original image as much as possible.

Same as hue and saturation blocks, independent brightness block applies different coefficients to defined color regions independently. After determination of each pixel's region, brightness coefficient of color region is multiplied with Y' component of same region. For increasing difference between red and green regions, red region's brightness is decreased while green region's brightness is increased.

None of the other five regions is affected by this modification and original image is also kept unchanged as much as possible. Results of these modifications on television

can be seen on Figure 10. Figure 10 shows color saturation sweep measurements that is taken by Calman Ultimate software. Left measurement belongs to conventional television that has no enhancement for color vision deficient person and right measurement belongs to television that has enhancement by proposed method. As it can be seen on measurements, color sweeps on red and green areas moved away from each other while other color channels are not affected that much.

At the end of the independent hue, saturation and brightness modifications on seven color channels, unmodified and modified pictures and their deuteranope simulations can be comparatively seen on Figure 11. After independent hue, saturation and brightness modifications, it is seen that color difference between red and green parts become more obvious as expected.

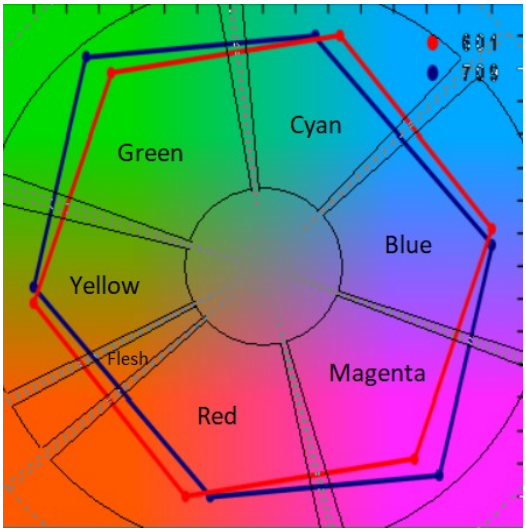

Figure 9: Defined color regions on C_bC_r plane

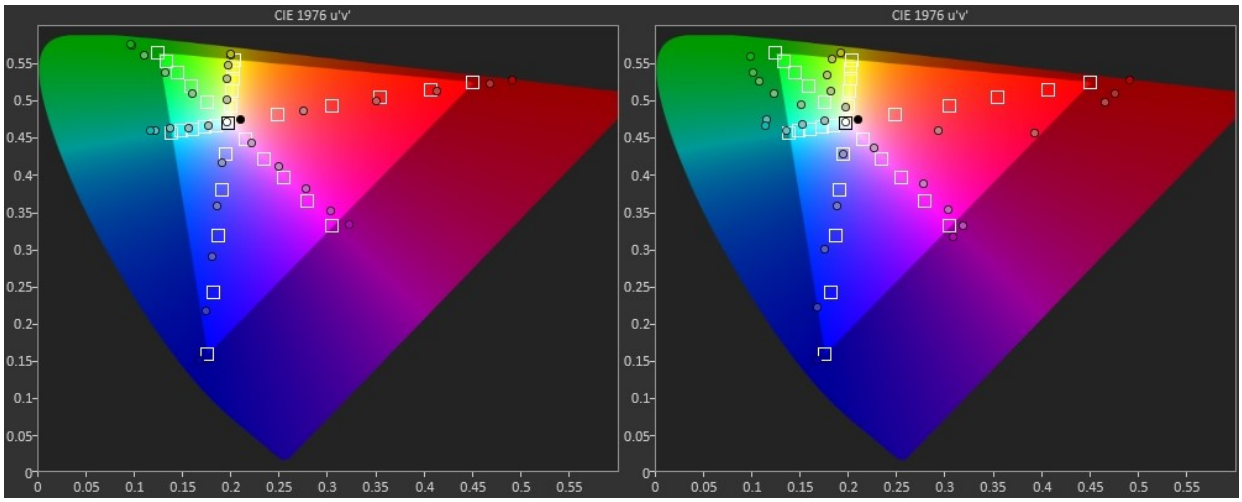

Figure 10: Saturation sweep – Left: Sweep of conventional television that has no enhancement for color vision deficient person, Right: Sweep of television that has enhancement by proposed method

Figure 11: Image comparison after color enhancements - Left top: Original Image, Right top: Deuteranope simulation of original image, Left bottom: Image after color enhancements, Right Bottom: Deuteranope simulation of image after color enhancements

3.3 Dynamic Luminance control (DLC) & Histogram Equalization

Dynamic Luminance Control (DLC - Dynamic Luma curve) algorithm is used to enhance contrast by considering different Y histograms for different images. DLC block uses histogram information to adjust luminance curve for better contrast. The DLC operation consists of two parts: histogram equalization and luma curve adjustment.

Hardware computes and reports the 32 fixed sections of histogram of the image frame at hand. Maximum, minimum luminance values, total sum of luminance and total pixel counts are also included in the hardware histogram report.

3.3.1 Histogram Equalization

In order to enhance the luminance channel's contrast by modifying the intensity distribution of the histogram, algorithm computes proper luminance curve based on the histogram information provided by the hardware. Contrast is increased by histogram equalization curve. Histogram equalization method is generally too strong to be real looking.

Histogram equalization is a method to process images in order to adjust the contrast of an image by modifying the intensity distribution of the histogram. The objective of this technique is to give a linear trend to the cumulative distribution function (CDF) associated with the image.

The processing of histogram equalization relies on the use of the cumulative distribution function. CDF is a cumulative sum of all the probabilities lying in its domain and defined by:

$$cdf(x) = \sum_{k=-\infty}^{x} (P(k)) \tag{3}$$

The idea of this processing is to give to the resulting image a linear cumulative distribution function. Indeed, a linear CDF is associated to the uniform histogram.

3.3.2 Luma Curve Adjustment

Dynamic contrast block composes luma curve from 3 static curves; “curve_high” for images that have high range average pixel luma (APL), “curve_medium” for images that have medium range APL and “curve_low” for images that have low range APL. These static curves and range limits can be programmable by registers. Mixture algorithm creates final luma curve from these three curves. After the whole frame is adjusted in terms of APL, the overall image contrast is improved by luma curve. Y value is fixed at the start point of curve and the end point of curve. Curve changes only middle points.

These two methods can be blended by curve_mix_alpha parameter. The main concern is that picture should have more contrast after this modification but at the same time, it must look natural.

At the end of the DLC modifications on luma, Figure 12 can show improvement of picture for deuteranope person. Comparison shows difference between original image, DLC block output and their deuteranope simulations. After DLC modification, it is seen that edge difference between red and green parts become more obvious as expected.

Figure 12: Image comparison after DLC enhancement - Left top: Original Image, Right top: Deuteranope simulation of original image, Left bottom: Image after DLC enhancements, Right Bottom: Deuteranope simulation of image after DLC enhancement

3.4 2-Dimensional(2D) Peaking Block

2D peaking block is a 2-dimensional 5x17 convolutional filter with programmable gains in a 5x17 pixel window on spatial domain. 2D convolutional filter is capable to increase or decrease horizontal, vertical and diagonal high frequency components of a picture according to frequency band coefficients simultaneously. 2D peaking block is used for enhancing object edges and details on different colors. In 2D peaking block, there is color-adaptive peaking part as an important difference on red-green color blindness enhancement. Color adaptive means filter has different band coefficients for each color channel that is defined on Y'CbCr domain. High peaking gain is applied on especially red and green parts for improving details and borders between these colors.

2D peaking mask is centered on each pixel of the initial image as it can be seen on Figure 13. For each position of the mask the pixel values of the image is multiplied by the corresponding mask coefficients and this operation continues as in a conventional convolutional filter. Mask coefficients is different for all color channels. By this feature, high peaking gain is applied especially on red and green parts for increasing details for red-green color blind people.

2D convolutional filter takes an input signal x[m,n], modifies it by difference equation and produces an output signal y[m,n]. 2D convolutional filter's basic equation is shown by Equation (4) where b(k,l) values denote mask coefficients and x[m,n] values denote pixel intensities.

$$y[m,n] = \sum_{k=-8}^{8} \sum_{l=-2}^{2} b_{k,l} x\,[m-k, n-l] \qquad (4)$$

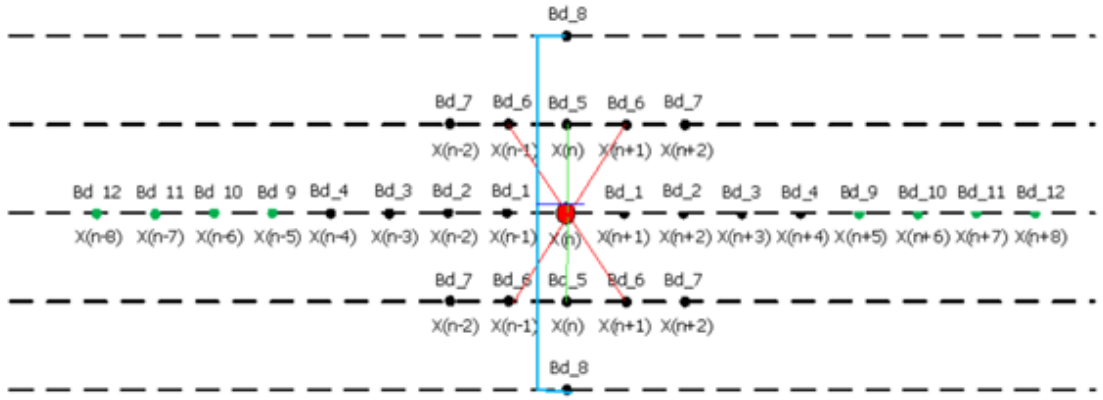

Figure 13: 2-Dimensional Peaking Mask

Figure 14: Image comparison after sharpness enhancements - Left top: Original Image, Right top: Deuteranope simulation of original image, Left bottom: Image after sharpness enhancements, Right Bottom: Deuteranope simulation of image after sharpness enhancements

At the end of 2-Dimensional Peaking enhancements, comparison pictures that is seen on Figure 14 can show improvement. Generally, object edges become more obvious and detail enhancement can be seen on both of processed images and simulation of it. This improvement provides more separable objects on image.

CHAPTER IV

EXPERIMENTS and RESULTS

4.1 Data Set

For assisting reproducibility of this study, data set is shared via referenced link [24]. Data set includes 2 main folders and 2114 images. All pictures were chosen from Flickr Public Domain pictures. Especially colorful pictures that are belong to nature and city categories were chosen for understanding success and distortion level on every color tones. Picture resolutions are variable according to aspect ratio but generally FHD resolution was preferred.

The first main folder includes Ishihara Plates that are used on experimental part by “Original”, “Ishihara Plates that were enhanced by Lookup-Table-Based Gradient Field Reconstruction Method”, “Ishihara Plates that were enhanced by Proposed Method” subfolders. The second main folder includes real image samples and their deuteranope and protanope simulations by “Original Pictures & Simulations”, “Pictures that were enhanced by Lookup-Table-Based Gradient Field Reconstruction Method & Simulations” and “Pictures that were enhanced by Proposed Method & Simulations” subfolders. “Pictures that were enhanced by Proposed Method & Simulations” includes 4 sub folders. These folders show every stage of proposed method on this study. Stage 1 includes outcome of Independent Hue, Saturation, Brightness Control stage and their deuteranope and protanope simulations. Stage 2 includes outcome of Dynamic Luminance control (DLC) & Histogram Equalization stage and their deuteranope and protanope simulations.

Stage 3 includes outcome of 2-Dimensional (2D) Peaking Block stage and their deuteranope and protanope simulations Stage 4 includes outcome of whole system pipeline and shows latest version of enhanced images by proposed method and their deuteranope and protanope simulations.

Figure 15 illustrates the folder schematic of data set.

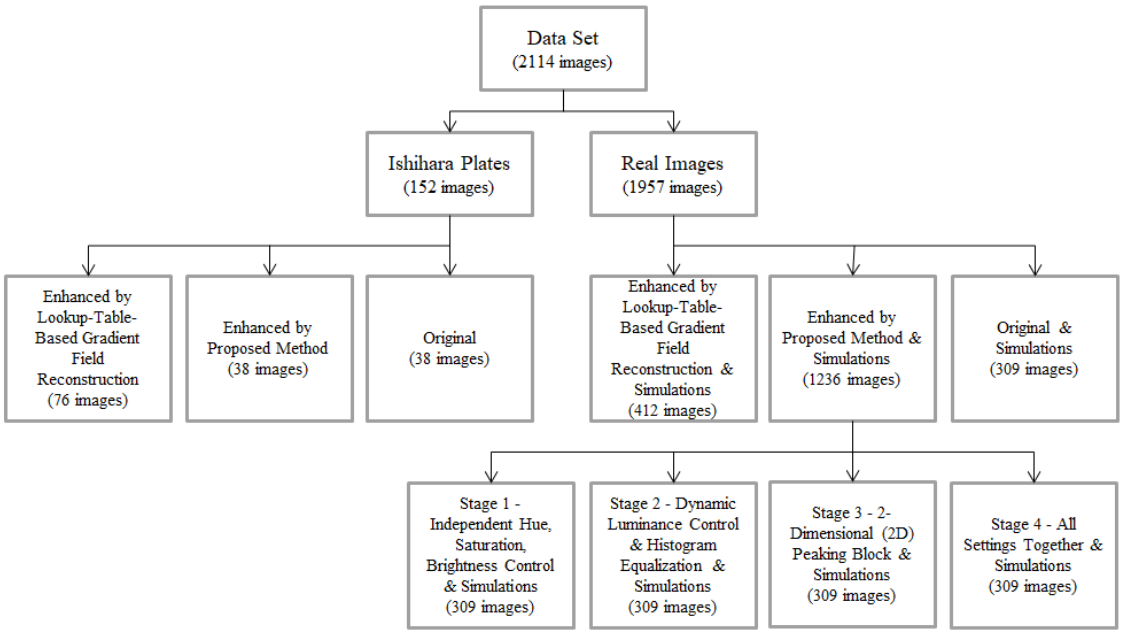

Figure 15: Data Set Folder Schematic

4.2 Experiments on Color Vision Deficient People

For obtaining success rate of proposed method, digital versions of Ishihara test plates that include 38 test plates were applied to seven red-green color vision deficient people by using a television set. Totally four televisions were used as experimental set; one television which includes picture enhancements with proposed method, one conventional television which has no image enhancement for CVD, one television which includes "Lookup Table Based Gradient Field Reconstruction" method's deuteranomaly solution and one television which includes "Lookup Table Based

Gradient Field Reconstruction" method's protanomaly solution.

As it is mentioned on part 2.2 Diagnosis Methods, test plates include numbers and continuous colorful paths. Every color vision deficient people has invited to room that has television set, separately. Ishihara Plates were shown one by one on four separate TVs at the same time and the color vision deficient people were asked as "Which number or how many uninterrupted paths are there in the pictures on these TVs?" as a first question. The second question was "Which TV is clearer in terms of shape of number or path?" Answers of first question were grouped as "Correct", "Wrong" and "Partial Correct". The correct answer rate was calculated by Equation 5.

$$Correct\ Answer\ Rate = \frac{\text{"Correct" Answer Number} + 0.5\ \text{"Partial Correct" Answer Number}}{Total\ Plate\ Number} \quad (5)$$

Answers of second question were grouped by rates of choices of color vision deficient people as rank 1, 2, 3, 4 or no vision. On this part of experiment, it is requested that ranking televisions 1 to 4 in terms of clarity of view. Rank 1 means the clearest view of pattern while rank 4 means that there is a vision on pattern but it is not as clear as the others. No vision means nothing is seen on pattern, any number or shape, by the CVD people; therefore, it is not possible to rank vision of pattern.

The comparison criteria are the correct answer rate and the ranking in terms of the clearest view. As it can be seen on Table 1, average correct answer rate of proposed method on this paper has the highest correct answer rate of 75.38% while conventional television has the lowest success rate as 50.38%. Proposed method seems to drastically increase the correct answer rate compared to performances on conventional televisions.

Table 1: Success Rate for CVD People

Success	Conventional	Proposed Method	Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly	Lookup-Table-Based Gradient Field Reconstruction - Protanomaly
Person 1	27.63%	**61.84%**	26.32%	60.53%
Person 2	44.74%	**67.11%**	63.16%	64.47%
Person 3	61.84%	**88.16%**	84.21%	80.26%
Person 4	55.26%	**89.47%**	85.53%	80.26%
Person 5	32.89%	**59.21%**	52.63%	55.26%
Person 6	64.47%	**88.16%**	86.84%	82.89%
Person 7	65.79%	**73.68%**	71.05%	67.11%
Average	50.38%	**75.38%**	67.11%	70.11%

Therefore, the sections that color vision deficient people have not seen on picture are made visible by 25.00%. At the same time, correct answer rate was increased by 8.27% when compared to “Lookup-Table-Based Gradient Field Reconstruction” method’s deuteranomaly solution and 5.27% according to “Lookup-Table-Based Gradient Field Reconstruction” method’s protanomaly solution. Proposed method increased detail on image for color vision deficient television watchers according to conventional television and previous proposed methods.

Ranking of the clearest view results on Table 2 shows that color vision deficient people choose the proposed method as the clearest view by 42.41%. As a summary, proposed method was chosen as rank 1 (the clearest view) by 42.41%, rank 2 by 14.73%, rank 3 by 17.41% and rank 4 by 0%. No vision rate is lowest on proposed method by 25.45%. This percentage is the highest on conventional television as expected.

Table 2: Average Ranking for CVD People

Average Ranking	Conventional	Proposed Method	Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly	Lookup-Table-Based Gradient Field Reconstruction - Protanomaly
#1	0.45%	**42.41%**	29.46%	6.25%
#2	0.00%	14.73%	18.30%	**43.30%**
#3	2.23%	17.41%	16.96%	**19.20%**
#4	**48.21%**	0.00%	0.00%	0.00%
No Vision	49.11%	**25.45%**	35.27%	31.25%

Detailed test results that include every Ishihara Plate number and answers of CVD people on comparison TV sets were shown on Appendix part as Table 5, Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11, respectively.

As an Ishihara Plate example, original Ishihara Test Plate Number 5, Ishihara Test Plate Number 5 which is enhanced by proposed method and their protanomaly simulations can be seen on Figure 17. As it can be seen, number on Ishihara Plate becomes visible for color vision deficient person with proposed method while it is invisible on original Ishihara Plate.

For understanding enhancement logic in more detail, three dimensional HSV color map of Ishihara Test Plate Number 5 can be analyzed on Figure 16. Figure 16 shows hue, saturation and brightness change on HSV color space. If color map of original image and enhanced image is compared, it can be seen that red and green parts of image are expanded on color space on enhanced version. Basically by this change, number on Ishihara Plate and background differentiated and number information is rescued from confusion band of color vision deficient person as it can be seen on Figure 17.

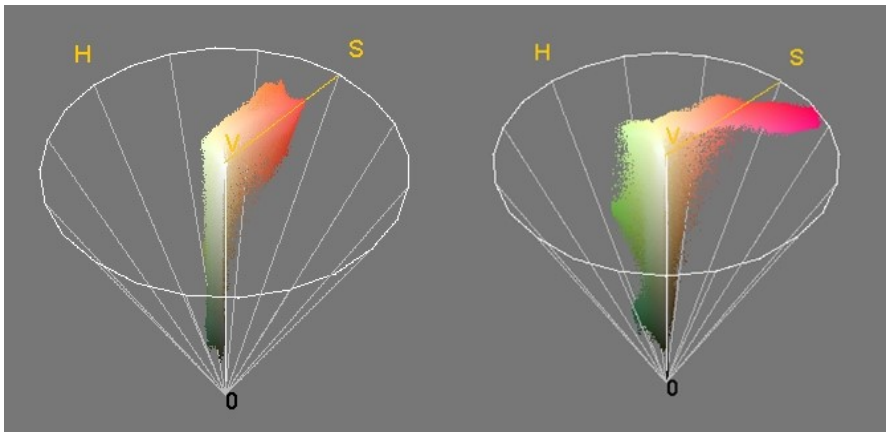

Figure 16: Ishihara Plate Number 5 color map comparison - Left: There dimensional color map of original Ishihara Test Plate Number 5, Right: There dimensional color map of Ishihara Test Plate Number 5 that is enhanced by proposed method

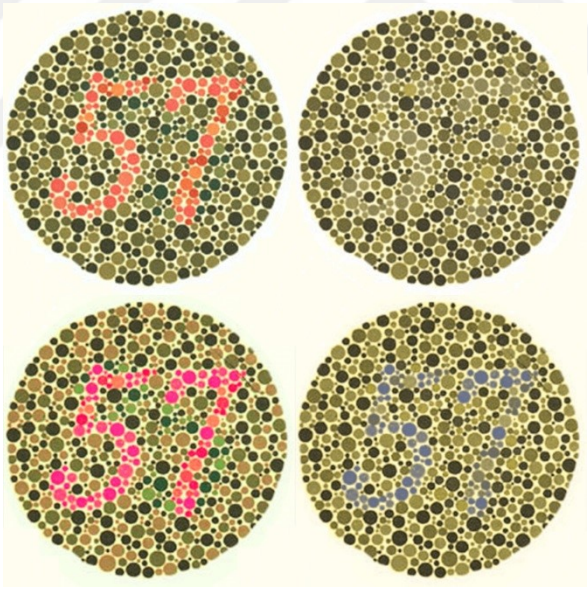

Figure 17: Ishihara Plate Number 5 comparison after enhancements with proposed method - Left top: Ishihara Test Plate Number 5, Right top: Protanope simulation of original Ishihara Test Plate Number 5, Left bottom: Ishihara Test Plate Number 5 after enhancements with proposed method, Right Bottom: Ishihara Test Plate Number 5 simulation of Ishihara Test Plate Number 5 after enhancements with proposed method

4.3 Experiments on People with Healthy Vision

For obtaining success rate of proposed method on people with normal vision, real images were applied to ten people with healthy vision by using same television set with previous experiment section 4.1.

103 units real image were showed on this TV set and ten people were asked as "Which television do you prefer to watch?" They ranked television 1 to 4 for every separate picture. Rank 1 means the most preferable image while Rank 4 means the worse picture between these set. Average ranking is the lowest for best picture while it is the highest for worst one.

Test result can be seen on Table 3. For every person ranking is in the same order as "Conventional", "Proposed", "Lookup-Table-Based Gradient Field Reconstruction – Deuteranomaly" and "Lookup-Table-Based Gradient Field Reconstruction – Protanomaly" methods respectively. Average ranking is the lowest for conventional TV as 1.41. Therefore it is the most preferable picture for people with healthy vision. This result is normal and expectable since image is not distorted on conventional TV. Between other three TVs, proposed method is the most preferable one with the second lowest ranking rate as 2.11.

Table 4 shows average rank rates for every TV set. "Conventional" TV was chosen Rank 1 by 72.91% averagely. The second TV which is chosen Rank 1 was "Proposed Method". This shows that proposed method is the most preferable TV set after "Conventional" one.

Table 3: Average Ranking for People with Healthy Vision

Average Ranking	Conventional	Proposed Method	Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly	Lookup-Table-Based Gradient Field Reconstruction - Protanomaly
Person 1	1.60	**2.13**	2.48	3.80
Person 2	1.85	**1.90**	2.28	3.96
Person 3	1.45	**1.94**	2.66	3.95
Person 4	1.19	**2.11**	2.73	3.97
Person 5	1.07	**2.27**	2.79	3.87
Person 6	1.02	**2.32**	2.67	3.99
Person 7	1.00	**2.40**	2.66	3.94
Person 8	1.68	**1.81**	2.54	3.97
Person 9	1.70	**2.15**	2.34	3.82
Person 10	1.50	**2.13**	2.60	3.77
Average	**1.41**	**2.11**	**2.57**	**3.90**

Table 4: Average Rank Rate for People with Healthy Vision

Average Rank Rate	Conventional	Proposed Method	Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly	Lookup-Table-Based Gradient Field Reconstruction - Protanomaly
Rank 1	72.91%	21.36%	5.15%	0.58%
Rank 2	15.73%	48.16%	34.56%	1.55%
Rank 3	9.13%	28.16%	57.96%	4.76%
Rank 4	2.23%	2.33%	2.33%	93.11%

Detailed test results that include every real image number and answers of people with healthy vision on comparison TV sets were shown on Appendix part as Table 12, Table 13, Table 14, Table 15, Table 16, Table 17, Table 18, Table 19, Table 20 and Table 21 respectively.

Figure 18: Image comparison after enhancements with proposed method - Left top: Original Image, Right top: Deuteranope simulation of original image, Left bottom: Image after enhancements with proposed method, Right Bottom: Deuteranope simulation of image after enhancements with proposed method

As a real image example, comparison of original image and image that is enhanced by proposed method can be seen on Figure 18. As it can be seen on simulation part of figure, red and green parts were differentiated for color vision deficient person while original image is not changed dramatically for people that have not color vision deficiency.

CHAPTER V

CONCLUSION

Consequently, maximum success rate has been increased to 75.38% correct answers by the proposed method. Therefore, our proposed method becomes the most successful method by 49.62% when increased correct answer rate of color vision deficient people is compared to conventional TV. Moreover, the clearest view is achieved when proposed method is applied while at the same time no-vision rate stays the lowest for color vision deficient people.

According to test results of people with healthy vision, conventional TV was chosen the most preferable picture for people with healthy vision by lowest average ranking by 1.41. This result is normal and expected since image is not distorted on conventional TV. Among other three TVs, proposed method is the most preferable one with the second lowest average ranking rate by 2.11. Ranking rates and average ranking differences are differing according to subjective criteria of people with healthy vision. People who likes natural images choose “Conventional” and “Proposed Method” ones as Rank 1 mostly while people who love attractive colors in images choose “Proposed Method” and “Lookup-Table-Based Gradient Field Reconstruction – Deuteranomaly” mostly as Rank 1. General idea about “Lookup-Table-Based Gradient Field Reconstruction – Protanomaly” at the end of the experiment is that image is over-saturated and unnatural. Therefore, it takes highest average ranking rate by 3.90 and becomes the least preferable method for people with healthy vision.

CHAPTER VI

FUTURE WORK

According to the experiment results on color vision deficient people, it is seen that the increasing amount of success rate varies between 7.89% and 34.21% for proposed method. Minimum increasing amount of success is seen on Person 7's results while maximum increasing amount of success rate is seen on Person 1's and Person 4's results. When results of these three people are analyzed in a more detailed fashion, type of color vision deficiency is seen to be "deutan" for all of them. When "no vision" and "wrong" answer conditions on conventional TV are checked pattern by pattern, similar pattern numbers are seen for all of them. For example; Pattern Number 13 has "no vision" condition for Person 1, Person 4 and Person 7 and it becomes visible for only Person 1 and Person 4 by proposed method while it can't become visible for Person 7 by the same method. Since all of them have same color vision deficiency type, there is no clue for explaining different reaction to proposed method on Pattern Number 13. This part of analysis can be noted as future work that should be co-worked with an ophthalmologist.

APPENDIX

Table 5: Detailed Test Results of CVD Person 1

Pattern Number	Pattern Correct Answer	Conventional			Proposed Method			Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly			Lookup-Table-Based Gradient Field Reconstruction - Protanomaly		
		Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking
1	12	12	C	4	12	C	1	12	C	3	12	C	2
2	8	-	W	No Vision	8	C	1	3	W	No Vision	3	W	No Vision
3	6	-	W	No Vision	6	C	1	-	W	No Vision	6	C	2
4	29	-	W	No Vision	29	C	1	70	W	No Vision	29	C	2
5	57	-	W	No Vision	57	C	1	-	W	No Vision	57	C	2
6	5	-	W	No Vision	-	W	No Vision	-	W	No Vision	5	C	1
7	3	-	W	No Vision	3	C	1	-	W	No Vision	3	C	2
8	15	-	W	No Vision	5	P	1	-	W	No Vision	5	P	2
9	74	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
10	2	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
11	6	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
12	97	-	W	No Vision	7	P	1	-	W	No Vision	-	W	No Vision
13	45	-	W	No Vision	45	C	1	-	W	No Vision	45	C	2
14	5	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
15	7	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
16	16	-	W	No Vision	96	P	1	-	W	No Vision	26	P	2
17	73	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
18	-	-	C	-	-	C	-	-	C	-	-	C	-
19	-	-	C	-	-	C	-	-	C	-	-	C	-
20	-	-	C	-	-	C	-	-	C	-	-	C	-
21	-	-	C	-	-	C	-	-	C	-	-	C	-
22	26	2	P	3	26	C	1	30	W	No Vision	26	C	2
23	42	4	P	3	42	C	1	-	W	No Vision	42	C	2
24	35	3	P	3	35	C	1	-	W	No Vision	35	C	2
25	96	9	P	4	96	C	1	9	P	3	96	C	2
26	2	1	P	4	2	C	1	1	P	3	2	C	2
27	2	0	W	No Vision	2	C	1	0	W	No Vision	2	C	2
28	0	0	C	-	0	C	-	0	C	-	0	C	-
29	0	0	C	-	0	C	-	0	C	-	0	C	-
30	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
31	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
32	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
33	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
34	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
35	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
36	1	0	W	No Vision	1	C	1	1	C	3	1	C	2
37	1	0	W	No Vision	1	C	1	-	W	No Vision	1	C	2
38	1	1	C	4	1	C	1	1	C	3	1	C	2
Total C			8			22			9			22	
Total P			5			3			2			2	
Total W			25			13			27			14	
Success			0.27632			0.61842			0.26316			0.60526	

Table 6: Detailed Test Results of CVD Person 2

Pattern Number	Pattern Correct Answer	Conventional			Proposed Method			Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly			Lookup-Table-Based Gradient Field Reconstruction - Protanomaly		
		Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking
1	12	12	C	4	12	C	1	12	C	3	12	C	2
2	8	3	W	No Vision	8	C	1	-	W	No Vision	8	C	2
3	6	6	C	3	6	C	1	-	W	No Vision	6	C	2
4	29	29	C	4	29	C	1	29	C	3	29	C	2
5	57	57	C	4	57	C	1	57	C	3	57	C	2
6	5	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
7	3	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
8	15	17	P	4	15	C	1	15	C	2	15	C	3
9	74	21	W	No Vision	71	P	1	71	P	2	71	P	3
10	2	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
11	6	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
12	97	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
13	45	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
14	5	-	W	No Vision	5	C	1	5	C	2	5	C	3
15	7	7	C	4	7	C	2	7	C	1	7	C	3
16	16	16	C	4	16	C	2	16	C	1	16	C	3
17	73	78	P	4	78	P	2	78	P	1	78	P	3
18	-	-	C	-	-	C	-	-	C	-	-	C	-
19	-	-	C	-	-	C	-	-	C	-	-	C	-
20	-	-	C	-	-	C	-	-	C	-	-	C	-
21	-	-	C	-	-	C	-	-	C	-	-	C	-
22	26	2	P	4	26	C	2	26	C	1	26	C	3
23	42	42	C	4	42	C	2	42	C	1	42	C	3
24	35	3	P	4	35	C	2	35	C	1	35	C	3
25	96	96	C	4	96	C	2	96	C	1	96	C	3
26	2	1	P	4	1	P	2	2	C	1	1	P	3
27	2	1	P	3	2	C	1	2	C	2	0	W	No Vision
28	0	1	W	-	0	C	-	0	C	-	0	C	-
29	0	2	W	-	0	C	-	0	C	-	0	C	-
30	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
31	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
32	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
33	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
34	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
35	1	0	W	No Vision	1	C	2	1	C	1	1	C	3
36	1	0	W	No Vision	1	C	1	1	C	2	1	C	3
37	1	1	C	4	1	C	1	1	C	2	1	C	3
38	1	1	C	4	1	C	1	1	C	2	1	C	3
Total C			14			24			23			23	
Total P			6			3			2			3	
Total W			18			11			13			12	
Success			0.44737			0.67105			0.63158			0.64474	

Table 6: Detailed Test Results of CVD Person 3

Pattern Number	Pattern Correct Answer	Conventional			Proposed Method			Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly			Lookup-Table-Based Gradient Field Reconstruction - Protanomaly		
		Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking
1	12	12	C	4	12	C	1	12	C	2	12	C	3
2	8	8	C	4	8	C	1	8	C	3	8	C	2
3	6	6	C	4	6	C	1	6	C	3	6	C	2
4	29	20	P	4	29	C	1	29	C	3	29	C	2
5	57	57	C	4	57	C	1	57	C	3	57	C	2
6	5	5	C	4	5	C	3	5	C	1	5	C	2
7	3	3	C	1	8	W	No Vision	8	W	No Vision	8	W	No Vision
8	15	19	P	4	15	C	3	15	C	1	15	C	2
9	74	74	C	4	74	C	3	74	C	1	74	C	2
10	2	-	W	No Vision	2	C	1	2	C	2	2	C	3
11	6	-	W	No Vision	6	C	1	-	W	No Vision	-	W	No Vision
12	97	-	W	No Vision	87	P	1	87	P	3	87	P	2
13	45	-	W	No Vision	45	C	1	-	W	No Vision	-	W	No Vision
14	5	5	C	4	5	C	1	5	C	2	5	C	3
15	7	7	C	4	7	C	1	7	C	2	7	C	3
16	16	16	C	4	16	C	1	16	C	2	16	C	3
17	73	73	C	4	73	C	1	73	C	2	73	C	3
18	-	-	C	-	-	C	-	-	C	-	-	C	-
19	-	-	C	-	-	C	-	-	C	-	-	C	-
20	-	-	C	-	-	C	-	-	C	-	-	C	-
21	-	-	C	-	-	C	-	-	C	-	-	C	-
22	26	28	P	4	28	P	3	28	P	1	28	P	2
23	42	43	P	4	42	C	3	42	C	1	42	C	2
24	35	36	P	4	35	C	3	35	C	1	35	C	2
25	96	96	C	4	96	C	3	96	C	1	96	C	2
26	2	1	P	4	1	P	3	2	C	1	2	C	2
27	2	1	P	4	2	C	3	2	C	1	2	C	2
28	0	0	C	-	0	C	-	0	C	-	0	C	-
29	0	0	C	-	0	C	-	0	C	-	0	C	-
30	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
31	1	0	W	No Vision	1	C	2	1	C	1	1	P	3
32	1	0	W	No Vision	0	W	No Vision	0	W	No Vision	0	W	No Vision
33	1	0	W	No Vision	1	C	1	1	C	2	0	W	No Vision
34	1	0	W	No Vision	1	C	2	1	C	1	1	C	3
35	1	0	W	No Vision	1	C	2	1	C	1	1	C	3
36	1	0	W	No Vision	1	C	1	1	C	2	1	C	3
37	1	1	C	4	1	C	1	1	C	2	1	C	3
38	1	1	C	4	1	C	1	1	C	2	1	C	3
Total C			20			32			31			29	
Total P			7			3			2			3	
Total W			11			3			5			6	
Success			0.61842			0.88158			0.84211			0.80263	

Table 7: Detailed Test Results of CVD Person 4

Pattern Number	Pattern Correct Answer	Conventional			Proposed Method			Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly			Lookup-Table-Based Gradient Field Reconstruction - Protanomaly		
		Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking
1	12	12	C	4	12	C	2	12	C	1	12	C	3
2	8	8	C	4	8	C	1	8	C	3	8	C	2
3	6	6	C	4	6	C	1	6	C	3	6	C	2
4	29	29	C	4	29	C	1	29	C	3	29	C	2
5	57	57	C	4	57	C	1	57	C	3	57	C	2
6	5	8	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
7	3	-	W	No Vision	8	W	No Vision	8	W	No Vision	8	W	No Vision
8	15	-	W	No Vision	15	C	2	15	C	1	15	C	3
9	74	-	W	No Vision	81	W	No Vision	81	W	No Vision	81	W	No Vision
10	2	-	W	No Vision	2	C	1	2	C	3	2	C	2
11	6	-	W	No Vision	6	C	1	6	C	2	6	C	3
12	97	-	W	No Vision	97	C	1	87	P	2	87	P	3
13	45	-	W	No Vision	45	C	1	-	W	No Vision	45	C	2
14	5	-	W	No Vision	5	C	1	5	C	2	-	W	No Vision
15	7	-	W	No Vision	7	C	1	7	C	2	7	C	3
16	16	16	C	4	16	C	1	16	C	2	16	C	3
17	73	18	W	No Vision	73	C	1	73	C	2	73	C	3
18	-	-	C	-	-	C	-	-	C	-	-	C	-
19	-	-	C	-	-	C	-	-	C	-	-	C	-
20	-	-	C	-	-	C	-	-	C	-	-	C	-
21	-	-	C	-	-	C	-	-	C	-	-	C	-
22	26	26	C	4	26	C	3	26	C	1	26	C	2
23	42	42	C	4	42	C	3	42	C	1	42	C	2
24	35	36	P	4	35	C	3	35	C	1	35	C	2
25	96	96	C	4	96	C	3	96	C	1	96	C	2
26	2	2	C	4	2	C	3	2	C	1	2	C	2
27	2	1	P	4	2	C	3	2	C	1	2	C	2
28	0	0	C	-	-	C	-	-	C	-	-	C	-
29	0	0	C	-	-	C	-	-	C	-	-	C	-
30	1	0	W	No Vision	1	C	2	1	C	1	1	C	3
31	1	0	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
32	1	0	W	No Vision	1	C	1	1	C	2	-	W	No Vision
33	1	1	C	4	1	C	1	1	C	2	-	W	No Vision
34	1	0	W	No Vision	1	C	1	1	C	2	1	C	3
35	1	0	W	No Vision	1	C	1	1	C	2	1	C	3
36	1	1	C	4	1	C	1	1	C	3	1	C	2
37	1	1	C	4	1	C	1	1	C	3	1	C	2
38	1	1	C	4	1	C	1	1	C	3	1	C	2
Total C			20			34			32			30	
Total P			2			0			1			1	
Total W			16			4			5			7	
Success			0.55263			0.89474			0.85526			0.80263	

Table 8: Detailed Test Results of CVD Person 5

Pattern Number	Pattern Correct Answer	Conventional			Proposed Method			Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly			Lookup-Table-Based Gradient Field Reconstruction - Protanomaly		
		Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking
1	12	12	C	4	12	C	2	12	C	1	12	C	3
2	8	3	W	No Vision	3	W	No Vision	3	W	No Vision	3	W	No Vision
3	6	6	C	4	6	C	1	6	C	2	8	W	No Vision
4	29	20	P	4	29	C	1	29	C	3	29	C	2
5	57	-	W	No Vision	57	C	1	57	C	3	57	C	2
6	5	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
7	3	5	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
8	15	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
9	74	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
10	2	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
11	6	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
12	97	-	W	No Vision	97	C	1	57	P	2	-	W	No Vision
13	45	-	W	No Vision	45	C	1	45	C	2	45	C	3
14	5	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
15	7	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
16	16	-	W	No Vision	16	C	1	-	W	No Vision	16	C	2
17	73	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
18	-	-	C	-	-	C	-	-	C	-	-	C	-
19	-	-	C	-	-	C	-	-	C	-	-	C	-
20	-	-	C	-	-	C	-	-	C	-	-	C	-
21	-	-	C	-	-	C	-	-	C	-	-	C	-
22	26	8	W	No Vision	28	P	2	28	P	3	26	C	1
23	42	6	W	No Vision	42	C	1	-	W	No Vision	42	C	2
24	35	3	P	4	35	C	2	35	C	3	35	C	1
25	96	9	P	4	96	C	2	96	C	3	96	C	1
26	2	1	P	4	2	C	1	2	C	3	2	C	2
27	2	1	P	4	2	C	1	2	C	3	2	C	2
28	0	2	W	-	-	C	-	-	C	-	-	C	-
29	0	0	C	-	-	C	-	-	C	-	-	C	-
30	1	0	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
31	1	1	C	4	-	W	No Vision	-	W	No Vision	-	W	No Vision
32	1	0	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
33	1	0	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
34	1	0	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
35	1	1	C	4	1	C	2	1	C	3	1	C	1
36	1	2	W	No Vision	1	C	1	1	C	3	1	C	2
37	1	2	W	No Vision	1	C	1	1	C	3	1	C	2
38	1	1	C	4	1	C	2	1	C	1	1	C	3
Total C			10			22			19			21	
Total P			5			1			2			0	
Total W			23			15			17			17	
Success			0.32895			0.59211			0.52632			0.55263	

Table 9: Detailed Test Results of CVD Person 6

Pattern Number	Pattern Correct Answer	Conventional			Proposed Method			Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly			Lookup-Table-Based Gradient Field Reconstruction - Protanomaly		
		Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking
1	12	12	C	4	12	C	3	12	C	1	12	C	2
2	8	8	C	4	3	W	No Vision	3	W	No Vision	3	W	No Vision
3	6	6	C	4	6	C	3	6	C	1	6	C	2
4	29	29	C	4	29	C	3	29	C	1	29	C	2
5	57	57	C	4	57	C	3	57	C	2	57	C	1
6	5	-	W	No Vision	5	C	3	5	C	1	5	C	2
7	3	3	C	4	3	C	3	3	C	1	3	C	2
8	15	15	C	4	15	C	3	15	C	1	15	C	2
9	74	24	P	4	74	C	3	74	C	1	74	C	2
10	2	2	C	4	2	C	3	2	C	1	2	C	2
11	6	6	C	4	6	C	1	11	W	No Vision	11	W	No Vision
12	97	-	W	No Vision	97	C	1	97	C	2	91	P	3
13	45	-	W	No Vision	45	C	1	44	P	2	75	P	3
14	5	5	C	4	5	C	2	5	C	1	5	C	3
15	7	7	C	4	7	C	3	7	C	1	7	C	2
16	16	16	C	4	16	C	3	16	C	1	16	C	2
17	73	73	C	4	73	C	3	73	C	1	73	C	2
18	-	43	W	-	-	C	-	-	C	-	-	C	-
19	-	-	C	-	-	C	-	-	C	-	-	C	-
20	-	4	W	-	-	C	-	-	C	-	-	C	-
21	-	-	C	-	-	C	-	-	C	-	-	C	-
22	26	26	C	4	28	p	3	26	C	1	26	C	2
23	42	42	C	4	42	C	3	42	C	2	42	C	1
24	35	35	C	4	35	C	3	35	C	1	35	C	2
25	96	96	C	4	96	C	3	96	C	1	96	C	2
26	2	1	P	4	1	P	3	2	C	1	2	C	2
27	2	1	P	4	2	C	3	2	C	1	2	C	2
28	0	0	C	-	-	C	-	-	C	-	-	C	-
29	0	2	W	-	-	C	-	-	C	-	-	C	-
30	1	2	W	No Vision	2	P	3	2	P	1	2	P	2
31	1	2	W	No Vision	1	C	1	1	C	2	-	W	No Vision
32	1	0	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
33	1	0	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
34	1	0	W	No Vision	1	C	3	1	C	1	1	C	2
35	1	0	W	No Vision	1	C	3	1	C	1	1	C	2
36	1	1	C	4	1	C	3	1	C	1	1	C	2
37	1	1	C	4	1	C	3	1	C	1	1	C	2
38	1	1	C	4	1	C	3	1	C	1	1	C	2
Total C			**23**			**32**			**32**			**30**	
Total P			**3**			**3**			**2**			**3**	
Total W			**12**			**3**			**4**			**5**	
Success			**0.64474**			**0.88158**			**0.86842**			**0.82895**	

Table 10: Detailed Test Results of CVD Person 7

Pattern Number	Pattern Correct Answer	Conventional			Proposed Method			Lookup-Table-Based Gradient Field Reconstruction - Deuteranomaly			Lookup-Table-Based Gradient Field Reconstruction - Protanomaly		
		Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking	Answer	Correct/ Wrong/ Partial Correct	Ranking
1	12	12	C	4	12	C	1	12	C	3	12	C	2
2	8	8	C	4	8	C	1	8	C	3	8	C	2
3	6	6	C	4	6	C	1	6	C	3	6	C	2
4	29	29	C	4	29	C	1	29	C	3	29	C	2
5	57	57	C	4	57	C	1	5	P	3	57	C	2
6	5	3	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
7	3	3	C	4	3	C	1	3	C	3	3	C	2
8	15	15	C	4	15	C	2	15	C	1	17	P	3
9	74	21	W	No Vision	74	C	2	74	C	1	21	W	No Vision
10	2	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
11	6	-	W	No Vision	-	W	No Vision	-	W	No Vision	-	W	No Vision
12	97	87	P	4	97	C	2	97	C	1	97	C	3
13	45	-	W	No Vision	5	P	2	5	P	1	5	P	3
14	5	5	C	4	5	C	1	5	C	2	5	C	3
15	7	7	C	4	7	C	1	7	C	2	7	C	3
16	16	16	C	4	16	C	1	16	C	2	16	C	3
17	73	73	C	4	73	C	1	73	C	2	73	C	3
18	-	-	C	-	-	C	-	-	C	-	-	C	-
19	-	-	C	-	-	C	-	-	C	-	-	C	-
20	-	-	C	-	-	C	-	-	C	-	-	C	-
21	-	-	C	-	-	C	-	-	C	-	-	C	-
22	26	2	P	4	26	C	2	26	C	1	2	P	3
23	42	4	P	4	4	P	2	4	P	1	4	P	3
24	35	3	P	4	35	C	2	3	P	1	3	P	3
25	96	96	C	4	96	C	2	96	C	1	96	C	3
26	2	1	P	4	1	P	2	1	P	1	1	P	3
27	2	1	P	4	1	P	2	1	P	1	1	P	3
28	0	0	C	-	-	C	-	-	C	-	-	C	-
29	0	0	C	-	-	C	-	-	C	-	-	C	-
30	1	0	W	No Vision	0	W	No Vision	-	W	No Vision	-	W	No Vision
31	1	1	C	4	1	C	1	1	C	2	1	C	3
32	1	0	W	No Vision	0	W	No Vision	-	W	No Vision	-	W	No Vision
33	1	0	W	No Vision	0	W	No Vision	-	W	No Vision	-	W	No Vision
34	1	0	W	No Vision	0	W	No Vision	-	W	No Vision	-	W	No Vision
35	1	0	W	No Vision	0	W	No Vision	-	W	No Vision	-	W	No Vision
36	1	1	C	4	1	C	1	1	C	3	1	C	2
37	1	1	C	4	1	C	1	1	C	2	1	C	3
38	1	1	C	4	1	C	2	1	C	1	1	C	3
Total C			22			26			24			22	
Total P			6			4			6			7	
Total W			10			8			8			9	
Success			0.65789			0.73684			0.71053			0.67105	

Table 11: Detailed Test Results of Person 1 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	4	2	3	**37**	1	4	2	3	**73**	3	1	2	4
2	2	1	3	4	**38**	2	1	3	4	**74**	2	1	3	4
3	4	1	3	2	**39**	1	3	2	4	**75**	1	2	3	4
4	4	1	2	3	**40**	1	3	2	4	**76**	3	1	2	4
5	2	1	3	4	**41**	1	3	2	4	**77**	2	1	3	4
6	2	3	1	4	**42**	1	4	2	3	**78**	1	3	2	4
7	3	1	4	2	**43**	2	1	3	4	**79**	2	3	1	4
8	2	3	1	4	**44**	1	3	2	4	**80**	1	3	2	4
9	1	3	2	4	**45**	1	3	2	4	**81**	2	1	3	4
10	3	1	4	2	**46**	2	1	3	4	**82**	2	3	1	4
11	1	2	3	4	**47**	2	1	3	4	**83**	2	1	3	4
12	1	3	2	4	**48**	1	3	2	4	**84**	1	2	3	4
13	1	4	2	3	**49**	1	3	2	4	**85**	2	3	1	4
14	3	1	2	4	**50**	2	1	3	4	**86**	3	1	2	4
15	1	2	4	3	**51**	1	4	2	3	**87**	2	1	3	4
16	1	2	3	4	**52**	2	1	3	4	**88**	1	2	3	4
17	1	4	2	3	**53**	1	2	3	4	**89**	2	1	3	4
18	1	3	4	2	**54**	2	1	3	4	**90**	1	3	2	4
19	1	3	2	4	**55**	1	2	3	4	**91**	2	1	3	4
20	1	2	3	4	**56**	3	1	2	4	**92**	1	2	3	4
21	1	2	4	3	**57**	2	1	3	4	**93**	1	2	3	4
22	1	3	2	4	**58**	3	1	2	4	**94**	3	1	2	4
23	1	4	2	3	**59**	1	3	2	4	**95**	2	1	3	4
24	2	1	3	4	**60**	1	3	2	4	**96**	2	1	3	4
25	1	3	2	4	**61**	2	1	3	4	**97**	2	1	3	4
26	1	2	3	4	**62**	1	3	2	4	**98**	1	2	3	4
27	1	3	2	4	**63**	1	3	2	4	**99**	3	1	2	4
28	1	2	3	4	**64**	3	1	2	4	**100**	3	1	2	4
29	1	3	2	4	**65**	1	3	2	4	**101**	1	2	3	4
30	1	2	3	4	**66**	1	2	3	4	**102**	1	2	3	4
31	1	4	2	3	**67**	1	3	2	4	**103**	3	1	2	4
32	2	1	3	4	**68**	1	3	2	4	**Average**	**1.60**	**2.13**	**2.48**	**3.80**
33	2	1	3	4	**69**	1	3	2	4	**Rank 1**	**56.31%**	**38.83%**	**4.85%**	**0.00%**
34	1	4	2	3	**70**	1	2	3	4	**Rank 2**	**29.13%**	**19.42%**	**47.57%**	**3.88%**
35	1	4	2	3	**71**	1	3	2	4	**Rank 3**	**12.62%**	**32.04%**	**42.72%**	**12.62%**
36	1	3	2	4	**72**	2	1	3	4	**Rank 4**	**1.94%**	**9.71%**	**4.85%**	**83.50%**

Table 12: Detailed Test Results of Person 2 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	3	2	4	**37**	1	3	2	4	**73**	1	2	3	4
2	2	1	3	4	**38**	1	2	3	4	**74**	1	2	3	4
3	3	1	2	4	**39**	2	1	3	4	**75**	3	1	2	4
4	3	1	2	4	**40**	1	3	2	4	**76**	1	2	3	4
5	3	1	2	4	**41**	1	3	2	4	**77**	2	1	3	4
6	1	2	3	4	**42**	1	3	2	4	**78**	2	3	1	4
7	2	1	3	4	**43**	3	1	2	4	**79**	1	2	3	4
8	1	3	2	4	**44**	3	2	1	4	**80**	1	3	2	4
9	1	2	4	3	**45**	1	2	3	4	**81**	3	1	2	4
10	3	1	2	4	**46**	2	1	3	4	**82**	2	1	3	4
11	1	2	3	4	**47**	1	2	3	4	**83**	3	2	1	4
12	2	3	1	4	**48**	1	2	3	4	**84**	1	2	3	4
13	2	3	1	4	**49**	2	3	1	4	**85**	2	1	3	4
14	3	1	2	4	**50**	3	1	2	4	**86**	1	3	2	4
15	1	2	3	4	**51**	3	1	2	4	**87**	2	1	3	4
16	2	1	3	4	**52**	3	1	2	4	**88**	3	1	2	4
17	2	3	1	4	**53**	1	2	3	4	**89**	3	1	2	4
18	2	3	1	4	**54**	2	1	3	4	**90**	1	2	3	4
19	3	1	2	4	**55**	1	2	3	4	**91**	1	2	3	4
20	1	2	3	4	**56**	3	1	2	4	**92**	1	2	3	4
21	2	1	3	4	**57**	3	1	2	4	**93**	2	1	3	4
22	1	3	2	4	**58**	4	2	1	3	**94**	1	2	3	4
23	1	3	2	4	**59**	1	3	2	4	**95**	1	2	3	4
24	2	1	3	4	**60**	3	1	2	4	**96**	2	1	3	4
25	1	2	3	4	**61**	3	1	2	4	**97**	3	1	2	4
26	1	2	3	4	**62**	1	3	2	4	**98**	3	1	2	4
27	2	3	1	4	**63**	1	3	2	4	**99**	4	3	1	2
28	3	1	2	4	**64**	3	2	1	4	**100**	2	1	3	4
29	1	3	2	4	**65**	2	1	3	4	**101**	1	3	2	4
30	1	3	2	4	**66**	1	2	3	4	**102**	1	2	3	4
31	1	3	2	4	**67**	3	1	2	4	**103**	1	2	3	4
32	3	2	1	4	**68**	1	3	2	4	**Average**	**1.85**	**1.90**	**2.28**	**3.96**
33	1	3	2	4	**69**	1	3	2	4	**Rank 1**	**46.60%**	**38.83%**	**14.56%**	**0.00%**
34	1	2	3	4	**70**	3	1	2	4	**Rank 2**	**23.30%**	**32.04%**	**43.69%**	**0.97%**
35	1	3	2	4	**71**	3	1	2	4	**Rank 3**	**28.16%**	**29.13%**	**40.78%**	**1.94%**
36	2	3	1	4	**72**	3	2	1	4	**Rank 4**	**1.94%**	**0.00%**	**0.97%**	**97.09%**

Table 13: Detailed Test Results of Person 3 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	2	3	4	**37**	1	3	2	4	**73**	2	1	3	4
2	2	1	3	4	**38**	1	2	3	4	**74**	1	2	3	4
3	1	2	3	4	**39**	2	1	3	4	**75**	3	1	4	2
4	2	1	3	4	**40**	1	3	2	4	**76**	2	1	3	4
5	2	1	3	4	**41**	2	1	3	4	**77**	2	1	3	4
6	2	1	3	4	**42**	2	1	3	4	**78**	1	2	3	4
7	1	2	3	4	**43**	1	3	2	4	**79**	1	3	2	4
8	1	3	2	4	**44**	2	3	1	4	**80**	1	2	3	4
9	1	3	2	4	**45**	1	2	3	4	**81**	1	3	2	4
10	2	1	3	4	**46**	1	2	3	4	**82**	2	1	3	4
11	1	3	2	4	**47**	2	1	3	4	**83**	2	1	4	3
12	2	3	1	4	**48**	1	2	3	4	**84**	1	2	3	4
13	1	3	2	4	**49**	1	3	2	4	**85**	2	3	1	4
14	1	2	3	4	**50**	2	1	3	4	**86**	1	3	2	4
15	1	3	2	4	**51**	1	2	3	4	**87**	2	1	3	4
16	1	3	2	4	**52**	1	2	3	4	**88**	3	1	2	4
17	1	2	3	4	**53**	2	1	3	4	**89**	3	1	2	4
18	1	3	2	4	**54**	2	1	3	4	**90**	1	3	2	4
19	1	2	3	4	**55**	1	2	3	4	**91**	2	1	3	4
20	1	2	3	4	**56**	1	2	3	4	**92**	1	2	3	4
21	1	2	3	4	**57**	2	1	3	4	**93**	2	3	1	4
22	1	3	2	4	**58**	1	2	3	4	**94**	2	1	3	4
23	1	3	2	4	**59**	1	3	2	4	**95**	1	2	3	4
24	2	1	3	4	**60**	1	2	3	4	**96**	2	1	3	4
25	2	1	3	4	**61**	1	2	3	4	**97**	2	3	1	4
26	2	1	3	4	**62**	1	3	2	4	**98**	2	3	1	4
27	1	3	2	4	**63**	1	3	2	4	**99**	1	2	3	4
28	1	2	3	4	**64**	1	2	3	4	**100**	2	1	3	4
29	3	1	2	4	**65**	1	2	3	4	**101**	1	3	2	4
30	1	3	2	4	**66**	1	2	3	4	**102**	1	2	3	4
31	2	1	4	3	**67**	1	2	3	4	**103**	1	2	3	4
32	2	1	3	4	**68**	2	1	4	3	**Average**	**1.45**	**1.94**	**2.66**	**3.95**
33	1	2	3	4	**69**	1	3	2	4	**Rank 1**	**59.22%**	**34.95%**	**5.83%**	**0.00%**
34	1	2	3	4	**70**	2	1	3	4	**Rank 2**	**36.89%**	**35.92%**	**26.21%**	**0.97%**
35	2	1	3	4	**71**	1	2	3	4	**Rank 3**	**3.88%**	**29.13%**	**64.08%**	**2.91%**
36	2	1	3	4	**72**	1	2	3	4	**Rank 4**	**0.00%**	**0.00%**	**3.88%**	**96.12%**

Table 14: Detailed Test Results of Person 4 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	2	3	4	**37**	1	2	3	4	**73**	2	1	3	4
2	2	1	3	4	**38**	1	2	3	4	**74**	1	3	2	4
3	2	1	3	4	**39**	1	2	3	4	**75**	2	1	3	4
4	2	1	3	4	**40**	1	3	2	4	**76**	2	1	3	4
5	1	2	3	4	**41**	1	3	2	4	**77**	2	1	3	4
6	1	2	3	4	**42**	1	3	2	4	**78**	1	3	2	4
7	1	2	3	4	**43**	1	3	2	4	**79**	2	1	3	4
8	1	2	3	4	**44**	1	2	3	4	**80**	2	1	3	4
9	1	2	3	4	**45**	1	2	3	4	**81**	1	2	3	4
10	1	2	3	4	**46**	2	1	3	4	**82**	1	2	3	4
11	1	2	3	4	**47**	1	2	3	4	**83**	1	2	3	4
12	1	2	3	4	**48**	1	2	3	4	**84**	1	2	3	4
13	1	3	2	4	**49**	1	3	2	4	**85**	2	1	3	4
14	1	2	3	4	**50**	1	3	2	4	**86**	2	1	3	4
15	1	2	3	4	**51**	1	2	3	4	**87**	1	2	3	4
16	1	3	2	4	**52**	1	2	3	4	**88**	1	2	3	4
17	1	3	2	4	**53**	1	2	3	4	**89**	1	3	2	4
18	1	3	2	4	**54**	1	2	3	4	**90**	1	3	2	4
19	1	3	2	4	**55**	1	2	3	4	**91**	1	2	3	4
20	1	2	3	4	**56**	1	2	3	4	**92**	3	1	2	4
21	1	2	3	4	**57**	1	2	3	4	**93**	1	2	3	4
22	1	4	2	3	**58**	1	2	3	4	**94**	1	2	3	4
23	1	3	2	4	**59**	1	2	3	4	**95**	1	2	3	4
24	1	2	3	4	**60**	1	2	3	4	**96**	1	2	3	4
25	1	3	2	4	**61**	1	3	2	4	**97**	1	3	2	4
26	1	2	3	4	**62**	1	2	3	4	**98**	1	2	3	4
27	1	3	2	4	**63**	1	3	2	4	**99**	2	1	3	4
28	1	2	3	4	**64**	3	1	2	4	**100**	1	2	3	4
29	1	2	3	4	**65**	1	2	3	4	**101**	1	2	3	4
30	1	2	3	4	**66**	1	2	3	4	**102**	1	2	3	4
31	1	3	2	4	**67**	2	1	3	4	**103**	1	2	3	4
32	1	2	3	4	**68**	1	4	2	3	**Average**	**1.19**	**2.11**	**2.73**	**3.97**
33	1	2	3	4	**69**	1	3	2	4	**Rank 1**	**82.52%**	**17.48%**	**0.00%**	**0.00%**
34	1	2	3	4	**70**	2	1	3	4	**Rank 2**	**15.53%**	**56.31%**	**28.16%**	**0.00%**
35	1	3	2	4	**71**	1	3	2	4	**Rank 3**	**1.94%**	**24.27%**	**70.87%**	**2.91%**
36	1	2	3	4	**72**	2	1	4	3	**Rank 4**	**0.00%**	**1.94%**	**0.97%**	**97.09%**

Table 15: Detailed Test Results of Person 5 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	2	3	4	**37**	1	3	2	4	**73**	1	2	3	4
2	1	3	2	4	**38**	1	2	3	4	**74**	1	2	3	4
3	1	4	3	2	**39**	1	3	2	4	**75**	1	2	3	4
4	2	4	3	4	**40**	1	3	2	4	**76**	1	2	3	4
5	1	3	4	2	**41**	1	3	2	4	**77**	2	1	3	4
6	1	3	4	2	**42**	1	3	2	4	**78**	1	2	3	4
7	2	1	3	4	**43**	1	3	2	4	**79**	1	2	3	4
8	1	2	4	3	**44**	1	3	2	4	**80**	1	2	3	4
9	1	3	4	2	**45**	1	2	3	4	**81**	1	3	2	4
10	1	3	2	4	**46**	1	2	3	4	**82**	1	2	3	4
11	1	2	3	4	**47**	1	2	3	4	**83**	1	2	3	4
12	1	3	2	4	**48**	1	2	3	4	**84**	1	2	3	4
13	1	2	3	4	**49**	1	3	2	4	**85**	1	3	2	4
14	1	2	3	4	**50**	1	2	3	4	**86**	1	2	3	4
15	1	2	3	4	**51**	1	3	2	4	**87**	1	2	3	4
16	1	3	2	4	**52**	1	2	3	4	**88**	1	2	3	4
17	1	4	2	3	**53**	1	2	3	4	**89**	1	3	2	4
18	1	2	3	4	**54**	1	2	3	4	**90**	1	2	3	4
19	1	3	2	4	**55**	1	3	2	4	**91**	1	2	3	4
20	1	2	3	4	**56**	1	2	3	4	**92**	1	2	3	4
21	1	3	2	4	**57**	1	2	3	4	**93**	1	2	3	4
22	1	2	3	4	**58**	1	3	2	4	**94**	1	2	3	4
23	1	2	3	4	**59**	1	2	4	3	**95**	1	2	3	4
24	1	2	3	4	**60**	1	2	3	4	**96**	1	2	3	4
25	1	2	3	4	**61**	1	2	3	4	**97**	1	2	3	4
26	1	2	3	4	**62**	1	2	4	3	**98**	1	2	3	4
27	1	2	4	3	**63**	1	2	3	4	**99**	1	2	3	4
28	1	3	2	4	**64**	1	2	3	4	**100**	1	2	3	4
29	3	1	2	4	**65**	1	2	3	4	**101**	1	2	3	4
30	1	2	3	4	**66**	2	1	3	4	**102**	1	2	3	4
31	2	3	1	4	**67**	1	2	3	4	**103**	1	2	3	4
32	1	3	2	4	**68**	1	2	3	4	**Average**	**1.07**	**2.27**	**2.79**	**3.87**
33	1	2	3	4	**69**	1	3	2	4	**Rank 1**	**94.17%**	**4.85%**	**0.97%**	**0.00%**
34	1	2	3	4	**70**	1	3	2	4	**Rank 2**	**4.85%**	**65.05%**	**26.21%**	**3.88%**
35	1	3	2	4	**71**	1	2	3	4	**Rank 3**	**0.97%**	**28.16%**	**66.02%**	**4.85%**
36	1	2	3	4	**72**	1	2	3	4	**Rank 4**	**0.00%**	**1.94%**	**6.80%**	**91.26%**

Table 16: Detailed Test Results of Person 6 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	3	2	4	**37**	1	3	2	4	**73**	1	2	3	4
2	1	2	3	4	**38**	1	3	2	4	**74**	1	2	3	4
3	1	2	3	4	**39**	1	3	2	4	**75**	1	2	3	4
4	1	2	3	4	**40**	1	3	2	4	**76**	1	2	3	4
5	1	2	3	4	**41**	1	3	2	4	**77**	1	2	3	4
6	1	2	3	4	**42**	1	3	2	4	**78**	1	3	2	4
7	1	2	3	4	**43**	1	3	2	4	**79**	1	3	2	4
8	1	2	3	4	**44**	1	2	3	4	**80**	1	2	3	4
9	1	2	3	4	**45**	1	2	3	4	**81**	1	2	3	4
10	1	2	3	4	**46**	1	2	3	4	**82**	1	3	2	4
11	1	2	3	4	**47**	1	2	3	4	**83**	1	2	3	4
12	1	2	3	4	**48**	1	2	3	4	**84**	1	3	2	4
13	1	3	2	4	**49**	1	3	2	4	**85**	1	2	3	4
14	1	3	2	4	**50**	1	3	2	4	**86**	1	2	3	4
15	1	3	2	4	**51**	1	2	3	4	**87**	1	2	3	4
16	1	3	2	4	**52**	1	2	3	4	**88**	1	2	3	4
17	1	3	2	4	**53**	1	2	3	4	**89**	1	2	3	4
18	1	2	3	4	**54**	1	2	3	4	**90**	1	2	3	4
19	1	3	2	4	**55**	1	2	3	4	**91**	1	2	3	4
20	1	2	3	4	**56**	1	2	3	4	**92**	1	2	3	4
21	1	2	3	4	**57**	1	2	3	4	**93**	1	3	2	4
22	1	3	2	4	**58**	1	2	3	4	**94**	1	2	3	4
23	1	3	2	4	**59**	1	2	3	4	**95**	1	2	3	4
24	1	2	3	4	**60**	1	2	3	4	**96**	1	2	3	4
25	1	2	3	4	**61**	1	2	3	4	**97**	1	2	3	4
26	1	2	3	4	**62**	1	3	2	4	**98**	1	3	2	3
27	1	2	3	4	**63**	1	2	3	4	**99**	3	2	1	4
28	1	2	3	4	**64**	1	2	3	4	**100**	1	2	3	4
29	1	2	3	4	**65**	1	2	3	4	**101**	1	3	2	4
30	1	2	3	4	**66**	1	2	3	4	**102**	1	2	3	4
31	1	2	3	4	**67**	1	2	3	4	**103**	1	2	3	4
32	1	3	2	4	**68**	1	3	2	4	**Average**	**1.02**	**2.32**	**2.67**	**3.99**
33	1	3	2	4	**69**	1	3	2	4	**Rank 1**	**99.03%**	**0.00%**	**0.97%**	**0.00%**
34	1	2	3	4	**70**	1	2	3	4	**Rank 2**	**0.00%**	**68.93%**	**31.07%**	**0.00%**
35	1	3	2	4	**71**	1	2	3	4	**Rank 3**	**0.97%**	**30.10%**	**67.96%**	**0.97%**
36	1	3	2	4	**72**	1	2	3	4	**Rank 4**	**0.00%**	**0.97%**	**0.00%**	**99.03%**

Table 17: Detailed Test Results of Person 7 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	2	4	3	**37**	1	3	2	4	**73**	1	2	3	4
2	1	3	2	4	**38**	1	2	3	4	**74**	1	2	3	4
3	1	2	3	4	**39**	1	3	2	4	**75**	1	3	2	4
4	1	2	4	3	**40**	1	3	2	4	**76**	1	2	3	4
5	1	3	2	4	**41**	1	3	2	4	**77**	1	2	3	4
6	1	4	3	2	**42**	1	3	2	4	**78**	1	3	2	4
7	1	2	3	4	**43**	1	2	3	4	**79**	1	3	2	4
8	1	3	2	4	**44**	1	3	2	4	**80**	1	4	2	3
9	1	2	4	3	**45**	1	2	3	4	**81**	1	3	2	4
10	1	2	3	4	**46**	1	2	3	4	**82**	1	2	3	4
11	1	2	3	4	**47**	1	2	3	4	**83**	1	2	3	4
12	1	2	3	4	**48**	1	3	2	4	**84**	1	2	3	4
13	1	2	3	4	**49**	1	3	2	4	**85**	1	2	3	4
14	1	2	3	4	**50**	1	2	3	4	**86**	1	3	2	4
15	1	2	3	4	**51**	1	3	2	4	**87**	1	2	3	4
16	1	2	3	4	**52**	1	2	3	4	**88**	1	2	3	4
17	1	3	2	4	**53**	1	2	3	4	**89**	1	2	3	4
18	1	3	2	4	**54**	1	2	3	4	**90**	1	3	2	4
19	1	3	2	4	**55**	1	3	2	4	**91**	1	2	3	4
20	1	2	3	4	**56**	1	2	3	4	**92**	1	2	3	4
21	1	2	3	4	**57**	1	2	3	4	**93**	1	2	3	4
22	1	3	2	4	**58**	1	2	3	4	**94**	1	2	3	4
23	1	3	2	4	**59**	1	3	2	4	**95**	1	2	3	4
24	1	2	3	4	**60**	1	2	3	4	**96**	1	2	3	4
25	1	2	3	4	**61**	1	2	3	4	**97**	1	2	3	4
26	1	2	3	4	**62**	1	3	2	4	**98**	1	3	2	4
27	1	2	3	4	**63**	1	2	3	4	**99**	1	3	2	4
28	1	3	2	4	**64**	1	2	3	4	**100**	1	2	3	4
29	1	3	2	4	**65**	1	2	3	4	**101**	1	3	2	4
30	1	2	3	4	**66**	1	2	3	4	**102**	1	2	3	4
31	1	3	2	4	**67**	1	3	2	4	**103**	1	2	3	4
32	1	3	2	4	**68**	1	2	3	4	**Average**	**1.00**	**2.40**	**2.66**	**3.94**
33	1	2	3	4	**69**	1	2	3	4	**Rank 1**	**100.00%**	**0.00%**	**0.00%**	**0.00%**
34	1	2	3	4	**70**	1	2	3	4	**Rank 2**	**0.00%**	**62.14%**	**36.89%**	**0.97%**
35	1	3	2	4	**71**	1	2	3	4	**Rank 3**	**0.00%**	**35.92%**	**60.19%**	**3.88%**
36	1	3	2	4	**72**	1	3	2	4	**Rank 4**	**0.00%**	**1.94%**	**2.91%**	**95.15%**

Table 18: Detailed Test Results of Person 8 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	2	1	3	4	**37**	1	3	2	4	**73**	1	2	3	4
2	3	1	2	4	**38**	2	1	3	4	**74**	1	2	3	4
3	3	1	2	4	**39**	2	1	3	4	**75**	3	1	2	4
4	3	2	1	4	**40**	1	3	2	4	**76**	1	2	3	4
5	3	2	1	4	**41**	1	3	2	4	**77**	3	1	2	4
6	4	1	2	3	**42**	1	3	2	4	**78**	2	1	3	4
7	3	1	2	4	**43**	1	3	2	4	**79**	1	3	2	4
8	1	2	3	4	**44**	2	1	3	4	**80**	1	2	3	4
9	1	2	3	4	**45**	2	1	3	4	**81**	2	1	3	4
10	3	1	2	4	**46**	1	2	3	4	**82**	1	3	2	4
11	1	2	3	4	**47**	1	2	3	4	**83**	2	1	3	4
12	1	2	3	4	**48**	1	2	3	4	**84**	1	2	3	4
13	1	3	2	4	**49**	1	3	2	4	**85**	2	1	3	4
14	3	1	2	4	**50**	3	1	2	4	**86**	3	1	2	4
15	1	2	3	4	**51**	1	2	3	4	**87**	2	1	3	4
16	1	2	3	4	**52**	2	1	3	4	**88**	1	2	3	4
17	2	1	3	4	**53**	1	2	3	4	**89**	2	1	3	4
18	1	2	3	4	**54**	2	1	3	4	**90**	1	2	3	4
19	1	3	2	4	**55**	1	2	3	4	**91**	2	1	3	4
20	1	2	3	4	**56**	2	1	3	4	**92**	1	2	3	4
21	1	2	3	4	**57**	3	1	2	4	**93**	2	1	3	4
22	1	3	2	4	**58**	3	1	2	4	**94**	1	2	3	4
23	1	3	2	4	**59**	1	2	3	4	**95**	1	2	3	4
24	3	1	2	4	**60**	3	1	2	4	**96**	1	2	3	4
25	1	3	2	4	**61**	3	1	2	4	**97**	2	1	3	4
26	1	2	3	4	**62**	1	2	3	4	**98**	2	1	3	4
27	1	3	2	4	**63**	1	3	2	4	**99**	3	1	2	4
28	2	1	3	4	**64**	1	3	2	4	**100**	3	2	1	4
29	1	2	3	4	**65**	1	2	3	4	**101**	1	2	3	4
30	1	3	2	4	**66**	1	2	3	4	**102**	3	1	2	4
31	1	3	2	4	**67**	2	3	1	4	**103**	1	2	3	4
32	1	2	3	4	**68**	2	1	3	4	**Average**	**1.68**	**1.81**	**2.54**	**3.97**
33	1	2	4	3	**69**	1	3	2	4	**Rank 1**	**56.31%**	**39.81%**	**3.88%**	**0.00%**
34	1	2	3	4	**70**	4	1	2	3	**Rank 2**	**21.36%**	**39.81%**	**38.83%**	**0.00%**
35	1	3	2	4	**71**	1	2	3	4	**Rank 3**	**20.39%**	**20.39%**	**56.31%**	**2.91%**
36	3	1	2	4	**72**	3	1	2	4	**Rank 4**	**1.94%**	**0.00%**	**0.97%**	**97.09%**

Table 19: Detailed Test Results of Person 9 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	2	3	4	**37**	1	2	3	4	**73**	2	1	3	4
2	4	1	3	2	**38**	1	2	3	4	**74**	1	2	3	4
3	1	2	3	4	**39**	1	2	3	4	**75**	3	2	1	4
4	4	1	2	3	**40**	1	3	2	4	**76**	1	2	3	4
5	1	3	2	4	**41**	1	3	2	4	**77**	3	1	2	4
6	1	3	2	4	**42**	1	3	2	4	**78**	1	2	3	4
7	2	1	3	4	**43**	1	3	2	4	**79**	1	3	2	4
8	2	3	1	4	**44**	1	2	3	4	**80**	1	3	2	4
9	1	4	2	3	**45**	1	2	3	4	**81**	3	1	2	4
10	4	2	1	3	**46**	1	2	3	4	**82**	1	3	2	4
11	1	2	3	4	**47**	1	2	3	4	**83**	1	2	3	4
12	1	3	2	4	**48**	1	2	3	4	**84**	1	2	3	4
13	2	3	1	4	**49**	1	3	2	4	**85**	1	2	3	4
14	4	2	1	3	**50**	1	3	2	4	**86**	1	3	2	4
15	1	3	2	4	**51**	1	2	3	4	**87**	2	1	3	4
16	1	2	3	4	**52**	4	1	2	3	**88**	2	1	3	4
17	2	3	1	4	**53**	2	1	3	4	**89**	3	2	1	4
18	2	3	1	4	**54**	1	2	3	4	**90**	1	2	3	4
19	2	3	1	4	**55**	3	2	1	4	**91**	3	1	2	4
20	1	2	3	4	**56**	1	2	3	4	**92**	1	2	3	4
21	1	2	3	4	**57**	3	1	2	4	**93**	2	1	3	4
22	1	3	2	4	**58**	1	2	3	4	**94**	1	2	3	4
23	1	2	3	4	**59**	1	3	2	4	**95**	1	2	3	4
24	1	2	3	4	**60**	4	3	1	2	**96**	4	2	1	3
25	1	3	2	4	**61**	4	3	2	1	**97**	1	2	3	4
26	1	2	3	4	**62**	1	3	2	4	**98**	1	2	3	4
27	1	4	2	3	**63**	1	2	3	4	**99**	4	2	1	3
28	1	2	3	4	**64**	4	2	1	3	**100**	4	1	2	3
29	1	2	3	4	**65**	1	2	3	4	**101**	1	3	2	4
30	1	2	3	4	**66**	2	1	3	4	**102**	3	1	2	4
31	1	3	2	4	**67**	1	2	3	4	**103**	1	3	2	4
32	3	1	2	4	**68**	2	1	3	4	**Average**	**1.70**	**2.15**	**2.34**	**3.82**
33	2	1	4	3	**69**	1	3	2	4	**Rank 1**	**63.11%**	**20.39%**	**15.53%**	**0.97%**
34	1	2	3	4	**70**	4	1	2	3	**Rank 2**	**15.53%**	**46.60%**	**35.92%**	**1.94%**
35	2	3	1	4	**71**	2	3	1	4	**Rank 3**	**9.71%**	**31.07%**	**47.57%**	**11.65%**
36	1	3	2	4	**72**	3	1	2	4	**Rank 4**	**11.65%**	**1.94%**	**0.97%**	**85.44%**

Table 20: Detailed Test Results of Person 10 with Healthy Vision

Image No	A	B	C	D	Image No	A	B	C	D	Image No	A	B	C	D
1	1	4	3	2	**37**	4	3	2	1	**73**	2	1	3	4
2	1	2	3	4	**38**	1	3	2	4	**74**	1	2	3	4
3	4	3	2	1	**39**	1	2	3	4	**75**	1	2	3	4
4	1	2	3	4	**40**	1	2	3	4	**76**	1	2	3	4
5	4	2	3	1	**41**	1	2	3	4	**77**	2	1	3	4
6	4	3	2	1	**42**	1	3	2	4	**78**	1	2	3	4
7	1	2	3	4	**43**	3	2	1	4	**79**	1	4	2	3
8	1	3	2	4	**44**	1	2	3	4	**80**	1	2	3	4
9	1	2	3	4	**45**	3	1	2	4	**81**	3	1	2	4
10	3	2	1	4	**46**	1	2	3	4	**82**	2	3	1	4
11	1	2	3	4	**47**	1	2	3	4	**83**	1	2	3	4
12	1	4	3	2	**48**	1	2	3	4	**84**	1	2	3	4
13	1	3	2	4	**49**	1	3	2	4	**85**	1	2	3	4
14	3	1	2	4	**50**	3	1	2	4	**86**	1	3	2	4
15	1	2	3	4	**51**	1	2	3	4	**87**	1	2	3	4
16	1	2	3	4	**52**	1	2	3	4	**88**	1	3	2	4
17	1	4	2	3	**53**	1	2	3	4	**89**	1	2	3	4
18	2	3	1	4	**54**	2	1	3	4	**90**	1	2	3	4
19	1	3	2	4	**55**	2	1	3	4	**91**	3	1	2	4
20	1	2	3	4	**56**	2	1	3	4	**92**	1	2	3	4
21	2	1	3	4	**57**	3	1	2	4	**93**	3	1	2	4
22	1	3	2	4	**58**	3	1	2	4	**94**	1	2	3	4
23	1	3	4	2	**59**	1	2	3	4	**95**	1	2	3	4
24	2	1	3	4	**60**	1	2	3	4	**96**	1	2	3	4
25	1	2	3	4	**61**	3	1	2	4	**97**	1	2	3	4
26	1	2	3	4	**62**	1	3	2	4	**98**	1	2	3	4
27	1	3	2	4	**63**	1	2	3	4	**99**	1	4	2	3
28	1	2	3	4	**64**	1	2	3	4	**100**	2	1	3	4
29	1	2	3	4	**65**	2	1	3	4	**101**	1	2	3	4
30	1	2	3	4	**66**	1	2	3	4	**102**	3	1	2	4
31	1	3	2	4	**67**	1	2	3	4	**103**	1	3	2	4
32	1	2	3	4	**68**	1	2	3	4	**Average**	**1.50**	**2.13**	**2.60**	**3.77**
33	4	3	2	1	**69**	1	2	3	4	**Rank 1**	**71.84%**	**18.45%**	**4.85%**	**4.85%**
34	1	2	3	4	**70**	3	2	1	4	**Rank 2**	**10.68%**	**55.34%**	**31.07%**	**2.91%**
35	1	3	2	4	**71**	1	3	2	4	**Rank 3**	**12.62%**	**21.36%**	**63.11%**	**2.91%**
36	1	2	3	4	**72**	1	2	3	4	**Rank 4**	**4.85%**	**4.85%**	**0.97%**	**89.32%**

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