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Applying the Visualization Technique to Solve the Human Color Blindness

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Abstract. Contributing in solving the problem of color blindness is one of the things that contribute to the survival of life. Since the problem of color blindness is a matter focused on colors, so data visualization can contribute to this disease by providing specific mechanisms for color correction. In this paper, new methods have been suggested by using data visualization principles that may contribute to distinguishing colors in an easy way. The results are based on the famous Ishihara's data sets, which is used to measure the degree of color blindness. The efficiency of the results is mathematically verified by using different comparison equations and methods.

Keywords: visualization, Ishihara, color blindness.

INTRODUCTION

Color blindness is one of the problems faced the humans, which leads to the loss of the ability to perceive and distinguish colors. Therefore, if there is something that contains convergent colors, the person with this disease cannot recognize the difference between them [1]. One of the solutions that can help reduce the risk of color blindness is the use of data visualization. Data visualization is a powerful and effective way to help interpret and understand data in an easy way [2-4]. This method greatly supports the basic needs of human beings, it tries to display and represent complex data, which leads to facilitate analysis and interpretation [5-7].

Colors are the basic components upon which the image depends, and it is explained by neural processes through the eye. The result of perception represents the response to the light projected on the object. The human eye can perceive colors if they are within the wavelength of 400-700 nm. Information can be expressed using colors, as some colors give instructions to users, for example, road maps are designed in a way that can be easily understood. The colors of road traffic signs may be incomprehensible to people with color blindness [8, 9]. Colors are the sensation generated in the brain and are associated with measurable phenomena that allow digital representation of data. The color consists of three main colors red, green, blue and other secondary colors consist of blending different components of the main colors and this model is called RGB. The computer uses a specific model to represent color. Three widely used color models, such as HSL, HSV and RGB [8, 10].

Color blindness is a reduced ability to perceive or difference in color. People with color blindness are unable to distinguish colors that contains close colors or shades that are difficult to distinguish. The effect of color blindness can be simple as buying fruits or choosing clothes, and it turns into something dangerous while reading traffic lights. Color blindness is a genetic disorder that occurs when one or more of the three types of receptors cells are missing or absent. It causes people to be unable to distinguish some or all of the colors due to receptor abnormalities, as in the Fig.1. There are three types of color blindness depending on the nature of color discrimination [11, 12]:

1) Monochromacy occurs when a person has only one of the three receptors cell or does not contain them. This type of color blindness is called full color blindness. Some people cannot see the colors only black and white, as an old movie or video. However, this type is very rare.

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2) Dichromatism is happened when one of the three cells is missing. This type is divided into three sections depending on the type of missing receptor:
   a) Protanopia: results in loss of red color sensitivity.
   b) Deuteranopia: occurs when it loses the ability to distinguish the green color.
   c) Tritanopia: Indicates the inability to perceive blue color.
3) Anomalous Trichromacy: This type is when the cells of the three receptors are existing, but one of them less sensitive. This type can be subdivided into three sections depending on the type of receptor damaged:
   a) Protanomaly less sensitive to red color.
   b) Deuteranomaly less sensitive to green color.
   Tritanomaly: less sensitive to colors in the color range of yellow and blue.

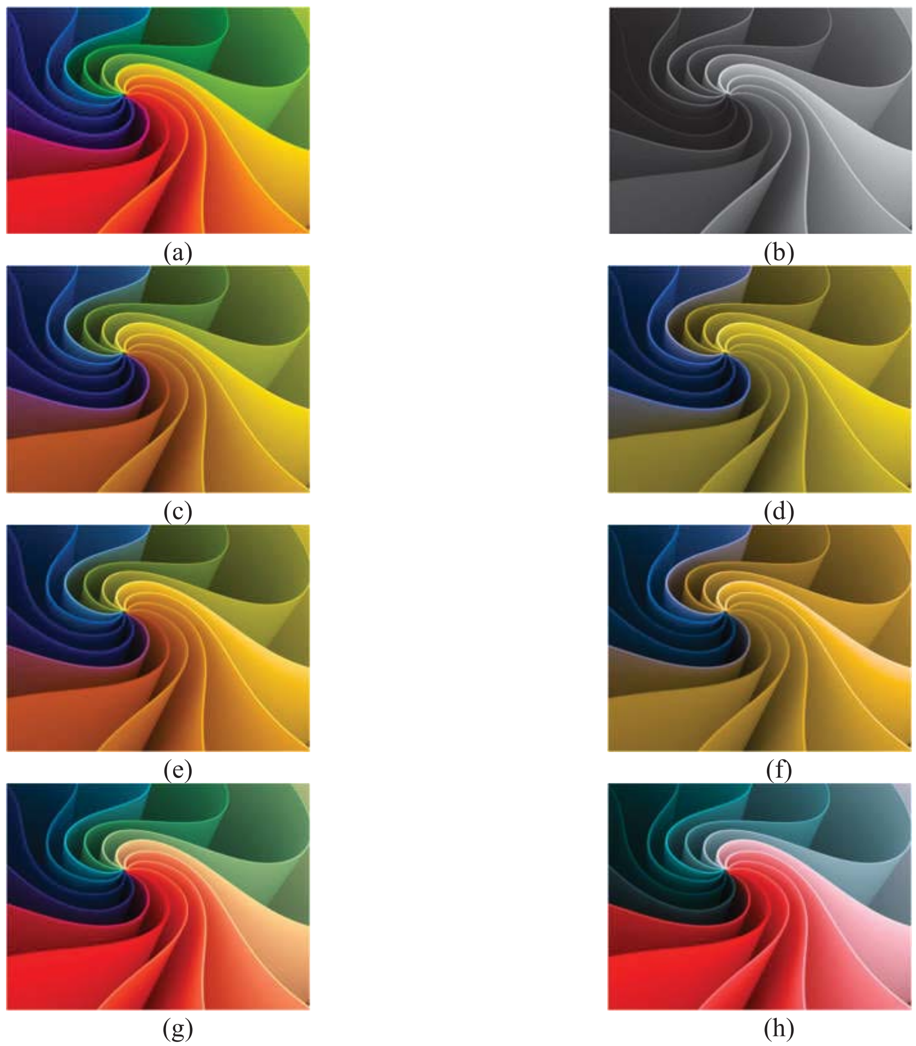


FIGURE 1. Color blindness types: (a) original image, (b) Monochromacy, (c) red_weak/Protanomaly, (d) red blind/Protanopla, (e) green weak/Deuteranomaly, (f) green blind/ deuteranopla, (g) blue weak /Tritanomaly, (h) blue blind/Tritanopla.

Red-green color blindness is the most common and causes problems in distinguishing between red and green colors. Thus, it can be seen red and green colors and their gradations as a single color. On the other hand, loss of ability to distinguish blue and yellow is rare. Partial color blindness affects some colors, while full color blindness affects all colors. Thus, who suffer from full color blindness often have serious eye problems as well [12].

In this paper, we try to study the problem of color blindness with an attempt to reduce the problem, by introducing new method using data visualization that attempt to correct the vision of colors.

SUGGESTED METHOD

Method 1: Color Recognition for People with Partial Color Blindness

People with color blindness are unable to distinguish some colors depending on the type of receptor damaged. New method has been suggested to help people distinguish colors without overlapping or distortion in the components of the visible thing. For example, those who suffer from the type Protanopia cannot distinguish the red color or its components when it exists with other colors. In order to overcome this type of blindness, the method increases the concentration of red and at the same time increases the intensity and saturation of the other colors. Since red color cannot be distinguished, this method tries to focus on distinguishing data components, ie, it tries to preserve the existing colors. Regardless of the resulting color of the components, it at least tries to maintain the number of colors. The suggested method (as in Fig.2. (a)) can be explained in the following steps:

1. Determine the type of color blindness to be treat
2. Read data (select where to view)
3. Depending on the type of color blindness (Protan, Deuteran or Tritan), the color is concentration corresponding to the type of blindness by the Equation 1.

$$A_i = IM_i * R_i \quad \text{.......(1)}$$

IM represents the image to be processed, where i= 1, 2, 3 which represents the channel of image

R represents the concentration value of the color corresponding to the affected cone, where the value of 1 is assigned to the correct cones, that mean their concentration are not change. The component of the affected cone has the value 2, as in the Equation 2.

$$R = \begin{cases} 2\ 1\ 1 & if\ Protanopia\ or\ Protanomaly \\ 1\ 2\ 1 & if\ Deuteranopia\ or\ Deuteranomaly \\ 1\ 1\ 2 & if\ Tritanopia\ or\ Tritanomaly \end{cases} \quad \text{.......(2)}$$

The step multiply the first channel in IM with the first value of the R and the second channel in IM is multiplying with the second value of the R and normalization the result of (A) to the range [0,1].

1. Converts the original image to the HSI color space in order to increase the density, saturation and storage of the output in the variable.
2. Depending on the type of color blindness, if partial color blindness (ie cones are intact but only one cone is deficient), the component to colors is shifted h 30 degrees only. Assuming that the weakness is 50% in the damaged cone, if the cones are intact but one cone is missing, the component is shifted to h 60 degrees only because each color in component h represents 60 degrees, as in Equation 3. The displacement is based on the damaged cone and its type, ie the method removes any green component if the damaged cone is sensitive to green. This is done by redistributing the data to the rest of the h components in the image to preserve the information in the image for easy identification by patients.

$$H(c) = \begin{cases} shift\ 30^o & if\ Anomalous\ Trichromacycolor\ blindness \\ shift\ 60^o & if\ \ Dichromatism\ color\ blindness \end{cases} \quad \text{.......(3)}$$

3. The saturation and density are increased for the components s, i in the image resulting from conversion (c) because color blindness leads to less saturation and density for the missing colors [19]
4. The resulting image is returned after increasing the saturation and density to the RGB color space
5. Combine the resulting image with the image in which the data is centered. In addition, the color differentiation is not lost because the colors are shifted in step 5; it may lose part of the color or differentiation. When the resulting image is combined the image with the color to be processed, the data is more differentiated.

Method 2: Color Analysis Method to Treat Full Color Blindness

The third type of color blindness is full color blindness. Although this type is rare, people with this type are not able to see only the colors black, white and grayscale. Thus, the previous suggested method is not successful to distinguish colors for this type of color blindness. A "color analysis" method is suggested in this section to overcome the problem of full color blindness.

The color image contains 3 channels of colors, therefore, the result of merging these channels is the color associated with each point of data. Full color blindness can only be seen in black and white, so the requirement to convert the 3-channel image to one channel is important (i.e. the one-dimension represents black, white and grayscale). In order to maintain data differentiation, principal component analysis (PCA) method is used. PCA is a common dimension reduction algorithm, it is a fast method and preserves as much of the original data as possible. The method is summarized as follows, and Fig. 2. (b) explain it:

1. Image data analysis: It is done by extracting the colors in the image with their locations. As it is defined that each color consists of three main channels r, g and b, the result of this process becomes a matrix size k * 3, where k represents the number of colors in the image. In order to keep data from being lost, the location of each color is saved in the image. Thus, the matrix of color location is formed by the size of (n*m), which is the size of the original image. Each of these location has a color number stored in the color matrix.
   Multidimensional data can be converted to one dimension in order to gain speed and avoid additional processing, but this process faces the problem of losing many points of color differentiation. Most convergent points contain similar colors with somewhat few differences, so maintaining these differences is important to maintain the overall layout. Therefore, the adjacent colors in the color space must maintain its juxtaposition when converting to one dimension. Any different colors should be kept different to avoid distorting the final vision.
2. Reduce the dimensions of the color matrix: After analysis, the results have colors of the visible part. In order to apply a fast and convenient method to reduce color dimensions from three channels to one without loss of information, PCA is applied. PCA is used to reduce the high data dimensions of color representation to one dimension.

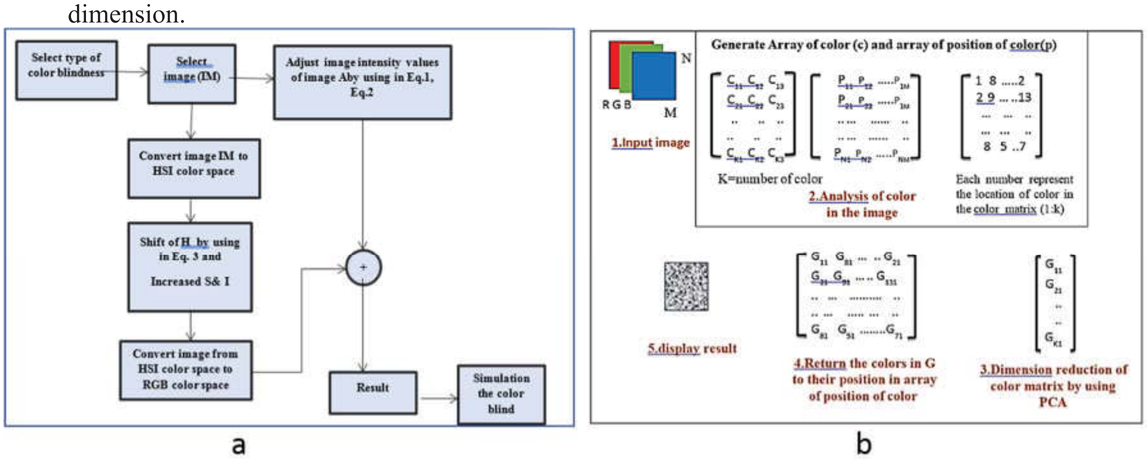


FIGURE 2. (a) Colour discrimination Method for Partial Colour Blindness . (b) Colour analysis Method to identify information for human colour blindness

RESULTS AND DISCUSSION

The Ishihara's 38 images data sets are used to check the efficiency of the proposed methods. Ishihara data sets have standard images for testing color blindness. The test contains a variety of color images, where each images contains a group of colored circles of random size and color. These circles form a number or object, which in turn must be visible to people with normal vision. People with color blindness cannot distinguish some numbers nor objects depending on the type of color blindness.

Table 1 shows the results of the processing of the Ishihara data sets when the sensitive cone of the red color is affected (completely or partially missing). In this table, it can be noted that the cases of color blindness cannot properly see the real images. There is a clear loss of information in the original forms, where this protanopia type is unable to recognize the red color. The third column in Table 1 illustrates this case, as much information has been lost and the ability to distinguish shapes has weakened. When applying the proposed method to assist this type of color blindness, the perception capacity has improved greatly. The fourth column in Table 1 shows that a lot of information could be understood, and that it was previously lost. Protanomay color blindness, as shown in column 5 of Table 1, is unable to distinguish shapes containing red. The reason, as it was mentioned earlier, is because of the weakness in the sensor for this color, which leads to the loss of this color with the rest of the perceived colors. Loss of this information for this case can be corrected using the suggested method, as in column 6 of Table 1. It highlights the ability of the proposed method to show the missing color and make the shape recognizable.

TABLE 1. Results of data processing for color blindness if the affected cone is sensitive to red color

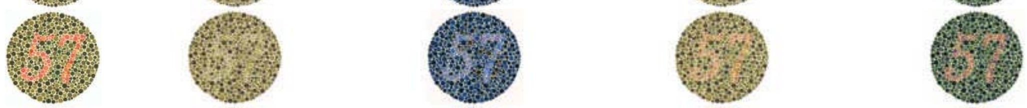
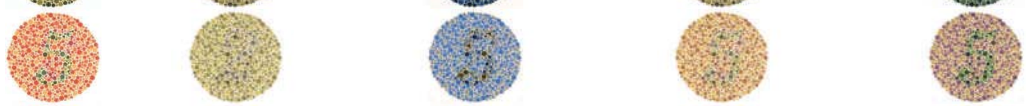
Number of tests	Original image	Colorblind of original data in (protanopia) color blind	Result of the proposed method to solve (protanopia) color blind	Colorblind of original data in (protanomaly) color blind	Result of proposed method to solve (protanomaly) color blind
1					
2					
3					
4					
5					

TABLE 2. Color blindness person can see part of image, and suggested method overcomes this weakness.

Number of tests	Original image	Colorblind of original data in (protanopia) color blind	Result of the proposed method to solve (protanopia) color blind	Colorblind of original data in (protanomaly) color blind	Result of proposed method to solve (protanomaly) color blind
1					
2					
3					

Table 2 contains images has the numbers 42, 35 and 96 respectively, when noticing the third column can only distinguish the numbers 4, 5 and 9 when focusing on the data. However, it cannot distinguish the second part of the numbers. After the processing by suggested method, the whole numbers can be distinguished and became more clearer. Thus, applying the proposed method help the color blindness person see the color. The goal of the processing is not to focus on preserving the rest of the colors that a person can see, but rather focus on distinguishing the person with the information inside the image through its colors. When changing any color to another color, it does not affect as long as the person is able to distinguish the information.

TABLE 3. Results of data processing for color blindness if the affected cone

Number of tests	Orginal image	Color blind of original data in (deuteranopia) color blind	Result of the proposed method to solve (deuteranopia) color blind	Colorblind of original data in (deuteranomely) color blind	Result of the proposed method to solve (deuteranomely) color blind
1					
2					
3					
4					

TABLE 4. Data processing results for color blindness if the affected cone is sensitive to blue

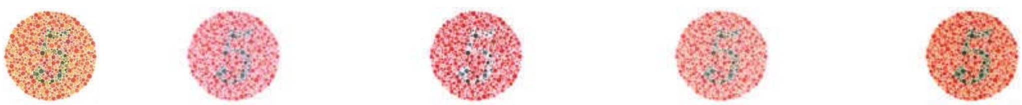
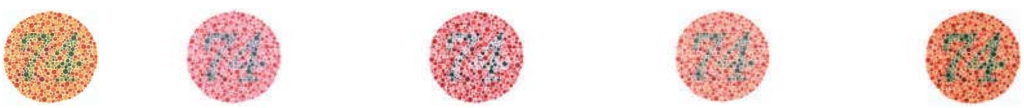
Number of tests	Original image	Colorblind of original data in (tritanopia) color blind	Result of the proposed method to solve (tritanopia) color blind	Colorblind of original data in (tritanomely) color blind	Result of the proposed method to solve (tritanomely) color blind
1					
2					
3					
4					

Table 3 shows the results of processing some of Ishihara's data sets when the sensitive cone of the green color is damaged (completely or partially missing). It can be noticed that the images of the third column are not clear, and the person cannot distinguish most of the numbers and figures in the images. For example, sequences 1 and 2, which contain the number 74 and 2, respectively, the number is not clear, with the difficulty of distinguishing the information inside the image. When processing data and applying the proposed method, it became easy to see the color, as in the fourth column. This good level of distinction is also achieved on the cases found in the fifth and sixth columns.

Table 4 represents cases where the blue-sensitive cone is damaged (completely or partially missing). When viewing the third and fifth columns, the matter is different when compared to the first and second tables. This is because a person with a sensitive cone of blue can distinguish some data easily and the numbers are clear. The results of the sixth column are data processing for color blindness in the fifth column. When processing data using the proposed method, the data became more focused and clearer to the person with color blindness.

TABLE 5. The results of the method's application color analysis to distinguish it for people with total colorblindness.

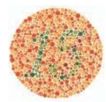
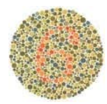
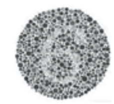
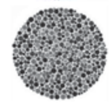
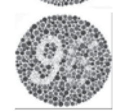
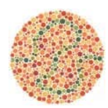
Number of tests	Original image	Colorblind of original data in (monochromacy) color blind	Result of the proposed method to solve (monochromacy) color blind
1			
2			
3			
4			

Table 5 represents the results of data processing using a color analysis method to simulate monochromacy of Ishihara data sets. A person with this type of color blindness cannot see the colors, where he only sees the white, black colors, and the hue between them. When applying the proposed method, it can be noted that the numbers have become visible and the numbers are clear and no distortion between them. Thus, the information has been preserved and none of the necessary information is lost. For example, in Sequence 1, the image contains the number 15. When this image is viewed by a person with total color blindness, he cannot distinguish this number. This state can be seen clearly in the third column, the images have become clear and the person with total color blindness can easily distinguish them. In addition, the sequence 3 contains the number 96; before processing this image, it is difficult to recognize the number 96. After processing, all information is clear and the number can be distinguished. Thus, applying the method of analyzing colors means it can preserve as much information as possible.

For the purpose of knowing the efficiency of the proposed method, it must be known the amount in which the colors were preserved of the image under processing compared to the original image. This is done by knowing the percentage between the number of colors in the processing image and the number of colors in the original image, as in the equation 4.

$$Percent\ of\ color = \frac{\text{number of color in image1}}{\text{number of color in original image}} * 100\% \text{........................(4)}$$

Where *image1* in Equation 4 represents the resulting image after applying one of the suggested methods with color blindness. If the percentage of the image that was processed is greater than the percentage of the image before processing, the resulting processing image is better and the person with color blindness can distinguish the information clearly. When the percentage is close to 1, the information maintained is significant. This leads to the conclusion that the information in the processed image is very close to the information in the original image.

TABLE 6. The percentage results of the proposed method when color blindness is Protanopia type. The first column is the sequence of panels (experiment number) and the second column represents the percentages of the proposed method and the third column is the percentages of the original data before processing.

No of exper.	Mean the process	Mean the no process
1	0.849	0311
2	0.750	0.281
3	0.792	0.262
4	0.893	0.280
5	0.895	0.294

No of exper.	Mean the process	Mean the no process
6	0.789	0.238
7	0.805	0.246
8	0.819	0.235
9	0.825	0.235
10	0.693	0.294
11	0.654	0.277
12	0.753	0.319
13	0.754	0.295
14	0.723	0.266
15	0.750	0.263
16	0.767	0.253
17	0.814	0.269
18	0.713	0.218
19	0.731	0.224
20	0.753	0.225
21	0.734	0.232
22	0.948	0.254
23	0.973	0.249
24	1.001	0.248
25	0.970	0.242
26	0.997	0.239
27	0.823	0.250
28	0.546	0.218
29	0.716	0.209
30	0.733	0.251
31	0.815	0.269
32	0.673	0.271
33	0.745	0.290
34	0.719	0.231
35	0.761	0.238
36	0.618	0.272
37	0.677	0.273
38	0.743	0.311

Table 6 shows the results for the percentage of Ishihara (38) images. In Fig. 3, it can be seen that the percentages of the proposed method for Protanopia type are much higher than the percentages of the original datasets. For example, in sequence 25, the percentage of the proposed method was 0.970, while percentage of the original datasets was 0.242. This difference in proportions can be seen in the rest of the results. This means that the results of the suggested method are very good for Protanopia color blindness.

Figures 3-8 show that the results of the color discrimination method is much better than the original data. When it has been seen by a person with partial color blindness, the suggested method is the best in terms of clarity and also a good ratio of the number of colors in the data processed. This indicates the efficiency of the proposed method when applied to address color blindness problems. When observing Fig. 9, the results of the proposed method of color analysis in some images are better than the results of the original datasets, and in other experiments the results are very close. In other experiments, the percentage of the original data is greater than the percentage of the number of colors in the results of the proposed method. The reason is that the number of colors in the monochromacy type is small. In some experiments, the proportions are almost close. In experiment 24, the percentage of the number of colors in the original data is 0.152, while the percentage of the number of colors for the proposed method is 0.151. The difference between the two ratios is very little and equals 0.000637, which is very small. The percentages in Figure 9 are less than 0.25 because the data has become one-dimensional, which led to a reduction in the number of colors in the data. However, the results of processing color blindness are good, as the numbers and objects in the images datasets can be easily distinguished. In terms of the percentage of the number of colors, the results are also close and good.

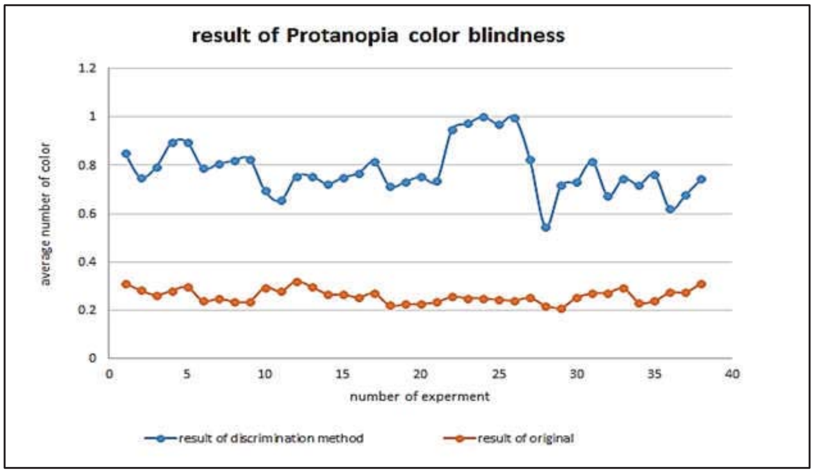


FIGURE 3. Percentage results of Ishihara images when processing Protanopia color blindness. Blue curve represents percentage results when applying the proposed method and red curve, percentage results before data processing (for original data)

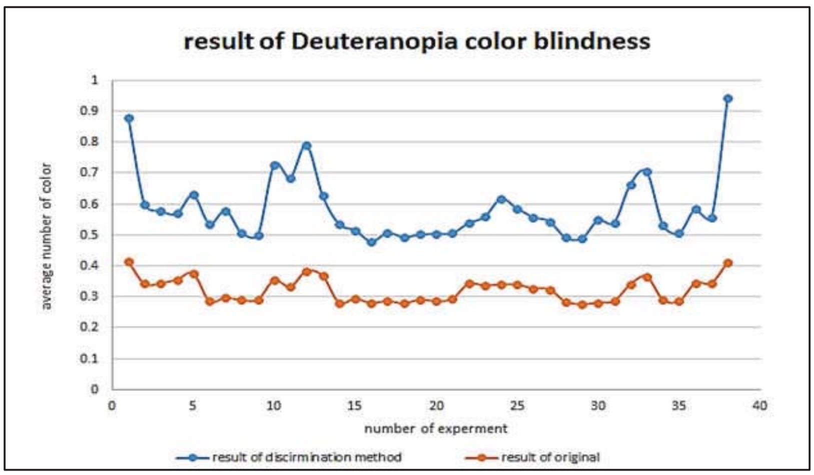


FIGURE 4. Percentage results of Ishihara images when processing deuteranopia color blindness. Blue curve represents percentage results when applying the proposed method and red curve, percentage results before data processing (for original data)

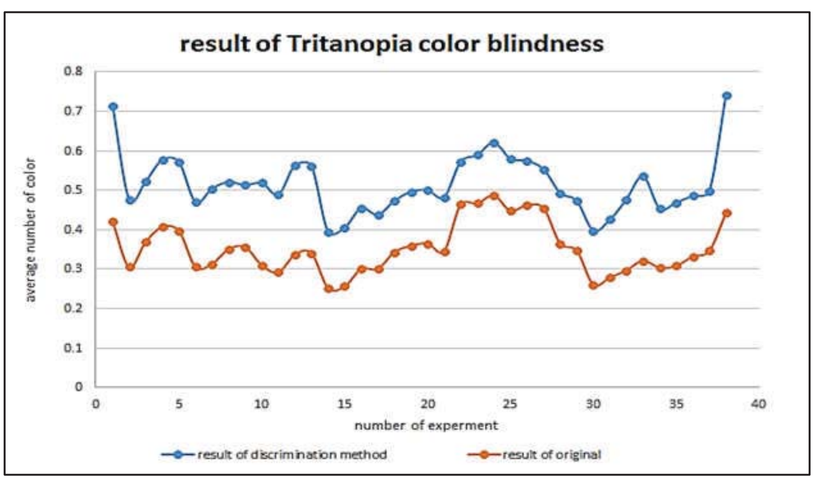


FIGURE 5. Percentage results of Ishihara images when processing tritanopia color blindness. Blue curve represents percentage results when applying the proposed method and red curve, percentage results before data processing (for original data)

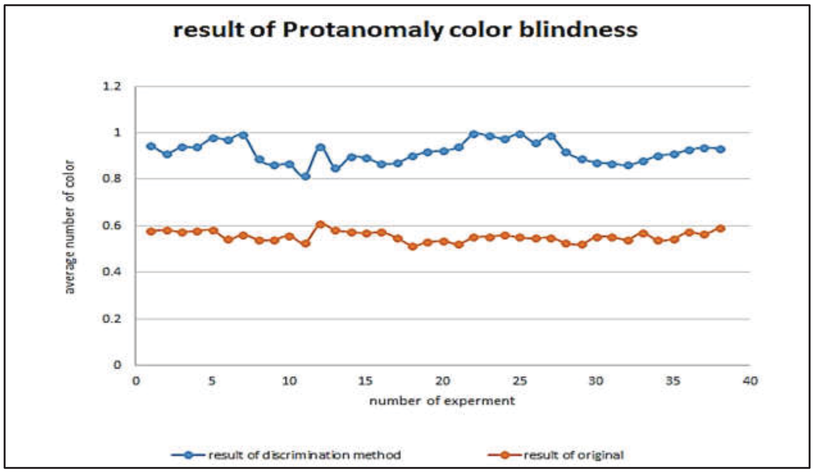


FIGURE 6. Percentage results of Ishihara images when processing protanomaly color blindness. Blue curve represents percentage results when applying the proposed method and red curve, percentage results before data processing (for original data)

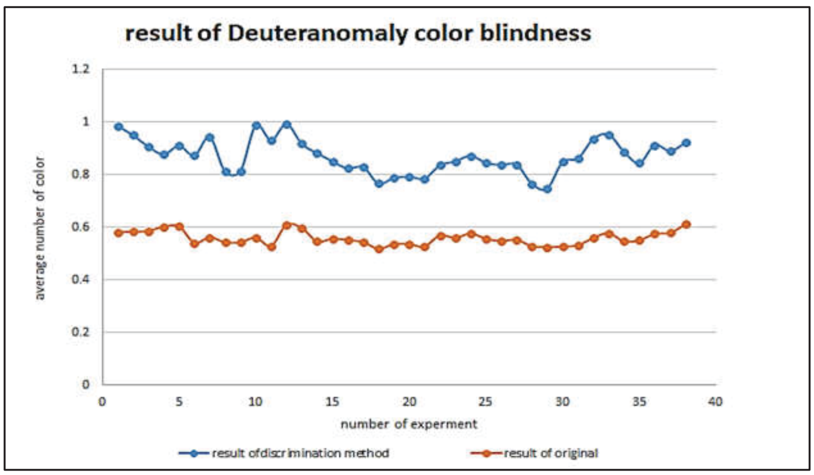


FIGURE 7. Percentage results of Ishihara images when processing deuteranomaly color blindness. Blue curve represents percentage results when applying the proposed method and red curve, percentage results before data processing (for original data)

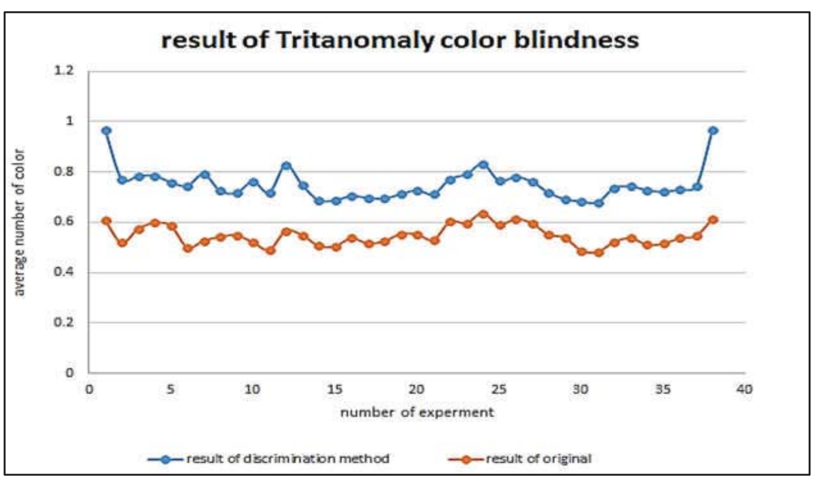


FIGURE 8. Percentage results of Ishihara images when processing tritanomaly color blindness. Blue curve represents percentage results when applying the proposed method and red curve, percentage results before data processing (for original data)

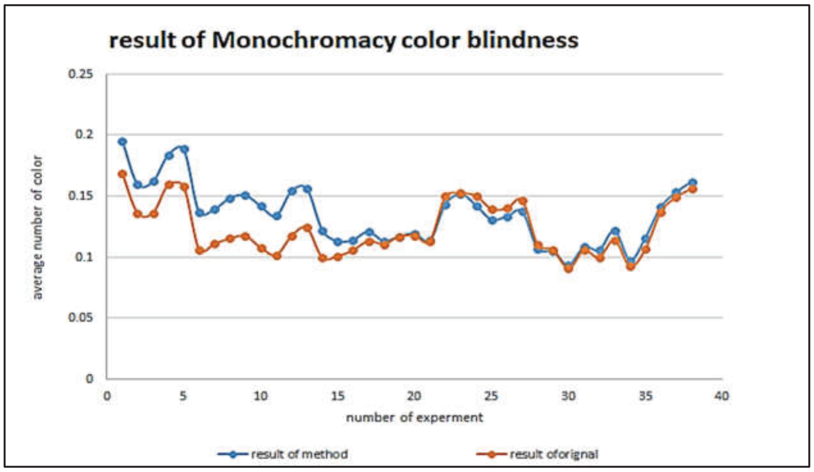


FIGURE 9. Percentage results of Ishihara images when processing monochromacy color blindness. Blue curve represents percentage results when applying the proposed method and red curve, percentage results before data processing (for original data)

CONCLUSIONS

If a person does not have problems in distinguishing colors, he cannot imagine how the vision will be when color blindness. In this paper, we presented two methods using data visualization for the purpose of improving the vision of people with color blindness. The proposed methods were able to clarify and distinguish the missing things, and have achieved successes and are proven through the results of experiments.

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