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Visualization Technique and PCA Method to Solve the Partial Color Blindness for Human

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Abstract. Among the blessings of God (Glory be to Him) upon humans is that people see the details of things in their surroundings in different colors. Unfortunately, some people have problems with correct vision, and the most important and common problem in this regard is “Color Blindness”. It is a disease that makes people unable to distinguish some colors, that is, seeing colors is not enough. So, the contribution to solving the problem of Color Blindness is important, because the hassle of Color Blindness leads to the non-discrimination of information seen via the infected person. Data visualization is one of the proposals that contributed to fixing the trouble of colour blindness. In this paper, we are going to explain the nature of this disease and its types, then we proposed a new approach by using data visualization technique and principal component analysis (PCA) that might contribute to easy data recognition and color blindness problem-solving. We are based on the famous "ISHIHARA" data set, which is used to measure Color Blindness. The efficiency of the results used to be mathematically tested the usage of equations and images by means of a website to simulate colour blindness, it is correct and information is clear and understandable for patient color-blindness.

INTRODUCTION

Many people have the ability to see colors that sense the frequency of light reflected from the body's surfaces. Nevertheless, color vision deficiency (CVD) is a common genetic condition [1, 2,3]. What the Color Blindness patient sees is very important and valuable for understanding the visual troubles that they may have in life. So, their low ability to distinguish certain colors is likely to be the best experience when looking over their eyes [4, 5].

About 4% of females and 8% of males in the world are affected by a specific type of color vision disorder, which ranges from a partial to complete lack of distinction of certain colors [6].

In many places in the world, people with color blindness are denied a driver's license. Some other professions in medicine, engineering, and other related fields have also placed some limitations on the ability to see color [7]. The presentation and displaying of various media on devices and in many ways do not take into account the lack of color vision on their user interface. Nevertheless, despite the poor distinction, it is clear that different colors do not affect people's learning and perception [1, 3, 8].

A large number of people with color blindness can live a lifetime without knowing that they have disabilities and abnormalities in their color vision [9]. At this time, with the development of computer science and information technology, it became necessary to help color-blind patients through the development of adaptive vision correction machines [6].

The vision for Color-Blind patients’ effects on the bases of colors, and this is exactly what it is expected to do. Designers could benefit from these perceptions to apply principles of "safe color schemes", which essentially work within the principle of (design for everyone). In several industries, Green and Red are still used to specify states that must be related to safety and danger [10, 11].

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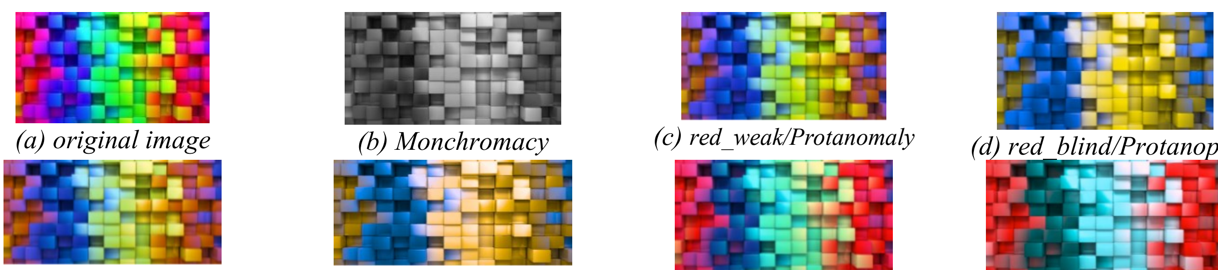
The technology called Digital Image Processing (DIP) can be useful to help human with Color Blindness notice and know information from pictures [12]. Moreover, given that there is a robust method of transmitting information, a visualization will reduce the cognitive burden associated with explaining the data. Absolutely, a visualization technique is very effective if it supports visual requests and expands memory.

In addition, the use of color to display data classes is regularly the best option when it regards encoding information. This refers to describing complex data objects as visual entities; It is appropriate to refer to data objects that check an additional feature in a visual way. Hence, it is good to visualize interrelated data elements [13,14, 15].

The massive majority of people have trichromatic vision. Based on [10, 15, 16, 17, 19], the color vision diseases such as Color Blindness can be categorized as:

1. **Anomalous trichromacy:** An aberration in the proportions of red, green, and blue. Anomaly trichromatic is divided into three categories:
   - Protanomaly: sensitivity to red is reduced.
   - Deuteranomaly: sensitivity to green is reduced.
   - Tritanomaly: color sensitivity in the blue-yellow range is reduced.
2. **Anomalous dichromatism**, i.e. The complete lack of sensitivity to red, green, or blue. Because one kind of cone is missing, it is provided in the form of:
   - Protanopia is the loss of red photoreceptors in the retina.
   - Deuteranopia is the absence of green photoreceptors in the retina.
   - Tritanopia is characterized by the absence of blue photoreceptors in the retina.
3. **Monochromatism** is a condition in which a person's capacity to detect color is completely lost. Color Blindness of this kind causes one to perceive the world in grayscale. Achromatic vision is an extremely rare vision disorder.

Figure 1 (a) indicates a clear colour image for humans with normal vision while Fig. 1 (b) to 1h is the colour images as considered by a Color Blindness Patient. We notice that, for example, Several of the colors in the image are almost identical, making it impossible to distinguish the information in the images.



(a) original image *(b) Monchromacy* *(c) red_weak/Protanomaly* *(d) red_blind/Protanopla*

(e) green_weak/Deuteranomaly *(f) green_blind/deuteranopla* *(g) blue_weak/Tritanomaly* *(h) blue_blind/Tritanopla*

FIGURE 1. Color blindness types

When monochromatism is seen as mono-spectral vision, it is impossible to distinguish visual characteristics based on color. monochromatism can also be thought of as a severe example of anomalous trichromacy. We solve this type of color blindness in the papers [3,14], and the other types of color blindness (Anomalous trichromacy and Anomalous dichromatism) are solved in this paper.

Now, through this paper, we presented an explanation and easy view of Color Blindness patients and color subjects in general. Then we proposed a technique to solve the issue of visibility for people with color blindness by using the techniques provided by visualization. Finally, we used "ISHIHARA" test to see how much data is being processed, and we depended on Coblis - a color blindness simulator - to simulate a Color Blindness person [19].

PROPOSED METHOD: HSVPCA METHOD TO SOLVE THE PARTIAL COLOR BLINDNESS

Principal Component Analysis (PCA) Method

The steps of the PCA method are as follows [20, 21]:

1. To create a new region, compute the original data centers and remove them from each value.
2. Determining the variation matrix.
3. Depending on the small target dimensions, PCA calculates the eigenvalues and eigenvectors of the covariance matrix cov.
4. Determine the primary component of transportation.

A new strategy has been proposed to assist people in distinguishing colors without the components of the visible item overlapping or distorting. For example, those with Protanopia can't tell the difference between red and its components when they're mixed with other colors. Our procedure raises the concentration of red while simultaneously increasing the intensity and saturation of the other Hues, in order to overcome this sort of blindness. Because the red color is difficult to differentiate, this technique focuses on identifying data components. Meanwhile, it seeks to retain the Hues that are already there. It tries to preserve the number of colors at least, regardless of the color of the components that arise. The following steps explain the proposed method and shown steps in the Fig. 2 & Fig. 3 :

1. Determine which color blindness should be treated.
2. Read the information (choose where to display the picture)
3. Depending on the kind of coloration blindness (Protan, Deuteran, or Tritan), the color will attention corresponding to the kind of blindness by using Equation1.

$$A_i = IM_i * R_i \tag{1}$$

Where, IM denotes the image to be processed, i=1, 2, 3 means the image channel, R represents a concentration value of the color corresponding to the affected cone, while the correct cones have the concentration value of 1, (meaning that their concentration do not change) and the impacted cone's component has a value of 2. As in Equation 2.

$$\boldsymbol{R} = \begin{cases} [211] & if\ Protanopia\ or\ Protanomaly \\ [121] & if\ Deuteranopia\ or\ Deuteranomaly \\ [112] & if\ Tritanopia\ or\ Tritanomaly \end{cases} \tag{2}$$

The step multiplies 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 normalizes the output of (A) to the range [0,1].

4. Converts the original data (the picture that is choosing to display) to the HSV color space to get higher accurate results and saved in the resulting image.
5. Depending on the type of color blindness, if the color blindness is partial (i.e. cones are intact but there is only one deficiency), so the component of colors h is shifted 30 degrees only. Assuming that a weak point is 50% in the damaged cone, if the cones are intact however there is one cone missing, the component h is shifted to 60 degrees only because each color in element h represents 60 degrees.

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

In Equation 3, the Displacement is based on the damaged cone and its type, i.e. the technique removes any red component if the damaged cone is sensitive to red color. This is done by using redistributing data to the rest of the H components in the picture to keep the information in the picture for easy identification by using patients. The purpose of this displacement is to help color blindness patients distinguish among the elements of the picture even if some colorings are modified because they can't see part of the colors and the data is dispensed to the relaxation of the colorings that it senses.

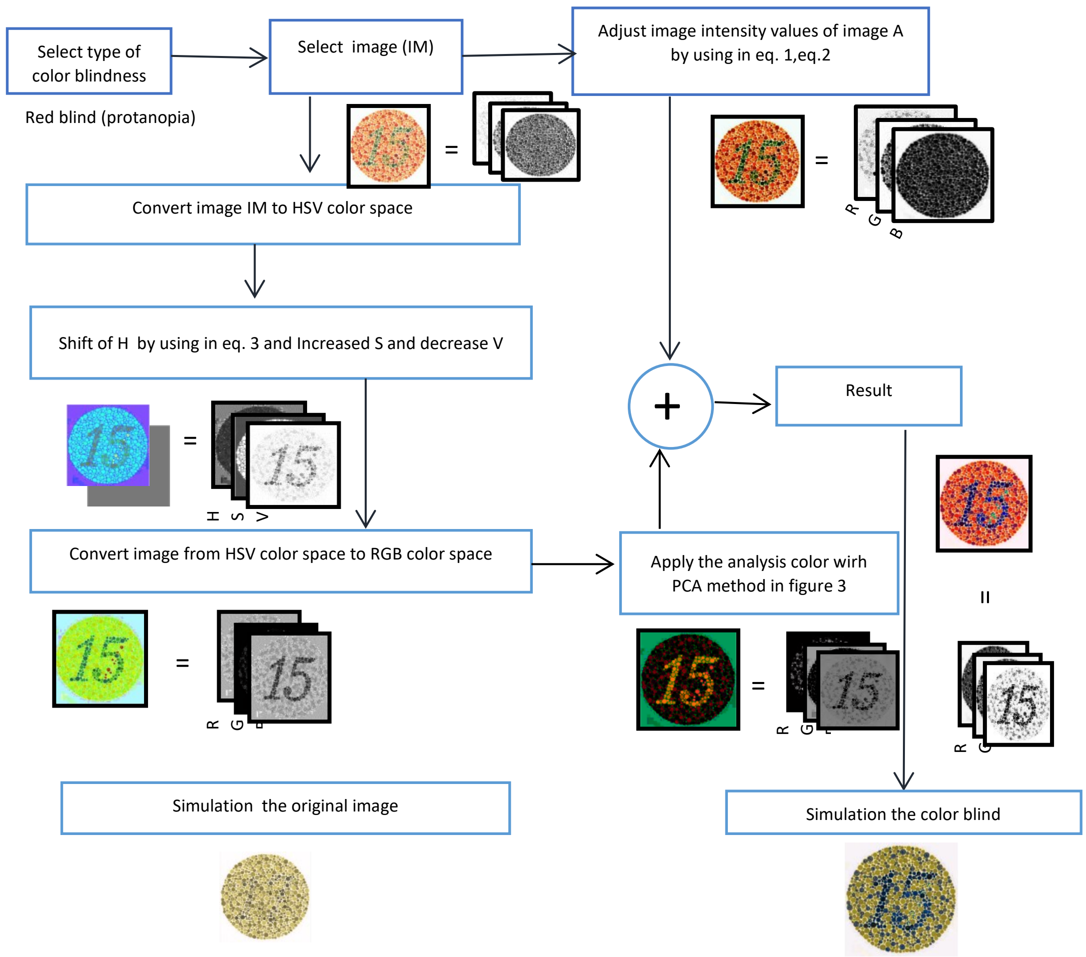


FIGURE 2. Color discrimination Method for Partial Color Blindness

6. The saturation of the component S increased, while the value of the component V decreased and the result is saved in the C variable.
7. Return the result to RGB color space.
8. Image data analysis: apply the color analysis method. The method includes the following steps, show the method in the Fig. 3:
   - **Analysis of color in the image:** The colors and positions of the colors in the image are extracted. Each color is consisting of three main channels (R, G, and B), the final result of this approach will be k*3-size matrix, where k means the number of colors in the image. To keep information from being lost, every color in the image should be saved. As a result, the color location matrix has a dimension of n*m, which corresponds to the size of the original image. The idea of color analysis is explained in the paper [3]. In order to preserve colors, the technique of analysis of colorings is the quality in phrases of color and data cohesion. After analyzing the colors, we will have a variety of colors per pixel to keep the information and not distort this data. We want to recognize the locations of each color in the data so that we will save the color value and its location in the picture so that we do not waste any of the essential information in the data.
   - **Redistribution of the color matrix:** After analysis, we have the color matrix. In order to implement a fast and convenient technique of color redistribution, PCA is applied. PCA is used to redistribute three dimensions into three other dimensions. In this case, for example, if we have a pink color, the output will

be another color, and this is the aim to obtain differentiation of all colors of the data without distortion or loss of data

- **Reposition colors:** Each location in the image is returned to the color corresponding to the output of the previous step, using a color location matrix.

9. Combine the resulting image with the image in which the data is centered. In addition, color differentiation is not lost because the colors are shifted and Redistribution in step 5; it may lose part of the color or differentiation. When the resulting image has been combined the image with the color to be processed, the data is more differentiated, and show the result.

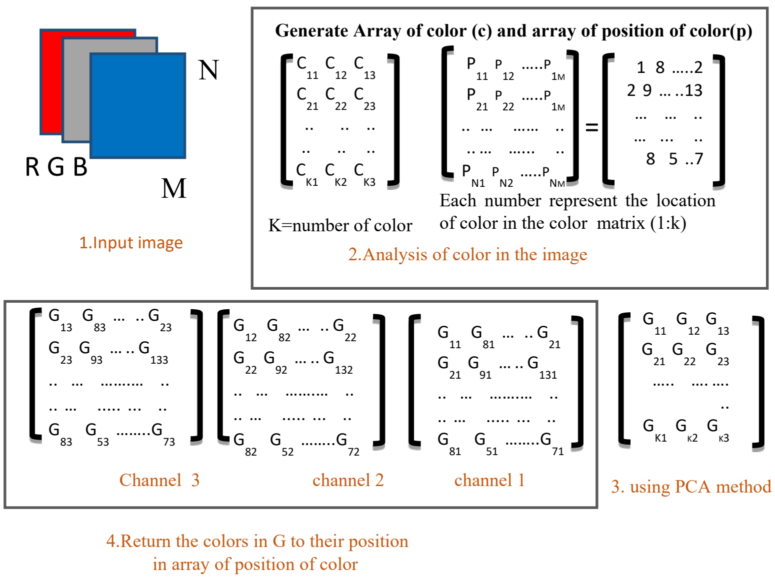


FIGURE 3. Color Analysis Method to Identify Information for People With Total Color Blindness

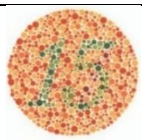
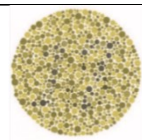
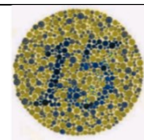
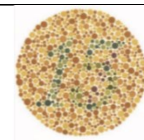
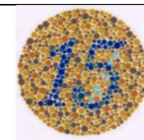
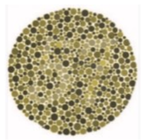
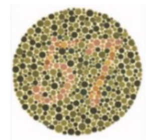
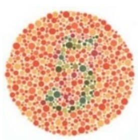
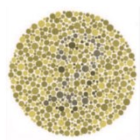
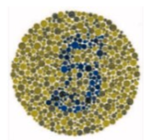
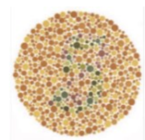
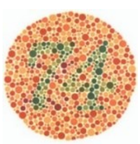
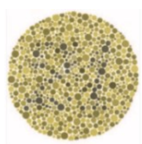
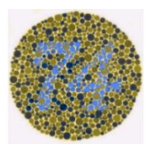
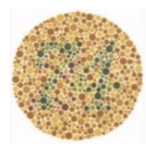
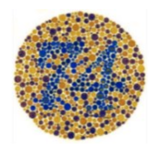
RESULT AND DISCUSSION

The suggested approaches are tested using 38 pictures of ISHIHARA data sets. Standard pictures for testing color blindness are included in the ISHIHARA. The test includes a variety of color pictures, each with a set of colored circles of varying sizes and colors. These circles represent a number or object that should be visible to people with normal vision. Depending on the kind of color blindness, people with color blindness are unable to recognize certain numbers and objects. We used the color blindness simulation system to simulate all of the different types of color blindness.

Table 1 shows the results of processing ISHIHARA data sets when the red-sensitive cone is damaged (completely or partially missing). In this table, the first column represents the sequence of pictures processed, the second column represents the original data and the content of this image is clear and can be viewed via the person who has a natural view. We observe in the third column that in the case of color blindness (protanopia), the eye is unable to distinguish red color. We note the loss of much information and the incapacity to distinguish forms. When applying the proposed technique of fixing this type of color blindness problem. We notice the ability of distinguish between forms or figures and that the information is clear and understandable, as shown in the fourth column in Table 1.

Protanomaly color blindness is unable to identify forms accurately, as seen in column5 of Table 1. As previously stated, this is due to inadequate red color sensing, which causes a loss of red color with perceived colors. The number is unclear in sequence 3, which contains number 5, and we can't differentiate the information within the image. As indicated in column 6 of Table 1, the infected person may readily notice the color when the data is processed and the proposed approach is used. As a result, the suggested approach can display the missing color and make the forms easily recognized. In processing, we focus on distinguishing the information in the image from its colors rather than preserving the remainder of the colors that a person can perceive. It doesn't matter whether a color is changed to another color as long as the individual can recognize the information.

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

No. of tests	Original image	Color-blind of original data in (protanopia) color blind	Result of the proposed method to solve (protanopia) color blind	Color-blind of original data in (protanomaly) color blind	Result of the proposed method to solve (protanomaly) color blind
1					
2					
3					
4					

The results of processing ISHIHARA data sets when the green-sensitive cone is affected (completely or partially missing) are shown in Table 2. The first column represents the sequence of the images processed, the second column represents the original data, and the content of images is clear and can be seen by a person with natural vision. What we found in the third column, for example, in sequences 3 and 4 of Table 2, which contain the numbers 57 & 3 respectively, the numbers are unclear, indicating that a loss of a lot of information and an inability to differentiate between forms, which also applies to the remainder of the pictures. When using the proposed method to solve the problem of this type of color blindness, we note the ability to discriminate between shapes and numbers, as well as the fact that the information is clear and intelligible in the fourth column of Table 2.

Deuteranomely color blindness, as shown in column 5 of Table 2, is unable to distinguish shapes clearly, the loss of part of the green color in the data. In column 6 of Table 2, when processing facts and applying the proposed method, the infected person can see color and distinguish numbers, shapes, and data that are understandable and clear.

Finally, if we observed Table 3 in which, the blue-sensitive cone is damaged (completely or partially missing). The first column represents the sequence of photos processed, the second column represents the original images, and the third column represents the pictures seen by a person who is missing the blue-sensitive cone, and has a tritanopia color blindness. The fourth column represents the result of processing images in the manner suggested for the same person in the third column. For fifth column, images are seen, related to a person with blue-sensitive cone damage and has a tritanomely color blindness. at last, column number six represents data processing results for color blindness in the fifth column.

Through our study, we observed that the third and the fifth columns are different from what were in Tables 1 and 2. This is because a person with a blue-sensitive cone can easily distinguish some data and numbers when processed by the suggested method, where, the information becomes extra focused and clear to the infected person, which means the person can see the forms easily.

Therefore, we need to know how much the colors of the processed image were retained compared to the original image in order to evaluate the effectiveness of the suggested method. This is accomplished by calculating the ratio of the number of colorations in the processed image to the number of colors in the original image and comparing it to the ratio of the number of colors in the original image (as perceived by the color-blind patient). As in Equation 4.

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

TABLE 2. Results of data processing for color blindness if an affected cone is sensitive to green color

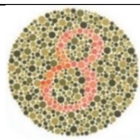
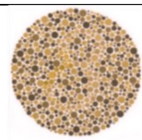
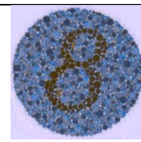
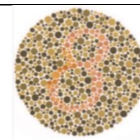
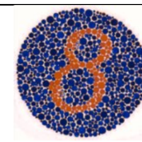
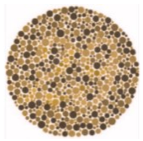
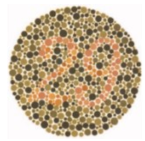
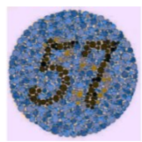
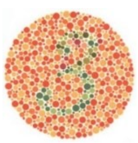
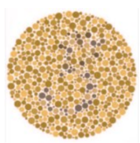
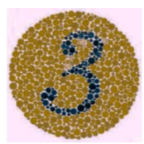
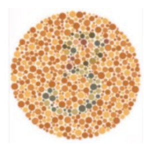
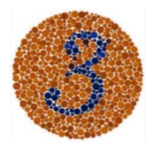
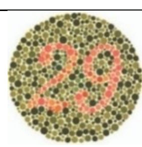
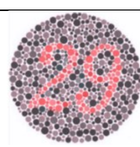
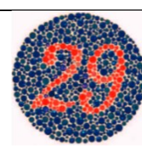
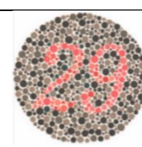
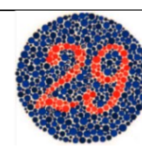
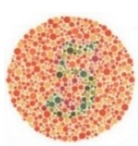
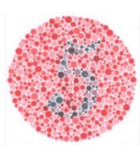
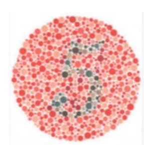
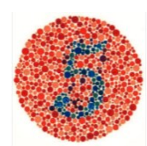
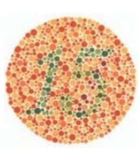
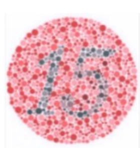
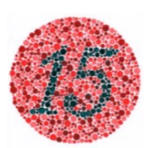
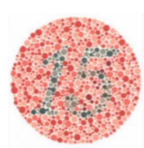
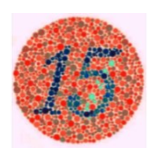
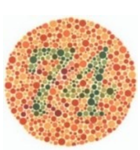
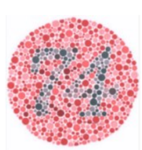
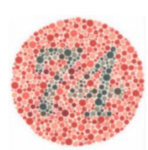
No. of tests	Orginal image	Color blind of original data in (deuteranopia) color blind	Result of the proposed method to solve (deuteranopia) color blind	Color-blind of original data in (deuteranomely) color blind	Result of the proposed method to solve (deuteranomely) color blind
1					
2					
3					
4					

TABLE 3. Data processing results for color blindness if an affected cone is sensitive to blue

No. of test	Original image	Color-blind of original data in (tritanopia) color blind	Result of the proposed method to solve (tritanopia) color blind	Color-blind of original data in (tritanomely) color blind	Result of the proposed method to solve (tritanomely) color blind
1					
2					
3					
4					

Where, Image 1 represents the final image after using the proposed methods with color blindness, or the image after the original image has been simulated with color blindness. The result of the processing image is better if the percentage of the processed image is greater than the percentage of the pre-processed image, and the color-blind person can distinguish the information clearly. When the ratio is close to one, mean that data is significant. As a result, the data in the processed image is very close to the information in the original image. When the results are close to zero, the image loses more information and it is not clear.

TABLE 4. The percentage results of the proposed method when color blindness is protanopia type

No. of experiment	Original	Mean of the suggested method	Mean of the no process	Number of experiments	Original	Mean of the suggested method	Mean of the no process
1	1090	0.917431	0.311009	20	1825	0.830137	0.225753
2	1529	0.892086	0.281884	21	1917	0.81951	0.232655
3	1513	0.873761	0.262393	22	1584	0.997475	0.254419
4	1355	0.968266	0.280443	23	1570	0.993631	0.249682
5	1343	0.997766	0.294862	24	1559	0.994227	0.248236
6	1745	0.731805	0.238395	25	1714	0.991832	0.242124
7	1629	0.759975	0.246163	26	1694	0.997639	0.239669
8	1632	0.783701	0.235294	27	1652	0.998789	0.25
9	1619	0.862261	0.23533	28	1974	0.719352	0.218338
10	1622	0.984587	0.294081	29	2043	0.714146	0.209496
11	1720	0.991279	0.287791	30	2139	0.647031	0.251052
12	1493	0.997991	0.301407	31	1773	0.660462	0.2696
13	1492	0.99866	0.295576	32	1793	0.923592	0.271612
14	1997	0.57336	0.2664	33	1585	0.984227	0.290221
15	1974	0.54306	0.263931	34	2002	0.563936	0.231768
16	1856	0.817888	0.253233	35	1716	0.652681	0.238345
17	1721	0.751307	0.26903	36	1540	0.996753	0.272727
18	1970	0.809137	0.218782	37	1403	0.997862	0.273699
19	1865	0.834316	0.224129	38	1095	0.913242	0.311416

In the Table 4, the percentage of the ISHIHARA images are shown. Note that, the percent of the proposed method for Protanopia are much higher than the percent of the original data sets, as shown in Fig. 4. For example, in sequence 25, the proposed technique had percent of 0.970, while the original data sets had 0.242. The rest of the results reflect the difference in ratios. This means that the results of the proposed method for color blindness Protanopia are excellent.

Figures 4 to 9 show that the results of the proposed method are much better than the original data. When a person with partial color blindness needs to see, the proposed method has the best in terms of clarity as well as a good percentage of the number of colors in the processed data. The values are very close to 1 and this indicates the efficiency of the proposed technique when applied to solve color blindness problems and preserve the information well. Whereas, if the person has a missing color cone, the results for the proposed method are not all close to 1, however, it is higher than the original data so that means the proposed method is effective.

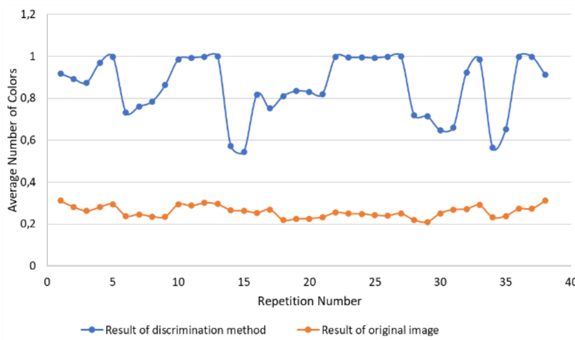


FIGURE 4. Result of Protanopia color blindness

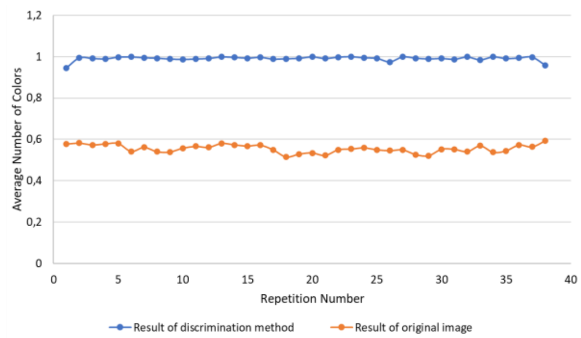


FIGURE 5. Result of Protanomaly color blindness

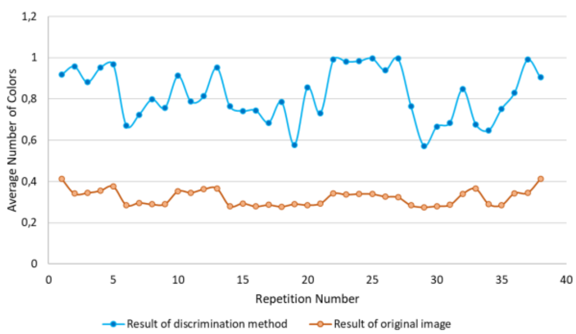


FIGURE 6. Result of Deuteranopia color blindness

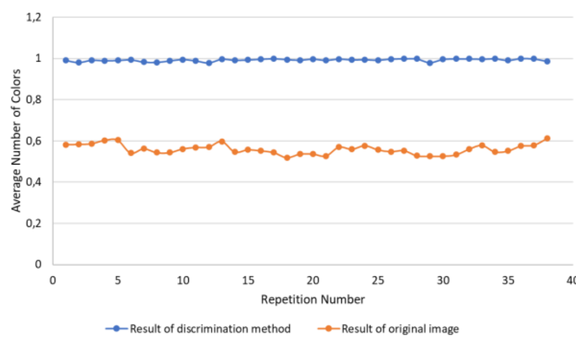


FIGURE7. Result of Deuteranomaly colorblindness

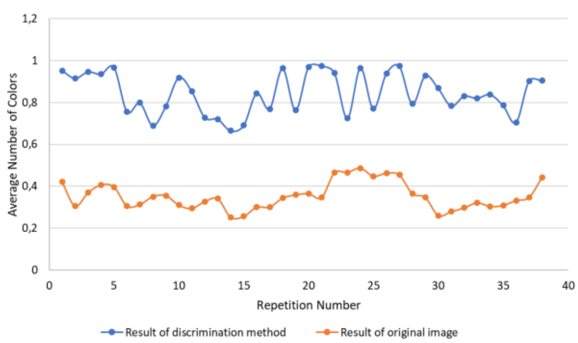


FIGURE 8. Result of Tritanopia color blindness

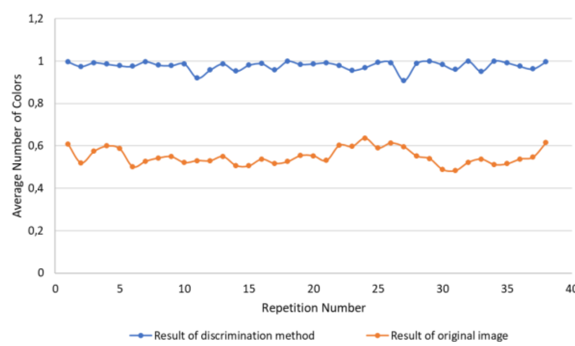


FIGURE 9. Result of Tritanomaly color blindness

CONCLUSION

A person with color blindness can not distinguish all the information around them. By using data visualization ways, we presented an approach to help people with color blindness to distinguish information and not get deformation or similarity in the data presented to them. The proposed fashion was suitable to clarify the information and distinguish between them, and it achieved success and proved the effectiveness of the proposed system through the results of trials.

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