Segmentation image re-coloring based on k-means clustering algorithm as a tool for partial color-blind people

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Abstract. Color blindness is one of the eye anomalies that can not distinguish one color from another. Therefore, the information contained in the image may be lost by color blindness people. To reduce the possibility of sufferers losing color information contained in the image, a system was built in the form of re-coloring on images based on the ability of color blindness sufferers to distinguish colors. This ability is measured based on RGB cluster owned by different people. This research using color based segmentation in the process of re-coloring. Image Segmentation using K-means Clustering was chosen because of short processing time with optimum result. A total of 15 images without the coloring process were tested on color blind subjects. The result is that only 20% of the information can be seen by the color blind subject. The output of this study is the image that has been re-colored. The result of this research is that 53% of the images can be seen by the color-blind subject by using color-based segmentation in each image, 60% of the image can be seen by the color-blind subject by using color-based segmentation on all images, and processing time is shorter than previous research.

1. Introduction

In recent years, due to presence of color printers and tools display, the use of color in multimedia content to provide high visual information has drastically increased [4]. Color is an important design component that is often used to encode information [5]. This is very important for more effective use of color for visual communication. If color is used as a means to provide information, then the information contained in the image may be lost when seen by people who are color blind [5]. People with limited color vision or color blindness will have difficulty distinguishing some colors that can be distinguished by normal people [4]. Images with almost the same color and shadow will be difficult to distinguish by people who are color blind [7].

In daily life, people who are color blind will face many problems in distinguishing colors, such as distinguishing colors from trees, leaves and traffic lights [9]. A lot of research has been done with the aim to help overcome the problems experienced by people who are color blind, as in [5] [4] [7] [6] [9]. These systems are able to help people who are color blind in distinguishing colors in images, but almost all of these studies are only focused on helping types of color blindness in general. Despite having the same type of color blindness, people with the same type of color blindness have many different abilities and weaknesses from one another [9].
Because of this deficiency, the authors will focus on re-coloring the image for all people with partial color blindness, not limited to the type of color blindness that exists. The previous research is [9] has been done to help people with color blindness based on their RGB color clusters. However, the drawback of the method used in this study is that the mapping optimization algorithm that is applied uses many resources and has a long computational time [9]. There is future work suggested by Dody Qori Utama on [9], that is using image segmentation to reduce computation time. Therefore, the author uses the K-means algorithm in the process of image segmentation based on color and Brute-force to do color mapping and re-coloring. Color mapping is done based on the results of the color blindness test by Dody Qori Utama on [8] in the form of an RGB cluster of people who are color blind.

Image Segmentation is an image classification process into some cluster. This method is one of the most commonly used methods to classify pixel from an image correctly into an application [3]. The image can be a grayscale or color image. The segmentation algorithm used in this study is K-means clustering. The result of image segmentation is the color clusters which contained in the image. Color mapping is then conducted to ensure that a color cluster with other color clusters can be distinguished by color blind subjects. The mapped color cluster will be a reference in the re-coloring process. The results of this study are re-colored image based on color clusters in the color mapping process.

The following formulation of the problem in this study is the first is what is the image coloring process for people with partial color blindness by utilizing image segmentation and RGB clusters from the results of color blindness testing? Second is what is the performance of the system output that has been built and the third is What is the processing time of the system that has been built? As for the limitations of the problem in this study, namely the image used is a color image, the image used is Ishihara plates with total 15, RGB cluster from color-blindness test, the test subjects amounted to one person, and testing is done by using a device with a minimum color accuracy of 90% RGB.

The purpose of this research is building an image re-coloring system utilizing image segmentation and RGB cluster to help color-blind subjects see information in the image, The output of the system is built in the form of an image whose information can be seen well by the subject of color blindness, and the last is better processing time than the previous system.

2. Related scheme

2.1. Comparative study

Several studies have built this system with a variety of different methods. The research of [4] using GMM (Gaussian Mixture Model) to get the color information on image. This research then builds a color weighting method to determine which colors are important for people with color blindness. This color weighting method is useful for optimizing the re-coloring process. Then, on the research [6] using Fuzzy simulation by utilizing the results of the test ishihara by the DaltonTest tool that provides a diagnosis of color blindness patients in the form of degrees of color blindness, protanomaly degree, and deuteronomaly degree. This result is used as a membership function in Fuzzy [6].

Next is [9] using optimization of color mapping by utilizing the results of the major color blindness test on [8] in color clusters from RGB. The advantage from the system that made on the research [9] is applicable to all partial color blindness compared to other methods which can only be applied to some degree of color blindness. However, the disadvantage of this method is the mapping optimization algorithm that is applied uses many resources and has a long computational time [9].

In the research [11] comparison of image segmentation using K-means and GMM. The result is the segmentation image by K-means is better than GMM, and the processing time by using K-means is very fast compared to using the GMM method. [11].
2.2. Color blind test based on RGB cluster

Color blind test based on RGB cluster, developed by Dody Qori Utama et al. is a test that aims to find out the ability of R, G, B cone cell to recognize the color [8][11]. The eyes of the subjects were tested based on low intensity to high intensity in each red, green and blue color by guessing the information which was represented by numbers such as the Ishihara test. The difference between this test and the Ishihara test is that this test can manipulate the intensity of the color. In addition, this test can measure the ability of our eyes to distinguish between red, green and blue.

![Output RGB Cluster](image)

Output from this test can be seen in the Figure 1. Three color clusters from Figure 3 is Red, Green, and Blue clusters. This cluster are describe how much color group that can be distinguish by Red, Green, Blue cone cell. Subjects with more clusters are able to distinguish more colors. Normal eyes have at least eight red clusters, eight green clusters and eight blue clusters [9].

The important formulas used in this test are:

\[
D(W_1, W_2) = Dr(R_1, R_2) + Dg(G_1, G_2) + Db(B_1, B_2)
\]

Explanation:
- \( D(W_1, W_2) \) is the color range \( W_1 \) with \( W_2 \)
- \( Dr(R_1, R_2) \) is the color range \( R_1 \) with \( R_2 \)
- \( Dg(G_1, G_2) \) is the color range \( G_1 \) with \( G_2 \)
- \( Db(B_1, B_2) \) is the color range \( B_1 \) with \( B_2 \)

To find the value of each red, green, and blue distance, the following formula is used:

\[
Dr(R_1, R_2) = \left( \left( \frac{i(im_1) - i(bb_{mi})}{i(bb_{mi})} \right) * 100\% \right) + \left( \frac{i(bam_{i+x}) - i(im_2)}{i(bam_{i+x})} \right) * 100\% \\
+ \left( (x - 1) * 100\% \right)
\]

(2)

\[
Dg(G_1, G_2) = \left( \left( \frac{i(ih_1) - i(bb_{hj})}{i(bb_{hj})} \right) * 100\% \right) + \left( \frac{i(bah_{j+y}) - i(ih_2)}{i(bah_{j+y})} \right) * 100\% \\
+ \left( (y - 1) * 100\% \right)
\]

(3)

\[
Db(B_1, B_2) = \left( \left( \frac{i(ib_1) - i(bb_{bk})}{i(bb_{bk})} \right) * 100\% \right) + \left( \frac{i(bak_{k+z}) - i(ib_2)}{i(bak_{k+z})} \right) * 100\% \\
+ \left( (z - 1) * 100\% \right)
\]

(4)

Explanation:
- \( im, ih, ib \) is the intensity value of red, green, and blue in color.
• $bbm_i, bbh_j, bbb_k$ is the lower boundary value of red, green, and blue on the color cluster.
• $bam_i, bah_j, bab_k$ is the upper boundary value of red, green, and blue on the color cluster.

If the distance from $D(W1,W2)$ is below 50%, then the colors $W1$ and $W2$ cannot be distinguished at all by the subject. If the distance from $D(W1,W2)$ is between 50% and 100%, then the colors of $W1$ and $W2$ are vaguely seen by the subject. If the distance from $D(W1,W2)$ is above 100%, then the colors of $W1$ and $W2$ can be distinguished by objects.

3. Proposed scheme
The dataset that used in this research is divided into two:

(i) The original digital image used on the Ishihara Test which has not been re-coloring is 15.

![Figure 2. Original Digital Image.](image)

(ii) RGB cluster from the results of color blindness tests in the study [8]. In this study, we use one person as a subject of color blindness. The results of the color blindness test by the subject are found in figure 3. From Figure 3 it was found that color blind subjects had five red clusters, seven green clusters, four blue clusters.

![Figure 3. Subjek Cluster.](image)

In general, this system will go through 3 stages (based on Figure 4). The initial stage is retrieving the cluster RGB data from the color blind subject and then making it as a dataset and doing image segmentation process. Then the color mapping process to ensure the color cluster in the image can be distinguished by color blind subjects. And the last is the coloring process. The output of this system is the image that has been repainted.
3.1. Image segmentation
The first step is image segmentation. This step is one important stage. At this step, image segmentation is based on color using clustering. Clustering has proven to be a very efficient method for image segmentation [2]. The Clustering algorithm that we use is K-means Clustering. K-means clustering algorithm is usually used to partition a data sheet automatically into a cluster $K$ [10]. In a color image, the dataset used is the values from RGB layer.

There are two ways in the segmentation process. The first is the color segmentation of each image using the initial $K = 50$ with the end result is different clusters. The second is to segment 15 images at the same time with the initial $K = 50$. $K = 50$ was chosen to get different color groups with the distance between colors and the centroid not far away. The result of this stage is the image that has been segmented based on the cluster. Each pixel in the image is labeled according to the cluster number of the clustering process.

3.2. Color mapping
After doing the image segmentation stage, then the next step is the color mapping stage. The input from this stage is the color representation of each image cluster and RGB cluster from color blindness test. Then, a comparison is made between the two colors by calculating the distance between the two colors. This calculation is used to find the distance value between the two colors.
symbolized as \( D(W_1,W_2) \). To calculate \( D(W_1,W_2) \) refers to the formula \[1\]. If \( D(W_1,W_2) > 100\% \), then there is not any changing from one of those colors. But, if \( D(W_1,W_2) \) between 50%-100%, then changes are made to one of the colors by increasing or decreasing the intensity value from R (Red), G (Green), B (Blue). This is done because of the colors with \( D(W_1,W_2) \) between 50-100% indistinguishable and \( D(W_1,W_2) > 100\% \) can be distinguish by subject \[8\].

Changes to the intensity value will affect the calculation of the distance between the two other colors. An approach with Brute-force is used to ensure the distance between each color in the K cluster >100%. The method is done by calculating two colors in each K cluster. If there is a change in the intensity value on W1 because \( D(W_1,W_2) < 100\% \), then the next process is calculate \( D(W_1,W_3) \). If \( D(W_1,W_3) > 100\% \), so the next process is calculate \( D(W_1,W_4) \). The process is carried out until the distance between colors in each K cluster >100%.

![Figure 6. Color Mapping Illustration.](image)

Figure 6 is color mapping process. On this stage, will change the data in K color cluster. There are 3 color clusters in the image. By entering the RGB values in K1, K2, and K3 before transformation, the following results are obtained:

- The distance between K1 and K2 is 67.5%
- The distance between K1 and K2 is 160%
- The distance between K1 and K2 is 92.5%

Then changes are made to each centroid of color cluster. This change is in the form of an increase or decrease in intensity value R, G, B. After the transformation process in the Figure 6, the RGB values in K1, K2, K3 can be modified. This transformation data will be used in the next process. One of the data is as follows:

- For K1, there is an increase in the intensity value of G layer by 20.
- For K2, there is an increase in the intensity value of G layer by 50.
- For K3, there is no changes.

The G layer is selected for the color mapping process because the number of green clusters in the RGB cluster subject is more than red and blue clusters. This indicates that the color blind subject is able to distinguish colors from the value in G layer more than the R and B layers. From this process, it was found that \( D(K_1,K_2)=130\% \), \( D(K_1,K_3)=110\% \), and \( D(K_2,K_3)=105\% \).

### 3.3. Re-coloring image process

After getting the K data change in the color cluster from the previous process, the coloring process is carried out. The coloring process itself is done in two ways, namely:

(i) Each pixel in the previous segmentation process has been get a label from the cluster index. Next, matching process with the cluster labels that exist in each pixel and making changes by adding value changes to the color mapping process with pixel values.

(ii) Each pixel in the previous segmentation process has been get a label from the cluster index. Next, matching the cluster labels in each pixel is done and changes are made by changing the pixel value with the centroid value that has changed in the color mapping process.
If the color mapping process shows that all the colors in the centroid can be distinguished, then there is no need for re-coloring. The results of this process can be seen in the Figure 7.

**Figure 7.** Re-colored Image.

### 4. Result and discussion

Test in this study was done by testing the color blind subject, whether the subject saw the information contained in the image or not. This test is carried out using original digital images and four re-colored images.

#### 4.1. The test results using k-means clustering for each image with initial K = 50

| Image | Real Number | Numbers read by the subject | Processing Time (seconds) |
|-------|-------------|-----------------------------|---------------------------|
|       |             | Original Image | Re-colored Image | 1st method | 2nd method | |
| 1.    | 7           | 7               | 7               | 7           | 7           | 52.10 |
| 2.    | 6           | -               | -               | -           | 5           | 29.71 |
| 3.    | 26          | -               | 26              | 26          | 26          | 55.00 |
| 4.    | 15          | -               | 15              | 15          | 15          | 18.60 |
| 5.    | 6           | -               | -               | -           | -           | 29.51 |
| 6.    | 73          | -               | -               | -           | -           | 18.81 |
| 7.    | 5           | -               | -               | -           | -           | 27.02 |
| 8.    | 16          | -               | 16              | 16          | 16          | 31.72 |
| 9.    | 45          | -               | -               | -           | -           | 26.48 |
| 10.   | 12          | 12              | 12              | 12          | 12          | 45.65 |
| 11.   | 29          | 28              | 29              | 29          | 29          | 22.56 |
| 12.   | 8           | 8               | 8               | 8           | 8           | 18.01 |
| 13.   | 74          | -               | -               | -           | -           | 51.72 |
| 14.   | 57          | -               | 57              | 57          | 57          | 55.98 |
| 15.   | 2           | -               | -               | -           | -           | 210.41 |

To determine the initial centroid of a cluster in K-means clustering with an initial K value of 50. The value of the R layer is middle value of the range between the first cluster is [1,15], then the second cluster is [16,31], etc. Then for the value of the G layer and B are 0. Then, the same
is done for G layer, and the layer values R and B are 0. The last two K are \( K_{49} \) and \( K_{50} \) is the RGB value of black and white. For the next process, it is done like K-means in general, except there is a difference in the process of determining the next centroid. If there are clusters that have no members at all, then the cluster will be removed. The end result of this scenario is the changing cluster value. For the K-means process itself, this scenario is done in every digital image. So, if there is another digital image that will be input into this system, then the K-means process is carried out again in the image. Which means, all images have their own segmentation through the process on the system.

Based on the table 1 column Original Image, obtained results that the subject sees information in three images correctly, information in one image incorrectly, and cannot see any information on 11 other images. That is, the subject is only able to see 20% of information in the original digital image. Based on the table 1 for the 1st method, obtained results that the subject can see information on eight images correctly, and cannot see any information on the other seven images. And for the second method, the result is that the subject can see information in eight images correctly, information in one image incorrectly, and cannot see any information on the other six images. These results indicate that the system gives the ability to color blind subjects to see 30% more information from 15 images than the original digital image.

4.2. The test results using k-means clustering of all images with initial \( K = 50 \)

| Image | Real Number | Numbers Read by The Subject | Processing Time (seconds) |
|-------|-------------|-----------------------------|---------------------------|
|       | Original Image | Re-colored Image | 1st method | 2nd method |         |
| 1.    | 7            | 7                           | -                        | -            | 0.65    |
| 2.    | 6            | -                           | -                        | -            | 0.38    |
| 3.    | 26           | 26                          | 26                       | 26           | 0.59    |
| 4.    | 15           | -                           | 15                       | 15           | 0.58    |
| 5.    | 6            | -                           | 6                        | -            | 0.58    |
| 6.    | 73           | -                           | -                        | -            | 0.58    |
| 7.    | 5            | -                           | -                        | -            | 0.58    |
| 8.    | 16           | -                           | -                        | -            | 0.61    |
| 9.    | 45           | -                           | 45                       | -            | 0.58    |
| 10.   | 12           | 12                          | 12                       | 12           | 0.56    |
| 11.   | 29           | 28                          | 29                       | 29           | 0.58    |
| 12.   | 8            | 8                           | 8                        | 8            | 0.58    |
| 13.   | 74           | -                           | -                        | 74           | 0.61    |
| 14.   | 57           | -                           | 57                       | 57           | 0.84    |
| 15.   | 2            | -                           | -                        | -            | 1.66    |

For the K-means process itself, this scenario is done in all digital images. So, the determination of the centroid in this test is done at the beginning for all digital images. Then, after getting the color clusters found in all images, then the color mapping process is carried out. The results of this color mapping are immediately used as a reference for each digital image when re-coloring. For this study, a cluster of 35 colors were found in all or 15 digital images. This color is then used as a centroid when segmenting again on each digital image.

Based on the table 2 for the first method, obtained the results that the subject can see information in six images correctly, and cannot see any information on the other nine images.
And for the second method, the result is that the subject can see information in the nine images correctly, and cannot see any information on the other six images. These results indicate that the system gives the ability to color-blind subjects to see 40% more information from 15 images than the original digital image.

4.3. Comparison of processing time

This research was made to overcome the weaknesses in previous studies. Due to previous research by Dody Qori Utama [9] which uses Brute-force to compare each pixel in the image has a weakness in processing time that is long enough so that this system was built to overcome these weaknesses. The data for three image samples is used as input for this Brute-force system. The processing time for the first image is 878 seconds, for the second image is 878 seconds, and the third image is 931 seconds.

The first comparison is made for systems that have been created using K-means against each image. The processing time for the first image is 52.10 seconds, for the second image is 29.71 seconds, and for the third image is 55 seconds. These results indicate that the system has provided better performance against processing time.

A second comparison is made for systems that have been created using K-means for all images. The K-means process for all images takes 4238 seconds. Then for the color mapping process from the cluster obtained from the K-means process takes 0.20 seconds. For re-coloring process in each image, the time spent is faster due to the determination of the centroid at the beginning for all images. The processing time for the first image is 0.65 seconds, for the second image is 0.38 seconds, and for the third image is 0.59 seconds. These results indicate that the system provides better performance than the two studies above, although it takes a long time in the process K-means for all images.

5. Conclusions

From the results of several tests that have been carried out in this study, the subject is only able to see information on 20% original digital image. Then information on 50-60% digital images can be seen by the subject after the re-coloring process. So it can be concluded that the system built is able to help color-blind subjects to be able to see more information on color images.

For the processing time itself, with K-means for each image gives the fastest time, it’s just that there is a K-means redundancy process if the inserted image is the same so that it will give a longer amount of time if the image is entered more. Meanwhile, for K-means of all images gives a long time in the segmentation process. However, this process will make it easier to re-color the image. That is, if more images are entered, then the coloring time can be faster than the previous system. Previous system in research [9], the system made takes a long time so the system in this study can be used to overcome the shortcomings in the study [9]. For the re-coloring process itself which uses two methods, the second method provides better results than the first method. The second method yields up to 20% better than the first method.

The suggestion for further research is the image re-coloring system using different segmentations that are able to provide better results and faster processing time than this research. Then for color-blind subjects and digital image datasets it is expected that more will provide more and accurate testing results.

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