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ANALYSIS OF LMS DALTONIZATION ALGORITHM FOR ADJUSTING IMAGE COLOR FOR DEUTERANOPIA

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ABSTRACT

Color Blindness is a vision deficiency that leads to missing out of some colors present in an image or video. This in turn affects the lives (both personal and professional) of people suffering from it. In order to limit or solve color blindness problems, digital image processing algorithms for adjusting image color have been proposed in the literature. Amongst the most prevalent, RGB color contrasting and LAB color correction algorithms are said to have no clear theoretical grounds. Both algorithms are based upon experimental procedures, mostly on trial and error in the presence of color blind subjects. LMS Daltonization is another type of algorithm that has little disadvantage on the adjusted images, as close scrutiny is required to observe any differences. In this work, LMS Daltonization method was analysed for Deuteranopia type of color blindness. All simulations were done in Matlab. Results of adjusted image color obtained proved that LMS daltonization is a good algorithm for adjusting colors in images for deuteranopia color blindness, as it has satisfied its quality as mentioned above

1. INTRODUCTION

Color blindness is a vision deficiency problem that leads to difficulty in obtaining some vital information present in an image or video [1]. People with complete color blindness see things in black, white and grey. The disorder of one or more sets of cones in the human eye results to color blindness. The bigger the variation in the photopigments the more the color perception of that individual differs from that a normal trichromatic individual. These cones are responsible for viewing in bright light, Color blind People have difficulty in distinguishing between certain colors. This may hinder their capability to carry out color and visualization related tasks, such as distinguishing between the colors of jerseys, looking for ripped fruits in the farm like berries, distinguishing between raw and cooked meat, reading railway maps or general maps, trying to understand some graphics, checking out an electrical circuit. This in turn affects their personal and professional lives.

Colors are seen as variable combinations of the three basic colors: Red, Green, and Blue (RGB) [2]. The colors we perceive in an object are determined by the type of light reflected from the object. Color blindness affects roughly 8% of human males and 0.5% females [2]. It is actually rare in women, because the main form of color blindness manifests as a defect in the X chromosome, this infer that most color blind people are men [1]. The choice of color is supposed to enhance readability. For those who suffer from color-blindness, the choice of colors may not be optimal.

Basically, there are three types of color blindness [1]:

1. Monochromacy: it is a type of color blindness whereby only one type of cone is present at the retina of the eye. With monochromacy, everything seems to be black, white and gray.
2. Dichromacy: two cone types are present in the retina. One type of cone is missing, and hence, the information about that particular wavelength is lost. Dichromacy is of three types [1] [3] protanopia: a situation where a person cannot see red color, deuteranopia: a situation where one

cannot see green color and tritanopia: a situation where one cannot see blue color

3. Anomalous Trichromacy: in this condition all the type of cones are present but are not aligned properly. Hence, the sensitivity to a particular color is reduced. Depending upon which cone is not aligned properly it is further divided into: Protanomaly: sensitivity to red color is reduced, Deuteranomaly: sensitivity to green color is reduced, and Tritanomaly: sensitivity to blue color is reduced.

The great majority of people with some degree of vision deficiency lack either red or green cones and cannot distinguish between the two, about ninety nine percent of the color blind individuals are unable to distinguish between red and green colors [1].

Many methods for improving the color perception of these color blind people have been presented [2] [4] [1] [5] [3]. To limit the scope of this work deuteranopia color blindness was selected for this work because it is one of the most prevalent types of color blindness [5].

There are existing methods used for adjusting images for color blind viewers. Some methods include:

1. Variation of retinex theory [7]
2. Non-linear mapping functions [10]
3. Histogram equalization [8]
4. Color contrast enhancement method [4], [6]
5. LMS Daltonization [1], [2]
6. LAB color correction [1], [2]

Though contrast is improved using the first four methods but the first three suffer from some drawbacks of manual supervision to change the value of the enhancement parameter, color shifts and color artifacts, as well "halo" effects respectively. However, the fourth method rectifies the problems of the first three by proposing an automatic image enhancement algorithm which was implemented using Matlab software. Both RGB color contrasting and LAB color correction algorithms have no clear theoretical grounds [2]. The algorithms are based upon experimental procedures, mostly on trial and error in the presence of a color blind subjects [2]. LMS Daltonization has little disadvantage on the adjusted images as close scrutiny is required to observe any differences [2], this is the reason why LMS Daltonization is chosen as the method to be analyzed.

Daltonization methods are methods used to automatically adjust color in images for color blind people [12]. Daltonization methods can assist color blind people by adjusting the colors of confusion in an image to improve the color blind people's perception of that particular color(s) [11].

Daltonization methods can be classified based on their features e.g. how to adjust/modify confusion colors (enhancement), whether confusion colors are adjusted/modified in total or less (processing area) [12]. The most common type of daltonization is the total/global recoloring, where the hue and sometimes the lightness of the confusion colors are shifted to increase the perceived contrast regardless of the spatial organization of objects and areas.

2. METHODOLOGY

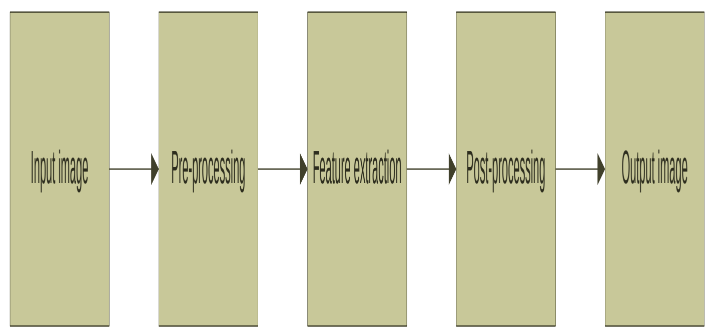

Fig 1 Block Diagram of Image Modification process (Source: [1])

Most image modification techniques are based on the process flow as in fig. 1, the input image, which is actually the image to be modified, the pre-processing stage, is where image acquisition is done and the conversion of the image from RGB color space to the required color space is done. The major work is carried out in the feature extraction stage, where the image is simulated as seen by the deuteranope or any other type of dichromacy, then the algorithm for adjusting the image color is then applied. The image is reconstructed so as to visualize the effect of the algorithm applied in the post-processing stage. Finally the output image is obtained which is the adjusted image.

2.1 Simulating Deuteranopia

The LMS daltonization method is selected as the existing method that will be analyzed. LMS daltonization is one of the good methods of adjusting images for deuteranopia and it has been used in many literatures [2]. [1], [5]. To start with, an image as seen in figure 2 was modeled in Microsoft paint, which comprises of three primary colors red, green and yellow. This image is termed the original image as it was used to simulate deuteranopia itself.

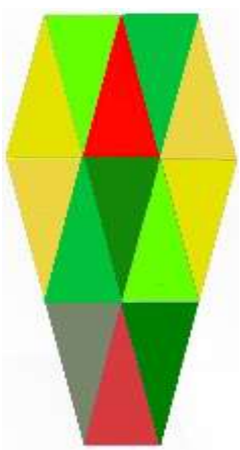

Fig. 2 Original image

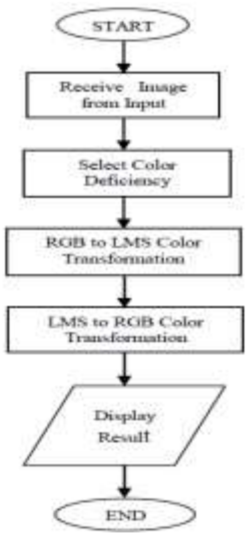

Fig. 3 Algorithm for simulation of image as seen by a deuteranopia patient (Source: Badlani & Deshmukh, 2016)

In order to understand how a deuteranopia patient perceives colors in images, there was need to simulate the image. Figure 3 is the process of simulating the deuteranopia color blindness. The Matlab inbuilt function "imread" was used to input the image (which is in RGB color space) into Matlab. The image was converted from RGB to LMS color space. A matrix multiplication is being carried out in order to achieve the conversion to LMS color space as follows:

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 17.8824 & 43.5161 & 4.11935 \\ 3.4565 & 27.1554 & 3.86714 \\ 0.02996 & 0.18431 & 1.46709 \end{bmatrix} \times \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

The above operation is done on each pixel of the image and it produces a new set of pixels containing information in the LMS color space. Next, the information associated with the Medium (M) cone (corresponding to the green wavelength) is been removed. In deuteranopia the information regarding the medium wavelength is perceived as information from the long (L) and short(S) wavelengths. This operation is carried using another linear matrix multiplication as follows:

$$\begin{bmatrix} L_{Deut} \\ M_{Deut} \\ S_{Deut} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0.494207 & 0 & 1.24827 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} L \\ M \\ S \end{bmatrix} \quad (2)$$

This leads to the removal of the medium wavelength information and the new M pixel is filled appropriately. Now deuteranopia is said to have been simulated.

2.2 LMS Daltonization Method

LMS daltonization was developed based on the flow diagram of digital image processing techniques as in figure 1 above. The following steps were accomplished in developing the LMS daltonization method: step no. 1 below explains how the digital image was inputted. Steps no. 2-5 explains how the pre-processing was carried out. Step no. 6-7 explains the feature extraction stage, the post processing was carried out in step no. 8-9, and finally output was obtained in step no. 10.

1. After the image acquisition, the image was imported into the Matlab command window using the matlab inbuilt command 'imread'
2. The size of the image which comprises of the image height, width and depth was also declared. Images are represented in matrix containing numbers, this numbers are referred to as pixels.

   [imageHeight, imageWidth, imageDepth] = size (imageRGB)

   The image depth represents the size of the matrix. Since it is an RGB image, it has a size of 3by3.

3. Other variables were also declared and initialised as follows:

   imageLMS = zeros (size(imageRGB))
   imageOut = zeros (size(imageRGB))

   rgbPixel = zeros(3,1), was also declared by generating a temporal entries which will be altered during code implementation. Note that (3,1) represent 3 by 1 matrix of the image RGB pixels. Similarly, for the LMS image, the pixels were declared in same manner by generating zero entries in its 3 by 1 matrix. Such that:

   lmsPixel = zeros (3,1)

4. Gamma correction of the RGB image was removed. Gamma correcting an image makes the noise in an image reduced. As for this work a gamma factor of 2.1 was used. Gamma correction allows for RGB values to be normalized.

   imageRGB = imageRGB.^ gamma

   The above command in Matlab means that the gamma operation must be applied to all pixel elements of the imageRGB
5. The original RGB image was then converted from RGB color space to LMS color space, in order to obtain the pixels of the image and do necessary color blindness computation using the following procedure: The conversion was carried out on each and every pixel of the image using equation (1) above:

   lmspixel(1:3) = rgb2lms * rgbpixel

6. Perform linear matrix multiplication in order to simulate deuteranopic view as performed earlier from equation (2) above.

7. The process of converting each individual LMS pixel to deuteranopic view is as follows:

   For y = 1: imageHeight
   For x = 1: imageWidth
   rgbpixel (1:3) = imageRGB (y,x,:)
   lmspixel (1:3) = rgb2lms * rgbpixel
   imageLMS (y,x,:) = deutAdjust * lmsPixel
8. To view the results of the simulation, the image was converted back to RGB color space. The inverse of the matrix in equation (1) above was computed on the LMS pixels with

   lmsPixel (1:3) = imageLMS (x,y,:) , this helped to grab out the adjusted pixel values of the adjusted LMS. image

   Finally the simulated image in RGB was obtained as:

   imageOut (x, y, :) = lms2rgb * lmsPixel, this function converts the LMS pixel back to RGB color space.

9. The image needed to be gamma corrected before displayed. The following command was used to achieve that:

   imageRGB = imageRGB. ^ (1/gamma)

   imageOut = imageOut. ^ (1/gamma)

10. Images were displayed using the Matlab function of "imshow" and are titled as fig. 1original image (RGB image), then fig. 2 image as seen by a deuteranopia (imageOut).
11. Daltonization algorithm was introduced here:

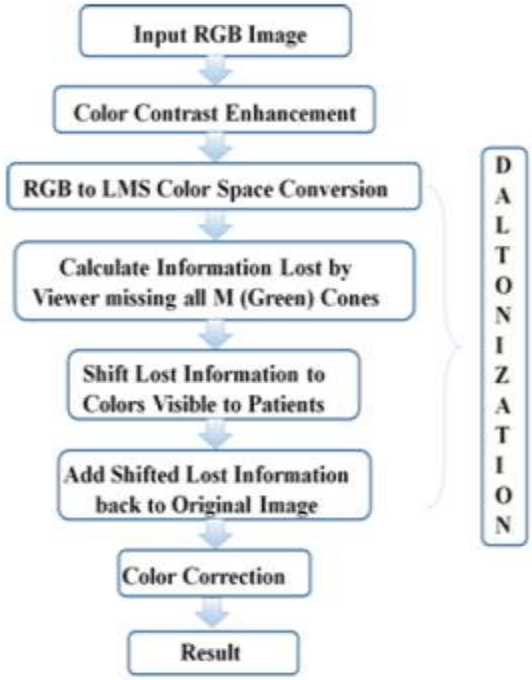

Fig. 4 Daltonization Procedure Integrated with Color Contrast Enhancement and LAB Color Correction (Source: [1])

The daltonization procedure as seen in the fig. 4 process block diagram is been described as follows:

i. Use the lost information from deuteranopia simulation to improve the original image i.e. Lost information = original image – image as seen by deuteranopia
ii. Lost information is converted from LMS color space to RGB color space
iii. Lost information is mapped to wavelengths perceived by the deuteranopia patient, i.e. long and short wavelengths via:

$$\begin{bmatrix} R_{map} \\ G_{map} \\ B_{map} \end{bmatrix} = \begin{bmatrix} 1 & 0.7 & 0 \\ 0 & 0 & 0 \\ 0 & 0.7 & 1 \end{bmatrix} \times \begin{bmatrix} R_{lost} \\ G_{lost} \\ B_{lost} \end{bmatrix} \quad (3)$$

iv. Add the mapped pixels into the original image

$$\begin{bmatrix} R_{adjust} \\ G_{adjust} \\ B_{adjust} \end{bmatrix} = \begin{bmatrix} R_{original} \\ G_{original} \\ B_{original} \end{bmatrix} + \begin{bmatrix} R_{map} \\ G_{map} \\ B_{map} \end{bmatrix} \quad (4)$$

Note that the operation in equation (3) does not tamper with the lost red and blue information, but rather spreads a proportion of the lost green into the red and blue. The new mapped RGB components are added to the original image as in equation (4). The pixel values were checked and concatenated in order to fall within the range of one and zero

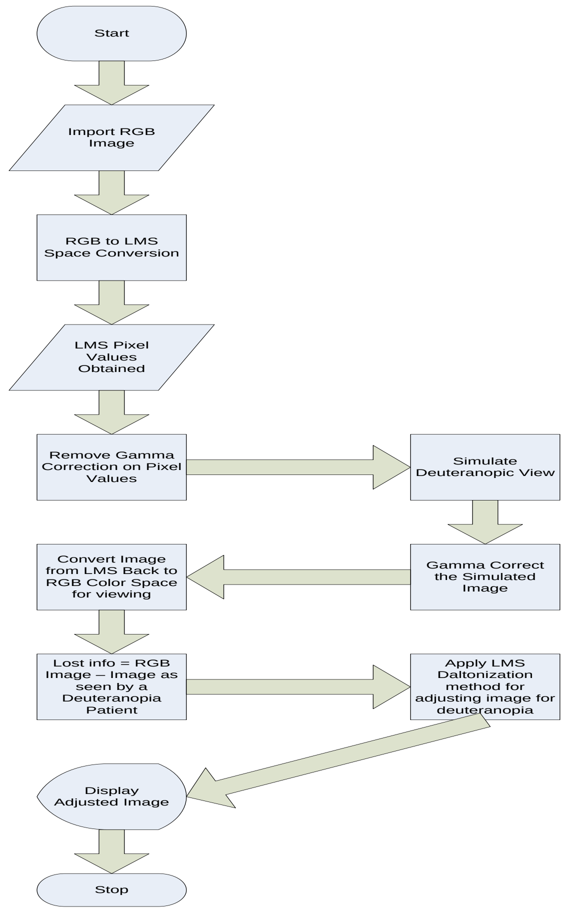

Fig. 5 Process of simulating and adjusting image color For Deuteranopia patient

3. RESULTS AND DISCUSSION

The process of simulating the view of a deuteranopia patient was adopted from [1]. This deuteranopia simulation helped to obtain the color difference (Lost Information) between the original RGB image and the images as seen by the deuteranopia patient. The color difference (lost information) was utilized in the LMS daltonization method for adjusting colors in images and the following results were obtained:

3.1 Results of Simulation of Image as Seen by Deuteranopia Patient

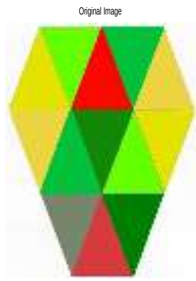

Fig. 7a Original Image

fig. 7b image as seen by deuteranopia Patient

Fig. 7c Original image

Fig. 7d Image as seen by a deuteranopia patient

The original images obtained (as in figures 7a, and 7c) from (www.rgbstock.com) were used as the original RGB images that were used for simulating the deuteranopia patient's view. The images are in the normal form i.e. only a person with normal trichromatic view can see the images in that normal form. The images as in figures 7b and 7d are the result of Simulation of the view of a deuteranopia i.e. how the person with deuteranopia vision deficiency sees the images in 7a, and 7c.

3.2 Image Color Adjustment via LMS Daltonization Method

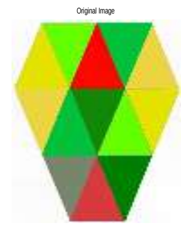

Fig. 7a Original RGB Image

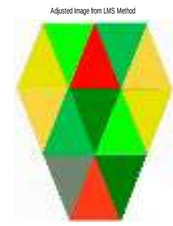

Fig. 8a Adjusted Image Color via LMS Daltonization

Fig. 7c Original RGB Image

Fig. 8b Adjusted Image Color via LMS Daltonization

Fig. 8c Original RGB Image

Fig. 8d Adjusted Image Color via LMS Daltonization

The figures in 7a, 7c, and 8c are the original RGB images, which served as the input images and whose colors where adjusted for better viewing by the deuteranopia patient. Figures 8a, 8b and 8d are the images whose colors have now been adjusted by LMS

Daltonization method, of which a slightly noticeable difference is been observed. The main difference spotted is that the red is made redder and the green becomes greener.

4. CONCLUSION:

LMS Daltonization method of adjusting colors in images for deuteranopes was adopted and analysed. This method shows how an image is been adjusted as seen by a normal person into the view of a deuteranope. This method will assist in getting images in the right perception for the deuteranope. In otherwords, the procedure will allow the deuteranope to be able to see colors that they have lost or missed due to color blindness.

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