IOSR Journal of VLSI and Signal Processing (IOSR-JVSP)
Volume 5, Issue 5, Ver. I (Sep - Oct. 2015), PP 15-20
e-ISSN: 2319 – 4200, p-ISSN No. : 2319 – 4197
www.iosrjournals.org

Image Color Transformation for Deuteranopia Patients using Daltonization

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Abstract: *Color vision deficiency is pretty common, in US about 8% of the males and 1% of females have color vision deficiency from birth [6]. People with color vision problem often have trouble in differentiating certain colors. Color vision deficient people are liable to missing some information that is taken by color. People with complete color blindness can only view things in white, gray and black. Insufficiency of color acuity creates many problems for the color blind people, from daily actions to education. The color blindness can be categorized into two different levels: green color deficiency and red color deficiency. The people with the blue color deficiency is less than 1%. Therefore the main focus of this paper is to develop a system that enables color deficient people to identify the green and red colors separately.*

This paper presents different approaches of adjusting images such that viewers suffering from dichromacy are able to recover image details and color dynamics. In specific, deuteranopia, a type of dichromacy, has been considered where the patients are unable to develop "green", or medium wavelength, cones in their eyes. Three different algorithms have been considered for that type of image processing technique which are LMS daltonization, color contrast enhancement, and LAB color adjustment techniques. Two different processing algorithms support to estimate the usefulness of these modified techniques. First deuteranopia has been simulated on both the original and processed images to view the algorithm's effects from the viewpoint of a color blind viewer. Second, the delta E value between the two images has been calculated in order to assess how prominently the image changes from the perspective of a non-color blind viewer. Color contrast enrichment provides the utmost advantage to color blind viewers, but also modifies the image most significantly for non-color blind viewers. LAB color correction has the tiniest effect in both cases, and LMS daltonization falls in between the other two techniques.

Keywords: *Color blindness, dichromacy, daltonization, enhancement, RGB, LMS, color space, wavelength, hue, delta E.*

I. Introduction:

Due to the massive use of colors in multimedia contents to convey visual information, it becomes more important to perceive colors for information interpretation. Unlike people with normal color vision, people with color deficiency have difficulties discriminating certain color combinations and color differences. Hence, multimedia contents with rich colors that can be well distinguished by people with normal color vision, may sometimes cause misunderstanding to people with anomalous color vision.

The human color vision is derived from the response of three cones (or photoreceptors) contained in the retina of the human eye. Normal color vision is known as trichromatic. It is initiated by the absorption of photons in three classes of cones, whose highest sensitivities lie in the three regions of the spectrum, the long-range wavelength (L), middle-range wavelength (M) and short-length wavelength namely. Adjustment of one of three classes of the cone pigments invokes Color Vision Deficiency (CVD). There are basically three types of Color Vision Deficiency. The first type is called dichromacy, while the most common is known as anomalous trichromacy. There may also happen an extreme case, named achromatopsia. In this study, only dichromacy has been addressed. Studying in deep the deficiency of dichromacy, it has been found that there are three basic types of dichromacy which are protanopia, deuteranopia and tritanopia. All colors visible for trichromacy (normal vision) are shown as two monochromatic hues. In protanopia the spectrum is seen in tones of yellow and blue and in deuteranopia there confusion of red and green. Relatively rare is the tritanopia, where the spectrum is seen in tones of red and green [7]. As an example, a color image with different vision problems is shown in figure (1).

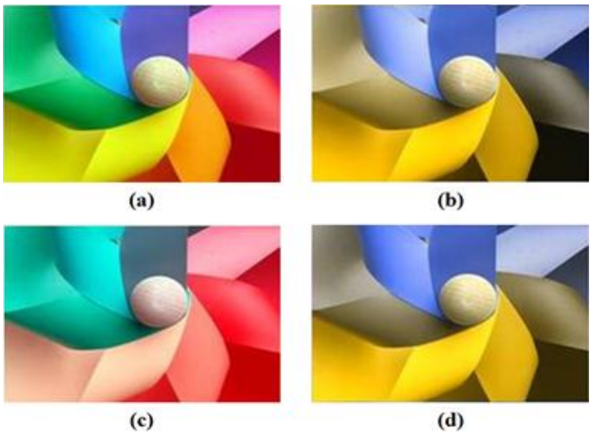

Figure 1: The figure of a color image with different vision problems (a) Normal color vision, (b) Green-blindness (Deuteranopia), (c) Blue-blindness (Tritanopia) and (d) Red-blindness (Protanopia).

To enhance the comprehensibility of images for color-deficient viewers, daltonization is proposed in [6] to recolor images for dichromats. In [8], the authors first increase the red/green contrast in the image and then use the red/green contrast information to regulate the brightness and blue/yellow contrast. In [9], Ishikawa *et al.* described the manipulation of webpage colors for color-deficient viewers. They first decompose a webpage into a hierarchy of colored regions and determine “important” pairs of colors that are to be improved.

The objective function is then defined to retain the distances of these color pairs, as well as to minimize the level of color remapping. This method is further extended to deal with a full-color images in [10]. On the other hand, Seuttgi Ymg *et al.* [11] proposed a method to modify colors for dichromacy and anomalous trichromacy. For dichromacy, a monochromatic hue is transformed into another hue with a lesser saturation, while for anomalous trichromacy, the presented method tends to keep the original colors. In [12], according to Rasche *et al.* a linear transformation has been used to convert the colors in the CIELAB color space and enforced proportional color differences during the remapping.

Basically, all the above-mentioned works may produce images that are more understandable to color-deficient viewers. However, recolored images may look very abnormal to viewers with normal vision. From the application point of view, images in the public place may be instantaneously detected by normal people and color-deficient people. For example, in a public transport system, many advertisements and traffic maps are carried in colors. Without concerning the needs of color deficiency, color-deficient people may face difficulty in understanding the image contents. On the different, if only concerning the requirements of color-deficient people, then these recolored images may look irritating to normal observers. Hence, in this paper, a recoloring algorithm has been developed to automatically construct a transformation to uphold details for color-deficient viewers while maintaining naturalness for standard viewers.

II. Methodology:

The algorithm used in this project is dependent on several steps which are explained one by one. The process flow diagram is shown in figure 2.

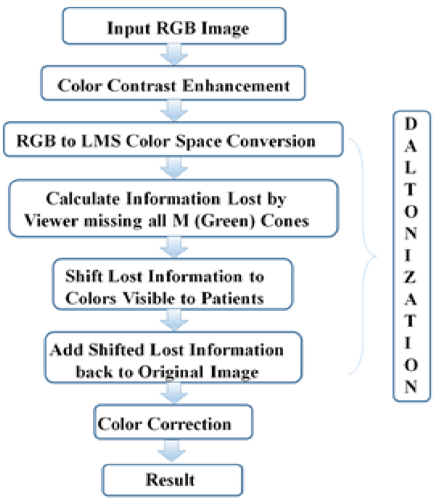

Figure 2: The figure represents the process flow diagram of the overall project

A. Color Contrast Enhancement

This process begins by considering the total pixels in the original image in order to provide room for pixel values to be increased and to remove the green and blue components leaving only the red component. For each pixel, three operations occur. The initial step is to increase the rate of the pixel's red component relative to pure red. Reds further from pure red are amplified meaningfully while reds already very close to pure red are only slightly increased. The green component of each pixel is operated next by applying exactly the same logic as used on the red components. Finally, for the pixels which are mostly red, the value of the blue component is reduced. For pixels that are mostly green, the blue component is increased. Thus an image is taken to enhance the RGB values in order to keep contrast between red and green. An algorithm has been introduced for this method where first, increase the reddish components for those images which are less red have been increased and keep constant the red color for those which are naturally red are kept constant. The image contrast enhancement algorithm is shown in figure (3).

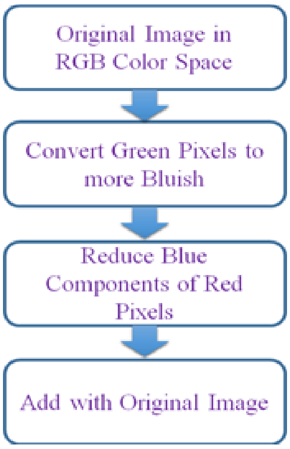

Figure 3: The figure shows the image color enhancement process

B. Daltonization:

Daltonization is a technique for adjusting colors in an image or a sequence of images for improving the color perception by a color-deficient viewer. Conversion of RGB coordinates into LMS, a color space suitable for calculating color blindness as it is signified by the three kinds of cones of the human eye, named after their sensitivity at wavelengths; Long (564–580nm), Medium (534–545nm) and Short (420–440nm). In this process, the image is first converted into the LMS color space. Since in matlab 'imread' function reads in images in the RGB color space, the image must be transformed from RGB to LMS. Luckily, the operation is a simple linear matrix multiplication operation. The operation, applied to every pixel of the image, produces a new set of pixels whose information is now distinct for the LMS color space. Now that the image presents in the LMS color space, information related with the M cone has been removed and replaced with information observed by L and S cones. Now that the medium wavelength information has been detached from the image and the new M pixel has been filled properly, deuteranopia has been replicated. In order to view the results, the final image is to be converted back to the RGB color space by repeating the matrix multiplication on each LMS pixel.

C. Delta E:

The second tool needed for measuring the effect of color blindness compensation techniques is Delta E. Delta E is a standard metric for calculating color alteration. This metric has been chosen to determine the level to which the algorithm changes the original image, i.e. negatively disturbing the image as seen by normal viewers. The Delta E algorithm is another simple procedure, designed for each pixel of an image. This function considers two images in order to estimate the color difference between them. Both images are first transformed from RGB to the LAB color space. Matlab contains a built in function that allows the user to change between these two color spaces; no such function exists for the prior RGB to LMS conversion. LAB pixel values hold lightness, L, and color coordinates A and B, based on a flattened version of the standard XYZ color coordinate space. The actual Delta E value for each pixel is measured as shown in equation (1).

$$\Delta E \sqrt{\left\{(L_2 - L_1)^2 + (A_2 - A_1)^2 + (B_2 - B_1)^2\right\}} \quad (1)$$

D. LAB Color Correction:

This algorithm, suggested in [13], actions to modify reds and greens of an image to enhance the color contrast and to clear for a color blind viewer. What sets this develop apart from RGB color conflicting is that it is executed in the LAB color space.

The algorithm generally functions as follows. The original image pixels are transformed from RGB to LAB color space. The first procedure is on each pixel's A component, where a positive A means it is closer to red and negative A means it is closer to green. Just as in RGB Color Contrasting, this A value is adjusted relative to its maximum, making positive values a bit more positive and negative values a bit more negative. Again, in each pixel the B component is adjusted relative to how green or red it is in order to bring out blue and yellow hues in the image. Finally, L, the brightness of the pixel, is also adjusted relative to the pixels A value. The image is rehabilitated back to the RGB color space and concatenated to ensure pixel values lie between zero and one.

As with RGB Color Contrasting, this algorithm absences clear theoretical basis. It is also based upon experimental processes relying mostly on trial and error in the presence of a color blind person. An implementation with these experimental values is found in [13].

III. Motivation:

Color blind viewer experiences many problems in everyday life which normally sighted people are just not aware of. Problems can arise in even the most simple of actions including selecting and preparing food, gardening, sport, driving a car and choosing cloths. Color blind people can also find themselves in trouble because they haven't been able to pick up a change in someone's mood by a change in color of their face, or not noticed their child getting sunburnt.

A few examples of daily life problem faced by the color vision deficient people have been mentioned. Most red/green color blind people won't know if they have cooked a piece of meat rare or well done and they are unlikely to be able to tell the difference between green and ripe tomatoes or between ketchup and chocolate sauce. Color blind people often try to eat unripe bananas because they can't tell the difference between a green unripe banana and a yellow ripe banana – to them because both of the colors are the same shade they think they are the same color. Color blind people can get quite cross with electrical goods which have red and green LED displays to indicate either that a battery needs charging or the machine is on standby. An example might be a handheld games console with an indicator light which changes from red to green depending upon whether the unit is fully charged or needs recharging. This can be very frustrating, particularly for a child.

In the UK color blindness is not considered to be a disability, but in other cultures color blindness is regarded as a defect. In Japan, for example, color blind people are excluded from a number of careers and in many communist countries color blind people are not permitted to drive because they are not always able to read colored lights correctly.

Relatively little research has been done into the effects of color blindness in everyday life. This is because until now the general population has been unaware of the difficulties that color blindness can cause on a daily basis. UK society has therefore on the whole treated color blind people no differently to people with normal color vision. Color blind people learn to manage quite well but this does not mean that their needs can be ignored.

The Color Blind Awareness organization aims to increase awareness of the needs of color blind people in everyday life. Some areas of industry, transport services and the armed forces are probably the only areas where it is accepted that color blindness could potentially cause problems and it is recognized that there are certain types of job which the color blind are not suited to. Industry is also forced by legislation to account for color blind people in the workplace but only for safety reasons.

Sadly most business people don't take account of whether all of their target audience can read or understand most of the documents or presentations which they produce.Amazingly hardly any businesses have yet to realize that they may be missing out on about 5% of their target markets because they are not aware of the effects of color blindness.

By far the most important oversight is the plight of color blind school children who are left to struggle in the classroom due to lack of awareness of the effects of their disability by both their parents and teachers. Even the India Government does not currently support color blind children in schools because in its opinion color blindness is not a Special Educational Need. Teachers are not given any training on the issue of color blindness or upon how to treat color blind children in a school environment.

Color Transformation of image is basically the modification of the image color in the other one. If an algorithm has been developed that will help the color deficient people to differentiate and to identify the various colors then the above mentioned problem of the color blind viewer may be reduced. Many researchers had worked in this field to reconstruct images for the people suffering from color blindness and to enhance image contrast. Many methods have been introduced to transfer the color of image for the color blind viewers [5]. Daltonization is a procedure for adapting colors in an image or a sequence of images for improving the colorperception by color-deficient viewers. In this research three algorithms are implemented for this Daltonization method.

IV. Result:

The result shown below helps us to identify the change in the color contrast which takes place while modifying the image for color blind viewers. Here an algorithm has been implemented in matlab to modify an image seen by a normal person to an image seen by a deuteranopia patient who have problem to distinguish basically green and red color. An image that includes red, green, blue and yellow colors have been chosen to show the effect of this algorithm according to vision of a normal person and a deuteranopia patient. Here the original image and image seen by a deuteranopia patient shown in figure 5(a) and figure 5(b) respectively. The original image consists of four different colors which are red, green, blue and yellow. It is observed that a normal person can distinguish four different colors but a person affected by deuteranopia can't distinguish red and green. So first this original image is taken in RGB color space shown in figure 5(a) then the color contrast enhancement shown in figure 5(c) has been done. After enhancing the contrasted image is used for LAB color correction for the deuteranopia patients. The LAB color corrected image is shown in figure 5(e). In the last step the LAB color corrected image has been converted to LMS matrix and the image has been adjusted by daltonization method. This method helps to distinguish the different colors shown by the deuteranopia patients in the same wavelength (shown in figure 5(f)). Again for better resolution and to enhance the quality of the recovered image and to make more clear the differences between colors, a process known as segmentation can also be done on the image but here we proceed in the above method. Finally modified image is shown in the figure (h). Now the difference version of image seen by deuteranopia patient before and after image processing can be compared by figure (b) and figure (h) respectively.

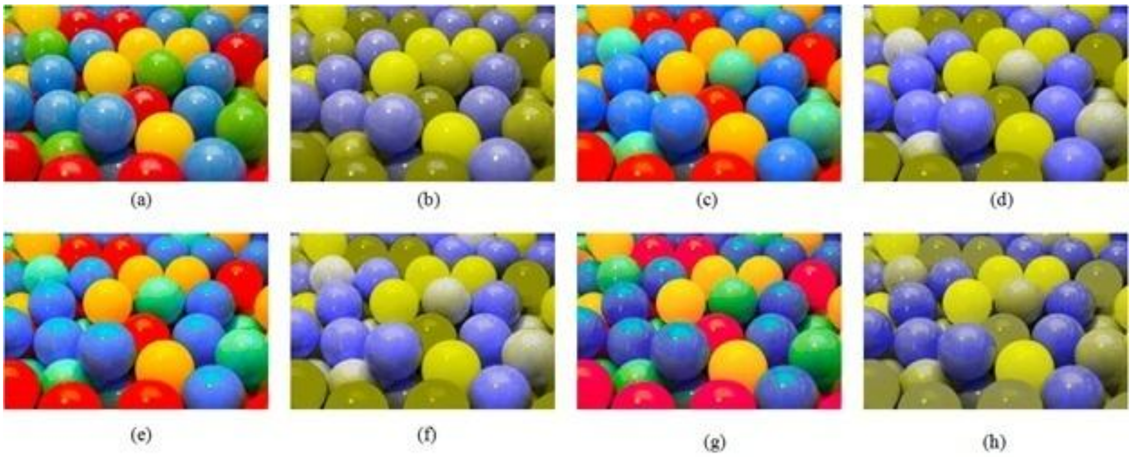

Figure 5: (a) Original image; (b) Image as seen by Deuteranopia patient(c) Contrasted image, (d) Contrasted image as seen by Deuteranopia patient.(e)Corrected image, (f) Corrected image as seen by Deuteranopia patient(g) Image adjusted for Deuteranopia patient; (h) Adjusted image seen by Deuteranopia patient

V. Discussion:

We consider an image as seen by normal people and then we try to visualize the image from the perspective of a color blind viewers.In the following step the image has been transformed step by step and in each stepthe image has been modified so as to bring it to an intermediate stage where it is partially visible to the Deuterapeniapatient.As we are not affected by the disease we find that there is a color shift between the original image and the adjusted one. Besides the color shift we find that pixels also differ due to their variations in the intensity. Now comparing Fig (b) and Fig (h) we can understand how the color shift by these algorithms such as red and green color can be distinguible by the deuteranopia patient.

VI. Conclusion:

The previous techniques show that the contrasting technique changes the image drastically for both color blind and non-color blind viewers.

Doing this project we get the opportunity to see the world through the eyes of someone suffering from color blindness and explores the effectiveness of different attempts to improve their world. It is exciting and humbling to learn from the perspective of others.

VII. Future Scope:

Recently, researchers tried to find a more effective and efficient way to solve the optimization problem in this paper, an intelligent daltonization algorithm for the people suffering from Dichromacy is proposed. More specifically the LMS technique is suggested. The principals of this method could be modified in the future to provide better visual information in a color image for people that are affected from other color deficiencies. To implement the LMS method is our next step. As the patients have some deficiency of color cones in their eyes, so they can not recognize the specific colors.

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