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An Assistive Model for ICT Applications for Color Blindness

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Abstract

Color blindness limits people from viewing true colors with their naked eyes. A color blind person faces various challenges in everyday life, be it from identifying the different traffic lights, choosing clothes, or using color dyes for concoction. A color blind person face problems to distinguish the right color in such cases. Similarly, colorblind struggles to find a software application suited to overcome their color impairment. Usually applications provide a particular feature that tends to provide a solution for a type of color blindness that might not be suitable for people having different types of color blindness. In this paper, we proposed a model which highlights mandatory features that software developers should keep in mind while developing color blind applications. This model will facilitate developers to address challenges faced by color blind by incorporating proposed features.

Keywords: Color blind application, color blindness, color blind application features.

Introduction

The recent development in the field of e-health provides deep understanding of ICT application to health domain ranging from improving the diagnosis to monitoring disease parameters to provide assistance to the disable community[1]. Inability of an individual to either see or distinguish different colors in the spectrum is known as color blindness. The lighting conditions should be considered as normal to identify a person as color blind. Different studies have been done to identify the effected populations to obtain figure at global level[2]. The impaired population is around 8% males while 0.4% females according to a study done in 2011 by BUPA. Color blindness which is inherited is observed in the restricted gene pool. This visual impairment is categorized as mild disability.

The visual system of humans are based on sensors cells known as photoreceptors which are part of retina in the eye. There are two types of photoreceptors which are known as rod and cone cells. The rod cells are sensitive to the illumination and are used to perceive the brightness of the scene. The perception of color is achieved by Cone cells. These are sensitive to the wavelength and get activated at different wavelengths. The human eye contains three types of cone cells (L M and S) which are activated at different wavelengths. Normally they function better in relatively bright light. These cells are responsible for the color blindness if defected. The L-cone gets activated at longer wavelengths (yellow-red), the M-cone are used to detect medium wavelengths which corresponds to green and the short wavelengths which corresponds to blue color in the spectrum are detected by the S-cone[3]. The human brain perceives the colors in the scene through the ratio of the signals obtained from the cone discussed above. Color blindness is either caused due to a defect in the cones or due to their absence[4]. Color blindness is generally categorized in four major categories namely protanopia, deuteranopia, tritanopia and monochromacy.

Protanopia: It is due to the complete absence of retinal photoreceptors and cause red-green color-blindness[5]. Figures-1a and 1b, shows a comparison of normal vision and protanopian color blindness as a pie-chart.

Figure-1a
Normal Vision

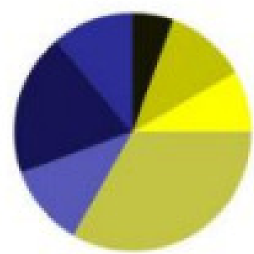

Figure-1b
Protanopia

Deuteranopia: It is found in people who lack green receptors in the retina of the eye. Figures-2a and 2b, shows a comparison of normal vision with deuteranopian color blindness as a pie-chart.

Figure-2a
Normal Vision

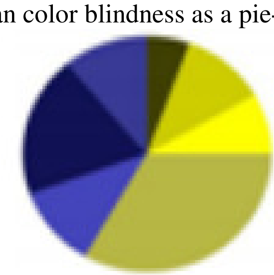

Figure-2b
Dueteranopia

Tritanopia: Lack of blue photoreceptors causes Tritanopia color blindness which is a blue-yellow variation. Figures-3a and 3b shows a comparison of normal vision with tritanopian color blindness as a pie-chart.

Figure-3a
Normal Vision

Figure-3b
Tritanopia

Monochromacy: It is the highest level of color blindness in which an individual is unable to see any color instead colors appear as shades of grey. Figures-4a and 4b shows a comparison of normal vision with monochromacy color blindness as a pie-chart.

Figure-4a
Normal Vision

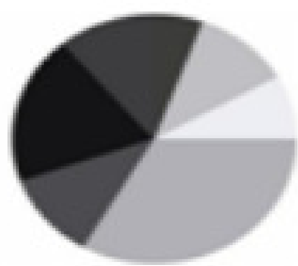

Figure-4b
Monochromacy[6]

In this paper the proposed model emphasizes features such as Daltonizer, Color Identifier, Harmonizer, and Simulator. Software developers could use those features in designing a generalized application. Considering different types of Color Vision Deficiencies (CVD), the proposed model could be beneficial for people having CVD, as it could enable them to easily interact with the surrounding environment.

Literature Review: Daltonization Method: According to the authors' the color perception of an image is improved[7] and it is a color conversion method. The color of the image is adjusted to a particular color value, so the visual perception of the image can be tolerated by the people with CVD. Several methods have been proposed for this purpose like Vischeck Daltonization method and Fidaner Daltonization method[8].

Simulation System of Color Blind Glasses by Image Processing: The authors' explain how we can personalize different tinted lenses for glasses which can help color blind to distinguish color. Their system finds a suitable color of lenses with the approach of normal vision chromaticity[8].

Color Identifier: This method is used to identify color of an object, it either searches in a database of images of colors and matches it to the current image, or matches pixel values from a given data set, also referred to as template matching, color object tracking etc.

Hertfordshire Color Blind Emulator: In this paper the authors' have developed an emulator named "HCBE". This emulator takes an image and adjust the color values such that a color blind person could properly identify the colors in the image. All four types on color blindness are considered in this emulator and it is chosen based on the particular individual[6].

Harmonizer: This method is used to harmonize colors and helps colorblind people to choose the right colors to wear by using different combinations of colors. The colors are normally selected from a database containing wide range of colors.

Methodology

Colblindor is an online platform created by Daniel Fluck who is also the author of "Color Blind Essentials"[9]. On this online forum the color blind people interact with each other discussing features related to color blind applications, and which feature they would like to see in an application. After interacting with the color blind people it was evident that there is no comprehensive application available. The applications available only provide a particular feature which is not helpful in fulfilling the essential needs of the color blind. Therefore by gathering information from that online platform we were able to create a comprehensive model.

Model: Our model comprises of four major features, namely Color Identifier, Daltonizer, Simulator, and Harmonizer.

Color Identifier: This feature identifies the color for the user from an image. It receives an image from the camera input, and then the user can select the region of interest in the image. Once that is done, the region of interest RGB values shall be calculated. It shall then compare the RGB values with the values of RGB in the database. By RGB we mean Red, Green, and Blue values. Each value is on a scale of 0 to 255.

Table-1
RGB Values

Color	Red	Green	Blue	Sample
Black	0	0	0	
Blanched almond	255	235	205	
Blue	0	0	255	
Blue violet	138	43	226	
Brown	165	42	42	
Burlywood	222	184	135	

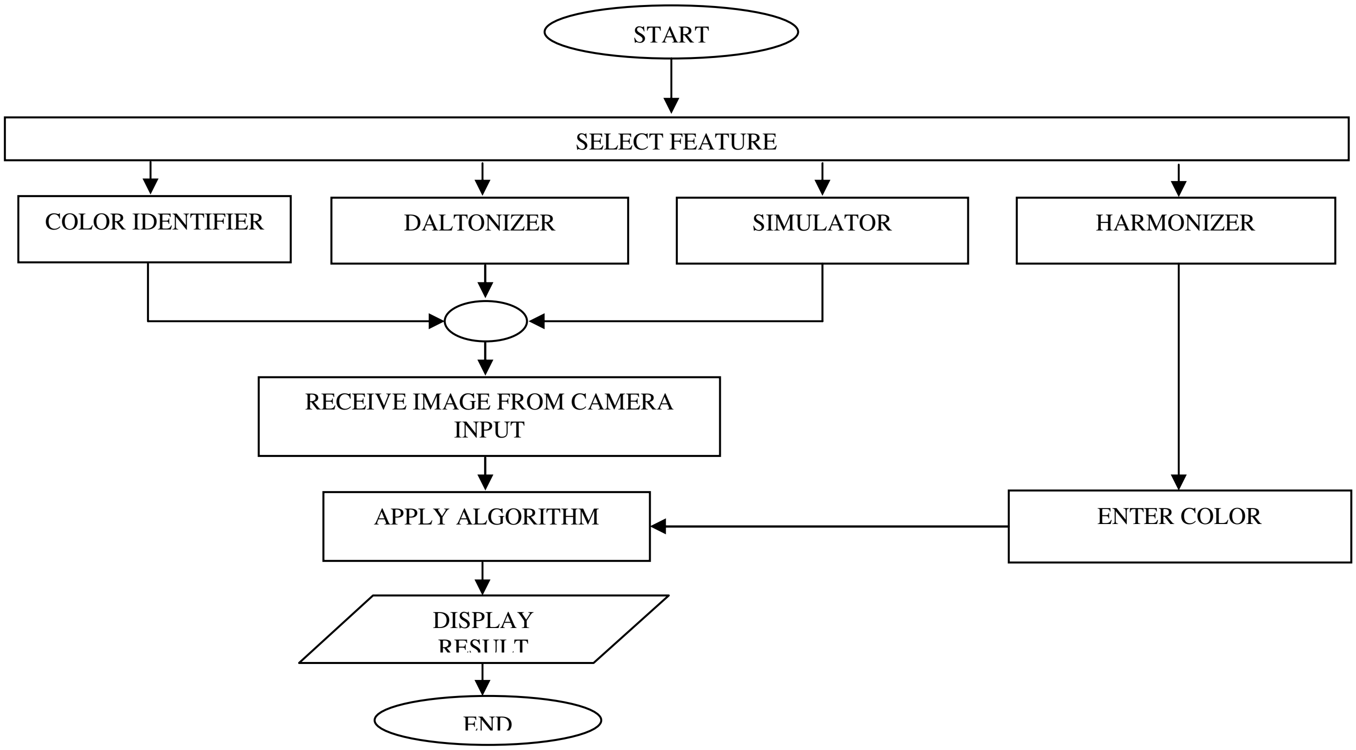

Figure-5
Proposed Model

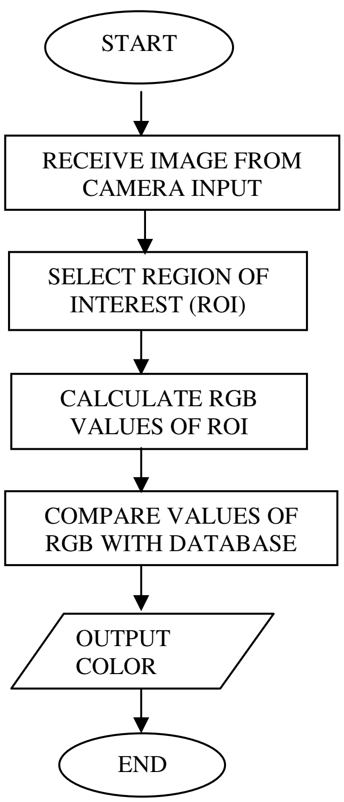

Figure-6
Algorithm of Color Identifier

Daltonizer: This feature daltonizes the image taken from the camera input which will enhance the color perception of an image. This is done by increasing the intensity of the red and green color. Using daltonization one is able to see variations in an image. Here is an example of the Gauguin Painting:

Figure-7
Gauguin Painting Daltonization Example

In the figure-7, images are numbered from 1 to 4, where 1 is the original image, 2 is the perceived image by the protanope, 3 is daltonized image of the original image and 4 is the daltonized image perceived by the protanope[10].

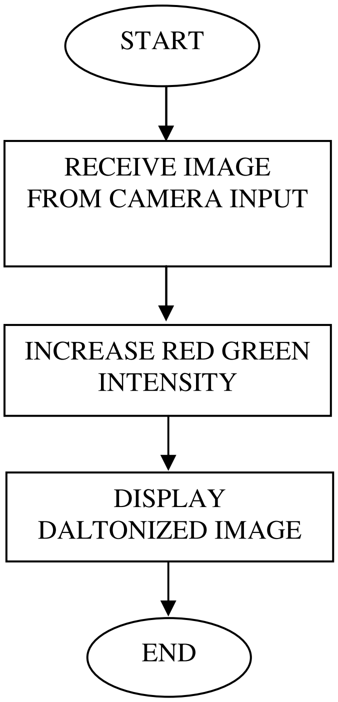

Figure-8
Algorithm of Daltonizer

Simulator: The simulator converts an original image into images perceived by Protanopia, Duetranopia, and Tritanopia. This will help a color vision person to easily understand how the color blind sees the particular image. To achieve this, cone values are modified using a matrix based linear algorithm proposed by Capilla. A conversion matrix is used to convert RGB values to LMS values; the conversion also depends on the type of color blindness. A transformation matrix, such as the one proposed by Viénot can be used to exactly simulate the values of the three cones. Viénot's transformation matrix used to convert RGB values to LMS values is defined as follows:

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = [\text{RGB\_to\_LMS}] \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} \begin{bmatrix} 17.8824 & 43.5161 & 4.11935 \\ 3.45565 & 27.1554 & 3.86714 \\ 0.0299566 & 0.184309 & 1.46709 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

L= 17.8824R + 43.5161G + 4.11935B (3)

M=3.45565R + 27.1554G + 3.86714B (4)

S= 0.0299566R + 0.184309G + 1.46709B (5)

Once the modification of the L, M, or S photoreceptor values are obtained, for a predefined type of color blindness, the RGB values are calculated from the LMS color values. To perform this conversion reverse transformation matrix algorithm of the Hertfordshire Color-Blind Emulator (HCBE) could be used. For Protanopia color blindness, the L photoreceptor values will be modified while for the Duetranopia color blindness the M photoreceptor values will be modified. To deal with Tritanopia, modification is done in the S photoreceptor values. Finally the result will be obtained as

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = [\text{RGB\_to\_LMS}]^{-1} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (6)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} \begin{bmatrix} 0.080944 & -0.130504 & 0.166721 \\ -0.0102485 & 0.0540194 & -0.113615 \\ -0.000365294 & -0.00412163 & 0.693513 \end{bmatrix} \begin{bmatrix} L \\ M \\ S \end{bmatrix} \quad (7)$$

R= 0.080944L -0.130504M + 0.166721S (8)

G= -0.0102485L + 0.0540194M – 0.113615S (9)

B=-0.000365294L-0.00412163M+0.693513S (10)

In the figure-9, the images are numbered from 1 to 4, where 1 is the original image, 2 is the perceived image by the protanope, 3 is the perceived image by the deuteranope and 4 is the perceived image by the tritanope.

Figure-9
Simulation

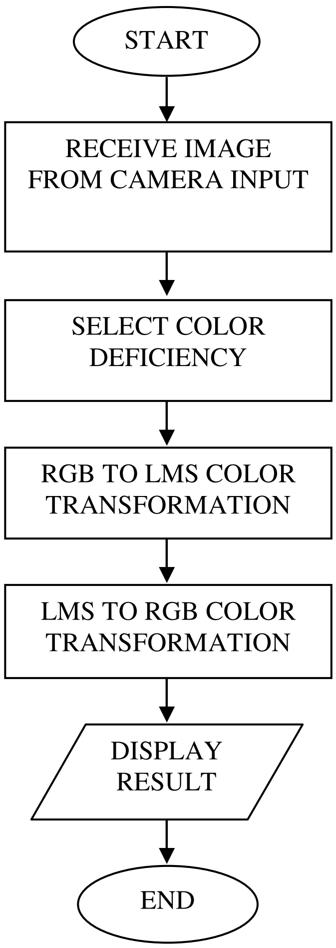

Figure-10
Algorithm of Simulator

Harmonizer: This feature is used to harmonize colors for the user. Name of the color shall be taken as input from the user. The harmonizer will then present all the color harmonies related to the color. These harmonies are basic color chords based on the color wheel which are as follows:

Complementary: Opposite colors on the color wheel are known as complementary colors (figure-11).

Analogous: Colors which are next to each other on the color wheel are analogous colors (figure-12).

Traid: The colors that are regularly spaced in the color wheel are traid colors (figure-13).

Split-Complementary: For the base color, it uses two adjacent colors to its complement (figure-14).

Rectangle (tetradic): Four colors are arranged in two complementary pairs (figure-15).

Square: Four colors are evenly spaced around the color circle; it is similar to the rectangle (figure-16).

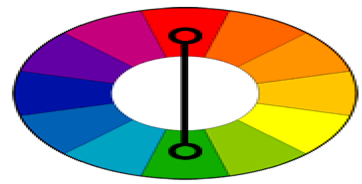

Figure-11
Complementary Color Wheel

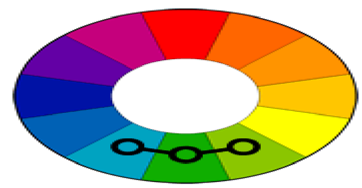

Figure-12
Analogous Color Wheel

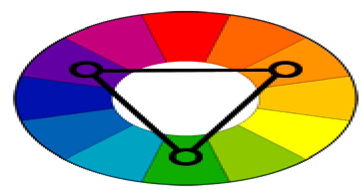

Figure-13
Traid Color Wheel

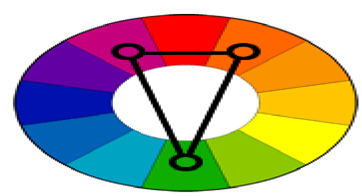

Figure-14
Split-Complementary Color Wheel

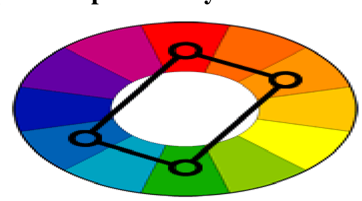

Figure-15
Rectangle (Tetradic) Color Wheel

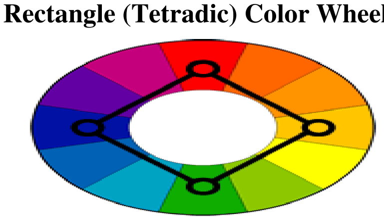

Figure-16
Square Color Wheel[11]

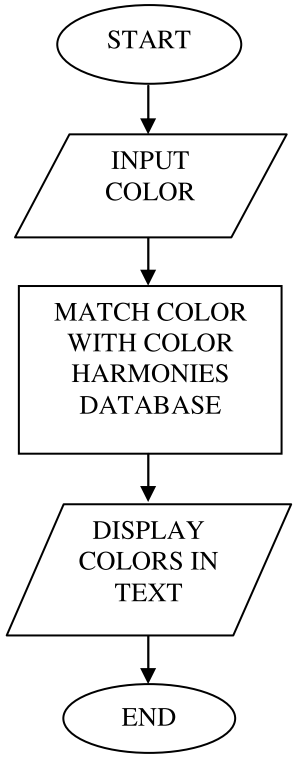

Figure-17
Algorithm of Harmonizer

Conclusion

The data analyzed and incorporated into the model concludes that this assistive model will enable software developers to create comprehensive ICT applications for color blindness. The features discussed in the model can further be improved with more efficient algorithms in future.

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