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Efficient Image Re-coloring Mechanism for Color Vision Deficient (CVD) Persons

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***Abstract*— Color blindness is the state of decreased ability to identify differences between colors. In order to help the persons having color blindness the colors in the images can be changed so that the persons can be able to recognize the colors. The process of recoloring of images is proposed which changes the colors in the images without affecting the originality of the image. The proposed approach identifies the colors in the images and then clusters the colors and finally color transformation is applied and the similarities were measured. The clusters were extracted from Fuzzy-C means clustering algorithm. The performance of the process is measured with the help of the naturalness and perceptibility. In the color identification step based on the color blindness of the person the color is identified from the RGB image. If the person contains red deficiency the red color regions from the images were alone identified. Similarly for green and blue color deficiency the color regions were extracted from the images. The performance of the process is measured based on the naturalness and perceptibility of the resulting color transformed image. The values were calculated based on the difference between the original RGB image and the transformed image.**

***Index Terms*— Color Blindness, Matlab image processing, color transformation, FCM clustering, Transformation matrix, perceptibility, Color Vision Deficient (CVD).**

I. INTRODUCTION

Colors are the visual perception of human eyes. When the perception property is malfunctioned, then it leads to color blindness. The image processing is an evolving technology that enables the researchers to yield better aid to the color blinded people. The color blinded people have difficulty in perceiving either one or more of the RGB colors. In this world, approximately 8% of the male and 0.5% of female population have the color vision deficiency. Out of these,

- 56% of people have all color blindness, medically termed as Deuteranomaly.
- Protanomony, 15%
- 14% of Protanopia
- 13 % of Deuteranopia

Tritanomaly and tritanopia is also a type of color blindness that is rarely found among the persons. The requirement of these CVD population becomes mandatory to enable them to perceive colors naturally. Color blindness is most prevalent impairment of vision that makes the person difficult to understand colors. In this digital era, multimedia has enriched the Quality of Service (QoS) in terms of resolution of colors. The color blinded people were not fortunate to view them with ease. The evolving image processing technologies have lend an aid to overcome their difficulty. Re-coloring is one such concept that helps the Color Vision Deficient (CVD) people. However along with the advantage, the re-coloring has the disadvantage of color transformation module. The transformation modules always have to face the following challenges such as

- Dimensionality information loss
- Issues on gamut mapping

If an image is mapped from the multispectral data to RGB or from RGB to color blinded person, the dimensionality gets reduced. This leads to the concept of metamerism. It is an effect that maps different color vectors to same color in the target space. While in case of Gamut mapping, the dimensionality of source and target remains same. However different sub spaces are defined over the multidimensional space. This will produce significant change from the original image. Hence the transformations must be performed by considering its effect of information loss. Thus recovering of those information becomes crucial. This involves various techniques. The aim of the paper is to give indiscriminate view to the people who have difficulty in discrimination of red and green colors. Daltonization is a procedure of color adaptation in an image to improve the color perception for a color-blind viewer. Color blind person can perceive only a narrow spectrum of colors. Hence transformation plays a vital role to display the original input contents in its own form is updated with the colors extracted based on the color deficiency of the particular person. There exists a wide class of transformation techniques between color spaces for various image processing problems. Preserving the salient features of the original image is mandatory for providing a quality transformational process.

The proposed novel color transformation approach helps both normal viewer as well as the CVD viewer to interpret the image with perceivable colors natural after re-coloration. The system architecture is designed in such way that the three channels are sub-divided soon after acquiring the image to be processed. The input image is read and the color deficiency of the CVD person is identified through the color identification module. The input RGB image is then separated accordingly in to the channels. The color is extracted with respect to the deficiency of the person. The colors are then clustered based on Fuzzy C Mean clustering and transformation is performed over the image. The transformation operation is handled with care to avoid information losses studied in the state-of –art techniques. Hence a transformation matrix is formulated and the image is transformed with efficient image reproduction.

The main objective of the proposed method is

- To identify and change the color of the input image
- To cluster the colors of the input image
- To transform the input images based on the transformation function of the image.

The following part of the paper is organized as follows. The prior works related to the re-coloring mechanisms are discussed with their methodologies and challenges associated with the transformation modules of those systems in section II. Section III gives a detailed information on the proposed image processing modules and their working. Section IV gives the evaluation which is supported by the simulation screen shots. The concluding words are provided in section V.

II. Related Work

Various research have been presented with various techniques. Out of which few were discussed.[1] performed adaptive color rendering process on map reading by the CVD persons. Pseudo color palette generation technique was extended with selection of proper color palette. The process retained the canonical colors of the objects.[2] presented a contrast based color conversion for avoiding the emotion distortion associated to that change in CVD persons.[3] illustrated a novel recoloring mechanism for color vision deficiency. The mechanism involved introducing color transformation that adjusted the component values of HSV color space. This technique was applicable for people who were red-green color deficient. [4] utilized the dynamic color transformation technique to improve the color perception of a CVD viewer. The work introduced daltonization algorithm for efficient transformation. The work produced good perceptibility and low computational complexity.[5] provided with the real-time solution to the CVD persons with a ubiquitous gadget design. This gadget was named “Chroma” that helped the color blind individuals to distinguish the colors, which they could not perceive. The gadget allowed the users to see real-time filtered image of the current scene. However the deployment of “Chroma” was not successful due to their increased power requirement to process and camera maintenance.[6] modelled spectral based system to work feasible with dichromacy and dichromacy. The model extracted the lost spectra of data as a difference matrix. The optimal spectral shift was carried out to increase the spectral visibility and to decrease the visual gap. The key novelty of the proposed model was

- Basic lost spectra acquisition
- Creation of projection matrix over the spectral spaces.
- Opponent Color Space (OCS) introduction
- Difference value of lost spectra calculation
- Daltonization (Color blindness correction)

Color blind persons have difficulty in perceiving not all colors, but certain colors. [7] presented the hue preserving image enhancement technique using Particle Swarm Optimization (PSO). The work involved introduction of intensity transformation function through which the quality of the image was measured. The rescaling was also performed to eliminate the gamut problem. The presented technique was experimented and compared their performance against hue-preserving color image enhancement without gamut problem (HPCIE) and a genetic algorithm based approach to color image enhancement (GACIE).Information lo loss always followed transformation process. [8] presented cluster based approach, which helped to optimize the transformation process. This method preserves the information and maintained natural mapping feasible.[9] discussed about the novel real time video recoloring algorithm for color blind persons. This new algorithm maintained temporal color consistency. The work utilized the fast color modification method to discriminate the colors viewed. The system involved less complex computations.[10] designed Laplacian colormaps to address the issue of information loss in a transformed image. The proposed method provides the generalized framework to preserve the structural information. The commutative property of the laplacian color maps were studied and implemented to provide image optimization for the color deficient viewers.[11] presented a novel daltonization method to re-color the image segments and to enhance the image perceiving quality. In the proposed work, since each segment was mapped separately, there exist the balance of re-coloring mechanism. The work was experimented with eight CVDs and found to be efficient and more natural.[12] used a color palette GUI to enable the user to select the color for editing and recoloring an image. However this was not adapted for colorblind persons. [13] created an application adaptable over smartphone for assisting the color deficient users. The touch screen was traced upon by the used to produce an enhanced contrast image to enable them to perceive image in the normal viewing condition. The app aided the user to carry out his daily tasks. The app used a transformation technique by which the data is sheared along the parallel lines in which the user’s cone sensitivity was affected.[14] presented the causes and limitation of color blindness and also discussed the possible solutions to deal with the issue.

[15] proposed an improved recoloring tool for providing aid for vision deficient web users. The proposed methodology provided reduced time complexity. They introduced a novel tool named FBRecolor which influences the relation between foreground and background colors. Thus the pair-differentiability, subjectivity and the naturalness were preserved. The work was implemented successfully even for the problematic websites with good color contrast ratio.[16] presented Self-Organizing Map (SOM) based clustering for helping the color blind persons to discriminate between the colors. The work analyzed the map structure using color conversion algorithm and worked efficiently. [17] presented a novel multilayer neural network based digital image color

conversion algorithm. The presented color conversion approach involved three layers of processing namely

- Image color conversion Layers
- Color blindness perpetual model Layers
- Color discrimination layers

This framework is modelled with the relative learning between input image and their discriminations.[18] preserved the color sequence by identification of important hue data and approximated the curve corresponding to the grid of values. Then the curve was mapped to the sequence of gray levels. This provided the undistorted resultant image. The final result was produced by combining the saturation values in the output with the original intensity channels.[19] analyzed the street map color scheme and improved the scheme for color vision deficient users. The overall appearance was preserved while the color adjustments were made.[20] addressed the common problems of color-blindness specific processing such as

- Gamut mapping
- De-colorization
- Image optimization
- Loss of original image information
- Color ambiguities
- Image distortions

The proposed method involved image specific transformation using laplacian Colormaps. They captured and preserved the structural framework of an image. The jointly diagonalizable eigenvectors were utilized. The relative conclusions were drawn and hence the mapping was performed between the obtained diagonalized results and the matrices commutativity. The image structure descriptors were obtained using the laplacian. Due to the fact that laplacians can be applied to any color space, the presented approach was generalized in nature, which can be applied to any kind of color conversions.

[21]The process of color transformation in images were done based on the LMS color space for the transformation. LMS color space modelled the complex human color perception and hence was found suitable for color blind people. The input images which were in RGB color space were transformed into CIELAB space and the color mapping functions were used for the transformation of colors in the images. The transformation process is optimized based on the optimization function and cost function for the color transformation process. The color clustering process is finally employed for the transformation of the input images. The performance of the process is measured based on naturalness and perceptibility of the transformation process. The naturalness is the important parameter that defined the originality of the reproduced image.

However various techniques have been proposed previously in the earlier papers, they showed the following demerits in their applications.

- The transformation process is processed over the whole image which is not desirable for specific color blinded people.
- There was a loss of pixel naturalness in an image when LMS and CIELAB color transformation was applied.
- There was huge scope for performance improvement.

III. Proposed Method

The proposed image recoloring mechanism helps the color blinded people to perceive the images without any loss of information due to processing. The input images were read from the user. Fig.1 depicts the flow diagram of the proposed system. The proposed approach involves three steps such as color identification, color clustering and color transformation. The Color identification process is employed based on the extraction of the Red, Green and Blue regions in the image. The extraction is performed based on the identification of the pixels with greater intensity.

The color clustering process works using fuzzy c means clustering for the separation of Red, Green and Blue color regions from the original and the complement images. The clustered regions were then used for the transformation of the identified input images. The transformation process is employed for the pixels identified in the color identification step. The performance of the mechanism is evaluated with the parameters called naturalness and perceptibility of an image. The modules of the proposed methodology includes

- Color Identification.
- Color Clustering.
- Color Transformation.

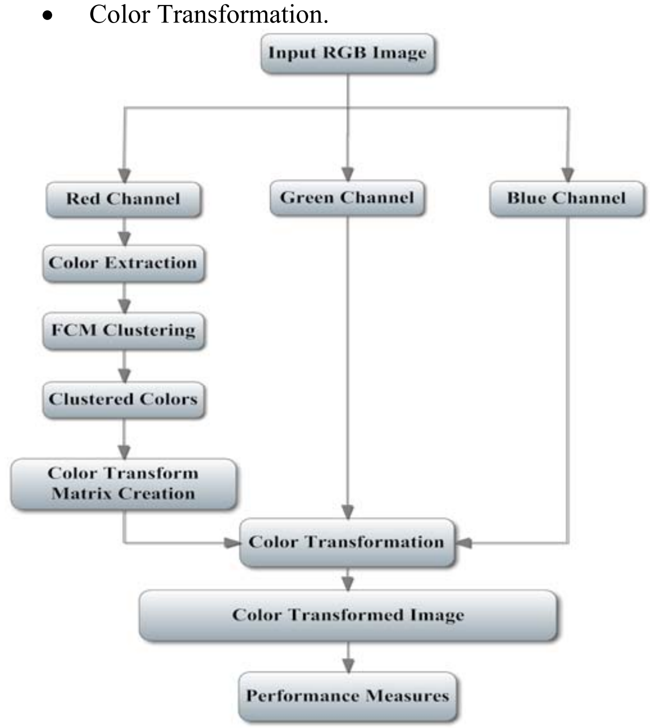

Fig.1 Flow diagram of the Proposed System

1. Color Identification:

The color identification is the first and foremost module of the proposed mechanism. It involves the selection of the color to be processed from the RGB image. The color selection is made based on the person with color vision deficiency. If the person have red deficiency, the system identifies the red color regions present in the image. Similarly, for deficiency of green and blue colors, the corresponding regions are identified. In order to extract the red color from an image, the maximum values of the red channel than that of green and blue channels are extracted. The identification step follows the following equation.

$$\gamma(X^\circ) = \begin{cases} 1, if\ R^\circ > G^\circ\ and\ R^\circ > B^\circ \\ 0, \quad\quad\quad\quad Otherwise \end{cases}$$

2. Color Clustering:

Clustering is the process of classifying or partitioning the set of data into various datasets. This process involves proper sharing of resources or characteristics. The color clustering process groups the image pixels whichever have similar colors in that images. The clustering can be performed in any of the two ways.

- Hierarchical Clustering
- Partitional Clustering

The hierarchical clustering involves clustering based on the previously established clusters. It can be either agglomerative or divisive clustering. And Partitional clustering clusters all the clusters at once. E.g., K mean clustering, fuzzy c means, QT clustering. Here Fuzzy c means algorithm is utilized for clustering of pixels. These categories of clustering is efficient to use for machine learning, data mining as well as image segmentation and image quantization.

Fuzzy C Mean clustering (FCM) theorizes that, it is a process of clustering by allowing one particular point of data to belong to two or more clusters. In fuzzy clustering, all the points are relative with respect to every cluster. This resembles the fuzzy logic and hence the degree of belonging will either be lesser if points are positioned at the cluster edge and higher if they are positioned at the center of the cluster. Each image point possess a set of coefficients to get positioned at the kth cluster. The fuzzy c-means algorithm is used to obtain the centroid of a cluster based on their degree of belonging to the cluster. Each clustered region represents regions of different intensity.

3. Color Transformation:

The linear transformation of certain image from its system of co-ordinates (RGB) to another system of co-ordinates is known as color transformation. Here, Color transformation process is performed based on the application of transformation matrix over the input images in the required color portions. The transformation matrix converts the original pixels from the images into different color based on the color blindness of the person. The color transformation matrix of the proposed method is as follows.

$$P = \begin{bmatrix} 1-2(q_2^2+q_3^2) & 2(q_1q_2-q_0q_3) & 2(q_0q_2-q_1q_3) \\ 2(q_1q_2-q_0q_3) & 1-2(q_1^2+q_3^2) & 2(q_2q_3-q_0q_1) \\ 2(q_1q_3-q_0q_2) & 2(q_0q_1-q_2q_3) & 1-2(q_1^2+q_2^2) \end{bmatrix}$$

Where Q – quadruple data of the proposed color transformation mechanism. During image transformation, the following aspects are also considered for obtaining efficient transformational model. The brightness of the image must be a continuous growing function of all the components in the input co-ordinates. The advantages of the proposed system are listed below

- Since the transformation is performed only over the region of interest, the system provides improved performance.
- The specific color blinded people are benefitted by the proposed technique.

IV. Performance Analysis

The proposed work is experimented in the windows operating system using MATLAB software application. The performance of the proposed system is evaluated based on the

- Image naturalness and
- Image perceptibility of the output image.

The work compared the subjective quality of the re-colored image with that of existing results. The subjective results are presented in Figures 4 and 5. The visual quality of the proposed work is also evaluated in terms of naturalness E_{nat} and perceptibility $E_{per.}$

Naturalness:

It is the quality of being natural. The naturalness of the image is the degree of reproducing an input image without altering the originality of the pixels. Fig. 2 provides the comparative analysis of the naturalness of the proposed and the existing method. The naturalness of an image pixel is calculated by the following equation (1).

$$E_{nat} = \sum_i \left|\left|X_i^o - \hat{X}_i^o\right|\right|^2 \quad (1)$$

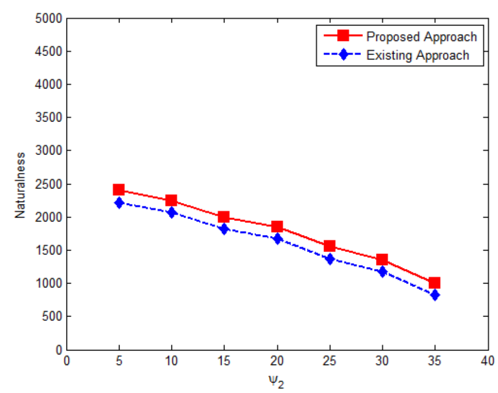

Fig. 2 Comparative analysis of Naturalness

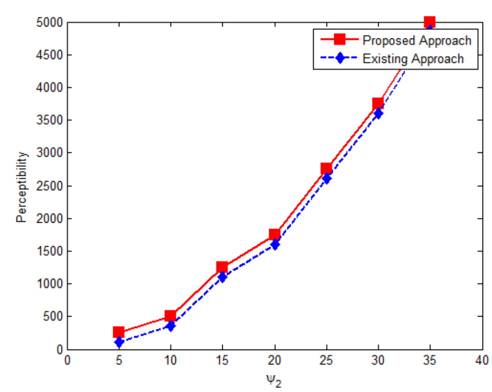

Fig. 3 Comparative analysis of Perceptibility

The following Fig. 4 (a) shows the input image of the user to be processed. The Fig 4 (b) shows the color transformed image of red color for a color blinded persons. Fig 5 (a) illustrates the green transformed output. Fig 5 (b) gave the blue transformed output of an image. Since the image doesn't contain any blue information, the transformed image resembles

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the input image itself. Thus from the depicted figures, it is clear that the proposed technique is the best recoloring mechanism without any loss of information.

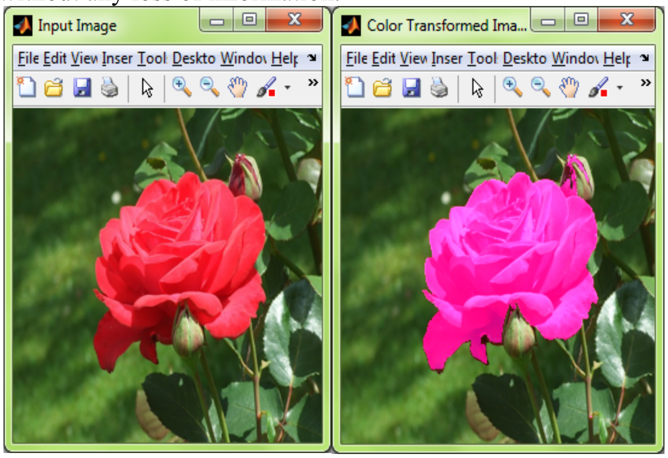
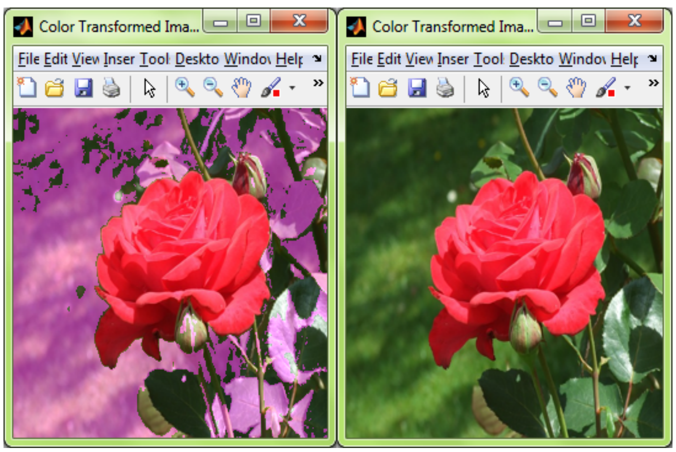


Fig. 4 (a) Input Image and (b) Output Red Color Transformed Image



(a) (b)

Fig. 5 Transformed Output Image (a) Green & (b) Blue color

Perceptibility:

The property of an image which denotes the degree of perceivability of an image by a user. The values are calculated based on the difference between original and transformed image. Fig. 3 provides the comparative analysis of the perceptibility of the proposed and the existing method. The equation to find the perceptibility of an image is given by equation 2.

$$E_{per} = \sum_i \sum_j \left(\left\| X_i^o - X_j^o \right\| - \left\| \hat{X}_i^d - \hat{X}_j^d \right\| \right)^2 \quad (2)$$

Performance:

The performance of the system is the amount of originality retrieved with respect to the input image. Fig. 4. This show the simulated results of improved perceptibility and good maintenance of naturalness of an input image.

The values of naturalness and perceptibility is tabulated in Table 1. The green has maximum value among the three components and their originality is retained without any flaw.

Table 1 Performance Measures Analysis

	Naturalness	Perceptibility
Red Channel Extraction	4194	172
Green Channel Extraction	16524	1119
Blue Channel Extraction	0	0

V. Conclusion and Future Work

Color blind people often find difficult to enjoy the true color of nature. The process of the transformation of color in the input images will be more beneficial for the color blind people. Color blind people cannot be able to identify specific colors in the images. The present work proposed a mechanism, which identifies the specific color in the images and transforms the image pixels within the identified region. The color identification process is performed by the identifying of the image pixels with greater intensity in the particular color space. The color identified regions are then clustered for exact identification of the transformed portion. The transformation process is done with the help of transformation function and the transformation matrix. The performance of the proposed system is evaluated in the Matlab simulation platform. The naturalness and perceptibility of an image is maintained and hence the mechanism is the better solution of the color blinded people.

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