

# Color Transformation Method for Protanopia Vision Deficiency using Artificial Neural Network

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**Abstract**—The objective of this project is to improve the ability of color discrimination for Protanope, who does not naturally develop red color or long wavelength cones. Intelligent method using image processing with Artificial Neural Network (ANN) is proposed to improve the ability of color discrimination as well as adjusting the images and colors. The image is stimulated by converting RGB space to LMS (long, medium, short) color space based on cone response and then modifies the response of the deficient cones. The linear multiplication matrix is referred to CIE color matching functions. Then the ANN is setting up by using the input/output from matrix conversion. The transformation of RGB color contrast technique is used to enhance contrast between red and green, which in general is green pixels appear to be bluer. Based on the result, the objectives are successfully achieved, which the ANN gives the minimum computational time than conventional matrix conversion, which is 36% increment. The changes of the image drastically for both color blind and non-color blind viewer. The result shows that the reds become redder and greens become greener from the image before being adjusted.

**Index Terms**—Artificial Neural Network; Image Processing; Color Transformation; Color Vision Deficiency.

## I. INTRODUCTION

The defective visual perception is a common occurrence, which is about 8% to 12% of men and 0.5% of the female population in the various forms of color vision disorder. Generally, 1 of 12 men and 1 of 200 women have color vision deficiency problem (based on global statistics from World Health Organization). Although there is no known medical method to correct this damage to human vision, it is considered that people who have such disorders suffer from a severe dysfunction [1].

Normal color vision is called trichromatic. It is originated by the absorption of photons in three classes of cones, whose peak sensitivities lie in three regions of the spectrum namely, the long-wavelength (L), middle-wavelength (M) and short-wavelength (S). Any alteration of one of three classes of cone pigments will affects Color Vision Deficiency (CVD). There are three kinds of CVD, which are Monochromacy, Dichromacy and Anomalous Trichromacy. In Dichromacy it can be broken down into three forms which are Protanopia, Deuteranopia and Tritanopia. This type is the most common category of color vision deficiency and it is called as red-green color vision deficiency [2, 3]. They have difficulty in differentiating between these two colors exactly, especially when their brightness is altered or come in a combination of

colors. In general, the problem with Dichromacy is the reddish and greenish colors look yellow hue. Some people may not even know they are affected by this CVD and yet, there are several researches still dealing with the problem caused by CVD. However, with modern images processing technology, it may be possible to design an aid to enhance the color blind's perception of color in everyday situations [4, 5].

Color transformation is generally a primary stage in the image processing application. Image simulation by using mathematical transformation has been done by [6-8], which used simple matrix conversion. The color transformation of an image can be adjusted manually by matrix conversion but that requires advance image manipulation technique with consume optimum time.

Artificial Neural Network (ANN) technique using Levenberg-Marquardt training method has been proven as an efficient method for color optimization and less time consumption for simulation process. The output from the conventional matrix conversion is being fed into ANN to be trained and is used to create complex relationship between input and output to find pattern in data [9]. This project proposes a method using color image processing to improve the ability of color discrimination for Protanope. The linear multiplication matrix is derived refers to CIE color matching functions. Then ANN is set up using the input and output from matrix conversion. The ANN is introduced to reduce computational time in image processing.

## II. COLOR CONTRAST ENHANCEMENT METHOD

Color contrast enhancement for Protanopia type CVD is very a critical part in order to differentiate between red and green colors. The process is shown in Figure 1. The RGB color model is based on the three primary colors, which are red, green and blue. The model is design in a software graphics program, Microsoft Paint.

In order to simulate an image to Protanope vision, the benchmark colors should be modeled. This benchmark will be used to transform any images with any color to be simulated to Protanope vision. The model is selected using 40 samples of colors, which are from the basic color of red, green, blue and yellow. The benchmarks colors are chosen by selecting the most confusion color in Protanope vision. Since the confusion is between red and green component, the arrangement of the

colors is based on the highest component of red and green in each colors. The concept of trial and error is done to get the results. Table 1 shows ten colors from basic color of green while Table 2 represents ten color of green perceived by Protanope.

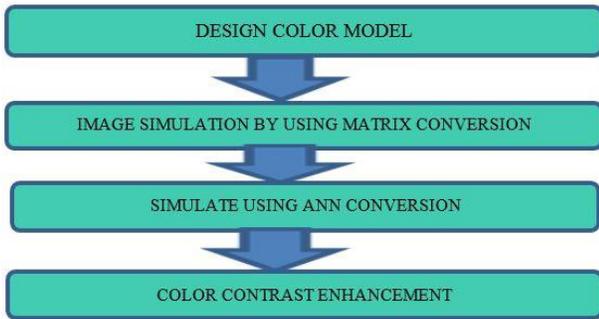


Figure 1: Color contrast enhancement process

Table 1  
Green Color Sample in RGB Component Values

HEX	RED	GREEN	BLUE	COLOR
#B2EC5D	178	236	93	
#7CFC00	124	252	0	
#66FF00	102	255	0	
#ACE1AF	172	255	17	
#77DD77	110	221	119	
#93C572	147	197	114	
#85BB65	133	187	101	
#87A96B	135	169	107	

Table 2  
Green Color (Perceive by Protanope) Samples in RGB Component Values

HEX	RED	GREEN	BLUE	COLOR
#F4DC60	244	220	96	
#FCE100	252	225	0	
#FDE100	253	225	0	
#E2D5AD	226	213	173	
#DCCA76	220	202	118	
#CBBA74	203	186	116	
#C1B068	193	176	104	
#837500	131	117	0	

A. Simulation of Color Model by Using Matrix Conversion

Figure 2 shows the flow for image pixel represented by RGB color coordinates to simulate the original image to protanope vision. For this project used standard CRT monitor with Chromaticity (x, y) of primaries and reference white of D65 in ITU-R BT.709 standard.

The simulation method of Protanopia is based on LMS system, which determines the colors in relation to the relative activation of L, M, and S cones, which is sensitive to long, medium and short wavelength light respectively. Initially, a transformation will be performed from the RGB space to the LMS space. This is achieved by a multiplication with a specific 3x3 matrix. The result of the previous multiplication should be submitted to a new linear transformation in order to eliminate the color

information not perceived by Protanope. Thus resulting new values  $L_p, M_p,$  and  $S_p$ . Finally, to get the final values  $R_p, G_p,$  and  $B_p$ , which finally simulating Protanope vision, just multiply the scales  $L_p, M_p,$  and  $S_p$  with the inverse relationship from LMS. Normal color vision can be modeled using cone fundamentals. The energy received by a particular L, M, and S cone can be represented as:

$$[L, M, S] = \int E(\lambda)[l, m, s] d\lambda \quad (1)$$

where Equation (1) is the light power spectral density and  $l, m, s$  are fundamental spectral sensitivity functions for cones.

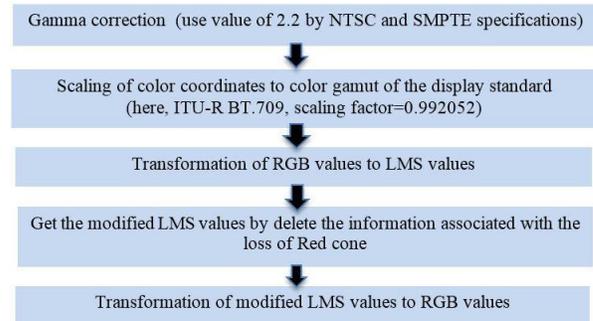


Figure 2: The process flow of the color model simulation

In dichromacy, one type of cone is absent or is not functioning properly. The normal three-dimensional color space is narrowed or limited to a plane. The plane in the LMS space can be defined as:

$$\alpha L + \beta M + \gamma S = 0 \quad (2)$$

where  $\alpha, \beta$  and  $\gamma$  are unknown parameter of a Dichromacy plane in LMS space. Solving the plane equation for red-green Dichromacy (protanopia) three known reference points are required. Origin (0,0,0), blue primaries ( $L_b, M_b, S_b$ ) and white primaries ( $L_w, M_w, S_w$ ) are used. Calculated  $\alpha, \beta,$  and  $\gamma$  parameters enable to map any original color to its version perceived by observers with red-green Dichromacy. In Protanopia the L and S values are unchanged, but a new value of M needs to be calculated using (3).

$$M = (\alpha L \gamma S) / \beta \quad (3)$$

For each image pixel represented by RGB color coordinates can be described in the following steps:

Step 1: Gamma correction

$$[R, G, B] = [R/255, G/255, B/255]^{2.2} \quad (4)$$

Step 2: Scaling of color coordinates to color gamut of the display standard (here, ITU-R BT.709, scaling factor=0.992052)

Step 3: Transformation of RGB to XYZ to LMS

$$\begin{bmatrix} Lp \\ Mp \\ Sp \end{bmatrix} = \begin{bmatrix} 0 & 43.5161 & 4.11935 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} X \begin{bmatrix} L \\ M \\ S \end{bmatrix} \quad (5)$$

**Step 4:** Get the modified LMS values by delete the information associated with the loss of red cone:

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 17.8824 & 43.5161 & 4.11935 \\ 3.45565 & 27.1554 & 386714 \\ 0.29956 & 0.184309 & 1.46709 \end{bmatrix} X \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (6)$$

**Step 5:** Inverse transforms LpMpSp to XYZ to RGB:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 0.88944 & -0.130504 & 0.116721 \\ 0.0102485 & 0.0540194 & -0.113615 \\ -0.000365294 & -0.00412163 & 10.693515 \end{bmatrix} = \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (7)$$

**Step 6:** Inverse gamma correction:

$$[R, G, B] = 255 * ([R, G, B]^{1/2.2}) \quad (8)$$

In terms of perception by Protanope colors, this simulated image can be used for needs of researchers to use for analysis furthering the next step of image processing.

### B. Simulation of Color Model Using Artificial Neural Network

ANN is introduced in this project in image simulation to reduce the computational time. In ANN the concept of Multilayer perceptron has been used. The multilayer feed-forward network was trained using an error back-propagation training algorithm. This algorithm adjusts the connection weights based on the back-propagated error computed between the input variables and the targeted output. This is a supervised learning procedure that tries to minimize the error between the desired and the predicted variable.

The neural network used consisted of one layers, which is three input layer of three neurons (one for each input variable), a hidden layer of three neurons and an output layer of three neurons which are the output variables. The three neurons in hidden layer is the number, which gives the best prediction result. The transfer functions used in hidden layer nodes are hyperbolic tangent function, while for output layer is a pure line function. The Mean Squared Error (MSE) is used as a performance measuring function.

For this project MLPs is used for Function Approximation. The Function Approximation process automatically uses a learning algorithm named Levenberg-Marquadt. This purpose is a task that performed by network trained to respond to input with an approximation of a desired function. There are several steps that must be followed to create the MLPs. The first step is setting the dataset division parameters. This dataset is from the output of fuzzy logic controller. The dataset is divided into training (adjustment of MLPs weight), testing (testing the trained MLP) and validation (check data periodically to avoid overhit sets). The next step is train MLP and finding the optimal MLP parameters. The number of hidden units, number of epochs and input/output lag spaces can be adjusted. For this project those following specifications were used for this algorithm.

### C. Color Contrast Enhancement

Color contrast enhancement is the process of adjustment an image's RGB values in order to enhance contrast between red and green and in general, make green pixels appear to be bluer. The flow of overall process is shown in Figure 3.

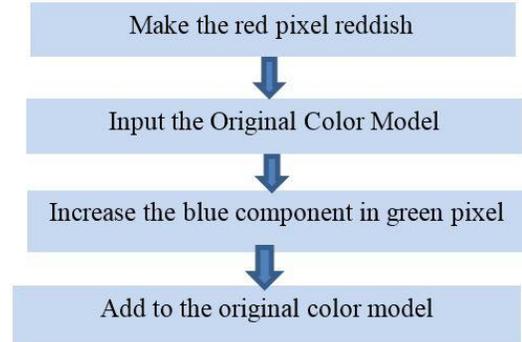


Figure 3: The image color enhancement process

This process begins by considering the total pixels in the original image in order to provide room for pixel values to the blue/yellow level based on the red/green contrast. For each pixel, there are three operations must been done. The first step is to increase the rate of the pixel's red component relative to pure red. Reds further from pure red are increase meaningfully while reds already very close to pure red are only marginally increased. Same goes to the green pixel. The green component is adjusted by applying exactly the same rules as used on the red components. Finally, for the pixels, which are mostly green, the value of the blue component is increased. For pixels that are mostly red, the blue component is reduced. 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 and keep contrast the red color for those that are naturally red.

Color Contrasting with RGB has no clear theoretical basis. It is also created according to experimental procedures relying mostly on trial and error in the existence of a color's blind observer.

## III. RESULT AND ANALYSIS

### A. Neural Network Evaluation

Levenberg-Marquardt algorithm is used for training the network. Training automatically stops when generalization stops improving, as indicated by an increase in the Mean Square Error (MSE) of the validation samples. The Mean Squared Error (MSE) is the average squared difference between outputs and targets. Lower values are better while zero means no error. Figure 4 shows the best validation performance 0.000026269 at epoch 101. The validation and test curves are almost the same. It is possible that some over fitting might have occurred if the test curve had increased significantly before the validation curve increased.

The next step in validating the network is to create a regression plot. This is to show the relationship between the outputs of the network and the targets. The network outputs and the targets would be exactly equal if the training was perfect but

the relationship is rarely perfect in practice. The three plots represent the training, validation, and testing data. The solid line represents the best fits linear regression line between outputs and targets. The dashed line in each plot represents the perfect result (outputs) equal to the targets. The R-value indicates the relationship between outputs and targets. If  $R = 1$ , this indicates that there is an exact linear relationship between outputs and targets. The Regression plot shown in Figure 5 shows the perfect correlation between the outputs and the targets since the validation and test results shows R values is greater than 0.9.

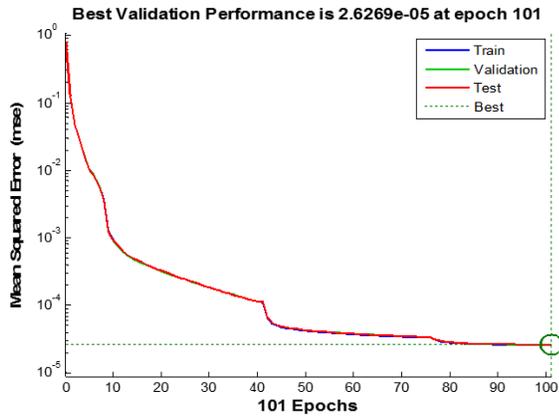


Figure 4: Neural Network overall performance

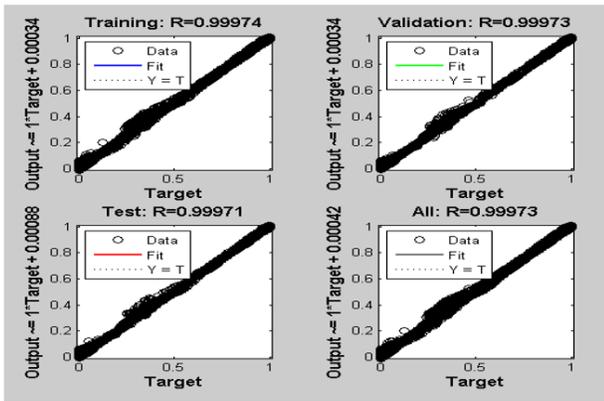


Figure 5: Neural Network training regression

The overall regression line value indicated a high regression value that was almost 99%. It means the results obtained for this project is accepted as the image converted is almost the same as found in Figure 6.



Figure 6: (a) Simulated image using Matrix Conversion, (b) Simulated image using Neural Network

### B. Color Transformation Performance

Table 3 and Table 4 show the color transformation results for the images extracted from the Matlab simulation and value of RGB component for each color images before and after Color Contrast Adjustment respectively. Based on the figure, the green colors appear to be bluer. The blue color remains as blue but it is adjusted in accordance to green and red contrast to make sure no confusion will occur between the transformed green and transformed blue. The transformed image looks less confusion to the Protanope CVD. They managed to see the edge between four colors clearly. Although they are not able see the image as seen by normal person but they managed to differentiate the colors after the transformation.

Table 3  
Images Before and After Color Contrast Adjustment

	Original Image	Simulated image
Before Color Contrast Enhancement		
After Color Contrast Enhancement		

Table 4  
Value of 8 RGB Components for Each Color Images Before and After Color Contrast Adjustment

Original Image				Original Image Contrast				Simulated Image Contrast			
R	G	B	Color	R	G	B	Color	R	G	B	Color
255	8	0		255	15	0		91	91	18	
215	59	62		255	45	0		99	99	18	
102	255	0		78	255	255		242	242	254	
3	192	60		5	246	255		233	333	255	
19	136	8		14	154	206		206	146	145	
0	0	255		11	12	195		10	10	189	
230	226	0		237	231	0		232	232	5	
236	213	64		249	207	1		210	210	11	

The proposed technique is tested and evaluated by using image of two resistors and the outputs are shown in Figure 7. The images processed using the neural network is to be found with very good visual quality of the image conversion. The 8 benchmark colors give a high flexibility to users to choose colors and images, as they prefer to make transformation to Protanope version.

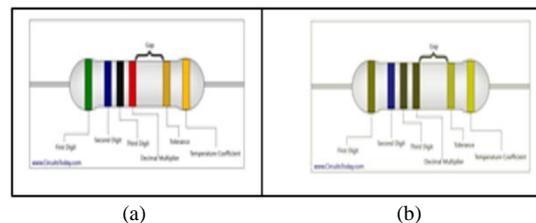


Figure 7: (a) Normal original image, (b) Simulated image seen by protanope

### C. Computational Time Measurement of Image

Table 5 presents the result of computational time for processing the image of normal vision to the image of Protanope vision. Processor Intel core i5, 2.40 MHz and 2.00 GB of RAM has been used. Analysis has been made based on the results from the conventional and the proposed intelligent ANN methods. Regarding on the Table 5, for image with size 173pix X 200pix, the processor took 0.4212 seconds to simulate the image by using matrix conversion while, 0.2055 seconds by using ANN, which is two longer than without ANN.

Evaluation is also conducted based on number of pixels. The results show the computational time is directly proportional to the increasing of image pixel, which the higher the image pixel, the higher the computational time. By comparing these two methods, the percentage of increment of time simulation from the smaller size to the biggest size of image by using matrix conversion is about 440% while the percentage of increment for ANN method is only 36%. ANN gives the minimum computational time than conventional matrix conversion.

Table 5  
Computational Time Using Conventional and Intelligent Methods

Method	Simulation time (s)			
	200x173	300x259	400x346	500x433
Matrix conversion 	0.4212	0.8624	1.5381	2.2776
Neural Network 	0.2055	0.2085	0.2404	0.2850

The performances of transformed image show some difference between the transformation using image processing and transformation using combination of image processing and ANN. The first method took about almost 3.8 seconds to process the image while the second method only took about 1.9 seconds. The overall result shows that the time taken for transforming image with image processing with ANN is faster than transforming image without ANN.

### IV. CONCLUSION

This paper presented image processing and Artificial Intelligent methods to improve the ability of color discrimination for Protanope color blindness. The integration of image processing and Artificial Neural Network (ANN) gave better performances in terms of efficiency, flexibility and computational time. Based on the result, the selected eight

benchmark colors presented very good visual quality of the image conversion after going through training and testing in neural network. The eight benchmark colors give a high flexibility to users to choose colors and images as they prefer to make transformation to Protanope version. A constructed ANN and the training using Levenberg-Marquardt training proved as an acceptable method. Furthermore, the confusion between red and green color is successfully eliminated by using color contrasting technique. Color Contrasting enhance contrast between red and green that make green pixels appear to be bluer.

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### REFERENCES

- [1] B. L. Cole, *Assessment of inherited color vision defects in clinical practice*. Clin Exp Optom, vol. 90, no.3, pp. 157-75, 2007.
- [2] Jacek Rumiski, Jerzy Wtorek, Joanna Rumiska, "Color Transformation Methods for Dichromats," in *Human System Interaction (HSI), 3<sup>rd</sup> IEEE International Conference*. 2010.
- [3] T. Ohkubo, K. Kobayashi, "A color compensation vision system for color-blind people," in *SICE Annual Conference*. 2008.
- [4] S. Poret, R. D. Dany, "Image Processing for Color Blindness Correction," in *Science and Technology for Humanity (TIC-STH), Toronto International Conference IEEE*. 2009, pp. 539-544.
- [5] Dabhoiwala, Mazgaonkar, Tole, "An Overview on Various Re-Coloring Methods for The Color Vision Deficient," *International Journal of Advance Foundation And Research in Science & Engineering (IJAFRSE)*, vol. 1, no.11, pp. 5-15, 2015.
- [6] Jeong Jae-Yun, Kim Hyun-Ji, Wang Tae-Shick, Ko Sung-jea, "An Efficient Recoloring Method with Information Preserving for the Color-blind," *IEEE Transactions on Consumer Electronics*, 57, no. 4, pp. 1953-1960, 2011.
- [7] J. Ruminski, M. Bajorek, J. Ruminska, J. Wtorek, A. Bujnowski, "Computerized Colour Processing for Dichromats," *Human - Computer Systems Interaction, AISC 98*, pp. 453-470, 1998.
- [8] J. P. Srividhya, P. Sivakumar, M. Rajaram, "The Color Blindness Removal Technique In Image by Using Gradient Map Method," in *2011 International Conference on Signal Processing, Communication, Computing and Networking Technologies (ICSCCN)*, 2011.
- [9] S. Sapnal, Dr. A. Tamilarasi, M. Pravin Kumar, "Backpropagation Learning Algorithm Based on Levenberg Marquardt Algorithm," *Computer Science & Information Technology*, pp. 393-398, 2012.
- [10] M. Egmont-Peterson, D. de Ridder, H. Handels, "Image processing With Neural Networks - A Review," *2002 Elsevier Science*, vol. 35, no. 10, pp. 2279-2301, 2002.
- [11] C. A. Curcio, K. R. Sloan, R. E. Kalina, A. E. Hendrickson, "Human photoreceptor Topography," *J Comp Neurol*, vol. 292, pp. 2279-2301, 2002.
- [12] N. Sutender, "Study of colour blindness in Jat Sikhs," *Indian J Physiol Pharmacol*, vol. 39, pp. 127-130, 1995.