Design of Mobile Application for Assisting Color Blind People to Identify Information on Sign Boards

Bhagya R Navada & Santhosh Krishna Venkata*

Department of Instrumentation and Control Engineering,
Manipal Institute of Technology, Manipal Academy of Higher Education,
Manipal 576104, Karnataka, India
*E-mail: kv.santhu@gmail.com

Abstract. Color blindness is a condition where a person cannot distinguish colors that are of similar contrast. This paper reports an attempt to develop a mobile phone application that can run on any Android or Windows smart phone. The developed application/software tool is able to assist color blind people by converting an image with low contrast to an image with high contrast. The objective of the proposed work was to develop a program on the LabVIEW platform to i) acquire the image whose information should be processed, ii) develop an algorithm to display a high-contrast crisp image of the actual dull image, and iii) identify the colors and characters present in the dull image for messaging to the user's phone. The work was implemented on the LabVIEW platform making use of various image processing tools to identify the color and text from the sign board that otherwise cannot be identified by color blind persons. The implementation was tested with several inputs to validate the performance of the proposed method. It was able to produce accurate results for more than 97.3% of the test inputs.

Keywords: *color blindness; image processing; LabVIEW; mobile application; rehabilitation.*

1 Introduction

Color has a key role in almost all areas of life as it is one of the main elements for characterizing people, objects, materials, etc. Thus color has an impact virtually everywhere; it is even used for teaching kindergarten students. Color is used more often as a point of attraction compared to any other tool. In industries color can be used to represent a range of parameters, where one color is used to represent the safe range and another one to represent the danger range; these changes in color provide feedback to the operator for smooth control of the parameters. Color is also used as a marketing tool to attract consumers.

Color blindness is the inability to identify or differentiate colors and it affects approximately 8% of men and around 1% of women. Color blindness can be for all the colors or for a few colors only, causing color blind persons to not be able

Received January 16th, 2017, 1st Revision April 25th, 2017, 2nd Revision June 19th, 2017, Accepted for publication November 30th, 2017.
 ISSN: 2337-5779, DOI: 10.5614/j.eng.technol.sci.2017.49.5.8

to recognize the difference between colors. Color blind people face many problems in life at different stages, from childhood to the end of their life.

Color is sensed by human beings when white light falls on an object and the reflected rays enter the eye. The retina of the eye has two types of light-sensitive cells, called rods and cones. Rods work in low light conditions to help night vision, while cones work in daylight and are responsible for color discrimination. There are three types of cone cells and each type has a different sensitivity to light wavelengths. One type of cone perceives blue light, another perceives green and a third perceives red [1]. For the vast majority of people with deficient color vision the condition is genetic and has been inherited from their mother, although some people become color blind as a result of diseases such as diabetes or multiple sclerosis, or they acquire the condition over time due to aging, medication, etc. [2]. Color blindness may also be because of cerebral infarctions, which is called acquired color blindness [3].

Some researchers have reported work in the area of the development of aiding tools for color blind people, some of which are discussed here. A wearable color recognition system has been designed by McDaniel ,*et al.* [4] for the recognition of color by visually impaired people. They concentrated on detecting the level of an acquired image by comparing it with a standard image. Their system consisted of a wearable device and a PC, making the system bulky. A color blindness testing system was developed by Ananto, *et al.* [5,6] with augmented reality for testing color blind people to find their type of color blindness. In this system, first, the user is tested for color blindness using the Ishihara test and then a color transformation is carried out to increase the contrast so that the user can see the virtual image with more clarity. An algorithm to detect the color of the object or sight area has been reported by Patel, *et al.* [7], which gives a speech output depending on the color of the object. Initially the system was trained for different colors by varying the intensities of RGB LED light and then a test image was given as input to identify its color. A prototype of a color sensing system was designed by McDowell [8] for detection of the color of an object using a microcontroller and LEDs. It uses two color sensors for detecting the color and then the color is displayed on a six-seven segment LED display. Registers with small memory are used for storing the color table, which reduces the accuracy of the color sensing system.

Some of the reported works in the area of color detection and pattern matching are listed here. An edge detection technique for differentiation of streetlights and traffic lights for the color blind has been reported by Harish, *et al.* [9]. A method for detection of the color and texture of clothes has been reported by Tian, *et al.* [10]. Detection was mainly based on a comparison of the image with a collected data set. Development of image descriptors by considering shape, texture, wavelet and color has been reported by Banerji, *et al.* [11] for classification of scene images.

Many researchers have worked in the area of edge and color detection, some of which are reported below. Selection of appropriate color components from each color space for detection of edges in images has been reported by Belmamoun, *et al.* [12]. An operator was found for color edge detection using Green's function, while recursive implementation of the operator was carried out for finding the optimal edges, as reported by Zareizadeh, *et al.* [13]. A method for color edge detection using nonlinear pre-filtering to remove Gaussian noise on the edges in images has been reported by Ou and Guang Zhi [14]. A color detection technique for detection of jaundice in newborn babies by pre-processing the image to discard the luminance component from YCrCb color space has been discussed by Mansor, *et al.* [15].

Several researchers have carried out research in the area of sign and character recognition. An algorithmic framework has been discussed by Goh, *et al.* [16] to identify the named entity and, based on verb analysis, a human activity the named entity performs. Lin and Scully developed an algorithm [17] for recognition of handwritten characters. Characters were constrained to be in a specific grid. A neural network architecture with combination of two subnets with complimentary similarity measure was developed by Namane, *et al.* [18] for character recognition. Niranjan, *et al.* have suggested a scheme [19] for recognition of Indian sign languages for improved communication of deaf and dumb people with society. The system was trained for different users using a back propagation neural network. A technique for enhancement of text in images was proposed by Saoud, *et al.* [20]. A handwritten-character recognition technique using gradient feature descriptors has been reported by Surinta, *et al.* [21]. Yi and Tian proposed a method in [22] for extraction of text from scene images. A structure model was prepared to identify characters based on which features are extracted, while text regions are detected using a color decomposition method.

From the reported works it can be seen that most of the researchers have reported image-processing techniques for color detection or edge detection, while some have developed an algorithm for identification of characters. However, very little work has been done for the aid of color blind people. The developed aiding systems are for detecting color blindness or the color of an object and not for detecting an exact phrase in the sight area of color blind people. This led us to develop the proposed method. The objective of this work was to develop a technique to identify color as well as the edges of letters to identify words. The identified color and words are sent in the form of a message to the user's mobile phone through GSM.

2 Problem Statement

An analysis of the existing systems for color blind people suggested the need for a much more interactive system. In the present generation, the mobile phone is a device that is used by most common people. Developing software using the existing infrastructure available in smart phones would be a boon to color blind people. The proposed work was done to develop a software application with the objective to design and implement a tool that is be able to:

1. Acquire images of a sign board in the color blind person's sight area.
2. Identify the background and text color.
3. Detect the edges of the characters on the sign board and further convert it to a high-contrast image using thresholding.
4. Recognize the characters using a feature extraction algorithm.
5. Identify the background and character color.
6. Text the information extracted from the sign board to the user via GSM.

When the text on the sign board is identified, it is sent as a messages to the color blind person, which is helpful for persons with any type of color blindness.

3 Problem Solution

A prototype system was built with the objectives as given in the previous section. A system based on a wireless camera and a PC was first implemented. The camera is placed in the visual region of the user, the camera captures the user's visual region (or a sign board whose information is to be read) on video, which is transmitted to the PC through a wireless transmitter, receiver and TV tuner card. The video is then converted into frames using the image processing tools of LabVIEW. These frames undergo a number of processing steps, such as: selecting the region of interest, thresholding, edge detection, and finally feature extraction for character identification. Thus, the detected color and words can be sent in text form to the user's mobile phone through GSM. A block diagram of the proposed technique is shown in Figure 1.

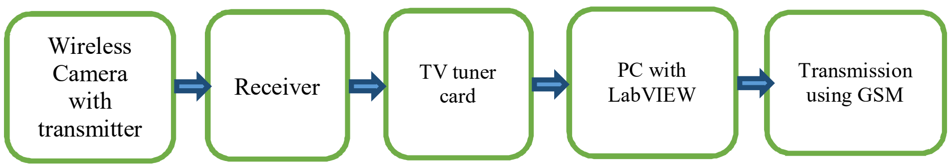


Figure 1 Block diagram of the proposed technique.

3.1 Experimental Setup

The experimental setup used for demonstration of the proposed work is shown in Figure 2. The setup consists of a wireless camera with transmitter, camera receiver, TV tuner card with USB connector, PC, GSM module and a RS 232 to USB converter.

3.2 Programming

The LabVIEW platform was used for designing the program that carries out the proposed work. LabVIEW was chosen because of its flexibility to interface real-time modules. The front panel of LabVIEW is designed to display images of various operations performed in the form of the actual image, the thresholded image, the image after edge detection, and the feature-extracted image. A text indicator can also be placed to display the detected characters. A numerical control is present to enter the mobile number of the user to which the identified text is to be transmitted. Text control is also present for feeding the communication type of the connected TV tuner card as input. The block diagram of LabVIEW consists of the program/algorithm to be carried out for achieving the proposed objectives. The complete operation is classified into the following stages:

1. Acquisition of video
2. Conversion to frames
3. Detection of region of interest (ROI)
4. Thresholding
5. Filtering
6. Character recognition
   a. Edge detection
   b. Feature extraction based on character geometry
   c. Neural network algorithm
7. Text output in ASCII
8. Messaging to GSM number

3.2.1 Acquisition of Video

A wireless camera is placed near the eyes of the color blind user. The receiver frequency is tuned for fine collection of the video and is connected to the PC through a USB TV tuner card. The video of the object viewed by the color blind person is captured by the camera and further transmitted via an RF transmitter to the TV tuner card receiver connected to the PC through USB.

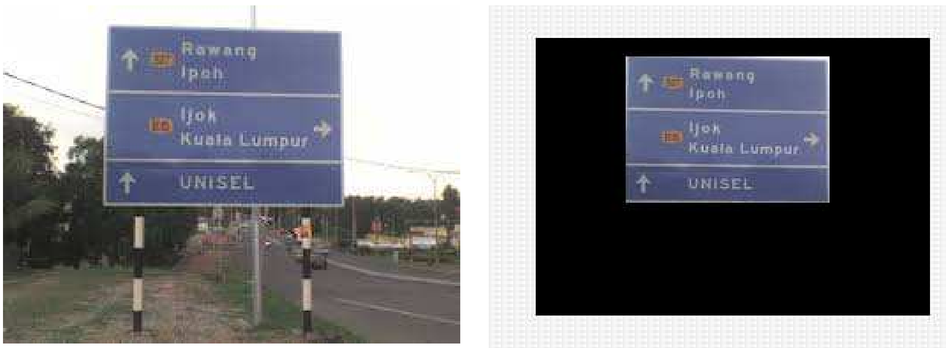
3.2.2 Conversion to Frames

The captured video is then processed using the vision assistant tool. The first step of processing is to convert continuous video to separate frames, retaining the type of video, using the 'grab' function. Then these data are converted to an image of a specific quality that is suitable for processing using the 'snap' function. The captured video is converted at a rate of 16 frames/second.

Figure 2 Experimental setup.

3.2.3 ROI

The next processing step is to identify the region of interest, or in the terms of the proposed work, selecting the sign board whose information is to be read in order to reduce the computational time and memory. Figure 3 shows the ROI process output. In the proposed work, a pixel coordinate selection algorithm is applied to compute the ROI. In the example, the rectangular coordinate technique is shown but similarly one can also use circular, triangular, etc. coordinate systems.



(a) (b)

Figure 3 (a) Image before ROI is performed, (b) image after ROI is performed.

3.2.4 Thresholding

Thresholding is a segmentation method where pixels are portioned depending on their intensity value. Three types of thresholding are carried out, i.e. global thresholding, variable thresholding, and multiple thresholding. Using a threshold value, the intensity of the picture is obtained as given by Eq. (1). The derived image pixel intensity is

$$i(x,y) = \begin{Bmatrix} 1, if\ f(x,y) > T \\ 0, if\ f(x,y) \le T \end{Bmatrix} \tag{1}$$

where f(x, y) is the intensity of the pixel at coordinates 'x', 'y'. *T* is the threshold value.

If *T* depends on the neighborhood of (x, y) then it is called local thresholding. In the case of multiple thresholding, the value of *T* is not unique.

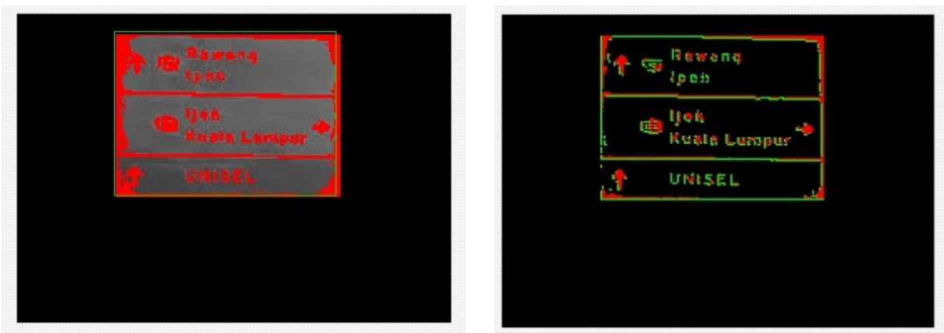
In the proposed technique, Otsu's method as described in [23], is used to compute the optimal value of the global threshold. Otsu's method is based on the interclass variance maximization principle. The choice of threshold *T* = k can be estimated by Eq. (2) and the optimal threshold value, k*, should satisfy the following condition:

$$\eta = \sigma_B^2(k)/\sigma_G^2 \tag{2}$$

where described in Eq.(3):

σ_G = global variance
σ_B = class variance

$$\sigma_B^2(k^*) = \max_{0<k<L-1} \sigma_B^2(k) \tag{3}$$



(a) (b)

Figure 4 (a) Image after thresholding, (b) image after filtering.

3.2.5 Filtering

The image obtained from the thresholding operation is often corrupted by random variations in intensity level due to reasons like bad illumination, spatial distance, etc., which leads to poor contrast in the image. Filtering is done to transform the pixel intensity value to enhance and smoothen the image. In the proposed technique, statistical scaling of the histogram equalization method described by Gonzalez and Woods in [24] is used for the purpose of filtering. Figure 4(b) shows the filtered output of the image under process. From the images obtained it is clear that color blind people will be able to read the text with higher accuracy as compared to the actual image.

In this phase, a color classifier is developed by training it with different samples. These samples are obtained from template images. Different colors are trained with different images and other color variations such as dark and light are also considered for training into different classes. Once the color classifier is finished, the next step is identifying the color from a given ROI of the acquired image. Once the region is selected, its color content is compared with the color distribution of the template color. A similarity score will be given as the output, which can be used for classification. The threshold value can be set by the user, and for more accurate results a higher score can be given.

3.2.6 Character Recognition

The next stage of the proposed work is to identify the characters present in the sign board. If the user is still not able to get clear information after thresholding and filtering of the image have been carried out, a technique is proposed that can read the text present in the image. This is possible only by identification of the separate characters. The first step towards character identification is to evaluate an edge detection algorithm. This algorithm is used to clearly distinguish each character in the given information window.

1. *Edge detection*

Edge detection is the process of identifying and locating crisp discontinuities in an image. These discontinuities represent sudden changes in pixel values along a neighborhood. The edge detection process is the first step towards feature extraction to identify characters. Several algorithms are available in the literature for carrying out edge detection. In the proposed technique, Roberts' cross operator as described by Davis in [25] is used. Eq. (4) provides approximation to the gradient magnitude:

$$G\big[f[x,y]\big] = |f[x,y] - f[x+1,y+1]| + |f[x+1,y] - f[x,y+1]| \tag{4}$$

For using convolution masks, Eq. (5) is derived as follows,

$$G\big[f[x,y]\big] = |G_a| + |G_b| \tag{5}$$

where

Ga =

1	0
0	-1

Gb =

0	-1
1	0

The output obtained after computation of the edges by the proposed technique is shown in Figure 5.

Figure 5 Image after edge detection.

2. *Feature extraction based on character geometry*

Feature extraction is the process of identifying the characters. In the present work we look for two features: one is 'start of alphabet' points and the other one is 'intersection points'. Start of alphabet points are points at which the initiation of a particular edge starts or terminates. We use a particular marker to identify these, i.e. the red rectangular objects in Figure 6. Similarly, for identifying the intersection points we use the nearest neighborhood algorithm along the edges. The intersection points are indicated by the green circles in Figure 6.

Figure 6 Image with features identified.

First, to identify the character skeletons, the entire ROI is considered as a grid of pixels represented in the form of a two-dimensional matrix. Analysis is carried on this pixel matrix to identify the features, which are further analyzed to identify the characters. Only separate words are considered for analysis, the proposed work does not consider joined words/cursive words and also only English language characters are considered.

3. *Starter of alphabet points*

These are the pixel points populated by only one pixel in the neighborhood of the character skeleton.

4. *Intersection points*

These are the pixel points primarily populated by more than one neighborhood point. These intersection points are further classified into two categories based on whether the neighborhood contains direct pixels or diagonal pixels. Direct pixels have either horizontal or vertical neighborhood points. Further, a unique code like '1' is used for intersecting points with one horizontal direct pixel, '2' for intersecting points with only one vertical direct pixel, and '3' for intersecting points with both horizontal and vertical direct pixels. '4' means the pixels have one diagonal intersection pixel, while '5' indicates two diagonally intersecting pixels. If the intersection pixel is formed by direct and diagonal pixels than it is read as '6' and, similarly, with diagonal pixels it is read as '7'. These database points are used based on the type of alphabet considered and are unique for each type of alphabet and language.

Once the feature extraction process is completed, we have a matrix consisting of data represented by start of alphabet points, intersection points, etc. Analysis of this matrix leads to character identification. In the proposed work, an artificial neural network based classification technique was developed.

5. *Neural network algorithms*

An artificial neural network (ANN) is a computation technique that mimics the thinking of the brain. In a neural network, each node performs a computation and each connection conveys a signal from one node to another labeled by a number called the 'connection strength', or weight, which indicates the extent to which the signal is amplified or diminished by the connection. Different choices for the weight result in different functions being evaluated by the network. If in a given network whose weights are initially random and given that we know the task to be accomplished by the network, a learning algorithm must be used to determine the values of the weight that will carry out the desired task. In the proposed work, an ANN is programmed to perform the task of classification, where the matrix obtained from the feature extraction algorithm is the input data and the target data is the ASCII value of the characters indicated by the extracted features. The function of the neural network is expressed by Eq. (6). The neural network function φ (i, j) is computed by using a back propagation structure, as shown in Figure 7.

$$O(i,j) = \varphi(i,j) * h(i,j) \tag{6}$$

where

O(i, j) = output vector/ target vector
φ(i, j) = ANN function
h(i, j) = input vector/ trained vector

The mathematical expression of the neural network function is given by the following equations:

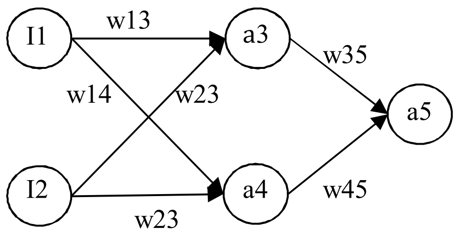


Figure 7 Structure of the neural network.

Eq. (7) and Eq. (8) represent the activation function:

$$v(\theta) = 1/(1 + e^{-\theta}) \tag{7}$$

$$v'(\theta) = (1 - \theta) * \theta \tag{8}$$

Eq. (9) to Eq. (11) represent the forward path computations:

$$a4 = v(z4) = g(x1 * w14 + x2 * w24) \tag{9}$$

$$a3 = v(z3) = g(x1 * w13 + x2 * w23) \tag{10}$$

$$a5 = v(z5) = g(a3 * w35 + a4 * w45) \tag{11}$$

Eq. (12) to Eq. (14) represent the computations for the backward path function:

$$\Delta 5 = error * v'(z5) = error * a5 * (1 - a5) \tag{12}$$

$$\Delta 4 = \Delta 5 * w45 * g'(z4) = \Delta 5 * w45 * a4 * (1 - a4) \tag{13}$$

$$\Delta 3 = \Delta 5 * w35 * a3 * (1 - a3) \tag{14}$$

For computation of weights Eq. (15), an ant colony optimization algorithm, and Eq. (16) are used:

$$w_{ij} = old_{w_{ij}} + \alpha * input\ \_activation_i * associated\_error_j \tag{15}$$

$$p_{i,j} = \frac{(\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta})}{\sum(\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta})} \tag{16}$$

where

$\tau_{i,j}$ = amount of pheromone on edge *i,j*
$\eta_{i,j}$ = desirability of edge *i,j*
α = parameter to control the influence of $\tau_{i,j}$
β = parameter to control the influence of $\eta_{i,j}$
Θ = learning rate

The amount of pheromone is updated according to Eq. (17) as follows:

$$\tau_{i,j} = (1 - \rho)\tau_{i,j} + \Delta\tau_{i,j} \tag{17}$$

where

$\tau_{i,j}$ = amount of pheromone on edge *i,j*
ρ = rate of pheromone evaporation
$\Delta\tau_{i,j}$ = amount of pheromone deposited, given by following Eq. (18).

$$\Delta\tau_{i,j}^{k} = \begin{cases} \frac{1}{L_k} & if\ ant\ k\ travels\ on\ edge\ i,j \\ 0 & otherwise \end{cases} \tag{18}$$

where L_k is the cost of the k^{th} ant's tour/length.

In the proposed work, a back propagation model is used with the ant colony optimization algorithm. A three-layered multilayer perceptron neural model is considered with six, six and five neurons in each of the hidden layers, respectively.

6. *Text output from ASCII*

The neural network algorithm is used to derive the ASCII codes of the characters from the extracted features of the image. Once computed, the ASCII code is converted to a text string using the ASCII to text string conversion palette of LabVIEW. Along with the conversion of the characters, an audio output is also placed to read out the displayed information of the characters.

3.3 Messaging to GSM Number

The detected parameters, namely color and characters, are now texted to the user's mobile phone number through GSM 300 by using VISA for communication. VISA is a lower layer of functions in the LabVIEW instrument driver VIs that communicate with the driver software. VISA by itself does not provide instrumentation programming capability. VISA is a high-level API that calls low-level drivers and is also platform independent.

GSM: The SIM 300 GSM module used here is the serial port connecting interface. It is used as a modem to send messages whenever prompted to do so by the user. This is done using the HyperTerminal option in the Windows OS and it needs a valid SIM card to send the messages to the desired number. To interface with the modem we have to use standard AT commands.

4 Results and Analysis

Once the design and implementation of the proposed work was completed it was subjected to testing. For testing, the proposed technique was used to read several sign boards along with performing the operations of thresholding to help color blind persons to read characters with ease. The results obtained from the proposed technique for two sample boards are as shown in Figures 8 and 9. Both figures contain four images: the acquired image, the edge detected image, the image after thresholding, and the image after feature extraction. Fig. 10 shows a screen shot on the mobile that received a text message with the information extracted from the image.

Around 200 images of different sign boards were used for testing and validation. Test samples with varying color, size, characters, etc. were selected.

The obtained results were influenced by the illumination and camera position, producing slight variations in the output. Using the 200 sign boards, a total of 3576 characters were tested of which 3480 characters were identified correctly, while there was an error in identifying 96 characters. The errors occurred mostly during the feature extraction of visually similar characters such as ‘x’ and ‘k’, ‘a’ and ‘q’, ‘s’ and ‘5’, ‘I’ and ‘1’, etc. The accuracy of the result produced in terms of identifying the correct characters was around 97.3%.

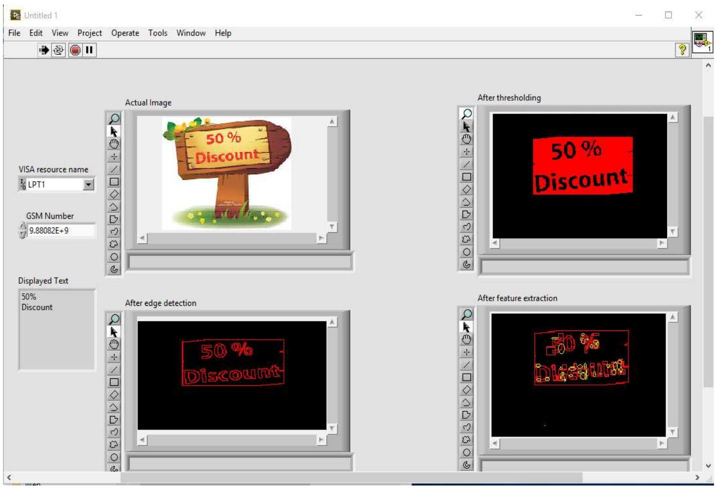


Figure 8 Result as seen on the front panel for case 1.

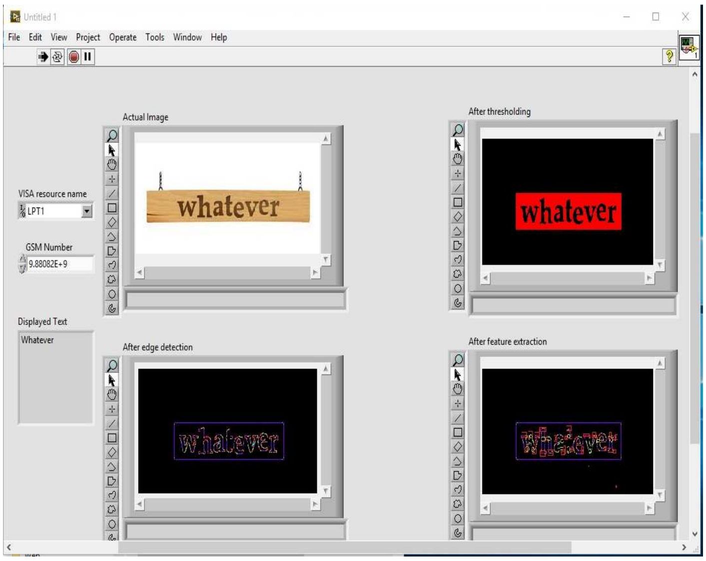
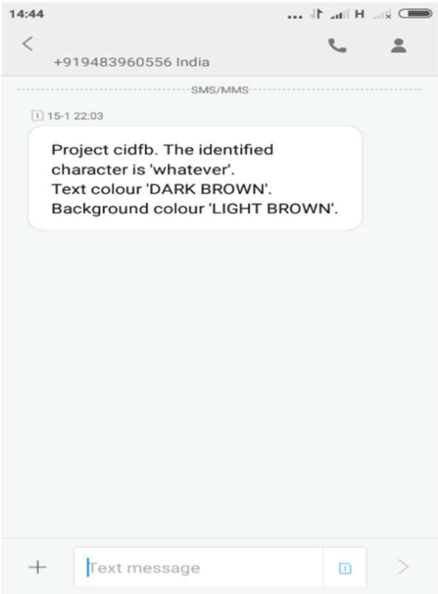
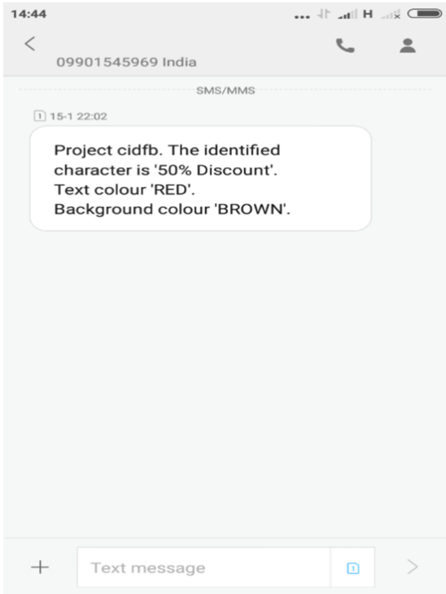


Figure 9 Result as seen on the front panel for case 2.



(a)



(b)

Figure 10 Screen shot of mobile display for: a) case 1, and b) case 2.

5 Conclusions and Discussions

Color blindness is a common condition, present in almost 8-10% of the total population. It should be noted that in most of the cases there is no medication or rehabilitation for overcoming the problem, making it difficult for color blind people to extract information from sources with similar colors for the background and the text. The proposed work is an attempt to design a technique that would be an aid for color blind people by extracting information in two possible ways. First, the image is captured and represented in terms of a high-contrast image, making it possible for someone who is color blind to read the information. The second technique is by sending the information to a mobile phone, making it easy to read.

For the implementation and execution of the test setup, a PC with LabVIEW was used. The test results show successful implementation of the proposed technique. Further, the LabVIEW VI implementation can be converted to a software application (app) that can be installed on any smart phone. The first phase of converting the program to an executable file was undertaken using the file conversion feature of LabVIEW. Development of an app from the extracted executable file is being worked on.

With this aid system, a person with any type of color blindness would be able to read written text on a signboard as the extracted data are sent to his mobile phone in the form of a text message. In character identification, Greek letters and freehand written letters were not considered but could be included in the future. In the phase of character identification, in total 3576 characters from 200 signboards were considered, out of which 3480 were identified correctly resulting in an accuracy of 97.3%. Some characters were not identified correctly due to a high degree of similarity between the characters; some of the characters that were not distinguished correctly were: 'x' and 'k', 'a' and 'q', 's' and '5', 'I' and '1', etc. When the image is taken, changing illumination is a major problem. As the illumination provided to the sight area differs, there will be slight variations in the obtained results. In future work, an algorithm could be developed to overcome the problems related to illumination.

References

[1] Sharpe, L.T., Stockman, A., Jägle, H. & Nathans, J., *Opsin Genes, Cone Photopigments, Color Vision, and Color Blindness*, in Color Vision: From Genes to Perception, Gegenfurtner, K. & Sharpe, L.T. (Eds.), Cambridge University Press, Cambridge, pp. 3-51, 1999.

[2] Judd, D.B., *Facts of Color-blindness*, Journal of the Optical Society of America, **33**(6), pp. 294-307, 1943.

[3] Pearlman, A.L., Birch, J. & Meadows, J.C., *Cerebral Color Blindness: An Acquired Defect in Hue Discrimination*, Annals of Neurology **5**(3), pp. 253-261, 1979.

[4] McDaniel, T.L., Kahol, K. & Panchanathan, S., *An Interactive Wearable Assistive Device for Individuals who are Blind for Color Perception*, In Proceedings of the 4th International Conference on Universal Access in Human-Computer Interaction, pp. 751-760, Springer Berlin Heidelberg, 2007.

[5] Ananto, B.S., Sari, R.F. & Harwahyu, R., *Color Transformation for Color Blind Compensation on Augmented Reality System*, In Proceeding of the 2011 International Conference on User Science and Engineering (i-USEr), pp. 129-134. IEEE, 2011.

[6] Harwahyu, R., Manaf, A.S., Ananto, B.S., Wicaksana, B.A. & Sari, R.F, *Implementation of Color-blind AID System*, Journal of Computer Science, **9**(6), pp. 794-810, 2013.

[7] Patel, I. & Goud, J., *Colour Recognition for Blind and Colour Blind People*, Int J. Eng Innovat Technol., **2**(6), pp. 38-42, Dec. 2012.

[8] McDowell, J., *Design of a Color Sensing System to Aid the Color Blind*, IEEE Potentials, **27**(4), pp. 34-39, 2008.

[9] Harish, M., Gudipalli, A. & Tirumala, R., *Enhanced Road Security using Edge Detection and Infrared Imagery*, Journal of Theoretical & Applied Information Technology, **58**(1), pp. 55-59, 2013.

[10] Tian, Y. & Yuan, S., *Clothes Matching for Blind and Color Blind People*, Proceedings of the 12th International Conference on Computers Helping People with Special Needs, Vienna, Austria, pp. 324-331. Springer Berlin Heidelberg, 2010.

[11] Banerji, S., Sinha, A. & Liu, C., *New Image Descriptors based on Color, Texture, Shape, and Wavelets for Object and Scene Image Classification*, Neurocomputing, **117**(14), pp. 173-185, 2013.

[12] Belmamoun, A., El Hassouni, M. & Hammouch, A., *On Selection and Combination of Relevant Color Components for Edge Detection,* Procedia Technology, **17**, pp.764-771, 2014.

[13] Zareizadeh, Z., Hasanzadeh, R.P. & Baghersalimi, G., *A Recursive Color Image Edge Detection Method using Green's Function Approach*, Optik-International Journal for Light and Electron Optics, **124**(21), pp. 4847-4854, 2013.

[14] Ou, Y. & GuangZhi, D., *Color Edge Detection based on Data Fusion Technology in Presence of Gaussian Noise*, Procedia Engineering, **15**, pp. 2439-2443, 2011.

[15] Mansor, M.N., Hariharan, M., Basah, S.N. & Yaacob, S., *New Newborn Jaundice Monitoring Scheme based on Combination of Pre-processing and Color Detection Method*, Neurocomputing, **120**, pp. 258-261, 2013.

[16] Goh, H.N., Soon, L.K. & Haw, S.C., *Automatic Dominant Character Identification in Fables based on Verb analysis – Empirical Study on the Impact of Anaphora Resolution*, Knowledge-Based Systems, **54**, pp. 147-162, 2013.

[17] Lin, W.C. & Scully, T.L., *Computer Identification of Constrained Handprinted Characters with a High Recognition Rate*, IEEE Transactions on Systems, Man, and Cybernetics, **6**, pp. 497-504, 1974.

[18] Namane, A., Guessoum, A., Soubari, E.H. & Meyrueis, P., *CSM Neural Network for Degraded Printed Character Optical Recognition*, Journal of Visual Communication and Image Representation, **25**(5), pp. 1171-1186, 2014.

[19] Niranjan, M., Ajtih, J. & Padmavathi, S., *Dynamic Indian Sign Language Character Recognition: Using HOG Descriptor and a Customized Neural Network*, International Journal of Imaging and Robotics™, **14**(3), pp. 35-46, 2014.

[20] Saoud, S., Mahani, Z., El Rhabi, M. & Hakim, A., *A Document Scanning in a Tough Environment: Application to Cameraphones,* International Journal of Imaging and Robotics, **9**(1), pp. 1-16, 2013.

[21] Surinta, O., Karaaba, M.F., Schomaker, L.R. & Wiering, M.A., *Recognition of Handwritten Characters using Local Gradient Feature*

descriptors, Engineering Applications of Artificial Intelligence, **45**, pp. 405-414, 2015.

[22] Yi, C. & Tian, Y., *Text Extraction from Scene Images by Character Appearance and Structure Modeling,* Computer Vision and Image Understanding, **117**(2), pp. 182-194, 2013.

[23] Otsu, N., *A Threshold Selection Method from Gray-Level Histograms*. IEEE Transactions on Systems, Man, and Cybernetics, **9**(1), pp. 62-66, 1979.

[24] Gonzalez, R.C. & Woods, R.E., *Digital Image Processing*, 2nd edition, Prentice Hall, 2002.

[25] Davis, L.S., *A Survey of Edge Detection Techniques*, Computer Graphics and Image Processing, **4**(3), pp. 248-260, 1975.