Journal of Energy & Environment

Journal homepage: journal.uniten.edu.my/jee

ISSN: 1985-7462

A Unified Color and Shape based Algorithm for Traffic Sign Detection System

Safat Bin Wali[a], Pin Jern Ker[a,b], M A Salam[c]

[a]Dept of Electrical Power Engineering, Universiti Tenaga Nasional, 43000, Malaysia
[b]Institute of Sustainable Energy, Universiti Tenaga Nasional, 43000, Malaysia
[c]Faculty of Engineering, Western University, Ontario, Canada

Keywords

Advance driver assistance system
traffic sign detection
color thresholding
segmentation
edge detection

Abstract

The road safety issue is being in an alarming condition due to the rapid increase in roads and vehicles. To solve the scenario, the automotive industry has developed an Advanced Driver Assistance System (ADAS) such as Traffic Sign Detection and Recognition (TSDR), Lane departure warning system, automatic braking system, and so on. Developing an efficient TSDR system is a difficult job due to the indecisive performance in the detection phase. Variation of illumination level and occlusion by surrounding physical objects are the major concern when developing the TSDR system. In this paper, the combination of color and the shape-based algorithm has been proposed to overcome the issues mentioned. The combination of two different detection techniques which are color thresholding segmentation and edge detection are used to extract traffic signs from the raw image. A success rate of 85% with a 0.701s operating time shows promising performance for real-time application.

1. INTRODUCTION

Traffic Sign Detection and Recognition (TSDR) system is an important application for the advance driver assistance system (ADAS). Due to the rapid incensement of industrialization and socialization, the number of traffic is increasing day by day and so as traffic accidents [1]. Traffic sign gives important information or rule about the roads and transports. Ignoring these signs may cause accidents. In adverse traffic conditions, drivers may not notice traffic signs and in such conditions, the TSR system comes into action. Developing a TSDR system is a difficult job because of variable lighting, illumination, and partial occlusion, different environmental conditions can affect the development of the detection system [2]. Therefore, an efficient detection system with a high accuracy rate and a low processing time is needed for the real-time application.

The different researcher has developed several methods to overcome the problems mentioned above such as; Content-Based Image Retrieval (CBIR), AdaBoost and Sum of Absolute Differences (SAD) technique are used for traffic sign detection [3], Fuzzy C-Mean (FCM) [4], Genetic Algorithms (GA) [5]. The most popular method for recognition of traffic sign is Support vector machine (SVM) and Neural Network (NN) [6], [7]. In [8], the result shows that in terms of processing time and accuracy NN performs better than SVM.

Image thresholding to the R, G, and B channels and the logical sums of the three channels to defines the region of interest (ROI) is done by Wali et al. [9] with a success rate of 93.3% whereas in [10], Color-Geometric Model (CGM) and SVM is used to classify the traffic sign into five categories.

The main purpose of this article is to develop an efficient traffic sign detection system under variation of intensity and reduce the illumination effect over the detection scheme by using image normalization in the preprocessing stage and a combination of both color segmentation and shape-based algorithm.

2. METHODOLOGY

The two main factors of differentiating a traffic sign from the surrounding are color and shape. In this study, color and shape-based detection techniques are proposed to extract the traffic signs from the raw image.

The proposed method can be divided into two stages such as; the image pre-process stage and the detection stage. In the proposed system, initially, the raw images are pre-processed, then the output of the pre-processed stage is used as an input to the detection phase. In the detection phase, two different detection techniques, color-based detection, and shape-based detection are applied to extract the ROI containing the traffic sign from the raw image. Figure 1 shows the proposed method for the detection and classification of traffic signs.

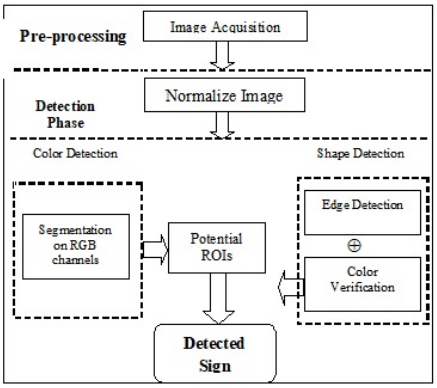


Figure 1. Proposed methodology

A. Pre-Processing Phase

Because of different lighting conditions and illumination problems, the raw images are initially pre-processed **16**. In the proposed method, normalization is applied using the following formula.

$$R'(i,j) = \frac{R(i,j)}{R(i,j)+G(i,j)+B(i,j)} \tag{1}$$

where is the normalized red pixel component and R, G, B is the red, green, blue components respectively.

B. Detection Phase

In the detection phase, a combination of color and shape-based detection algorithms are implemented. Two independent techniques will generate two outputs in this phase. A normalized image is used as the input image in the detection phase for both techniques.

In the color-based detection technique, the normalized image is thresholded in RGB channels accordingly to extract the potential of ROIs that contain the traffic signs. To do that, initially, the mode pixel value in RGB channels of the normalized image is determined respectively. The mode pixel value is the color of the sky or white color objects. Pixels' value that less than the mode pixel value (x=72) are the dim color pixel which does not have high color saturation in the RGB channels.

From Figure 2(a), (b) and (c) the region of high color saturation object contains a high number of pixels which consist of the traffic sign and noise from the background object. To extract the actual traffic sign, the mode value is multiplied with a constant value that varies with the camera sensor used. Normalized image is threshold using the threshold value shown in Figure 2 for each channel.

$$threshold_{red} = \beta \times \max pixelvalue \tag{2}$$

$$BW_{red}(i,j) = \begin{cases} 1, R'(i,j) > threshold_{red} \\ 0, R'(i,j) < threshold_{red} \end{cases} \tag{3}$$

The result of the red and blue channel is a logical sum up to extract all the red, yellow, and blue traffic signs in the raw image. Further processing is done by filtering according to the area and the ratio of the object width to height as in (4).

$$\text{Object detected} \begin{cases} accept, 200 < area < 2500, 0.8 < \frac{objectwi}{objecthe} \\ discard, otherwise \end{cases} \tag{4}$$

The filtered image will be then fed into the classification phase for further process as discussed in detail later.

C. Shape-Based Detection

After Pre-processing, the normalized image is used as the input image in the shape-based detection technique. As normalized image may consist of too much noise smoothing process is applied to eliminate the weak edge from the background. The Gaussian low pass filter is being applied to the normalized image using formula (5) and (6);

$$H_g(x,y) = \frac{1}{2\pi\sigma^2} \cdot e^{\frac{x^2+y^2}{2\sigma^2}} \tag{5}$$

$$H(x,y) = \frac{H_g(x,y)}{\sum_x \sum_y H_g} \tag{6}$$

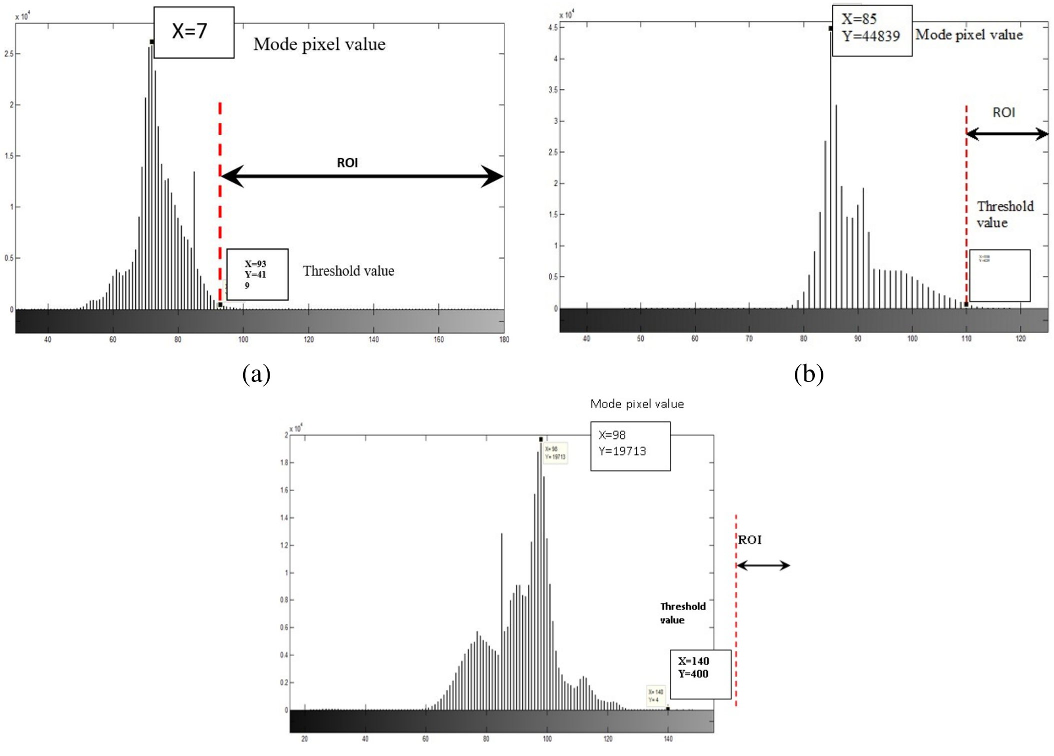
where x is the distance from the origin on the horizontal axis, y is the distance from the origin in the vertical axis, and σ is the standard deviation of the Gaussian distribution. x and y are defined as 5 in this project. Blur image from the Gaussian low pass filter is then converted into an edge image using Canny edge detector as shown in Figure 3.

The edge image is generated by the canny edge detector is labeled according to the connected lines in the image. Connectivity is checked before labeling is done. A connectivity check can be performed in 4 or 8 neighborhood pixels around the pixel of interest (center) as shown in Figure 4.

Connected pixels will have the same intensity or is the same pixel value for a binary edge image. The pixels that are connected are considered as part of the same object regardless of whether they are connected along the horizontal, vertical, or diagonal direction. The labeled edge image is then analyzed from object to object by filter the size of the object using Equation (4). The objects which fulfilled the criteria are then verified with the color on three points along the x-axis, A, B, and C on the normalized image as shown in Figure 5.

3. RESULTS AND DISCUSSIONS

In this section, the performance evaluation of the proposed system is studied. The system is developed and analyzed



(c)

Figure 2. Histogram of red (a), green (b), and blue (c) channel of the normalized image

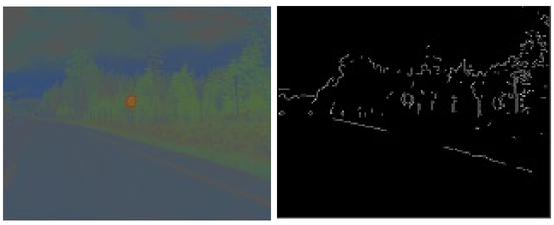


Figure 3. Edge image with 1.5 as high thresholds and 1.2 as low threshold

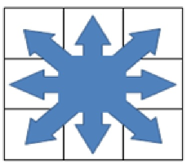


Figure 4. 8-connected connectivity check

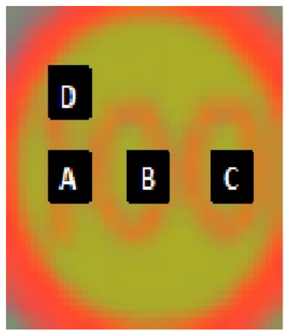


Figure 5. Coordinate of verification pixel

in Intel(R) Core (TM) 2 DUO CPU 2.00GHz and 4GB of RAM using the image processing toolbox of MATLAB R2007a.

A. Dataset

The 300 test images are collected from a publicly available dataset [9] which consists of Swedish traffic signs. Point-Grey Chameleon with a 1296x964 resolution at 18 fps was used to record the video in different weather conditions with an approximate 41-degree field view. The test images are consisting of 187 images with a traffic sign and 113 images without any traffic signs. In the initial stage, the test images are scaled down to 640×480 pixels to reduce the processing time.

B. Pre-Processing Results

Normalization is applied in this phase expected will eliminate the shadow and illumination problem. Figure 6(b) shows that the input image is normalized concerning the logical sum of the 3 channels. The traffic sign color is more saturated than the background color as shown. The high illuminated pixels are decreased to a lower intensity value and appear in grey in the image.

(a) (b) (c) (d) (e) (f)

Figure 6. Image pre-processing and normalization outcome: (a) Input image. (b) Resulting image (c) Shadowed image (d) Resulting image (e) Illuminated image (f) Resulting image (failure)

C. Detection Results

In the color detection phase, the traffic sign is segmented through thresholding the image using the threshold value computed from Fig.10. The coefficients of the RGB channel are 1.3, 1.3, and 1.43. A higher threshold value for the blue channel is used because of the outdoor color temperature on the image. While for shape detection, the traffic sign is extracted through the width-length ratio and color around the center. The performance and processing time are discussed are divided into four categories; False Positive (FP), False Negative (FN), True Positive (TP), and True Negative (TN). The overall performance of the detection phase is tabulated in Table 1.

Contributions of TP and FP from two techniques which are color and shape-based detection techniques are analyzed. 74% and 72.8% of 162 hit rates contributed from color and shape detection techniques respectively.

Table 1. Contingency Matrix of Sign Detection Method

Result classes	Hit Rate
TP	162
TN	81
FP	19
FN	38
Total	**300**

Mean whereas, the percent error of color detection is 8% and 3.3% for shape-based detection from the 10% detection error rate. The result is tabulated in Table 2.

Table 2. Performance of Detection Techniques

Performance	Color Based Detection	Shape-Based Detection	Overall Detection
TP	74% (120)	72.8% (118)	89.5% (162)
FP	8% (15)	3.3% (6)	10.5% (19)
		Total	**100% (181)**

From the data in Table 1, detection phase sensitivity, specificity, and accuracy values are computed as follows.

- Sensitivity: $\frac{TP}{(TP+TN)} = 86.1\%$
- Specificity: $\frac{TN}{(TN+FP)} = 83\%$
- Accuracy: $\frac{(TP+TN)}{(TP+TN+FP+FN)} = 85\%$

The sensitivity, specificity, and accuracy of the detection phase are analyzed in the illumination condition on the images as in Table 3 It shows that the proposed method has better sensitivity during medium and low illumination level but has a higher specificity during high illumination level. The accuracy of the detection phase at different illumination levels is about the same with the lowest 83.5% for high illumination level, 85.2%, and 87.5% for medium and low illumination level respectively.

The errors source on color-based and shape-based detection are identified manually. The deviation from the color-based detection technique is due to the color temperature on the image. A high illuminated image as in Figure 6(e), the color identity of the traffic sign loss under the illumination and color temperature effect. Hence, the color of the traffic sign could not be extracted out.

Table 3. Sensitivity and Specificity concerning Different Illumination

Illumination Level	Sensitivity (%)	Specificity (%)	Accuracy (%)
High	79.5	89	83.5
Medium	91.5	78	85.2
Low	90.4	80	87.5

Besides that, the color temperature effect inherits from the pre-process phase also gave significant effects on the shape-based detection technique. On the other hand, traffic signs that are too small also being filtered out even though been extracted from the detection technique. There are some cases that the traffic sign extracted combines with a nearby object as in Figure 7.

(a) (b)

Figure 7. Example of FN: (a) original image. (b) extracted image

The specific processing time for every stage is showed in Table 4. The overall processing time for the system is 0.701s with 0.122s for the pre-process phase, 0.0786s for color-based detection, and 0.36 for shape-based detection.

4. CONCLUSION AND RECOMMENDATION

This proposed color and shape-based traffic sign detection system show a promising performance with a 0.701s processing time and 85% accuracy rate. The proposed system is verified with a dataset consisting of different environmental conditions. The experimental outcome displays high accuracy in detecting illuminated traffic signs. Despite the system has successfully developed, there is still room for

Table 4. Processing Time for The System

Pre-process	
Task	Processing Time (s)
Resized image	0.053
Normalization	0.069
Color-based detection	
Task	Processing Time (s)
Threshold computation	0.045
Color thresholding	0.156
Filtering object	0.018
Shape-based detection	
Task	Processing Time (s)
Smoothing	0.009
Edge detection	0.269
Labeling image	0.058
Object Filtering	0.009
Verification	0.001
Sign extraction	0.014
Total	**0.701**

improvement. However, the system failed to detect highly distorted or illuminated traffic sign images. In future work, fully robust systems with more accuracy rate for detection and completely minimize the effect of illumination can be suggested.

ACKNOWLEDGMENT

The authors are thankful for the financial support provided by Universiti Tenaga Nasional under grant no 20190101LRGS.

REFERENCES

[1] S. B. Wali, M. A. Abdullah, M. A. Hannan, A. Hussain, S. A. Samad, P. J. Ker, and M. B. Mansor, "Vision-based traffic sign detection and recognition systems: Current trends and challenges," *Sensors*, vol. 19, no. 9, p. 2093, 2019. DOI: 10.3390/s19092093.

[2] F. Larsson and M. Felsberg, "Using fourier descriptors and spatial models for traffic sign recognition," in *Scandinavian conference on image analysis*, Springer, 2011, pp. 238–249. DOI: 10.1007/978-3-642-21227-7_23.

[3] A. Hussain, M. Hannan, A. Mohamed, H. Sanusi, and A. Ariffin, "Vehicle crash analysis for airbag deployment decision," *International journal of automotive technology*, vol. 7, no. 2, pp. 179–185, 2006.

[4] F. Qin, B. Fang, and H. Zhao, "Traffic sign segmentation and recognition in scene images," in *2010 Chinese Conference on Pattern Recognition (CCPR)*, IEEE, 2010, pp. 1–5. DOI: 10.1109/ccpr.2010.5659271.

[5] F. Zaklouta and B. Stanciulescu, "Real-time traffic sign recognition in three stages," *Robotics and autonomous systems*, vol. 62, no. 1, pp. 16–24, 2014. DOI: 10.1016/j.robot.2012.07.019.

[6] F. Zhu, J. Ning, Y. Ren, and J. Peng, "Optimization of image processing in video-based traffic monitoring," *Elektronika ir Elektrotechnika*, vol. 18, no. 8, pp. 91–96, 2012. DOI: 10.5755/j01.eee.18.8.2634.

[7] K. Kaplan, C. Kurtul, and H. L. Akİn, "Real-time traffic sign detection and classification method for intelligent vehicles," in *2012 IEEE International Conference on Vehicular Electronics and Safety (ICVES 2012)*, IEEE, 2012, pp. 448–453. DOI: 10.1109/icves.2012.6294316.

[8] M. A. Hannan, S. B. Wali, T. J. Pin, A. Hussain, and S. A. Samad, "Traffic sign classification based on neural network for advance driver assistance system," *Przeglad Elektrotechniczny*, vol. 90, no. 11, pp. 169–172, 2014.

[9] S. B. Wali, M. A. Hannan, S. Abdullah, A. Hussain, and S. A. Samad, "Shape matching and color segmentation based traffic sign detection system," *Threshold*, vol. 90, p. 255, 2015. DOI: 10.15199/48.2015.01.06.

[10] S. M. Bascón, J. A. Rodríguez, S. L. Arroyo, A. F. Caballero, and F. López-Ferreras, "An optimization on pictogram identification for the road-sign recognition task using svms," *Computer Vision and Image Understanding*, vol. 114, no. 3, pp. 373–383, 2010. DOI: 10.1016/j.cviu.2009.12.002.