Real Time Road Sign Detection using Hybrid Colour Segmentation and Invariant Shape Detection

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ABSTRACT

Road Sign detection and recognition systems provide an additional level of driver assistance, leading to improved safety for passengers, road users and vehicles. It can be used to benefit drivers by alerting them about the presence of road signs to reduce risks in situations of driving distraction, fatigue, poor sight and weather conditions. Although a number of systems have been proposed in literature; the design of a robust algorithm still remains an open research problem. This research aims to resolve some of the outstanding research challenges in road sign recognition systems, while considering variations in colour illumination, scale, rotation, translation, occlusion, computational complexity and functional limitations. The key contribution of the research is the ability to detect and recognize six types of speed limit signs and stop sign with an accuracy of 88% and efficiency of 97% by addressing the current speed level of the vehicle for up to 80 kmph.

Keywords-Road sign, segmentation, classification, neural network, colour space

1.0 INTRODUCTION

The speed of vehicles is one of the key components behind road accidents. Most drivers neglect the speed limit specified on speed signs. When the speed of the vehicle is high, drivers are unable to control the vehicle properly, thus the damage caused due to speed is high. The main objective of this research is to propose a solution which will analyse road signs, and assist the driver to minimize road accidents by providing a safe drive.

1.1 Related Work

The road sign detection process is divided into two main stages by many researchers in this area ([1], [2], [3], [4]). The first stage is road sign detection, which detects the road sign in an image using different techniques such as colour based sign detection and shape based sign detection. The second stage is Road sign recognition, which recognizes the input road sign by comparing the pre-configured or pre-trained set of road signs. Thereafter, road sign classification is conducted. Most researches have used different classification techniques such as template matching, Neural Networks and Support Vector Machine (SVM) classifier. Colour is one of the main components when identifying different road signs. The colour space used should have the ability to be applied in all situations, and it should result in the same colour every time without the variations in exposure. Brkic [9], Greenhalgh and Mirmehdi [1], have used the RGB colour space for their work. When considering their work, those have issues of applying the same colour space in different situations because of the sensitiveness of the RGB colour space.

The detection may defer due to the lighting conditions and weather conditions. Even though RGB is the standard, and is easy to represent, it is not easy to separate the colour and intensity. As described in Sallahet al [5], they have used HSI and

HSV colour space. When considering the HSI and HSV, same advantages could be obtained from both ways, such as separating information about colour and colour intensity. Brkic [9], and Cardarelli [6], have not chosen HSV color domain due to its own computational complexity. Since HSV domain enables evaluating color and intensity quantities separately, it is more reliable in changing lighting conditions. However, changing the domain from RGB to HSV increases computation time.

The YCrCb colour space has also been used by a few researches [7]. As per the existing work conducted, the key reason for not using RGB and HSV is because YCrCb separates luminance from chrominance information. Therefore YCrCb is constant in different light and weather conditions. Road signs consist of simple geometric shapes such as circle, triangle and octagon. When considering shape based detection with colour based detection, it addresses the issues which are caused by colour based detection, such as shape not changing due to weather or lighting conditions. The main purpose of shape based segmentation is to extract and identify images where road signs exist.

Greenhalgh and Mirmehdi[1] have illustrated two algorithms for the road sign detection process. First algorithm has been implemented to identify grey levels according to geometrical criteria. Second algorithm has been implemented using hue and saturation in HSV colour space. An image has been separated into regions of 16x16 pixels and regions have carried out a labeling process considering a certain threshold. Shape detection process has been conducted by using the geometrical analysis of edge contours. Broggi et al, [8] have proposed a road sign detection system with two main modules called sign detection and sign classification. Sign detection process is based on colour and shape. Images were divided into regions by converting the RGB images into HSV colour space. Regions which contain the hue were identified by considering S and V components. A shape extract module has been used to extract the road sign according to the details of the road sign, and template matching technique has been used for the identification process. Siogkas and Dermatas[9] have implemented a colour classifier using the hue and saturation components gained through HIS colour space. The binary image has been generated by multiplying two images, and normalized to 256 grey levels. For the shape detection, two genetic algorithms have been used. Genetic Algorithms (GA) and Simulated Annealing (SA) have been used for shape analysis. A detection rate of 90.4% is achieved by GA compared to 82.9% for SA. The detection of the sign has been achieved through normalized correlation and for the classification, neutral network has been used.

2.0 IMPLEMENTATION

The implementation is carried out mainly according to two main stages, which are road sign detection and road sign recognition.

Road sign detection

Different techniques and algorithms have been implemented to detect the road sign form the captured input.

Road sign recognition

Recognition stage has been implemented after processing the detection stage. Pre-configured and pre-trained set of road signs have been used with a neural network as a part of the recognition process.

Figure 1, illustrates the overall system flow for the proposed system.

2.1 Colour Segmentation

A robust approach towards real-time road sign colour segmentation process has been implemented with an algorithm, with a combination of two colour spaces (HSV and YCrCb), by considering the dominant attributes of those colour spaces in order to address colour changes that occur due to different lighting and weather conditions.

Colour segmentation is used to distinguish regions in interested colour from uninterested regions. As per the proposed solution, the implementation for detecting the speed sign regions which are surrounded by red colour, are considered as potential candidate regions, which may contain the speed limit sign or the stop sign.

In order to accomplish the potential candidate regions, the implementation uses a combination of HSV and YCrCb colour spaces, because the properties of these colour spaces have the ability to separate the brightness information from the colour information. The separation of the brightness information from the chrominance or chromaticity reduces the effect of uneven illumination in an image. The utilization of chrominance or chromaticity in the YCrCb and HSV colour space provides the opportunity for robust detection. Therefore, the implemented solution has been able to improve the identification of red colour regions which may defer due to the lighting and weather conditions, by combining the YCrCb and HSV colour spaces. The HSV colour space enables evaluating colour and intensity values separately; each image frame is converted to HSV domain. As the first step of the colour segmentation process, images are converted from RGB colour space to the HSV colour space.

The colour characteristics of the sign are analysed by using the hue component of HSV colour space. For each pixel in the image, hue based detection values for red colour is achieved by two sets of ranges as lower range (H= 0 to 10) and upper range (H= 160 to 180).

As for the next step of the colour segmentation (Table 1), the vectors which are obtained from the upper and the lower range of 'H-Hue' are merged and created into a new vector which has the detected regions for the red colour.

In order to increase the accuracy of colour segmentation, YCrCb colour space is applied to the original image frames as the next step of the colour segmentation process. In YCrCb, the 'Y' coordinate is strongly dependent on brightness; the red colour segmentation is only considering the Cr (red-difference Chroma) and Cb (blue-difference Chroma) values. According to previous researches and testing, the distribution of red colour in YCrCb space which is used for the implementation is shown in Equation 1 below. A pixel can be considered as a red pixel if the Cr, Cb values are meeting the following conditions:

$$Red\ pixcel \begin{cases} 128 \leq P_{Cr} \leq 217 \\ 97 \leq P_{Cb} \leq 132 \end{cases}$$

Equation 1 - YCrCb Red pixel range

The vectors obtained from the HSV colour segmentation and YCrCb colour segmentation process is combined and creates a new vector which has the identified red regions. This hybrid colour segmentation is able to detect road signs where the colour of the sign fades with time as a result of long exposure to sun light, and road signs which are affected by weather conditions such as fog, rain and clouds.

2.2 Shape Segmentation

As the next step of the implementation, several constraints on the shape properties are used to eliminate some of the candidates which cannot be a sign. The colour segmented image is used for shape based segmentation. The implementation of the shape based segmentation classifies the road signs into two main groups. The first group consists of road signs with a circle as the candidate for speed limit signs, and the second group consists of road signs with the shape of an octagon as a candidate for stop signs.

2.2.1 Circle Detection

Hough transform is applied, in order to detect circular traffic signs. The colour segmented image is taken as the input for circle detection. Therefore it has only the red regions. Circle detection is done to identify whether red regions contain the shape of a circle.

Minimum and maximum radius for a circle is defined empirically as 50 and 120 to eliminate the very small and very large circles. These values are obtained by testing a series of road signs. Minimum distance between two centres of consecutive circles is defined to reduce false detection of road signs. It eliminated detection of two circles due to the thick red border of the road sign. A list of vectors which contain x_{c}, y_{c}, r for detected circles are returned as the output of the circle detection process. Following Table 2 contains the result obtained in the circle detection process.

In a real time scenario, the chance of obtaining overlapped road signs is very low due to having a significant distance between one road sign and another. Therefore the algorithm is implemented with an option of having minimum distance between two centres of circles which enabled false detection of circles, so that only the candidate circles could be focused on in a speed sign. Also, the algorithm addresses the detection of multiple shapes on a given frame (Table 3).

Road signs are sometimes covered with another object nearby such as from another board. Therefore the full road sign is not shown. Hough Transform circle detection addresses to identify even discontinued circles. Also, if the circle appears towards the edge of the frame, or part of the circle is cut due to having the circle on the edge of the frame, Hough Transform circle detection algorithm handles both scenarios (Table 4). Moreover, the Implementation of the Hough transforms also addresses detection of circles which are captured from different angles.

2.2.2 Octagon Detection

Octagon detection is done to detect the candidate inputs for a stop sign. In order to detect the octagon, a new algorithm has been implemented. This algorithm has the ability to detect octagons with different orientations.

As the first step of the octagon detection algorithm, in order to reduce the noise of the image, Gaussian filter is applied. 'GaussianBlur' Canny edge detection is applied to the noise removed image in order to detect the edges on the image.

The octagon is a type of polygon. Therefore as the next step of the algorithm, the implementation checks whether there are any available polygons or contours in the edge detected image. Most of the time, an image consists of many contours, therefore the area of the candidate polygon is calculated by considering the area of the octagon which needs to be identified. The implementation travels through the identified contours, and identifies only positive contours of an octagon. The minimum area of a positive polygon is defined according to a threshold value. The next step of the algorithm checks the number of available sides of the detected polygon, and if the side count is equal to eight, the detected polygon is categorized as a candidate for an octagon, and passed on for further evaluation. A stop sign contains the stop word in the middle of the sign, therefore the middle of the detected polygon contains white pixels. Hence, the algorithm checks if the white pixel count is greater than a threshold value from the total pixel count. The polygons which match the pixel ratio are passed to the corner detection.

A corner of an octagon is 135 degrees. The algorithm checks for the angle between the points identified, and if the angles of the eight corners are 135 ± 10 ($125 < x < 145$) degrees, the polygon is recognised as an octagon (Figure 2). As a threshold value, ten degrees are added empirically to address different orientation or angles of octagons (Figure 2, 3). Feature Extraction and Classification.

Colour and shape combination of segmentation reduces the number of false alarms. Hence, it decreases the number of objects to be sent for classification. In this manner, the efficiency of the system is improved. The results obtained from the shape detection are passed to the classification process. As the next step, the detected circles are cropped separately according to the x and y coordinate information, along with the radius obtained by the circle detection process. Since the shape identification process uses the colour segmented image, it contains less information. Therefore the obtained x and y is applied to the original image by considering the radius of the circle, and extracts the region which contains the detected circle. In order to crop the detected area, a rectangle is plotted surrounding the circle through x and y coordinates. After extracting the candidate region for the road sign, the extracted region is resized to 100px x 100px image in order to maintain a common size for all the detected regions.

As the next step of the implementation process, in order to extract pixels from the cropped image which represents the candidate for road sign, the image is threshold by using the adaptive threshold technique. In order to pass only the region of interest, the threshold image is combined with a boxed template as shown in Table 5.

2.2.3 Artificial Neural Network for Speed Sign Classification

Multilayer feedforward neural networks have been designed for the speed sign classification and stop sign classification process. The extracted region of interest (ROI) of the threshold image is given as an input for the neural network. The input stage is composed by 400 neurons.

Neural network of the speed sign classification has six neuron outputs which are given according to the number of speed sign classes. Hence, the output layer is set to have 6 neuron nodes, hidden layer neuron nodes are set to be 16. The Neural network composed for the stop sign classification contains only one output neuron. The activation function for each layer is standardized to be the sigmoid activation function because the sigmoid function is a strictly increasing function which exhibits a graceful balance between linear and nonlinear behaviour.

The network is trained with around 250 images for each class by addressing various situations. As shown in Table 6, the value obtained for the tested 100 kmph road sign is the highest value received from the network. The output result values are compared with the threshold value which was obtained by using the given data set. Speed sign is identified only if the output result is greater than the threshold value.

3.0 EVALUATION

The overall application testing was conducted by addressing various components in order to evaluate the accuracy and efficiency of the system. The application was implemented to recognize road signs with a variation of vehicle speed levels. Testing is done for the recognition of speed limits with six speed ranges of the vehicle. When the speed range is 30 to 60 kmph, in most cases, the application has obtained an average of 100% accuracy level. The case where the speed level is 80 to 100 kmph, accuracy of the detection was 69%. Therefore as the speed of the vehicle increases, the recognition accuracy reduces. For the vehicle speed of 60 to 80 kmph, accuracy is 78% to 88%. As the main evaluation point, the application is able to detect and recognize speed signs from 0 to 100 kmph of vehicle speed with an average accuracy rate of 88%.

The overall application efficiency and accuracy was calculated from 250 images. Out of 250 images, 225 images have been detected and recognized. Therefore 88% (87.66) accuracy level was gained for identification of seven road signs with different weather, lighting conditions and variation of speed level of the vehicle. The efficiency is captured from the time taken to process and recognize the relevant road sign. Efficiency is captured from two main scenarios, from quality of the image and overall time taken to process images which fall into three criteria such as with speed signs, stop signs and without speed or stop signs. Overall, 100 images were input to test these three criteria and have achieved an average time of 0.0467 seconds. The Table 7 illustrates the evaluation with the existing researches.

4.0 CONCLUSION

The main goal of this research is to present a road sign recognition system along with a speed assistant which will provide assistance to a vehicle driver to identify road signs and maintain the allocated speed limit. This minimises road accidents which occur due to the speed of the vehicle, and not following road signs properly. The research performed assisted in gaining a deep understanding of the technologies available at present with regard to sign detection and recognition, and the type of techniques that are suitable to apply for different scenarios were also identified. Algorithms have been proposed for segmentation and classification. The proposed algorithms in this research were tested on a total of seven Sri Lankan road signs. The application has obtained an accuracy of 88% and efficiency of 0.0467 seconds (46.7 milliseconds) by addressing vehicle speed level of 0 to 100 kmph.

A number of contributions were proposed. However, there exist possibilities to further enhance the research work which can lead to further improvement of the functionality and robustness of the algorithms proposed. The application only addresses road signs captured during the day time, thus the research can be further enhanced by addressing road sign detection during night time as well. As a possible improvement for the road sign detection at night, it can be done by implementing a colour pixel enhancement algorithm for colour segmentation in night time detection.

5.0 REFERENCES

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APPENDIX

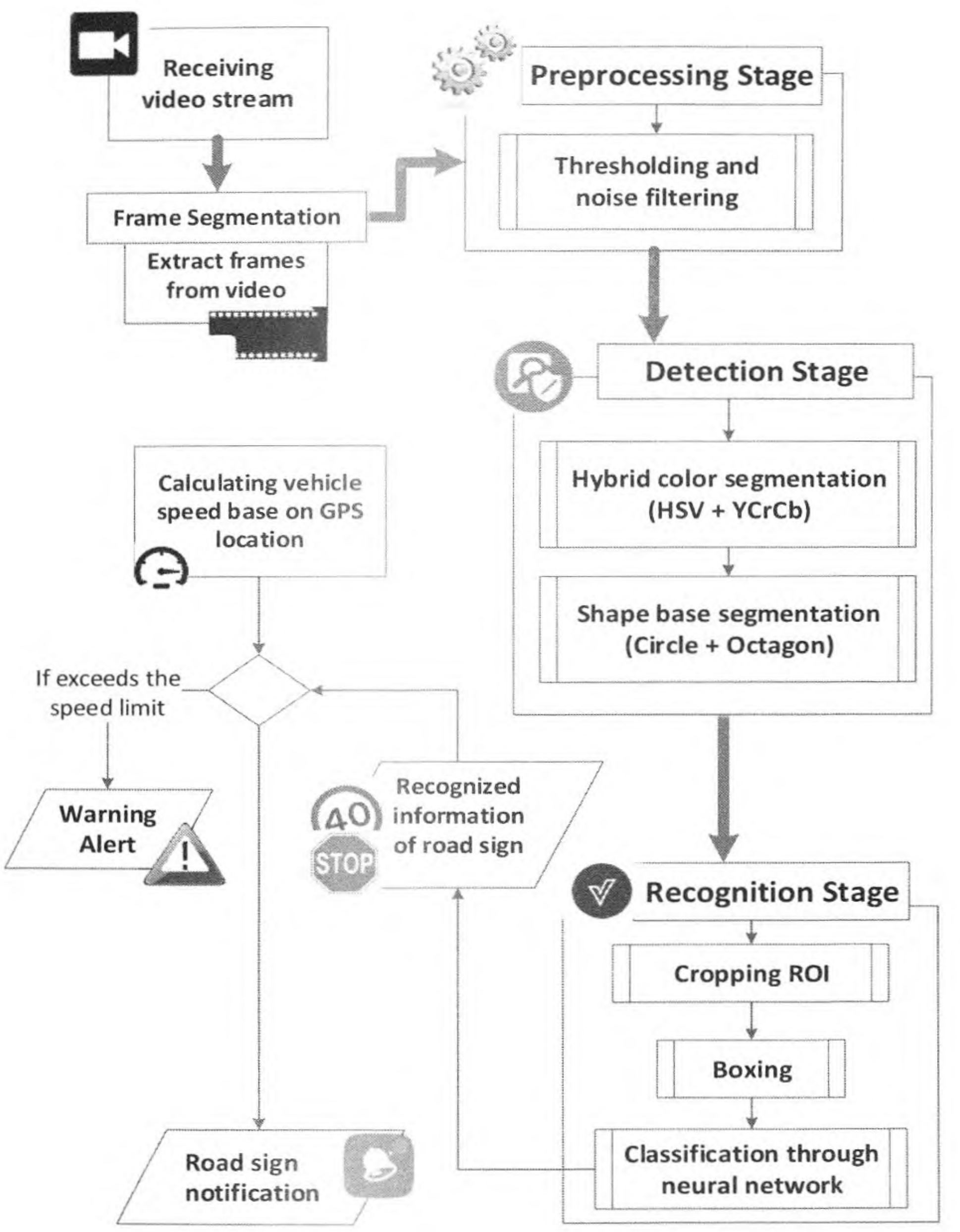


Figure 1- Overall system flow

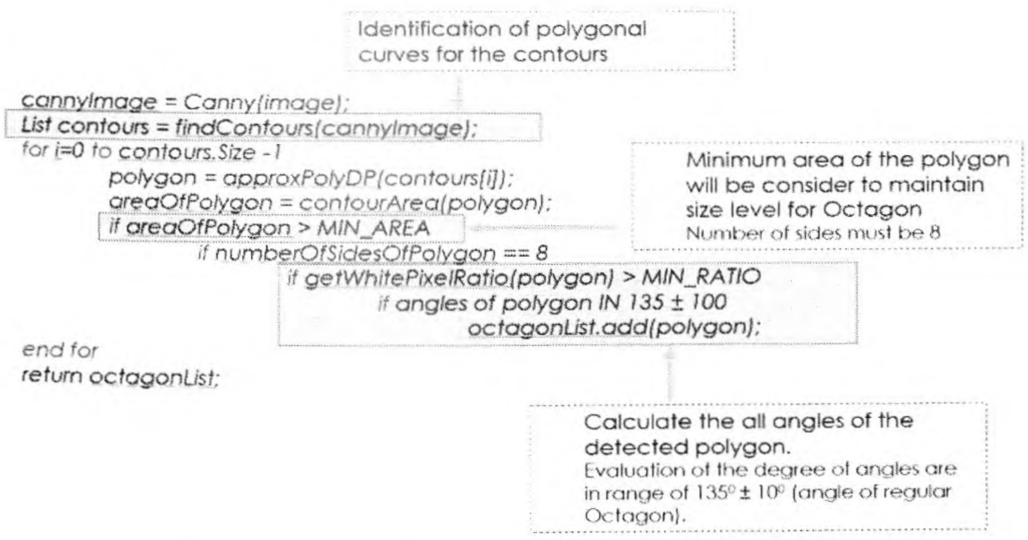


Figure 2 - Octagon Detection Algorithm

Figure 3 – Example of Octagon Detections

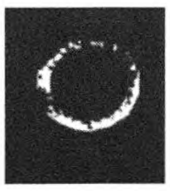
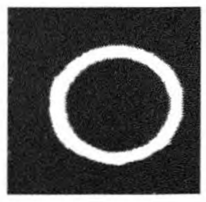
Input Image	After applying lower red hue range	After applying upper red hue range	Combination of both hue ranges
			

Table 1 - Example of Colour segmentation

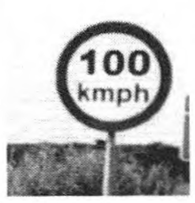
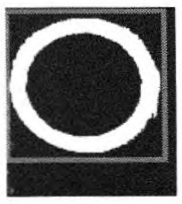
Input image	After colour segment	After applying Hough Transform	
			

Table 2 - Example of circle detection

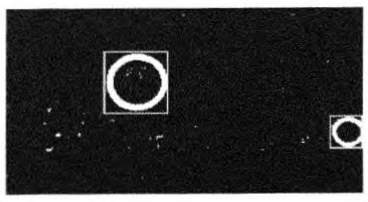
After applying Hough Transform	
	

Table 3 - Example of multiple sign detection

Input	Colour segmented	After applying Hough Transform

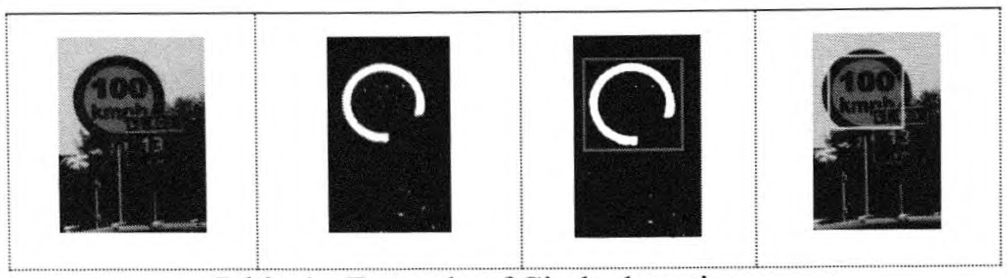


Table 4 - Example of Circle detection

Threshold image	Template	Extracted text area
		

Table 5 - Boxing process

Extracted Region	Classification Result
	100 : 0.9303 80 : 0.0046 70 : 0.0046 40 : 0.0344
	100 : 0.9807 80 : 0.0138 70 : 0.0006 40 : 0.0013
	100 : 0.0009 80 : 0.3561 70 : 0.8687 40 : 0.0021
	100 : 0.003 80 : 0.9790 70 : 0.0217 40 : 0.0153

Table 6 - Classification Results

	Research		No. road signs addressed	Maximum vehicle Speed	weather conditions	Accuracy	Efficiency
	Title	Author					
1	Real-time speed-limit-sign recognition on an embedded system using a GPU	Muyan-Özçelik, P Glavtchev, V Ota, J. M. Owens, J. D.	4	50 kmph	Not addressed	75%	
2	Road Sign Detection and Recognition by Using Local Energy based Shape Histogram (LESH)	Edirisinghe, E Zafar, U Iffat, Z	5	40 kmph	Addressed	96%	53%
3	Image Based Detection and Recognition of Road Signs	Sathiya, S Balasubramanian, M Sivaranjini, R	3	55kmph	Not addressed	89%	70%
4	Shape-based road sign detection for a driver assistance system	Loy, G. Barnes, N.	3	45 kmph	Not addressed	95%	
5	Shape Matching and Color Segmentation Based Traffic Sign Detection System	Wali, Safat	1	40 kmph	Addressed	94%	92%
6	Color-Based Road Sign Detection and Tracking	Lopez, L D Fuentes, O	2	50 kmph	Not addressed	97%	72%
7	Incremental Detection of Text on Road Signs from Video with Application to a Driving Assistant System	Wu, W	-	45 kmph	Not addressed	84%	
8	Speed Sign Recognition using Shape-based Features	Abukhait, J	2	-	Not addressed	86%	66%
	Proposed Application	Lahiru Yapa	7	70 kmph	Addressed	88%	97%

Table 7 - Overall evaluation with existing work