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Road Sign Detection and Recognition System for Real-Time Embedded Applications

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***Abstract*—In this paper, we propose a road sign detection and recognition algorithm for an embedded application, which requires computationally simple but accurate algorithms. The algorithm is developed by using the Hue Saturation Intensity (HSI) color space to segment the road signs color (red, yellow, blue and white) and the regions of interest (ROI) in order to locate and determine the shape of the road sign (diamond, square, hexagonal and circular) in real street-view images. The shape is then used to classify road signs into four categories, i.e. warning, mandatory, prohibitory and informational signs. The characteristics of the shapes such as area and perimeter variables are used to identify the symbols in the road signs. These variables are compared with the template library which we have developed. The proposed algorithm is tested on the Malaysia's road signs which are captured on the roadside in their real environment. Experimental results on the accuracy of the road sign detection are reported in this paper. The proposed algorithm will be implemented in a real time embedded system using Xilinx Video Starter Kit Board- Spartan-3a DSP 3400A Edition.**

***Keywords*—Road Sign, HSI color space, Region of Interest (ROI)**

I. INTRODUCTION

Road sign provide meaningful information that can help driving in a manner that is safe for the driver and other road users. The information provided by the road signs is categorized into colors and shapes for easy identification [1].

Based on the road accident statistics released by the international transport forum, Malaysia has the highest death rate compared to other countries with 23.8 deaths on the road for every 100,000 populations in 2009 [2].

Most of accidents are attributed to either reduced attention of drivers or that they simply choose to ignore the road signs. The weather condition like rain and sometimes heavy fog and dew, especially during early morning and late evening, also have been reported as being some of the causes of many accident cases [3][4].

Therefore, the recognition of road signs will be a great help to reduce the number of traffic accidents and deaths. The development of road sign detection and recognition systems using image processing technology will ensure that each driver is aware of the rules and hazards on the road and will hopefully reduce the number of accidents and deaths.

The development of the system is divided into two major objectives:

1) Segmentation of road signs using colots information from real images using color thresholding technique.

2) Classification of road signs based on the region of interest determined by the color segmentation stage.

Many techniques have been developed to detect and recognize road signs [5][6][7][8]. Normally, the design of road sign detection and recognition algorithm is composed of two phases: detection and recognition [9]. Color segmentation is the most common method applied for the initial detection of road signs [10].

Ghisio *et.* al [11] proposed a procedure with three phases which composed of color segmentation, shape detection and sign classification using neural network. They use RGB color space in order to reduce processing time, and employ simple models of pattern matching, edge detection and geometrical cues in the recognition phase.

Lopez and Fuentes [12] detected the road signs in CIELab color space, and modeling color pixels using Gaussian distributions. Their approaches are tested using image sequences with extreme clutter.

Wu *et.* al [13] converted images into HSV color space to detect the road signs. They also used morphological techniques to reduce noise environment. Finally, the road signs are extracted using geometric property.

Lalonde and Li [14] described a color indexing approach to isolate the road signs. Road signs are identified by comparing color histogram produced by the extracted road signs images with those pre-stored in a database.

Shneier [15] detected the road signs using rules that limit colors and shapes and require signs to appear only in limited regions in an image. Then, road signs are recognized using a template matching method and tracked through a sequence of images.

Farag and A. Hakim [16] used Bayesian approach for detecting road signs from input images based on color information. Scale Invariant Feature Transform (SIFT) is employed in order to extract a set of invariant features for detecting the road signs labels. Road sign recognition is done by matching the extracted features with previously stored features of standard signs.

Fang *et.* al [17] studied an approach for detecting and tracking road signs in complex traffic scenes. In the detection phase, two neural networks are developed to extract color and shape features of traffic signs from the captured images. In the tracking phase, Kalman filter is used to track road signs that are identified in the preceding phase through image sequences.

Liu *et.* al [18] applied Step Genetic Algorithm(Step-GA) and Simple Vector Filter(SVF) for recognizing road signs from moving images. The Step-GA code with search region limits is employed to detect the position and size of the road signs; their SVF was employed to segment the road signs colors.

This paper is an extension to our previous work [19] which provide several enhancements to the proposed shape classification methods (i.e. Hough Transform to Shape Measurement- Extent) in order to select the best technique with high efficiency and less processing time for the implementation in embedded systems.

In general, HSI color space and a simple algorithm based on region of interest (ROI) [20] are used to detect the shape of road signs. The characteristics evaluation in the region of interest (ROI) will indicate the shapes of the road signs whether they are triangular, diamond, rectangular, square, circular or hexagonal. Library templates of a MATLAB-based algorithm are developed by considering shape measurements. The ratios of area and perimeter are finally determined to recognize the actual image of the road signs such as a crossroad sign, a stop sign, and others.

II. Methodology

In this paper, we present a system for the detection and recognition of the road signs which consists of three phases:

1) Phase 1: Color Segmentation: The regions of the road sign colors are segmented from real images by using HSI (Hue, Saturation and Intensity) color thresholding technique for chromatic signs. In addition, achromatic color decomposition technique is used to segment white signs from images.

2) Phase 2: Shape Classification: The shapes of road signs are classified into four patterns by computing Extent value. Road signs are then classified into four categories: prohibitory, warning, informational and mandatory.

3) Phase 3: Symbol Recognition: The symbols of road signs are recognized by comparing shape measurement- Area and Perimeter ratios with the template values. The template values are based on standard images without noise.

Fig.1 illustrates a standard approach for road signs classification in Malaysia; this approach is used in the proposed flow of detecting and recognizing road signs.

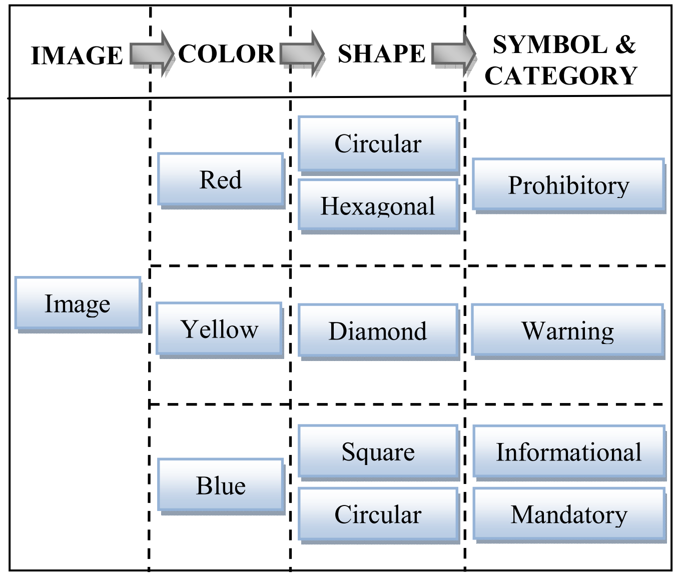

Figure 1. Standard Approach of Road Sign Classification

A. *Phase 1: Color Segmentation*

The HSI color space is very comparable to human sensitivity of colors. The hue and saturation elements are sufficient to extract road sign colors in a real environment based on fixed thresholds. The hue element represents the perceived colors (red, yellow and blue for road signs), which are within the interval [0, 360]. The saturation represents how much white light has been added to a pure color and is within the interval [0, 255]. The RGB color spaces are converted to HSI color spaces by using the following equations (1)-(4) proposed in [21]. The theta, θ, is measured with respect to the red axis of the HSI model as indicated in Fig. 2.

$$Hue = \begin{Bmatrix} for \quad B \le G, \quad Hue = \theta \\ for \quad B > G, Hue = 2\pi - \theta \end{Bmatrix} \tag{1}$$

with

$$\theta = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-B)]}{[(R+G)^2+(R-B)(G-B)]^{1/2}}\right\} \tag{2}$$

$$Intensity = \frac{(R+G+B)}{3} \tag{3}$$

$$Saturation = 1 - \frac{3}{(R+G+B)}\left[min(R,G,B)\right] \tag{4}$$

The hue elements only consider the chromatic colors of the road signs. Nevertheless, the achromatic color like white signs can be determined by equation (5) [22]:

$$Achr = \frac{abs(R-G)+abs(G-B)+abs(B-R)}{3D} \quad (5)$$

where R, G, and B are the brightness of the individual color, and D is the extraction degree of the achromatic color; where D is set to 20. Acr value that is less than 1 indicates an achromatic color while Ach value of more than 1 indicates a chromatic color.

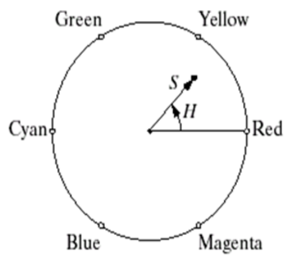

Figure 2. HSI model

Fig. 2 shows the ranges of red color are within the interval [0, 60] and [300, 360]. However, the hue element is normalized to the range [0, 1] by dividing it by 360º. As a result, the ranges of red colors are within the interval [0, 0.166] and [0.833, 1]. The threshold values for segmenting road signs colors are set in Table 1 after an analysis of the hue and saturation values of manually selected road signs parts in Matlab was done.

TABLE I. THRESHOLD SETTING FOR SEGMENTING ROAD SIGNS COLOR IN REAL IMAGES

Color	Threshold Value
Red	H $\leq$ 0.027 or H $\geq$ 0.833
Yellow	H $\leq$ 0.166 and H $\geq$ 0.055 and S $\geq$ 0.350
Blue	H $\leq$ 0.650 and H $\geq$ 0.527
White	S $\leq$ 0.200

The thresholding process results in a binary image in which background pixels are represented by 0's, and the road signs object pixels by 1's. After the color segmentation phase, the region is analyzed using pre-processing methods like filtering operations and morphological operations.

B. *Phase 2: Shape Classification*

The regions obtained from the segmentation phase are simply classified into variety of shapes in this phase. The shapes considered are diamond, square or rectangular, hexagonal and circular. Shape classification is carried out corresponding to the Extent [20] produced by the binary image. Extent is a specific ratio of pixels in the region of interest to the pixels in the bounding box. The total pixels in the region of a shape refer to the area of that shape and the total pixels of a bounding box refer to the area of the bounding box [20].

$$Extent = \frac{Total\ Pixels\ of\ ROI}{Total\ Pixels\ of\ Bounding\ Box} \quad (6)$$

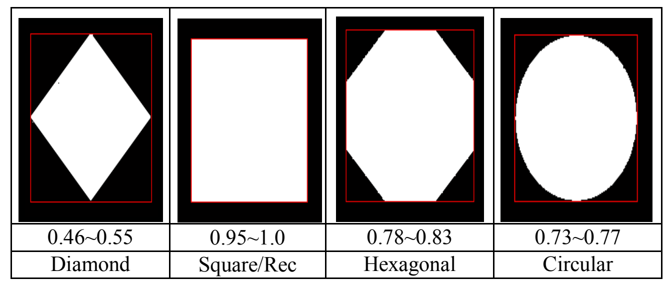

Figure 3. Four Patterns of Road Signs Shapes.

Fig. 3 shows four shapes pattern and their corresponding range of Extent values obtained from standard images.

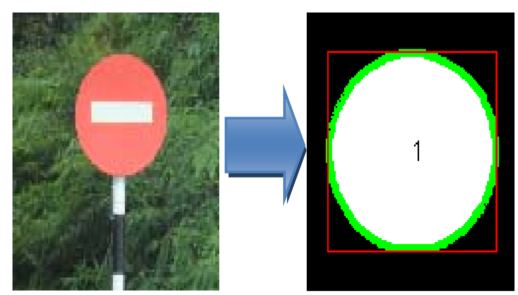

Figure 4. Shape classification corresponding to Extent

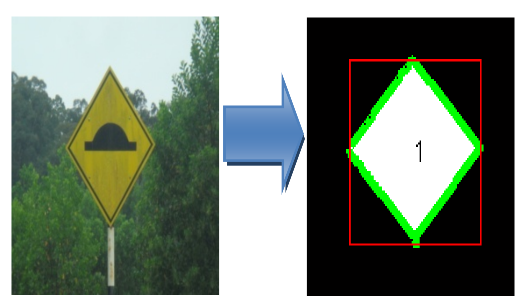

Figure 5. Shape classification corresponding to Extent

Fig. 4 and 5 show the actual signs that have been captured in real environment in Universiti Teknologi PETRONAS which have been identified as a circle and a diamond shape based on the Extent value.

Green lines in the binary shapes represent the boundary of the shape detected and the red frame represents the bounding box produced based on the smallest rectangle containing the shape region. The label '1' indicated that one object has been detected by the color segmentation phase.

C. *Phase 3: Symbol Recognition*

The shape region and their bounding box obtained from the shape classification process are normalized into a fixed dimension of 180 x 180 pixels, preparing it for the recognition process. Then, all ranges of area and perimeter ratios for different symbols will be compared with the reference ratios of standard images.

The equation for both area and perimeter ratios are given in (7) and (8).

$$\text{Area Ratio} = \frac{\text{Area of Symbol Region}}{\text{Area of Shape Region}} \tag{7}$$

$$\text{Peri Ratio} = \frac{\text{Area of Symbol Region}}{\text{Area of Shape Region}} \tag{8}$$

Fig. 6 shows some example of the results of the recognition process based on the area and perimeter ratios. The ratios for standard sized road signs are stored as variables in Matlab.

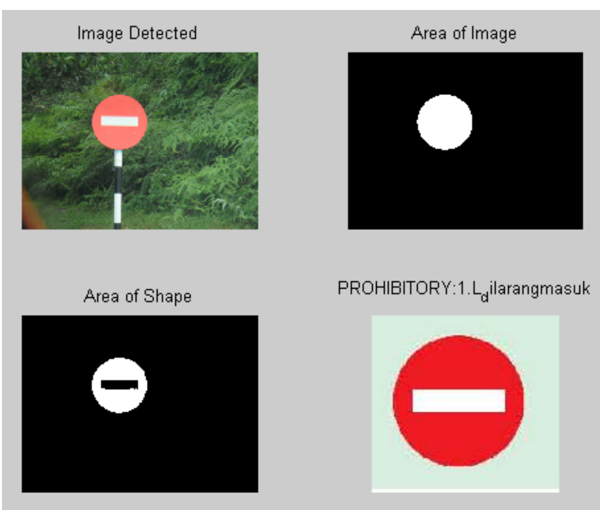

Figure 6. Road sign recognition based on ratios of area and perimeter in MATLAB software

According to the template that was proposed in [19], the measurements of Extent are almost equal for all different scaling value (corresponds to the various distances between the observer and the road signs in straight roads) and rotation methods (corresponds to road signs in corner and hilly roads).

III. EXPERIMENTAL RESULTS

In order to evaluate the effectiveness of the proposed method, numerous traffic signs were captured with different viewpoints in real image scenes. The proposed algorithm was applied to those images and the results are reported in this section:

A. *Results of Phase 1: Color Segmentation*

From Table II, out of sixty-five signs that were tested, the total number of correct segmentation of randomly chosen road signs is fifty-nine and the total number of failed segmentation of road signs is six. The percentage of correct segmentation of road signs is 90.7% while the percentage of failed segmentation is 9.3%.

TABLE II. PERFORMANCE OF ROAD SIGNS COLOR SEGMENTATION

Color of Road Signs	Situation	Image Samples	Correct Detection	Failed Detection
	Day	15	14	1
	Night	5	4	1
Yellow	Day	18	18	0
	Night	5	3	2
Blue	Day	17	17	0
	Night	5	3	2
TOTAL		65	59	6

B. *Results of Phase 2: Shape Classification*

From Table III, the fifty-nine road signs that were correctly segmented in the color segmentation phase were tested in the second phase to classify road signs shapes based on the Extent value. The total number of correct classification is 58 out of 59 signs and the total number of failed classification is only one sign. Therefore, the percentage of correct classification of road signs is 98.3% while the percentage of failed classification is 1.7%.

TABLE III. PERFORMANCE OF ROAD SIGNS SHAPE CLASSIFICATION

Shape	Test	Pass	Fail
Diamond	21	21	0
Square	12	12	0
Hexagonal	5	5	0
Circular	21	20	1
TOTAL	59	58	1

The results of the road sign symbol recognition phase are not presented here since we need to collect more samples of real road sign images with different symbols and locations. The results of this method will be compared to the value produced by the library templates.

Fig. 7(a) - (d) shows the results of color segmentation and shape detection phases in several different conditions.

IV. CONLUSION AND FUTURE DIRECTION

In this paper, the proposed methods of road signs detection and recognition system based on color and shape is proposed. The proposed algorithm is implemented and tested in MATLAB. In the segmentation phase, the HSI color space is used to segment the color of road signs and the Extent value is then used to classify the shape of the road signs. In the recognition phase, Area and Perimeter ratios are calculated to recognize the road signs.

Most road signs can be correctly detected and recognized by the proposed method with the accuracy of 90.7% for the segmentation phase based on color extraction. On the other hand, the proposed method for classifying the shapes of road signs is extremely accurate with 98.3%.

More samples need to be tested in order to get a better evaluation of the algorithm in achromatic color in the color segmentation phase by considering road signs in various situations and weather condition, i.e. cloudy, sunny and rainy.

Even though this method has been designed using simple technique, but it has good performance that is proven by experimental results in term of less time processing and can be used in various weather condition, thus making it suitable for real time embedded applications.

We are currently working on collecting numerous road signs images in real environment and enhancing the symbol recognition method by using neural networks to compare the extracted variables (i.e. features) with our library templates in order enhance the system performance in recognizing the road sign symbols correctly.

For real time embedded system, this algorithm will be implemented in FPGAs using Xilinx System Generator (XSG). This design will integrates Matlab, Simulink and XSG development platforms in hardware implementation using Xilinx Video Starter Kit Board- Spartan-3a DSP 3400A Edition.

Figure 7(a). Rectangular sign in night time

Figure 7(b). Circular sign

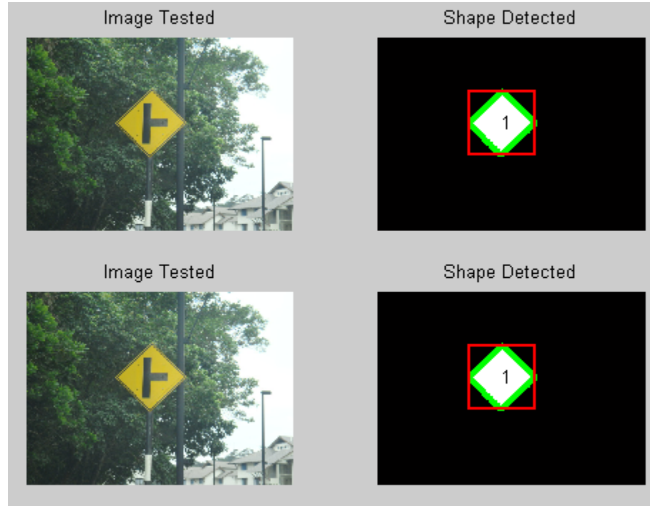

Figure 7(c). Diamond signs with different scale on straight road

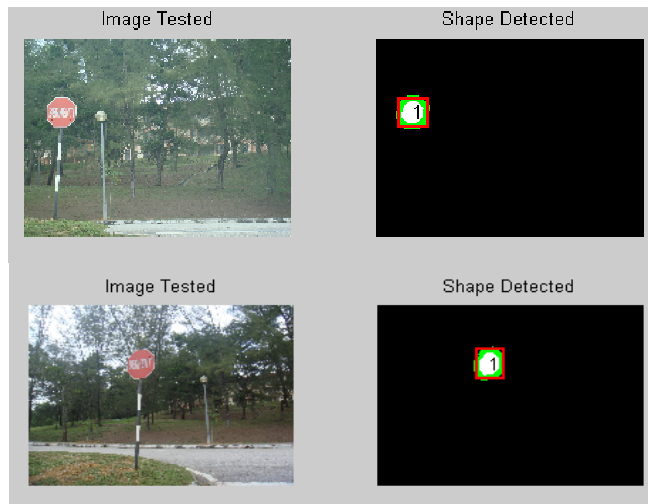

Figure 7(d). Hexagonal signs with different angle when upward hills

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