

Traffic Road Sign Detection and Classification

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ABSTRACT:

Traffic road sign detection is important to a robotic vehicle that automatically drives on roads. As the colors of most traffic road signs are blue and red, in this paper, we use Hue- Saturation- Intensity (HSI) color space for color based segmentation at first. Using important geometrical features, the road signs are detected perfectly. After segmentation, it turns to classify every detected road signs. For this purpose, we employ and compare the performance of three classifiers; they are distance to border (DTB), FFT sample of signature, and code matrix. In this work, we use the code matrix as an efficient classifier for the first time. Although the achieved accuracy by code matrix is greater than the two referred classifiers in average, the main advantage is simplicity and so less computational cost.

KEYWORDS: Road sign detection, Road sign classification, Code matrix.

1. INTRODUCTION

Traffic road signs are very important in guiding direction for drivers, prompting behaviors of drivers and ensuring the traffic safety. Therefore, the automatic road signs' detection has already become an important research topic in the field of the intelligent vehicles. There are a number of important issues that need to be addressed. These issues are lighting and weather condition, rotation, scaling and in some case partial occlusion. The traffic road sign detection system usually includes the three distinct stage processes: the first is detecting the most likely image area is known as the region of interest (ROI), and it may contain the traffic sign. The second is classifying each ROI as being one of the traffic sign categories, and the third is recognizing the traffic road sign content.

Color is often used for detecting the road signs. This process is called color segmentation. In general the RGB images are converted to other color spaces for instance L^*A^*B [1] and HSI [2] whereas the brightness information is distinguished. Usually the traffic signs' segmentation in a specific color space is performed by using an appropriate threshold. As the RGB components are too sensitive to lightening changes, this well-known color space is rarely used in the traffic road sign segmentation [3-4] by defining a threshold. Although other color spaces such as YUV are also used [5], the Hue-Saturation-Intensity (HSI) is the most applied color space for this purpose. Because of forming the color information in H and S component and brightness of image is centralized in I component. The proper threshold on H and S band were used [6] to extract the red and blue colors. Nonlinear

transformation over H and S was employed [7] to enhance the desired red and blue colors. In [8] a method to deal with only the stop sign was presented. The warning signs were exclusively processed in [9]. The set of interesting signs were considered to be triangle and circle [10], so they are localized by using color analysis, priori knowledge and edge detectors as well. The shape and color in a wide angle of view were combined [11] to segment the circle and triangle.

Since the traffic road signs follow strict shapes, circle or triangle or square, edge detector [4], [12], cross correlation based on template matching [2], Haar wavelet [13] and FOSTS model [14] are methods that were used for classification the road signs shapes.

In this paper, first we use the HSI color space in order to determine ROIs. Then, we check some important geometrical features and localize any existed road signs in an image. In the next step, any detected traffic road signs' are classified as circle, triangle and square by using three different methods and compare the performances of these three classifiers together.

The paper is organized as follows: traffic sign detection method is explained and detection experimental results are reported in section 2, three different classifiers are explained in section 3, classification experimental results of using the three classifiers are written in section 4, and finally in section 5, we draw some conclusions.

2. TRAFFIC ROAD SIGN DETECTION

As colors of most road traffic signs are blue and red, we use color information to detect ROI. As Fig. 1 shows, these two colors may also be seen on several

other objects such as informative plates, building, cars, or people clothes. So, in order to minimize the number of wrong detected regions, some region features such as area, aspect ratio, mass center, orientation, and active pixels ratio are to be checked. Those regions are considered as ROIs that satisfy these features in addition to have blue and red colors. The Block diagram of our proposed algorithm to detect the road traffic signs are sketched in Fig. 2. We explain the details in following subsections.

2.1. Color Based Segmentation

The purpose of color based segmentation is separating the ROI from the other objects present in an image. The HSI color space allows decoupling the color, saturation and intensity information. So, an image is converted to HSI model. The characteristics of hue and saturation channel components identify two different colors, but the intensity value does not give any valuable information about colors so the last component in HSI color space is not used.



Fig. 1. Blue and red color used on informative plate (top-left), traffic light (top-right), and a car (bottom).

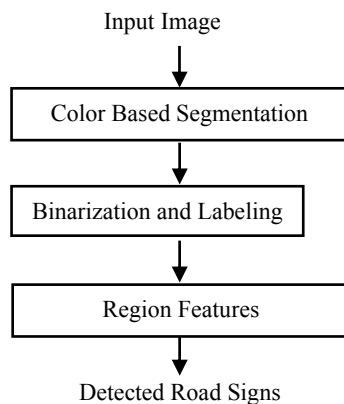


Fig. 2. The block diagram of traffic road sign detection.

The block diagram of our proposed method for color based segmentation shown in Fig. 3. The filtering equations are

$$\text{Saturation} = e^{-\frac{(s-240)^2}{(110)^2}} \quad (1)$$

$$\text{Hue - red} = e^{-\frac{(h-10)^2}{500}} + e^{-\frac{(h-250)^2}{500}} \quad (2)$$

$$\text{Hue - blue} = e^{-\frac{(h-160)^2}{1000}} \quad (3)$$

and they are illustrated in Fig. 4, where the horizontal axis indicates the value range of hue or saturation component and the vertical axis indicates the output filter that placed between 0 and 1. In general, Hue (H) has value in [0 – 255] range, it is close to 160 for blue color and it is close to 10 or 250 for red color. The variances of these filters are determined according to test more than 100 images. According to the block diagram that is sketched in Fig. 3, the output of hue-red and hue-blue are multiplied to saturation filter output and pixels with values less than 0.4 are discarded, it means that they are not considered to be the road sign. These functions in the block diagram (Fig. 3) are called as HS-blue and HS-red and finally using an adder, the color based segmentation is finished.

2.2. Binarization and Labeling

In this section, we binarize the color based segmentation image at first, Fig. 5. So the resulting '1' valued pixels correspond to sign road color and other pixels take value '0'. After labeling, frequently more than one region are candidate to be the road sign, so some important geometric features are acquired in order to choose the correct sign region among all candidate regions.

2.3. Region Features

Analyzing some region feature allows discarding numerous wrongly detected regions. The geometrical region feature that should be controlled are listed and explained in following.

- **Area:** number of pixels with value '1' in a region. Using this feature discard wrong candidate regions almost without extra computation.
- **Aspect ratio:** height per width of bounding box. Bounding box is the smallest rectangle with edge parallel to x and y axis containing the region. Almost all signs have a square bounding box and the aspect ratio value is among 0.84 and 1.13.
- **Mass center:** frequently, a road sign is symmetric shape, so the computed mass center is to be located near the center of the bounding box. As it is shown in Fig. 6, a region that its mass center is not near the center of bounding box is not a road sign.

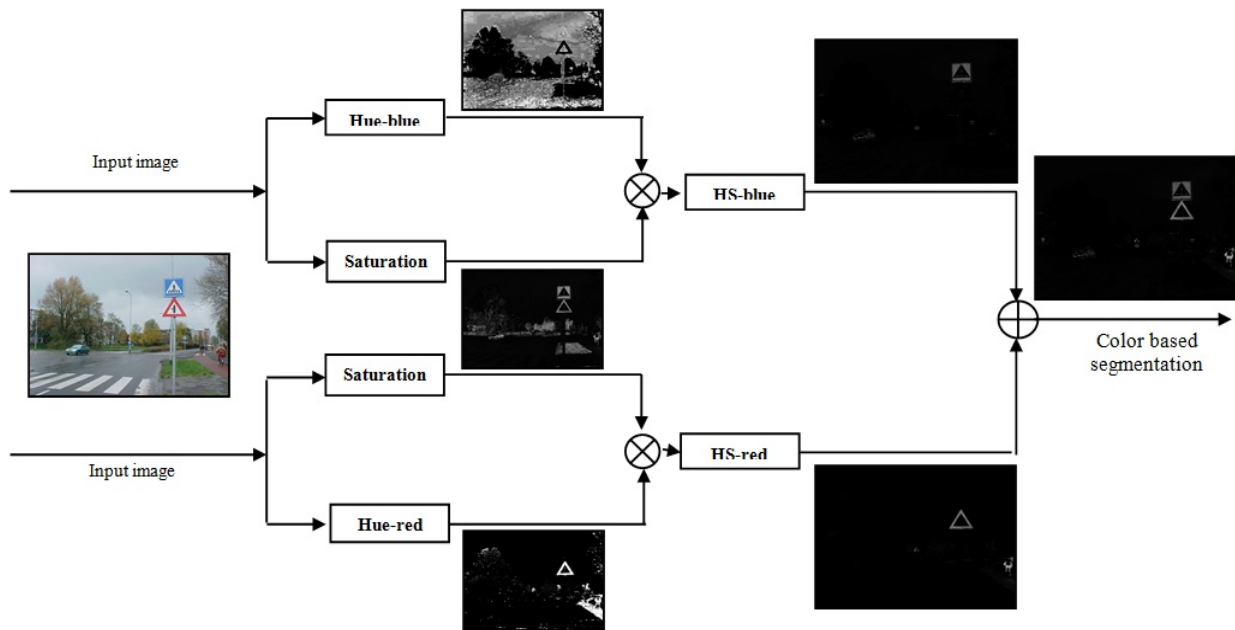


Fig. 3. Block diagram of color based

- **Orientation:** the angle between the x axis and the major axis of an embedded ellipse. The obtained value is as same as the second order moment of region.
- **Active pixels ratio:** number of white pixels per the total number of pixels that exist in a bounding box. This feature is named region fulfillment. Testing all road signs existed in our data base, the value of active pixels ratio is among [0.6, 0.95]. Obviously, active pixels ratio for triangle is minimum and for square is maximum.

The road sign segmentation output are shown in Fig. 7 for six sample images. As it is seen, even for images with complex background and low resolution, our algorithm is succeeded to segment any existed road signs. Any way, in this work, we use the standard database, [17], it includes 60 image that were captured from natural scenes. The accuracy of our method for road sign segmentation is written in Table 1.

3. CLASSIFICATION

In this paper, duty of classification means obtaining the shape type and in general the traffic road signs are three shapes: circle, triangle and square. Following in brief, we express some problems exist in classification, then we explain three classifier. In this paper for the first time, we use the directional vector or code matrix as a classifier. At the end, an algorithm for classifying only circles is also described.

- **Projection distortions:** Camera projection when the sign is not parallel to the image plane can lead to geometric projection distortions. Under such circumstances, for instance, a circle is imaged as an ellipse, an equilateral triangle as a scalene one, or a rectangle as a general quadrilateral.
- **Scaling:** The size of the projection of the sign in the image plane depends on the distance from the camera to the sign. As the camera approaches the sign, the blob corresponding to the object get bigger.
- **Rotations:** Differences in tilt angles between the image plane and the sign are reflected as object rotations.
- **Occlusions:** Partial occlusions of the sign alter the shape of the blob. This is more likely to happen within cities than on non-urban roads.

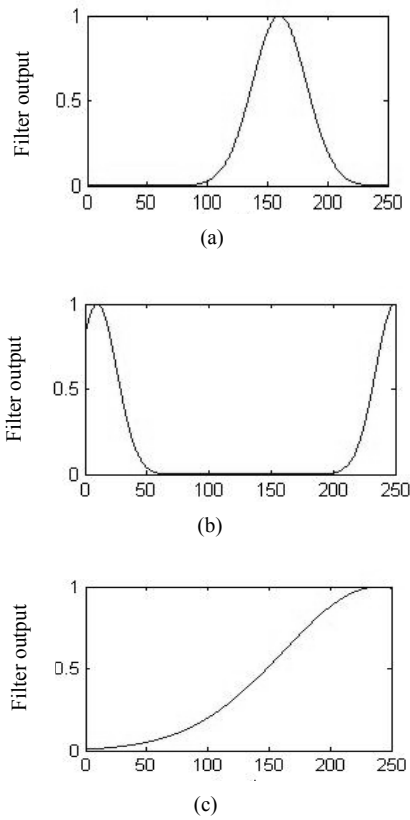


Fig. 4. Filter output diagram for (a) Hue-blue component (b) Hue-red component and (c) Saturation component.



Fig. 5. Two sample of original images (first column), and binarization results (second column).

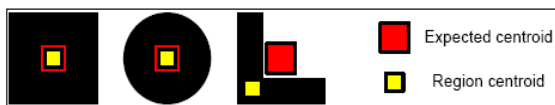


Fig. 6. Mass center criteria.



Fig. 7. Detection and segmentation of road signs in natural scene, input image (first column), and segmented sign (second column).

- **Camera noise:** Camera noise can be seen as segmentation problem in such a way that the mask returned by the segmentation block is not a shape with perfect edges, but a version with its edges altered by noise.

In the next section we propose three methods with three feature vectors for shape classification that these vectors are robust to rotation, scaling, and in some case to occlusion.

3.1. Distance to Border Feature Vectors

The first method that we consider for shape classification is distance to border vectors (DTB) [16]. In general DTB is four feature vectors that include the distance value of external contour of a blob to the bounding box, as it is shown for triangle in Fig. 8. The four extracted DTB vectors for circle, triangle and square are shown in Fig. 9. Classifying based on DTB vectors can be done according to obtained the variance value or hamming distance. Obviously the variance value of DTB vectors for circle is bigger than square whereas the variance value of DTB vectors of triangle is between them two. So using the variance value of DTB vectors and specifying two thresholds, the shape type is determined. Another way is computing the hamming distance between the DTB vectors of segmented signs and standard DTB stored vectors. In general, DTB shape classification is robust to translation, scaling, rotation and occlusion.

3.2. FFT Sample of Signature

Performing this classifier, a signature as the distance of mass center to boundary of segmented object [15] is determined by varying angles, Fig. 10(a). The extracted signatures for circle, triangle and square are shown in Fig. 10(b). The 32 points discrete Fourier transform (DFT) of every signatures are computed and the simple nearest neighbor using the square Euclidean distance is employed for classification. Furthermore, as it is seen in Fig. 10(c), the amplitude of first quarter of DFT coefficients is significant and the rest are affected by noise. So we use only 8 coefficients of DFT for classification by the simple nearest neighbor. As an example, an original image is shown in Fig. 11(a) and the obtained signature and DFT coefficients of the segmented road sign (square) are illustrated in Fig. 11(b) and Fig. 11(c). This method is invariant to rotation, because we compute absolute value of DFT samples. Also this method is invariant to scaling because we compute the signature of the normalized sign. Notice that the computational time for this method is more than the previous method because we work with nonlinear equation during computing the DFT samples.

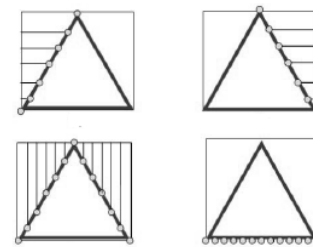
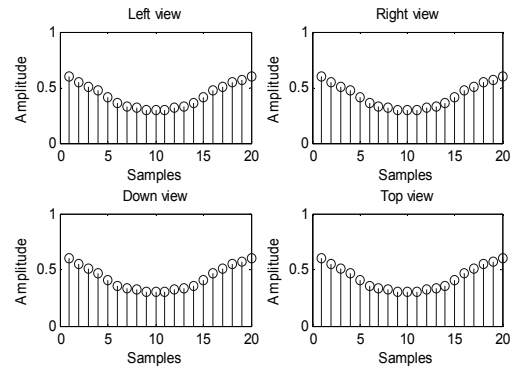
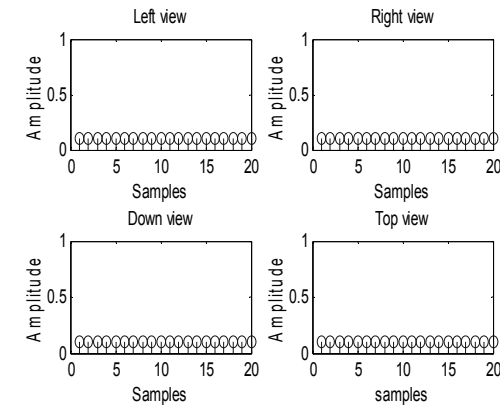


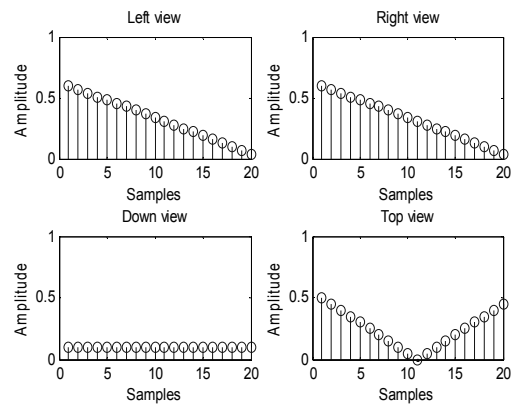
Fig. 8. The DTB vectors for triangle shape.



(a)



(b)



(c)

Fig. 9. Four DTB vectors for (a) circle, (b) square, and (c) triangle.

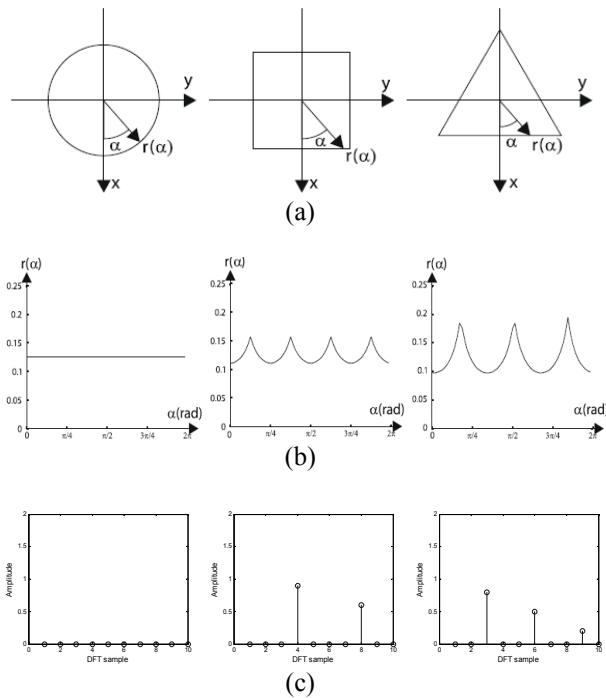


Fig. 10. Shape signature and DFT samples, (a) reference shapes, (b) signatures associated, and (c) DFT samples of circle, square and triangle.

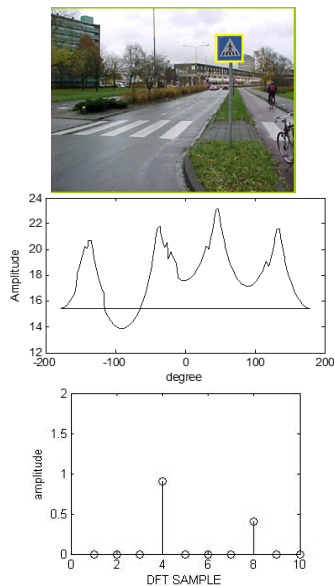


Fig. 11. The signature of a segmented road sign and DFT samples, (top-left) input image, (top-right) related signature, and (bottom) DFT samples.

3.3. Directional Vector

Chain codes are a classical type of computer program that were used to code the shape of objects. This coding method is based on direction of pixels that placed in contour of shape. They can therefore be used for robotic vision systems. In this paper, the direction

chain code is used for shape classification because of its simplicity and low storage requirement. In this method we employ directional vector (code matrix) for road sign classification. At first we use canny edge detection algorithm for road segmented sign. It means the values of pixels that belong to edge are 1 and other is equal to zero. Then edge shape is converted to a directional vector which is named as code matrix. By using elements of code matrix, classification of detected sign is done. For this purpose we consider 8-neighbour for every pixel that is recognized as edge. This means that we consider the local of neighbor's pixel that placed in 0, 45, 90, 135, 180, 225, 270, 315, 360 angels. For any considered angle, a specific value is allocated, a sample procedure is presented in Fig. 12.

In this work, we consider 4-neighbor grid for each edge pixel belong to simple shapes: circle, square, and triangle. Our propose allocation value and two shapes (square and triangle) and their code matrix are seen in Fig. 13.

We notify that the accuracy of classification based on code matrix is independent of where the start point is chosen. In addition, performing the algorithm is easy. After generating the code matrix, we compute its average value and classify the shape as circle, square, and triangle. We know, all pixels in squares are placed in vertical and horizontal direction, so the obtained average value of code matrix is close to 8 (the allocated value to horizontal and vertical as it is seen in Fig. 13). on the other hand, more than 70% of all pixels belong to triangle are diagonal, so the average value of extracted code matrix is close to the allocated value to diagonal as it is seen in Fig. 13. In the case of circle shape, the diagonal state is less than triangle, but is more than square shape and the horizontal state is more than triangle shape and less than square shape. So the main problem in using the code matrix as a classifier is obtaining the threshold values properly. As an example in Fig. 14, we consider the three normalized, segmented and edged shapes and we write in Table 2 the percentage of pixels that are placed in vertical, horizontal and diagonal direction as well (they are acquired from 20 images of every shapes). Now if we allocate value 'a' to both vertical and horizontal directions and value 'b' to diagonal direction, the average value of generated code matrix for circle, triangle and square are:

$$av - circle = \frac{a(36 + 33) + b(31)}{100} = \frac{a(69) + b(31)}{100} \quad (4)$$

$$av - triangle = \frac{a(28 + 20) + b(52)}{100} = \frac{a(48) + b(52)}{100} \quad (5)$$

$$av - square = \frac{a(42 + 43) + b(15)}{100} = \frac{a(85) + b(15)}{100} \quad (6)$$

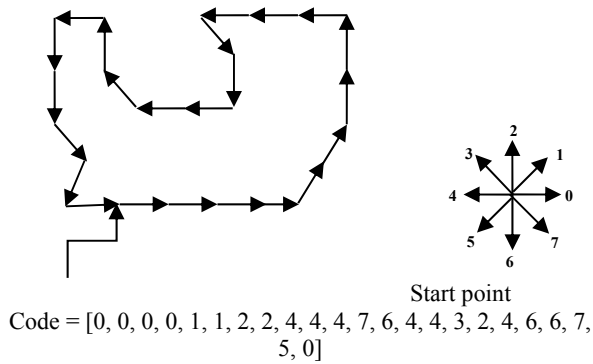


Fig. 12. A sample shape (top-left), matrix code allocated (top-right), and generated chain code.

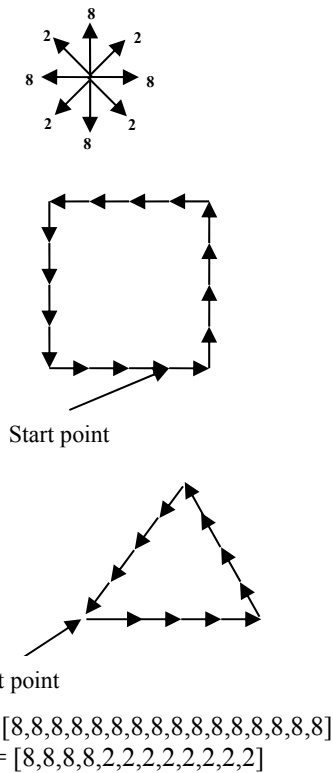


Fig. 13. The code matrix allocation (top), square, and triangle shapes and generated the chain codes.

Table 1. The accuracy of our proposed algorithm for road signs segmentation.

Traffic sign type	Number of test images	Number of correct	accuracy (%)
circle	20	20	100
triangle	20	18	90
square	20	17	85

Table 2. Pixel ratio in different shapes.

Shape type	Horizontal pixels (%)	Vertical pixels (%)	Diagonal pixels (%)
circle	36	33	31
square	42	43	15
triangle	28	20	52

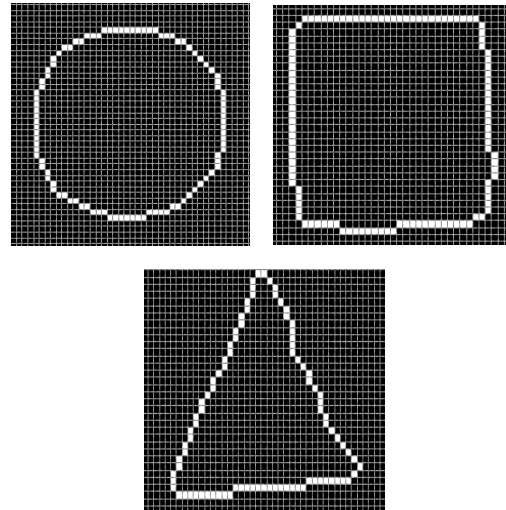


Fig. 14. Location of edge pixels in simulated segmented signs: circle, square, and triangle.

Although value ‘a’ and ‘b’ are optional, they should not be close together. In this work we consider a=8 and b=2, the average value for above three shapes are 6.14, 4.88 and 7.1 in order.

3.4. Region Growth Circle Classifier

In this section we suppose a method that can be used to detect circle shape that named region growth. In this procedure we determine the center of segmented sign. Firstly, we consider the small circle that its center is the center of detected blob and radius is about 2 pixels. At each stage of small circle growth we calculate the correlation between grown circle and detected sign. We continue this process until the radius of growing circle exceeds the bounding box edge. If really our detected sign be a circle then in one stage of region growth the correlation output is large and considerable, this indicates that the edge pixels of growing circle has maximum matching with a circle shape that exists in the image. In other word we have a circle with certain central coordinate and obvious radius equal to grown circle. Simulated result for this method presented in Fig. 15. Notice that the matching between the segmented sign and ideal circle with same radius is computed and written near the shape.

After classification the road signs, we use both information about color and shape type to categorize the road traffic signs according to contents in Table 3.

4. CLASSIFICATION EXPERIMENTAL RESULT

An efficient algorithm for segmentation and classification of road traffic signs in natural scenes is proposed in this paper. Our images include different types of traffic signs under variant illumination and weather condition. The images resolution is 480×640 pixels. The data base in [17] is used for shape classification. We have detected and segmented the road signs in section 2, and reported the segmentation accuracy in Table 1. In this section we classify the three different shapes by using DTB, signature and code matrix. The accuracy achieved by these classifiers are written in Table 4, 5 and 6.

The main advantage of using the code matrix is simplicity. The algorithm run time for code matrix is 350 msec, whereas for DTB and signature are 1200 msec and 850 msec in order. In addition, the average accuracy achieved for recognition the three shapes by code matrix is 89.3 percent, whereas for DTB and signature are 87.6 and 85 percents in order.

5. CONCLUSION

In this paper we proposed HSI color space and considered the geometrical features in order to segment the traffic road signs. Then we employed the code matrix as a shape classifier for the first time. Our experimental results proved that using code matrix achieved convenient accuracy. In addition, the implementation is simple and that causes low computational cost and then possibility of online image processing.



Fig. 15. Real images (first column) and circle detection results (second column), the computed correlation value is written beside the each shape. .

Table 3. Classify the traffic road sign based on shape and color information.

Color	Shape	Meaning
Red Rim	Circle	Prohibition
Red Rim(UP)	Triangle	Danger
Red	Circle	STOP
Blue	Circle	Obligation
Blue	square	Recommendation

Table 4. The classification results using the DTB vector classifier.

Traffic sign type	Test sample	Number of correct	Accuracy (%)
circle	20	15	75
square	17	17	100
triangle	18	16	88

Table 5. The classification results using the FFT sample of signature classifier.

Traffic sign type	Test sample	Number of correct	Accuracy (%)
circle	20	19	95
square	17	15	88
triangle	18	13	72

Table 6. The classification results using the directional vector classifier

Traffic sign type	Test sample	Number of correct	Accuracy (%)
circle	20	17	85
square	17	17	100
triangle	18	15	83

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