ROAD SIGN DETECTION AND RECOGNITION USING COLOUR SEGMENTATION, SHAPE ANALYSIS AND TEMPLATE MATCHING

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Abstract:

The paper presents a system for detection and recognition of road signs with red boundaries and black symbols inside. The detection is invariant to varying lighting conditions and shadows. The algorithm is tested on RGB images taken from camera. These images are converted to HSV colour space. Colour segmentation for red regions is applied on the whole image. All red regions are labeled forming objects. Each of the red objects is tested for its shape. Final image contains only those red objects which are triangular or circular in shape. Finding the black regions within the accepted red objects area, results in extraction of pictogram. This pictogram is then matched with templates in database, hence recognizing the meaning of road sign. The paper presents a revised edition of fuzzy shape detector and a recognition module that uses template matching to recognize rotated and affine transformed road signs.

Keywords:

Color segmentation; Shadow Invariant; Fuzzy shape detector; Template matching; Rotation Invariant

1. Introduction

Road sign detection and recognition is an important constituent in the design of the autonomous vehicle. A system that reads and interprets the road signs relieves the driver an extra burden of checking the road signs, and helps him concentrate on his driving.

There maybe many difficulties involved in the detection process due to the changing weather and fading or shadowing of the road signs colours, hence depriving image of the ideal conditions of detection and recognition.

Many systems that cater with these environmental complexities have been proposed [7 - 17]. All these systems though vary from each other present a common goal. Some have limited their scope to the detection while some present techniques on recognition while there are some that give us a complete system of detection and recognition. From the available literature one finds a variety of options for the colour space selection to deal with fading, changing light intensities and shadowing (the common problems in that maybe encountered). Each colour space has its own pros and cons. Similarly there maybe many options varying in complexities for shape detection and then finally for recognition.

The layout of the paper is as follows; Sections 2 gives a system overview, section 3-8 each give a summary of the major sub-processes involved in the detection and recognition process. Section 9 and 10 reveals the conclusions that can be drawn from progress so far and future plans.

2. System overview

The idea is to make a system that can be used for the future real time system. Currently the system works on offline RGB images. Images for testing have been taken from an online database [18] maintained by Fleyeh for researchers.

System takes an RGB image taken from a camera. It extracts all the red regions using color segmentation. The red region detected may contain some other undesired red regions e.g. a red colored advertisement board. In order to remove these undesired blobs filtration is applied. In filtration, first the regions are categorized as objects using 8-connected region algorithm. Then the objects that do not satisfy the size range for the sign are removed. Finally, the non circular and non triangular regions are removed by passing each object through the shape detector. The output image contains only those regions that are suitable candidates for being a road sign; they have a red boundary, are circular or triangular and have enough pixel area. Owing to this resultant image the black pictogram inside the road sign is extracted from the inner regions of red objects. Each extracted pictogram is isolated and matched with sign

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templates of known meanings in database. If matched the meaning is associated to the road sign.

The input image is not processed if there is no red object in it. Fig. 1 shows the major system's modules and fig. 2 shows a working example of the process.

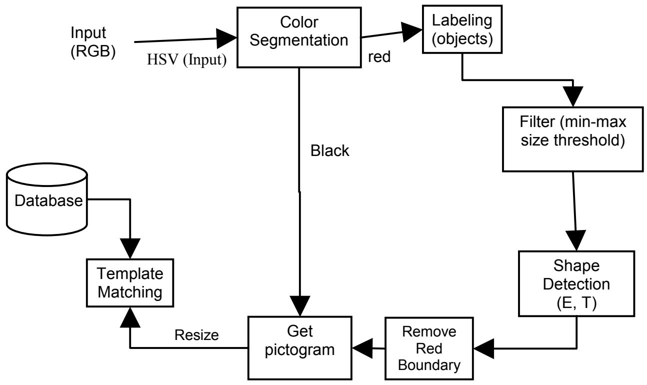

Figure 1. System's Module Diagram

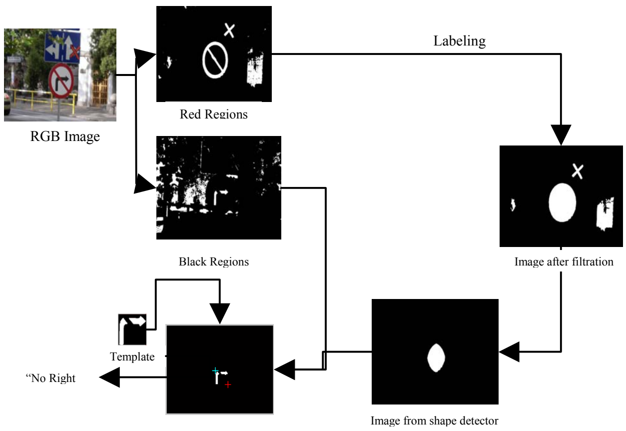

Figure 2. Example of the System developed so far

3. Colour segmentation

The default colour space i.e. RGB poses many variations with changing light intensities, fading and shadows. So we convert the colour space to one that is most invariant to the mentioned three major problems; the HSV colour space. This particular colour space is chosen because Hue is invariant to changing light intensity as it is shadow-invariant, multiplicative/ scale invariant, additive/shift invariant and is invariant under saturation changes [2]. Hue is unaffected by shadows and highlights on the object when illumination is white [4].

The colour space and thresholds range proposed in [2] are found to be the best. In the algorithm while normalized Hue is used as a priori knowledge to the algorithm, normalized Saturation and Value are used to specify and avoid the achromatic subspaces in HSV colour space specified by Vitabile et al. [3].

The Hue image formed gives the red regions in the image. For black regions, either gray scale image of the original image can be chosen and applied with suitable thresholds to give binary results, or achromatic region thresholds can be applied to the S and V images of the HSV color space as shown below in fig. 3.

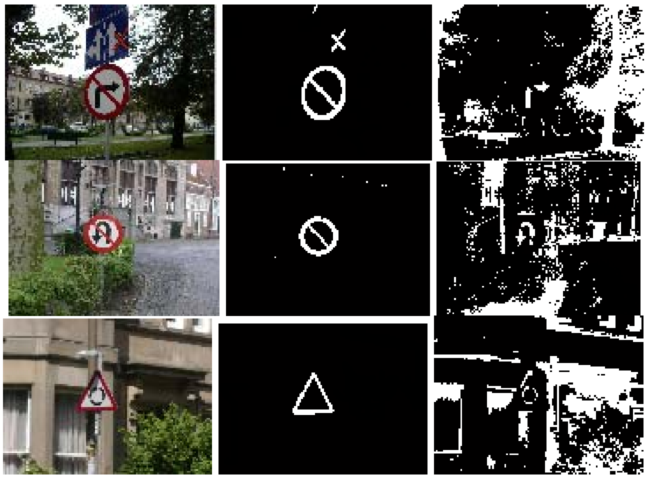

Figure 3. Colour Segmentation: original, red and black

4. Labelling

This method decides whether there are any red objects in the image that need to be processed. So, all 8-connected white pixels in the segmented image are considered under one label i.e. treated as one object. If there are no such objects then the current image has been dealt with, and the next image in the sequence is selected for colour segmentation.

In order to facilitate the filtration and shape recognition process, before starting the labeling process, all the enclosed regions formed after colour segmentation are filled to become solid objects.

5. Filteration

The filtration process decides if the objects size is large enough for the Pictogram classifying algorithm to recognize the road sign symbol. It calculates the *area* of each object and compares it to a *threshold size*. If area is calculated to be less than the *minimum* value, then the object is made a part of the background and similarly for maximum threshold. Else it is selected for further processing.

With images of size 640 × 480 pixels, the minimum and maximum threshold area size was set to 300 and 30000 pixels respectively.

By the filtration process all the candidates which may have a road sign within recognizable limits are passed through for further processing.

6. Shape detection

Fuzzy Shape Descriptor uses the region properties of objects in an image e.g. area and center of mass to recognize their shapes. These properties which we will call "shape measures" would be calculated for each object of the filtered image and they will become the input to the Fuzzy Shape Recognizer. Analyzing the values of the inputs, the object would be categorized in one of the descriptions of geometrical shape types. Currently since only circular and triangular signs are considered so two geometrical shape measures are used to decide which shape an object may have. They are ellipticity (E) and triangularity (T).

The module's overview diagram is as shown below in fig. 4.

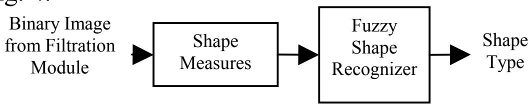

Figure 4. Shape Detection Module Overview

Road sign may not always appear in the ideal shape of its type. Its shape may be somewhat transformed i.e. scaled, rotated, etc. Moments can be used as they can easily be made invariant to affine transformations, rotations and scale.

The stable and practical equation of invariance, I_1 given in [6] states:

$$I_1 = (\mu_{20}\mu_{02} - \mu_{11}^2) / \mu_{00}^4 \qquad (1)$$

Where μ_{20}, μ_{02} and μ_{11} are the second order central moments, and μ_{00} is the zero order central moment.

To measure the ellipticity (E) and triangularity (T), the following equations are used:

$$E = \begin{cases} 16\pi^2 I_1 & \text{if } I_1 \le 1/(16\pi^2) \\ 1/(16\pi^2 I_1) & \text{otherwise} \end{cases} \qquad (2)$$

$$T = \begin{cases} 108 I_1 & \textit{if } I_1 \le (1/108) \\ 1/(108 I_1) & \textit{otherwise} \end{cases} \qquad (3)$$

Ellipticity (E) and Triangularity (T) ranges over [0, 1] and for perfect ellipse or triangle their value is 1.

A previous fuzzy system for shape detection has been proposed by Fleyeh [1], which utilizes the work of [6] just mentioned. However in Fleyeh's system, E and T variables consist of three membership functions; low, one and high; where 'high' corresponds to the values of E and T higher than 1. Whereas according to [6], the values range between 0 to 1 for both E and T. They do not go beyond 1.

The new proposed fuzzy classifier consists of two fuzzy input variables, and one output variable as shown in fig.5-7. The input variables are T and E while for the output it is Shape. T and E have two groups each; low and one; where 'low' designates shape measures too low for being called a circle or triangle and 'one' designates the high chances of the shape being circle or triangle.

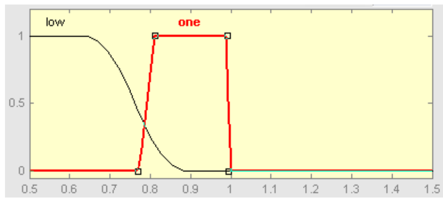

Figure 5. The T Membership Functions.

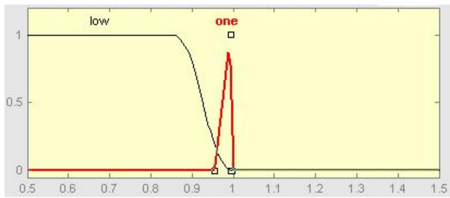

Figure 6. The E Membership Functions.

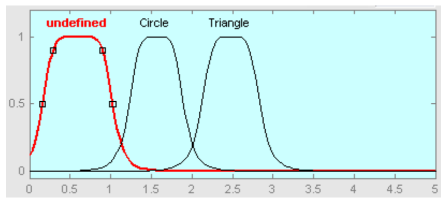

Figure 7. Output Membership Functions.

To perform the classification of objects, three rules are used as follows:

1. If (T is One) then (Shape is Triangle)
2. If (E is One) then (Shape is Circle)
3. If (T is not One) and (E is not One) then (*Shape* is Undefined)

The module showed 94% accuracy as shown in Table 2. Most of the incorrect detection of sign is because of presence of objects with similar properties as road signs in background.

Figure 8 gives an idea of the filtration and shape detection modules together.

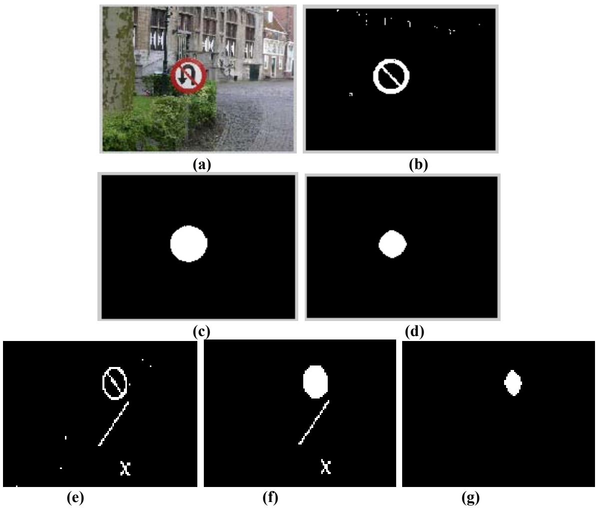

Figure 8. (a) original image (b) (e) red colour segmented (c) (f) after filteration (d) (g) after shape detection

7. Pictogram extraction

Till now the shapes considered included the red boundary regions of the road sign. Once the shape has been recognized the red border is cut off to isolate the white region that actually contains the road sign pictogram.

After being removed of the red boundaries, the new image indicates possible regions where road sign pictogram may lie. An AND between the image formed and the black-region image gives the pictogram as shown in fig. 9.

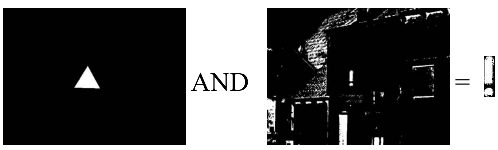

Figure 9. Demonstration of pictogram extraction

8. Pictogram classification

The extracted pictogram (cropped) is resized to a set standard, the size of templates in the database which were taken to be 16x16 pixels.

The templates in the database are arranged into two classes circle and triangle so that the number of candidates for matching do not comprise of the entire database.

Each relevant template is rotated degree by degree till 30 degree in both clockwise and anticlockwise direction and then correlated with each of the extracted pictogram. The correlation technique fails to deal with affine transformations. Therefore to handle affine transformations, affine transformed templates are kept. Since the correlation involves 16x16 pixel sized objects the method is suitable for runtime. Fig. 9 gives an idea of templates in database.

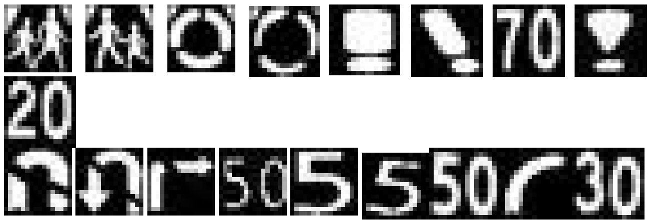

Figure 10. Some templates from database

Experimental results as shown in Table 1 helped in setting 0.7 as the threshold value or the matching criterion for matching.

Table 1. Threshold for template matching

Threshold Value	Matching Images (%)	Unmatched Images (%)
0.9	60	40
0.8	72	28
0.7	86	14

The accuracy for the module was estimated to be 86%, as shown in Table 2.

9. Discussion

The colour segmentation method used is invariant to lighting conditions and shadows. Various other colour spaces used by many researchers (which include normalized RGB, RGB, LUV) maybe made invariant to changing lighting but cannot be made invariant to shadows. Even in systems where HSV colour space is selected, the Hue and Saturation component are treated together e.g. an AND between the two. This method is not robust to shadows. Fleyeh [2] in his paper shows that only Hue is invariant to shadows and changing lighting conditions. So treating solely Hue while avoiding the achromatic regions as shown in the paper, makes the segmentation module invariant to changing lighting conditions as well as shadows.

The shape detector used is invariant to the three types of transformations i.e. rotation, scale and affine. The methods for shape detection used so far for road sign shape detection are based on either fitting a curve, corner detection, Fourier descriptors, template matching etc but these techniques are not robust enough to handle all the three types of transformations. The only problem the shape detector faces is, if the road sign contour is not complete, i.e. some type of occlusion may have occurred in the segmentation module.

The recognition phase tries to make recognition through normalized correlation invariant to rotation up to 30 degrees. A method can be devised to make the correlation invariant to the affine transformations too.

We may use some other intelligent mean for recognition of shape and pictograms. Neural networks with supervised learning maybe an appropriate choice. Occlusion to some extent maybe handled. And the problem of affine transformations can be overcome. Some strategy can be formulated to decrease the training time for the network. Furthermore, for real-time applications, the training maybe done while the car's engine is being revved to life.

10. Conclusion

The system developed was aimed to overcome real time problems. To some extent the detection phase ensures that. However in the recognition the common real time problem of transformations affine in nature cannot be efficiently handled. Secondly the shape detection phase fails if the sign is occluded enough such that the red boundary of the sign is not complete.

The overall system accuracy was estimated to be 86% as shown in Table 2.

Table 2. System Algorithm Results

Total test images	Colour Segmentation with filtration (%)	Shape Detection (%)	Recognitio n (%)
100	96	94	86

11. Future plans

Current development is on offline data. Once able to process still images, same algorithms can be used for real time application. Secondly, some means to handle slight occlusions shall be devised. Thirdly, instead of Template Matching, other methods shall be pondered over to make recognition invariant to affine transformations.

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