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Vision Based Road Sign Detection and Recognition

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Abstract: ***Traffic regulation is an important concept in the modern society. For maintaining safety in the flow of traffic, government all over the world have taken steps to develop certain rules, known as traffic rules. Some of the traffic rules are directly displayed on roads in terms of traffic signs. Traffic signs are those that use a visual/symbolic language about the road ahead that can be interpreted by drivers for making driving safe and convenient. This paper proposes an autonomous traffic sign detection, which would detect, recognize and interpret the meaning of the traffic signs for the driver and will provide a great help in reducing the road accidents and the deaths caused by it. The system mainly has two phases, 1) Sign detection, 2) Recognition. In detection phase a two stage algorithm is performed (i) detection through color image segmentation using HSV color space on color-images (ii) Validation of the obtained region of interest taking advantage of the shape properties of the road signs. In recognition phase the regions of interest are finally represented using HOG descriptors and are fed into trained Support Vector Machines (SVMs) in order to be classified and finally the driver is alerted by providing voice indication of the recognized sign.***

Keywords: Traffic Sign detection, traffic sign recognition, HSV color space, voice indication.

1. Introduction

Road signs provide visual or symbolic representation of the road ahead and hence have a direct impact on ones daily life as possible life threats can easily be formed due to a lack of concentration. Since road signs play an important role in road safety, it becomes one of today's research subjects aiming for automatic detection and recognition of road signs. A lack of concentration or ignorance is not only the need of automatic detection and recognition of the traffic sign but also the lack of knowledge about the traffic sign increases the need of automation. Drivers should have the knowledge of cyclist signs, pedestrian signs, obligatory signs and advisory signs etc. as ignorance of any sign can cause possible accident hazard. Although, today's technology cannot process all visual inputs as a human being, by a system focusing on some specified portion of this process, the workload of drivers can be decreased.

A traffic sign recognition system could be developed as part of an Intelligent Transport Systems (ITS) that continuously monitors the road in order to inform the driver in time about upcoming traffic signs to provide navigation. A traffic sign recognition system can be used in conjunction to other Advanced Driver Assistance Systems (ADAS) such as lane departure warning systems, in-car navigation systems, adaptive cruise control system, automatic parking etc. As a result, a complete driver assistance system can be obtained which will not only lead to advancements to technology but also reduce potential risk to life. For this purpose, automatic means of detecting and recognizing traffic signs is considered.

Road sign detection and recognition is achieved through two main stages

- Detection
- Recognition.

In the detection phase, the image is pre-processed, enhanced, and segmented according to the sign properties such as colour or shape or both. The output is a segmented image containing potential regions which could be recognized as possible road signs. In the recognition stage, each of the candidates is tested against a certain set of features (a pattern) to decide whether it is in the group of road signs or not, and then according to these features they are classified into different groups. The system can be implemented by either colour information, shape information, or both combining colour and shape may give better results if the two features are available, but many studies have shown that detection and recognition can be achieved even if one component, color or shape, is available.
This paper proposes a method for automatic traffic sign recognition system which searches the image for road sign. Detection algorithms are based on colour or shape or both for segmentation. RGB color space represents a colour directly as red, green and blue. But the colour of outdoor images depends on environmental conditions. Hence here we use colour segmentation in HSV colour space. For shape based filtering we use Hough transform to validate the colour segmented candidate object according to shape such as triangle, circle rectangle. The color and shape features are utilized to detect and extract the exact position of the traffic sign. Further the traffic sign is recognized using HOG descriptors which are fed into Support Vector Machines (SVMs).

2. Related Work

There is great deal of existing literature in the application domain of road sign detection and recognition. This is the study of the state-of art approaches. Figure.1 illustrates the general framework used in the majority of the road sign detection and recognition approaches proposed in literature. These approaches largely differ due to the differences in the algorithms used within each of the three functional blocks shown in the figure below

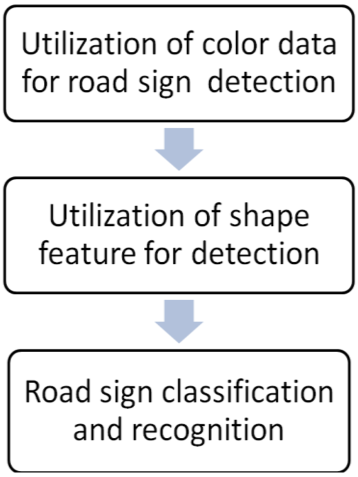

Figure 1: General framework of road sign detection and recognition

Traffic sign recognition algorithms literature is divided into two stages. The first one is the detection stage which aims at segmentation of the road scene containing traffic sign and finally extraction of regions of interest (ROI) from an image. The identified ROIs are inserted into the second stage, namely the recognition stage, in order to be classified.

2.1 Detection

For the detection stage, two main ways exist; detection based on colour details of traffic signs and detection based on shape details. The combination of the above two is also used in some works. Considering the color information of traffic sign, some works are as mentioned below. The work of Kim et al. (2006) in which the RGB colour space is used, and detection is performed through dynamic thresholding and also the work of Broggi et al. (2007) in which chromatic equalization is performed using gamma correction and afterwards, regions of interest are selected by thresholding the image in the RGB colour space [6]. Experiments which used HSV colour spaces are presented in the work of Wang (2009). HSI model is regarded as most suitable intended for traffic sign detection by simply Fang et al. because it presents human color perception where colors of traffic indication are originally chosen to help attract human attention.

Concerning the shape detection approach, this technique is preferred because it does not depend on illumination conditions. The work done by Marcin L. Eichner, Toby P. Breckon proposed sign detection via color and shape. In the work of García- Garrido et al. (2005) and Hatzidimos (2004) the classical Hough transform to detect lines in the image are used [2]. Moreover, in work done by García-Garrido et al. (2005) circular Hough transform is also applied, in order to detect circular traffic signs [2]. The work done by Lafuente-Arroyo S,(2005) used Distance to Borders (DtB) measurement and linear SVM method to get traffic sign shapes [3]. It is robust for rotation and occlusion, but it is very complicated to orient the candidate blob to a reference position. Fast Fourier transform (FFT) is used to analyze shape signature described by Gil Jiménez P. (2008), shows a great robust to object rotation, scaling and partial occlusion [3].

2.2 Recognition

The main aim of recognition procedure is to classify each region of interest that has been detected to the class that it belongs. Recognition can be carried out by many already existing techniques which include simple template matching or via other detailed techniques which include machine learning, like Artificial Neural Networks (ANN) and Support Vector Machines (SVMs). Image features that can be used for the recognition can be in different forms like HOG descriptors, SIFT descriptos and Zernike moments . In work of Siogkas and Dermatas (2006) and Piccioli et al. (1994), template matching is applied to the extracted regions of interest in combination with the measure of cross-correlation. Further the works that state the use of complicated methods include the machine learning techniques. Some works stated as those by Min Zhang which used color based segmentation, FFT for shape analysis and recognition by extraction of HOG features which are used for training Support Vector Machines [4]. The work done under neural networks are those by Marcin L. Eichner, Toby P. Breckon proposed sign detection via color and shape, then classification of sign using trained neural network. Similar works that constitute the state of art using Artificial Neural Networks for the recognition stage are Nguwi and Kouzani (2008). There are many more works which constitute the state of art for the automatic detection and recognition of the road sign.

3. Traffic Sign Detection and Recognition System

A general workflow model for the prototype of the system for the detection and recognition of traffic sign is shown in fig 2. It mainly consists of three stages: video capturing, detection of the traffic sign in the image frame and the recognition phase. The colour segmentation is used for detection of the sign within the image. Before applying the segmentation the image that is acquired specially in different environmental conditions require some preprocessing for the reconstruction of the image. Objects with similar colour as that of traffic sign may also be segmented out of the image as sign candidate. To filter these candidate objects, shape segmentation is used further to detect true traffic sign. In this way region of interest that is the traffic sign is separated from the background image. The next step is to compare the candidate region with the images of the traffic sign that has been already stored into the database. For this comparison to take place the feature of both the ROI and the database images are obtained using which they are further classified. Finally the driver is made alert by playing the corresponding voice for recognized traffic signs.

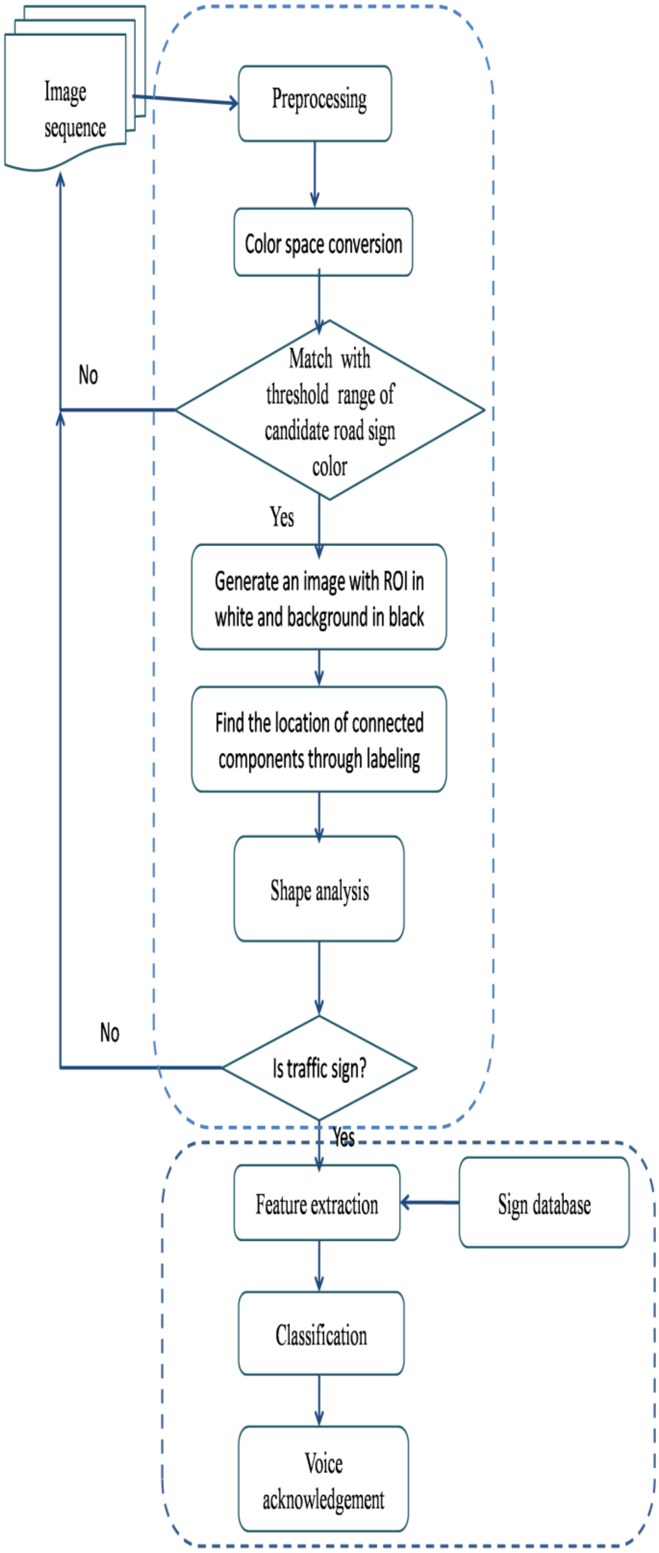

Figure 2: General workflow model of the system

3.1 Detection of Traffic Sign Location

Traffic signs have two major features: Shape (square, circle, triangle, etc.) and Color (red, yellow, blue, green). Detecting shapes in an urban environment is very challenging and unreliable due to complications in image acquired. Also, environmental conditions play an important role in the detection procedure. On the other hand, traffic signs deliberately use raw/strong colors that stand out in any surrounding which makes its detection possible. Hence, color information can be considered as one of the better feature for traffic sign analysis.

3.1.1 Color Segmentation

The first part of the algorithm involves the detection of possible traffic sign locations based on color information. The image is captured by the camera. Each image thus captured is then processed. Initially, before color segmentation some preprocessing on the image captured by the camera is required. Some example image containing traffic sign is shown in figure 3.

Figure 3: Image containing traffic sign

For image preprocessing, first step is to analyze the intensity of color components, and if it is in the limited range, it is necessary to apply stretching to the dynamic range of intensities of color components which is nothing but image normalization [5]. After normalization of the image captured the next stage is performing some primary image processing for image reconstruction. The primary image processing includes the operation of Wiener filtration to eliminate noise in the image thus enhancing the sign detection and recognition. Any blurring algorithm such as Gaussian filter can be used for the same. The image of preprocessing mainly shows its effect mainly to the images having low light illumination which can be seen in figure 4.

Figure 4: Image after preprocessing

After pre-processing the images which was performed mainly to increase the detection rate, the next step is actual segmentation based on color. For extracting and analyzing color information, there are several options regarding the choice of color space representation. RGB color space is not suitable since it does not provide a linear space for color variations. Using YUV (color space in terms of one luma (Y') and two chrominance (UV) components) works for detection of red/yellow/orange objects however it fails for proper detection of white/black or low intensity colors. Therefore, we use the HSV (Hue-Saturation- Value) color space. Hue is the color information which represents the dominant color of a pixel. Saturation is the purity of the color, the higher it is, the more pure the color is. Value is the intensity of the color. The benefit of this color space is to code the color on one single plane instead of three planes as is the case in the RGB color space.

HSV color space model. The formulas for conversion of RGB color space into HSV space are as follows

$$V = \max(R, G, B) \quad (1)$$

$$H = \begin{cases} \frac{G-B}{\max(R,G,B)-\min(R,G,B)}, if\ R = \max(R,G,B) \\ 2 + \frac{B-R}{\max(R,G,B)-\min(R,G,B)}, if\ G = \max(R,G,B) \\ 4 + \frac{R-G}{\max(R,G,B)-\min(R,G,B)}, if\ B = \max(R,G,B) \end{cases} \quad (2)$$

$$S = \begin{cases} 0, if\ max(R,G,B) = 0 \\ \frac{\max(R,G,B)-\min(R,G,B)}{\max(R,G,B)}, otherwise \end{cases} \quad (3)$$

$$H = H * 60, for\ all\ values\ of\ H \quad (4)$$

$$H = H + 360, \text{if } H < 0 \quad (5)$$

Candidate objects are generated using the process of thresholding. Thresholding is nothing but the procedure that creates a binary image; pixels with values within a predefined threshold are assigned value 1, and all the others are set to 0. Thresholding values for these components are decided through the method of analysis on several signs that have been segmented manually considering multiple views under different illumination and weather conditions. Thus for a particular color thresholds are defined to filter out that particular color. The pixel values for Hue component range between 0^0- 360^0 and for the Saturation component between 0- 255 and also for the Value component between 0-255.

3.1.2 Noise Removal

This step is required basically to remove false candidates that have been wrongly detected as regions of interest. In order to remove the number of detected regions (possible traffic signs), we apply morphological function which help smoothen the image and remove artifacts [4]. The segmented binary candidate road sign represents shape and its contents in most cases of the colour segmentation output. The contents of the road signs can create difficulties in the shape classification as one shape can represent various contents of the road signs. To avoid this complexity morphological region filling is applied on binary candidate road signs. The isolated pixels (noise pixels) are removed from binary images by erosion operation. Further reduction in the false candidate is by eliminating regions with relatively small area, as small ROIs will result in unsuccessful recognition, even if a traffic sign is correctly detected. Overall, the number of detected color boxes is reduced greatly. With these pre-processing for the images before shape analysis, we are able to improve the speed and accuracy of the program which is very helpful for the next operation labeling. Connected components algorithm is then applied to the binary images in order for the blobs to be appropriate labeled and form ROIs. Labeling operation is used to separate the multiple boundary boxes detected. After applying the above stated noise removal on the image obtained after color filtration the image obtained can be as shown in figure 5.

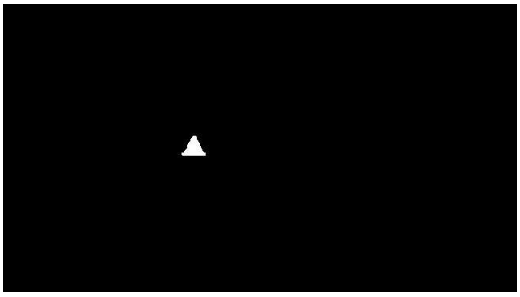

Figure 5: Image after noise removal

3.1.3 Shape Classification

In the natural scene that is captured for traffic sign detection there are some complex backgrounds similar to the traffic signs color, basing solely on color inspection for traffic sign detection is not reliable. However, detection methods based on the shape can further eliminate the background which has similar colors, because the complex backgrounds often do not have the special shape of traffic signs. Hence an effective measure for filtering is required without losing the traffic signs. The shape characteristic is thereby used. There are mainly four shapes. Triangle representing alert sign, circle representing compulsory, rectangle for information sign and octagon meant only for STOP. Any traffic-sign shape should fall into any of the following shape categories such as circular, rectangular, triangular, pentagonal, and octagonal. The region of interest that is obtained from the previous step detection are validated in this stage depending on their shape using Hough transform [2].

The HT is a feature extraction technique used in digital image processing. To extract features from digital images, it is useful to be able to find simple shapes - straight lines, circles, ellipses and the like - in images. HT is a 2D non-coherent operator which maps an image to a parameter domain. The Hough Transform (HT) method is to detect lines, using the parametric representation of a line:

$$r = x * cos(\theta) + y * sin(\theta) \quad (6)$$

From equation (6), the variable r is the distance from the origin to the line along a vector perpendicular to the line. Theta (θ) is the angle of the perpendicular projection from the origin to the line measured in degrees clockwise from the positive x-axis. . Fig. 6 shows the parametric representation of a straight line.

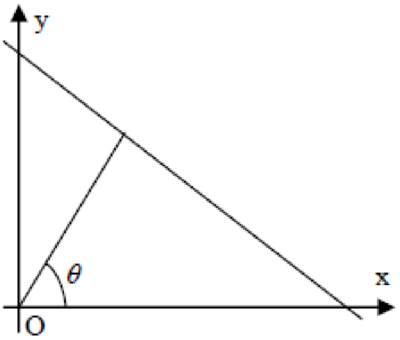

Figure 6: Parametric representation of a straight line

HT algorithm uses an array called accumulator to detect the existence of a line. For each pixel and its neighborhood, HT algorithm determines if there is enough evidence of an edge at that pixel. A voting procedure is carried out in the parameter domain. The number of dimensions of the parameter space equals to the number of parameters needed to fully define the curve or line as seen in equation (6) that line is represented by two parameters r and theta.. The circle is mathematically expressed using equation (7)

$$(x - x_0)^2 + (y - y_0)^2 = r^2 \tag{7}$$

These three parameters that are used in the equation representing circle form the accumulator array. A voting procedure is carried out in the parameter domain and. combinations with the highest values of votes are more likely to represent circles [2]. Thus, implementation of the Hough transform helps in the validation of the above color segmented output to decide whether it is a possible candidate region which can be further sent for the recognition procedure. The complete sign detection after the color filtration and shape filtering can be shown in figure 7 with a bounding box highlighting the road sign that is detected.

Figure 7: Traffic sign detected

3.2 Sign Recognition

The last stage of the algorithm is the recognition of the traffic signs. The key principle is to match the detected signs to a database (library) of traffic sign templates. Several techniques can be used for this purpose. The target of the recognition procedure is to assign each region of interest to the class that it belongs. If the match is found sound notification is given to the driver, interpreting the meaning of the candidate sign. . If the ROI does not match with any of the templates in the database (library) of traffic sign templates, the Candidate image is discarded. But the false rate is generally less since the candidate images with no blobs have already discarded using the noise removal and also the shape classification.

For the recognition stage, regions of interest are represented using Histogram of Oriented Gradients (HOG) proposed by Dalal and Triggs (2005) [7]. Initially, HOG descriptors have been applied specifically for pedestrian detection. HOG features have been widely used for object recognition, as they are robust to scale. Histogram of Oriented Gradients (HOG) is feature descriptors. The traffic sign candidate extracted have distinguishing shape and color features hence HOG is used as it is used generally for capturing color and shape as one feature. HOG is that in which local appearance and shape within an image can be described by the distribution of intensity gradient. The implementation of algorithm requires dividing the images into small connected region called cells. The horizontal and vertical derivatives are obtained from a gradient detector, the components of magnitude and orientation for each pixel will be given. The gradient at each pixel is the gradient with the greatest magnitude among the gradients computed on each of the channels. Then rescaling each region in to 64*64 pixels and describe it by 16x16 blocks of 8x8 cells with 8 pixels. Extracted output from HOG is given to SVM classifier to analyze and recognize patterns and used for classification. Finally, after the classification is done the driver is provided a voice acknowledgement of the sign being recognized.

4. Conclusion

In this paper, a methodology for road sign detection and recognition is presented and described, taking into consideration different factors. The system detects the traffic sign and recognizes the traffic sign and finally gives a sound notification. The proposed algorithm is based on HSV color space, morphological functions, shape analysis using Hough transform, feature extraction using HOG descriptors and classification of traffic sign. The method is fast as the system discards the images having signs of shapes other than the basic shape at the initial phase. As the future scope, increment in the robustness of the system can be done so that it can perform better in all kinds of atmospheres and luminance conditions.

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