A Review and Comparative Analysis of Recent Advancements in Traffic Sign Detection and Recognition Techniques

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ABSTRACT

This paper presents a comprehensive study of the automatic detection and recognition of traffic sign. The object of this review is to reduce the search for quality Traffic sign recognition system and to indicate the potential regions for increasing the efficiency, accuracy and speed of the system. The traffic sign carry the very important and valuable safety information through the peculiar characteristics. Different categories of traffic sign with their characteristics are presented. The practical difficulty that arises in actual time traffic sign is summarized. It describes also the techniques used for the detection, recognition and classification of the traffic signs. The traffic sign detection using color and shape detection are most commonly used. Some authors also used adaboost detector and decision tree method for detection. Most of the researcher used different type of Neural Network for recognition and classification. Some of the authors used fuzzy classifier and genetic algorithm. Template matching and model based method is also used for classification. A lot of improvements are still required for development efficient, fast, robustness traffic sign recognition system.

Keywords: *Traffic sign recognition, sign characteristic, lterature survey.*

1. INTRODUCTION

INTELLIGENT Transport Systems (ITS) are used to maximize transportation safety and efficiency by means of various predictive techniques [1]. Traffic sign recognition (TSR) holds the prime position in the field of ITS [2]. For assisted driving and autonomous driving, the TSR extracts the data from the digital image and recognize as valid traffic sign [3]. Normally the drivers need to be very vigilant and cautious to identify traffic signs at the right time. This is required to avoid any dangerous situation on road. Identify traffic signs especially in poor weather conditions depend very much on the physical and mental health of the drivers [4]. The visual perception abilities of driver can be affected by stress, tension, physical illness or toxicities [5]. A fast real-time and robust automatic TSR system can support and disburden the driver, and thus, significantly increase driving safety and comfort [6].

TSR system uses computer vision and artificial intelligence to extract the road signs from outdoor images in uncontrolled lighting conditions. The traffic signs may also be occluded by other objects, and may suffer from different problems like fading of colors and disorientation. The TSR system can be divided into three stages:

- Image acquisition,
- Sign detection and
- Sign recognition.

The three-stage block diagram of TSR is shown in figure 1. In first stage a real time video from the camera mounted on the top of the vehicle can be used as an input. Detection of traffic sign directly from video may be complex; hence detection are mostly preferred by using collection of static images of sign extracted from video are mostly preferred.

In second stage the extracted images are pre-processed, enhanced and segmented according to shape and color of traffic sign. The detection methodology is one of the important factors of TSR, as it reduces the large search area into small region of interest for recognition of possible traffic sign. The detection stage should be efficient and fast enough to reduce the total processing time of TSR.

In third and final stage, each candidate present in the region of interest is tested against set of features to decide whether the detected candidate is a traffic sign or not. The shape, pictogram and text present in

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the sign based features are mainly used for classification.

Fig. 1 : Block diagram of TSR

Traffic sign with peculiar color and shape convey the necessary information on the road. It also gives warnings and help driver for safe and convenient driving. In this study an effort has been made to review and analyze various techniques used to detect and recognize traffic sign. Finally a comparative analysis is made between different techniques and related scopes. The resultant outcome is further discussed for fast and efficient TSR System.

This paper is organized as follows: the next section presents the characteristic of traffic sign that can be used to detect and recognize traffic sign, potential difficulties that may arise during pre-processing of images. Thereafter, the article discuses the detection and recognition methodologies, comparative analysis of various methods, focused on TSR application. The later part deals with post thoughts and conclusions.

2. DIFFERENT TRAFFIC SIGN AND CHARACTERISTICS

The traffic signs are broadly classified as Warning sign, prohibitory sign, Regulatory Sign and Information sign. Traffic signs possess typical characteristic in the form of color and 2D shape [7]. These color and shape make them different from natural and man-made objects. The Red, Blue, Green, Orange, Yellow, Black and White color of specific wavelength are selected to make traffic sign recognizable easily even under complex environment. The triangle, circle, octagon and rectangle shape are used to design the traffic sign. In addition to color and shape some sign also contain pictogram and text. A fixed text fonts and character heights are used to make it different from other man-made boards [8].

2.1 Warning Sign

Warning sign contain Red colored border with white color background some countries also use yellow background. They alert the driver with a hazard ahead and also shows road layout on the roadway. Equilateral triangle with triangle pointing down is used for Yield sign while triangles pointing up are used for other warning sign. Level - crossing signs Y and T intersections curves comes under this category.

Fig. 2 : Dirfferent Signs

2.2 Prohibitory Sign

Prohibitory sign prohibits certain types of maneuvers, restricts the actions of the drivers and road users or unwanted traffic depending on the symbols on the sign. The category includes No Entry, No Parking, and Speed Limit Signs etc. Circle with white background and red borders are use for prohibitory sign with few exceptions: An octagon with red background and white borders is used for STOP sign, while blue background with red border is used for 'No Parking' and 'No Standing' sign.

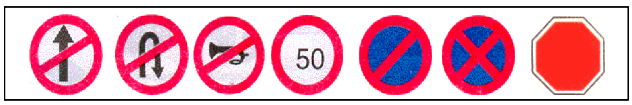

Fig. 3 : Prohibited Sings

2.3 Regulatory Sign

Regulatory sign or Mandatory sign are used to control the actions of the drivers. Circle with blue background and thin white borders are used for this category. White arrow mark is used for regulatory signs to regulate the traffic.

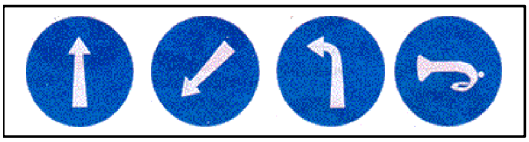

Fig. 4 : Mandatory Sings

2.4 Information Sign

Information signs are used to convey the important information about the telephone booth; petrol pumps etc. which may be required for the driver in emergency. Rectangle with blue background is used for such information while Rectangle with Green background is used for mileage information mileage.

Fig 5 : Information Sings

The shape and color description are summarized in Table 1.

Table 1 : Shape and colour Discription

Traffic Sign	Shape	Color
Warning	Equilateral Triangle Pointing up	White or Yellow Background / Red border
Yield	Equilateral Triangle Pointing down	White or Yellow Background / Red border
Prohibitory or Regulatory	Circle	White or Yellow Background / Red border
No Parking, No standing	Circle	Blue Background / Red border
Stop	Octagon	Red Background / White border
Information	Rectangle	Black
Directive/Information	Rectangle	Blue
Guidance and mileage	Rectangle	Green / Blue

3. POTENTIAL DIFFICULTIES IN RECOGNITION

There are various factors that affect the detection and recognition of traffic signs. Improper appearance of sign in video due to complex weather condition, color standard, obstacles,Interlacing effects, motion blur are among them.

3.1 Weather condition

The Shadow due to sunny environment may appear in the image. The color of the sign changes with the position of sun. Some colors may appear darkened or lightened. The color of sign fades with time due to long exposure to sunlight and pollution in the air. The visibility of traffic signs is also affected by fog, rain and snow [9-10]. Poor illumination due to change in weather may affect the detection of sign.

3.2 Color standards

The color standard used for traffic sign among the countries may be different.

3.3 Obstacles

The presences of the obstacles like trees, buildings, vehicles and pedestrian in the picture also affects the detection and recognition of traffic sign.

3.4 Disorientation

The sign on the road may be disoriented from its idle position. This disorientation may also trouble in automatic sign detection .

3.5 Motion blur and interlacing effects

The camera used for the recording may have interlacing. Taking pictures of traffic sign with a camera mounted on vehicle (especially of objects moving at high speed) blurring is inevitable and there isn't much we can do to prevent it. But if you discover that the camera is shaking, it is easy to make the camera static (i.e. use a tripod or even put in on an even surface) and decrease blurring, as shown in figure 6.

Figure 6 : Traffic Sign, recording by placing camera on vehicle

4. DETECTION TECHNIQUES

Traffic sign convey the valuable information in the form of color, shape, symbol and text, but colors and shape plays the key role in traffic sign information. The detection of traffic sign is mostly based on color and shape. Thus study of detection methodology is divided into three groups.

- Color - based detection.
- Shape - based detection.
- Others.

4.1 Color - based detection

Color based segmentation is commonly used for detection either to identify likely signs or eliminate regions that are unlikely to contain signs. Color is a dominant visual feature that transfers key information to the driver. This color based information can be extract from the digital image using various techniques like color thresholding, region growing, dynamic pixel aggration, histogram etc. The distinguish feature of traffic sign based on color simplify the process of detection.

The main disadvantage of RGB color-based detection is that illumination source varies not only in intensity but also in color as well as. Hence color space conversion is mostly used for detection. Separating the color information from the brightness information by converting the RGB color space into another color space, gives good detection abilities depending on the color cue. There are many color spaces available in the literature among them are the HSI, HSV, YIQ, and YUV color systems. The hue-saturation systems

are the mostly used in road sign detection .

Benallal and Meunier[11] found that the difference between R and G and the difference between R and B channels could form two stable features in road sign detection. Escalera[12] et al. used a color-thresholding technique to separate road sign regions from their backgrounds on the RGB space. A color ratio between the intensity of the specific RGB color components and the sum of intensity of RGB is used to detect strong colors in the image. Miura used a different relation between the RGB components by considering one component as a reference. Estevez[13] et al. used a redness measure to locate stop, yield, and "do not enter" signs using RGB color space.

Kehtarnavaz and Ahmad[14] used a discriminant analysis on the YIQ color space for detecting various road signs from videos. In HSV color space, Vitabile[15] et al. applied sub-space dynamic thresholding technique to find all possible road sign candidates according to their specific colors and then further improved their system using the FPGA language for hardware implementation. Fleyeh used an improved hue, lightness, and saturation (HLS) color space to detect color road signs from road scenes. Since a road sign uses different colors (such as red, blue or green) to demonstrate its functionalities such as warning or direction, different detectors should be designed to tackle its color variations. Pacheco[16] et al. used special color barcodes under road sign for detecting road sign in vision-based system. Lalonde and Li[17] propose Color indexing for identifying road sign.

4.2 Shape - based detection

Shape, being another important parameter of traffic sign, can be used for detection. The different methodologies that can be used to detect the shape-based features are canny edge detection, corner detection, Radial Symmetry.

Barnes and Zelinsky[18] adopted the radial symmetry feature to locate possible road signs and then verified them using a correlation technique. Piccioli et al.proposed a template-matching scheme to search all possible road signs from images. In addition, Wu et al. used a corner feature and a vertical plane criterion to cluster image data to different categories so that each road sign can be found. Moreover, Blancard used an edge linking technique and the contour feature to locate various road sign candidates and then verified them according to their perimeters and curvature features. The shape feature also can be learned from a set of training samples. Haritaoglu et al.[19] used support vector machines and texture-like features to train a classifier to detect road signs. Garcia et al.[20] extended the Hough transform to find any curves in an image to detect circular and stop signs.

4.3 Other methods of detection

Apart from the color and shape based method many researchers used Fuzzy, Neural Network, genetic algorithm, Adaboost techniques for detection.

Fang et al. [21] used neural networks to locate regions that may be the center of signs. Both color (hue) and shape features are used. Candidate signs are tracked through time using a Kalman filter and signs are verified by a set of rules concerning the colors and shapes of the regions. Genetic algorithm used by Aoyagi and Askura1 to identify road sign from gray-level images, but the limitation of crossover, mutation operator, and optimal solution are not guaranteed. Hassan Fleyeh used fuzzy approach to extract the color of sign by converting RGB space into HSV color space. C. Bahlmann et al[22] and Lienhart and Maydt[23] presented an extension of the original Haar-like features set, demonstrating that Adaboost converges faster and with better results when the features set is large.

5. CLASSIFICATION METHODOLOGIES

The detection stage provides the group of candidate that could be probable road signs. The recognition state decides whether the candidate is a traffic sign or not. A robust recognizer possesses good discriminative power, low computational cost. It should also robust to noise and be capable to recognize in real time applications.

Neural networks like Multi Layer Perceptron (MLP), Radial Basic Function (RBF) are most commonly used for recognition and classification of road signs. The main advantage of neural network classifier is that the input image does not required to transformed into another representation space. Also the classification depends only on the correlation between the network weights and the network. The

training overhead is the main disadvantage of Neural Networks. The fixed architecture of MLP is not suitable for real time application. It requires redesign of whole architecture in case of object classes increases.

The template matching is another technique used for classification. In order to get good matching this technique requires considerable amount of computations to transform the objects into the representation space such as Hough space, or the Fourier domain. Also this technique doest have any mechanism to deal with new unknown signs, which can enter the scene.

Apart from NN and template matching, Model based recognition can also be used for recognition. Many researchers used Behavioral vision model Hidden Markov Model[24] and Bayesian generative model for recognition.

6. CONCLUSION

The shape, edge, color, Adaboost features are used for detection. The color based and shape based gives good accuracy of detection separately but to overcome the constraint of color and shape based most of the works used combination of both color and detection of traffic Adaboost converges faster and with better results when the features set is large. The main disadvantage of adaboost detection is that due to the exhaustive search over the features set, the training time grows with respect to the number of features. Dimension reduction techniques can be used to reduce the high dimensional data for generation of the most significant features.

Table 2 : Object Detection Methods

S. No	Detection Technique	Category	Method	Recognition Technique	Method	Rate or Comp. Cost	Ref. /year
1	Color Segmentation in RGB.	Color	RGB color is directly segmented.	Template Matching	The result of detected stage is scaled to a size of 48X48 and is compared with stored sign template of same size.	63 – 86 %	**17** 2005
			To overcome the problem of illumination the RGB colors are normalized by intensity.	RBF Neural Network	Principal Component analysis is used to reduce dimension and Fisheres's Linear Discriminant is used to get discriminating features and RBF NN is used to recognize.	95%	**24** 2008
2	Color Space transformation	Color	In HSV color space color are quantized to specific 8 colors then horizontal and vertical projection of specific color are used for detection	Hidden Markov Model	The candidate detected are sorted using HMM and the first ranked is regarded as recognized result.	P4,1.6GHz, 512 MB, Image size 88X88 required 1.5 s	**16** 2006
			Color model CIExyz is used for segmentation.	Behavioral Model of Vision (BMV)	BMV model is used to recognize complex gray level image with respect to shift, plain rotation and in certain extent to scale.	88 – 90 %	**28** 2002
			HSL color space is used and detection is performed on the basis of marginal distribution of color regions	Template Matching	Phase only correlation and partial template matching is used to recognize.	90.1%	**30** 2008
			Dynamic threshold in pixel aggregation process on HSV color space is used for segmentation.	MLP Neural Network	MLP topology has been fixed by the input data number, by the output classes and making an RGB values compression (3: 1) between the input layer and the hidden layer.	84 – 100%	**17** 2001

			A statistic linear model of color change space that makes road sign colors be more compact and thus sufficiently concentrated on a smaller area	RBF Neural Network	a radial basis function (RBF) network is used to train a classifier to find all possible road sign candidates from road scenes.	95.6%.	**37** 2008
3	Hough transformation, corner detection	Shape	HSI color space is used. Hough transform is used to detect the triangular and circle sign. The corner detection method is used to divide connected triangular sign and circle shape sign.	RBF Neural Network	RBF-NN is used to identify the traffic sign and k-d tree is used to recognize the sign.	95.5%	**27** 2007
4	Edge detection and fit ellipse.	Shape	Gaussian filter and Canny edge detection is used to enhance image. Thresholding is used to convert a B/W image into binary and then contour and fit ellipse is used to detect the sign.	MLP Neural Network	MLP is trained with supervised back-propagation learning technique	37.27 msec	**32** 2007
5	Adaboost	Others	Detection is based on a boosted detectors cascade, which allows the use of large feature spaces.	Forest ECOC	A battery of classifiers is trained to split classes in an Error-Correcting Output Code (ECOC) framework.	6% Error Rate	**25** 2009
6	Gabor Features		Gabor wavelets are used to encode visual information and extract features	SOM	Self Organizing Maps are used to cluster and classify the traffic signs.	96%	**29** 2008
7	Linear Support Vector Machine		HSI color space to extract candidate blobs using color thresholding then the sign are detected using linear SVM	SVM	The recognition of traffic sign is based on SVMs with Gaussian kernels. Different SVMs are used for each color and shape classification.	44.90% to 93.24%	**26** 2007

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