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A Study on Automatic Detection and Recognition Techniques For Road Signs

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ABSTRACT

Traffic signs provide valuable information about the road and play a vital role in safe and smooth driving. But, while driving at high speed, these signs might get missed. To tackle with such problem, the automatic road sign recognition system has been introduced. This system helps in improving driver assistance system which is a development in Intelligent Autonomous Vehicles technique. This paper discusses about the various existing methods used in detection and recognition of traffic signs, the challenges that occur in dealing with live images and lastly concludes with a chronological and brief tabulation of all the referred work.

Keywords: *Road signs, Colour, Shape, Pixel, Detection, Recognition, Template.*

I. Introduction

The task of driving is completely based on visual information processing.
Road signs guide drivers for direction, gives current traffic situations, prohibit or permit certain directions and warn them of any special road conditions. [7] The objective of this system is to detect and classify road signs from within real-time colour images captured by an image-sensor on-board of the vehicle. The system attempts to develop such a warning system which can alert the driver about the approaching road signs early enough to prevent road accidents from happening.
But various challenges are faced while developing an Automatic Road sign recognition system, such as-

- Appearance- The colour appearance of traffic signs is a crucial issue. As, the outdoor lighting conditions varying from day to night may affect the colour display of road signs within images. Season and weather conditions also affect the light strength. In addition, road sign images may be affected by shadows from surroundings.
- Road signs images also suffer from bluffing effect caused by the vibration of moving vehicle.
- As the direction of sign is not always ideal, so the shape and pattern of sign within an image can be affected. Sometimes the shape of signs also changes due to storms.
- Road signs are often confused with other surrounding objects and many times, obstacles such as trees, lamp posts, buildings, etc occlude the signs.[7]

These are unavoidable challenging issues faced during road sign detection and are the reason why this is becoming a growing area of research since the 1980's. [15]
The whole system is generally divided into three phases, namely-

- Detection phase- In this phase, the road sign or a candidate area is searched within the obtained digital image.
- Classification/Recognition phase- Here, the candidate area or the detected shape is identified into a road sign.
- Finally, the obtained result is presented to the user.[12]

These phases are carried out using different techniques, which take advantage of the distinct colour and shape based features of the road signs.
The techniques are divides into:

1.1. Colour Based Techniques

Colour is the most distinctive feature of a road sign. The applied colours are chosen in such a way that, they are easily visible from far and they correspond to a specific wavelength in the visible spectrum. The most commonly used colours are the primary colour (Red, Green, and Blue) and yellow (a secondary colour). Colour Segmenting is the most commonly used technique, which extracts out the coloured road sign from the surrounding. Arturo de la Escalera, [17] suggested the hue; saturation; intensity (HSI) system is very invariant to lighting changes. But, the disadvantage of HSI is that its formulas are nonlinear, and if special hardware is not used, the computational cost is prohibitive. But, colour cannot be considered as a reliable feature for detection [5]. Some widely used colour-based techniques are summarised below:

1.1.1. Colour Thresholding Segmentation. This technique isolates objects by converting grayscale images into binary images. Image thresholding is most effective in images with high levels of contrast. The advantage of obtaining first a binary image is that it reduces the complexity of the data and simplifies the process of recognition and classification. Ghica et al. [1] used thresholding to segment pixels in a digital image into object pixels and background pixels. The technique is based on calculating the distance in RGB space between the pixel colour and a reference colour. [18], [19].

1.1.2. Region Growing. This approach uses a seed in a region as a starting point and expands as groups of pixels with a certain colour similarity. The approach can be implemented in the HSI colour space. As it requires a seed to start and ends when certain criteria are met, it may run into a problem when ending conditions are not satisfied [6].

1.1.3. Dynamic Pixel Aggregation. This is another approach of colour segmentation. In this method it is performed by introducing a dynamic threshold in the pixel aggregation process on HSV colour space. The main advantage of dynamic threshold is to reduce hue instability in real scenes depending on external brightness variation. This method has been implemented by Vitabile et al. [4].

1.1.4. Image Pre-Processing. The aim of pre-processing is an improvement of the image data that suppresses unwanted distortions or enhances some image features important for further processing. This process produces a corrected image that is as close as possible, both geometrically and radio metrically. The main purpose of applying correction is to reduce the influence of errors or inconsistencies in image brightness values [4].

1.1.5. RGB Transformation. A camera mounted on a moving car produces an RGB image. An important part of colour-based detection system is colour space conversion, which means converting the RGB image into another form that simplifies the detection process. This means separating the colour information from the brightness information by converting the RGB colour space into another colour space, which gives good detection abilities depending on the colour cue. This method has been used in [4], [5] for detection purpose.

1.1.6. CIECAM97 Model. CIECAM97 is one of many colour appearance models. Shaposhnikovet al.[2] used this model to perform pre-processing. It breaks down the illumination environment and the colour stimulus. The CIECAM97 model uses the colour stimulus, the colour of white, the background, and the surround field to calculate its representation of the stimulus colour. CIECAM97 represents the stimulus colour using lightness, chroma and hue. In [3] the accuracy was found to be more than 90%.

1.2. Shape Based Techniques

Another important feature of road sign, as mentioned earlier is “Shape”. It can also be used for detection purpose. It does not require colour information [7]. The system exploits *a priori* shape knowledge about signs to select a candidate sign regions in the binary images obtained by the image sensor. Then a classification is done on the shape using a similarity coefficient between a set of image samples representing each road sign shape and a segmented region.[4],[19]

Due to lack of standard colours, Shape detection is preferred for road signs recognition as the colours found on traffic signs changes according to illumination and it also reduces the search for a road sign regions from the whole image to a small number of pixels. [12]

Some common approaches based on shape are:

1.2.1. Distance Transform Matching. In this technique, edges in the original image are found and then a distance transform (DT) image is built. A DT image is an image in which each pixel represents the distance to the nearest edge. Its advantage over other techniques is that it is capable of detecting objects of arbitrary shapes when dealing with non-rigid objects. It also uses a template hierarchy to capture the different shapes of object. Gavrila et al. [9] has used this technique for detection purpose**.** The method is used to detect road signs both on-line and off-line with a detection rate of about 90%.

1.2.2. Hierarchical Spatial Feature Matching (HSFM). Paclík et al.[11] developed a classification module based on Hierarchical Spatial Feature Matching (HSFM) method. In the detection stage, a list of regions where the signs are likely to exist was generated. This list is passed to the classification module, by which each region is either labelled with the sign type found in this region, or marked as a rejected region.

1.2.3. Regions Extraction. Since the images are taken outdoors, the obtained images are very noisy. Noise reduction filters and morphological filters can be applied to enhance each region contour. A classical region growing algorithm has been used to fix the region of interest coordinates. We do not consider regions with an area less than 20x20 pixels since their information cannot be successfully recognized. [4]

1.2.4. Similarity Detection. Vitabile et al. [4] performed Similarity Detection technique by computing a similarity factor between a segmented region and set of binary image samples represent each road sign shape. Both colour and shape information is considered for detection process. The performance of this approach was reported to be good with triangular shape giving the lowest hit rate.

1.2.5. Template matching. Template matching is a technique that identifies the parts on an image that match a predefined template [17]. It can be easily performed on grey images or edge images. Ohara et al.[8] used template matching for sign recognition. A sub-area of size NxN is selected, and small defects and noises are filled in or deleted. The pixel values are normalised by the maximum and minimum values of the input sub-area. The size is also normalised depending on the template to be matched, and the closeness with the template is calculated. A recognition rate of over 95% is achieved. [8]

1.2.6. Hough Transform. Hough transform is a method for estimating the parameters of a shape from its boundary points. Gareth et al. [10] used Hough transform to isolate features of a particular shape within an image. It is most commonly used for the detection off lines, circles or other parametric curves. It can give robust detection under noise and partial occlusion. Its advantage is that it is conceptually simple, easy to implement and handles missing and occluded data very gracefully. However Hough transform is computationally complex for objects with many parameters and requires lot of memory that makes it not a good choice for real-time applications.

1.3. Other Techniques

Some other techniques, apart from colour-based and shape-based methods are mentioned below-

1.3.1. Neural Network. Ohara et al.[8] used a small and simple neural network (NN) to detect the colour and the shape of road signs. The original colour image is first treated by a Laplacian of Gaussian filter (LOG). A colour NN classifier is then used to segment the image according to the colour under recognition in RGB colour space. A shape NN is used after that to check whether each image contains an object with the shape of a road sign. When a shape is found, template matching is applied for final recognition. There are two distinct advantages of using neural networks. First, the input image does not have to be transformed into another representation space. Second, the result depends only on the correlation between the network weights and the network. Neural Networks are being implemented in [4], [1], [15], [8] and etc.

1.3.2. Genetic Algorithm. Genetic Algorithm can be used to search for traffic sign in a scene image. Yuji et al. [13] has used this approach. The image is matched by giving the gene information. Its advantages are simple using, low memory demands, using of simple computation algorithm and ability of parallelism. The disadvantage of genetic algorithm is non-deterministic work time and non-guarantee finding of the best solution.

1.3.3. Laplace Kernel Classifier. Paclik et al. [11] used the Laplace kernel classifier to classify road signs. The signs are divided into nine groups depending on their shapes and colours. This kernel is based on Laplace probability density, and the smoothing parameters of Laplace kernel were optimised by the pseudo-likelihood cross-validation method. The algorithm is tested on more than 4900 noisy images.

1.3.4. Nearest Neighbour Classification. Nearest Neighbour Classification is a straightforward and classic type of classification. An image in the test set is recognised by assigning to it the label of most of the closest points in the learning set. All images are then normalised to certain value. The image in the learning set that best correlates with the test image is then the result. [16]

II. Discussions

As has been mentioned earlier, the identification of road signs can be carried out by two main stages: detection, and recognition. By invoking a combination of colour and shape, it is possible to take advantage of both techniques to detect traffic and road signs. Each approach has its own positive properties and difficulties. However, an adaptive hybrid approach can invoke one technique under certain circumstances and invoke the other under different circumstances. Even when this adaptive approach is not in use, combining colour and shape in any sign detection method has the advantage of using the information available from both sides of the problem. Colour based detection is used over shape based, to increase the computational speed. Techniques using shapes could be a good alternative when colours are missing or when it is hard to detect colours. Shape-based techniques should be able to avoid difficulties related to invoking colours for sign detection and robust to handle in-plane transformations such as translation, scaling and rotation.

Results of the template matching algorithms and the neural networks approaches are nearly the same. However, template matching is a more time consuming process, because each time the candidate shall be compared by each template, including its shifted versions.

On the other hand, training neural networks with lots of deformed versions of training set is possible. Moreover, the processing time of the neural network does not directly depend on the number of the members of training set. Thresholding uses only grey level value and no spatial information is considered. Therefore, the major shortcoming of the threshold is that there is often an overlap between grey levels of the objects in the breast and the background. Many techniques are robust and are able to detect and recognise the road signs with high accuracy. But none of these can be totally immune to the problems faced by the automatic road sign recognition system. Research in this field is still necessary and requires more attention.

III. Conclusion

The traffic sign recognition is a very helpful driver assistance technique for increasing traffic and driver safety. The future intelligent vehicles would take some decisions about their speed, trajectory, etc. depending on the signs detected. In this paper, a brief description and a review of the existing automatic road sign recognition research has been given. It includes, description of the various methods, a short discussion on the techniques and finally a tabulation of the different techniques is presented.

Colour-Based Techniques					
Sl. No.	**Technique**	**Developer Name**	**Development Year**	**Performance**	**Reference**
1.	Colour Thresholding Segmentation	Ghica et al. Kuo et al. Salem et al.	1995 2007 2010		[1] [18] [19]
2.	Region Growing	Yuille et al.	1998		[6]
3.	Dynamic Pixel Aggregation	Vitabile et al.	2001	86.3%-95.7%	[4]
4.	Image pre-processing	Vitabile et al.	2001		[4]
5.	RGB transformation	Vitabile et al. Alberto et al.	2001 2007		[4] [5]
Shape-Based Techniques					
1.	Distance Transform Matching	Gavrila et al.	1999	90%	[9]
2.	Hierarchical Spatial Feature Matching (HSFM)	Paclik et al.	2000		[11]
3.	Regions Extraction	Vitabile et al.	2001		[4]
4.	Similarity Detection	Vitabile et al.	2001		[4]
5.	Template matching	Yves et al. Ohara et al.	2001 2002	95%	[17] [8]
6.	Hough Transform	Gareth et al.	2004		[10]
Other Techniques					
1.	Neural Network	Ghica et al. Arturo et al. Vitabile et al. Ohara et al.	1995 1997 2001 2002	84%-100% >95	[1] [15] [4] [8]
2.	Genetic algorithm	Yuji et al.	1996		[13]
3.	Laplace Kernel Classifier	Paclik et al.	2000		[11]
4.	Nearest neighbour classification	Escalera et al.	2004		[16]

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