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Real Time Detection and Recognition of Indian Traffic Signs using Matlab

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Abstract— Traffic Sign recognition system is a part of driving assistance system that automatically alerts and informs the driver of the traffic signs ahead. In this paper an efficient real time sign detection system is proposed for Indian traffic signs. Car cameras that capture video are integrated with an in-vehicle computing device. Image frames may be blurred and corrupted by Gaussian noise due to motion of vehicle and atmospheric turbulence. Hence Image enhancement is done using median filter and nonlinear Lucy-Richardson for de-convolution. Colour segmentation using YCbCr colour space along with shape filtering through template matching of colour detected candidates are used to detect sign from images as colour and shape easily distinguishes a sign from its background. The classification module determines the type of detected road signs using Multi-layer Perceptron neural networks.

Index Terms— Traffic Sign detection, Lucy-Richardson de-convolution, median filter, YCbCr colour space, template matching, neural network.

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1 INTRODUCTION

INTELLIGENT vehicles are becoming a part of our day to day life. Due to carelessness of drivers while driving and Violation of traffic rules, a large number of accidents occur today. Intelligent Transport Systems (ITS) play a great role in safe driving and in saving lives of pedestrians as well as in saving time and money. These systems are interconnected to the emerging technologies such as internet, General packet radio service (GPRS), Artificial Intelligence, smart sensors, Geographical Information Systems (GIS) and many more. ITS gives great importance to the field of road sign detection and recognition as it is a part of driving assistance system and autonomous navigation system. These systems must be fast and robust to detect sign in real time.

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There are mainly two distinguishable phases for automatic traffic sign recognition system. First is the detection phase and the second is recognition phase. In the detection phase system 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 YCbCr colour space. For shape based filtering we use template matching to match the colour segmented candidate objects to shape such as triangle, circle, rectangle and octagon. If a match is found then depending on colour and shape we detect it exact position of the traffic sign and is extracted. By shape and color it is classified into one of the four categories. Further the traffic sign is recognised by multi-layer neural network for each category.

In Section II, we review previous work. In section III a study about the characteristics of traffic signs have been done. Then, in Section IV, we outline the methodology used, which includes detection and recognition of the signs from videos. In Section V, we describe the experimental results to illustrate the performance of the system. Finally, conclusions are drawn in Section VI.

2 RELATED WORK

A lot of research has been carried out for designing a robust traffic sign recognition system. Many authors use RGB colour space to identify traffic sign. Benallal et al. [3] studied the behaviour of RGB components of several road

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sign to sunset. Difference between any two components alone was considered for colour segmentation. The other colour spaces such as HSI, HSV, YIQ, YCbCr, CIExyz are available in literature. Since HSV colour is closely related to human perception Ching-Hao Lai [1] used colour quantisation in HSV colour space. Kentaenavaz et al. [5] performed discriminant analysis in YIQ colour space to detect signs in image frames from Video. Jitendra et al. [2] uses YCbCr colour space for colour segmentation for detection as it is independent of variable illumination characteristic. CIExyz colour model along with LCH (Lightness, Chroma, Hue) colour space was for colour segmentation for images under varying conditions by X.W. Gao et al. [4]. It could predict colour as accurate as an average observer.

Shape is another important characteristic of traffic sign that is used for segmentation. Varying techniques have been used for shape based segmentation such as canny edge detection, Hough transform, template matching, radial base symmetry and corner detection. Lorsakul et al. [7] pre-processed image using Gaussian filter and canny edge detection for enhancement of edges. Kuo et al. [8] used geometric characteristic of traffic sign. Hough transform together with corner detection and projection to detect the exact position of the road sign. Ching Hao Lai et al. [1] uses a traditional template based shape recognition method to detect red circle and red triangle traffic signs. Fast radial symmetry was used to detect circular signs by Barnes et al.[9] from image stream obtained from a camera mounted on car. Escalera et al. [10] used optimal detectors to find corners from the convolution of the image with a mask called correlation filters.

To recognize traffic signs, various methods for automatic traffic sign identification have been developed and show promising results. In the classification phase, the system evaluates the regions found by the detection phase and identifies the signs. The common approaches for classification are as follows: 1) neural network (NN) 2) nearest neighbor classification 3) support vector machine (SVM) 4) genetic algorithm (GA) and 5) co-relation based pattern matching. Neural Networks precisely represents a technology used in traffic sign recognition.

3 CHARACTERISTICS OF ROAD SIGNS

Traffic signs have been designed so that they are easily recognisable from natural and driving environment. The colour for traffic sign are chosen such that, it serves different purposes and is also distinguishable for the driver while driving. The signs are represented by fixed shapes like triangle, circle, octagon, and rectangle. The combined feature of colour and shape are used by driver to distinguish a traffic sign. Hence an automated system also uses the same principle of 'the colour and shape property of traffic signs'. With respect to the road the traffic signs are located at well-defined locations so that the drivers can more or less expect the position of the sign. The road sign may contain text as a string of characters or pictogram or both to represent the meaning of the sign. They are characterised by using fixed text fonts and character heights. There are a number of traffic signs in India categorized as WARNING (40), COMPULSORY (27), REGULATORY (10) and INFORMATORY (15). This makes a total of 92 traffic signs all together. These signs are mainly characterized by colour and shape. Figure 1 shows the different types of Indian traffic sign and their description are discussed below.

1) *Warning Sign*: A triangle with red coloured border and white background represents a warning sign. Different pictograms in black are used to represent the various warnings. These signs alert the driver with hazard ahead.

2) *Compulsory Sign:* Compulsory signs uses circle with red border and white background. These signs restrict the action of drivers depending on the pictogram represented on the sign. Signs with a cross prohibit the driver from certain decision such as *no left turn or no 'U' turn etc.* Speed limit signs are also included in this category of traffic signs, with speed limit as the pictogram. Another exception is octagon with red background with STOP in white and blue circle with red border and cross represents '*no parking sign*'.

3) *Regulatory Sign:* They are mandatory sign to control the action of the drivers on road. They are used to regulate the traffic flow and vehicles moving on road. Blue circle with white border represents a regulatory sign. While the arrows within it represent the movement of the vehicle on road.

4) *Information Sign:* Important information like nearby hospitals, telephone booth, first aid, petrol pumps etc. come under this category. This information helps the driver in emergency in need. White rectangle with thick blue border and the necessary pictogram represents the required pictogram. Parking information is also included in this category.

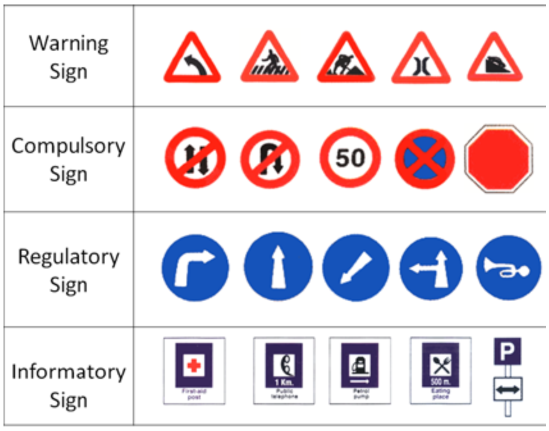

Fig. 1 Different category of traffic signs

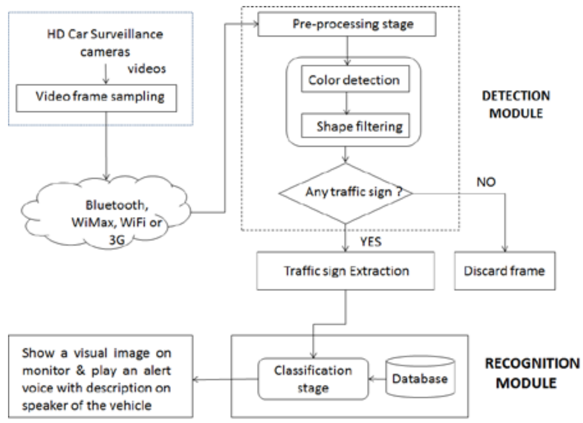

Fig.2 Prototype of the Proposed System

However identification of traffic sign is still a challenging task due to different geographic and weather conditions like cloudy day, raining or foggy day. The lighting conditions are uncontrollable since it is time dependent and seasonal, for example day light and night fall. More over the signs are of different types. Distance between the sign and video capturing device is a factor. The blurring of the image is dependent on the speed of the moving vehicle. Other problems are sign may be disoriented, damaged, faded or occluded. There may be similar objects as in colour or shape. Hence most sign detection system use both colour and shape as distinguishing feature and pre-processing techniques for image enhancement for coping with the varying lighting conditions.

4 METHODOLOGY

A prototype of the proposed system for the detection of Indian traffic sign is shown in fig 2. It mainly consists of four stages: video capturing, pre-processing, detection and its classification of the traffic sign in the Image frame.

Videos are captured using HD car surveillance camera, sampled to get images according to a particular frame rate. These images are processed for image enhancement according to environmental conditions. The colour segmentation is used for detection of the sign within the image. Objects with similar colour (red or blue) 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 and to which class it belongs to. The detection stage must be fast and robust to speed up the computation of the real time detection system. The output of the detection stage is input to the recognition stage where neural networks are used for classification. Since four different networks are used training and classification is easier, robust and faster.

A prototype of road sign detection and recognition system is shown in figure 2. In the detection phase, the acquired image is pre-processed, enhanced, and segmented according to the sign properties of color and shape. The potential objects are then normalized to extract the features and then input to recognition phase.The main steps included can be summarized as:

1) Image extraction from the video.

2) Image enhancement for different lighting and whether conditions.

3) Selecting candidate objects based on colour.

4) Filtering the candidate objects based on shape.

5) Recognising the filtered object using neural network

6) Give visual image of the recognised sign and audio for the type of category of the traffic sign.

4.1 Image extraction and Pre-processing

Video is taken by a HD car Cam that records videos of high definition 720p mounted on the moving vehicle. The video is then transmitted to the in-vehicle computing device through HDMI cable. It is also able to capture good images at night using infrared night vision technology. The image extraction stage then samples the video at a particular frequency rate to get the image frames. Each of the image frames are then pre-processed and then sent to the detection stage to classify into any of the 4 categorical classes.

Images must be sampled from the video as sign can be detected only in individual frames. Also all frames need not be sent to detection stage. According to the speed of the moving vehicle the number of frames being processed can be increased or decreased. If the vehicle moves at greater speed means the number of frames sent for detection must

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also increase. This also depends on the resolution and video capturing speed of the camera.

Since videos are captured using cameras installed in a moving vehicle the images might appear blurred. Also the brightness, contrast, clarity are affected by time of day, location and weather conditions. Due to climatic conditions or calibration difference, noise may also be encrypted along with the image. This would increase the difficulty of detection and therefore some pre-processing is required to reduce their influence according to varying conditions.

Images captured by a moving vehicle may have a blurring effect and edges may appear vague and washed out. The efficiency of frequency domain techniques can be used to remove motion blur from the images. Similarly images may be corrupted by white Gaussian noise due to atmospheric turbulence. The main challenge during suppression of noise is preservation of integrity of fine image structures. Weiner filter employs linear de-convolution method but gives poor results when noise is present. Hence high quality filters like Lucy-Richardson, which are non-linear, are used in the proposed paper. Median filtering for coloured images is also used as noise is removed without blurring of edges. Median filters are non-linear filter and gives better results than averaging filters.

Fig. 3 Blurred image due to motion

Fig.4 Filtered and histogram equalized Image

Figure 3 shows an image affected by atmospheric disturbance and motion blur. Fig. 4 shows image processed by median filtering and convolved with Lucy-Richardson filter followed by histogram equalization for varying lighting conditions.

4.2 Colour Based Segmentation

Traffic sign can be classes into two groups mainly as red traffic sign [warning and compulsory] and blue traffic signs [regulatory and information signs]. Since colors are distinguishing feature of traffic sign, colour extraction is an effective solution for candidate selection from an image. Hence colour segmentation is performed in YCbCr color space due to the following reasons.

1)Though RGB colour space represent colour image directly human eye has different sensitivity to colour and brightness.

2)The illumination variation can be solved by converting RGB to YCbCr colour space.

3)YCbCr is a colour space used in video streams.

4)YCbCr represents colour as brightness and two colour components as the difference of two signals, whereas RGB represents colour as Red, Green and Blue.

In the YCbCr space, the colour value of a pixel is determined by the planes Cb (Blue Chroma) and Cr (Red Chroma). As their names indicate, Cb determines how close is the colour of a pixel to blue, and Cr to red. In this colour space, the Y component represents the Luma (brightness).To compute YCbCr from RGB (normalized in the range [0, 1]), the following equation set must be used.

Fig. 5 Image captured during day light

Fig. 6 (i) Cb plane Fig. 6 (ii) Cr plane.

Thresholding technique is then used to separate the red and blue colour objects in the image. Output is a binary image. Morphological operation is done to close open area. Region properties are applied to get boundary box properties of the region of interest of the candidate objects. Fig. 5 shows an image taken during day time And Fig.6 (i) and (ii) shows the Cb and Cr plane. The thresholded images for blue and red pixels are shown in fig. 7 (i) and (ii).

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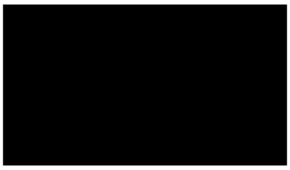

Fig. 7 (i) Cb plane threshold

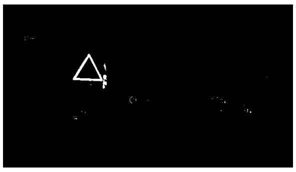

Fig. 7 (ii) Cr plane threshold

4.3 Shape Based Filtering

Though colour segmentation is used for initially selecting the candidate objects, shape detection is used for filtering off the candidates. First step is labelling the connected regions. All connected candidate pixels are grouped using 8-neighbors. There will be more than one candidate object. 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. Shape and colour distinguishes one of the four categories.

Shape detection based on a similarity measure between the binary image of the colour segmented road sign and the objects of the template database. Both sample and segmented image must have the same dimensions or else resized. First, the road sign is normalized to a size of 50 * 50 pixels by linear interpolation. Secondly, the normalized cross-correlation between the road sign and the templates of the database related to the proper shape is computed. A score list of the best N templates that fall within a fixed range of the maximum value is considered. An angle rotation has been performed to increase the robustness against uncertainties due deformation. Angle of rotation for each sample sign, segmented region is rotated from -15 to +15 degrees with a step of 3 degree. The similarity coefficient is calculated to find the greatest similarity factor for the angle value. The distance measure (squared Euclidean distance) is used for cross correlation for template matching.

$$d^2_{f,t}(u,v) = \sum [f(x,y) - t(x-u, y-v)]^2$$

If the term Σ f(x, y)² is considered constant then the remaining cross correlation term is a measure of the similarity between the image and the template feature.

$$C(u, v) = \Sigma f(x, y)\, t(x-u, y-v)$$

The colour segmented image after thresholding is matched with the different templates in the database. If the similarity measure for the match is greater than a threshold value then it is detected as a traffic sign and classified into any of the four classes discussed above based on the shape and colour of the sign. The triangle template was matched in the Cr plane. Since we got the template within the Cr plane matched with a triangle we can classify the traffic sign in the image frame as a warning sign.

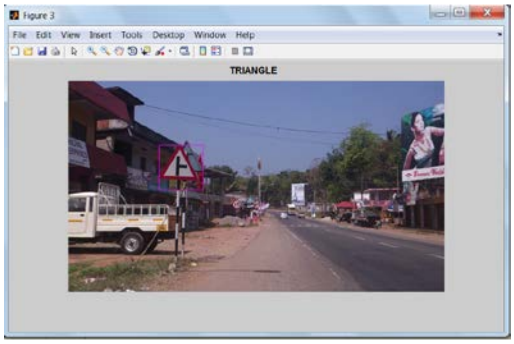

Fig.8 Detected traffic sign as warning sign

The output for the detected sign for the input image is shown in Fig. 8 with classification as warning sign.

5 Classification using neural network

The recognition module is used to confirm a candidate region as a traffic sign and classify the exact type of sign within the four categories. Neural networks are a suitable for recognition and classification of road signs. Main two advantages of using neural networks is that, the input image does not have to be transformed into another representation space. Second, the result of the classification depends on the correlation between the network weights and the network itself is assumed to be chosen from the beginning. Furthermore, by using neural networks it is possible to avoid problems concerning template matching where considerable amount of computations must be performed to transform the objects into another representation space. The main disadvantage using multi-layer neural network is the requirement of training data images. Since standard database does not exist for Indian traffic signs.

The database is divided into learning, validation and test sets. The first one is used for MLP training. The second one is for validation, during training to improve generalization property of the network fig. 9(i). The last one is to evaluate the performance of the trained MLP fig. 9(ii).

Fig. 9(i) Dataset used for training and validation

Fig. 9(ii) Test data for evaluation

The main task of the classification module is to classify the extracted regions of interest presented to its input into the road-sign category they belongs. Here the MLP networks have been employed to implement the classification module because they have proven to be good classifiers and have been able to successfully solve several object recognition problems.

Initially pre-processing is required which is a series of operations performed on the extracted traffic sign from the image. It essentially enhances the image rendering it suitable for feature extraction. The segmented traffic symbol is initially subtracted from background using masking operation and also masked by either red or blue to remove the triangle, circle or rectangle i.e. the respective shapes. It's followed by the various morphological operations Binarization and Thinning. Binarization process converts a gray scale image into a binary image using global thresholding technique. Erosion of the image and filling the holes present in it are also performed to produce the pre-processed image suitable for feature extraction. Fig 10 shows the steps in pre-processing.

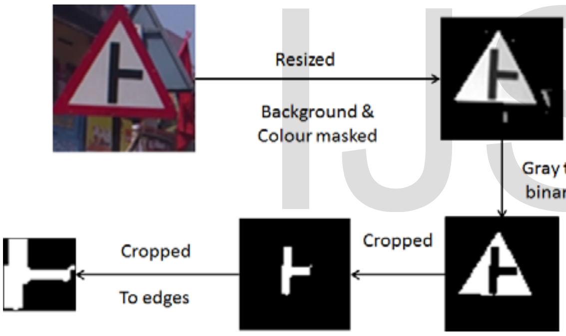

Fig.10 Pre-processing steps

In this stage, the features of the symbol that are crucial for classifying them at recognition stage are extracted. This is an important stage as its effective functioning improves the recognition rate and reduces the misclassification. Every traffic sign image of size 25 x 25 pixels is divided into 25 equal zones, each of size 5 x 5 pixels as shown in fig. 11.

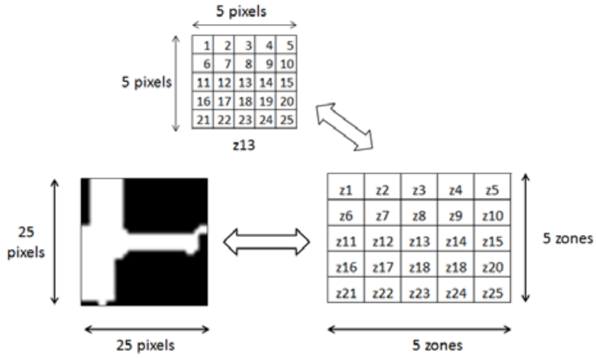

Fig. 11 Procedure for feature extraction

Each zone has 25 pixels present as its feature. These 25 sub-features values are averaged to form a single feature value and placed in the corresponding zone. This procedure is sequentially repeated for the all the zones. There could be some zones whose foreground pixels are empty. The feature values corresponding to these zones are zero. Finally, 25 features are extracted for each sign.

Four feed forward back propagation neural networks having two hidden layers and 25 inputs each are used to perform the classification. The hidden layers use log sigmoid activation function, and the output layer is a competitive layer, as one of the traffic signs are to be identified. The feature vector is denoted as X where X = ($f1$, $f2$,…,fd) where f denotes features and d is the number of zones into which each sign is divided. The number of input neurons is determined by length of the feature vector d. The total numbers of traffic signs n determines the number of neurons in the output layer. The number of neurons in the hidden layers is obtained by trial and error. The most compact network is chosen and presented. The neural networks with architecture 25-100-100-n are used here where 'n' depends on the number of traffic signs in the given category. An example network for training and testing is shown in fig. 12.

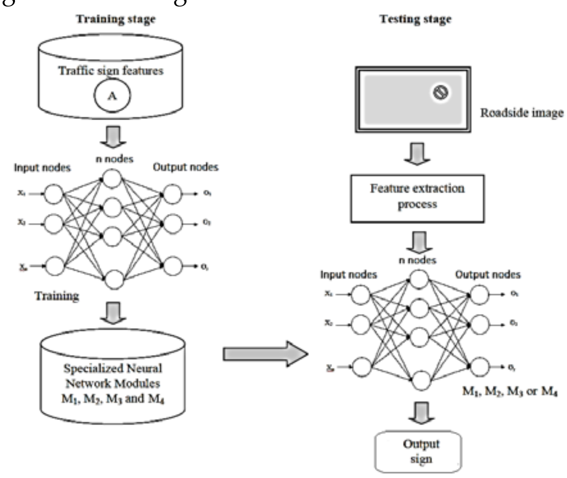

Fig. 12 Overview of training and testing stage of the neural network modules

6 EXPERMINETAL RESULTS

The performance of the traffic sign detection system using the proposed method has been evaluated using several images. The results are depicted in Table 1.

TABLE I
PERFORMANCE OF PROPOSED METHOD

Traffic sign	No: of sign	Colour detected correct	Shape filtered correct	Correct classified	False classified
Warning	15	15	14	13	2
Compulsory	24	24	22	21	3
Regulatory	5	5	5	5	0
Informative	11	11	10	10	1
Efficiency		100%	94.72%	90.45%	9.55%

7 CONCLUSIONS AND FUTURE WORK

Traffic sign detection based on color and shape is presented in this work. YCbCr color space is used for color segmentation to overcome the illumination sensitive characteristic of RGB space. Template matching using Euclidean distance approach for correlation is used for the classification of sign based on shape. The color classification rate observed is 100 % with shape classification rate about 94 %. The correct recognition rate observed is about 90 %. It shows that YCbCr colour space & Template matching is quite efficient for detection. The recognition rate can be improved further by increasing training data. This pre-classification improves recognition rate. The detected sign classified can easily be an input to four neural networks trained for each class. Hence recognition phase is easier, faster and much more efficient than training a single network for the whole set of traffic sign.

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