Techniques for Traffic Sign Classification using Machine Learning- A Survey

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ABSTRACT
The Road Sign Recognition is a field of applied computer vision research concerned with the automatically detection and classification of traffic signs in traffic scene images. The aim of the present paper is to study various classification techniques that can be used to construct a system that recognizes road signs in images. The primary objective is to develop an algorithm, which will identify various types of road signs from static digital images in a reasonable time frame.
In the current paper, we will study various learning systems that are based on prior knowledge for classification. A road sign recognition system faces a classical problem of pattern recognition, meaning classifying between different road signs. On top of that, the location of the road sign in the picture is unknown. Once these obstacles are overcome, such system could be integrated in a Smart Driver System. A variety of MATLAB Image Processing Toolbox commands can be used to determine if a road sign is present in current image. Neural network or other classification techniques can be applied in order to classify the road signs. Finally, the relevant sign is highlighted and output to the screen. Some of the examples where this technique is used is Ford Focus, BMW-7 series, Mercedes-Benz E-class, Volkswagen, etc. car.
But still, identification of road signs invariantly with respect to various natural viewing conditions still remains a challenging task. This is so because color information is affected by varying illumination; Road signs are frequently occluded partially by other vehicles; many objects are present in traffic scenes which make the sign detection hard; road signs exist in hundreds of variants often different from legally defined standard; the algorithms must be suitable for the real-time implementation
The study consists of three parts: road sign detection, classification and GUI. The actual imaging processing including color space conversion, color-thresholding is applied to determine if a road sign is present. If present, the sign will be resized and classified. The data which obtained by neural network training is used to classify the road signs. GUI will be created for user to interactive with the algorithm. The system will have the potential to help in improving road safety.

General Terms
Pattern Recognition, Neural Network, Image Classification Techniques.

Keywords
Computer vision, road/traffic sign classification, ANN, SVM and KNN.

1. INTRODUCTION
In traffic environments, Traffic Sign Recognition (TSR) is used to regulate traffic signs, warn drivers, and command or prohibit certain actions. Fast real-time and robust automatic traffic sign detection and recognition can support and disburden the driver, and thus, significantly increase driving safety and comfort. An automated road-sign recognition system may play an important role in alerting drivers of road conditions making driving safer. Generally, traffic signs provide the driver with a variety of information for safe and efficient navigation. Automatic recognition of traffic signs is, therefore, important for automated intelligent driving vehicle or for driver assistance system [1]. However, identification of traffic signs with respect to various natural background viewing conditions still remains a challenging task. Traffic Sign Recognition - An automatic road sign recognition system should be able to first detect, and then identify a set of road signs from within images. Such a system should be able to analyze the road scene image captured by the camera, extract the road sign region and make intelligent decisions. In addition, it must appropriately alert the driver of the road sign ahead. Automated road sign recognition is a difficult task. There are a number of important issues that need to be taken into consideration. These include: illumination conditions, direction of sign's face, status of paint on signs, placement of multiple signs near each other, torn and tilted signs, variations in sign's scale, obstacles such as tree, image sensor's properties, car vibrations, etc. Systems usually have been developed into two specific phases [2, 4].

- *First phase*: it is normally related to the detection of traffic signs in an image using image processing.
- *Second phase*: it is related to recognition of those detected signs, which deals with the interest of performance in an artificial neural network.

The efficiency and speed of the detection play important roles in the system. To recognize traffic signs, various methods for automatic traffic sign identification have been developed and shown promising results. Neural Networks precisely represents a technology used in traffic sign recognition.

1.1 Detection Phase
In the detection phase, the acquisition image is preprocessed, enhanced, and segmented according to the sign properties of color and shape. The traffic sign images are investigated to detect potential pixel regions which could be recognized as possible road signs from the complex background. The potential objects are then normalized to a specified size, and input to recognition phase. The detection algorithms are normally based on shape or color segmentation. Therefore we can say that road sign detection and identification methods can be classified into two main groups: Colour-based, and Shape-based.

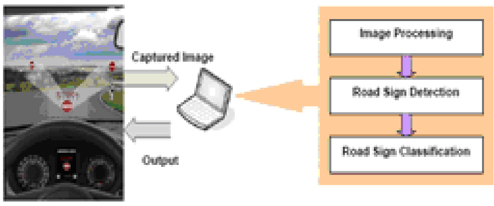

Fig.1: Working of System

1.1.1 Color Based Detection

Most existing road sign recognition systems include colour segmentation process that extracts out the colour road sign objects from the background for recognition. The colours used in road signs are often simple primary colours. Several techniques on colour-based recognition such as HSI/HSV Transformation, Region Growing, ColourThresholding Segmentation, Dynamic Pixel Aggregation, and etc. have been developed.

- *Color Neural network:* Neural networks can be trained to group and recognize patterns of colors. NN technique is discussed in the section 3.1.
- *HSI / HSV transformation:* The image captured by camera is represented by its RGB (Red Green Blue) value, and HSI value can be obtained after transformation. In HSI color space, chromatic information is represented by the hue coordinate, and intensity coordinate captures varying light conditions. Also, HSI color space is very similar to human perception of colors.This algorithm makes segmentation in adversely illuminated road sign boards possible because hue value is invariant for the illumination.
- *Color Thresholding Segmentation:* This is one of the earliest techniques used for image segmentation [3]. The purpose of thresholding is to classify pixels of an image into 'object pixels' or 'background pixels'.

The main drawback of colour segmentation is the outdoor illumination which affects the colour acquired by the imaging sensor. Most colour-based techniques run into problems when the illumination source varies with both intensity and colour. This is the main reason why many researchers have tried to come up with algorithms for separating the incident illumination from the colour signal perceived by the imaging sensors.

1.1.2 Shape Based Detection

Detection by shape forms the second main group of road sign recognition techniques. Comparing to colour-based approaches, shape-based techniques would have to deal with imperfect shape problems and the sign appearance. Shape is an important attributes and its detection does not require color information. However the selection of an object recognition scheme for the detection of road signs based on their shape will have to address more issues than color, for example:

- Sign may appear in cluttered scenes.
- Imperfect shape.
- Variance in scale.
- Variation in size.

Shape detection [3] requires robust boundary detection or matching algorithm to detect the relevant shapes. Moreover even if the shape is identified, it can be confused with several other shapes of man-made objects such as commercial signs and building windows. Several techniques on shape-based recognition have been developed. These include: Distance Transform Matching, Hierarchical Spatial Feature Matchingetc. Shape detection techniques are more robust to changing illumination because they detect shapes using boundary information. Shape detection necessitates robust edge detection and/or matching algorithm to detect the relevant shapes. The common recognition approaches based on shape are:

- *Shape Neural Network:* Neural nets can be used to match a shape of an input object by using the threshold value. It is usually used in conjunction with Color Neural Network. Good results have been shown. It is more robust.
- *Template Matching:* All signs to be recognized are stored in a database. Each potential sign is normalized in size and compared to every template of the same shape by using normalized cross-correlations. With this encoding, a template is built for an object, and a correlation computation can be defined, which serves as a measure for computing matches between templates. The method is fast and can easily be modified to include new classes of signs.
- *Similarity Detection:* Signs shape detection is done by computing a similarity factor between a segmented region and set of binary image samples representing each road sign shape. The method assumes that both sample and segmented image have the same dimensions.
- *HSFM (Hierarchical Spatial Feature Matching):* It can be used to search scene image for the geometrical shapes, which may correspond to the road signs. In HSFM, local orientations of image edges and hierarchical templates are used for shape detection. The algorithm input is the traffic scene image and the output is a list of candidate regions. It uses Sobel processes to extract the edge information.

1.2 Recognition Methods

The first paper on the road sign recognition appeared in Japan in 1984. A growing number of solutions have been proposed for road sign detection since then. In general, those solutions include detection phase and classification phase.

- Detection subsystem is to search for corresponding road signs.
- Classification is to evaluate regions found by the detection subsystem.

Road signs are designed to offer their basic meaning by the combination of color and shape. There are broadly two major methods applied for road sign recognition as discussed abov i.e. color-based and shape-based.

2. IMAGE PROCESSING STAGES

Any image classification system goes through numerous phases including: data acquisition, preprocessing, feature extraction, classification and post-processing where the most crucial aspect is the preprocessing which is necessary to modify the data either to correct deficiencies in the data acquisition process due to limitations of the capturing device sensor, or to prepare the data for subsequent activities later in the description or classification stage. Data preprocessing [2] describes any type of processing performed on raw data to prepare it for another processing procedure. Hence, preprocessing is the preliminary step which transforms the data into a format that will be more easily and effectively processed. Therefore, the main task in preprocessing the captured data is to decrease the variation that causes a reduction in the recognition rate and increases the complexities. Thus, preprocessing is an essential stage prior to feature extraction

since it controls the suitability of the results for the successive stages.
After acquisition of image we perform Image Extraction and Sign Detection. The images that will be taken by a video camera will pass through the Image Extraction block .The Sign Detection and Extraction Stage extracts all the traffic signs contained in each image and generates the small images called Region of Interest (ROI). Each ROI will be valuable parameter input to Recognition Stage which is the final part. Image classification cannot be applied without the help of Image Processing and/or Artificial Intelligence.

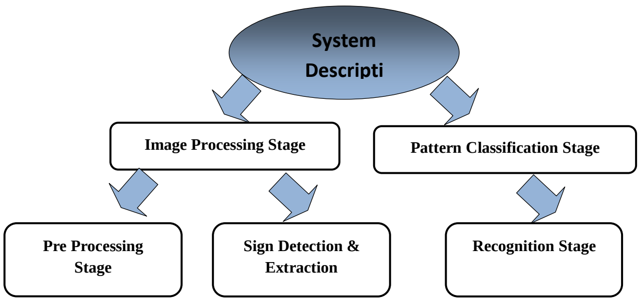

Fig. 2: Block diagram of the system description

2.1 Image Preprocessing

2.1.1 Smoothing and Filtering

Images are often degraded by noises. Noise can occur during image capture, transmission, etc. Noise removal [12] is an important task in image processing. Filters are required for removing noises before processing. They are of many kinds as linear smoothing filter, median filter, wiener filter and Fuzzy filter. Any mathematical operation directly on the image matrix is spatial filtering. Any of the two types may be used: Linear-spatial filters or Non-linear spatial filters.
Spatial filtering is the process of dividing image into its constituent spatial frequencies, and selectively altering certain spatial frequencies to emphasize some image features. This technique increases the analyst's ability to discriminate detail. Generally the types of spatial filters that may be used in image pre-processing are: Low pass filters and High pass filters.

2.1.2 Linear smoothing filters

One method to remove noise is by convolving the original image with a mask that represents a low-pass filter or smoothing operation. A smoothing filter sets each pixel to the average value, or a weighted average, of itself and its nearby neighbors; the Gaussian filter is just one possible set of weights. Smoothing filters tend to blur an image, because pixel intensity values that are significantly higher or lower than the surrounding neighborhood would "smear" across the area. Because of this blurring, linear filters are seldom used in practice for noise reduction; they are, however, often used as the basis for nonlinear noise reduction filters. Linear smoothing filters and Adaptive Filters are examples of linear-filters. Median filters and fuzzy filters are examples of Non-Linear filters.

2.1.3 Adaptive Filters

The wiener function applies a Wiener filter (a type of adaptive filter) to an image adaptively, tailoring itself to the local image variance. If the variance is large, wiener performs little smoothing. If it is small, wiener performs more smoothing. This approach often produces better results than linear filtering

2.1.4 Median filters

A median filter is an example of a non-linear filter and, if properly designed, is very good at preserving image detail. To run a median filter:
1. Consider each pixel in the image
2. Sort the neighboring pixels into order based upon their intensities
3. Replace the original value of the pixel with the median value from the list
Median filters are good at removing salt and pepper noise from an image and also cause relatively little blurring of edges, and hence are often used in computer vision applications

2.1.5 Fuzzy filters

Fuzzy filters provide promising result in image-processing tasks that cope with some drawbacks of classical filters. Sometimes, it is required to recover a heavily noise corrupted image where a lot of uncertainties are present and in this case fuzzy set theory is very useful. Each pixel in the image is represented by a membership function and different types of fuzzy rules that considers the neighborhood information or other information to eliminate filter removes the noise with blurry edges but fuzzy filters perform both the edge preservation and smoothing.

2.2 Feature Extraction

The recognition phase starts with feature extraction [7] representations of images. These features are usually corners and edges. Ideally all edges of objects and changes in color should be represented by a single line. The generalized form of edge detection is gradient approximation and thresholding.The boundary of an object is generally a change in image intensity. Using a first order gradient approximation changes in intensity will be highlighted, and areas of constant intensity will be ignored. To find changes in intensity we need to examine the difference between adjacent points. Standard edge and corner detection algorithms such as Sobel filtering and Canny edge detection can be applied to colour/gray images to generate binary feature maps.

2.2.1 SobelFiltering [10]

Most edge detection methods work by assuming that the edge occurs where there is a discontinuity in the intensity function or a very steep intensity gradient in the image. Using this assumption, if one takes the derivative of the intensity value across the image and find points where the derivative is maximum, then an edge could be located. The gradient is a vector, whose components measure how rapid pixel value is changing with distance in the x and y direction.Out of the many methods of detecting edges; different methods may be grouped into these two categories:
i. Gradient: The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image.
ii. Laplacian:The Laplacian method searches for zero crossings in the second derivative of the image to find edges.
The Sobel operator is an example of the gradient method. The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial gradient that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input greyscale image.

2.2.2 Canny Edge Detection

The Canny Edge detector (Canny, 1986) is currently the most popular technique for image processing. It is used in a wide range of applications with successful results.

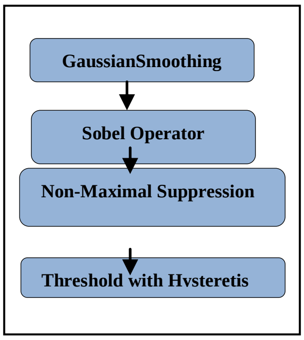

Fig. 3: Edge detection using Canny Algo.

It should satisfy the following 3 objectives:

1. Optimal detection with no spurious responses
2. Good localization with minimal distance between detected and true edge position
3. Single response to eliminate multiple responses to a single edge.

Optimal smoothing and Gaussian filtering was used for achieving the first aim. The second aim is for accuracy. Non-maximum suppression (peak detection) is used for this. It retains all the maximum pixels in a ridge of data resulting in a thin line of edge points. The third aim relates to locating single edge points in response to a change in brightness. This requires getting a first derivative normal to the edge, which should be maximum at the peak of the edge data where the gradient of the original image is sharpest. Calculating this normal is usually considered too difficult and the actual implementation of the edge detection is as in figure above.

3. TECHNIQUES OF IMAGE CLASSIFICATION

The main task of the detection module is to preprocess the input image and extract out the areas that contain road sign pattern. The detection module then forwards this ROI to the classification module for recognition. 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 belong to. Different techniques in image classification like Artificial Neural Networks (ANN), Support Vector Machines (SVM), Fuzzy measures, Genetic Algorithms (GA), Fuzzy support Vector Machines (FSVM) and Genetic Algorithms with Neural Networks are being developed for road sign recognition and classification.

The techniques [9] are as follows:

3.1 Artificial Neural Network (ANN)

ANN is a parallel distributed processor [8, 9] that has a natural tendency for storing experiential knowledge. They can provide suitable solutions for problems, which are generally characterized by non-linear ties, high dimensionality noisy, complex, imprecise, and imperfect or error prone sensor data, and lack of a clearly stated mathematical solution or algorithm. A key benefit of neural networks is that a model of the system can be built from the available data. Image classification using neural networks is done by texture feature extraction and then applying the back propagation algorithm.

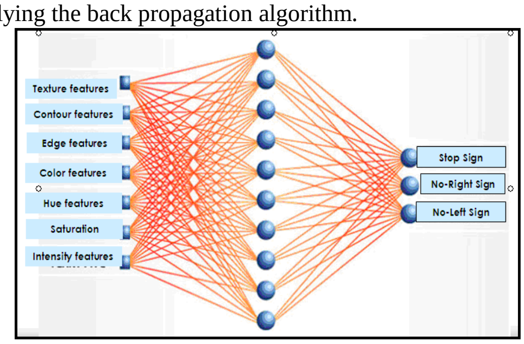

Fig 4: Schematic of a NN

Color is the most important and significant visual feature in road sign. The segmented potential regions are extracted as input in detection stage. Most existing road sign recognition systems include colour segmentation process that extracts out the colour road sign objects from the background for recognition. Neural networks are then trained to group and recognize patterns of colors. Color segmentation neural network can be used to reduce the color resolution of image from 65500 colors to a universal palette of eight colors. When used in classification, neural net can recognize traffic signs within a region of interest. Shape Neural network can be used to match a shape of an input object, threshold value can be used tell whether or not the shape matches. It is usually used in conjunction with Color Neural Network.

Figure 4 shows a schematic of a NN [4, 10, and 12] with the possible features that may be used to classify road signs.Input neurons take in the image's features & these properties are then used to train the network input signal propagates through the network in a forward direction, on a layer-by-layer basis. Work has been done using Multilayer-Perceptrons and Back propagation NN's.

3.2 K-Nearest Neighbor (K-NN)

K-NN [5] is the most straightforward and classic type of classification and machine learning algorithm. An object is classified by a majority vote of its neighbors. Object is assigned to the class most common amongst its k-nearest neighbors. When given an unknown sample, a k-nearest neighbor classifier searches the pattern space for the k training samples that are closest to the unknown sample."Closeness" is defined in terms of Euclidean distance, where the Euclidean distance, where the Euclidean distance between two points,

X=(x1, x2……., xn) and Y= (y1, y2,….,yn) is

$$d(X, Y)=\sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

An image in the test set is recognized by assigning to it the label of most of the closest points in the learning set.All images are then normalized to certain value. The image in thelearning set that best correlates with the test image is then the result. For the recognition process an adaptive approach a distance-weighted k-Nearest Neighbor classifier for traffic sign recognition may also be used. Let us look at the problem of classifying an object in R with its given attribute vector X. According to Baye's rule the object belongs to class Y if the probability of Y given X is a maximum:

$$P(Y \mid X) \approx P(X \mid Y)\, P(Y) \rightarrow \max$$

Where P(Y) is the prior probability of Y. Using p training objects whose attribute vectors are defined as codebook vectors we can estimate P(Y) by n_y/p, where n_y is the number of the training objects which belong to class Y. To estimate P(X | Y) we first select k neighbors of X among all codebook vectors and then use k_y / k as a approximation of P(X | Y), where By is the number of those selected neighbors which belong to class Y. This leads to the well-known k- Nearest Neighbor (k-NN) classification rule: assign to an unclassified object that class most heavily represented among its k- nearest neighbors in R_n.Training samples are used to compute the feature vector for each of the traffic sign class. The resulting point in multi-dimensional space represents the class's identity. A feature vector is an n-dimensional vector of numerical features of the image [Texture feature, Shape features, Edge features, HSI features etc.]

To determine a query traffic sign's correct match, a ROI is extracted using the Sign Detection & Extraction module. A feature vector of this ROI is then computed. Its difference from each traffic sign class will represent its feature similarity vector. The feature similarity vectors are then normalized and weighted, and their Euclidean distance is calculated in the high-dimensional space. The order of the resulting vector of class distances represents the order of similarity. The class with the lowest reported distance is the class that will be identified as the likely recognized traffic sign. Thus we can say that classification is done by comparing feature vectors of different points.

3.3 Support Vector Machine (SVM)

SVM's [13, 14] are a relatively new machine-learning tool and have emerged as a powerful technique for learningfrom data and in particular for solving binary classification problems.SVM supports both regression and classification tasks and can handle multiple continuous and categorical variables.

Even though SVM is considered easier to use than Neural Networks, users that are not familiar with it will often get unsatisfactory results at first. A classification task usually involves separating data into training and testing sets. Each instance in the training set contains one target value" (i.e. the class labels) and several attributes" (i.e. the features or observed variables). The goal of SVM is to produce a model (based on the training data) which predicts the target values of the test data given only the test data attributes.In SVM, the aim is to find an optimal separatinghyper plane (OSH) between the two data sets.SVM finds the OSH by maximizing the margin between the classes. The main concepts of SVM are tofirst transform input data into a higher dimensional space by means of a kernel function and then construct anOSH between the two classes in the transformed space. Those data vectors nearest to the constructed line inthe transformed space are called the support vectors.

[13] discusses a method using Linear SVM. The first step in classification is to compute the feature vectors that go as the input to the linear SVM.Once the feature vectors for the candidate ROI are obtained, the shape classification process is initiated. SVM are based on the concept of decision planes that define decision boundaries. A decision plane is one that separates between a set of objects having different class memberships. It performs classification tasks by constructing hyper-planes in a multidimensional space that separates cases of different class labels. The paper [13] uses linear SVMs and recognizes the traffic signs based on shape classification.

3.4 Other Techniques

Principle Component analysis (PCA) [2] is used to orthogonalize the features so as to reduce the dimension of input vector of neural network,The PCA presents the information of original data as the linear combination of certain linear irrelevant variables. Mathematically, PCA transforms the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate, the second greatest variance on the second coordinate, and so on. Each coordinate is called a principal component. The authors of [2] discuss a feature extraction method for traffic sign recognition based on Two-Dimensional Principal Component Analysis (2-DPCA).

Based on the templates of road signs, Fang et al. [7] built two separate neural networks to extract relevant color and shape features of signs which were further integrated in a fuzzy way. This approach was reported to be accurate but computationally very intensive.Fuzzy measures show the detection of textures by analyzing the image by stochastic properties. The fundamental stochastic properties of the image are isolated by different kinds of stochastic methods, by non-linear filtering and by non-parametric methods. Fuzzy support vector machines (FSVM) was proposed to overcome the n-class problem in Support Vector Machines.[7]

3.5 Comparative Study of Techniques

We now try comparing the work done using various classification techniques like artificial neural networks, K-Nearest neighbor, support vector machines, fuzzy logic, and genetic algorithms with respect to several parameters. ANN is useful for classification and regression and more tolerant to noisy inputs. In ANN, over-fitting may result if too many attributes/ features are used. K-NN is based on the use of distance measures and is one of the simplest classification schemes. However, the k-NN rule doesn't take the fact that different neighbors may give different evidences into consideration. The objects which are close together (according to some appropriate metric) will belong to the same category and so to have a more robust classification , we might wish to weigh the evidence of a neighbor close to an unclassified object more heavily than the evidence of another neighbor which is at a greater distance from the unclassified object. A distance weighted k-NN classifier can be used to assign an unknown object to that class for which the weights of the representatives among the k nearest neighbors sum to the greatest value. SVM are based on the concept of decision planes that define decision boundaries and model non-linear class boundaries. SVM provide good generalization performance and over-fitting is unlikely to occur in SVM.Computational complexity and complexity of decision rule is reduced in SVM. However,work on traffic sign recognition based on SVM algorithm has been still few.

In Fuzzy measures different stochastic relationships can be identified to describe the properties of the image but prior knowledge is very important to obtain good results. Genetic algorithms [6] are primarily used in optimization and always have a good solution. But the computation of scoring function is non-trivial. Genetic Algorithms can be used in feature classification and feature selection and are efficient at searching within a complex search space.

4. APPLICATIONS and FUTURE SCOPE

Road sign provides meaningful information that can help driving in a manner that is safe for the driver and other road users. The information provided by the road signs is categorized into colors and shapes for easy identification. Most of road accidents are attributed to either reduced attention of drivers or that they simply choose to ignore the road signs. The weather condition like rain and sometimes heavy fog and dew, especially during early morning and late evening, also have been reported as being some of the causes of many accident cases. Therefore, the recognition of road signs will be a great help to reduce the number of traffic accidents and deaths. The development of road sign detection and recognition systems using image processing technology will ensure that each driver is aware of the rules and hazards on the road and will hopefully reduce the number of accidents and deaths.

The Road Sign Recognition project (RSR) is a field of applied computer vision research concerned with the automatically detection and classification of traffic signs in traffic scene images acquired from a moving car. The application of the system will be to help in improving road safety. The RSR can be the subsystem of Driver Support System (DSS). The aim is to provide DSS with the ability to understand its neighborhood environment and so permit advanced driver support such as collision prediction and avoidance. The application can also prove to be important to a robotic vehicle that automatically drives on roads.

Important future work to be done for present topic would be to work on a collection of large number of road sign images, expanding database, re-train the neuron network. This would also involve studying more robust techniques for detection of images which will recognize traffic signs during poor lighting conditions also. The system can be enhanced using cost-effective techniques, which would assist the driver in notifying the distance between the road sign and the current position of the car. Even the system can be expanded to detect and differentiate between in-animate and living objects for e.g. people crossing the roads.

5. CONCLUSION

Traffic sign recognition is a primary goal of almost all road environment understanding systems. A vision system for traffic sign recognition was developed by DAIMLER-BENZ research Center Ulm. The two main modules of the system are detection and verification (recognition). Here regions of possible traffic signs in color image sequence are first detected before each of them is verified and recognized. In this paper we have paid our attention onto the various verification and recognition methods/techniques.

During the detection process, each color image taken with a camera is first segmented into some regions according to the color-values of each pixel. After color-classification each region in a labeled image is checked whether it satisfies certain constraints on its size and color combinations with neighbor regions etc. and only if these constraints are satisfied the region can be marked as a region of interest (ROI) for the following recognition process. Now the task of the recognition process is to verify if a given ROI is really a traffic sign and to identify the pictographic symbol of the ROI if it was verified.

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