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Recognition Of Traffic Symbols Using K-Means And Shape Analysis

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Abstract

The traffic symbol recognition system plays an important role in recognition of traffic symbol.The proposed traffic symbol recognition system is based on color image segmentation with the integration of shape analysis. The presented system is robust, which is able to recognize traffic symbols with any color and any of the existing shapes (e.g., circular, rectangular, triangular, pentagonal, and octagonal) and is invariant to transformation (e.g., translation, scale and occlusion). The proposed system uses two different methods Peri2Area and boundary touching point for analyzing different shapes of the traffic symbol and the correlation coefficient pattern matching for the recognition of the traffic symbols. There are three main stages in the proposed algorithm: 1) segmentation by clustering the pixels based on the color features to find the regions of interest (ROIs); 2) traffic-sign detection by using two novel shape classiffication criteria, i.e., the relationship between area and perimeter and the boundary touching point 3) recognition of the traffic symbol using correlation coefficient to match the unknown symbols with the known reference traffic symbols stored in the database. The proposed framework provides a novel way to detect a traffic symbol by integrating image features with the geometric shape information. Experimental results on real-life images show a high success rate and a very low false hit rate..

Keywords- Clustering, boundary Point Touching (BPT), correlation coefficient, segmentation

1. Introduction

Traffic symbol detection and recognition is an essential task for regulating and guiding the traffic. The traffic symbols carry much useful information which aids to drive the vehicles in right direction and speed, provide information about the current state of the traffic. The system will also be helpful for maintaining the highways and avoiding the obstacles. Generally, traffic symbol detection and recognition is divided into three stages: symbol detection, classification and recognition. Detection stage is responsible for identifying region of interest (ROI) from the picture frame that is taken by a video camera mounted on top of a vehicle. ROI is the most likely part of the image that may contain traffic symbols. The second stage of automatic detection and recognition of traffic symbol system is the classification stage. In this stage each ROI is classified according to their shape and color. In the last recognition stage, individual traffic symbol is recognized from its class [1]

A. Challenges

Though it seems to be simple to detect and recognize traffic symbol from the captured images, there are many challenges that system has to take into account as the varying lighting conditions., blur occurred due to capturing the image from moving vehicle, displacement of the traffic symbols, multiple traffic symbols blocking each other, faded traffic symbols due to effect of whether elements, obstruction of traffic symbols by either natural or artificial elements like trees or street posters and the presence of objects having similar type of shape and color as traffic symbols[2].

2. Related Work

There are many approaches used by the system for detection and recognition of traffic symbols from the natural image. Mainly the system consists of detection phase and classification phase. The detection phase widely uses the segmentation technique for finding the

region of interest (ROI). The various approaches used for the image segmentation could be as follows.
a) Edge detection in gray level image and analysis.
b) Histogram thresholding with a given color space.
c) Feature extraction and clustering.

In the classification phase, the system analysis the regions obtained in the detection phase and identifies the traffic symbol. The common approaches for classification are

1) Neural Network
2) Nearest neighbour classification
3) Support vector machine
4) Genetic algorithm
5) Correlation based pattern matching

When working with the gray-level images, the search is mainly based on the shape and can be quite computationally expensive. For traffic symbol detection, several methods have been developed based on shape recognition. T. Ueta and Y. Sumi and N. Yabuki and S. Matsumae [3] used a self-organizing map (SOM) to extract a contour line and recognize the traffic symbol shape from it. R. Belaroussi and J. Tarel [4] proposed a geometric model of the image gradient orientation to detect triangular symbols. R. Marmo and L. Lombardi [5] used optical flow analysis to identify the rectangular symbols and then by searching gray-level discontinuity on the image and Hough transform for detection of Milepost symbols. Loy and Barnes [6] implemented an algorithm based on fast radial symmetry, where patterns of edge orientations are exploited to detect triangular, square, and octagonal traffic symbols. However, gradient based feature detection is, by nature, sensitive to noise, and many shape detectors are slow in computing over large images. Color images are more complex than gray scale images as instead of a single intensity value for a pixel, each pixel is usually denoted by three component values as red, green and blue. Clustering based methods are ideal to use for segmentation of color images.

Clustering algorithms can be either hierarchical or partitional. Hierarchical techniques involve the clusters themselves being classified into groups, where the process is repeated at different levels to form a tree. Partitional techniques forms clusters by optimizing a clustering criterion, where the classes are mutually exclusive thus forming a partition of the data Statistical clustering is the most common form of clustering, which involves assigning each occurrence of a particular color to one particular cluster regardless of whether each pixel having the color are located near to each other spatially in the image, in which case these pixels would not form a valid segment from the visual point of view. C. Bahlmann and Y. Zhu and R. Visvanathan and M. Pellkofer and T. Koehler [7] detected symbols using a set of color-sensitive Haar wavelet features obtained from AdaBoost training and temporal information propagation. Classification was performed using Bayesian generative modeling with temporal hypothesis fusion. X. Baro and S. Escalera and J. Vitri and O. Pujol and P. Radeva [8] proposed a novel binary classifier through an evolutionary version of AdaBoost to avoid the limitations of the original boosted classifiers in terms of the dimensionality of the feature space. A. Ruta and Y. Li and X. Liu [9] used an image representation and discriminative feature selection method for traffic-symbol recognition. The classifiers based on the image features have a major drawback that, due to the exhaustive search over the feature set, the training time grows with respect to the number of features. Color-based symbol detection relies on color, whereas the grayscale method concentrates on the geometry/shape of the object. Recent works have used both color segmentation and shape recognition to improve the detection rates. First, candidate regions are selected using color features, and then, an edge based method is employed to the perimeter of the regions for the detection step. X. Chen and J. Yang and J. Zhang and A. Waibel [10] presented an approach to detect and recognize Chinese symbols and translated the recognized text into English. The technique embeds multi resolution and multi scale edge detection, adaptive searching, color analysis, and affine rectification in a hierarchical framework to handle text in different sizes, orientations, color distributions, and backgrounds. King Hann Lim, Li-Minn Ang, Kah Phooi Seng [11] discussed new hybrid technique for traffic sign detection. This system is combination of knowledge based analysis and radial basis function neural classifier (RBFNN). Firstly the traffic signs are detected from the natural image using color image segmentation technique. The extracted signs are then passed to the recognition system for classification. The recognition system consists of three stages: color histogram classification, shape classification and RBF neural classification. Unique color and shape of traffic signs are used to classify them into smaller subclass and then can be easily recognized using RBFNN. In this system traffic sign features are from the image using principle component analysis. Then the most discriminant features are obtained using the Fisher's Linear Discriminant (FLD). Siti Sarah Md Sallah, Fawnizu Azmadi Hussain, and Mohd Zuki Yusoff [12] proposed new method for road sign detection and recognition algorithm for an embedded application. The algorithm uses Hue Saturation Intensity (HSI) color space to segment and locate the region of interest (ROI) and determines the shape of the road sign(diamond, square, hexagonal and circular) in natural images. The shape is then used to classify road symbols in four categories i.e. warning, mandatory, prohibitory and informational signs. Here the characteristics of the shapes such as area and perimeter variables are used to identify the symbols in road signs. These variables are compared with the template library. Madhusudan Joshi, Mohan Jeet Singh and Saurabh Dalela [13] presented colored traffic detection using correlation techniques based on joint transform correlation (JTC). In this paper, author proposes the application of multichannel correlation for automatic colored traffic sign detection. Mohammad S. Alam and C. N. Wai [14] proposed the Fringe-Adjusted Joint Transform Correlation technique (FJTC). Fringe-Adjusted JTC is one that gives better correlation performance than JTC for target detection. In FJTC, the joint power spectrum (JPS) is multiplied by the filter called Fringe-adjusted filter (FAF) before applying the IFT. Vavili Andrey and Kang Hyun Jo [15] proposed the detection and recognition algorithm for road signs of different category. As color and shape of traffic symbol provides vital information, they used the RGB color space to detect the symbol. Again to fight with changing conditions due to lighting and weather such as dark illumination, rainy and foggy weather, two restriction rules are used. First rule is bounding constraints for each color component which provides good detection result in images in good lighting condition. Second rule is using normalized color information and allows sign detection in dark images. Shape of information sign is different from the shape of warning and restricting sign. So the recognition process used here depends upon the shape of sign. Sign candidate is extracted from image and classified it as circle or triangle using background shape histograms. Then inner part of the mask is converted into binary mask and template matching algorithm is used for final recognition. Particularly in this paper, author tries to find out the inner meaningful part with the help of template matching. Auranuch Lorsakul and Suthakurn [16] proposesd Traffic Sign Recognition (TSR) in which first images are pre-processed with several image processing techniques such as threshold techniques, Gaussian filter, canny edge detection and then neural network is used to recognize the traffic sign patterns. Jung Chieh Hsien, Yi-Sheng Liou and Shu Yuan Chen [17] proposed a novel road sign detection and recognition method. In this projection technique is used to determine the position of the road sign in image. Then the Hidden Markov model is used to match the detected road sign with the image in the database. In this color images in RGB color space are first converted into HSV color space and then quantized into specific colors. The vertical and horizontal projections of whole images in the specific colors existing in road sign are used to detect the positions of the road signs. The recognition stage uses only the local features around the detected positions. The horizontal and vertical projections of the background in the local area are used to remove irrelevant road signs. The candidate road signs are then sorted using Hidden Markov model. The one with the first rank is considered as the recognition result. X. W. Gao and L. Podladchikova and D. Shaposhnikov and K. Hong and N. Shevtsova [18] used new approach for segmenting traffic signs from the image using the CIECAM, a standard color appearance model. Color is the most dominant features in retrieving the road symbols from the natural image. Due to change of whether conditions, such as sunny, cloudy and rainy, the color of the traffic may appear different. The color spaces such as HIS, RGB, L*a*b* are normally limited to only one lighting conditions. But the CIECAM color appearance model outperforms in other color space in all conditions. Tang Jin, Liang Xiong, Xie Bin, Chen Fangyan [19] proposed a method which combines color and shape to detect the traffic symbol. In this Hue and saturation are used to detect the red color of the sign. Circles are detected through the improved round-degree method. An improved Kalman filter is used to track multiple targets in the next frames. For recognition of traffic symbol, the feature extraction method based on the two dimensional Principal Component Analysis (2DPCA) is proposed. Miguel Angel Garcia -Garrido, Miguel Angel Sotelo and Ernesto Martin -Gorostiza [20] proposed a system which consists of three stages: first, detection using Hough transforms to get the information about edges of the image; second classification using neural network and final stage is tacking which uses the Kalman filter. Y. Nguwi and A. Kouzani [21] proposed a system which consists of two modules: detection and classification. The detection module segments the image using HIS color space and locates the traffic symbol. The classification module determines the type of detected traffic symbol using a series of one to one architectural multi layer perceptron neural networks. Hua Huang, Chao Chen, Yulan Jia, and Shuming Tang [22] proposed two stage automatic detection and recognition algorithm. In first stage, color segmentation and Hough transform are used for ROI detection. Considering the difference between the actual road symbol and the standard road symbols, the pictograph on road symbols is extracted for recognition. Adaptive Hausdorff distance based on similarity weighting is used in recognition stage. Ian Sebanja, D. B. Megherbi proposesd [23] a multi-layered hierarchical scheme containing three phases. Traffic symbol color segmentation, shape recognition and classification. The system is robust and invariant to rotation, scaling and image translation. The traffic symbol shape detection and traffic symbol recognition and classification are both based on principal component analysis (PCA). Jitendra N. Chourasia, Preet Bajaj [24] proposed an algorithm that uses the YCbCr color space for color image segmentation. The extraction and detection of traffic symbol is using color of the traffic symbol. The sign is extracted by considering the maximum distance of the pixels from centroid. The minimum Euclidean distance classifier is used to detect the shape of the symbol. Perceptron neural network is used to recognize the traffic symbol. Woong-Jae Won, Sungmoon Jeong, and Minho Lee [25] proposed new pre-processing method for detecting traffic symbol based on visual salience map model. As the traffic symbols have dominant color contrast against environment, color information with center surround difference normalization is used as an input feature extraction to reduce the noise influence as well as intensify the color characteristics. Edge feature map is used to reflect the shape characteristics of traffic symbol. The weighted sum of color feature map and edge feature map finally constructs traffic symbol saliency map. Fei Qin, Bin Fang, Hengjun Zhao [26] proposed the system that detects candidate regions as maximally stable external regions (MSERs), which offers robustness to the various lightning conditions. Recognition is based on cascade of support vector machine (SVM) classifiers that were trained using histogram oriented gradient (HOG) features. Xiaoguang Hu, Xinyan Zhu, Hui Li and Deren Li [27] proposed a new two stage method. Firstly, two way integration method including both methods drived by task and methods drived by data is used for segmentation, which improves accuracy of detection. And then edge extraction and morphological operations are used to obtain enclosed area. The shape of enclosed area is determined by the circularity and central double cross shape measurement in order to detect the prohibition signs.

Our proposed traffic symbol detection and recognition algorithm consist of three phases : i) detection ii) classifaction and iii) recognition. Detection phase consist of image segmentation using k-means clustering along with De-correlation streatching.Classification phase consist of shape analysis process and recognition phase consist of 2-D correlation for pattern matching.

3. Proposed System

The flowchart of the proposed traffic symbol detection and recognition system which is presented in this paper is illustrated in fig .1.

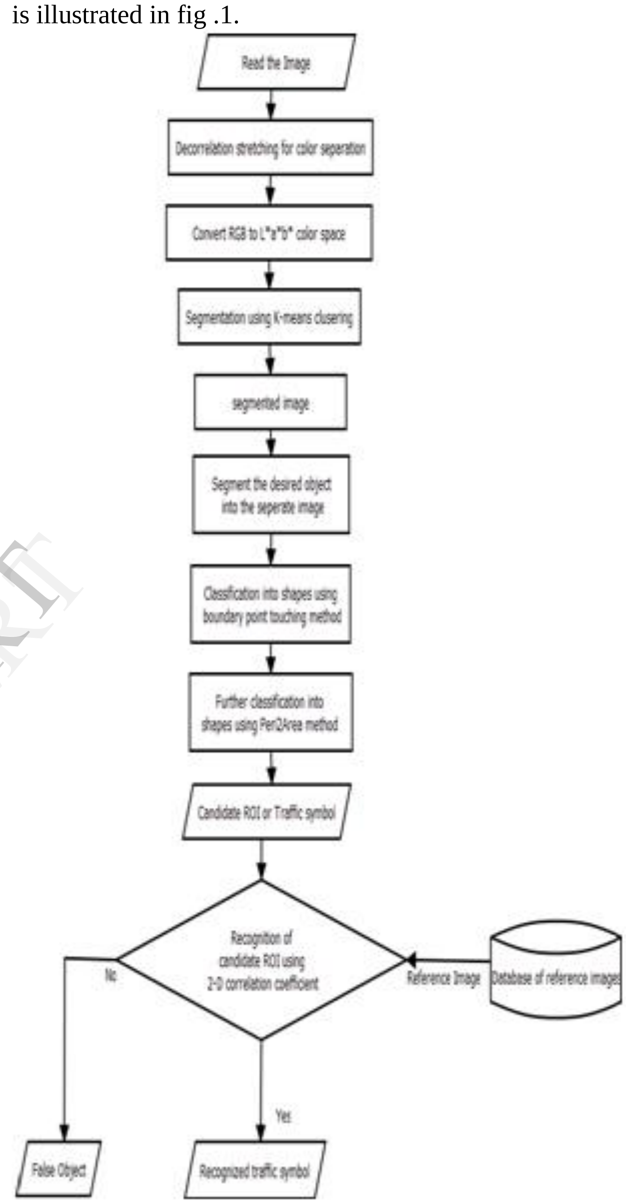

Fig. 1 Flowchart of proposed system

The traffic symbol detection and recognition system detects the traffic symbol using the color feature and the geometric shape analysis. The detection phase is initiated by performing De-correlation stratching which enhances the color separation of an image with ban to band correlation and segmentation of the image on color feature using k-means clustering. The segmented

regions are then verified using the possible feature of the traffic symbol such as maximum and minimum size limit and aspect ratio in order to discard the non traffic symbols and filter the highly possible traffic symbols. Afterwards the geometric shape classification process is carried out to classify the traffic symbols in different shape categories and discard the traffic symbol which doesn't fit themselves into any of the given shape.
Finally, the recognition of the detected traffic symbol is carried out using 2D- correlation technique which finds the correlation between reference image and target image. And the target image having the maximum correlation with reference image is recognized known traffic symbol.

4. Segmentation

Segmentation of the image is done based on color features with unsupervised K-means clustering method.

A) De-Correlation Stretching

De-correlation stretching is used for enhancing the color separation of an image with band-to-band correlation. These color separations improvise the visual interpretation and makes the color feature more discriminating. The numbers of color bands used in the image are three. The color intensity of the pixel are transformed into the color eigenspace of the band by band correlation matrix, stretched to equalize the band variances and then are transformed back to original color bands.

B) Color Space Selection

While segmenting the image, it is important to do the color space selection as the cluster distribution depends on the color space. Normally, the color image is expressed in the RGB color space but it is not a perceptually uniform color space. The L*a*b color space, adopted as an international standard in the 1970 , provides perceptually uniform color space. It means that the Euclidean distance between two color points in CIELAB color space corresponds to perceptual difference between two colors by the human vision system. That's what we are using L*a*b color space. This can independently control color and intensity information. The L*a*b space consists of a luminosity layer L* a chromaticity layer a* indicating where color falls along the red-green axis, and a chromaticity layer b* indicating where the color falls along the blue-yellow axis. All of the color information is in the a* and b* layers, so that the color features are extracted from the a* and b* components. We consider the local energy content of the a* and b* components as features for image segmentation.

C) K-Means Clustering

.K-Means clustering along with L*a*b* color space is used for image segmentation in unsupervised fashion. The k-means clustering is one of the simplest clustering techniques, for which the objective is to find the partition of the data which minimizes the squared error or the sum of squared distances between all points and their respective cluster centers. This procedure consists of following steps as described below

1) Read the frame in a JPG format from the video captured by the camera.
2) Use de-correlation technique for color separation of an image.
3) Convert the image into L*a*b* color space.
4) Specify the number of clusters and the criteria to define how close two objects are to each other.
5) Label all pixels in the image with the cluster index.
6) Using pixel labels, separate the objects in images by color. It will result in five images.
7) Determine the index of the cluster containing the desired object

5. Shape Classification

The traffic-symbol has perfect shape and color. The shape of traffic-symbol can be classified as circular, rectangular, triangular, square, diamond, pentagonal, and octagonal. In this stage, two shape recognition methods are used combinly for detecting the region of interest and false positive. The first method used is boundary touching point method and second method is Peri2Area.

A) Boundary Point Touching

In this method, the boundary points on the region of interest (ROI) which are touching or close to the eight different points means vertex and the center of each edge on bounding box are obtained. For circular and diamond shape, there are four points that will touch the bounding box edges at the middle.

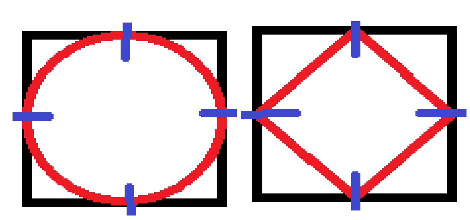

Fig. 2 Circular and Diamond shape detection

For triangular shape, there are also four points which will touch the bounding box i.e. midpoint of the top edge of bounding box and corner and midpoint of bottom edge of bounding box. If the triangle is reverse, then it will touch the midpoint of bottom edge of bounding box and corner and midpoint of the top edge of the bounding box.

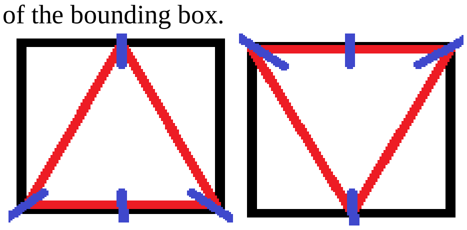

Fig. 3 Triangular shape detection

For rectangular and square shape, there are eight points which will touch the bounding box i.e. the midpoints of all edges and all vertex of the bounding box.

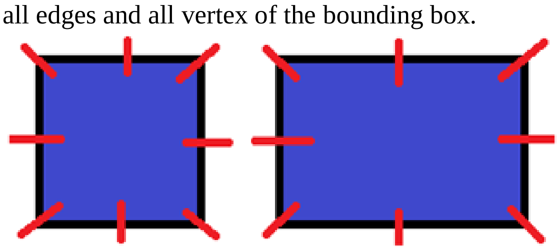

Fig. 4 Square and Rectangular shape detection

So in this way, we can easily recognize different shapes and can easily remove the false regions.

But there is still ambiguity in differentiating some shape such as circle and diamond, square and rectangle. So the regions showing such ambiguity are passed to second stage of verification. In this stage, Peri2Area parameter is calculated for each shape. Any particular shape has a unique value of the parameter Perimeter2/Area, which is a constant for that shape. This parameter is named Peri2Area. Both these features have the inherent characteristic of being independent of translation, scaling, and 2-D rotation of an image and would not only help identify the correct shape but also help reject the false objects (for example, cars and buildings) that are still present in the segmented image as candidate ROIs.

B) Peri2Area

Peri2Area of a candidate ROI, the total number of pixels in a blob is accounted as the area of that blob, and the sum of the distances between adjacent pixels in the boundary of the blob is accounted as the perimeter. The decision boundaries for shape classification based on the values of Peri2Area are determined by employing linear interpolation on the precise values of Peri2Area for different shapes. The value of Peri2Area for different shapes is as follows.

6. 2-D Correlation Coefficient Technique

Correlation is a method for establishing the degree of probability that a linear relationship exists between two measured quantities. Pearson's correlation coefficient, r, is widely used in statistical analysis, pattern recognition, and image processing. For monochrome digital images, the pearson' s coefficient is defined as

$$r = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mn} - \bar{A})^2)(\sum_m \sum_n (B_{mn} - \bar{B})^2)}} \qquad (1)$$

Where A_{mn} and B_{mn} are the intensity values of the pixel in target and reference image respectively.

Also $\bar{A}$ and $\bar{B}$ are the mean intensity values of target and reference images respectively.

In this method, we will use the correlation function which computes the correlation coefficient between the A and B. where the A and B are target and reference images of same size. The correlation function returns the value r which is scalar double.

Ideally the correlation coefficient has the value r=1 if two images are absolutely identical, r=0 if they are completely uncorrelated and r=-1 if they are completely anticorrelated. In theory, we would obtain an r value of 1 if the images are perfectly same and a value less than 1 if alteration or movement has occurred. In practice, due to distortion, noise present and slightly variation in the target image, an r value is less than 1.

One of the advantages of Pearson's correlation coefficient is that it condenses the comparison of two 2D images down to a single scalar, r. Additionally, the correlation coefficient is completely invariant to linear transformation of A and B. As a result, r is insensitive (within limits) to uniform variations in brightness or contrast across an image.

In recognition stage, the correlation between the target image and the reference images from the database is computed. The reference image having highest correlation with the target image is identified as the recognized traffic symbol.

7. Experimental Results

The traffic symbol recognition system must be accurate and fast enough to recognize the traffic symbol in order to avoid the upcoming hazards. So to evaluate the performance of the proposed system, large number of images tested.

The collection of test and reference image mostly obtained from the Google image. Fig.5 shows the representative sample of these images. The segmentation, detection and recognition results obtained from the proposed method are shown in Fig. 5

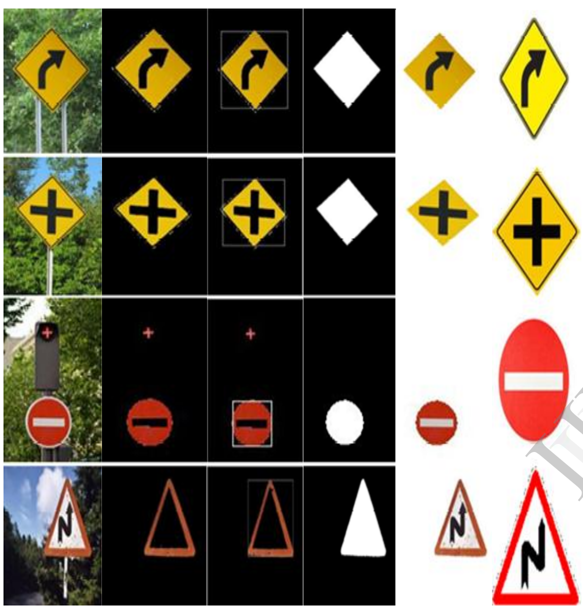

Fig. 5 (a) Original image (b) Segmented image using proposed algorithm (c) Detected object in the image (d) Binary image (e) Cropped desired object from the original image (f) Recognized traffic symbol from the database

The detection of candidate ROI using method in [1] is shown in Fig. 6

In this method Circular Gabor filter is used for obtaining the discriminate features and then k-means clustering method is used to obtain the candidate ROI. Circular Gabor filter is computationally heavy. But in the proposed method, the entire process of segmentation is divided into two stages. In first stage, the enhancement of color separation of the image using decorrelation stretching is carried out and then in the second stage, the regions are grouped into a set of five classes using K-means clustering algorithm. Using this two step process, it is possible to reduce the computational cost by avoiding the feature calculation for every pixel in the image.

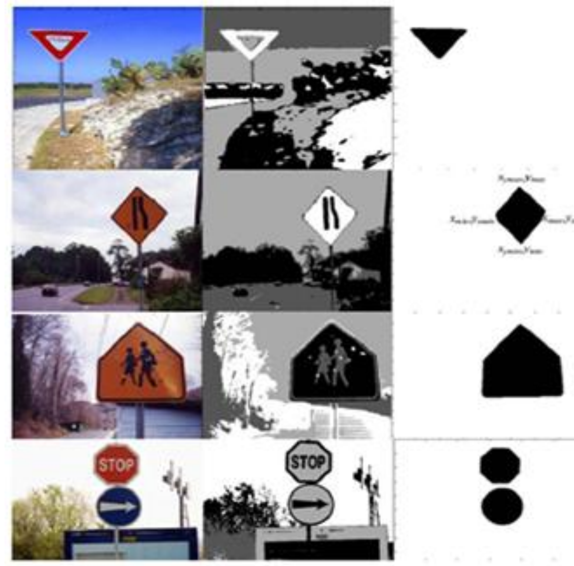

Fig. 6 Detection of candidate ROI using the method in [1]

Table I
Results of Traffic Symbol Classification

Shape	Test	Pass	Fail
Diamond	26	23	3
Triangle	26	24	2
Circular	26	24	2
Square	11	9	2
Rectangle	11	9	2
TOTAL	100	89	11

In classification stage, Peri2Area and boundary touching method in together show the better results of recognition of shape of candidate ROI as shown in Table I. This shape recognition stage considerably reduces the time required in final stage of recognition of the traffic symbol.

Table II
Results of Final Recognition Stage

Total number of images	90
Total number of signs	100
Number of different traffic signs	34
Detection of traffic signs	81
False detection	13
Number of misses	6

To evaluate the performance of the proposed traffic symbol recognition system, the images containing the traffic symbol taken in different lighting conditions are tested. Table II show the results obtained from the final stage of the traffic symbol recognition system. The numbers of image tested on the proposed system are 90 which contains total of 100 traffic symbol of 34 different types of signs. Out of which 81 traffic symbols are recognized correctly, 13 traffic symbols are detected incorrectly and 6 of the traffic symbol are missed by the system.

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