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Indian Traffic Sign Detection and Recognition

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Abstract
Traffic Sign Recognition system is a very significant part of the Intelligent Transportation System, as traffic signs assist the drivers to drive more carefully and professionally. The main aim of this work is to present an efficient approach for detection and recognition of Indian traffic signs. Information regarding color and geometrical shape of traffic signs are utilized by the system for localizing the traffic sign in the acquired image. An RGB color saliency attention model of traffic sign makes use of an algorithm, which discriminates the sign candidate from other objects. Morphological shape filter is exploited for extracting the geometrical information of the traffic sign. Nearest neighbor matching-based recognition is performed between localized candidate features and stored Indian traffic sign database (ITSD) features. Speed up robust features (SURF) of a traffic sign is used in nearest neighbor matching to find out the resemblance between the traffic signs. System robustness is cross-examined for illumination, scale, rotation variations, similar color and shape variations, a standard data set is also considered to evaluate the system performance. The simulation results illustrate that the proposed system is working effectively under various hazardous condition.

Keywords Vision system · Traffic sign detection · Traffic sign recognition · Speed up robust feature

1 Introduction

Traffic sign detection and recognition have been receiving attention in recent years. It is even considered as one of the most important tasks for the intelligent vehicle. Traffic sign detection and recognition play an important role for advanced driver assistant system [1] as well as autonomous driving vehicles [2]. Traffic signs are placed beside the road to accomplish many roles such as; Information about the road condition ahead, instruction to be followed at the major cross roads, and guides the drivers to ensure proper functioning of road traffic [3]. General approach for traffic sign detection system deals with detection and recognition [4]. Furthermore, it is expected from a traffic sign detection model that it must have advanced knowledge on the region of interest [5]. According to the generated model and wide information present in a road scene, the developed model should be able to sense the region of attention. Practically while analyzing the acquired image in real time; it is difficult to identify the region of interest in advance which forms to be the limitation of the system [6].

Automatic traffic sign detection and recognition have been the subject of many studies [7], although reference to them has appeared since 1990 [8, 9]. Traffic signs have unique shape and color that distinguishes them from surroundings. This information can be utilized for detection and recognition [9]. Numerous segmentation techniques have been accounted in the literature since the arrival of digital image processing. The majority of the detection system makes use of color information as a method of segmenting the image [10–14]. Traffic signs might be recognized in different ways due to many impacts such as illumination variations, scale variation, motion blur, geometric distortions, weather conditions, and complex background. Problems discussed above affect the segmentation which is the fundamental step in high-level detection and recognition of traffic signs. Various color model such as Hue Saturation Value (HSV) [15, 16], YUV [17] and International Commission on Illumination Color Appearance Model (CIECAM97) [18] have been used to overcome the illumination variation problems. Combined model of HSV [15] and YUV [17] are used by [18] to segment the red road sign. Many of researchers worked towards depicting the disproportion in detection as they used only shape information of grey scale images and entirely ignore the color information [19, 20]. Shape based method utilizes the edge information of the image for detecting the traffic sign shape. However, the shape-

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based detections are of high computation cost process as the detection rate of processing depends on the quantity of extracted edges. Vitabi et al. [15] used the summation of pixels to know the geometric form of the sign while Hechri et al. [21] used template matching based traffic sign detection. Hough transform is used in [22] to detect the edges and select the contour which has resemblance with traffic signs. Miruta et al. [22] used applied Hough transform for circular shape of traffic sign signals. Shape based detection system detects false traffic sign candidate for any similar candidate at the road. To overcome this, color information is necessary for discriminating between the similarly shaped objects. Some researchers focused to develop feature based robust traffic sign detection method which can perform well under the various hazardous condition [23, 24]. Creusen et al. [25] elaborated the Histogram Oriented Gradient (HOG) descriptor to unify the color acquaintance using the CIELAB and Y C_b C_r color spaces, while Overett et al. [26] presented two variant formulations of HOG features for the detection of speed signs in New Zealand. Some commercial traffic sign detection systems [27, 28] are also available in the market but they are useful for very limited set of signs such as system developed by [28] is able to detect only speed limit signs.

In order to raise the visibility of traffic sign for drivers, traffic signs with different designs of predefine colors, shapes, and patterns are fitted on roads. In general, the traffic signs across the world are mostly represented either on diamond shaped or triangular shaped sign boards. Apart from the shape, color is also an important parameter which differentiates the different countries traffic signs. These traffic signs provide information regarding rules to be followed, and instructions to the commuter for proper functioning of road traffic. Accordingly, Indian traffic signs are classified into three classes as per the information they provide. Mostly, Indian traffic sign has their geometrical shape as; triangular, circular, inverted triangular, octagonal and rectangular with red, blue and green colors. Many researchers [29–31] used these color and shape information to detect and recognize the Indian traffic sign. HSV color and kernel extreme learning machine-based model was proposed by devpriya et al. [29] to recognize Indian traffic sign. Simple color based detection causes fault detection due to similar color of objects present on the road. Combined information of color and shape is utilized by Huda Noor et al. [30] to detect the Indian traffic sign. Illumination variation causes a problem in vision-based detection system hence, [30] utilized Y Cb Cr color model to overcome illumination variation problems, while shape of the traffic sign is extracted with the help of template matching. In [29], kernel extreme learning based neural network is trained by utilizing the color, shape, statistical and textures features to recognized Indian traffic sign. While multilayer perceptrons based neural network is trained by [30] to recognize the Indian traffic sign.

In [31], RGB, Y Cb Cr, and NTSC (National television system committee) color space model are used to segment and detect the traffic sign. Here instead of recognising the developed technique classifies the traffic sign in to three levels with the help of a neural network. In the first level of classification, the signal is classified as warning, compulsory, regulatory and informatory while in the second level of classification, the signals are classified as prohibitory and non-prohibitory. In the third level of classification, the signals are classified according to picture present in the traffic sign such as; human, vehicle, arrow and others. Classification process proposed in [31] may classify the signal in to various levels, yet it is unable to interpret the correct meaning of individual Indian traffic sign. There are many traffic signs which have different meaning but they are classified in to same class if a system adopts classification technique proposed in [31]. Neural network-based recognition needs high computational training time and training data making it unsuitable for real time processing.

Traffic sign has unique color and shape information which are very adaptable features for localizing the traffic sign in an acquired image. There is still a problem to detect the color and shape of a sign due to variation in environmental condition such as illumination, weather conditions, and viewing angle. So, it is important that the inbuilt color model and shape model for traffic sign detection should be robust, even if it faces environmental variations. From this perspective, proposed work adapted a visual saliency enhanced model [29] for detecting the Indian traffic sign in acquired image. In this research, visually enhanced color information and shape information is combined to localize the traffic sign. Features used by [29–31] for recognition purpose are not suitable for dynamic nature of traffic sign in acquired image. Traffic signs which are present in the acquired image change its scale, view angle, and position in every frame. To solve this issue, vision-based traffic sign recognition should be invariant for all these changes to enhance the accuracy of the system. Therefore, in this work, SURF features [32] are adapted for recognition purpose. The SURF features are observed to be scale, translation and rotation invariant making them best suitable for traffic sign recognition. Neural network-based recognition required high processing time and training data, while simple nearest neighbor based matching does not require any training time. In this work, nearest neighbour-based matching is performed. System performance is evaluted on various number of images under diffferent light condition. System robustness is also evaluted for scaling, translation, rotation and illumination variation problems. A standard data is also adapted to evaluate the generalization of the system. Results depicted that the traffic recognition accuracy is good. To illustrate the significance of the proposed method over available method this work is compared with the recognition accuracy in literature.

Further sections of the paper are arranged as: Section 2 provides information about the Indian traffic sign such as color, shape, and category according to the information they provide. Detail description of approaches used in detection and recognition described in Section 3. Simulation results are discussed in Section 4 and finally work is concluded in Section 5.

2 Indian Traffic Sign Data

Each traffic sign gives some information, and according to the information they provide, Indian traffic sign may be classified in to three classes [33] such as mandatory, cautionary and informatory. Most of the traffic signs have red, blue and yellow color, while most of the traffic signs have triangular circular, inverted triangular, octagonal and rectangular shape. These shapes and color information are very beneficial for detecting the traffic sign in an acquired image. Table 1 gives some information about Indian traffic sign according to their shape and color. The Indian traffic signs were classified in to three classes, and its detail is given below.

2.1 Mandatory Traffic Sign

This class of traffic signs help in smooth traffic movement and ensures to road users that they understand the rules, regulations, and restrictions. If any driver disobeys to these laws, then they are subjected to offence. Some samples of mandatory signs are shown in Fig. 1.

2.2 Cautionary Traffic Sign

This traffic sign helps in alerting about the dangerous situation on the road in advance. Advanced knowledge of road conditions helps drivers to take an essential action and avoid the difficulties. Figure 2 shows samples of cautionary traffic signs.

2.3 Informatory Sign

This class of traffic sign guides the road users about their destination, distance from destination, path and an alternative path for their destination. It also tells about the significant location such that public toilets, hospitals, nearby parking, etc. informatory signs sample are depicted by Fig. 3.

Table 1 Traffic sign information based on color and shape

Color	Shape	Sign
Red	Triangle	Cautionary
Red	Circular	Mandatory
Red	Inverted Triangle	Give Way
Red	Octagon	Stop
Blue	Rectangle	Informatory
Blue	Circle	Mandatory

3 System Overview

Figure 4 depicts the flow diagram of simulated work. Two main steps detection and recognition are adapted for this operation. In detection process, the system detects the traffic sign in acquired image and makes an annotation as region of interest for further processing. Recognition step performs matching between detected candidate features and traffic sign data base features. Input of recognition system is an annotated region image while output is the annotated image resembling pair with data base. Description of steps adapted for implementing the work is given as follow:

3.1 Traffic Sign Detection

In traffic sign detection, the system extracts the traffic sign location in an acquired image. Localizing the region of interest in an image involves many processing steps such as pre- processing, color analysis, shape analysis, etc. A detailed description of traffic sign detection implementation is given as:

3.1.1 Image Acquisition

Images are acquired using a high quality $\frac{1}{4}''$ CMOS sensor with resolution 1600×1200. Pixels information highly depends on light conditions; hence images are acquired under different light conditions to check the robustness of the system. 500 images are captured. Out of which, 300 images were captured in the day time while 200 images were captured at the night time. High resolution images need higher processing time, so the captured images are resized to 512×512 for further processing. Large image requires large memory as well as high processing time, so captured images reduced upto 50%. However, reducing image size below 50% certainly improves the speed but may cause loss of information which reduces the detection performance. Information of captured images is given in Table 2, and Fig. 5a–g show some sample of the acquired image. The class of the image is uint8 which represnts an unsigned integer 8 bit image where all the pixel information values are positive and in the range 0–255. JPEG image format is used in this work because of its universal adaptability with various devices and great for web use.

3.1.2 Pre-Processing

Mostly traffic sign detection system detects the false candidates due to illumination changes and environmental changes.

Fig. 1 Sample images of mandatory Indian traffic sign training data set

The purpose of pre-processing is to increase the detection rate for a traffic sign. In this work, combined information of color and shape is utilized for localizing the traffic sign. Color information is highly sensitive for illumination variation hence in pre-processing step the system tried to make this color information more robust. Various techniques for different color space model are described in [34] which help us to find the suitable candidate of a traffic sign. RGB color information is used by the proposed system to normalize the color in the pre-processing step. Figure 5a–g shows the sample of the acquired image and Fig. 6a–g shows the color normalized image of the acquired image.

Fig. 2 Sample images of cautionary Indian traffic sign training data set

Fig. 3 Sample images of informatory Indian traffic sign training data set

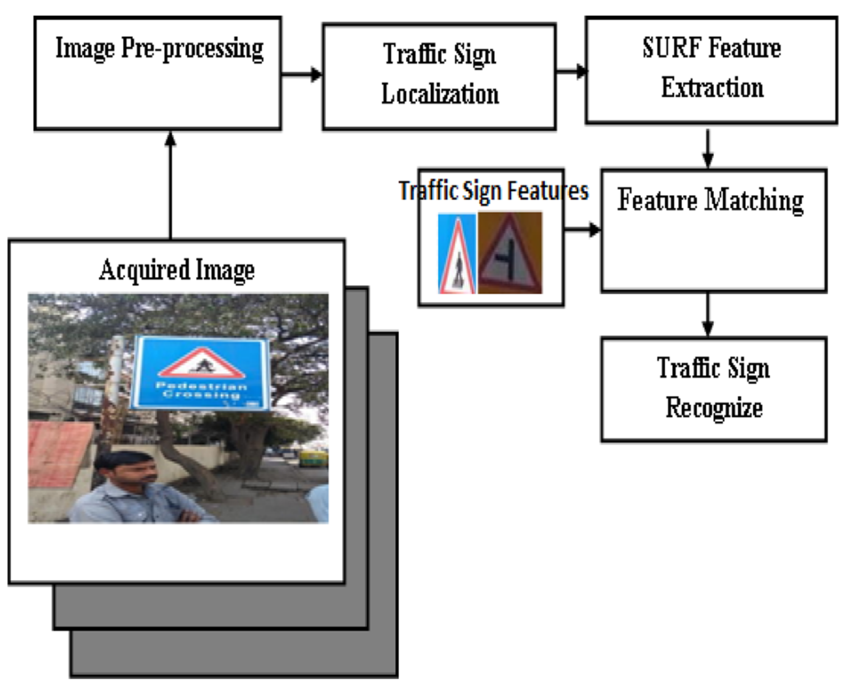


Fig. 4 Proposed traffic sign detection and recognition system

Table 2 Acquired sample images for processing

Sample Images / Information	Image captured during day time	Image captured during night time
		
No. of images in data set	300	200
Actual image size	1600 X 1200	1600 X 1200
Image resize	512 X 512	512 X 512
Class	Uint8	Uint8
Image file format	JPEG	JPEG

3.1.3 Color Analysis

In this step, traffic sign is extracted on the basis of its color information. A proper threshold value is chosen which extracts the traffic sign candidate information. In [35], color segmentation techniques are described in detail for each color of a traffic sign and suggest the threshold value for extracting the interested candidates. In this step, the input image is normalized RGB image while the output is a binary mask of the detected traffic sign. Eqs. 1, 2 and 3 show the segmented image for red, blue and yellow traffic sign candidate.

$$Red(i,j)=\begin{cases} True & if\ r(i,j)\geq Th_R \\ & and\ g(i,j)\leq Th_g \\ False & otherwise \end{cases} \tag{1}$$

$$Blue(i,j)=\begin{cases} True & if\ b(i,j)\geq Th_B \\ False & otherwise \end{cases} \tag{2}$$

$$Yellow(i,j)=\begin{cases} True & if\ r(i,j)+g(i,j)\geq Th_Y \\ False & otherwise \end{cases} \tag{3}$$

$$I_c(i,j)=I_{(Red,Blue,Yellow)} \tag{4}$$

Where Red(i,j) is red color segmented image. Blue(i,j) is blue color segmented image. Yellow(i,j) is yellow color segmented image. Ic(i,j) is a combined representation of the segmented color image for different colors. r(i,j) is normalized red plane. g(i,j) is normalized green plane. b(i,j) is normalized blue plane. Figure 7a–g shows the color based segmented traffic sign candidate.

3.1.4 Shape Analysis

Besides traffic candidates, Color based segmentation results also provide information about some more available candidates which have a similar color. Hence shape based information is extracted over the color based segmented result. A brief description of shape based traffic sign detection is given in [36]. Most of the Indian traffic signs are in triangular and circular shape hence for extracting the exactly suitable candidate the system uses this information. Various geometrical shapes can be detected with the help of morphological operation [35]. Therefore, these morphological shape filters are used for extracting the traffic sign. In this step, the input image is a contour image of an acquired road scene while the output is a binary mask which indicates similar shape to traffic signs. Equation 5, shows a segmented image after shape analysis.

$$I_s(i,j)=\begin{cases} True & if\ Th_{min}\leq I_{cn}(i,j)\leq Th_{max} \\ False & Otherwise \end{cases} \tag{5}$$

Where, I_s (i, j) is the segmented image after shape analysis. I_{cn} is detected contour image.

(a) (b) (c) (d) (e) (f) (g)

Fig. 5 **a**–**g** Original image sample under different light condition

(a) (b) (c) (d) (e) (f) (g)

Fig. 6 **a**–**g** Color normalized image

3.1.5 Traffic Sign Localization

In traffic sign localization, Traffic sign location is foundout by combining the shape and color information. Equation 6 depicts the mathematical expression for final traffic sign localized image.

$$I_{TR} = I_c(i,j) \cap I_s(i,j) \tag{6}$$

Where I_{TR} is localized traffic sign image. Figure 8a–g shown the final extracted traffic sign candidate.

3.2 Traffic Sign Recognition

After localizing the traffic sign in the acquired image, next processing step is to recognize the detected traffic sign. In recognition, the system identifies the matches between the detected candidate and traffic sign data base. Traffic sign information varies according to light variation, an image capturing device motion and scale variation. Hence the proposed system uses illumination invariant, translation invariant, rotation and scale invariant features which make the system more robust. In this work, SURF features based recognition is performed to identify the traffic sign. Surf features are extracted from the annotated region of an acquired image and match these features with extracted features of Indian traffic sign data (ITSD) base. Indian traffic sign data base description is given below. SURF algorithm is used due to its robustness and fast processing [37]. Figure 9 shows the traffic sign recognition work flow. SURF based traffic sign recognition is completed mainly in three steps such as key point detection, key point description and feature matching [38], description is given as:

3.2.1 Indian Traffic Sign Data

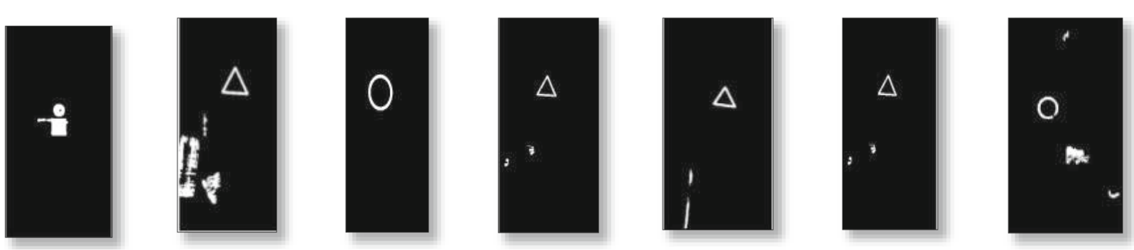
In the recognition process, Indian traffic sign data base is required for matching purpose. To prepare the real Indian traffic data, the traffic signs are manually cropped from captured images, and some traffic sign data are adapted from [33]. There are total 87 traffic signs in ITSD data base [33], out of it, 20 signs are for mandatory class, 34 signs for cautionary and 33 signs are for informative class. Table 3 is providing the information of Indian traffic sign.

3.2.2 Surf Feature Extraction

SURF features extraction consist of two steps, first is key point detection and then assign a descriptor to that key point. Detail description of key point detection and descriptor is given below.

Key Point Detection Key point detection detects relatable interest points in an image. In surf key point detection, SURF builds a pyramid of response map with a different level within an octave. Extrema is found in SURF pyramid which is a key point. In the spatial domain, a key point is selected among 8 neighbours while in spatial scale domain (SURF), extrema decide among 26 neighbours. The key point is the maxima among 8 neighbours in existing level and its 9 neighbours in below and 9 in the level above. Finding extrema is known as non-maximum suppression in a $3 \times 3 \times 3$ neighbourhood. Figure 10 depicts the process of finding the local extrema between level, octaves, and neighbourhood.

In SURF feature, key points find with the help of Hessian based blob detection technique. Hessian matrix determinant is



(a) (b) (c) (d) (e) (f) (g)

Fig. 7 **a**–**g** Detected traffic sign candidate after color analysis

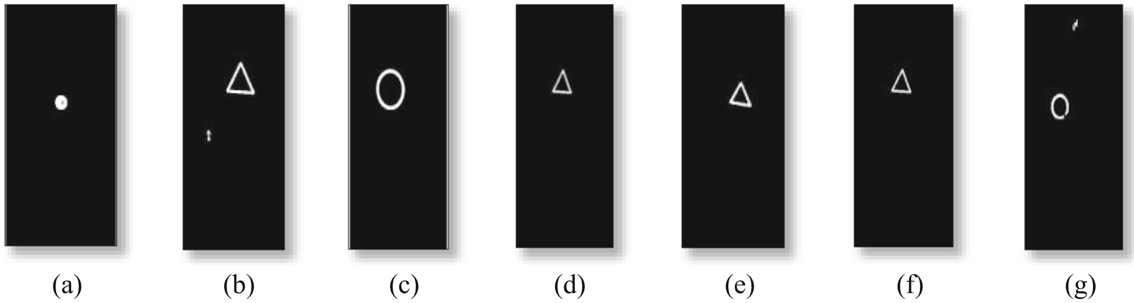


Fig. 8 **a**–**g** Detected traffic sign candidate after color and shape analysis

an expression of the local change around the area [37]. Equation 7 shows the mathematical expression of hessian matrix.

$$H(x,y) = \begin{bmatrix} L_{x,x}(x,\sigma) & L_{x,y}(x,\sigma) \\ L_{x,y}(x,\sigma) & L_{y,y}(x,\sigma) \end{bmatrix} \quad (7)$$

where

$$L_{x,x}(x,\sigma) = I_x \otimes \frac{d^2 g(\sigma)}{d\, x^2} \quad (8)$$

$$L_{y,y}(x,\sigma) = I_x \otimes \frac{d^2 g(\sigma)}{d\, y^2} \quad (9)$$

$$L_{x,y}(x,\sigma) = I_x \otimes \frac{d^2 g(\sigma)}{d\, x, y} \quad (10)$$

Where $L_{xx}(x,\sigma)$, $L_{yy}(x,\sigma)$ and $L_{xy}(x,\sigma)$ in Eq. 7 represents, the second derivative of Gaussian with respect to horizontal, vertical and combination of both. Convolution process takes high computing time. Therefore, SURF uses an integral image and approximated kernel for speeding up the process. Equation 11 shows the expression for integral of image.

$$I(x) = \sum_{i=0}^{i\le x} \sum_{j=0}^{j\le y} I(x,y) \quad (11)$$

The use of integral image allows, determining the value in a rectangular area with random size using 4 look-ups. The Gaussian kernels which are employed in the Hessian matrix have to descretized and cropped before applying them. These kernels are approximated with rectangular box filters.

In the image, a grey area proportional to 0 in the kernel where as white area corresponds to positive value while the black area represents the negative value. In this way, determine the approximated convolution efficiently for randomly sized kernel utilizing the integral image. Equation 12 depicts the determinant of hessian matrix with an approximated kernel.

$$Det(Hess) = D_{xx} \times D_{yy} - (W \times D_{xy})^2 \quad (12)$$

Where D_{xx}, D_{yy}, and D_{xy} are discrte kernels corresponding to $L_{xx}(x,\sigma)$, $L_{yy}(x,\sigma)$, and $L_{xy}(x,\sigma)$ respectively. The weight W

Fig. 9 Process flow diagram for trafffic sign recognition

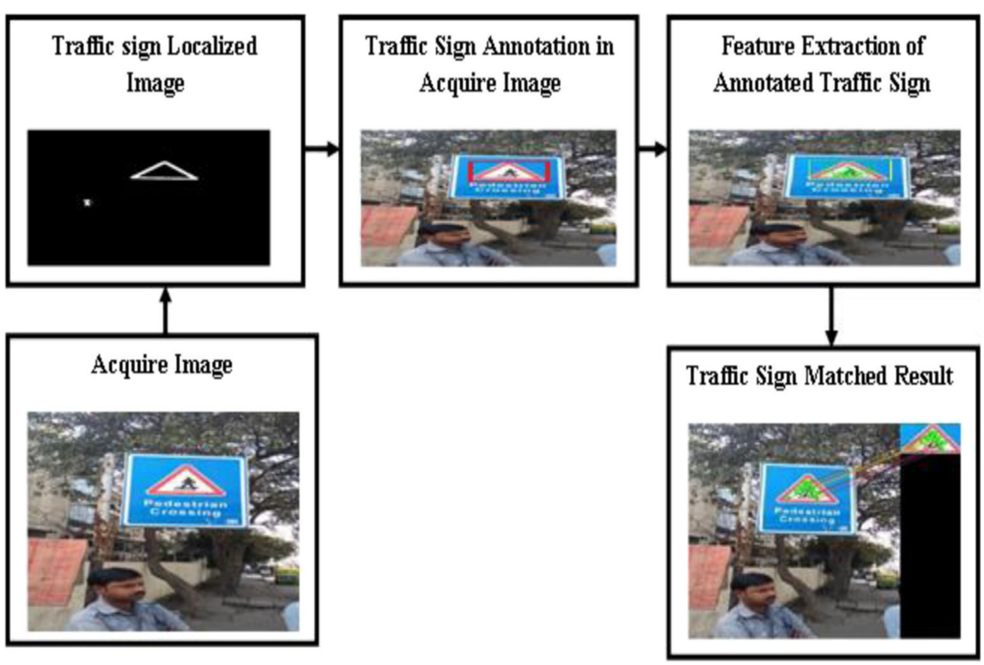
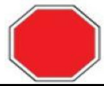


Table 3 Sample of Indian traffic sign class

Information / A sample of traffic sign class	Mandatory 	Cautionary 	Informatory 
No. of traffic sign in class	20	34	33
Size	36 X 36	36 X 36	36 X 36
Class	Uint8	Uint8	Uint8
Format	JPEG	JPEG	JPEG
Interpretation of traffic sign	Stop	School ahead	Men at work

has been considered as 0.9 as given in [37].

Descriptor Descriptor gives an especial and vigorous descriptor to the features. Descriptor generation is totally depending on the area that is surrounded by the key points. In SURF descriptor, interest area with the 20s is utilized. This interest area is further sub-divided in to 4 × 4 sub area. Sub area describes by wavelet response in the x and y direction. The wavelet response in the x and y direction is referred to as d_x and d_y respectively. Gaussian centred filter is applied at the interest points which give robustness against the deformation and translation. Figure 11, [37] depicts the process of finding descriptor. In each sub area, a feature vector f_v is determined across 5 × 5 samples. Descriptor for interest points is 16 vectors for concatenated sub areas. Finally, normalization of descriptor performs, which make the descriptor more robust against contrast variation. This normalization process considers as linear scaling of the descriptor. While checking the performance and precision, it is found that this set up is optimal [37]. The mathematical expression for calculating the feature vector of a traffic sign is given in Eq. 13 while Fig. 9 depicts the extracted surf features on surface of Indian traffic sign template.

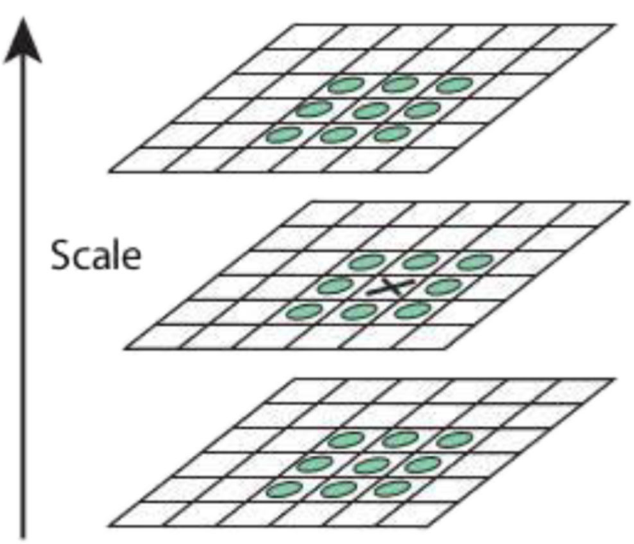


Fig. 10 Local extrema finding in SURF

$$f_v = \{\sum dx, \sum|dx|, \sum dy, \sum|dy|\} \tag{13}$$

3.2.3 Feature Matching

The system extracts the features of Indian traffic sign data (ITSD) template and features of an acquired image. Nearest neighbour rule [39] is used for matching the features between the query image features and traffic sign data base features. The feature vector of key points for a given traffic sign is express in Eq. 14.

$$F_v = \left[k_{p_1}, k_{p_2}, k_{p_3}, \ldots, k_{p_n}\right] \tag{14}$$

Where n represents the number of key points and K_{pi} is the descriptor of the extracted key points i = 1, 2……...n.

The distance between a features vector of query sample F_{Vt} with a feature vector of train sample F_{Vtr} can be formulated as in given Eq. 15.

$$dist(Fv^t, Fv^{tr}) = \frac{1}{n}\sum_{i=1}^{n_t}\min\left(dist\left(k_{pt}^t, k_{pt}^{tr}\right)\right) \tag{15}$$

Where dist = distance between query traffic sign image and traffic sign data base. n_{tr} and n_t = number of key points in training data set and query data set. This distance recognizes the resemblance between the detected traffic sign candidate and data base system. Minimum the distance from a particular sign, it means maximum the similarity with that.

Some sample of Indian traffic sign template is shown in Fig. 12.

4 Simulations and Result

Simulation results of traffic sign detection and recognition discussed in this section, implemented on a 3.7- GHz Intel Core i7 processing unit under MATLAB 2017a. Although, there is a sufficient amount of standard data is available for traffic sign detection purpose, however, a real image data set for Indian traffic sign is prepared

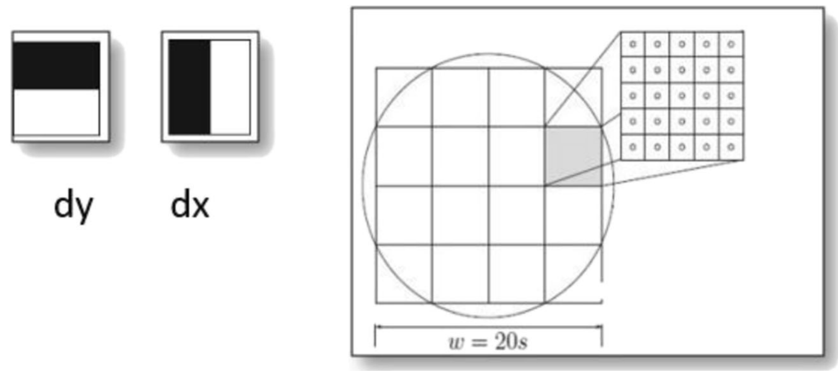


Fig. 11 Descriptor vector finding in SURF

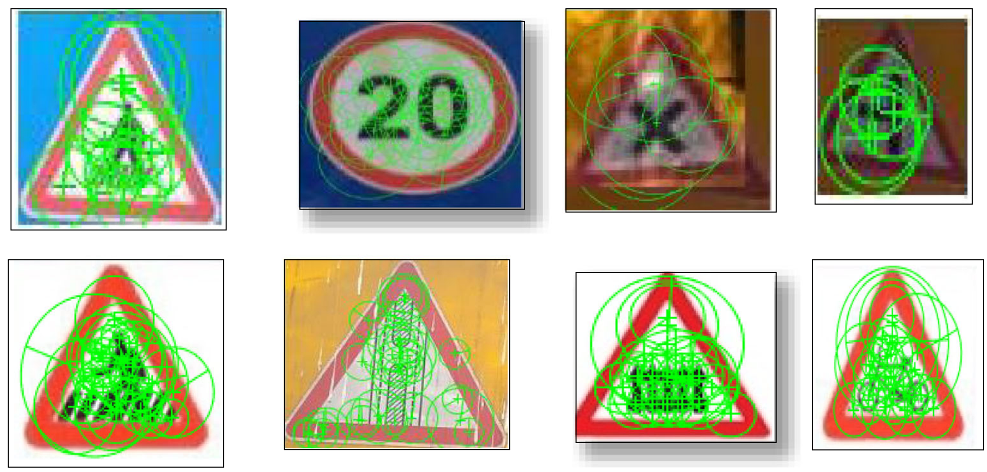
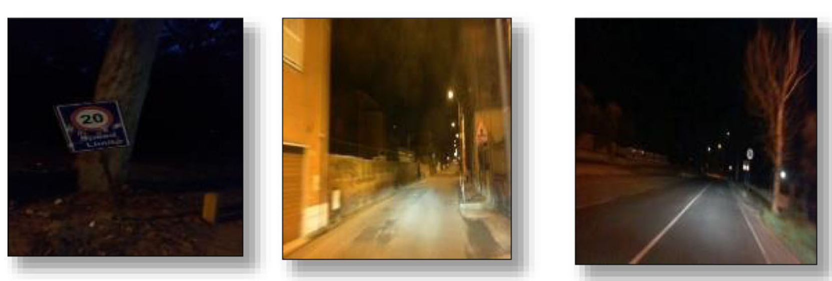


Fig. 12 Sample of Indian traffic sign templates and their SURF features

manually for achieving the robustness under real Indian environment. Large collection of vehicle images captured with a digital camera of resolution 1600 × 1200. These data sets include many challenging image frames such as images affected by illumination variation, geometric distortion, demolition and partially occlusion. The higher resolution of an image needs higher processing time hence captured images are resized to 512 × 512 for further

(a) Testing sample images acquired during day time

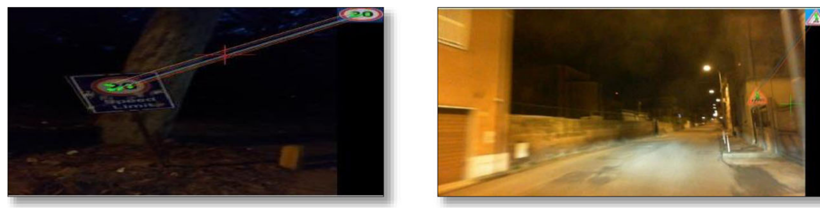


(b) Testing sample images acquired during night time

Fig. 13 **a**–**b** Testing sample acquired image under different light condition

(a) (b) (c)

Fig. 14 **a**–**c** Traffic sign recognition result of day time images



(a) (b)

Fig. 15 **a**–**b** Traffic sign recognition result of night time images

processing. Recognition data prepared by acquiring the images under different light conditions. Some of the data is captured during day time, and some is captured during night time. Figure 13 is showing some example of the acquired images under different light condition. In Fig. 13 a, image samples shown are captured during day time while Fig. 13b is an example of image samples captured during night time. Traffic sign template is also prepared by manually cropping the traffic sign. This traffic template is used for matching purpose. SURF features of traffic sign template store in database and then match the feature among this data base and SURF features of traffic sign localized in the acquired image.

Total 500 images are taken to evaluate the performance of the proposed system. Out of 500, 300 images are captured during day time, and 200 images are captured during night time. Figure 14a–c show examples of recognized results for day time captured image while Fig. 15a–b show results for night time captured images. There are total 87 [37] traffic sign in Indian traffic sign data base, and every traffic sign convey a different message to the driver for effective navigation. Detected traffic sign candidate is matched with these data base, according to this match, driver interprets the traffic sign and takes action accordingly. As shown in Fig. 11a, the system recognized that the perfect matching is pedestrian detection for detected traffic sign candidate in an acquired image hence driver follows the rules for safe navigation of themselves and for the other pedestrian.

System performance is evaluted on a various number of images under diffferent light condition and, on the basis of that, Recognition accuracy of traffic sign for day time images and night time images is shown in Table 4. The mathematical expression for recognition accuracy is given in Eq. (16). Results depicted the recognization of 296 correct traffic sign candidates out of 300 images for day time, while194 correct traffic sign candidates were recognized out of 200 images captured during night time. Henece,recognition accuracy of the system is 98.66% for day time images while it is 97% for night time images.

$$Accuracy = \frac{Correctly\ Recognised\ Images}{Total\ Images} \tag{16}$$

Table 4 Traffic sign recognition performance

Images captured	No. of images	Correct recognition	Incorrect recognition	Accuracy
Day time	300	296	4	98.66%
Night time	200	194	6	97%

Fig. 16 Recognition of traffic sign image with Illumination variation

Table 5 Recognition performance with illumination varitaion

Images captured	No. of images	Correct recognition	incorrect recognition	Accuracy
Day time	100	99	1	99%
Night time	75	73	2	97.3%

(a) Matching before resizing (b) Matching after resizing

Fig. 17 Recognition of traffic sign image with scale variation

To evaluate the system robustness for illumination variation, scale variation, rotation variation some cases study is also considered, as described below and a standard traffic sign data from Italian traffic signs (DITS) [40] is also adapted for cross checking the system performance.

4.1 Evaluation of the Proposed System with Illumination Variation

Illumination variation robustness is examined by taking the template of a traffic sign and acquired traffic sign image of different color. Figure 16 shows the matching points result. From the figure, it is clear that the color of traffic sign template back ground is blue while the background of the traffic sign in the acquired image is yellow, but the system recognized the true matching points. Table 5 shows the recognition performance for illumination invariant cross check. To evaluate the system performance, System considered 100 images captured during day time and 75 images captured during night time.Results show that system accuracy is 99% for daytime images and 97.3% is for night time images.

Table 6 Recognition performance with scale varitaion recognition

Images captured	No. of images	Correct recognition	incorrect recognition	Accuracy
Day time	100	98	2	98%
Night time	75	72	3	97.3%

4.2 Evaluation of Proposed System with Scale Variation

Scale variation robustness is examined by resizing the acquired image and performs matching on the acquired image and resized the image. Figure 17a show matching result before resizing the acquired image and Fig. 17b show a matching result after resizing the acquired image. From the figure, it is clear that even, the sizes of the images are different, but the system recognized the true match. Table 6 shows the recognition performance for scale invariant cross check. To evaluate the system performance, System considered 100 images captured during day time and 75 images captured during night time. Results show that system accuracy is 98% for day time images and 97.3% is for night time images.

4.3 Evaluation of Proposed System with Rotation Variation

System robustness about the rotation variation is verified by performing the matching between template features and rotated image. Figure 18 shows the result of matching points. It is

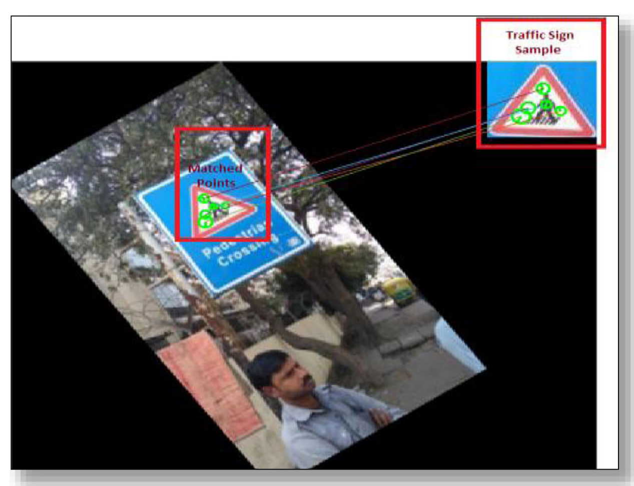


Fig. 18 Recognition of traffic sign image with rotation variation

Table 7 Recognition performance with rotation variation

Images captured	No. of images	Correct recognition	incorrect recognition	Accuracy
Day time	100	99	1	99%
Night time	75	73	2	97.3%

Table 8 Recognition performance with similar color and shape

Images captured	No. of images	Correct recognition	Incorrect recognition	Accuracy
Day time	100	99	1	99%
Night time	75	71	4	94.6%

clear from the figure that even acquired image is rotated, but the system finds all correct matches. Table 7 shows the recognition performance for rotation invariant cross check. To evaluate the system performance, System considered 100 images captured during day time and 75 images captured during night time. Results show that system accuracy is 99% for day time images and 98.6% is for night time images.

4.4 Evaluation of Proposed System with Similar Shape and Color Variation

System robustness for similar color and shape is cross checked by taking a template of a traffic sign with similar shape and color but different meaning from the traffic sign present in the acquired image. Figure 19 shows the matching points in acquired traffic sign image and traffic sign template image. From figure, it is clear that all the matching points lie outside the traffic sign hence it is not a good matching candidate; it means the system is recognizing that even traffic sign has the same shape and color information, but it has a different meaning. Table 8 shows the recognition performance for similar color and shape cross checking. The system is evaluated for 175 images; 100 images are taken under day time captured image while 75 images from night time captured the image. Results

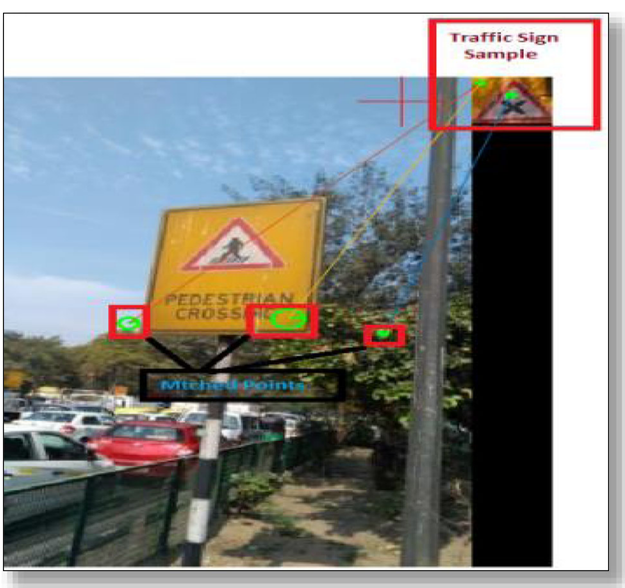


Fig. 19 Recognition of traffic sign image with similar color and shape

show that system accuracy is 99%for day time images and 94.6% is for night time images.

4.5 Performance Evaluation with Standard Traffic Sign Data

Standard data of traffic sign (DITS) [40] is also adapted to verify the system performance. DITS test data set consist total 458 images under a different lighting condition such as day time, night time and foggy images. The System evaluated only for 200 images. 100 images considered from day time captured images while 50 images from night time and 50 images taken from the foggy image data base. Table 9 shows the recognition performance for standard data set. Results show that system accuracy is 98% for day time images, 94% is for night time images and 92% is for foggy images.

4.6 Comparison with Existing Methods

Comparative analysis of Indian traffic sign detection and recognition system is evaluated for training time and recognition accuracy. Table 10 shows the training time required for different recognition system. Recognition is performed by simple nearest neighbour matching hence proposed system does not requires any training time. The overall matching time required for a single frame matching is only 0.729 s. The total time taken for traffic sign detection and recognition is 36.20 s for a single image. Training based traffic sign detection needs a lot of training time [29] as shown in Table 10 hence these methods are less suitable for real time processing. Proposed traffic sign detection and recognition method are very much time efficient which can be a good choice for real time processing.

Huda noor et al. [30] recognized Indian traffic sign with the help of feed forward neural network and devpriya et al. [29] recognized the Indian traffic sign with the help of kernel extreme

Table 9 Recognition performance of standard data with data base DITS

Images captured	No. of images	Correct recognition	Incorrect recognition	Accuracy
Day time	100	98	2	98%
Night time	50	47	3	94%
Foggy	50	46	4	92%

Table 10 Training time and recognition accuracy comparison for various methods

Methods	Training required	Recognition accuracy
SVM [29]	~142 h	90.16%
CNN-ELM [29]	~35 h	92.48%
CNN-HLSGD SINGLE [29]	~102 h	94.18%
DEEP CNN-KELM [29]	~2 h	94.47%
Proposed method	~00 h	97.83%

machine learning. In [29], neural network (NNW) based recognition model is trained for different kernel such as linear, polynomial, sigmoid, Gaussian and wavelet kernel and compare the results which obtained by different kernel-based model. Proposed traffic sign detection used simple nearest neighbor based matching but, we used the surf features which are translation, rotation, scale, and illumination invariant hence its recognition accuracy is very good. Table 11 shows the recognition accuracy of the existed method and the proposed method for Indian traffic sign data. Recognition accuracy of standard data which was adopted to evaluate the system performance is also shown in Table 11. Figure 20 is depicting the bar graph of recognition accuracy for the existing and proposed method. Over all accuracy of the proposed system for ITSD is 97.83% while recognition accuracy for the italic traffic sign data set (DITS) is 94.66%. The result shown in bar graph is concluded that overall performance of the system is very much accurate.

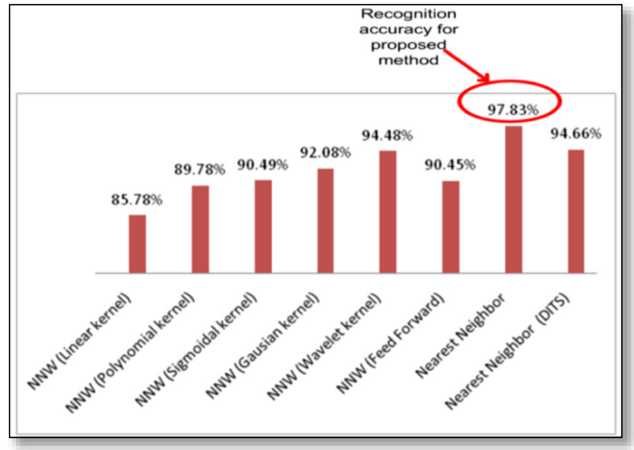


Fig. 20 recognition accuracy for Indian traffic sign

5 Conclusions

Traffic sign detection and recognition system proposed in this work reveal good performance under many hazardous conditions such as illumination variation, scale variation and rotation variation. The proposed system utilized combine information of color and shape to localize the traffic sign in the acquired image. Color saliency is enhanced for traffic sign candidate by normalizing the color information. SURF feature of traffic sign template data base and localized traffic signs are matched to recognize the traffic sign candidate. Results showed that proposed system achieved recognition accuracy for day time is about to 98.66% while for night time captured image is 97%, overall recognition accuracy of the proposed system is 97.83%. System robustness is cross checked by recognizing the traffic sign under various hazardous conditions such as illumination variation, scale variation, rotation variation, and similar color and shape variation. Apart from this, a standard data DITS is also adapted to evaluating the system performance. The results depicted an efficient functionality of the developed algorithm.

Table 11 recognition accuracy comparison for various methods

Method	Dataset	Recognition accuracy
NNW (Linear kernel) [29]	ITSD	85.78%
NNW (polynomial kernel) [29]	ITSD	89.78%
NNW (Sigmoid Kernel) [29]	ITSD	90.49%
NNW (Gaussian Kernel) [29]	ITSD	92.08%
NNW (Wavelet Kernel) [29]	ITSD	94.48%
NNW (Feed forward) [30]	ITSD	90.45%
Nearest Neighbor (Proposed)	ITSD	97.83%
	DITS	94.66%

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Compliance with Ethical Standards

Conflict of Interest The authors, Altaf Alam and Zainul Abdin Jaffery, declare that they have no conflict of interest relating to this work and publication.

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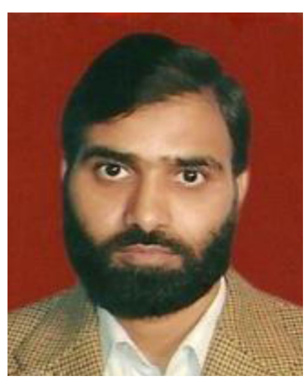

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