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A Vision based Indian Traffic Sign Classification

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Abstract: In this paper, an algorithm is proposed to classify the Indian traffic sign as mandatory cautionary and informatory class. In order to complete the task, system extracted the speed up robust features (SURF) from the Indian traffic sign data, and exploited these features to train support vector machine (SVM) algorithm. Combination of SURF features and SVM classifier makes system robust for scale variation, rotation, translation and illumination variation as well as generalization is achieved. Dimension of features have been reduced by choosing a sub set of features. Whisker and box plot visualization utilized to understand the features data. Whisker plot visualization concluded about the range, skewness, median and outliers of feature data therefore, it makes the system capable to keep good features and back out from irrelevant features. Feature refinement reduces the computational complexity. The results evaluated narrate that the overall performance of proposed algorithm is efficient.

Keywords: Vision System, Indian traffic sign classification, Speed up robust feature, Whisker and box plot, Support vector machine.
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I. INTRODUCTION

Traffic sign detection and recognition is an important part of intelligent transportation system. Traffic sign informs about the important rules to driver which makes his driving skills effective, hence to become a good driver every driver should be familiar with these signs. Indian traffic signs are categorized in to three groups according to information which they provide [1]. These categories are mandatory, cautionary and informative signs. Mandatory signs ensure free movement of traffic and make the road users aware of certain laws, regulations, restrictions and prohibition. If any vehicle user disobeys these signs, then according to law they are considered for offence. Cautionary signs make aware the road user from hazardous condition on road. Informative signs guide the road user about the alternative routes, destination information, distance from the places and prominent location like food joints, public toilet, nearby hospital, parking information etc.

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In literature traffic sign recognition work is carried out either by comparison, which is a difficult task due to work implementation on different data, or by detection classification and tracking, which is only focused on classification part. However, on the basis of techniques used for classification, traffic sign classification may be categorized in to two parts. Firstly, some researcher used hand craft features such as HOG [2], LBP [3], SIFT [4] and BRISK [5].
Secondly, some researchers used deep learning and convolution neural network for traffic sign recognition. In hand crafted feature based classification, a classifier trains on extracted features and performs recognition. Random forest and K-d trees classifier trained with different size of HOG descriptor and distance transform features in [2], to perform the classification.HOG feature of HIS color space combined with local self similarity features to train the random forest classifier in [6]. Although random forest based classifier produces significant score for each variable, but it does not provide a feature subset selection to reduce the feature dimension. Another disadvantage of random forest classifier has been observed that it over fit for some data set. To reduce the over fitting problem, A linear discriminant analysis (LDA) based classifier trained in [7] with HOG feature for traffic sign classification. Real time processing achieved in [8] by using the multi threaded programming technology CUDA on a mobile GPU. Multi threaded programming is a time consuming process, hence it requires a high processing hardware like GPU. Although, GPU resolve the processing time problem but on the other hand it increases the cost. Support vector machine based classification performed in [9] by utilizing the HOG, LBP and Gabor features. Support vector machine (SVM) based classifier naturally resist to over fitting on a feature data set and effectively draw a hyper plane between the classes [10].Multi scale centre symmetric local binary pattern (MS-CSLBP) as local feature and discrete wavelet transform (DWT) as global features are combined to train the SVM classifier in [3] to recognize the traffic sign. Scale invariant feature transform (SIFT) based code book is generated and trained SVM classifier in [11] to classify the traffic sign. Speed up robust features (SURF) is used with artificial neural network (ANN) classifier to recognize the traffic sign in [12]. K nearest neighbor (K-NN) search method is combined with SURF features in [13]. In deep neural network, feature extraction and training is not required separately, it extracts the features from large data of training set and understand the pattern. Convolution neural network extracted the invariant features from 32 x 32 color image of Germanium traffic sign image data and perform a supervised way of classification in [14].

Circular shape of Germanium traffic sign recognized in [15] by developing a simple architecture of deep neural network. CNN architecture for traffic sign is proposed in [16], consist two stages of convolution layer, two fully connected layers and a soft max layer. A combination of multilayer perceptions and convolution neural network with GPU is used in [17] to enhance the system performance, multilayer perceptrons neural network trained on HOG descriptor while CNNs trained on raw pixel information.

A new CNN architecture for traffic sign proposed in [18], it used Rectified Linear Units (ReLU) as activation function.

CNN based traffic sign classification needs high amount of image data to classify the traffic signs. High amount of data needs high processing time hence it demands the high speed processing hardware. Some of researchers used a parallel processing unit like GPU to overcome the high computational cost. Although GPU reduces the processing time but at the same time it increases the cost of system. Another main drawback of CNN is generalization. Generalization means, when we check the performance of a system in a new image which contains the object that was used in training process, but while testing any change in the size and color of the object reduces the performance of CNN. CNN is also not robust for motion blur. On the other hand SVM naturally resist the over fitting on training data and effectively draw a hyper plane between the classes. SVM draw a hyper plane by selecting the support vector hence once a hyper plane is drawn then most of the data other than the support vectors become irrelevant. Means if support vectors have selected once then small changes to data cannot affects the hyper plane, therefore generalization is very well for SVM based classifier. Classifier performance and robustness mainly depends on the features which were used in training. Vision system for traffic sign recognition is a part of intelligent transportation system, where dynamic nature of background cause problem. Dynamic background means camera mounted on the vehicle and it moves during the image acquisition. Hence, there will be motion blur in images and the objects in image will change their position, view angle and size continuously. To enhance the system performance over dynamic background, features selected for traffic sign classifier training should be robust under translation, rotation and scale variation. HOG descriptor describes shape of object effectively but it is not robust for scale variation and rotation variation [19]. Local binary pattern (LBP) features extraction is a simple and efficient texture operator, it is illumination invariant as well as rotation in variant [20] but it is not robust for scale variation. SURF feature uses integral image and descretized kernel approximation while extracting the features hence, it is a fast processing feature descriptor and it is robust for translation, rotation and for scale variation [21]. Most of the researcher used classification as recognition, for example, if there are 23 type of traffic signs then they classified in to 23 classes [22]. Ruta et al. [23] classified traffic sign in to 48 classes. Another approach such as color and shape based classification performed in [24].

This paper proposed an efficient algorithm for classification of Indian traffic sign. Main objective of this work is to develop a system which classifies the Indian traffic sign according to information they provides. Detection and recognition is not considering in this work, only classification of traffic sign performed. In order to full fill the objective, SURF features are extracted from the Indian traffic sign data (ITSD) and SVM algorithm is trained to make the classifier. Combination of SURF features and SVM classifier makes system robust for scale, rotation, and translation and illumination variation as well as achieved well generalization. A sub set of SURF feature chosen from the extracted SURF feature to reduce the dimension. Redundant features dropped out by analyzing the whisker and box plot of features data. Box plot visualization given information about the range, skewness, median and outliers of feature data therefore it make the system, capable to keep good features and drop the irrelevant features.

Further sections of the paper are organized as follows: Indian traffic sign classification process flow discussed in section 2. In section 3, simulation implementation and result are discussed and finally, Work is concluded in section 4.

II. INDIAN TRAFFIC SIGN CLASSIFICATION SYSTEM

Figure 1 is depicturing the process flow diagram of the proposed Indian traffic sign classification system. In this work, system classifies the traffic sign, either as a mandatory sign, cautionary sign or informative sign. Traffic sign divided into more than two classes, hence Gaussian kernel based SVM classifier is trained which draw hyper plane among the traffic sign classes. Speed up robust features (SURF) is utilized in classifier training process. Traffic sign classification involve several steps such as: data preparation, feature extraction, feature refinement, train the model and finally make the prediction. Detail description of implementation process is given as:

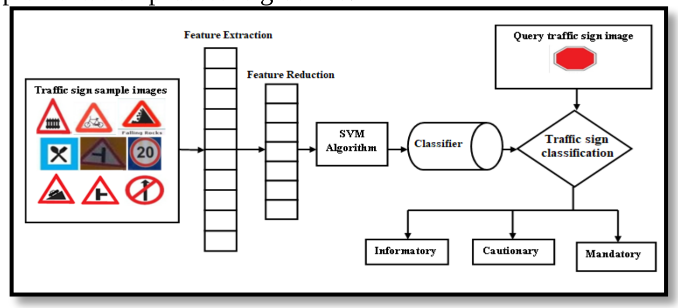
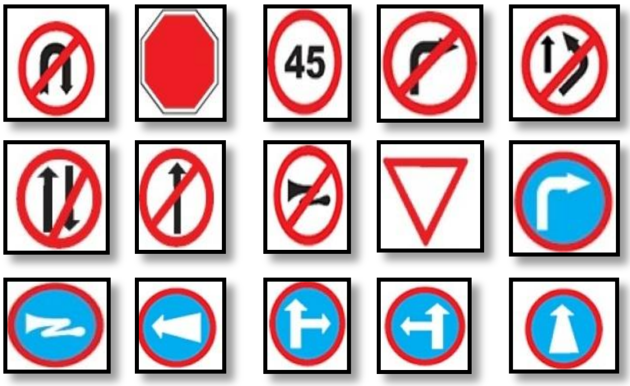


Fig.1. proposed, process flow diagram of indian traffic sign classification

A. Training data collection

To prevent the miss classification of unknown traffic signs it is very important to train the classifier model on all possible traffic signs. Although there are plenty of standard traffic sign training data but, aim of this work is to develop a classifier model for Indian traffic signs. Hence, real data of Indian traffic signs (ITSD) is prepared. Indian traffic images are acquired and cropped manually to extract the traffic signs. To enhance the system performance, training images are captured under different light condition such as some of traffic sign are captured during day time and some of the traffic sign are captured during night time. Indian traffic sign details and data are also adapted from [26].There are total 87 traffic sign in ITSD data base, out of it, 20 signs are for mandatory class, 34 signs for cautionary and 33 signs are for informative class. Figure 2 (a-c) shows the sample of traffic sign images for mandatory cautionary and informatory classes.



(a) Sample images of mandatory Indian traffic sign training data set.

(b) Sample images of cautionary Indian traffic sign training data set.

(c) Sample images of informatory Indian traffic sign training data set.

Fig. 2(a-c). sample of Indian traffic sign data set for different classes

B. Data Augmentation

In data augmentation, numbers of traffic sign images data are increase by adding some synthetic data. This process enhances the classification system performance. To increase the data, minor changes such as flip, rotate, translate and resize are performed on the existing data. In this work to increase the traffic sign data, Traffic sign of different scale and different rotation is added in training data set to make the system more generalize for multi scale and multi view of traffic sign. Figure 3 shows some augmented images sample for scale variation and, figure 4 shows some augmented images sample for view point variation.

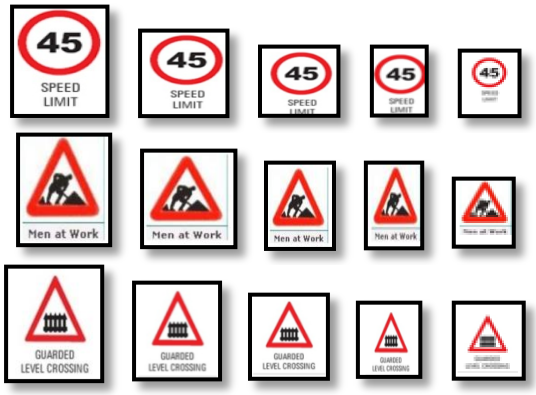


Fig. 3. Augmented images sample of scale variation

Fig. 4. Augmented images sample of scale variation

C. Feature extraction

This work utilized SURF features for classification of Indian traffic signs. Surf features are extracted from the traffic sign data base and classifier is trained with these features. SURF features are used due to its robustness for illumination, rotation, translation and scale variation , feature extraction process consume less time [21].

SURF feature extraction is completed mainly in two steps such as key point detection and key point description, SURF features extraction details are given as follows:

D. Key point detection

Key point detection detects relatable interest points in image. In SURF key point detection, SURF builds a pyramid of response map with different level within octave. Extrema is found in SURF pyramid which is a key point. In spatial domain, key point is selected among 8 neighbors while in spatial scale domain (SURF), extrema decides among 26 neighbors. The key point is the maxima among 8 neighbors in existing level and its 9 neighbors in below and 9 in the level above. Finding extrema is known as non-maximum suppression in a 3×3×3 neighborhood. Figure 5 depicts the process of finding the local extrema between level, octaves and neighborhood.

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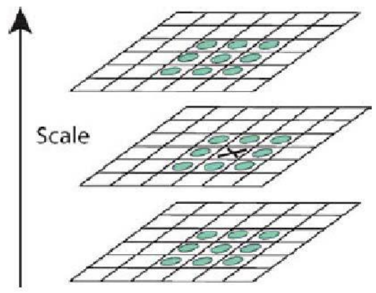


Fig.5. Local extrema finding in SURF

In SURF feature, key points find with the help of hessian based blob detection technique. Hessian matrix determinant is an expression of the local change around the area [26]. Eq. 1 shows the mathematical expression of hessian matrix.

$$H(x,y) = \begin{bmatrix} L_{x,x}(x,\sigma) & L_{x,y}(x,\sigma) \\ L_{x,y}(x,\sigma) & L_{y,y}(x,\sigma) \end{bmatrix} \quad (1)$$

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

$$L_{y,y}(x,\sigma) = I_x \otimes \frac{d^2 g(\sigma)}{d y^2} \quad (3)$$

$$L_{x,y}(x,\sigma) = I_x \otimes \frac{d^2 g(\sigma)}{d x,y} \quad (4)$$

Where $L_{xx}(x,\sigma)$,$L_{yy}(x,\sigma)$ and $L_{xy}(x,\sigma)$in Equation 1represents, second derivative of Gaussian with respect to horizontal vertical and combination of both. Convolution process takes high computing time therefore SURF uses integral image and approximated kernel for speeding up the process. Equation 5 shows the expression for integral of image.

$$I(x) = \sum_{i=0}^{i \le x} \sum_{j=0}^{j \le y} I(x,y) \quad (5)$$

By employing integral image, the value in a rectangular area with random size using 4 look-ups is determined. The Gaussian kernels which are employed in Hessian matrix have to be descretized and cropped before applying them. These kernels are approximated with rectangular box filters. In an image, grey area is proportional to 0 in the kernel, where as white area corresponds to positive value while black area represents the negative value. In this way, determine the approximated convolution efficiently for randomly sized kernel utilizing the integral image. Equation 6 depicts the determinant of hessian matrix with approximated kernel.

$$Det(Hess) = D_{xx} \times D_{yy} - (W \times D_{xy})^2 \quad (6)$$

The corresponds and discrete kernels are mentioned to as D_{xx} for $L_{xx}(x,\sigma)$, D_{yy} for $L_{yy}(x,\sigma)$, and D_{xy} for $L_{xy}(x,\sigma)$. The value of W is highly sensitive for scale variation but it can fixed at 0.9 [26].

E. Descriptor

Descriptor gives a special and vigorous descriptor to the features. Descriptor generation is totally depends on the area that is surrounded the key points. In SURF descriptor, interest area with 20s is utilized. This interest area is further sub-divided in to 4x4 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. Fig. 6, [26] depicts the process of finding descriptor.

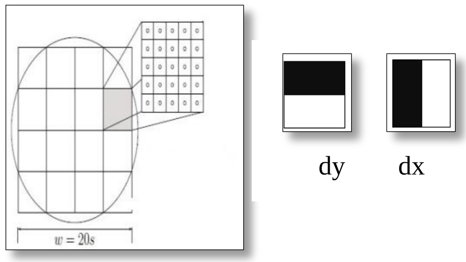
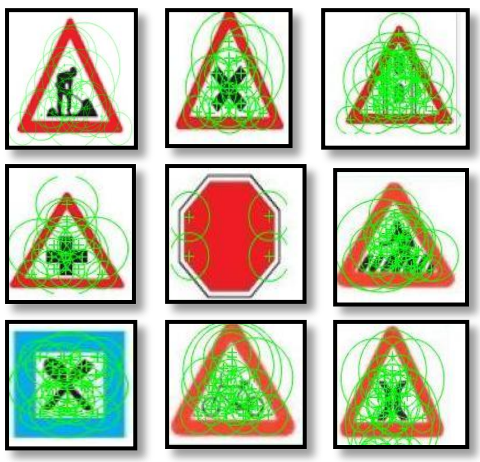


Fig.6. Descriptor vector finding in SURF

In each sub area, a feature vector f_v is determined across 5x5 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, check the performance and precision, it is found that this set up is optimal [21]. Mathematical expression for calculating the feature vector of traffic sign is given in equation7 while, Figure 7 depicts the extracted surf features on surface of Indian traffic sign template.

$$f_v = \left\{ \sum dx, \sum |dx|, \sum dy, \sum |dy| \right\} \quad (7)$$



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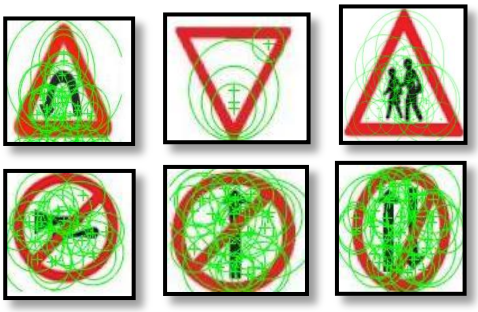


Fig.7. SURF features plot on traffic sign

F. Feature reduction

In feature reduction, feature subsets are selected by removing the features that are not relevant or reduntatnt. Clssification system follows only single objective for both fetaure subset selection and feature extraction that avoid the overfitting problem. Feature subset can selects by understanding the feature data, a better understanding of data yields better results from the classification algorithm. Understanding of data make any system able to clean and best present the feature data. Data visualization is an effcetive way to understand the available features data and it helps to spot the outliers. Whisker box plot visualization is used in this work for understanding the features and spot out the out liers. Figure 8 shows the whisker box plot for traffic sign, box plot visualizes the data and gives information about the range of features data, skewness of features data, median of data and it spot the ouliers in feature data. In figure, red points are outliers hence , system avoid these outliers when selects the sub set of feature . range of feature is also selected with the help of these features boxes. Figure 9 (a) is whisker box plot for mandatory class and their zoomed out plot is figure 9 (b). figure 10 (a) depicts the whisker box plot for cautionary class and figure 10 (b) depicts the zoomed out of whisker boxes plot for cautionary class. Whisker box plot of informatory class is shown in figure 11 (a) while its zoomed out is shown in figure 11(b).

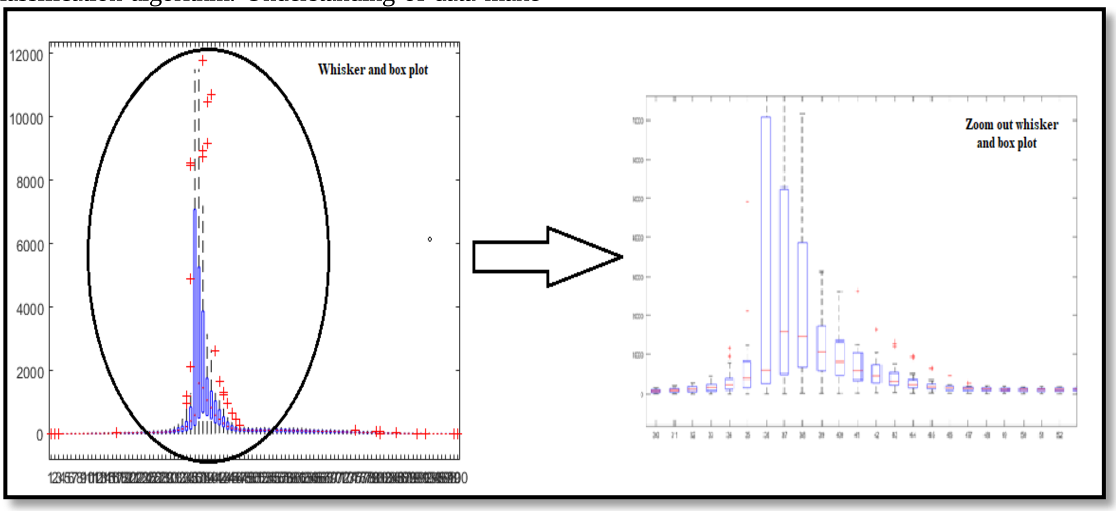
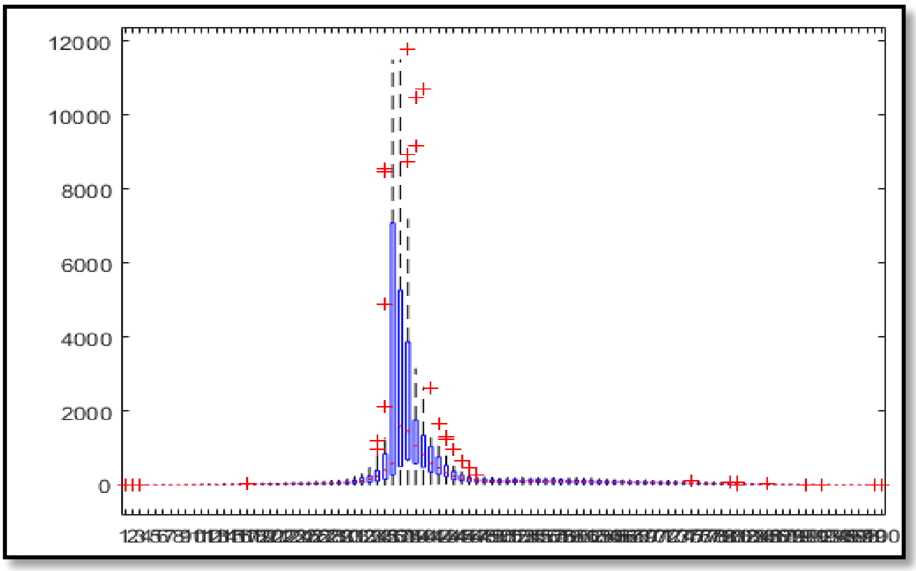
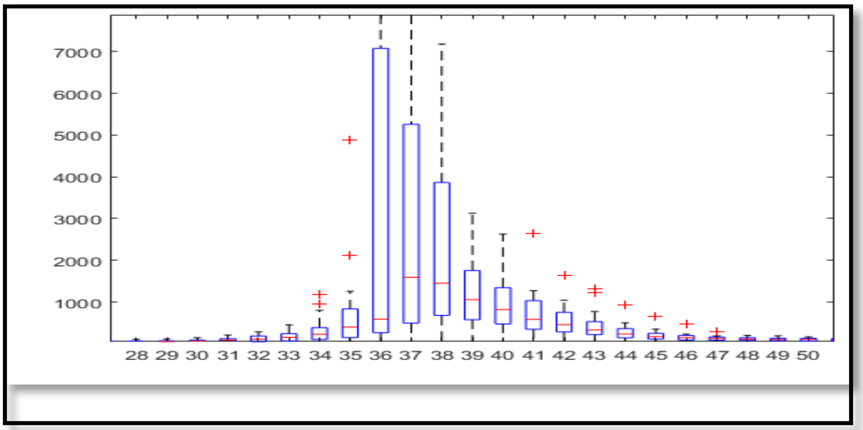


Fig. 8. Whisker box plot for traffic sign features data

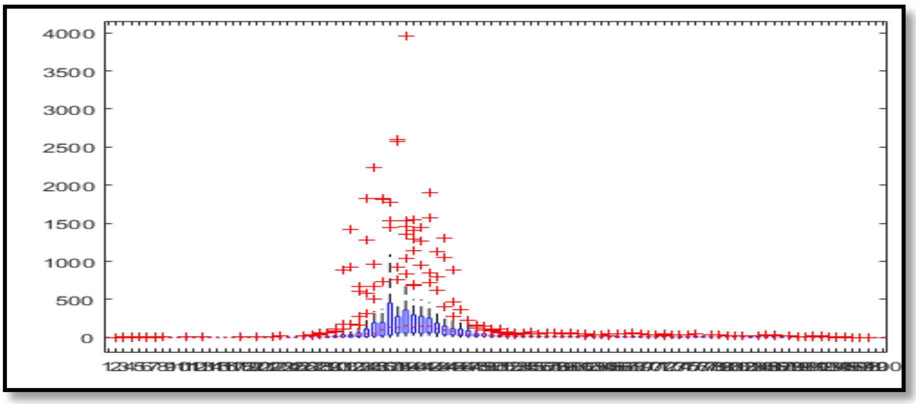


(a) Whisker and box plot of mandatory sign

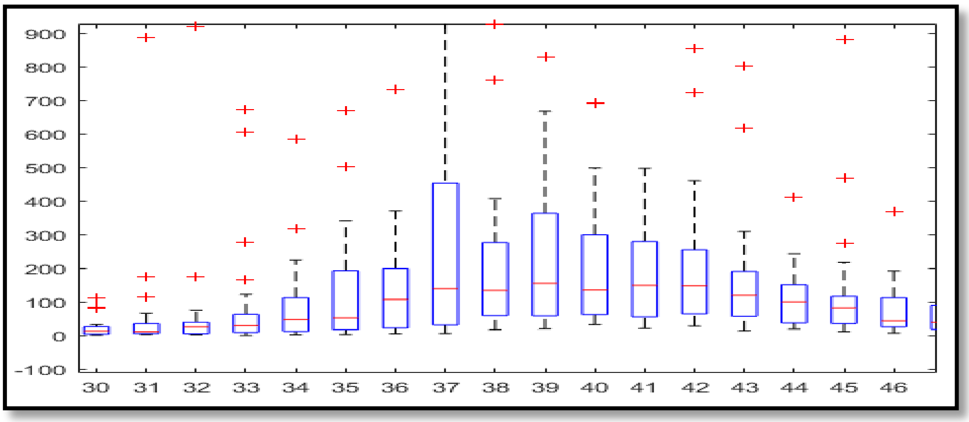


(a) Zoomed out box plot of mandatory traffic sign

Fig. 9(a-b). Whisker box and its zoomed out plot for mandatory traffic sign



(a) Whisker and box plot of cautionary traffic sign



(b) Zooomed out box plot of cautionary plot

Fig. 10(a-b). Whisker box and its zoomed out plot of cautionary traffic sign

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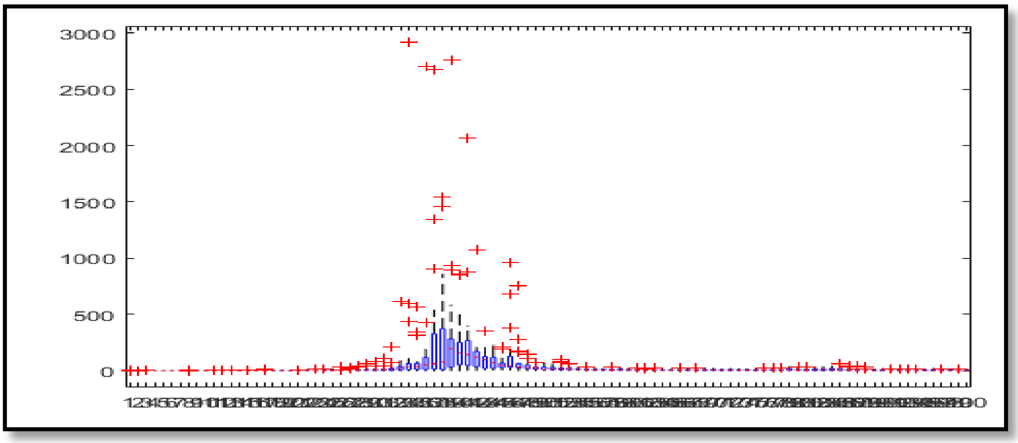
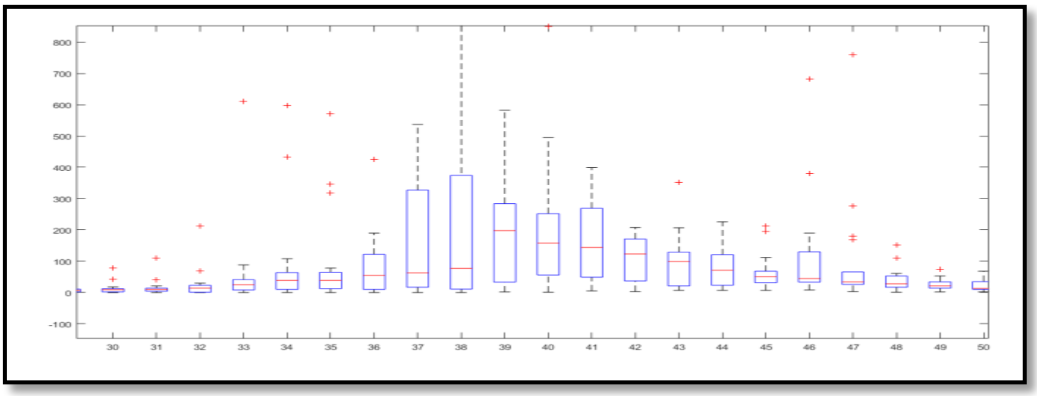


(a) Whisker and box plot of informatory sign



(b) Zoomed out box plot of informatory sign

Fig.11 (a-b). Whisker box and its zoomed out plot of informatory traffic sign

G. Train the classification system

SVM algorithm is trained with gaussian kernel to classify indian traffic sign. Kernel based classification verifies the hyper plane which discriminate the classes. Support vector machine extracts the support vectors from the observation features and these vectors helps to draw the hyper plane among the classes [27]. Mostly support vector machine which are used for classifying the two classes are known as linear support vector machines [28]. In this work, three classes are differentiated from each other hence; a kernel approach used which is suitable for multi class classification [29]. Gaussian kernel is used for finding the non-linear decision boundaries and measure the distance between a pair of features [29]. The SVM function is mathematically denoted in Equation 8.

$$f(x) = \sum_{i=1}^{N} \alpha_i y_i k(x_i, x) + b \qquad (8)$$

Where N is the size of training data while X_i is extracted support vectors and α_i is weight. y_i is labelled class, b is biasing value and $K(x_i, x)$ is kernel function. This system is used Gaussian kernel for trained the model. Equation 9 expresses the mathematical equation for Gaussian kernel.

$$k(x, x') = \exp\left(-\frac{\|x - x'\|^2}{2\sigma^2}\right) \quad \text{for } \sigma>0 \qquad (9)$$

Equation 10, Final value of SVM function for Gaussian kernel is find out by Putting the kernel k (x, x') function in Equation 8.

$$f(x) = \sum_{i=1}^{N} \alpha_i y_i \exp\left(-\frac{\|x - x'\|^2}{2\sigma^2}\right) + b \qquad (10)$$

H. Decision

Indian traffic sign data set is classified in to three classes hence system is predicted that the traffic sign is mandatory, cautionary or informative. Decision related expression is shown in Eq. 11.

$$prediction = \begin{cases} y = -1 & Sign \quad Mandatory \\ y = 0 & sign \quad Cautionary \\ y = 1 & Sign \quad Informatory \end{cases}$$

(11)

III. SIMULATION AND RESULT

Classification of Indian traffic signs is performed on a HP desktop of 3.7-GHz Intel core i-7 processing unit under MATLAB 2017a. To implement the Indian traffic sign classification, Indian traffic sign data prepared manually by cropping the traffic sign from captured real time road images. Images captured during different light condition to make the system more robust for illumination variation.

Data augmentation takes place to increase the number of Indian traffic sign. Number of traffic sign increased by adding the synthetic data of different scale and view point. Proposed classification system is trained over the SURF features to enhance the performance under scale, rotation and translation variation. SURF features extracted from the traffic sign of mandatory, cautionary and informatory classes and store these data for further analysis. Feature sub set selected from the feature data base to reduce the complexity and enhance the performance of proposed classification system. Dimension of SURF features data reduced or sub set of feature is selected by visualizing the SURF features of traffic sign in whisker and box plot. Whisker and box plot visualization of features data helps to analyze and understand the available data, and make any system able to clean the redundant and keep best features. SVM algorithm is trained over these rectified features which classify the Indian traffic sign in to mandatory, cautionary and informatory class.

Total 2400 traffic sign images data taken for simulation, 800 traffic sign images for each mandatory, cautionary and informatory class. Training and testing data is divided in to 8:2 ratio, 80% data utilized to train the classifier while 20% of data considered for testing the performance of classifier. Table-I shows confusion matrix of proposed system. Confusion matrix concluded that system achieved 100% accuracy for mandatory sign, 99% for cautionary sign and 90% for informative sign. It is clear from the confusion matrix that system never misclassified the mandatory sign but it misclassified informative sign one time as mandatory sign and also misclassified informative sign ten times as cautionary sign. True positive rate (TPR) and false positive rate (FPR) of proposed classifier is shown in table-II. Results conclude that true positive rate for mandatory sign is 100 %, for cautionary sign is 99% and 90% is for informative sign. Positive prediction value (PPV) and false discovery rate (FDR) related information of the classification system is given in table-II. Positive predictive value for mandatory sign is 100%, for cautionary sign is 92% and 99% is for informative sign. Mathematical equation for TPR, FPR PPV and FDR is given as:

$$PPV = \frac{TP}{TP+FP} \quad (12)$$

$$FDR = \frac{FP}{TP+FP} \quad (13)$$

$$FPR = \frac{FP}{FP+TN} \quad (14)$$

$$TPR = \frac{TP}{TP+FN} \quad (15)$$

Table-I: Confusion matrix of proposed classification system

True Class	Predicted Class		
	Mandatory	**Cautionary**	**Informatory**
Mandatory	100%	0%	0%
Cautionary	1%	99%	0%
Informatory	0%	10%	90%

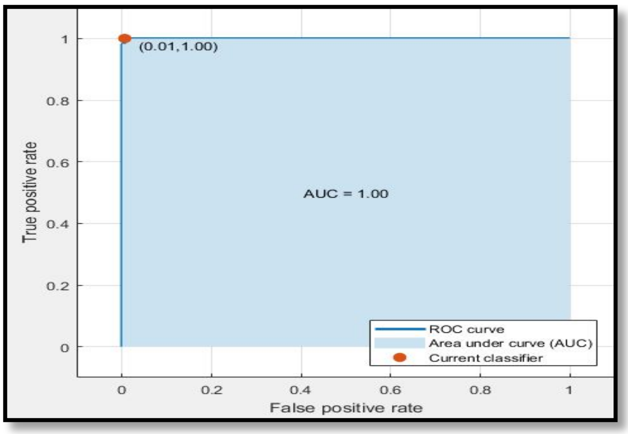
Table-II: True positive and false positive rate of proposed classification system

	Mandatory	Cautionary	Informatory
TPR	100%	99%	90%
FPR	0%	1%	10%

Table-III: Positive predictive value and false discovery rate of proposed classification system

	Mandatory	Cautionary	Informatory
PPV	100%	92%	99%
FDR	0%	8%	1%

ROC curve of mandatory, cautionary and informatory classes is shown in figure 12 (a-c). Roc curve show false positive rate and true positive rate curve. Results show that minimum area under the curve is .98 while maximum area under the curve is 1. Area under the curve for all the traffic sign class is nearby equal to 1 hence it can conclude that the proposed system separated all the classes very effectively.



(a) ROC curve for mandatory class

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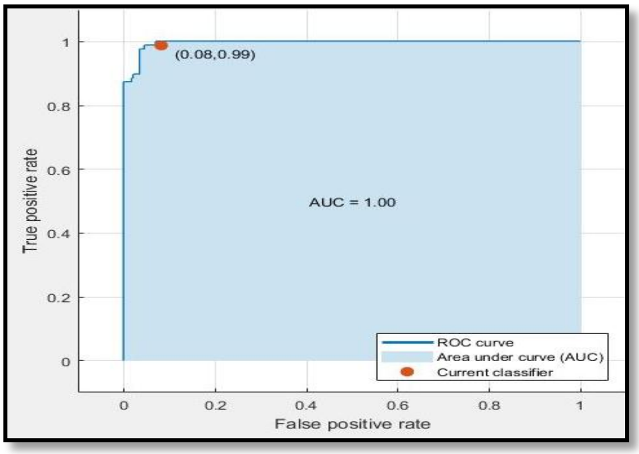
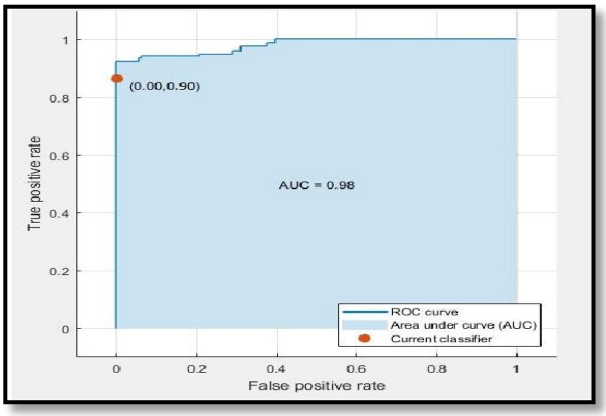


(b)ROC curve for cautionary class



(c) ROC curve for informatory class

Fig. 12(a-c). ROC curve for traffic sign SVM trained model

IV. CONCLUSION

Indian traffic sign classification system is proposed in this work. An algorithm is developed which classifies the Indian traffic signs as: mandatory, cautionary and informatory. The Proposed system utilized SURF feature of Indian traffic signs to train the support vector machine classifier. Real image data of Indian traffic signs are obtained by capturing various images under different light conditions and extracting the traffic signs by cropping them. SURF features of the traffic sign data are extracted and their dimensions are reduced to form a feature subset. Whisker and box plot visualizations were used to understand the extracted features. The box plot visualizes the data, from the visualization the system keeps the best features and cleans the redundant data. Gaussian kernel based SVM classifier is trained with the extracted subset of SURF features which draw a hyper plane between the classes. System achieved 100% accuracy for mandatory class, 99 % for cautionary class and 90 % accuracy achieved for informatory class. Performance evaluation of proposed system is observed and its classification accuracy is satisfactory.

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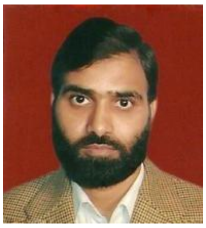

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