A Comprehensive Study on Traffic Sign Detection in ITS

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***Abstract*—Intelligent transportation system (ITS) is comprised of several component like Commuter information, Traffic management, vehicle info, public safety etc. To ensure the smooth flow of traffic, the recognition and apprehension of traffic signs are fundamental building blocks of the system. In real time scenario this system Driver Personal Assistant (DAP) can assist driver to travel in stress-free environment and which is one of the reason researchers are engrossed for expansion of such type algorithms in this direction. Due to various symbols of traffic sign images in various countries brought up by shifting perspectives, motion blur, lighting, and other parameters, accurate detection is a big challenging. Several techniques comprise of Artificial Intelligence, Machine learning and Deep Learning has been established in real time span for the enhancement of object detection and recognition of traffic sign. The content is potential for researchers' association and has developed meaningful interest in several studies on optics -based TSDR (detection and Recognition of Traffic Sign). Three major component detection, Recognition, and classification combined in any algorithm make the system useful for deployment in real time. Variety of techniques had been communicated over a period. All-inclusive brief summary for traffic sign detection is presented in this paper. In addition to this exhaustive summary of algorithms, on detection, recognition and classification are investigated and grouped in tabular representation. An algorithm based on CNN has been implemented and shows better accuracy and less percentage loss in detection of GTSRB traffic sign data set.**

Keywords— Artificial Intelligence, Deep Learning, Intelligent transportation system, Machine Learning, Personal Assistant Driver, Traffic Sign Detection and Recognition

I. I.INTRODUCTION

Since, twenty-first century, vehicles have taken over as the dominant mode of transportation, and since their population has been continuously escalating. This creates significant issues for transportation networks which includes traffic congestion, safety, and pollution. Intelligent transportation systems (ITSs) were proven as a solution for this issue. ITSs may successfully combine vehicles, people, technology, and infrastructure into a single system by utilising the most recent information and communication technologies.

Major contribution of ITSs is to provide support to driver or an auxiliary guidance ; this phenomenon is termed as UVD [1]ITS also provides safe driving, accidents prevention and better congestion alleviation, Goods delivery system ,minimize hazardous [2] emissions. Many technical advancements after 2nd world war keep their focus on automobile industry to enhance methods for driver Assistance and as a result, this field drew a lot of researcher's attention to full fill the vision of ITS and indirectly completes the dream of smart city. Some advanced system based on Artificial intelligence , IoT ,Cloud, and Blockchain technology should be emerged in order to provide lead to reduction in traffic time. Across the globe Traffic signs contributes the meaningful insights to drivers and informs about potential dangers. Therefore, implementation of traffic signals ensures the safety of both motorists and pedestrians on the ro ad.

Traffic sign detection and recognition are fundamental components of intelligent Transportation system which can further guide autonomous driving and provide support to drivers in order to understand the meaning of traffic sign.

If driver is not able to understand the insight of traffic sign it may lead to delay or might stuck in traffic jam or accident. As different countries have variation in traffic signs there must be a unified framework which can detect and recognize[3] sign throughout the globe uniformly. A growing number of applications for the TSDR system have sparked attention in recent years [4] . There are numerous challenging issues in this field that have yet to be adequately addressed and improved upon. To our knowledge, the following items are among the most important:

1. variations in lighting conditions
2. Traffic signs disfigurement
3. The shape of a traffic sign
4. Obstacles blocking traffic signs

Fig. 1. distorted traffic sign image

Major factor which affects road sign vision are temporary because of optics based parameters and Inclement environment like Heavy rain, Thunderstorms. Improper posting of signs can make the same enduring. Here, Figure 1 demonstrate an instance of distorted traffic sign image.

Now the systematic outline of this paper is discussed as follows: Section 2 presents an introduction about traffic sign.

The next section contains technologies based on detection, recognition, and classification. The same section also contains review and comparison among techniques. Current datasets of transportation also included in section 4. In Section 5 basic recognition-based model has been discussed

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and their outcomes are listed for accuracy in training and validation steps. Section 6 outlines still present questions and adversities facing by researchers in domain of traffic sign related processing. However, it is expected that the publication of upcoming papers will encourage original work in the domain of Intelligent Transportation Systems (ITS).

II. Traffic Sign Description

Pictorial representation for supervising traffic movement is deployed on road sides which assist road users to smooth and safe journey. milestones (Wood/Stone) were typically located along roads and highways to deliver information to commuters about distances, directions, and others. As transportation system developed further directional arms-based signs are added. INDIAN traffic signs are in both English and the state language on most state highways and city streets. National highways contain signs in both English and the state language**.**

A. Traffic Signs are primarily of three types:

1) Mandatory Signs – These Signs give orders. These signs are compulsory for the traffic which uses a specific area of road. mandatory road sign is generally round with red border some of them are blue also violation of these signs attracts heavy fines and punishment and it could also lead to major crashes.

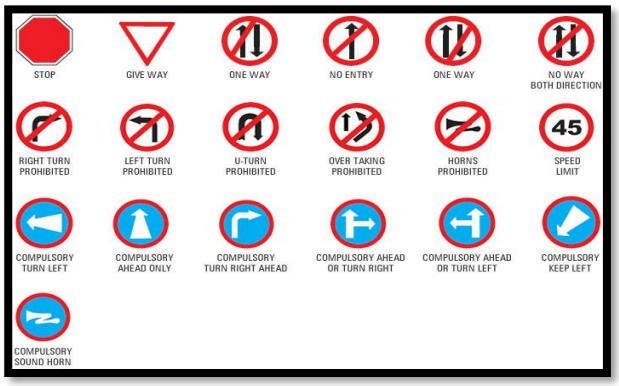

Fig. 2. Mandatory sign images

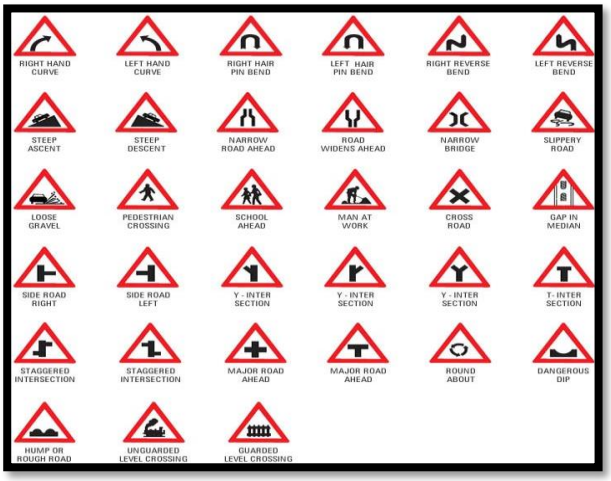

Fig. 3. Cautionary sign images

2) Cautionary Signs –These signs are main to caution the driver about the hazards of situation line ahead on the route cautionary signs are triangular with red border. The drivers, accordingly, take necessary actions to handle the situation.

3) Informatory Signs – These signs are providing information on direction, destination, roadside facilities to Road users. these signs as generally facilitate to driver and normally blue in colour

they can also have direction arrow and the distance of facility from the sign.

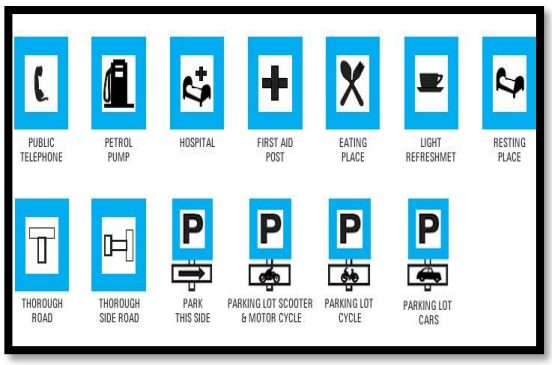

Fig. 4. Informatory Sign

III. Literature Survey

Despite the Vienna Treaty's clearly stated provisions there are still differences in traffic sign designs across nations, and even in a single country. A significant amount of work done by researchers in computer vision and machine learning algorithms [5]in recent years to tackle the problem of detecting and identifying[6] traffic signs through automatic means. The recognition of traffic sign is extremely complex job. Including non-uniform illumination of the scene, fading effect by the relative movement [7] between the camera and the signs, occlusion by other objects or vehicles imposes hurdle for the recognition of signs.

Finding the sign, recognizing it, and discriminating one sign from another are its three basic functions . Hence the major component of it should be bifurcated into three parts, the tracking , detection, and classification.

1. Detection
2. Recognition
3. Classification

Finding traffic signs in the photos of the input image is what detection [3]is concerned with., where-as classification is about finding valuable insights in image about type of sign. In images ROI defines the regions which contain more relevant information about image.

ROI based identification of traffic sign provided by algorithms gives more accurate result.[8].

The biggest challenge in detecting traffic signs, however, is their modest size; they often take up smaller amount of the sign. Furthermore, in terms of accuracy, detection of minor traffic signs plays major role then identification of large traffic signs.

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A. Traffic sign detection:

Now firstly traffic sign detection-based paper has been analysed and major techniques are listed .

1) Color based:

The colour attribute [9] of traffic signs is unique and eye-catching which assist drivers for differentiation of signs and it can lead to development, design of colour-based detection methods. The same can be divided into following categories.

1. RGB based thresholding[10]
2. Hue and saturation thresholding
3. Chromatic/achromatic decomposition[11]
4. Pixel classification[12]

2) Shape based:

triangle, circle, rectangle, and octagon are fundamental blocks of traffic signs.

1. Shape detection- Special shapes [13] are identified by Hough transformation-based methods.
2. Analysing and matching shapes[14]Various algorithms are designed for circular, triangular, and octagonal signs.
3. Fourier transformation[15] Fourier descriptors were used by Larson to express traffic signs, Variation of intensity according to pixel position can also use to determine the content. This can also be amalgamated with the object model (star-based) for the various sign categories.

3) Machine learning based:

Machine learning-based traffic sign detection techniques are providing advanced state-of-the-art outputs in multiple domains of current scenario. With technical advancement various machine learning algorithms such as random forests [19], support vector machine (SVM) [16], [17] , [18]logistic regression and artificial neural networks(ANN) are incorporated for this objective.

a) Svm based

Support vector machine is essential algorithm for detection of traffic. This framework handles entity detection as a SVM classification problem, where each sub-image is sorted as objects or backgrounds. [20], [21] developed a scalable fuzzy support vector machine.

b) ADA Boost Method:

AdaBoost and cascade-based methods are promising algorithms in detection scenario for transportation domain. Various real time issue like face recognition, vehicle detection, license plate investigation, etc are implementing these type algorithms. The most common feature utilised in various detection issues is the Haar-like[22] feature. The grey level difference of traffic signs can be expressed by the Haar-like property. Rectangular feature Multi-Block Local Binary Pattern (MB-LBP) is also emerging in this field. Prominent methods based on AdaBoost are Real AdaBoost, Gentle AdaBoost, Discrete AdaBoost [23]and others.

They can identify and list highly recommended features weak classifiers in the same way we have in ensemble techniques. ROI extraction-based techniques can also be integrated with AdaBoost detection process.

4) Deep learning based

Numerous deep neural network topologies have emerged in previous years. with the advancement of deep learning ,implementation of DL methods in ITS are growing day by day. This section provides a list of algorithms for traffic sign detection with respect to deep learning techniques. Multiple CNN based algorithms are discussed with their variants. A brief overview regarding CNN has been presented to provide user a hassle-free understanding of the topic.

a) CNN: Neural networks are considered foremost component of AI, and major part of deep learning algorithms. CNNs include many node layers[24] such as an input layer, few hidden layers, and output layer. Nodes of one layer are interconnected to the nodes of another layer with associated weight component and threshold value.

Node is activated only if the outcome of any individual node is crossing the specified threshold value, and it is also expected to send data to the subsequent layer of the CNN. No data is communicated to the next layer in case of threshold criteria not satisfied.

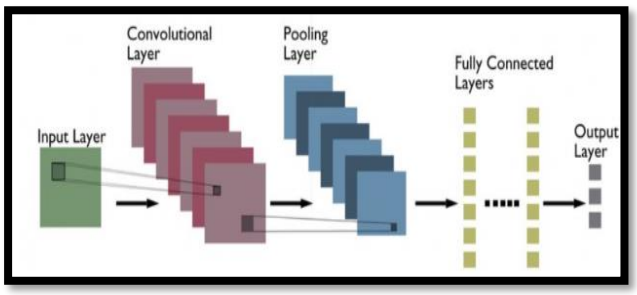

Fig. 5. CNN basic diagram

Convolutional neural networks[25] are well suited for image, speech, or audio signal inputs as they are designed to keep in mind these facts and provide better results. CNNs have three types of layers namely:

1. Convolutional layer
2. Pooling layer
3. Fully-connected (FC) layer

1. Convolutional layer: -This is core building block of CNN, which is handling major computation. It is comprising of following parts, input image, a filter function , and feature map. Kernel is acting as filter, which can move across the multiple segments of the image, to check availability of characteristics. This process is defined as convolution.
2. Pooling layer: - It can also term as down sampling. It minimizes number of parameters in the input. Further kernel implements the aggregate function to the numbers in receptive nodes., generating the output values. This will offer help to mitigate difficulty, efficiency optimization, and minimize concept of overfitting It is of following types:
   - Max pooling .
   - Average pooling
3. Fully-Connected Layer- Every node in the next layer is associated with directly to node in the previous layer. Based on feature extraction classification are executed in

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every layer. Further a SoftMax activation function is used to categorize images correctly. This will give a numerical value of probability from 0 to 1.

The above discussion regarding CNN summarizes the key point regarding CNN and now variants of CNN discussed which are used in the detection of traffic sign.

CNN implementation for the TSD problem in transportation system begins in [26].

Multiple researchers implement CNN classifier to categorize objects in the image from backgrounds with help of ROIs extraction methods to get candidates. Networks like You only look once (YOLO) have fast performance. This [5] implement YOLOv2 in the transportation system for real-time traffic sign detection.

R-FCN [27], Mask R-CNN [28] utilizes multi-task learning to generate Faster R-CNN. There are three outputs generated by Mask R-CNN: label associated with class, bounding -box offset and an object mask. Speed and accuracy of Fast R-CNN is superior to R-CNN.

Feature map is generating the required proposal in step 1 , features were input directly into the subsequent classifier, this provides advantage in terms of memory utilization. Moving forwards a ROI -pooling layer was integrated for generation of fixed size features from the region in step 1.

B. *Traffic sign recognition:*

Once detection of object in the image has successfully completed, the next step is proper recognition of object in the image. When it comes to traffic sign domain it is utmost important to recognise with high accuracy rate as it is used in real life applications.

ConvNet [29] was modified by Pierre Sermonette in feeding stage features in classifier. This system produced the better accuracy of 98.97%. Multistage real-time Traffic Sign Recognition system[30] comprises of a segmentation, a detection, and a classification phase is given by Ms Fatima. For content identification, tree classifiers, K-d tree and Random Forest, are implemented. Further enhancement in terms of feature selection can be performed by Random Forest and Fisher's Criterion.

Scale invariant feature transformation were introduced by Benjamin. In [31]. It can also integrate with shape-based approaches. Further addition of contracting curve density (CCO) methods provides more refine result for detection. Therefore, a significant amount of increase in performance of subsequent classification module are observed. Next a summary table has been presented to compare the techniques related to recognition.

C. *Traffic sign classification*

After ROI (Region of interest) localization classification algorithms are implemented to discover the fundamental parts of the detected traffic signals, insights of identified traffic sign image and with this information classification algorithms will provide traveller/drivers data to better understand traffic rules that traffic sign is enforcing. Further classifier receives features as input which differentiate the images from others. In addition to this template matching, decision tree ,genetic algorithm etc can also perform Classification.

TABLE I. VARIOUS RECOGNITION ALGORITHMS

Author	Technique	Advantage
Sebenza [21]	Multilayer hierarchal system, based on PCA	Took only 2.5 Second for detection and recognition, used in US
Lafuente-Arroyo[22]	Advanced Kalman filter	Fast and advanced method
Ohara, H.[23]	Kalman filter	Well perform in recognition
De La Escalera[24]	Based on genetic Algorithm	Unaffected by illumination
Chen, L[25]	ADA Boost, CHT	Real time and robust with recognition

The low-measure technique of template matching involves searching the entire picture with respect to pixels or moving out small window over the image to matching Ohara et al. [32] and Torresen et al.both employed it for TSDR. with a success ratio of 90% on dataset of imaged photos. It has advantages of being quick, simple, and accurate. This method's disadvantage is that it is extremely susceptible to occlusions and background noise.

The second most popular classification technique makes use of an ANN (ANN). Major upper hand of ANN classifier [33] is the simultaneously recognition and classification of objects and it also show positive trend in speed and accuracy.

IV. TRAFFIC SIGN DATA SETS

A data set is a collection of data. In this domain of traffic sign various dataset contains set of images and information related to traffic through which observations, measurements, study, or analysis is carried out to perform new experiment. A brief summary of well-known data sets is listed below:

1. The German Traffic-Sign Detection Benchmark (GTSDB) : (objective: detection, Classes:43, total images:900)
2. The German Traffic-Sign Recognition Benchmark (GTSRB): (Objective: Recognition, Classes:43, total images:50000+)
3. The Belgium Traffic Signs (BTS) dataset :
4. (Objective: detection, Classes:62, total images:25634)
5. The Mapping and Assessing the State of Traffic Infrastructure (MASTIF) : (objective: detection and Recognition, Classes:9, total images:4875)
6. The Swedish traffic-sign dataset (STSD) : (objective: detection and Recognition, Classes:7, total images:20000)

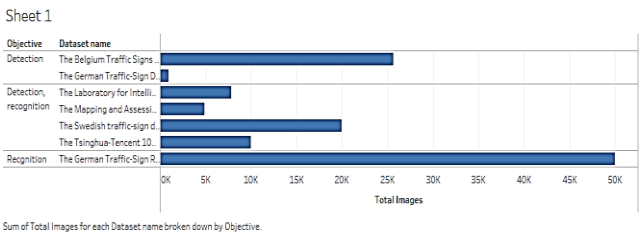

Fig. 6. Summary of datasets

7. The Laboratory for Intelligent and Safe Automobiles (LISA) Dataset (objective: detection and Recognition, Classes:49, total images:7855)

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8. The Tsinghua-Tencent 100K dataset : (objective: detection, and recognition, Classes:49, total images:100,000)

V. Experiment Work

In this section, traffic sign recognition has been performed by DENSE-Net. The Recognition system trained using The German Traffic-Sign Recognition Benchmark (GTSRB).This is a frequently cited datasets used in traffic sign engineering. The CNN based classifier classifies every input into 43 sign classes. This model is used for image classification using the Sequential model from Keras. The model consists of a sequence of layers:

1. The first layer is a convolution layer contains 16 filters of 3x3, using the ReLU activation function. This layer also specifies the input shape of the model.
2. Next layer is another convolution layer with 32 filters of size 3x3, using the ReLU.
3. Third layer is based on max pooling with a pooling window of 2x2. This layer reduces the size of the input .
4. The fourth layer is a batch normalization layer. This layer normalizes the activations of the previous layer.
5. 64 and 128 filters are present in fifth and sixth layers respectively. Kernel size is 3x3 and activation function ReLU is used.
6. The seventh layer is max pooling layer with a pooling size of 2x2.
7. The eighth layer is another batch normalization layer.
8. The ninth is a flatten layer, which transform the 3D output into 1D vector.
9. The tenth layer is a dense with 512 units and the ReLU activation function.
10. The eleventh layer is another batch normalization layer.
11. The twelfth layer is a dropout layer with a rate of 0.5. This layer randomly sets half of the units in the previous layer to which helps prevent overfitting.
12. The final layer is dense with 43 units and SoftMax activation function and categorize into classes.

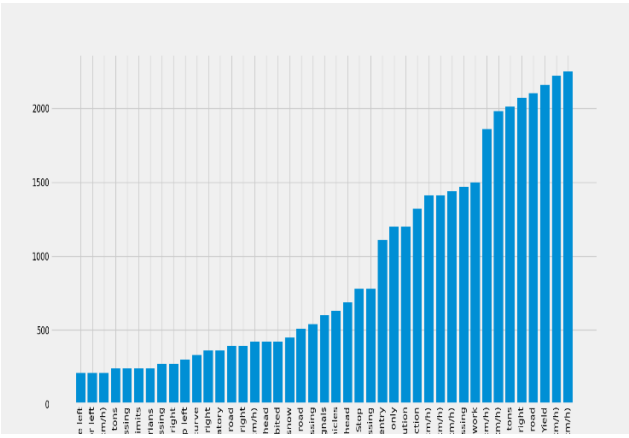

Fig. 7. pictorial representation of dataset

A. Dataset

GTSRB dataset comprises over 50,000 images from all the 43 classes of signs. An overview of dataset is presented with bar chart-

Further for pre-processing of data all images are resizing the images to 30x30x3. Then changing the list to NumPy array. Training data and validation data are separated.

Following parameters values are set

TABLE II. Parameters Description

SNO	PARAMETER	VALUE
1	shear range	0.15
2	width_shift_range	0.1
3	zoom range	0.15
4	height_shift_range	0.1
5	rotation range	10

B. Result analysis-

This subsection focuses on evaluating the performance of the model. Model is going to train with 30 epochs. Accuracy and **loss** measure is used for performance. Confusion matrix is also generated for the algorithm. Confusion matrix consist of actual value and predicted values which provide visualization of the performance of an algorithm.

TABLE III. TP,TN,FP,FN Description

	ACTUAL AND PREDICTED
TP	SAME
TN	SAME
FP	DIFFERENT
FN	DIFFERENT

With the help of confusion Matrix, Accuracy ,Precision , Recall and F1-score can be calculated with following formulas.

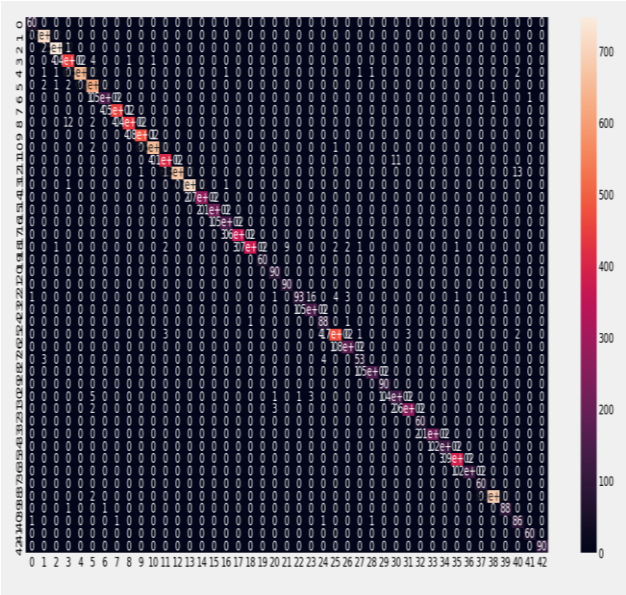

Fig. 8. Generated Confusion matrix

ACCURACY=

(TRUE POSITIVE+TRUE NEGATIVE)/(TP+TN+FP+FN)

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PRECISION = (TRUE POSITIVE) / (TP+FP)

RECALL = (TRUE POSITIVE) / (TP+FN)

F1-SCORE= 2* PRECISION * RECALL / (PRECISION +RECALL)

THE SIZE OF CONFUSION MATRIX IS 750* 750 .

Now moving to testing phase of the model set of images are provided to model to further check that is there any variation in actual result and predicted result. Figure 9 contains various images of actual and predicted output for many classes belongs to 43 classes in dataset. Various test case results are displayed below in Fig: 9,10,11.

Fig. 9. Test images result1

Fig. 10. Test images result 2

Fig. 11. Test images result 3

The above figure shows the various traffic sign with actual category and predicted category. The model performs well in this process. Furthermore, evaluation metrics "ACCURACY " and "LOSS" both are calculated. AL_LOSS , VAL_ACCURACY is also computed which shows significant results are obtained.

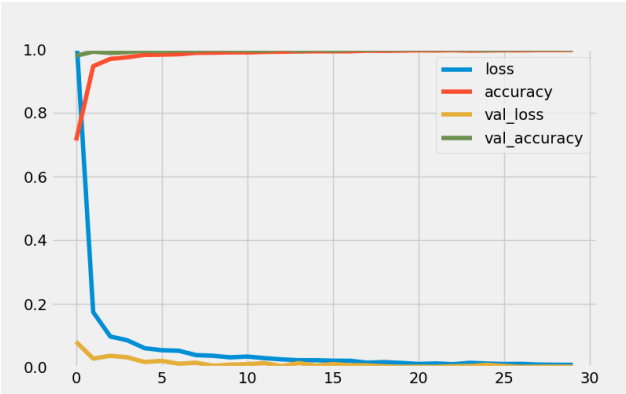

Fig. 12. Accuracy and loss in training and validation

VI. Current Issues And Challenges

Formerly used tools and technologies in this domain were not well performed due to many real time parameters. Complex driving, small sizes, rotation, occlusions, illumination effect etc also create difficulty to tackle with AI based applications.

A handful methods emphases on detection problem in night, such as street lighting, dark lighting, and headlight reaction. Poor weather conditions like snow, fog, shower was not considered in past approaches. For future research prospects, modern techniques and updated data sources that is capable of dealing with night and bad weather conditions are needed for improving current approaches. However, there are few non-technical provocations in real environment which may degrade its performance. These challenges that are required to be take into consideration while developing a system.

Following issues are discussed:

- Unavailability of common data set
- Simultaneous appearance of many traffic signs
- Real time scenario

VII. Conclusion

Fundamental key takes away of this research article is to explore various component of innovation in the domain of self-activating TSDR and to catalogues the major approaches to enhance understanding of topic. Apart from this ,it also offers analytical view of different algorithm and models for variety of purpose like recognition, detection of traffic rule-based images ,which also comprises of latest research problems , challenges, and present time view of TSDR. With the evolution of intelligent transportation system , experimentation in this direction has shown remarkable extension.

Basically, three main steps are followed like Detection, classification and identification. Every subdomain had numerous methods and algorithms. As pros and cons are associated with every algorithm, the hunger to search for better technique is still there. As far as real-world traffic scenario is considered, due to poor image quality, extreme weather environment, illumination variation , blur motion , occlusion, scalability and rotation etc algorithms still need improvements. Further due to multiple variation in traffic sign image , background effects impose challenges to researchers.

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Which derive a path for development of detection and classification algorithm for assimilation of colour and shape-based information. Rate of detection and recognition should be improved and with this average processing time per frame in video should minimize as future scope.

This will lead to reduce accident rate and increase the public safety in transportation. As continuous evolution in autonomous vehicles is in trend , this algorithmic based assistance TSDR can also integrated with autonomous vehicles.

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