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A Convolutional Neural Network Classifier for Recognition and Detection of Traffic Signs

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Abstract: The objective of this paper is to design Convolutional Neural Network (CNN) Classifier using Keras API with Tensorflow as backend to identify traffic or road signs with high accuracy and low loss. The code is written in Python programming language. Deep Learning domain based CNN, in recent years, have made extraordinary progress in the field of image classification and object identification. The network is trained, validated and tested using German Traffic Sign Detection Benchmark dataset which comprises of 43 categories of signs and around 52,000 distinct traffic sign color images. Implementation of this network into an accessory device assumes a significant place inside the automobiles which can ensure safety to driver's life and is considered as a very useful feature for self-driving automobiles. Artificial Intelligence is advancing and progressing rapidly in such a way that this technology has turned out to be a game changer in almost all sectors like Automobile, Medical, Social media, Analytics, Education, Retail etc. Researchers of this field started showing more interest in creating innovative and useful technologies, out of which, Assistance System for Driving is still under progress. Most of the automobile companies like Honda, Ford, Audi, Tesla, and Benz etc. are working to bring self-driving cars into existence. Driving Assistance Systems have gotten an ever increasing number of considerations from various automobile companies. Among different elements of self-driving assistance technology, the traffic sign identification has gotten one of the most significant weightage since it gives cautions to the drivers to relieve the stress during driving and mostly reduces road casualties.
Keywords: Convolutional Neural Network (CNN), Classifier, Python, Deep Learning, GTSRB, Image classification, Visualization, Detection, Dropout and Traffic signs.

I. INTRODUCTION

A. Problem Statement

Road traffic accidents and deaths has become an unpredictable and ceaseless global issue. Practically every day, we run over the update on some mishap related to road casualties on the TV, radio and web. A great many people continue to neglect and overlook the risks engaged with their reckless driving by not bounding to the traffic or road rules thus, these mishaps occur.

Here is a list of different factors leading to road fatalities:

1) Careless driving like over speeding, violation of rules, inability to understand traffic signs, avoiding safety measures like seat belts and helmets, alcohol consumption by drivers.
2) Break failures, tire burst, headlights issue and over-burdening of vehicles.
3) Bad weather conditions like heavy rainfall, fog, snow and wind storms.
4) Passerby negligence like crossing at wrong places.
5) Awful road conditions. For example, damaged road, potholes, disintegrated street converging of provincial roads with parkways and roads with irregular speed breakers.
6) Travellers blunders like projecting their body outside vehicle, travelling on footpaths, getting a running transport and so forth.

As per the World Health Organization (WHO), more than 1 million individuals are knocked off on the world's roads every year [1].

According to Annual Global Road Crash Statistics, roughly 1.35 million people kick the bucket in road crashes every year, on normal 3700 individuals lose their lives. In addition, an extra 20-50 million endure non-deadly injuries, frequently bringing about long term disabilities [2].

Fig. 1 represents number of deaths per 100,000 individuals due to road traffic accidents. The red colored countries depict that highest death rate is recorded there, green colored countries indicate average death rate, whereas in gray colored countries low death rate is recorded.

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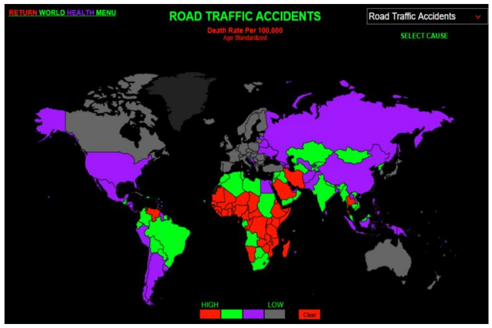

Fig. 1 Worldwide Road Traffic Death Rate per 100,000 people, Source: WHO 2018

B. Why learn and notice Traffic signs or Road rules?

Traffic signs portray an indispensable job in coordinating, advising and controlling road user's conduct with an end goal to make the roads as safe as possible for everybody. This marks that information on traffic signs as fundamental, not only for new drivers or riders expecting to breeze through their driving theory test, however for all road users like drivers, walkers, motorcyclists and those in charge of animals (like dog walkers). They speak to decides that are set up to protect you, and help to impart messages to drivers and people on foot that can keep everything under control and diminish mishaps. They are gadgets set along, adjacent to, or over a parkway, street, pathway to direct, caution, and control the progression of traffic, including engine vehicles, bikes, walkers, equestrians, and different travellers [3]. The intention of the traffic or road rules is to prevent road casualties and to hold individual responsibility for utilization of our roads, and in implementing so some become enhanced, more secure and all the more socially mindful road users.

C. Is it necessary to keep updated about traffic signs?

Yes. We live in the midst of progress. Society, innovation and the economy all have their impact in changing the manner in which we travel. New traffic signs passing on new messages and in new configurations are acquainted from time with time, so drivers or riders who finished their driving assessment a couple of years back need to stay up with the latest signs to comprehend or be in accordance with lately introduced traffic or road signs.

B. Solution

Along these lines, this project is picked so as to limit the road casualties brought about via automobiles because of infringement of traffic rules and unawareness of all traffic signs meaning by drivers as a factor. This paper presents a modern solution to minimize the problem factor. The methodology taken to implement a solution to put a stop to road accidents made via automobile drivers is by ensuring that each traffic or road sign along the road way they are driving is notified to them with the help of a high resolution mini camera installed at front of the automobiles, so that they will stick to the traffic rules and drive cautiously. Mini camera fitted plays a fundamental role in recognizing traffic or street signs embedded at distinct places and in various road ways. In the wake of perceiving a specific sign, it alarms the driver about the traffic sign and its significance. In this way, that the driver adheres to the directions that are tracked and produced by the camera which will be shown on the noticeable screen introduced inside in the car. The role of the camera is only to detect and capture the traffic sign objects. The process of analyzing and classifying the traffic signs is executed by a Convolutional Neural Network (CNN) model implemented.

D. What is CNN?

A Convolutional Neural Network (CNN) is a Deep Learning algorithm which can take in an input image, assign significance to different viewpoints or objects in the image by updating the training model parameters like weights and biases, and have the option to separate one from the other. It is a class of deep neural networks, which have its applications in fields like image and video recognition, recommender systems, image classification, medical image analysis, natural language processing and financial time series [4].

In this paper, the CNN model or algorithm is carried out using Python programming language and its core libraries Keras and Tensorflow. In addition to, libraries like Numpy, Pandas and Matplotlib are also utilized. The compilation of entire python code and the generation of outputs are performed on an open source web application Jupyter Notebook.

Both the theoretical work and practical implementation of the CNN model is mentioned in the proposed modeling section.

II. RELATED WORK

In this paper, a deep learning based street traffic signs identification strategy is created which is extremely encouraging in the improvement of Advanced Driver Assistance Systems (ADAS) and self-driving vehicles [1]. The framework architecture is intended to draw out chief features from digital images of traffic signs to arrange them under various classes. The introduced technique utilizes an altered LeNet-5 system to separate a profound representation of traffic signs to play out the recognition process. It is comprised of a Convolutional Neural Network (CNN) altered by interfacing the yield of all convolutional layers to the Multilayer Perceptron (MLP). The preparation is led utilizing the German Traffic Sign Dataset and accomplishes great outcomes on recognizing traffic signs.

Yujun Zeng, et.al [2] model is especially for automated driving and driver assistance. Its precision relies upon two characteristics: feature exactor and classifier. In this paper, a novel CNN-ELM model is proposed, which incorporates the CNN's tremendous ability of feature learning with the remarkable performance and execution of ELM. Right off the model CNN learns profound and robust features and afterward ELM is utilized as classifier to direct a fast and quick classification. Experiments on German traffic sign identification benchmark (GTSRB) show that the proposed technique can get competitive outcomes with state-of-the-art algorithms and with less calculation time. In this thesis, a model is created by Jinamin, Viktor [3] for detection of edge of the road, objects on the road, traffic lights and traffic signs using Canny edge detection, threshold, Hough method and SURF algorithm.

Kwangyong Lim, et.al [4] presents a General Purpose Graphics Processing Unit (GPGPU) based real-time traffic sign detection and recognition method. Though there have been numerous ways to deal with traffic sign recognition in different exploration fields, this model is designed to defeat the downsides of previous approaches and improve processing speeds, by proposing a strategy that 1) is robust against illumination changes, 2) utilizes GPGPU-based continuous traffic sign location, and 3) performs region detection and recognition utilizing a various leveled model. This strategy produces stable outcomes in low illumination environments.

Yoshinori Komokata, et.al [5] proposed a road sign classification system utilizing C-CNN (cascade convolutional neural system) classifier. The cascade data is planned so the classifier can undoubtedly converge with the data. Their framework comprises of six phases of Network in Network (NiN) design based CNN classifier. The information growth strategy is utilized to enhance the training and testing dataset which likewise tests the heartiness of our framework. The chosen Japan street sign dataset comprises of ten classes with 7,500 models for each class. Each image cropped from real street images is taken by the camera joined to the head of the vehicle. From the analyses, the framework is more productive contrasted to bag-of-features method. The execution session of framework is less than 20 ms utilizing proper hardware configuration, which is reasonable for continuous application approaches like an autonomous car or driver assistance. Altaf Alam and Zainful Abdin Jaffery's proposed algorithm [6] is to categorize the Indian traffic sign as obligatory preventative and informatory class. So as to finish the assignment, 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 is utilized to understand the features data. Whisker plot visualization concluded about the range, skewness, median and outliers of feature data therefore, it makes the framework proficient to keep great features and back out from irrelevant features. Feature refinement lessens the computational unpredictability.

Jean de Dieu, et.al center thought is to utilize CapsNet to distinguish and do grouping of road traffic sign. Capsule network model has accomplished the best in class exactness of 98.3% on German traffic sign recognition benchmark dataset [7, 1]. Capsule networks comprise of capsules as opposed to neurons. Capsule is a gathering counterfeit neural system that performs convoluted interior calculations on their data sources and typifies the outcomes in a little vector. Each capsule catches the relative position of the object and if the object present is considerably more powerful at including invariance than the primitive routing introduced by max-pooling. Caps Net comprises of numerous layers and the principal layer is called essential containers where each capsule gets a little aspect of the open field as info and attempts to recognize the posture of particular pattern.

A quick and completely parameterizable GPU execution of a Deep Neural Network (DNN) that doesn't need cautious structure of pre-wired component extractors, which are somewhat learned in a supervised way is constructed. Joining different DNNs prepared on distinctively preprocessed data into a Multi-Column DNN (MCDNN) further lifts recognition performance, making the framework insensitive additionally to varieties conversely and light [8, 4].

In Yingying Zhu, et.al [9] proposed strategy two network models are utilized. One is completely convolutional network prepared at pixel-level to anticipate the coarse sign regions; the other is CNN that makes final categorization of traffic or road signs. The two systems are adjusted and prepared dependent on STSD. The proposed technique use FCN to remove coarse sign areas to diminish the number of proposals of EdgeBox, while guaranteeing that the identification or detection rate isn't decreased.

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III. METHODOLOGY

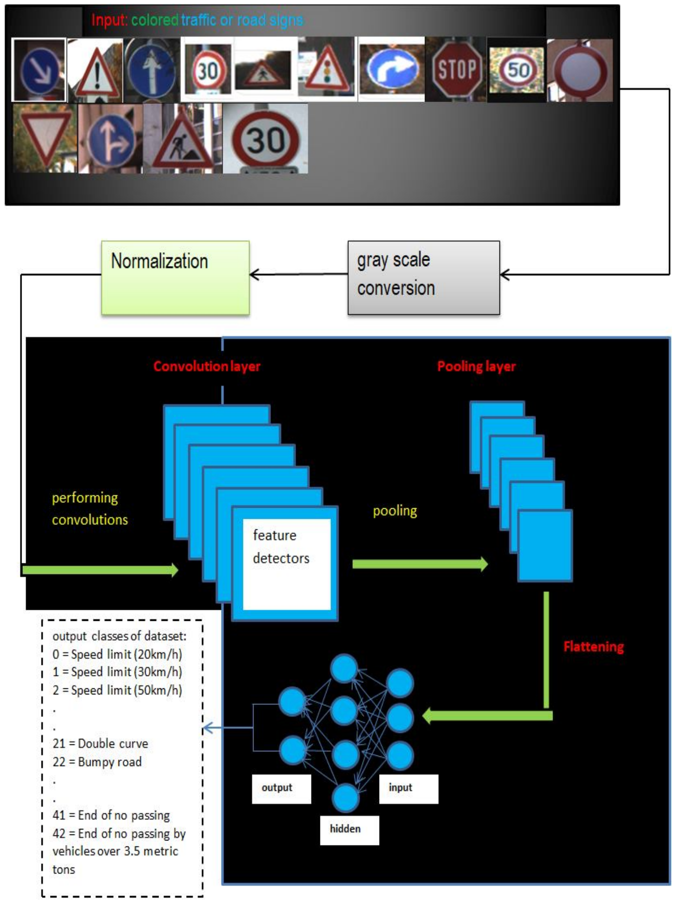

Fig. 2 Proposed models' architecture

A. Dataset

[7, 1] GTSRB – German Traffic Sign Recognition Benchmark images and classes available in Kaggle community is chosen as the dataset for this paper. The dataset consists of 43 labeled classes and around 52,000 colored images in total. Here, the entire dataset is partitioned into 3 types:

1) *Training Dataset:* The actual data which is used to train the network model. It is also used for gradient calculation and weight updates.
2) *Validation Dataset:* The data which is helpful in fine tuning the model hyper parameters. As this dataset plays a vital role during development stage of model, it can also be called as development set.
3) *Testing Dataset:* The dataset used for testing the trained network model. This dataset should never been introduced to the model during training.

Fig. 3 Visual representations of the splits of dataset

Generally, in any convolutional neural network models, only training and testing datasets are used. But in our network model along with training and testing, validation dataset is also utilized.
Why do we need validation or development dataset?
Validation dataset is used to perform cross-validation which avoids data over fitting of the network. It makes sure that our network model is able to generalize and not memorize the data.

B. Gray scale conversion

Originally, the dataset includes color traffic sign images which are 32 pixels wide and 32 pixels in length. The color images comprises of three channels (RGB: Red, Green, and Blue). It is typically not prescribed to utilize color images to prepare a convolutional neural network, as it diminishes the performance of the network. Accordingly, the color images are changed over to gray scale images.

Why do programmers incline toward gray scale images to color images so as to build Convolutional Neural Network (CNN)?

Generally, using a color image increases the number of inputs 3 times compared to gray scale image. In correspondence to the point stated, the number of trainable parameters of network is high which sometimes tend to over fit the data. Therefore, we convert color images to gray scale images in order to attain high accuracy of network by minimizing the number of trainable parameters.

C. Normalization

Normalization of data takes place after converting the color images to gray scale images.

Normalization of data can be defined as a combinational process of scaling and centering of data.

1) Scaling ensures that the entire data lies on same scale. It improves the accuracy and convergence speed of the network.
2) Centering is all about balancing the data around a fixed point which ensures whether each input parameter (i.e., image pixels in this paper) has a similar data distribution or not.

D. CNN classifier

The entire network end to end takes traffic sign images as inputs and generates a target label as output. The classifier is made up of following four layers to achieve the objective of this paper.

1) *Convolutional Layer:* It is a CNN layer where convolutions are performed on the input image. This layer comprises of user-specified parameters like number of kernels, kernel size and number of feature detectors. Feature detectors are used to perform feature extraction from the image. After convolutions are performed on the image, a linear function named relu (rectified linear unit) is activated. The sparsity of feature maps can be increased by using relu.
2) *Pooling Layer:* It is another building block of CNN. The feature maps generated by applying convolutions on the image are passed to pooling layer. The functionality or purpose of pooling layer is to reduce or compress the size of feature maps. It means the number of parameters and computations in the network are reduced. This layer operates independently on each feature map.
3) *Flattening Layer:* This layer is usually present in between the convolutional layer and fully densely connected layer. In this layer, the output generated by pooling layer is flattened by converting the pixel values of image into a single array of values.
4) *Fully and Densely connected Layer:* This layer is termed as the base layer of Convolutional Neural Network. It consists of bunch of inputs, hidden layers and outputs. The flattened array values are passed as input, which go through this layer to classify the traffic sign images. As it is a neural network, all input, hidden and output layers are treated as neurons.

E. Target or output labels

The traffic signs present in our dataset gets classified under the mentioned 43 target or output classes.

Table I
List of 43 Target Labels

S No	Class label	S No	Class label
0	Speed limit (20km/h)	22	Bumpy road
1	Speed limit (30km/h)	23	Slippery road
2	Speed limit (50km/h)	24	Road narrows on the right
3	Speed limit (60km/h)	25	Road work
4	Speed limit (70km/h)	26	Traffic signals
5	Speed limit (80km/h)	27	Pedestrians
6	End of speed limit (80km/h)	28	Children crossing
7	Speed limit (100km/h)	29	Bicycles crossing
8	Speed limit (120km/h)	30	Beware of ice/snow

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9	No passing	31	Wild animals crossing
10	No passing for vehicles over 3.5 metric tons	32	End of all speed limit
11	Right-of-way at the next intersection	33	Turn right ahead
12	Priority road	34	Turn left ahead
13	Yield	35	Ahead only
14	Stop	36	Go straight or right
15	No vehicles	37	Go straight or left
16	Vehicles over 3.5 metric tons prohibited	38	Keep right
17	No entry	39	Keep left
18	General caution	40	Roundabout mandatory
19	Dangerous curve to the left	41	End of no passing
20	Dangerous curve to the left	42	End of no passing by vehicles over 3.5 metric tons
21	Double curve		

IV. RESULTS AND DISCUSSIONS

A. *Performing Image Visualization*

This is done with the help of matplotlib python library. The data is shuffled using scikit learn to make sure that network does not learn order of the images. Fig. 4 & Fig. 5 represents random traffic sign images along with their predefined label shown as a number (from 0 to 43) on top of it. The images are contained in grid whose dimensions (length and width) are customized by user. The length and width values of grid multiplied outputs the number of traffic sign images displayed.

Fig. 4 Grid format of 25 traffic sign images with accurate output label

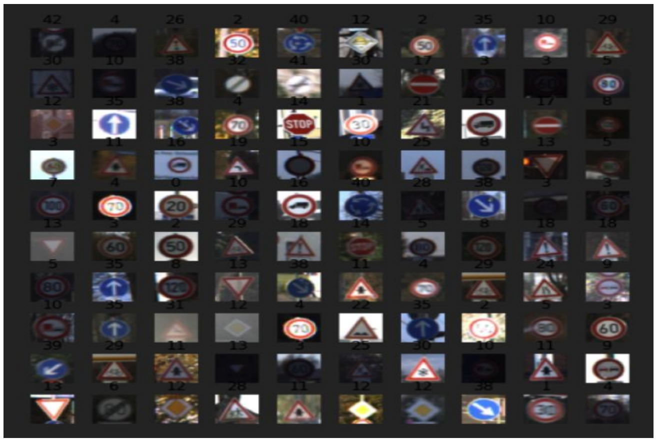

Fig. 5 Grid format of 100 traffic sign images with accurate output label

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B. Color, Gray scale and Normalized image Visualization

Fig. 6 depicts transformation of a color traffic sign image to gray scale image and then to a normalized image.

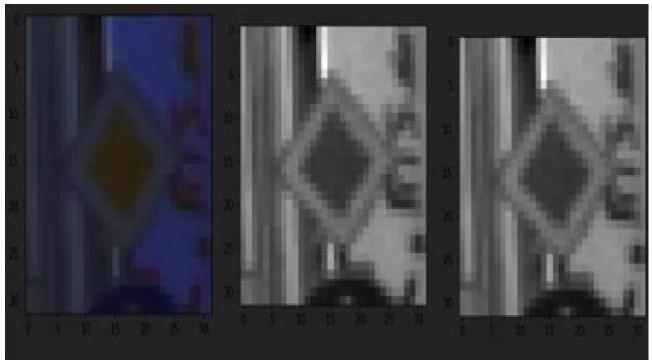

Fig. 6 A color, gray scale and normalized traffic sign image

C. Practical Implementation of Dropout Technique to Improve Network Accuracy

Dropout is a regularization technique for reducing over fitting in Convolutional Neural Networks. This technique improves the accuracy of classifier network to dropping a number of neurons which developed co-dependency among each other during training.

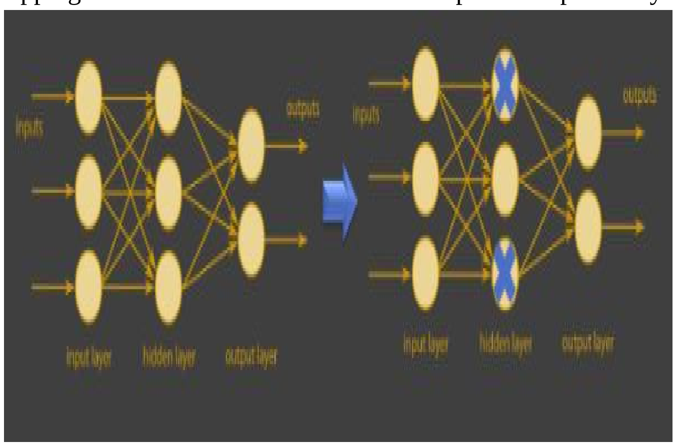

Fig. 7 Reducing number of neurons using dropout technique

The above process can be explained practically using Fig. 8 & Fig. 9. Fig. 8 represents CNN without implementation of dropout technique. As you can see, number of parameters to be trained are 155,215 are shown at the end.

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 28, 28, 6)         156
_________________________________________________________________
average_pooling2d (AveragePo (None, 14, 14, 6)         0
_________________________________________________________________
flatten (Flatten)            (None, 1176)              0
_________________________________________________________________
dense (Dense)                (None, 120)               141240
_________________________________________________________________
dense_1 (Dense)              (None, 84)                10164
_________________________________________________________________
dense_2 (Dense)              (None, 43)                3655
=================================================================
Total params: 155,215
Trainable params: 155,215
Non-trainable params: 0
```

Fig. 8 Implementation of network without dropout

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Fig. 9 clearly illustrates the CNN classifier redefined using dropout technique. Using this technique, number of neurons are reduced which in turn minimizes number of trainable parameters to 64,511.

```
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 6)         156
_________________________________________________________________
average_pooling2d_1 (Average (None, 14, 14, 6)         0
_________________________________________________________________
dropout (Dropout)            (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
average_pooling2d_2 (Average (None, 5, 5, 16)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_3 (Dense)              (None, 120)               48120
_________________________________________________________________
dense_4 (Dense)              (None, 84)                10164
_________________________________________________________________
dense_5 (Dense)              (None, 43)                3655
=================================================================
Total params: 64,511
Trainable params: 64,511
Non-trainable params: 0
```

Fig. 9 Implementation of network with dropout

D. Accuracy and Loss Comparison of Training and Validation Data

From Fig. 10 & Fig. 11 it is clear that as number of epochs increases, accuracy of training and validation data increases whereas loss of training and validation data minimizes.

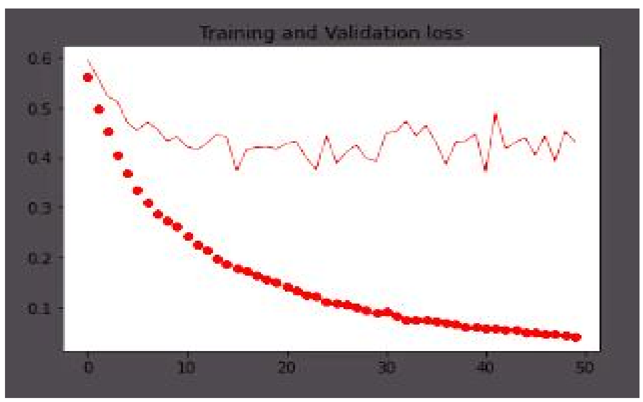

Fig. 10 Loss plot of training and validation data

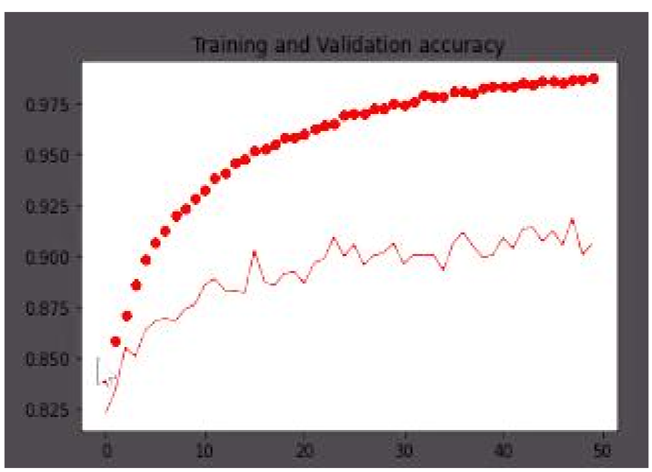

Fig. 11 Accuracy plot of training and validation data

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E. Assessing the Network Classification Performance using Testing Data

From Fig. 12 it can be concluded that the Convolutional Neural Network designed for classifying traffic sign images works accurately and faultlessly. The network classifier is trained and tested with the testing data.

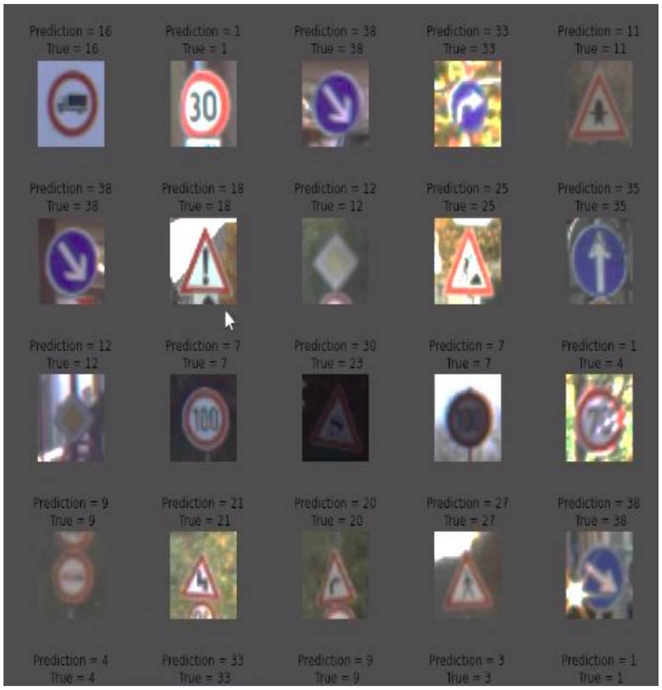

Fig. 12 Result of testing data generated by CNN classifier

V. CONCLUSION

In this paper, a Convolutional Neural Network based classifier is implemented to recognize and classify traffic or road sign images. Initially, the images chosen are colored. They are converted to gray scale and normalized by applying simple computations using python language. And then the manipulated traffic sign images are sent to CNN classifier with fixed and learnable layers like convolutional layer, pooling layer, flattening layer and fully connected dense layer for detection and categorization. In between sets of convolutional and pooling layers, dropout regularization technique is added to the network. This technique minimizes number of neurons in hidden layers of neural network and leads to increase in performance of network. The network after getting trained, validated and tested shows an overall accuracy of 98.70% and loss of 4.15% for training data, whereas for validation data accuracy is 90.38% and loss is 4.3%. During testing the accuracy of network is 95.3%.

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