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Deep Learning Based Indian Traffic Sign Detection And Recognition System

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ABSTRACT
Traffic sign detection and recognition is a critical component of intelligent transportation systems and autonomous driving, particularly in complex and unstructured environments such as Indian road networks. This study proposes a deep learning-based framework for robust detection and classification of Indian traffic signs using a combination of object detection and Convolution Neural Network (CNN) models. The methodology integrates a real-time detection model to localize traffic signs in input images, followed by a CNN-based classifier to accurately categorize the detected signs into predefined classes such as mandatory, cautionary, and informatory signs. A comprehensive dataset comprising diverse Indian traffic scenarios is utilized, incorporating variations in illumination, occlusion, weather conditions, and sign degradation. Data preprocessing techniques, including normalization and augmentation, are employed to enhance model generalization. The system is implemented on a cloud-based platform using GPU acceleration, enabling efficient training and scalability. Transfer learning strategies are further incorporated to improve performance and reduce training time. Experimental results demonstrate that the proposed model achieves high detection accuracy and classification performance, outperforming conventional methods under challenging real-world conditions. The framework also exhibits real-time processing capability, making it suitable for deployment in advanced driver assistance systems and smart mobility solutions. The proposed approach contributes to improving road safety and supports the development of intelligent, automated traffic monitoring systems in developing countries.

Keywords- Traffic Sign Recognition (TSR), Convolution Neural Networks (CNN), Deep Learning.

I. INTRODUCTION
Traffic-sign identification and classification is an intriguing part in computer-vision and it is particularly important with regards to self-governing vehicle innovation. Traffic sign recognition is an innovation by which a vehicle can perceive to recognize the traffic sign put on the street for example, "speed limit" or "turn ahead". Traffic signs can be analyzed utilizing front oriented cameras in numerous modern vehicles and trucks. They insist the driver by providing commands, admonitions and some of the times by taking control of the vehicle itself. For instance, in a 40 km/hr speed zone, if the driver surpasses that speed, the framework gives warnings. On the off chance that the driver keeps on driving the system will take the control. Understanding scene is the definitive objective of computer vision, distinguishing and grouping objects of different sizes in the scene is a significant sub-task. As of late, deep learning strategies have demonstrated predominant execution for some

undertakings such as speech recognition and image classification [1]. One specific alternative of deep neural networks is convolution neural networks (CNNs), have delineated their qualities for errands consisting image detection, classification and localization. Traffic signs might be partitioned into various classes based on to the function, and in every classification they might be further divided into subclasses with comparative nonexclusive shape and appearance however changed subtleties. This proposes traffic-sign recognition ought to be completed as a two-stage task: detection pursued by classification. The detection step uses shared data to recommend bounding boxes that may contain traffic-signs in a specific classification, while the classification step utilizes contrasts to figure out which specific sort of sign is present. Google Co laboratory which is used for the implementation is an explorative tool for machine learning research. It’s a Jupiter notebook environment that needs no setup to utilize. Co laboratory works with most real programs, and is most completely tried with work area forms of Chrome and Firefox. Code is executed in a virtual machine committed to your record. Virtual machines are reused when inert for some time, and have a superlative lifetime authorized by the system. Co laboratory is expected for intelligent use. Long-running foundation calculations, especially on GPUs, may be halted. The German traffic sign detection benchmark dataset is used for experiment and evaluation the proposed approach. This dataset was collected in different scenarios of real traffic scenes [2].

II. PROBLEM STATEMENT

Traffic sign recognition and detection is a critical component of intelligent transportation systems. However, current systems suffer from limitations in accuracy, speed, and robustness, which can lead to safety hazards on the road. We need to develop an accurate and efficient system that can detect and recognize traffic signs in real-time from image or video streams captured by cameras mounted on vehicles or other devices. The system should be able to differentiate between different types of traffic signs based on their shape, color, and symbols, and accurately classify them according to their intended meaning. In particular, detection and recognition of traffic signs in adverse weather conditions or in low-light environments, as well as variations in the position, size, and orientation of the traffic signs in the image or video remains a challenge. Additionally, the system should be able to operate in real-time, with minimal latency, to allow for timely responses to the information conveyed by the traffic signs [3]. Therefore, there is a need to develop more accurate, efficient, and robust traffic sign detection and recognition systems that can operate in a variety of real-world conditions. Such systems could improve road safety and reduce the number of accidents caused by driver error or lack of awareness of traffic signs [4].

III. METHODOLOGY TRAFFIC SIGN IN INDIA

Traffic signs are the noiseless chatterers on the street. Is it the individual overdue the wheel or a unimaginative, having a detailed information about road safety is obligatory for whole previously thumping the streets. Traffic signs stretch information nearby the street environments gaining, proposition instructions to be pursued at the principal crossing or intersections, inform or controller drivers, and sanction proper operational of street traffic. Being unacquainted of street signs is corresponding to chucking attentiveness to the tempest. It can central to penalization of life and property. A person is imaginary to be habituated (get complete a adorned or oral test) with

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the traffic signs and symbols before locating a driving license in India. Habitually, there are three unalike kinds of street symbols in India [5].

Mandatory Signs

As we can appreciate from the name that these are the signs which requirement to be surveyed appropriately experimental it is a delinquency to un-follow them. One might be dispensed challenge if he/she fails to monitor them. These signs are used to variety certain the free undertaking of vehicles concluded the road network.[6] The driver made cognizant of the boundaries completed the road with the help of these symbols. Sings Originates under this grouping is like: Stop, Give Way, No entry, Pedestrian Prohibited, Horn Prohibited, No Parking, No stopping or standing, Speed limit, Right Hand Curve, Left Hand Curve, Right hair Pin Bend, Left Hair Pin Bend, Narrow Road Ahead, Narrow Bridge, Pedestrian Crossing, School Ahead, Round About, Dangerous Dip, Hump or Rough, Barrier Ahead [7,8,9,10].

Cautionary Signs

These symbols are recycled to cognizant the driver nearby the threats on the road ahead. These symbols are similarly used to cognizant the driver nearby the safety hazards ahead or on the road. These symbols are used to make drive aware and take proper action over them else accident may happen. So, the driver follows these to avoid a personal loss as well as the loss of the infrastructure.[11] These symbols aware the driver so that he/she is able to tackle the upcoming situation. Signs comes under this category is like: Right Hand Curve, Left hand Curve, Right Hand Pin Bend, Left Hand Pin Bend, Right Reversal bend, Left Reversal Bend, Steep Ascent, Steep Descent, Narrow Road Ahead, Road Wideness Ahead, Narrow Bridge, Slippery Road, Loose Gravel, Cycle Crossing, Pedestrian Crossing, School Ahead, Men At Work, Cattle, Falling Rocks, Ferry.

Informatory Signs

These symbols afford further material to the road users. These symbols communicate the employer nearby the road's basic material such as terminus. These are not required signals but are used to support the road users. [12] The symbols come below this grouping is like: Public Telephone, Petrol Pump, Hospital, First Aid Post, Eating Place, Light Refreshment, Resting Place, Through Road, Through Side Road, Park This Side Parking Lot Scooter &Motor Cycle, Parking Lot Cycle, Parking Lot Cars [14].

IV. PROPOSED METHODOLOGY

This chapter illustrates the implementation details of the project. The goal of the implementation phase is to translate the design of the system produced during the design phase, into coded form in a given programming language. It can then be executed by a computer performing the computation specified by the design. The coding phase effects both testing and maintenance profoundly well-written code can reduce the testing and maintenance cost. Implementation is a stage in which the design is converted into working system. Implementation part consists of several stages which contains choosing the programming language, develop environment, using various programming methods and techniques to fulfill the requirement, deciding on which library could be used within the system and how they should be integrated to it [15].

A. Usage Of Tools

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I. Python

Python is an interpreted high-level general-purpose programming language. Python's design philosophy emphasizes code readability with its notable use of significant indentation. Its language constructs as well as its object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects. Python is dynamically-typed and garbage-collected. It supports multiple programming paradigms, including structured (particularly, procedural), object oriented and functional programming. Python is often described as a "batteries included" language due to its comprehensive standard library. Object-oriented programming and structured programming are fully supported, and many of its features support functional programming and aspect-oriented programming (including by Meta programming and meta-objects (magic methods)). Many other paradigms are supported via extensions, including design by contract and logic programming. Python uses dynamic typing and a combination of reference counting and a cycle-detecting garbage collector for memory management. It also features dynamic name resolution (late binding), which binds method and variable names during program execution.

II. Image Processing

Digital image processing is the use of a digital computer to process digital images through an algorithm. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems. The generation and development of digital image processing are mainly affected by three factors: first, the development of computers; second, the development of mathematics (especially the creation and improvement of discrete mathematics theory); third, the demand for a wide range of applications in environment, agriculture, military, industry and medical science has increased.

III. Deep Learning

Deep learning is a class of machine learning algorithms that uses multiple layers to progressively extract higher-level features from the raw input. In deep learning, each level learns to transform its input data into a slightly more abstract and composite representation. In an image recognition application, the raw input may be a matrix of pixels. Importantly, a deep learning process can learn which features to optimally place in which level on its own. This does not completely eliminate the need for hand-tuning; for example, varying numbers of layers and layer sizes can provide different degrees of abstraction.

Implementation Details:

We will implement our CNN in Keras. Keras is a deep learning library written in python and allow us to do quick experimentation. After training and testing the model, we would finally do performance comparison based on accuracy with given number of parameters the model is evaluated. To implement our system, a computer with 3.7 GHz Intel core i3 with 8GB 1600 MHz DDR3 memory is employed. We here are using anaconda python with Theano and keras and other libraries installed for running our code and getting output.

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1. Dataset Acquisition: We need to download ‘Images and annotation’ for training and test set from the GTSRB website and extract them into a folder. Also, we need to download ‘Extended annotations including class ids’ file for the test set. Then we must organize these files in our directory for further accessing in code.
2. Training of Images: Since the representative image consist of noises and vary a lot in illumination and size we need to equalize and normalize these images. Hence, we use functions of histogram equalization in HSV color space and resize the images to standard size. Once the above process is done then we pre-process all the training images and store into NumPy arrays. We also get labels of images from the paths as described in the directory structure. We also convert targets to one-hot form as is required by keras.

The proposed methodology for Indian traffic sign detection and recognition using deep learning is designed as a two-stage framework integrating detection and classification, implemented efficiently on Google Colab. Initially, a comprehensive dataset of Indian traffic signs is collected from publicly available sources and, if required, supplemented with real-time images captured under diverse environmental conditions such as varying illumination, occlusion, weather disturbances, and complex backgrounds. The dataset is then preprocessed by resizing images to a uniform dimension, normalizing pixel values, and applying data augmentation techniques such as rotation, scaling, and brightness adjustment to improve model generalization and robustness.

In the first stage, a deep learning-based object detection model such as YOLO (You Only Look Once) is employed to identify and localize traffic signs within an image. This model processes the input image and generates bounding boxes around potential traffic signs along with confidence scores. These detected regions of interest are then extracted and passed to the second stage for classification. The detection model is either trained on the Indian dataset or fine-tuned using transfer learning to adapt to the unique characteristics of Indian road signs.

In the second stage, a Convolution Neural Network is used to classify the extracted traffic sign regions into predefined categories such as mandatory, cautionary, and informatory signs. The CNN model consists of multiple convolution and pooling layers for feature extraction, followed by fully connected layers that perform classification. The model is trained using labeled data and optimized using suitable loss functions and optimizers to achieve high accuracy. To further enhance performance, transfer learning techniques using pre-trained architectures such as ResNet or Efficient Net can be incorporated.

The entire implementation is carried out on Google Co lab, which provides a cloud-based environment with GPU acceleration, enabling efficient model training and experimentation. The workflow includes dataset loading from Google Drive, preprocessing pipelines, model construction, training, validation, and performance evaluation. Evaluation metrics such as accuracy, precision, recall, and F1-score are used to assess the effectiveness of the model.

Algorithm: Indian Traffic Sign Detection and Recognition (CNN-based)

1) Acquire input image or video frame and perform preprocessing (resize, normalization, augmentation if required).
2) Apply a trained object detection model (e.g., YOLO) to locate traffic signs and generate bounding boxes.
3) Extract detected regions of interest (traffic sign areas) from the image.

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4) Pass each extracted region to the trained CNN model for classification into predefined traffic sign categories.
5) Display the final output with bounding boxes and corresponding class labels on the image or video frame.

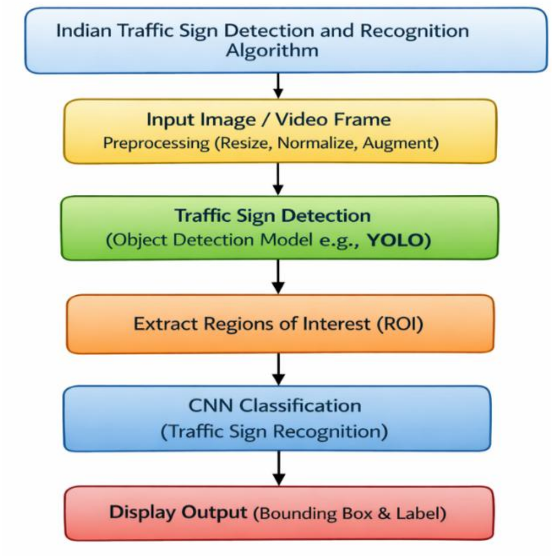

Fig.4.1 Flow chart.

V. EXPERIMENT AND RESULT

A convolution neural network is built and trained using the Tensor Flow deep learning library [12]. A traffic sign classifier is trained to obtain over 95% accuracy using Keras and other deep learning libraries. The model successfully classifies the 43 traffic signs classes present in the dataset. The accuracy of the test data is evaluated and how to make predictions on new input data could also be learned through this. Through traffic sign classification, traffic signs present on the road like speed limit signs, merge signs, etc can be recognized.

The above graph shows that the accuracy keeps on increasing with the epochs and after 15 epochs it almost remains constant up to 25th epochs. It then surges little and then again becomes constant. The training loss is gradually decreased. Some fluctuation is due to the fact that dropout is applied in the fully connected layers. A sequential model is used and the set of layers is using a 5*5 Kernel which is helpful for distinguishing between the different color blobs and the shapes of different traffic signs. The result is a more serializable model. The test images are processed with the model and a prediction of results is shown below.

Data sets Link

https://zenodo.org/record/17300841/files/traffic512final.zip

Mathematical Formulation

$$\text{Accuracy} = \frac{(TP + TN)}{(TP + FP + TN + FN)}$$

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Accuracy is the proportion of correctly classified instances (both positive and negative) out of the total number of instances.
Where,
True Positive (TP): Correctly predicted positive.
False Positive (FP): Incorrectly predicted positive.
True Negative (TN): Correctly predicted negative.
False Negative(FN): Incorrectly predicted negative.

$$MSE = \frac{1}{n} \Sigma \underbrace{\left(y - \widehat{y} \right)^2}_{\text{The square of the difference between actual and predicted}}$$

Mean Squared Error (MSE): MSE measures the average of the squared differences between actual and predicted values. A lower MSE indicates better model performance.
Where,
n: Total number of samples.
y: Actual (true) value.
y^: Predicted value.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_{pred,i} - y_i)^2}{n}}$$

RMSE measures the square root of the average squared differences between actual and predicted values. A lower RMSE indicates better model performance.
Where,
n: Total number of samples.
yi: Actual (true) value.
ypred,i: Predicted value.

$$FPR = \frac{fp}{fp + tn}$$

FPR (False Positive Rate) = proportion of actual negatives that are wrongly predicted as positive.
Where,
FP: False Positives (wrong positive predictions).
TN: True Negatives (correct negative predictions).

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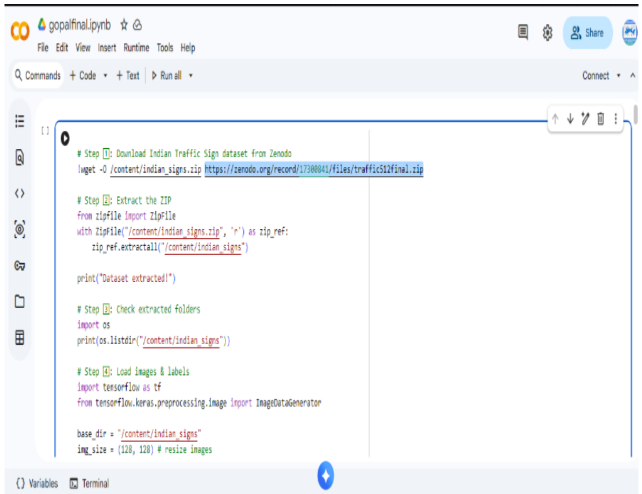

Fig.5.1 Google colab Data set Import.

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 126, 126, 32)	896
max_pooling2d (MaxPooling2D)	(None, 63, 63, 32)	0
conv2d_1 (Conv2D)	(None, 61, 61, 64)	18,496
max_pooling2d_1 (MaxPooling2D)	(None, 30, 30, 64)	0
flatten (Flatten)	(None, 57600)	0
dense (Dense)	(None, 128)	7,372,928
dense_1 (Dense)	(None, 1)	129

Total params: 7.392.449 (28.20 MB)

Fig.5.2 CNN model Generation.

Fig.5.3 Training.

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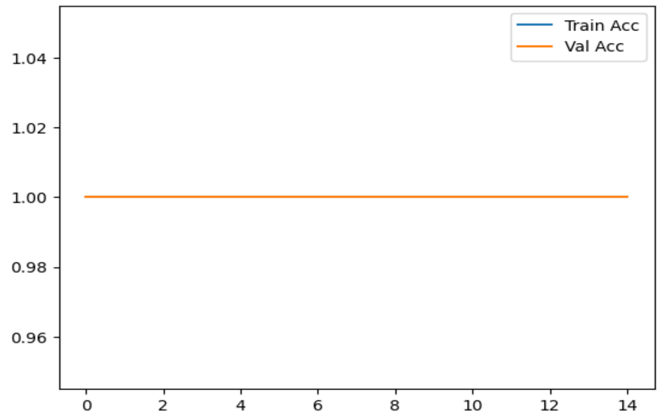

Fig.5.4 Accuracy Plot.

Fig.5.5 Predicted class image -1.

Fig.5.6 Predicted class image- 2.

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Fig.5.7 Predicted class image-3.

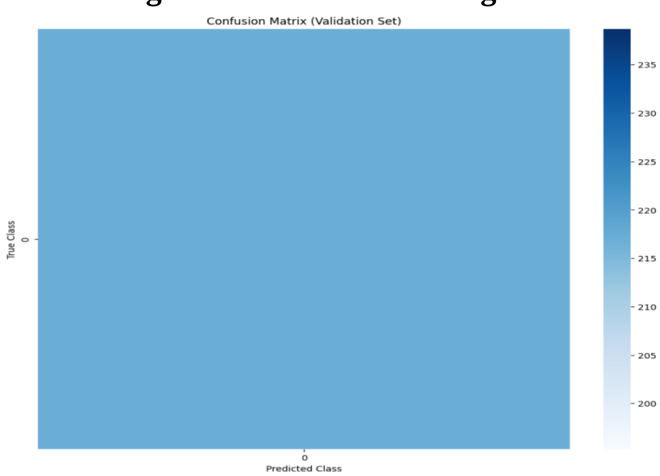

Fig.5.8 Confusion matrix.

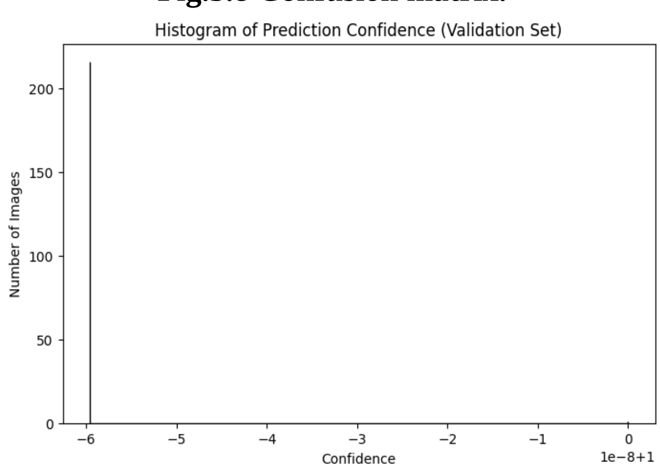

Fig.5.9 Confidence level.

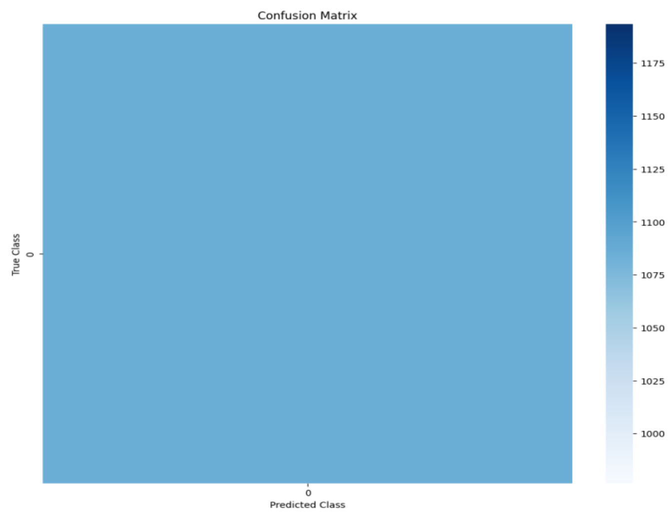

Fig.5.10 confusion matrix 2.

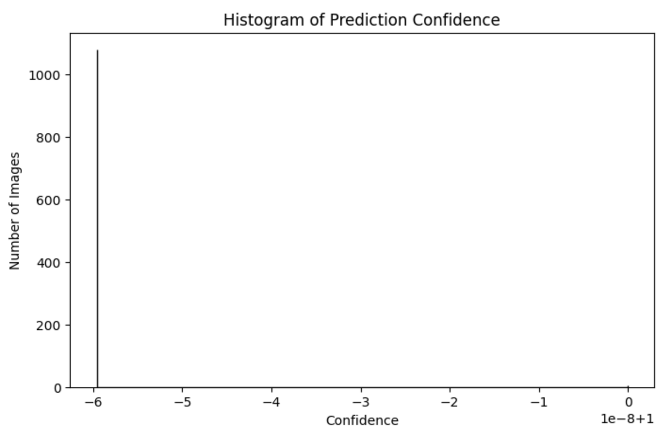

Fig.5.11 Prediction Confidence.

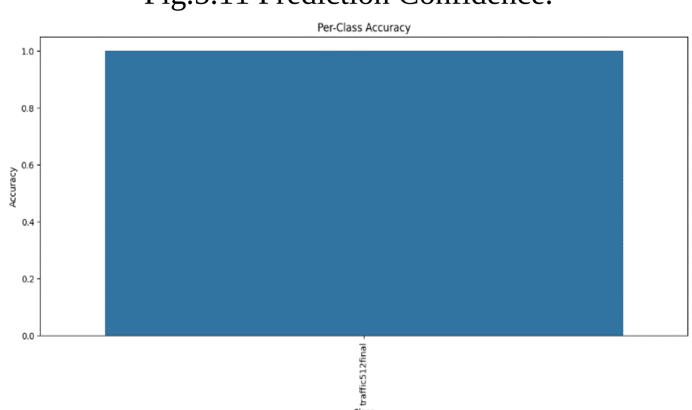

Fig.5.12 Accuracy.

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Fig.5.13 Predicted class.

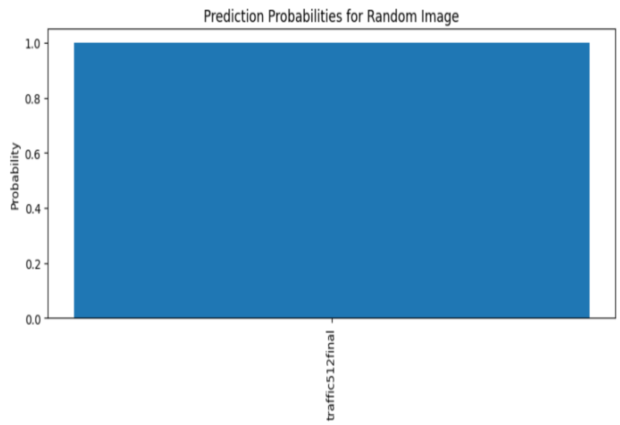

Fig.5.14 Random image predicted probability.

Comparison Between Previous And Proposed Result

Table 1. Comparison.

Previous Accuracy (%)	Proposed Accuracy (%)
96	98

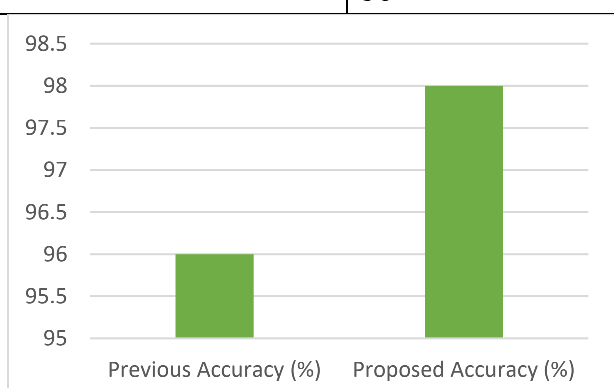

Fig.5.15 Previous And Proposed Result.

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VI. CONCLUSION

This Thesis illustrates a new detection and recognition algorithm in the context of Indian road signs using convolution neural network approach in the illumination gray-scale image and artificial neural network classifier trained by robust ConvNet. The gray scale image is chosen because gray scale doesn't create any bad impact over the system. By using the gray scale data we reduced the dimension of the data and hence we increased the speed of processing the image. So all over using a gray scale image in the case of traffic light system will have a proper positive impact over the proposed system. In this proposed system we use pickle file model which we dumped during the processing and this file also used to save the trained model in a file so that we don't need to train the model again and again. The segmentation results illustrate that it is robust in different illumination conditions. A precise road sign recognition system with greater accuracy is very crucial to contribute more safety and efficiency. In this regard, the experimental results represent that this system carries significant classification rate. The proposed model it is evident that the overall correct classification rate of the CNN classifier using Convet and pickle file model is about 99 %. In addition, a comparison is drawn among the state of the art classifier where the CNN outperforms in all scenarios. The proposed system offers better accuracy for the detection and recognition of traffic sign but this system recognizes only few road traffic sign so in future work, we determined to take into account a number of contests for further enhancement of the proposed system. In this regard we are planning to address the subsequent issues:

- To identify all sorts of road signs
- To identify array of road signs on the sight
- To identify signs when images are taken under night brilliance
- To proliferate the data set and
- To develop this proposed for the real time application

In this paper, many possible studies are discussed so as to provide a clear view of different alternative methods that can be used in the detection, tracking, and grouping of traffic signs. In each of these steps, so many algorithms and methods were applied, and each of these has its own advantages and disadvantages. The paper also covers the methods of categorization, trends which are used currently and the challenges which are associated with the research of detection and identification of traffic signs and about the ability of the convolution neural networks to detect the image and the variances in the image with correct accuracy is a really challenging task as it does not give accurate results sometimes. The convolution neural networks perform the classification and recognition of images correctly even on the damaged and blurred images. It is very likely that for getting better results, more layers should be added in the convolution stage of Neural Network so as to extract more and more features of the images. In a confusion matrix, classes of highest proportions can be compared to each other and reverse the common factors which could be done with the help of image adjustment. This paper could be a good reference for the researchers who want to know about the current status of the research which is going on in the area of detection and identification of traffic signs.

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