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Automatic Helmet Detection and License Plate Identification using Convolutional Neural Networks

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***Abstract* -Two-wheelers are the popular mode of transport in the country. Due to its increased usage, the rate of two-wheeler accidents has also raised significantly. According to a recent survey, the majority of motorcyclists do not wear helmets, which accounts for approximately 32% of two-wheeler accidents. This issue should be put forth to the people, to understand the seriousness. As a result, the government has deemed riding a motorcycle without a helmet a criminal violation. Manual systems were implemented to perform the identification of people not wearing helmets,however, it was not efficient at all times since it was a tedious process. Thus, automation of this system is required. The existing automated approach provides a low accuracy. In this paper, we propose a convolutional neural network(CNN) based approach for automatically detecting helmets from real-time surveillance videos. The frames from the surveillance video are initially acquired and the key frames are extracted in the suggested approach. Then these key frames are classified as motorcycles or not, using CNN method. Then the motorcyclists without the helmet are identified using the CNN method. Lastly, the violator's license plate's characters are recognized using Support Vector Machine(SVM) classifiers and is stored in the database for generating and sending the fine amount to the violators through SMS using the Twilio API.**

Keywords- Key frame extraction, Helmet detection, Convolutional neural network, License plate identification, Support Vector Machine, Twilio API

I. INTRODUCTION

Two-wheeler accidents have risen up unexpectedly in recent years because of the carelessness and also the remorseless driving of the motorcyclists. About 25% of road accidents are caused because of driving two-wheelers. The maximum number of road crash injuries is reported in Tamil Nadu.

The most hazardous mode of transport is two-wheelers because if there is an accident, the rider as well as the people alongside will get affected. In 2016, 44,000 people died in two-wheeler fatalities, while 52,500 people died in road accidents, accounting for roughly a third of all road deaths [18]. Two-wheeler accidents are a big problem not only in India, but also throughout the Southeast Asian region.

According to a recent report issued by the United Nations, helmet use can save roughly 15000 lives. According to a UN motorcycle helmet research, motorcyclists are 26 times more likely than passenger car drivers to die in a traffic accident. Wearing a proper helmet helps riders prevent 69 percent of injuries and increases their survival probability by 42 percent. According to one analysis, about 35 Lakhs individuals could die in motorbike accidents between 2008 and 2022.

Another study by the United Nations in the year 2015 showed that the survival rate of motorcyclists can be increased by 42% if helmets are used while driving. The government has also made it mandatory for the motorcyclists to wear helmets and violating this could result in a punishable offense. Manual systems were implemented to perform the identification of people not wearing helmets, however, it was not efficient at all times since it was a tedious process. Many automated systems were also not as efficient as expected.

Image processing and convolutional neural networks have recently shown tremendous results in image classification and object detection and it's an enormously evolving field. CNN has shown highly accurate results in classifying images.

The aim of the paper is to automatically identify the people not wearing a helmet while driving motorcycles and recognize their license plate and send the calculated fine to the respective people. First the motorcycles are detected. Then the helmets are identified, after which the license plate of the violators is recognized for further actions. The main intention is to make the compulsory use of helmets to prevent the risks coupled with it.

This paper is organized as follows: The relevant works are discussed in Section 2, the proposed system is discussed in Section 3, the experimental findings are discussed in Section 4, and the conclusion is presented in Section 5.

II. RELATED WORKS

In recent years, several studies were published to categorize the moving objects as motorcycles and to identify the motorcyclists not wearing helmets. Classification of vehicles, object detection and helmet identification were the processes implemented in the existing systems. To gain further knowledge, the following are some literature research that are covered in this section.

Messelodi S et al [7] suggested a computer vision system for the classification and identification of cars on metropolitan roads. In this paper, eight 3D models are created and used for classification of vehicles. The models are built using the dimensions of the vehicle. The models are built for pedestrian, cycle (motorcycle and bicycle), minibus, small car, car, open truck, closed truck, bus, etc. A separate model is created for every captured image and is compared with the existing models. The model which matches the best with the captured image model defines the vehicle class. One of the major issues is that it doesn't differentiate between a cycle and motorcycle model because they fall under the same class(cycle). The classification is based on the geometric information of the image which is an inefficient technique. Certain parameters such as camera angle, height, focal length etc., should have thesame value, if these parameters are changed then there won't be any match with the existing models and newmodels have to be created.

Leelasantitham A et al [6] based on traffic engineering information, built a framework for identifying and classifying moving Thai automobiles. In this paper, the detection of vehicles is based on traffic engineering methods. The vehicles are divided into five categories: motorcycles, bicycles, and tricycles are in the first group; vans and cars are in the second; small trucks and minibuses are in the third; buses and medium-sized vehicles are in the fourth; and trailers and heavy trucks are in the fifth. The width and length of the image are used to categorize the image. The classification accuracy is less since only 76 images are used for training. The roadways on which the photos are recorded have an impact on the system's performance. For instance, if the system is applied to a different road then all parameters should be changed.

Another study by Sonoda S et al [14] used a sequential background extraction technique to develop a system for detecting moving objects at junctions. The major goal is to inform drivers so that accidents at crossroads can be avoided. The Adaptive Gaussian Mixture Model (AGMM) is used for identifying the moving objects. After the identification, the Lucas-Kanade tracker method is used to track moving objects that appear in various positions across a video frame sequence. The tracking algorithm determines whether there occurs any collision between the vehicle and the pedestrian at the intersection. If any occurs, then it issues a warning. The major issue is thatthere are high chances for false positives as the pedestrian may change the route after the warning is issued.

Chiu C-C et al [2] suggested an occlusion segmentation technique for motorbike recognition and tracking. A helmet recognition system is used in order to identify whether the motorcyclists are wearing helmets or not. The system assumes that the helmet region will be in the shape of a circle. The image edges around the region where the motorcycle is located are determined for helmet identification. Eventually, the edge points that look like a circle are enumerated. The edge points define the helmet if this enumerated count is larger than the predetermined threshold value. If the helmet is detected, the motorcycle too is located in the same area. The basic parameters such as camera angle, height, and helmet radius must be input to the system during the calibration step. All parameters should be modified whenever any condition changes, such as the road on which the system operates or the camera height.

A system for automatically tracking and classifying motorcycles with and without helmets was proposed by Chiverton J [3]. It uses the SVM classifier, which is trained with histograms of motorcyclists' head region images computed with the HOG descriptors. The background is calculated using the Adaptive Gaussian Mixture Model (AGMM) technique. The static images and individual frames of the video stream are used in the procedure for extracting histograms. This method obtained 83% accuracy for classification of motorcyclists and 85% accuracy for detection of helmets. The major issue in this method is that the image data may be corrupted due to occlusions.

R.V. Romuere et al. [12] proposed a categorization and motorbike detection system, as well as a system for identifying the motorcyclists without helmets. In this approach, the wavelet transform is used as a descriptor and the random forest approach is used as a classifier to classify vehicles. Following vehicle detection, the helmets are detected using a hybrid descriptor that extracts features using both CHT and HOG. The objects are accurately classified using a multilayer perceptron classifier. This method achieved an accuracy of about 97.78% for vehicle classification and 91.37%for helmet detection. Since this method uses the hand engineered features there may be occlusion of objects and illumination effects.

Wen C-Y et al [17] suggested a circular arc detection method based on the modified CHT. The threshold levels are manually defined in this approach in order to compute the edges in the image. Then CHT isapplied subsequently on the image. The transform looks for circular sections, such as helmets. This approach is applied for the surveillance of ATMs as most of the ATM criminals wear helmets to hide their faces. The major drawback of this approach is that it uses only geometric resources for the identification of helmets which are not sufficient. It may sometimes be confused with a human head as it is of the similar shape as that of the helmets.

Waranusast R et al [16] proposed a system termed machine vision approaches for motorcycle safety helmet detection. The AGMM technique is used to detect moving objects. Then, based on three characteristics, objects are classed as motorcycles or not: 1) The area of the bounding box that contains the image. 2) The proportion of the bounding box's height and breadth. 3) the H band's standard deviation in the HSV colour space around a rectangle in the object's centre. The approach's key advantage is that it allows for passenger counting depending on the number of heads visible in the photograph. Finally, a categorization is made using color information as well as geometric information from the head region. The k-nearest neighbors(KNN) classifier uses these features to distinguish between motorcycle riders who wear helmets and those who do not. The method achieved a success rate of about 95% in motorcycle detection and 83.82% in passenger counting. This method suffers from a majorissue of occlusion.

Chen Z et al [1] proposed an idea for detecting tracking and classifying vehicles. The vehicles are counted and categorized into four groups using this method: car, van, bus, and motorcycle (including bicycles). The tracking algorithm is the kalman filter, the image features are extracted using the HOG descriptor, and the classifier used is SVM. When the weather and lighting conditions change, the accuracy of this method reduces.

All the above papers, discuss if the motorcyclists wear helmets or not, using different algorithms. But all the systems show many issues related to parameters such as height, width, aspect ratio etc. Issues such as occlusion, helmet shape and size were also reported. The papers did not show much accuracy and were not efficient enough. Hence an efficient system is proposed below.

III. PROPOSED SYSTEM

In the present traffic system, both manual and automated strategies for recognizing the general population not wearing helmets aren't productive. So as to influence the general population to submit to the obligatory utilization of helmets, this paper proposes a computer vision-based system for automatic detection

of helmets. In this methodology, the frames are captured from the input video and after that, the key-frames are separated from the captured frames. At that point the image segments are classified into motorcycles or not using convolutional neural networks. When the motorcyclists are detected, their head is situated at the locale of intrigue and the image segment is tested for the presence of helmets utilizing the CNN model. On the absence of helmet, the license plate of that bike is captured and the characters are perceived utilizing the Support Vector Machine technique. The extracted license plate numbers are utilized for recovering the motorcyclists' data from the database for generating and sending the fine through SMS. The proposed system consists of the following:
(1) Motorcycle detection; (2) Helmet detection;
(3) License plate identification

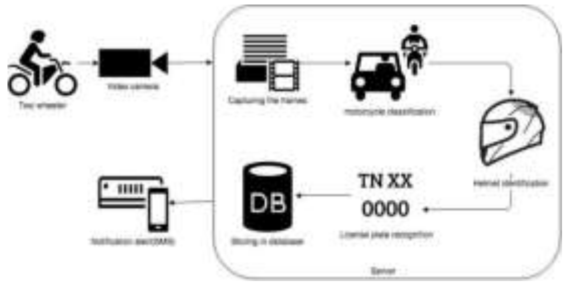


Figure 1: System Architecture

A. MOTORCYCLE DETECTION

In the motorcycle detection section, initially, all the frames of the input video are captured and the key frames are selected. The segmented image suffers from noise which is rectified using the morphological processes. Then the image segments are to be classified as motorcycles and other vehicles. The classification of the vehicles is performed using the convolutional neural network (CNN) model. The CNN model is stack of several layers such as convolutional layers and pooling layers, which are used for feature extraction. Following the feature extraction, is the fully connected layer which performs the actual classification. The CNN model is initially trained withthe dataset, which is then used for classifying between the vehicles as motorcycles or not. If the motorcycles are detected, the corresponding image segments are processed for detection of helmets. Figure 2 illustrates the flow of the vehicle classification module.

B. HELMET DETECTION

Before the helmet detection, it is required to determine the region of interest (RoI). The region of interest is the head position in this case, one fifth region from the top of the image segment is calculated, then the head region is located. The histogram is used to create a sub-window for the head area. Then the process of identifying the helmets is carried forward. The distinction between helmets and non-helmets is made using a CNN model. The convolution layers and the pooling layer retrieve the features from the image

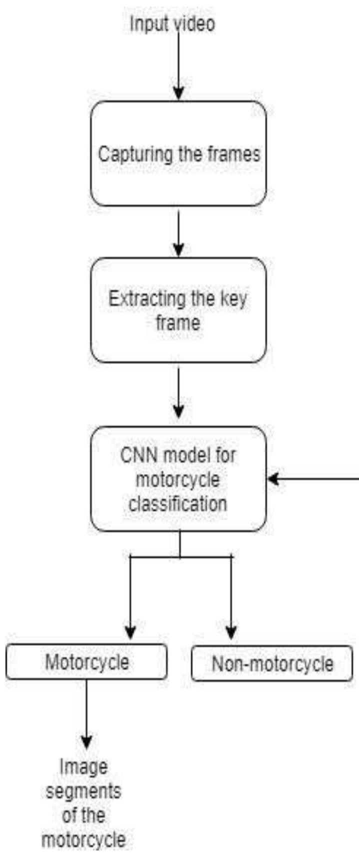


Figure 2: Motorcycledetection

segments, while the fully connected layer does the classification. The model is initially trained using the available datasets and divided into two categories: helmets and non-helmets. Then the image segments of the head region of the motorcyclists is passed to the CNN model. If thehelmets are not detected then the license plate of the violator is detected using the image segments of the two-wheelers. Figure 3 illustrates the sequence of steps to be performed in the helmet detection process.

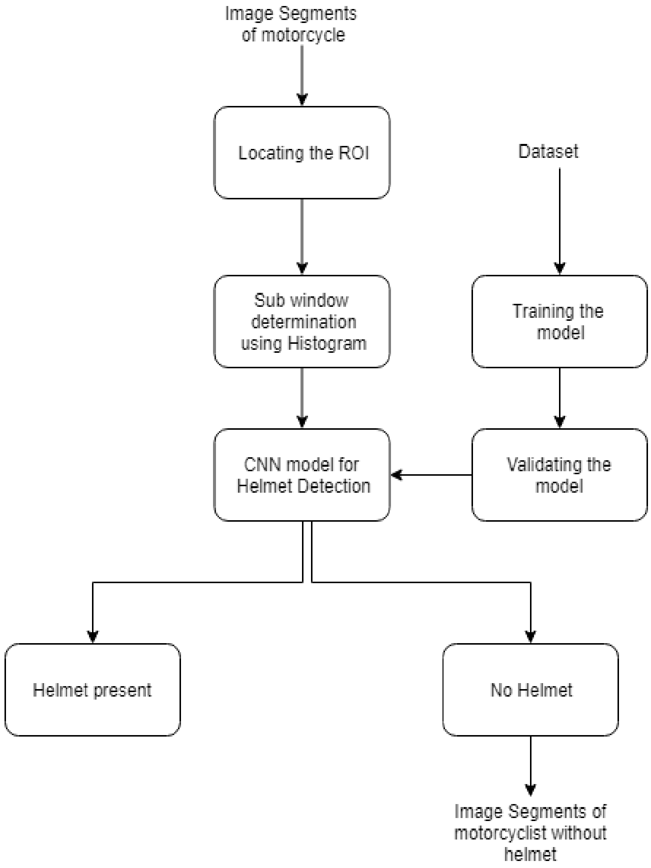


Figure 3: Helmet detection

C. LICENSE PLATE IDENTIFICATION

The captured images of the motorcycles are first saved in the system. Two processes are done for improved accuracy, the image is scaled first and then transformed to a binary image. The region of interest is then calculated using number plate localization method. Each individual character is separated out using the concept of connected component analysis (CCA). After which, license plate's characters are recognized using Support Vector Machine(SVM) classifiers and is stored in the database. Then these characters are used to retrieve information from the database to generate the fine andsend to the violator through SMS. The notification is sent to the violator through Twilio API. Figure 4 represents the detailed flow of steps involved in license plate identification.

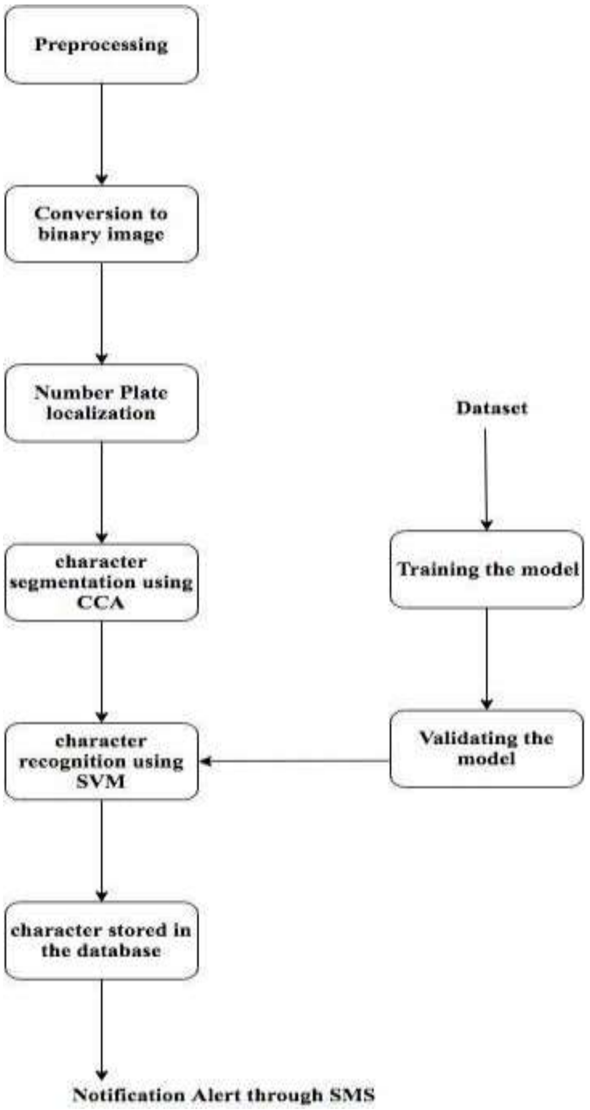


Figure 4 License plate identification

IV. EXPERIMENTAL RESULTS

The image databases used to evaluate the technique were derived from recordings acquired on the open streets using vehicle segmentation. The video was captured using charge-coupled device (CCD) camcorders placed on public streets. The footage was created in a variety of lighting scenarios and has a resolution of 1280 x 720 pixels with a frame rate of 30 frames per second. The two image datasets that are utilized in this methodology are:

- ❑ Database1 - 3877 images
- ❑ Database2 - 255 images.

The principal database comprises of vehicle images captured under various conditions on the open streets. In the vehicle classification stage, shots from database1 are used. This database is acquired from 110 minutes of video and is made out of 3877 images as shown in the figure 5 which are partitioned as frames:

- ➔ 2762 images of large vehicles , and
- ➔ 1115 images of motorcycles.

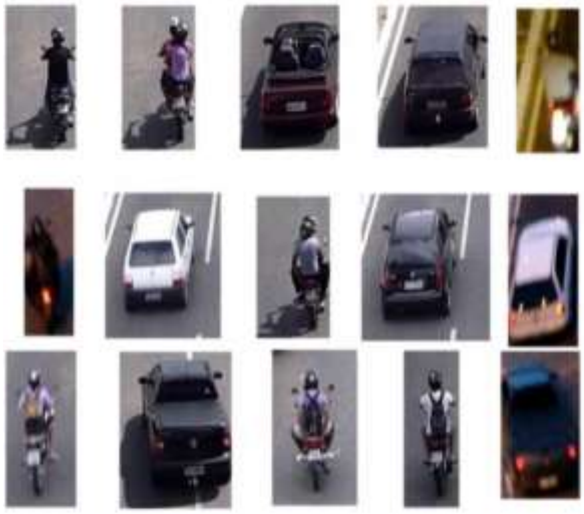


Figure 5: Image from database1

The second database comprises of images of motorcyclists with and without the helmet. The imagesof the database are used in the helmet detection stage. This database is acquired from a 40-minute video and is made out of 255 images as shown in the figure 6 which are partitioned as frames:

- ➔ 151 images of motorcyclists with helmet, and
- ➔ 104 images of motorcyclists without a helmet

Figure 6: Image from database2

A. VEHICLE CLASSIFICATION

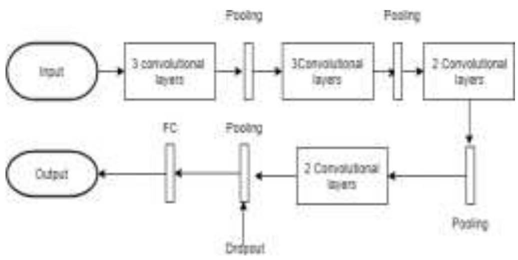
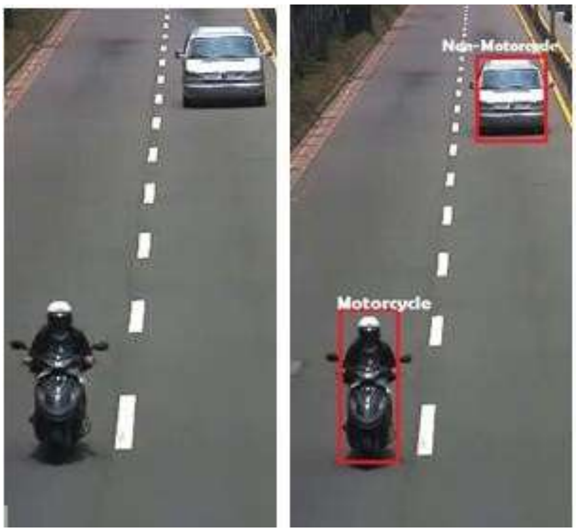


Figure 7: CNN model for vehicle classification

For motorcycle detection, a CNN model with 10 convolutional layers, 4 max-pooling layers, and 1 fully connected layer for classification is used and it is shown in the figure 7. To avoid overfitting, dropout is used in the final max-pooling layer. The model is prepared and tested using 5-fold cross-validation. A binary classifier is used in which class 0 represents motorcycles while class 1 indicates non-motorcycles. The image segments of the motorcyclists are saved, which is utilized for the detection of helmets. This module gives an accuracy of 99.6%. Figure 8 shows the detection of motorcycle from input image frames.



(a) (b)
Figure 8:(a) Input image frame from the video; (b) Motorcycle detected image.

B. HELMET DETECTION

For the helmet detection stage, a CNN model with 6 convolutional layers, 3 max-pooling layers, and 1 fully connected layer is used and it is shown in figure 9. The max-pooling layer uses the dropout here to avoid the overfitting problem. The model is tested and trained using 5-fold cross-validation. A binary classifier

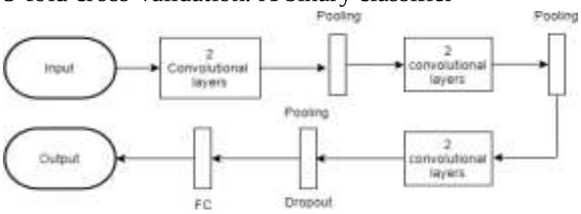


Figure 9: CNN model for helmet detection

is utilized in which class 0 represents motorcyclists without helmet while class 1 shows motorcyclists with helmet. The image segments of the motorcyclists without the helmet is saved, which is utilized for extracting the license plate number of the motorcyclists. This model gives an accuracy of about 98.8%. Figure 10 shows helmet detection steps.

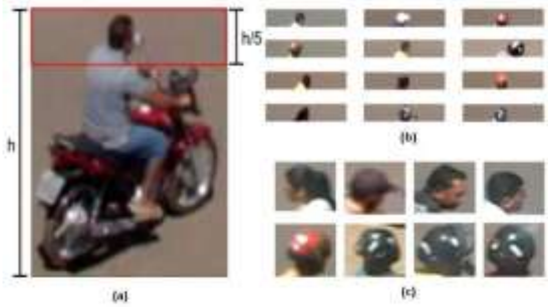


Figure 10:(a) The RoI refers to the region bounded by the rectangle; (b) RoIs derived from motorcycle shots obtained during the segmentation step; (c) Images of computed sub-window.

C. LICENSE PLATE IDENTIFICATION

The license plate number is found using the recorded shots of the motorcycle from the previous stage. To improve accuracy, the image segment is first converted to a grayscale image, which is then converted to a binary image. The connected regions in the images are identified using the connected component analysis (CCA). For recognizing the license plate, some of the typical characteristics of a license plate isused such as their rectangular shape, the aspect ratio, etc. Once the license plate is detected, every individual character is isolated and are mapped using the concept of CCA. These characters are recognized using the SVM algorithm where the SVM model is trained usingthe available dataset. To verify the model's correctness, a 4-fold cross validation was performed. Following the training phase, the SVM model is used to identify the characters obtained in the previous stage, and the results are saved in the database. Then, these characters are used to recover data from the database to generate the fine and send to the violator through SMS using the Twilio APIs. Figure 11 illustrates the output of the license plate identification model.

(a)

(b)
Figure 11:(a) The Contour image (b) identified vehicle plate number

On the basis of performance criteria such as overall accuracy, sensitivity, and kappa coefficient, the suggested system is compared and evaluated with other existing algorithms. The accuracy of the classifier is measure of correct predictions compared to the total number of data points. Simply expressed, it is the ratio between the number of correct predictions made by the classifiers and the total number of predictions made by the classifiers..

Accuracy = TP+TN / TP+FP+TN+FN

Where

True positive (TP) = the number of casescorrectly recognized as positive

False positive (FP) = the number of cases incorrectly recognized as positive

True negative (TN) = the number of cases correctly recognized as negative

False negative (FN) = the number of cases incorrectly recognized as negative

Table 1 shows the comparison results of the algorithms used for vehicle classification. The CNN algorithm delivers the best results, as seen in the table.

Table 1 Results of vehicle classification usingdifferent algorithms

Algorithm	Kappa Coefficient	Sensitivity	Overall Accuracy
NVB	0.8609	0.9732	0.9516
MLP	0.9140	0.9732	0.9547
CNN	0.9532	0.9886	0.9816

The comparison results of the algorithms employed for helmet detection are shown in Table 2. The CNN algorithm delivers the best results, as seen in the table.

Table 2 Results of helmet detection usingdifferent algorithms

Algorithm	Kappa Coefficient	Sensitivity	Overall Accuracy
NVB	0.8767	0.9515	0.9572
MLP	0.8844	0.9724	0.9618
CNN	0.9308	0.9930	0.9778

The comparison results of the algorithms employed for license plate identification are shown in Table 3. The SVM method delivers the best results, as shown in the table.

Table 3 Results of License plate identification using different algorithms

Algorithm	Kappa Coefficient	Sensitivity	Overall Accuracy
NVB	0.6948	0.9327	0.8471
RFC	0.7456	0.81731	0.8784
SVM	0.7850	0.8173	0.8980

Figure 12 depicts the overall performance of vehicle classification. On the basis of the above-mentioned performance indicators, it is compared to two different classification algorithms: NVB and MLP. The CNN algorithm, it can be seen, delivers the best results of all.

Figure 12 Performance Analysis of Vehicle Classification using Different Classifiers

Figure 13 depicts the overall performance of the helmet detection. On the basis of the above-mentioned performance indicators, it is compared to two different classification algorithms: NVB and MLP. The CNN algorithm, it can be seen, delivers the best results of all.

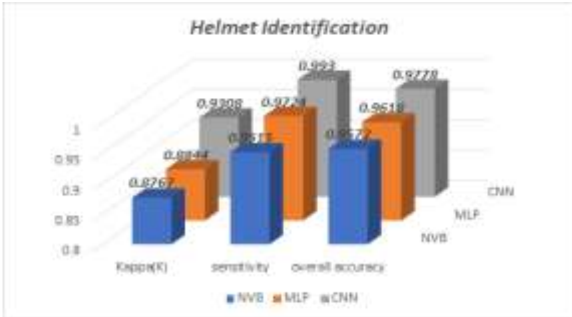


Figure 13 Performance Analysis of Helmet detection using Different Classifiers

Figure 14 Performance Analysis of License Plate Identification using Different Classifiers.

The entire performance of the proposed system's license plate identification is shown in Figure 14. It is compared to NVB and Random Forest Classifier (RFC)., which are two other classification techniques.

It can be observed that the SVM algorithm for classification produces the best result among all.

V. CONCLUSION AND FUTURE WORKS

This paper proposes a system to identify the motorcyclists not wearing helmets and then identify their license plate. Following are three modules used for this purpose:(1) Motorcycle detection; (2) Helmetdetection; (3) License plate identification

At first, the moving objects are detected and classified as motorcyclists or not, utilizing the CNN method. After which the motorcyclists not wearing helmets are distinguished utilizing the CNN model. The license plate of the violators is perceived utilizing SVM classifiers. The perceived characters are stored in a database to recover the data of the violator. At that point after the data is recovered from the database, thebill is sent to the violator through SMS. Further in thefuture, the efficiency of the system can be improved by capturing the images and videos of the moving vehicles from multiple angles.

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