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Vehicular Safety System using Deep Learning and Computer Vision

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Abstract

While many technological solutions have been implemented for accident detection, not many have focused on accident prevention. Accidents have been an everlasting concern as they have caused heavy injuries and death tolls on a large scale. There has been an everlasting increase in the rate of accidents and violation of traffic laws and wrongdoers managing to escape from the legal ramifications of predominantly Hit-and-Run cases. This entails a system to alleviate the occurrence of accidents and deaths caused. Focusing on this, a viable solution that focuses on preventing such circumstances by detecting accident-causing behaviour has been proposed. If accidents take place, it ensures the victim gets their rightful compensation. The research encompasses two modules, Prevention and Recovery. The prevention module uses Deep Learning and Computer Vision to detect whether the driver is drowsy and issues an alert employing CNN. The recovery module focuses on detecting occurrences of accidents and acquiring information about the parties involved in the same. Moreover, the prototype detects drowsiness, and detects and saves the accident footage in real-time enabling information acquisition.

Keywords: Vehicular Safety, Hit-and-Run, Information Acquisition, CNN, Driver Attention, Behavioral Detection, Deep Learning, Computer Vision

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1. INTRODUCTION

Road transport has become an omnipresent and integral part of human life over the decades. This poses the need for a system that embraces the main aspects comprising road safety. A system that sends informational messages about the location of an accident site to the necessary local emergency services for corrective action is necessary. To orchestrate an efficient vehicular safety system, there is a need to develop a system that caters to prevention as well as recovery pertaining to road accidents.

The objective of the proposed study is to develop two modules:

1. Prevention
2. Recovery

In the prevention module, the factors contributing to the driver's distraction are focused upon. The system alerts when it finds an indication of drowsiness.

In the recovery module, the issue of Hit and Run cases is tackled. From the footage, the license plate/fast tag of the perpetrator who flees the scene is recognized and pertinent information is acquired to ensure that the victim gets their insurance claim.

The proposed study aims at providing a cohesive solution by encompassing necessary features required in all aspects of accidents and improving upon them in terms of usability and effectiveness focusing on prevention and recovery separately. The study focuses on overcoming the drawbacks of the existing systems such as neglect when it comes to prevention and recovery only when the victim is injured and solely focuses on taking them to the hospital.

Hit-and-run cases have been around for decades. However, tracking the perpetrators of such crimes has been almost impossible. A system that detects the distraction of the driver in the prevention module and tracks down the owners of the vehicles involved in the accident in the recovery module is proposed. This would be beneficial to a very large demographic.

Figure 1. Prevalent causes of accidents [21]

2. LITERATURE REVIEW

In [1], detection of driver distraction in real-time using CNN was presented. Vanilla CNN was employed. This study focused on a deep neural network approach to reducing accidents caused by inattentive drivers. The driver's activities were extracted from the driver image dataset using a CNN-based algorithm, which was then used to categorise the distracted driver into multiple categories, such as texting, using a mobile device while driving, arriving late, driving normally, drinking alcohol, etc. The proposed method in [2] involved automatic car insurance using image analysis using CNN. The system identified and assessed the damage incurred to the vehicle and identifies the varied types of destruction to bring about an estimated cost for insurance claims.

In [3], an automatic and fast vehicle number plate detection was developed using a Neural Network with YOLOv3 and Optical Character Recognition (OCR). The application was built with Java and was embedded with Google maps for effective and accurate patient tracking with the help of location markers. The technology initially recognises the car before taking a picture of it. Using the image, the car number plate region was retrieved. The results are only performed on pre-captured owner identification using Neural Network segmentation in a picture. OCR technology was employed for character recognition. The obtained information was then contrasted with the entries in a database to produce specific data such as the owner of the car, the location of registration, the address, etc.

In [4], a review of driver inattention monitoring was presented. OpenCV with built-in Haar cascades was employed. The system continuously monitors the driver and driving behaviour and alerts the driver if he gets distracted and drowsy. The system proposed in [5] was a human driver's drowsiness detection system. The CNN methodology used the closing of eyes and yawning to detect fatigue and drowsiness and provided an alert sound when detected. The problem is that on analysing the hand angle position on the steering wheel and the eyes of the driver and on the occurrence of drowsiness, the model doesn't stop the car.

A vehicle accident detection on highway and communication to the closest rescue service was proposed in [6]. The system aims to identify the victims of traffic accidents using the information from the sensor fusion-based algorithm. These features were implemented by using Sensor Fusion based algorithm and geo-fencing. In [7], a Computer Vision based accident detection in traffic surveillance using Mask R-CNN was put forth. The main objective was to offer a quick and easy method for resolving the problem of traffic accident detection that can work effectively and quickly supply crucial information to responsible authorities. A drawback of this system is its incapability to accurately detect and track moving vehicles in areas with high traffic density.

In [8], a driver drowsiness detection by applying deep learning techniques to sequences of images was developed. Linear SVM combined with HOG Recurrent CNN was used. In order to prevent traffic accidents, the construction of an advanced driving assistance system specifically focused on driver sleepiness detection was described. It is essential that fatigue detection in a driving environment is performed in a non-intrusive manner and that the driver is not troubled by alarms when they are not drowsy.

In [9], analysis of collisions from driving-camera footage R-CNN for auto insurance was executed with YOLO and Mask. The strategy entails using artificial intelligence to automatically evaluate insurance claims for accidents. This study used the well-known deep learning models YOLO and Mask R-CNN to find crashes in videos taken by car dash cams.

Based on driver monitoring and verbal interaction, symptom detection and intervention were deployed in [10]. The prototype included a basic architecture with driver monitoring and verbal communication systems based on many sensors using KNN. It dealt with the problem of verbal interaction of the driver while engaged in driving that could also lead to the distraction of the driver and ultimately in a plausible accident. In [11], a real-time drowsiness detection of a model using Computer Vision (OpenCV built-in Haar cascades) was proposed. The major goal is to create a system that reliably provides relevant speech alerts in real-time while accurately detecting a driver's tiredness based on eyelid movement and yawning. The other goals include creating a system that identifies driving intoxication by routinely observing the driver's eyes, particularly the retina.

In [12], the approach of a smart accident detection & insurance claims system based on IoT was addressed. The application focused on automatically informing the closest hospital, police force, and insurance provider to swiftly reach the scene of the accident and carry out their tasks. These features are executed using IoT and GSM. Research [13] showcased an overview of CNN-based license plate recognition techniques. A myriad of studies has been done on reading license plates, which has resulted in the creation of new techniques and the modification of old ones. In the study, various methods for implementing license plate recognition systems were broken down, focusing on CNN. The emphasised techniques' advantages and disadvantages were explored. Also ways to make some of the chosen CNN-based approaches even better were mentioned.

In [14], it was suggested to use the H-RNN algorithm for deep learning-based accident detection from CCTV cameras in emergency scenarios. The primary thought of the methodology was to join a video skim with sets of key edges coordinated in groups to empower quick perusing of the entire video. In [15], the use of VANET for a novel accident prevention system and IoT for a remedial system was put forth. The study offered a remedy that combines preventive and remedial techniques to get around the shortcomings of the current system. Using VANET technology, the preventive system works. The focus of the corrective system is on informing the nearby hospitals of the location so that they can offer prompt assistance. However, this may not be efficient in generating ad-hoc responses in remote locations, and the delay would be higher.

In [16], an extensive survey on accident detection using deep learning was conducted. The application incorporates methodologies: CNN with LSTM GSM and GPS model to identify an accident using the video footage that cameras have captured. The system includes such a design as a tool that assists accident victims in their time of need by promptly identifying an accident and thereafter notifying the appropriate authorities through SMS, etc. The major goal is to use cutting-edge deep learning algorithms to quickly identify accidents as they happen.

In [17], Machine Learning with visual behaviour was employed for drowsiness detection. It proposed employing CNN, OpenCV, and Dlib to extract certain features from the mouth and counting yawning, and a convolution neural network model was used to identify tiredness. In [18], a car damage assessment to automate insurance claims was proposed using Mask R-CNN. The system proposed an approach to the problem of detecting and classifying damaged parts of car images and ultimately developing an end-to-end system that generates a cost report for the damaged car. Detection was achieved using Image Processing, Deep Learning, and Transfer Learning techniques. In [19], a system for automatically identifying license plates based on colour image processing was proposed. For implementation, it is suggested to use an automatic Chinese LPR system based on colour image processing. The use of template matching based on minimum Euclidean distance was made. In [20], a deep learning method for detecting mobile phone use while driving was suggested. The suggested algorithm consists of two phases. First, is facial tracking and detection. Second, the cell phone in the candidate region is found using the driver's cell phone detection approach based on CNNs.

The above citations encompass a wide array of technological domains which has heralded the vision of use cases from a different standpoint. The employment of up-and-coming technologies like Deep Learning and IoT or legacy technologies like OCR and Web Scraping have been intertwined skillfully to produce great solutions to problems that cater to the world's needs.

Given that many systems have been implemented in the realm of accidents, they mostly boil down to certain aspects like focusing on alerting the nearest hospital in the event of an accident or an overall prevention system. This entails a system that focuses on other aspects of tackling the overall predicament of accidents. Looking at the solutions which focus on prevention, there are ML, DL, and IoT-based implementations of object detection systems that incorporate lane and pothole detection along with object detection like trees and poles which were implemented abroad. However, this wouldn’t be suitable for Indian roads.

Coming to the technical aspects of the implementation, there were many pitfalls pertaining to accuracy and loss of quality of footage in terms of resolution and segmentation while processing. It is unable to give results to their full potential owing to obstacles like darkness and wearing sunglasses, etc. These shortcomings have been reasonably overcome in recent years, alleviating delays, and bottlenecks due to inevitable aspects such as poor lighting or distance.

3. METHODS AND MATERIALS

The method utilizes the artificial neural networks that resembles the functioning of the human brain' neural networks function. Convolutional Neural Network, or CNN, is one of the most effective networks in the Deep Learning. In the Prevention module, the video is captured using a webcam where the face of the driver is detected using the Haar cascade algorithm and then the eyes are detected. Then the CNN model is used to detect the status of the eye with an accuracy of x%.

Haar Cascade Classifier is used for the detection of the face, and Eye Aspect Ratio (EAR) is used on both eyes. Based on its landmarks, the EAR is defined as the ratio between the height and width of the eye. If the EAR goes below a threshold value i.e., the closing of eyes for a particular period, an alert in the form of an alarm will be heard by the driver.

$$EAR = \frac{||p2 - p6|| + ||p3 - p5||}{2||p1 - p4||}$$

Figure 2. Eye Aspect Ratio [22]

Convolutional layers are typically placed next to pooling layers. It was primarily used to speed up calculations, save memory, and cut back on the volume. One of CNN's most often utilised shifts is Max Pooling. The kernel is chosen and the largest number is obtained from the matrix.

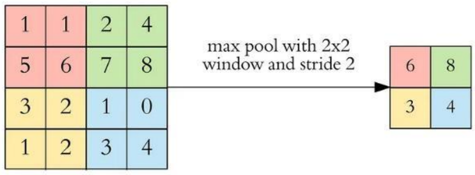

Figure 3. Max Pooling

A 2D or 3D array is input into the fully connected layer from the preceding layer and is converted into a 1D array. A convolutional neural network's output layer displays the likelihood of the classifications. It is calculated using the "Softmax" function. The probability calculation equation is shown below.

$$\sigma(X_j) = \frac{e^{x_j}}{\Sigma_i e^{x_i}}$$

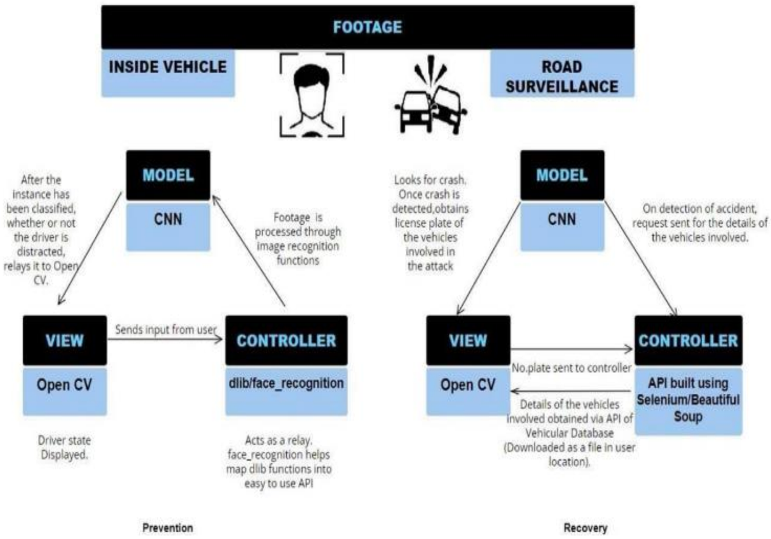

Figure 4. Architecture Model

- The above architecture diagram (Fig.4) shows the complete flow of the application with details of the two submodules - Prevention module and the Recovery module. Footage recording the facial features of the driver would compute results for the prevention module whereas recordings of the external environment of the car would be used up for post-accidental measures pertaining to the insurance claim. The MVC (Model-View-Controller) architecture is depicted in Fig. 4. Model and View are common in both modules, which is CNN and OpenCV.

- In prevention methods from dlib, an exclusive face recognition library is used. Recovery uses an API to recognise the vehicle owners.
- The different modules in this study are listed below:
- Prevention Module
- This module involves monitoring the footage of the driver inside the car. It looks out for the drowsiness of the driver. Once detected, an alert is issued.
- Recovery Module

This module comprises the main objective of the system, tackling the issue of hit-and-run cases. It monitors the footage of streets. It is on the lookout for accidents. Once a crash is detected, it obtains the license plate of the vehicles involved and fetches the owner details from the vehicular database. Thereby, the owner details are downloaded in the system location.

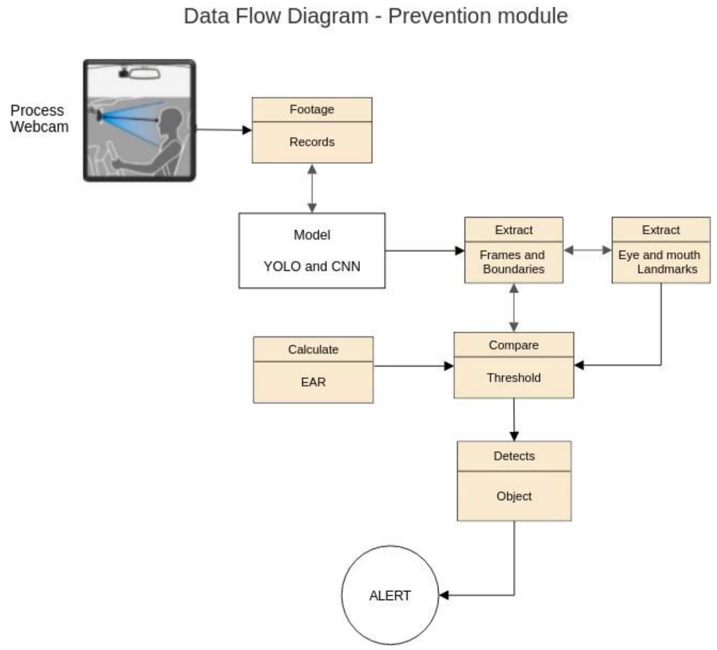

Figure 5. Dataflow Diagram of Prevention Module

This data flow diagram is depicted to show how information flows between the functionalities provided in the module. The data goes through some of the predominant functionalities being the Extraction, Comparison, Calculation and Detection. Incoming arrows represent the retrieval of data and outgoing arrows represent inputting new data to storage.

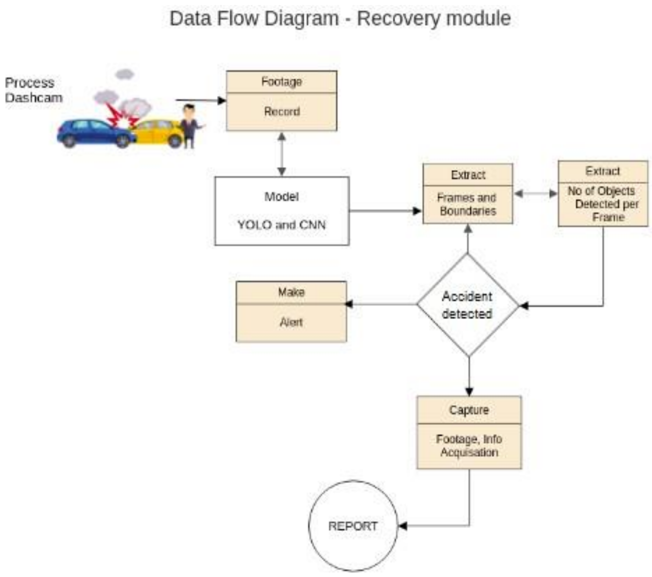

Figure 6. Dataflow Diagram of Recovery Module

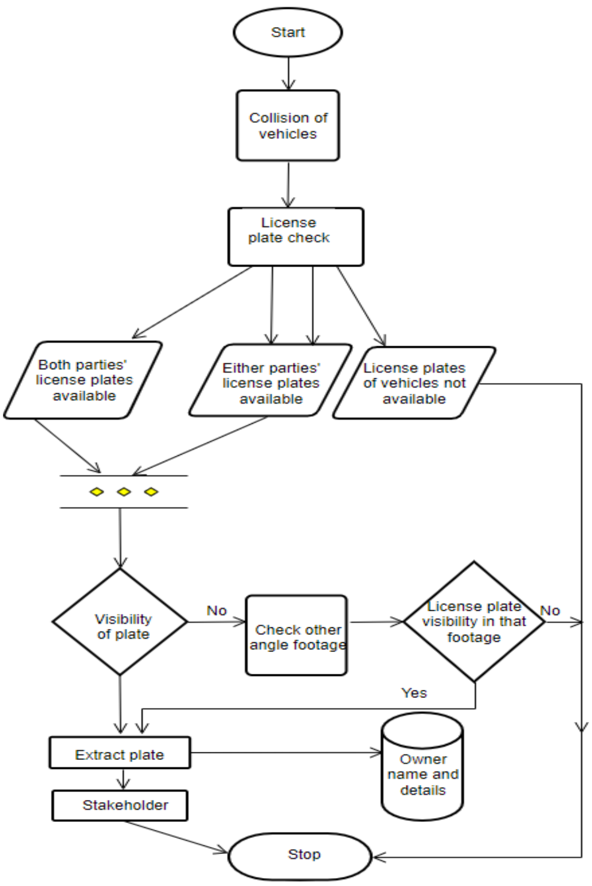

Figure 7. Flowchart of tracking down hit and run cases

Fig. 6 shows the way data flows between each module and how the information is acquired from each module.

Fig 7 depicts the following steps:

• The acquisition takes place incrementally.

• First, the model detects an accident. On detection, the license plates of the vehicles involved in the scene are sent to the API to query the owner's details.

• The details are downloaded in the user location.

4. RESULTS AND DISCUSSION

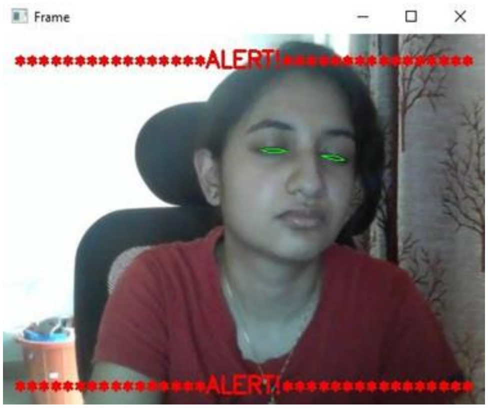

Figure 8. Drowsiness Detection

The above image demonstrates the detection of drowsiness with the parameter EAR. Haar cascades have been employed since the algorithm does not require extensive computation and is suitable to run in real-time. Improvements must be made to ensure accurate detection even in poorly lit conditions.

The system incorporates features such as real-time analytics in driving, distraction detection, posture analysis, and passenger detection. It makes use of multiple deployment models such as edge and cloud. It makes weather-independent decisions and is compatible with any kind of camera. It facilitates live tracking and trip analytics.

The proposed drowsiness detection model is compatible with integrated webcams and can be deployed using any camera. Haar being a lightweight algorithm is suitable for cost-effective real-time deployment. However, fine-tuning with respect to making it work in all kinds of lighting is needed.

Figure 9. Accident Detection Results

Furthermore, the accident detection model was prototyped using CNN. It detects crashes of vehicles and has been able to detect pedestrians hit by vehicles as well. The accuracy achieved so far is 87% with respect to making it work, in all kinds of lighting.

Table.1. compares the various features of the proposed system with similar features that are available. As discussed in the literature survey, on referring to various research, the hypothesis that hit-and-run cases haven't been tackled enough was derived. The features are being proposed to address this need prominently. Furthermore, the methods are adopted keeping in mind the issues that were there in the existing models

Table 1. Comparison of the existing vs the proposed system

Existing System	Proposed System
The drowsiness detection system is memory intensive. It is platform-dependent.	It is lightweight making it easily compatible across platforms. Deployment is made simpler.
Alerts are sent to the nearby hospital once an accident occurs.	Live alert of occurrence and saving of the accident snaps in the surveillance location.
Needs additional hardware to be implemented. And each car must have it installed.	Doesn't need any device to be installed in every vehicle. The deployment is centralized.
CCTV footage is manually parsed and manual mapping with RTO records.	Along with live storage, OCR is employed to obtain details without any intervention.

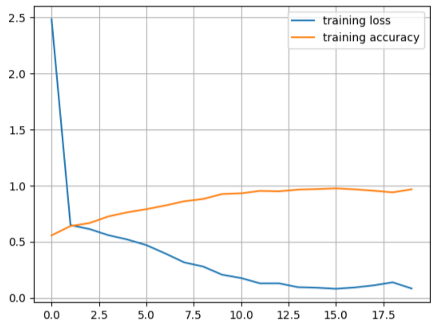

Figure 10. Graph representing training loss and accuracy

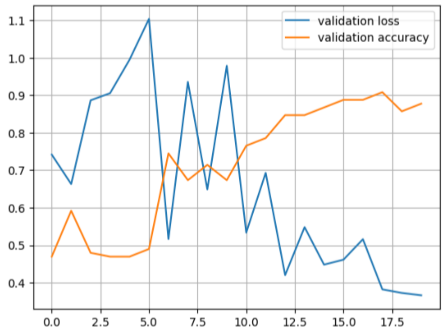

Figure 11. Graph representing validation loss and accuracy

The graphs of the training loss vs training accuracy and validation loss vs. validation accuracy over the number of epochs are shown in Fig.10. and Fig.11. respectively. This is instrumental when optimisation needs to be made for deployment and enables efficient decision-making in the same regard.

5. CONCLUSION

The drowsiness detection module has been implemented along with a model for accident detection. Improvisation for drowsiness detection needs to be done enabling it to work well in dim-lighted conditions as well. Similarly, the accident detection model needs to be optimised further to facilitate its use in the sphere of hit-and-run cases. Following these improvements, the detection of the vehicles or objects that collided and extraction of the license plates of the parties involved, and the real-time recording of the incident in the user's location needs to be implemented. Successful implementation of the same will serve as a prototype that would help tackle hit-and-run cases thereby ensuring victims their-rightful-insurance-claims.

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