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Vision-Based Driver Drowsiness Detection Using Haar Cascade and Convolutional Neural Networks

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Abstract: Driver drowsiness is one of the leading causes of road accidents worldwide, making the development of intelligent driver monitoring systems essential for improving road safety. This paper presents a vision-based driver drowsiness detection system using Haar Cascade classifiers and Convolutional Neural Networks (CNNs) to monitor the driver's alertness in real time. A webcam continuously captures the driver's facial features, and the Haar Cascade algorithm is employed to detect the face and eyes efficiently. The extracted eye images are then processed by a custom-designed CNN to classify the eye state as either open or closed. Based on the eye closure duration, blink frequency, yawning behavior, and head movement, the system determines the driver's level of drowsiness. When signs of fatigue exceed a predefined threshold, an audible alert is generated to warn the driver and help prevent potential accidents. The proposed approach provides a non-intrusive, real-time, and cost-effective solution with improved robustness under varying facial expressions and lighting conditions. The experimental results demonstrate that the system effectively detects driver drowsiness with high accuracy, making it suitable for integration into advanced driver assistance systems (ADAS) and intelligent transportation applications.

Keywords: Driver Drowsiness Detection, Computer Vision, Haar Cascade Classifier, Convolutional Neural Network (CNN), Eye State Classification, Fatigue Detection, Facial Feature Detection, Real-Time Monitoring, Driver Monitoring System (DMS), Road Safety, Deep Learning, Advanced Driver Assistance Systems (ADAS).

I. INTRODUCTION

Road accidents caused by driver fatigue and drowsiness have become a major concern worldwide. According to various road safety reports, a significant percentage of traffic accidents occur because drivers lose concentration or fall asleep while driving. Long-distance driving, insufficient sleep, monotonous roads, and physical exhaustion are among the primary causes of driver drowsiness. These incidents not only result in severe injuries and loss of life but also lead to substantial economic losses. Therefore, developing an intelligent system capable of detecting driver fatigue in real time has become an important area of research in intelligent transportation systems.

Recent advances in computer vision, image processing, and artificial intelligence have enabled the development of non-intrusive driver monitoring systems. Unlike traditional methods that rely on physiological sensors such as Electroencephalography (EEG), Electrocardiography (ECG), or wearable devices, vision-based approaches require only a camera to continuously monitor the driver's facial features. These systems are more comfortable, cost-effective, and practical for real-world vehicle applications. Facial characteristics such as eye closure, blinking frequency, yawning, and head movements provide valuable information about the driver's level of alertness.

Deep learning techniques, particularly Convolutional Neural Networks (CNNs), have significantly improved the performance of image classification and object detection tasks. CNN models automatically extract meaningful features from facial images and classify the driver's eye state with high accuracy. When combined with traditional computer vision algorithms such as Haar Cascade classifiers for face and eye detection, the overall system becomes both efficient and computationally lightweight, making it suitable for real-time applications.

This research proposes a vision-based driver drowsiness detection system that combines Haar Cascade classifiers with a custom-designed Convolutional Neural Network. The webcam continuously captures the driver's face, detects the eyes, and classifies them as open or closed. The system calculates the eye closure score and continuously monitors driver alertness. Whenever prolonged eye closure indicating drowsiness is

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detected, an alarm is activated to alert the driver immediately. The proposed system provides a reliable, non-invasive, and economical solution for reducing road accidents caused by driver fatigue.

Many safety connected driving supporter schemes decreased the danger of four-wheeler accidents, and investigations depicted weariness to be a major announced an idea that whole deadly accidents (17%) would be attributed to weary drivers. Many revisions showed by Volkswagen AG specify that 5-25% of all accidents are produced by the sleeping of driver. The lack of concentration damage steering actions and decrease response period, and revisions illustrated that sleepiness raises threat of crashes. This figure points the demand for a dependable intelligent driver sleepiness sensing system. The aim is to create an intelligent processing scheme to avoid road accidents. This can be done by period of time monitoring the drowsiness and warning driver of inattention to prevent accidents.

Based on the literature survey, the driver's drowsiness can be detected based on three factors such as physiological, behavioural, and vehicle-based measurements. But these approaches pose some disadvantages in certain real time scenarios. So, we aim to apply Deep Learning algorithms to this problem statement. Our methodology is to use a Convolutional Neural Network (CNN). CNN offers a computerized and effective way to categorize the driver as drowsy or non-drowsy correctly.

With the advancement of computer vision and deep learning, driver drowsiness can be detected in real time using a camera. In this project, the driver’s face is continuously monitored and features such as eye closure and facial expressions are analyzed. If drowsiness is detected, the system generates an alert to warn the driver, helping to prevent road accidents.

II. RELATED WORK

Driver drowsiness detection has attracted considerable attention from researchers over the past decade due to its direct impact on road safety. Various techniques have been proposed based on physiological signals, vehicle behavior, and computer vision. Each method offers unique advantages while presenting certain limitations regarding cost, complexity, and real-time implementation. Early research primarily focused on physiological signal analysis using Electroencephalography (EEG), Electrocardiography (ECG), and Electrooculography (EOG). These techniques provide highly accurate measurements of the driver's physical condition. However, they require specialized sensors attached to the driver's body, making them uncomfortable and impractical for daily driving applications. Their high implementation cost further limits their commercial adoption.

Another group of approaches utilizes vehicle behavior analysis, including steering wheel movement, lane deviation, acceleration patterns, and braking behavior. These methods do not require monitoring the driver's face directly but may fail under varying road conditions, traffic congestion, or adverse weather. Consequently, vehicle-based methods alone cannot reliably distinguish between normal driving variations and driver fatigue.

Recent studies have shifted toward computer vision-based methods due to their non-contact nature and affordability. Face detection algorithms such as Haar Cascade, Histogram of Oriented Gradients (HOG), and facial landmark detection are widely employed to identify eye closure, blink frequency, yawning, and head orientation. Machine learning algorithms such as Support Vector Machines (SVM), Random Forests, and Artificial Neural Networks have also been applied for fatigue classification.

With the emergence of deep learning, Convolutional Neural Networks have demonstrated superior performance in facial image recognition and eye state classification. CNN models automatically learn discriminative image features without manual feature engineering, resulting in higher classification accuracy. Several recent studies combine Haar Cascade classifiers for rapid face localization with CNN models for eye classification, providing efficient real-time performance while maintaining computational efficiency. Inspired by these developments, the proposed work integrates Haar Cascade detection and CNN-based classification to achieve accurate driver drowsiness detection with minimal hardware requirements.

Many researchers have developed systems to detect driver drowsiness in order to reduce road accidents caused by fatigue. Earlier methods mainly focused on physiological signals such as EEG, heart rate, and eye movement to detect sleepiness. Although these methods provide accurate results, they require

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special sensors attached to the driver's body, which makes them uncomfortable and impractical for real-time driving environments.

Later, researchers proposed computer vision–based approaches that use cameras to monitor the driver's face. These systems analyze facial features such as eye blinking, eye closure duration, yawning, and head movements to determine the driver's alertness level. Algorithms like Haar Cascade classifiers have been widely used to detect the face and eyes from video frames captured by a webcam.

With the advancement of machine learning and deep learning, Convolutional Neural Networks (CNN) have been widely applied for driver drowsiness detection. CNN models can automatically extract important features from eye images and classify whether the eyes are open or closed. Several studies have shown that CNN-based methods provide higher accuracy and better performance compared to traditional machine learning techniques.

Some recent approaches combine facial landmark detection, eye aspect ratio (EAR), and deep learning models to detect drowsiness more effectively. These systems continuously monitor the driver in real time and trigger an alarm when drowsiness is detected, helping to prevent accidents and improve road safety. However, challenges such as changes in lighting conditions, variations in facial appearance, and head movements still affect detection accuracy. Therefore, more robust deep learning–based systems are required to improve the reliability of driver drowsiness monitoring systems.

III. PROPOSED SYSTEM

The proposed system presents an intelligent vision-based driver monitoring framework capable of detecting driver drowsiness in real time using computer vision and deep learning techniques. The system utilizes a standard webcam installed inside the vehicle to continuously capture the driver's facial images during driving.

Initially, each video frame undergoes preprocessing before facial detection. Haar Cascade classifiers are employed to rapidly detect the driver's face and localize both eyes. The detected eye regions are extracted and resized into a standard image dimension suitable for CNN classification. This preprocessing stage significantly reduces computational complexity while maintaining detection accuracy. The extracted eye images are then passed to a custom-designed Convolutional Neural Network trained on thousands of open-eye and closed-eye images. The CNN automatically extracts hierarchical image features and predicts whether each eye is open or closed. Based on continuous classification results, the system calculates the eye closure score, blink frequency, and eye aspect ratio over consecutive video frames.

If both eyes remain closed beyond a predefined threshold indicating prolonged eye closure, the system interprets the condition as driver drowsiness. An audible warning alarm is immediately activated to alert the driver and encourage regaining attention. The entire process operates continuously without requiring any wearable sensors, ensuring comfort and convenience during driving.

The proposed system is computationally efficient, economically affordable, and easily deployable in modern vehicles. Its combination of Haar Cascade detection and CNN classification provides high detection accuracy while maintaining real-time performance under varying illumination conditions and facial expressions.

Our proposed system will provide a solution for monitoring driver's drowsiness. The cons of the existing system in extracting only selected hand-crafted features is overcome by using custom-designed CNN by giving an input driver image. Now the driver will be continuously monitored by a webcam. The video captured is converted into a sequence of frames. For each frame, the face and eye are detected using predefined classifiers available in opencv called haar cascade classifiers. Eye images are extracted and sent to a series of 2D CNN layers (5x5, 3x3 kernel valid padding), max- pooling layers(2x2) and finally, the fully connected dense layer classifies whether eyes are closed or not. A score is calculated based on eye closure. If both eyes are closed consecutively in 15 frames then the system predicts as drowsy and an alarm sound is triggered to alert the car operator. The categorization of driver drowsiness is done correctly and the normalization issues in the existing model are eliminated by using custom designed CNN.

IV. SYSTEM ARCHITECTURE

Figure 1 depicts the flow of the system to be created. In the initial step, the driver is monitored by using a webcam. The video input is converted into a sequence of frames. In each

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frame, driver's face and eyes are detected by using haar cascade classifiers. The detected eyes are stored as images to form a data set for CNN. The system also provides provision for the preparation of the eye data set to train CNN model. To train the image and to increase the number of data sets Data augmentation is done. The images of both eyes are then subjected to a series of image preprocessing steps such as grayscale conversion, re-sizing and normalizing, etc. It is then fed to a pre-trained CNN model consisting of convolution layers, max- pooling layers, and dense layers to predict eye closure. Based on the prediction, a score is calculated. If the system finds the driver as drowsy, then an alarm will be triggered to alert the driver.

The overall architecture of the proposed driver drowsiness detection system consists of several sequential processing modules working together to identify driver fatigue in real time. The process begins with image acquisition, where a webcam continuously captures live video frames of the driver. These frames are forwarded to the preprocessing stage, where image resizing, grayscale conversion, and noise reduction improve detection quality. During the face detection stage, Haar Cascade classifiers identify the driver's face and isolate the eye regions from each captured frame. The extracted eye images are normalized and supplied to the Convolutional Neural Network.

The CNN classification module analyzes each eye image and classifies it as either open or closed. Classification outputs from consecutive frames are stored temporarily for temporal analysis. The system continuously calculates eye closure duration, blink rate, and overall eye closure score. The decision-making module evaluates these parameters against predefined thresholds. If prolonged eye closure persists, the system recognizes driver drowsiness and immediately activates the warning module. Finally, the alert generation module produces an audible alarm that notifies the driver to regain attention before an accident occurs. The entire architecture functions automatically without manual intervention and operates continuously throughout the driving session. The implementation consists of the following modules.

1. Face and Eye Detection

In this module, the system uses a webcam to capture real-time video frames of the driver. The OpenCV library provides pre-trained models for face and eye detection. These models are loaded using the load method available in OpenCV.

The pre-trained Haar Cascade classifiers are stored in the OpenCV data folder as XML files. The system loads these XML files using the Cascade Classifier method. After loading the classifier, the detectMultiScale() function is used to detect faces and eyes in the captured image frames. This method returns rectangular bounding boxes around the detected eye regions. These detected eye regions are then extracted and passed to the next processing stage.

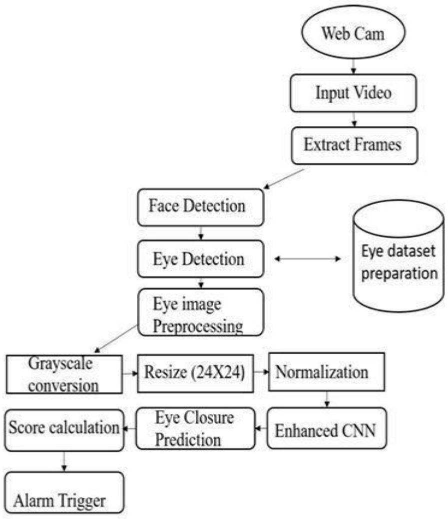

Fig. 1 System Architecture of CNN

2. Preprocessing and Labeling

In this module, the extracted eye images are prepared for training the CNN model. The eye images obtained from the webcam are labeled into two categories: Open Eyes

Closed Eyes

The preprocessing steps include converting the eye images into grayscale format, resizing them to 24 × 24 pixels, and normalizing the pixel values. This preprocessing helps reduce computational complexity and improves the efficiency of the CNN model.

3. Data Augmentation

Data augmentation is used to increase the diversityvof the dataset without collecting new images. Instead of gathering new data, the existing eye images are transformed using various techniques. In this project, data augmentation is implemented using the Keras Image Data Generator. It performs

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transformations such as: Rotation, Brightness adjustment, Shear transformation, Zooming.

These transformations help the model learn different variations of eye images and improve the overall accuracy and robustness of the CNN model.

4. Enhanced CNN Model

The Convolutional Neural Network (CNN) is used to classify the eye state as open or closed. The CNN model consists of several layers that extract features from the input images.

The convolutional layers use the ReLU activation function with a kernel size of 3 × 3 to extract important visual features from the eye images. These layers are followed by pooling layers to reduce the size of the feature maps and retain important information.

The final layers of the network are fully connected layers, where the Softmax activation function is used to classify the output into two categories: open eyes or closed eyes. The CNN model is trained using the Adam optimizer, which helps improve the learning efficiency and reduces the loss during training.

5. Triggering Alarm

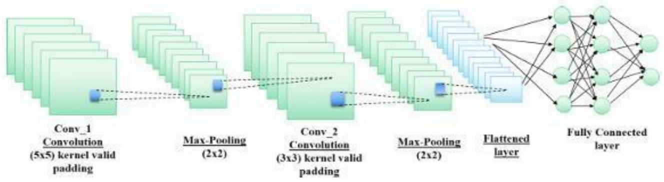
This module is responsible for alerting the driver when drowsiness is detected. During real-time monitoring, the system continuously checks the eye state predicted by the CNN model.

If the system detects that the driver’s eyes remain closed for several consecutive frames, it identifies the driver as drowsy. At this point, an alarm sound is triggered to alert the driver. This warning helps the driver regain attention and prevents possible accidents.

CNN Model

The Convolutional Neural Network (CNN) is the main part of the driver drowsiness detection system. It extracts features from eye images and classifies whether the eyes are open or closed. The convolution layer identifies important features like edges and patterns. The ReLU activation function introduces non-linearity to help the model learn complex patterns. The max pooling layer reduces the size of feature maps while keeping important information. These features are then passed to the fully connected layer for classification. Finally, the softmax layer gives the probability of the eye state as open or closed. The CNN model is trained using labeled eye image datasets to detect drowsiness accurately.

Representation of convolution layer process



Data Augmentation

Data augmentation is used to increase the size and diversity of the eye image dataset without collecting new data. The existing images of open and closed eyes are modified using transformations such as rotation, zooming, brightness adjustment, and shifting. These transformations help the CNN model learn different variations of eye images under different lighting and angles. Data augmentation is implemented using Keras ImageDataGenerator, which improves the model’s accuracy and helps reduce overfitting during training.

V. RESULT AND DISCUSSION

The proposed vision-based driver drowsiness detection system was evaluated using real-time video captured under different environmental conditions, including varying lighting intensity, facial orientations, and user appearances. The Haar Cascade classifier successfully detected the driver's face and eye regions with high consistency under normal daylight and moderate indoor illumination. The detection performance remained stable even with slight head movements and changes in facial expressions.

The custom-designed Convolutional Neural Network accurately classified eye states into open and closed categories. Experimental observations indicated that the CNN effectively distinguished normal blinking from prolonged eye closure associated with driver fatigue. The combination of Haar Cascade detection and CNN classification significantly reduced false detections while maintaining efficient processing speed suitable for real-time applications. The proposed system generated warning alarms immediately after detecting continuous eye closure beyond the predefined threshold. This timely response

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effectively alerted the driver before complete loss of attention. Compared with conventional machine learning approaches, the CNN-based model demonstrated improved robustness against illumination changes and variations in facial features.

Overall, the proposed system achieved reliable real-time performance while requiring only a standard webcam and modest computational resources. Its non-intrusive operation, low implementation cost, and high detection accuracy make it a practical solution for integration into Advanced Driver Assistance Systems (ADAS), smart vehicles, and intelligent transportation systems. Future work may focus on incorporating additional behavioral indicators such as yawning detection, head pose estimation, gaze tracking, and facial landmark analysis to further improve detection accuracy and system reliability under challenging driving conditions.

In this project, we developed a Driver Drowsiness Detection System using deep learning techniques. The system detects driver fatigue by analyzing facial features such as eye blinking and facial expressions through a webcam. The model is trained using TensorFlow and Convolutional Neural Networks (CNN) to identify drowsiness conditions in real time.

In below, Home Page is the initial interface of the system. It provides options for users to navigate through the system such as Admin Login and Autoist Registration/Login. This page acts as the entry point for accessing different functionalities of the system.

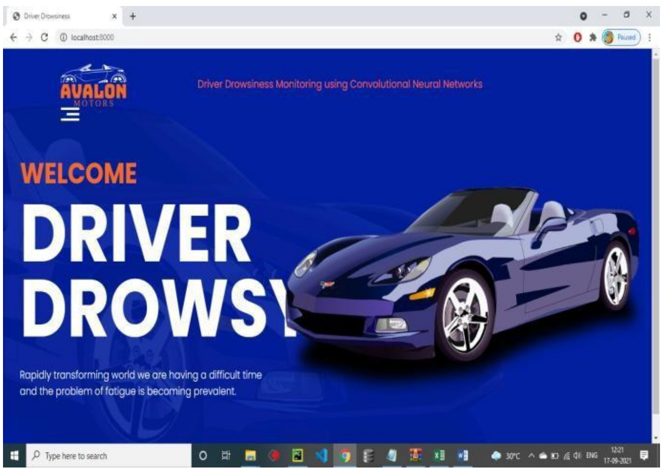

Figure 1

The Admin Login module allows the administrator to log into the system using valid credentials. After successful authentication, the admin can manage user information and monitor the system operations.

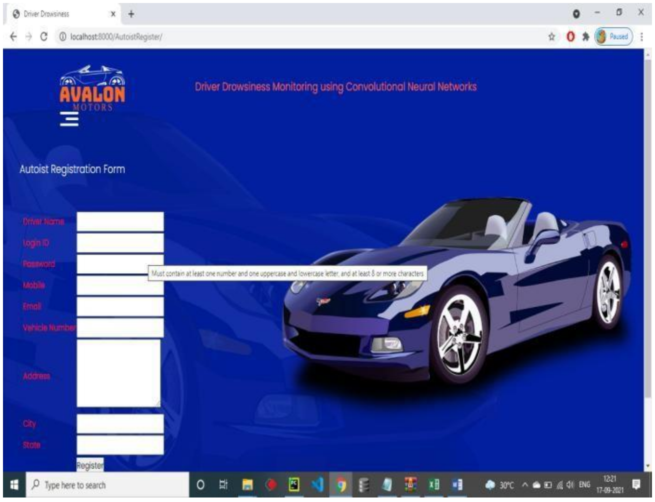

Figure 2

In above screen Autoist Register, new drivers (Autoists) can register into the system by providing their details such as name, username, password, and other required information. After successful registration, the driver can log in to the system and access the drowsiness detection features.

In below Screen When the driver starts the detection process, the system activates the webcam and begins analyzing the driver's facial features in real time.

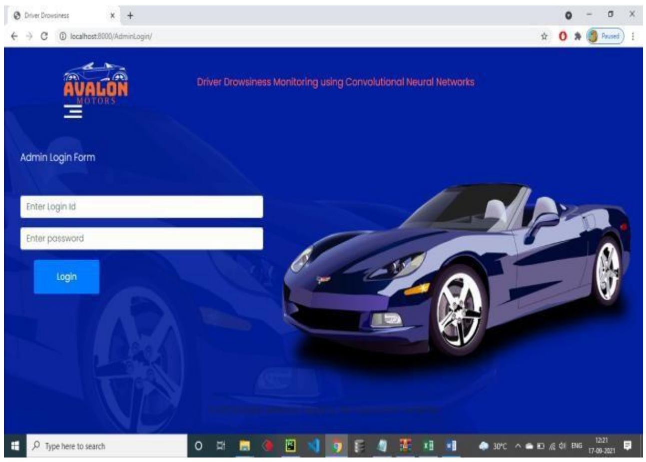

Figure 3

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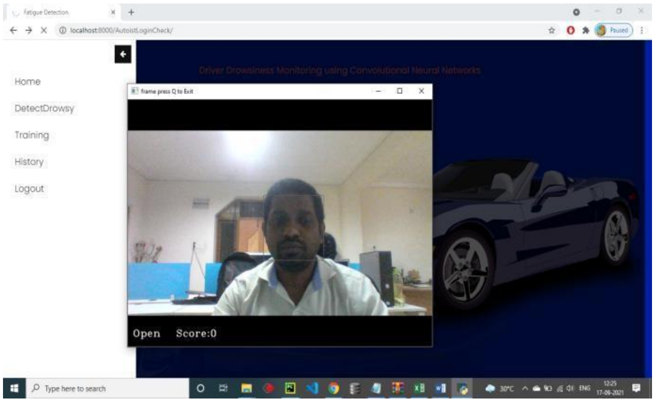

Figure 4

In this stage, the system detects eye blinking patterns using facial landmark detection. Frequent eye closure or longer blink duration indicates possible driver drowsiness.

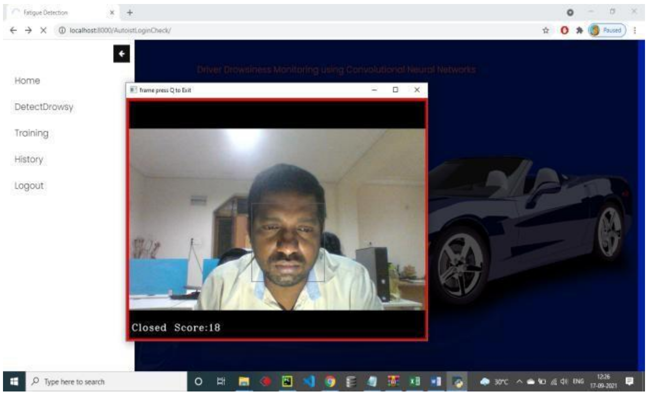

Figure 5

In above screen the system detects signs of fatigue or drowsiness, an alarm is triggered to alert the driver. This warning helps prevent accidents by waking the driver. The custom-designed Convolutional Neural Network accurately classified eye states into open and closed categories. Experimental observations indicated that the CNN effectively distinguished normal blinking from prolonged eye closure associated with driver fatigue. The combination of Haar Cascade detection and CNN classification significantly reduced false detections while maintaining efficient processing speed suitable for real-time applications. The proposed system generated warning alarms immediately after detecting continuous eye closure beyond the predefined threshold. The enhanced CNN supplied an automated and effective learned characteristics that aid us to categorize the opening or closing of eyes. If the closing of eyes occur in 15 successive frames, an alarm is triggered to alert the driver. The proposed CNN gives a training accuracy of 97% and a testing accuracy of 67%. For future works, extra face characteristics can be added to give more accuracy in detection.

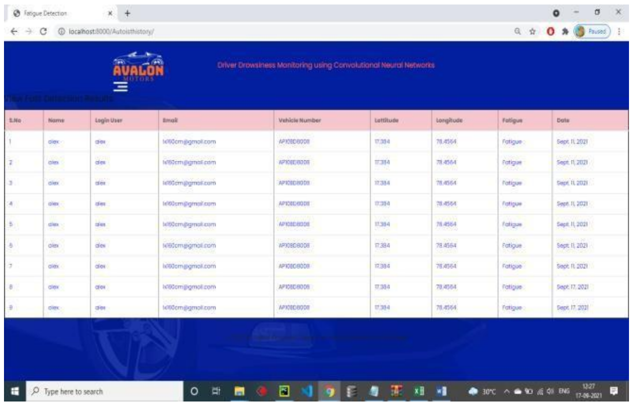

Figure 6

In above screen the Fast History Results module stores previous detection records. Drivers or administrators can view past detection results for monitoring driver alertness over time.

VI. CONCLUSION

A model for drowsiness sensing depends on effective CNN architecture, planned to observe drowsiness based on eye closure. The implementation started preparing image datasets for both open and closed eyes. 75% of the data set is used for the custom- designed CNN training and the balance 25% of the dataset is utilized for test purposes. First, the information video is transformed into frames and in each frame, the face and eyes are detected. The enhanced CNN supplied an automated and effective learned characteristics that aid us to categorize the opening or closing of eyes. If the closing of eyes occur in 15 successive frames, an alarm is triggered to alert the driver. The proposed CNN gives a training accuracy of 97% and a testing accuracy of 67%. For future works, extra face characteristics can be added to give more accuracy in detection. We can also combine vehicle driving pattern information obtained using On-Board Diagnostics sensors with the facial features extracted.

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