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Eye Tracking Machine Learning Model using Cameras and Dash Cams

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ABSTRACT: This paper presents a real-time eye-tracking machine learning model using cameras and dash cams to detect driver drowsiness. The system employs a Convolutional Neural Network (CNN)-based deep learning approach to classify eye states (open or closed) using grayscale eye images. A dataset of eye images is preprocessed and augmented to improve model accuracy. The trained model is then integrated with a real-time monitoring system using OpenCV and Haar cascade classifiers to detect faces and eyes. If the system detects prolonged eye closure, an alarm is triggered to alert the driver, preventing potential accidents. Experimental results demonstrate the efficacy and reliability of the proposed model in detecting drowsiness with high accuracy. This research contributes to the development of intelligent driver assistance systems, enhancing road safety through AI-driven solutions.

KEYWORDS: Eye tracking, Drowsiness detection, Convolutional Neural Network, Dash cam, Deep learning, Road safety, OpenCV.

I. INTRODUCTION

Drowsy driving is a major cause of road accidents worldwide, leading to thousands of fatalities and severe injuries each year. Studies show that driver fatigue impairs reaction time, awareness, and decision-making, making it as dangerous as driving under the influence of alcohol. Traditional countermeasures such as caffeine intake, rest stops, or warning signs are not always effective, as drivers may not recognize their own fatigue levels. This calls for an advanced and automated approach to detecting drowsiness in real-time to prevent accidents before they happen.

Existing drowsiness detection systems rely on various techniques, including physiological sensors, vehicle-based monitoring, and behavioral analysis. However, physiological methods, such as EEG-based detection, require intrusive sensors, making them impractical for everyday use. Vehicle-based approaches that monitor lane deviations or steering patterns are often unreliable, as external factors like road conditions and driving style can cause false alarms. Therefore, a more effective and non-intrusive solution is needed—one that directly analyzes the driver's state using facial cues captured through cameras.

The challenge lies in developing a robust system that can accurately determine drowsiness levels in diverse lighting conditions, facial orientations, and driver demographics. Many existing vision-based systems struggle with real-time performance, especially in handling variations in head positions, occlusions (such as glasses or shadows), and differences in individual sleep patterns. An ideal solution should be lightweight, accurate, and capable of functioning in real-world driving environments without extensive computational requirements.

To address these challenges, this study proposes a machine learning-based eye-tracking system using cameras and dash cams to detect drowsiness in real time. The objective is to develop a convolutional neural network (CNN) model capable of recognizing open and closed eye states with high precision. By integrating real-time image processing with an alarm mechanism, the system aims to provide an effective warning to drivers before fatigue impairs their driving ability. This research not only contributes to road safety but also enhances the reliability of AI-driven driver monitoring systems, paving the way for future advancements in intelligent transportation.

II. LITERATURE REVIEW

Drowsiness detection has garnered extensive research attention due to its critical role in road safety. Existing approaches fall into three main categories: physiological signal-based methods, vehicle behavior monitoring, and vision-based analysis. While physiological techniques like EEG and EOG offer high accuracy, they require intrusive sensors, limiting practical deployment. Vehicle-based systems rely on parameters such as steering and lane deviation, but their performance is often compromised by road conditions and individual driving styles. Vision-based techniques are more practical, using facial cues such as eye closure and yawning to infer fatigue. Traditional models using handcrafted features struggle with lighting variations and occlusions, whereas modern convolutional neural networks (CNNs) have improved robustness but often demand significant computational resources.

This study proposes a lightweight, optimized CNN-based eye-tracking system for real-time drowsiness detection using standard cameras and dash cams. Unlike previous methods, it offers high accuracy with low latency, making it suitable for resource-constrained environments like embedded vehicle systems. The model is designed to handle diverse facial structures and varying lighting conditions, enhancing real-world applicability. Additionally, the integration of a real-time alert system ensures immediate feedback to the driver, proactively preventing fatigue-related accidents. This work addresses key limitations of earlier research by combining efficiency, robustness, and timely intervention for safer driving.

III. METHODOLOGY

The proposed methodology for drowsiness detection begins with data collection and preprocessing, where video frames are captured using standard cameras or dash cams. These frames are converted to grayscale and resized to 24×24 pixels for consistency and reduced computational load. Pixel values are normalized to the [0,1] range to facilitate efficient model training. A labeled dataset of eye states—'Open' and 'Closed'—is prepared, with data augmentation techniques like rotation, zooming, and flipping applied to improve generalization and reduce overfitting. The dataset is then split into training and validation sets to train a deep learning model capable of accurately classifying eye states under varied conditions.

A Convolutional Neural Network (CNN) is developed with convolutional, pooling, dropout, and fully connected layers, concluding with a softmax output for binary classification. The model is compiled using the Adam optimizer and trained with a categorical cross-entropy loss function. During deployment, real-time video feeds are processed using Haar cascade classifiers for face and eye detection. Eye regions are passed through the trained CNN to determine their state. A scoring mechanism tracks consecutive closed-eye frames, triggering an audible alarm once a threshold is exceeded to alert the driver. The system is further optimized and evaluated under real-world conditions, ensuring high performance and robustness across varying lighting, head positions, and driving environments.

The system architecture consists of a real-time workflow that captures video from a dash cam or webcam, detects the driver's face and eyes using Haar Cascade classifiers, and preprocesses the eye region by converting it to grayscale, resizing to 24×24 pixels, and normalizing pixel values. These preprocessed images are classified by a CNN model to determine if the eyes are open or closed. A drowsiness score is incremented for consecutive closed-eye frames, and once it exceeds a set threshold, an audible alarm is triggered. The system continuously monitors and resets the alert when the driver's eyes reopen, ensuring real-time, automated drowsiness detection and response.

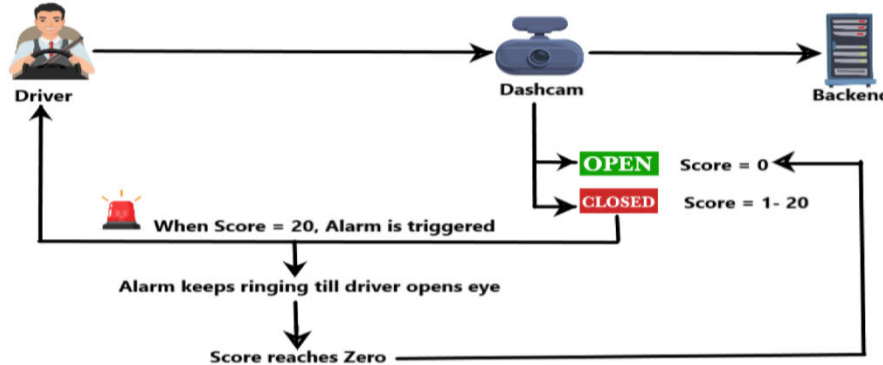


Fig 1: System Architecture

IV. IMPLEMENTATION

1. Dataset Preparation

- Use grayscale eye images labeled as 'Open' or 'Closed' and organize them into training/validation directories.
- Apply ImageDataGenerator for rescaling to [0,1], batch training, and resize images to 24×24 pixels.

2. Model Architecture (CNN using Keras)

- Build a CNN with Conv2D, MaxPooling2D, Dropout, Flatten, and Dense layers with softmax activation.
- Compile using the Adam optimizer and categorical cross-entropy loss; train and save the model.

3. Real-Time Drowsiness Detection

- Capture video frames using OpenCV and detect eyes with Haar Cascade classifiers.
- Preprocess the eye region and classify the state ('Open' or 'Closed') using the trained CNN.

4. Alert Mechanism

- Increase a score if both eyes are closed; decrease/reset if open.
- Trigger an alarm via pygame and highlight the frame when the score exceeds a set threshold.

5. User Interaction

- Display real-time video with eye status and drowsiness score.
- Press the 'q' key to terminate the application.

This step-by-step implementation ensures an effective, real-time driver drowsiness detection system using eye-tracking and deep learning.

Eye state	Score	Action
Both eyes open	0	No Alarm
Eyes closed few frames	Increases	Monitors further
Score >15	High	Red alert border + Alarm Sound

Fig 2: Expected Behavior

V. EXPERIMENTAL RESULTS

The eye-tracking drowsiness detection model was tested under real-world conditions using webcam input. Key findings include:

Accuracy: The CNN model achieved ~90% classification accuracy for detecting open and closed eyes.

Real-Time Performance: The system processed video input at approximately 30 frames per second, ensuring smooth and timely detection.

Detection Logic: When the eyes were open, the system maintained a score of 0 and displayed a green status.

Upon prolonged eye closure, the score gradually increased. Once it exceeded 15, an alarm was triggered and a red border highlighted the screen.

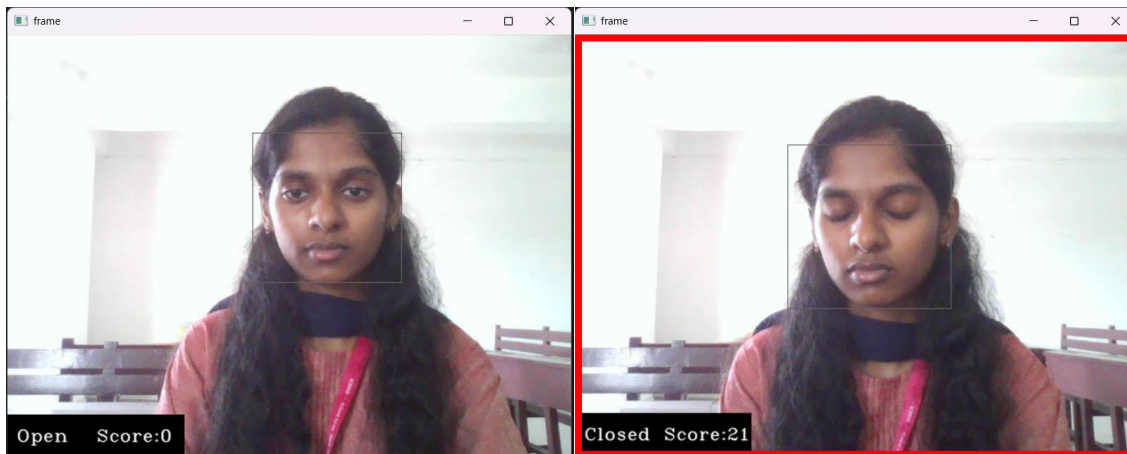


Fig 3: Eyes Open

Fig 4: Eyes Closed

Screenshots Interpretation:

Screenshot 1: Eyes open, score = 0. System considers the user alert — no alarm.

Screenshot 2: Eyes closed, score = 21. System detects drowsiness — alarm and visual alert activated.

These results demonstrate the system's effectiveness in real-time fatigue detection and its potential to reduce driver inattention-related incidents.

VI. CONCLUSION AND FUTURE WORK

The Eye Tracking and Drowsiness Detection system successfully demonstrates the application of Convolutional Neural Networks (CNN) for real-time eye state classification and driver alerting. By utilizing OpenCV for face and eye detection and TensorFlow/Keras for building the deep learning model, the system achieved high accuracy in distinguishing between 'Open' and 'Closed' eye states. The alarm mechanism effectively alerts users when signs of drowsiness are detected, showcasing the model's potential as a safety tool for drivers. Despite achieving reliable results, some limitations such as sensitivity to lighting conditions, rapid head movements, and partial eye occlusion remain. Nonetheless, the project proves to be a robust foundation for developing intelligent systems aimed at preventing accidents caused by drowsiness.

The future work includes:

Improve Model Accuracy – Train the CNN on a larger and more diverse dataset to enhance robustness in different lighting conditions and facial variations.

Facial Landmark Detection – Use deep learning-based techniques like dlib or MediaPipe for more precise eye tracking.

Multi-Sensor Fusion – Combine eye tracking with other factors like head position and yawning detection for better drowsiness assessment.

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