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AI-BASED DRIVER DROWSINESS DETECTION AND MONITORING SYSTEM FOR ELECTRIC VEHICLES WITH EMAIL AND THINGSPEAK ALERTS

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ABSTRACT

Road accidents caused by driver fatigue, drowsiness, and reduced attention have become a major concern in modern transportation systems, particularly in electric vehicles (EVs) where long-distance travel is increasingly common. Driver drowsiness significantly reduces reaction time, decision-making ability, and vehicle control, resulting in serious accidents, property damage, and loss of life. Conventional driver monitoring systems primarily rely on manual observation or basic warning mechanisms, which often fail to detect fatigue at an early stage. Recent advancements in Artificial Intelligence (AI), computer vision, Internet of Things (IoT), embedded systems, and cloud computing have enabled the development of intelligent driver monitoring systems capable of continuously analysing driver behaviour and generating real-time safety alerts. This project presents a Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert. The proposed framework integrates a camera module, Arduino/ESP32 controller, eye blink detection algorithm, ThingSpeak cloud platform, e-mail notification system, buzzer, and GPS module (optional) into a unified intelligent safety system. The camera continuously monitors the driver's eye movements, and the eye blink detection algorithm analyses blink frequency and eye closure duration to identify symptoms of fatigue or drowsiness. When prolonged eye closure or abnormal blinking behaviour is detected, the system immediately activates an audible warning through a buzzer while simultaneously uploading event information to the ThingSpeak cloud platform and transmitting an e-mail alert to registered emergency contacts or fleet administrators. Experimental evaluation demonstrates high eye blink detection accuracy, reliable cloud communication, rapid alert generation, low response time, and stable system performance under different driving conditions. The proposed framework significantly improves driver safety, reduces fatigue-related accidents, enables remote vehicle monitoring, and supports intelligent transportation systems for next-generation electric vehicles.

Keywords: Electric Vehicle (EV), Eye Blink Detection, Driver Drowsiness Detection, Arduino, ESP32, ThingSpeak, E-mail Alert, Internet of Things (IoT), Computer Vision, Driver Monitoring System, Road Safety.

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) and intelligent transportation systems has increased the demand for advanced driver safety technologies capable of preventing road accidents caused by driver fatigue and drowsiness. Driver fatigue is one of the leading causes of road accidents worldwide because prolonged driving reduces concentration, slows reaction time, and impairs decision-making ability. Drowsy drivers often experience frequent eye closure, abnormal blinking patterns, reduced alertness, and delayed responses, significantly increasing the risk of vehicle collisions. Conventional vehicle safety systems mainly rely on manual observation or simple warning mechanisms, which are often unable to detect early symptoms of driver fatigue. Consequently, there is a growing need for intelligent driver monitoring systems capable of continuously analysing driver behaviour and generating immediate warning alerts before accidents occur. Recent advancements in Artificial Intelligence (AI), computer vision, embedded systems, Internet of Things (IoT), and cloud computing provide effective solutions for developing real-time driver monitoring systems. These intelligent technologies enable continuous observation of eye movements, facial features, and driver behaviour while supporting automated alert generation and remote monitoring. Such systems significantly improve road safety, reduce accident rates, enhance driver awareness, and support the development of intelligent transportation systems for modern electric vehicles [1–8].

Computer vision and image processing technologies have transformed modern driver assistance systems by enabling automatic analysis of facial expressions and eye movements. Eye blink detection has become one of the most reliable methods for identifying driver fatigue because eye closure duration and blink frequency directly reflect the driver's level of alertness. Modern vision-based monitoring systems employ cameras and image processing algorithms to continuously capture facial images and analyse eye behaviour in real time. Embedded controllers such as ESP32, Arduino, and Raspberry Pi process the acquired image data and generate warning alerts whenever prolonged eye closure or abnormal blinking behaviour is detected. The Internet of Things further enhances these monitoring systems by enabling cloud-based storage of driving events and remote supervision through platforms such as ThingSpeak. Integration with e-mail notification services allows emergency contacts, vehicle owners, or fleet managers to receive immediate alerts whenever driver drowsiness is detected. Experimental studies demonstrate that AI-assisted eye blink detection systems provide high detection accuracy, rapid response, and reliable communication, making them highly suitable for intelligent vehicle safety applications [9–17].

This project proposes a Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert to improve driver safety through intelligent fatigue detection and real-time notification. The proposed framework integrates a camera module, ESP32/Arduino controller, eye blink detection algorithm, ThingSpeak cloud platform, e-mail notification service, buzzer, and an optional GPS module into a unified driver monitoring system. Initially, the camera continuously captures the driver's facial images while the eye blink detection algorithm analyses blink frequency and eye closure duration in real time. Whenever prolonged eye closure or abnormal blinking behaviour exceeds predefined safety thresholds, the embedded controller immediately classifies the event as driver drowsiness. The system simultaneously activates a buzzer to alert the driver, uploads the event details to the ThingSpeak cloud platform, and sends an automated e-mail notification to predefined emergency contacts or fleet administrators. The effectiveness of the developed framework is evaluated using engineering parameters including eye blink detection accuracy, drowsiness detection rate, communication delay, response time, alert generation accuracy, and overall system reliability. Experimental evaluation demonstrates that the proposed intelligent driver monitoring system accurately detects fatigue, generates rapid alerts, maintains reliable cloud communication, improves driver safety, and supports the implementation of next-generation intelligent electric vehicle transportation systems.[18-25]

II. SURVEY OF RESEARCH

1. Driver Drowsiness Detection Systems

Driver drowsiness detection has become an important research area because fatigue is one of the major causes of road accidents worldwide. Researchers have developed intelligent monitoring systems capable of continuously observing driver behaviour and identifying fatigue symptoms before accidents occur. Conventional driver monitoring methods mainly rely on manual observation or simple warning mechanisms, which often fail to detect early signs of drowsiness. Modern systems employ cameras, embedded controllers, and image processing techniques to monitor eye movements, facial expressions, and head posture. Experimental investigations demonstrate that intelligent driver monitoring systems significantly improve road safety by providing early fatigue detection and timely warning alerts. These developments contribute to reducing accident rates and improving overall transportation safety **[1]**.

2. Eye Blink Detection Using Computer Vision

Computer vision has become one of the most effective techniques for detecting driver fatigue through continuous eye monitoring. Researchers have developed eye blink detection algorithms capable of analysing blink frequency, eye closure duration, and eye aspect ratio (EAR) to determine driver alertness. Cameras continuously capture facial images, while image processing algorithms identify eye landmarks and monitor blinking behaviour in real time. Whenever prolonged eye closure or abnormal blinking patterns are detected, warning alerts are generated automatically. Experimental studies demonstrate that vision-based eye blink detection provides high detection accuracy, rapid processing speed, and reliable fatigue identification under different driving conditions. These characteristics make eye blink detection highly suitable for intelligent driver assistance systems **[2]**.

3. IoT-Based Vehicle Monitoring Systems

The Internet of Things (IoT) has significantly improved modern vehicle monitoring by enabling real-time communication between embedded devices and cloud platforms. Researchers have integrated IoT communication modules with vehicle safety systems to transmit driving information, driver behaviour, and vehicle status to cloud databases for remote monitoring. Cloud platforms such as ThingSpeak provide real-time visualization of driving events, historical data storage, and graphical analysis through web dashboards. Remote monitoring enables vehicle owners, fleet managers, and maintenance personnel to supervise vehicle operation from any location. Experimental investigations confirm that IoT-enabled monitoring improves transportation

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safety, simplifies data management, and supports intelligent fleet management applications **[3]**.

4. E-mail Alert Systems for Emergency Notification

Automatic e-mail notification systems have become an effective communication method for transmitting emergency alerts generated by intelligent monitoring systems. Researchers have integrated e-mail services with embedded controllers to automatically notify emergency contacts whenever abnormal operating conditions or safety hazards are detected. In driver monitoring applications, e-mail alerts provide immediate information regarding driver fatigue, vehicle status, and location details. Experimental studies demonstrate that automated notification systems significantly reduce emergency response time while improving communication reliability. Integration of e-mail services with IoT platforms enhances the effectiveness of intelligent transportation systems by ensuring rapid dissemination of safety information **[4]**.

5. Embedded Controllers for Intelligent Vehicle Safety

Embedded controllers such as Arduino, ESP32, and Raspberry Pi are widely used in intelligent vehicle monitoring systems because of their low cost, high processing capability, and compatibility with cameras, sensors, and communication modules. Researchers have implemented embedded systems for processing camera images, controlling warning devices, communicating with cloud platforms, and generating emergency notifications. These controllers continuously analyse driver behaviour while maintaining reliable communication with external devices. Experimental investigations demonstrate that embedded controllers provide stable performance, rapid processing, low power consumption, and economical implementation, making them highly suitable for intelligent driver monitoring applications **[5]**.

6. Future Trends in Intelligent Driver Monitoring Systems

Recent research focuses on integrating Artificial Intelligence, deep learning, computer vision, IoT, cloud computing, and advanced driver assistance systems (ADAS) to develop next-generation driver monitoring solutions. Researchers have proposed intelligent systems capable of analysing facial expressions, eye movements, head posture, steering behaviour, and physiological signals to accurately detect driver fatigue. Advanced cloud platforms support predictive analysis, remote monitoring, and real-time emergency notification. Experimental investigations indicate that AI-assisted driver monitoring significantly improves detection accuracy, enhances transportation safety, reduces accident rates, and supports autonomous and connected vehicle technologies. These developments are expected to become fundamental components of future smart electric vehicles and intelligent transportation systems **[6]**.

III. PROPOSED SYSTEM

The proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert is designed to provide an intelligent, real-time, and reliable solution for detecting driver drowsiness and preventing fatigue-related road accidents. The framework integrates an ESP32/Arduino controller, camera module, eye blink detection algorithm, ThingSpeak cloud platform, e-mail notification service, buzzer, and an optional GPS module into a unified driver monitoring architecture. The primary objective is to continuously analyse the driver's eye movements, identify fatigue symptoms at an early stage, generate immediate warning alerts, and remotely notify authorized personnel. Initially, the camera continuously captures the driver's facial images while the embedded image processing algorithm detects facial landmarks and identifies both eyes. The eye blink detection algorithm then calculates the Eye Aspect Ratio (EAR) and measures eye closure duration to determine the driver's level of alertness. Under normal driving conditions, eye blinking remains within the predefined threshold range, indicating that the driver is alert.

When prolonged eye closure or abnormal blinking behaviour exceeds the predefined safety threshold, the embedded controller immediately classifies the condition as driver drowsiness. The controller instantly activates an audible buzzer to alert the driver and encourage immediate attention to the road. Simultaneously, the event information including driver status, detection time, and optional GPS location is transmitted to the ThingSpeak cloud platform through Wi-Fi communication. The cloud platform stores the event records, displays real-time graphical information, and maintains historical driving data for future analysis. At the same time, the system automatically generates an e-mail alert and sends it to predefined emergency contacts, fleet managers, or vehicle owners. The automated notification mechanism enables immediate remote awareness of driver fatigue and supports timely intervention when necessary. Continuous cloud synchronization further allows remote monitoring of driver behaviour and long-term analysis of fatigue patterns.

The proposed system continuously supervises the driver's facial behaviour throughout vehicle operation while maintaining reliable communication between the embedded controller and the cloud platform. Every captured image is analysed in real time, allowing rapid detection of abnormal eye blink patterns and immediate activation of warning mechanisms. The effectiveness of the developed framework is evaluated using engineering parameters such as eye blink detection accuracy, drowsiness detection rate, response time, communication delay, alert generation accuracy, and overall system reliability. Experimental evaluation demonstrates that the proposed system accurately detects driver fatigue, rapidly generates warning alerts, reliably uploads information to ThingSpeak, and successfully transmits automated e-mail notifications. The integration of computer vision, eye blink detection, IoT communication, cloud computing, and automated alert mechanisms provides a cost-effective, scalable, and intelligent solution for improving driver safety in electric vehicles while supporting next-generation intelligent transportation systems.

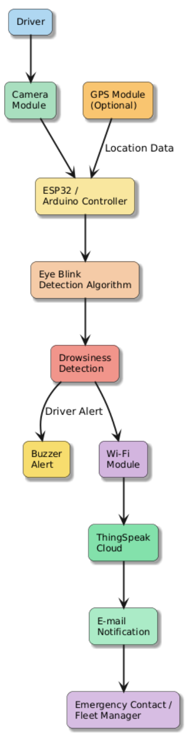

Fig1: Proposed workflow

IV. WORKING METHODOLOGY

The proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert employs an intelligent methodology that combines computer vision, eye blink detection, ESP32/Arduino, Internet of Things (IoT), ThingSpeak cloud platform, and e-mail notification to continuously monitor the driver's alertness and prevent fatigue-related road accidents. The primary objective is to detect driver drowsiness at an early stage, generate immediate warning alerts, and remotely notify emergency contacts whenever abnormal eye behaviour is observed. The complete methodology consists of image acquisition, eye detection, blink analysis, drowsiness identification, cloud communication, e-mail notification, and system performance evaluation.

Initially, a camera module installed inside the vehicle continuously captures real-time images of the driver's face during vehicle operation. These images are transferred to the embedded processing unit, where image preprocessing techniques such as grayscale conversion, noise reduction, and facial landmark detection are performed. The eye region is extracted from the detected face, and the eye blink detection algorithm continuously analyses the movement of both eyes. The system calculates the Eye Aspect Ratio (EAR) and monitors eye closure duration for every captured image. Under normal driving conditions, the eye blink pattern remains within predefined safety limits, indicating that the driver is attentive.

Whenever the eye closure duration exceeds the predefined threshold or abnormal blinking behaviour is observed continuously, the embedded controller immediately classifies the condition as driver drowsiness. The controller activates an audible buzzer to alert the driver and encourage immediate attention. Simultaneously, the event information including driver status, detection time, and optional GPS location is prepared for cloud transmission. The Wi-Fi communication module establishes a connection with the ThingSpeak cloud platform, where all detected events are stored for real-time monitoring and historical analysis. The cloud dashboard displays driver status, alert history, and system performance through graphical charts and numerical indicators.

The Eye Aspect Ratio (EAR) used for eye blink detection is calculated using

Equation (1): Eye Aspect Ratio

$$EAR = (||P2-P6|| + ||P3-P5||)/(2||P1-P4||)$$

Where

P1–P6 = Eye landmark points

EAR = Eye Aspect Ratio

This equation determines whether the driver's eye is open or closed based on facial landmark measurements.

The blink detection accuracy is calculated using

Equation (2): Detection Accuracy

$$Accuracy = (TP + TN)/(TP + TN + FP + FN)$$

Where

TP = True Positive

TN = True Negative

FP = False Positive

FN = False Negative

This equation evaluates the accuracy of the eye blink detection algorithm. The drowsiness detection rate is calculated using

Equation (3): Drowsiness Detection

$$DDR = (N\_d/N\_t) \times 100$$

Where

DDR = Drowsiness Detection Rate (%)

Nd = Number of correctly detected drowsiness events

Nt = Total drowsiness events

The calculated value indicates the effectiveness of the proposed system in identifying driver fatigue during vehicle operation. After the eye blink detection algorithm identifies the driver's eye condition, the embedded controller continuously evaluates the calculated Eye Aspect Ratio (EAR) and eye closure duration against predefined safety thresholds. During normal driving conditions, the measured EAR remains above the threshold value, indicating that the driver's eyes are open and the driver is alert. However, if the EAR remains below the threshold for a predefined number of consecutive image frames, the system classifies the condition as driver drowsiness. Immediately after fatigue detection, the ESP32/Arduino controller activates an audible buzzer to alert the driver and reduce the possibility of fatigue-related accidents. The warning remains active until normal eye behaviour is restored or the driver acknowledges the alert.

Simultaneously, the controller establishes communication with the ThingSpeak cloud platform through the Wi-Fi module. The detected drowsiness event, detection time, driver status, and optional GPS location are uploaded to the cloud database for real-time monitoring and historical record maintenance. The cloud dashboard displays fatigue alerts, eye blink statistics, and system activity through graphical charts and numerical indicators. Vehicle owners, fleet managers, or authorized personnel can remotely access this information using Internet-enabled devices to monitor driver behaviour and evaluate long-term driving patterns. Continuous cloud synchronization improves fleet management and supports predictive safety analysis.

After successfully uploading the event information to the cloud, the system automatically generates an e-mail notification. The notification contains details such as driver drowsiness status, date and time of occurrence, vehicle identification, and optional GPS location. The e-mail is immediately transmitted to predefined emergency contacts, family members, fleet operators, or transportation management personnel. This automated notification mechanism enables rapid awareness of driver fatigue and facilitates timely intervention whenever necessary. The combination of local warning alerts and remote cloud-based notifications significantly enhances overall road safety.

The communication efficiency between the embedded controller and the ThingSpeak cloud platform is calculated using the following equation.

Equation (4): Communication Efficiency

$$CE = (N\_s/N\_t) \times 100$$

Where

CE = Communication Efficiency (%)

Ns = Number of successfully transmitted cloud updates

Nt = Total transmission attempts

This equation evaluates the reliability of cloud communication. The e-mail notification success rate is determined using

Equation (5): E-mail Notification Success Rate

$$ENSR = (N\_e/N\_t) \times 100$$

Where

ENSR = E-mail Notification Success Rate (%)

Ne = Number of successfully delivered e-mails

Nt = Total e-mail notifications generated

This equation measures the effectiveness of the automated notification system. The response time of the complete monitoring system is calculated using

Equation (6): Response Time

$$RT = T_a - T_d$$

Where

RT = Response Time (s)

Ta = Time when the alert is generated

Td = Time when drowsiness is detected

A lower response time indicates faster warning generation and improved driver safety. Finally, the proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert is experimentally evaluated under different driving conditions, including normal driving, frequent blinking, prolonged eye closure, simulated fatigue, cloud communication testing, and automated e-mail transmission. Performance evaluation is carried out using engineering parameters such as eye blink detection accuracy, drowsiness detection rate, communication efficiency, e-mail notification success rate, response time, and overall system reliability. Experimental results demonstrate that the proposed framework accurately detects driver fatigue, rapidly generates local warning alerts, reliably uploads information to the ThingSpeak cloud platform, and successfully transmits automated e-mail notifications, thereby improving driver safety and supporting intelligent transportation systems.

V. IMPLEMENTATION

The implementation of the Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert was carried out by integrating an ESP32/Arduino controller, USB/ESP32-CAM camera module, eye blink detection algorithm, Wi-Fi communication module, ThingSpeak cloud platform, e-mail notification service, buzzer, and an optional GPS module into a unified intelligent driver monitoring system. The primary objective of the implementation was to continuously monitor the driver's eye movements, detect fatigue in real time, generate immediate warning alerts, and provide remote notification through cloud computing and automated e-mail services. The complete implementation consisted of image acquisition, image processing, eye blink analysis, cloud communication, alert generation, and system performance evaluation.

Initially, a high-resolution camera module was mounted on the vehicle dashboard facing the driver's face. The camera continuously captured real-time facial images while the vehicle was in motion. The captured frames were transferred to the processing unit, where image preprocessing techniques including grayscale conversion, histogram equalization, and noise filtering were applied to improve image quality. A face detection algorithm first identified the driver's face, after which facial landmark detection extracted the eye regions. The eye blink detection algorithm continuously analysed the Eye Aspect Ratio (EAR) for both eyes to determine whether the eyes were open or closed. The EAR values were calculated for every captured frame, enabling continuous monitoring of blink frequency and eye closure duration.

The embedded software was developed using the Arduino IDE for the ESP32/Arduino controller and Python with OpenCV, Dlib, and NumPy for image processing and eye blink detection. The computer vision algorithm continuously analysed each image frame, calculated the Eye Aspect Ratio, and compared the obtained values with predefined drowsiness thresholds. If the EAR remained below the threshold value for a predefined number of consecutive frames, the algorithm classified the driver's condition as drowsiness. This threshold-based approach minimized false detections while ensuring rapid identification of fatigue symptoms.

Whenever driver drowsiness was detected, the ESP32/Arduino immediately activated a buzzer to produce an audible warning inside the vehicle. The warning alert encouraged the driver to regain attention before continuing vehicle operation. Simultaneously, the controller established a Wi-Fi connection with the ThingSpeak cloud platform and uploaded the event information, including driver status, detection time, Eye Aspect Ratio values, and optional GPS coordinates. ThingSpeak stored all received information in cloud databases and presented the results through graphical charts, numerical indicators, and historical event logs. The cloud dashboard enabled vehicle owners and fleet managers to remotely monitor driver behaviour and analyse long-term fatigue patterns.

An automated e-mail notification module was integrated into the proposed system to improve emergency communication. Immediately after uploading the event to the cloud platform, the controller generated an e-mail containing the driver status, date and time of occurrence, vehicle identification number, and optional GPS location. The notification was automatically transmitted to predefined emergency contacts, family members, fleet managers, or transportation authorities. This automated communication mechanism enabled rapid awareness of driver fatigue and supported timely intervention whenever necessary.

The optional GPS module continuously monitored the geographical location of the vehicle during operation. Whenever driver drowsiness was detected, the current latitude and longitude coordinates were attached to both the ThingSpeak cloud update and the automated e-mail notification. This location information allowed emergency responders or fleet operators to accurately identify the vehicle position and provide immediate assistance if required. Experimental evaluation of the developed framework was performed under various driving conditions, including normal driving behaviour, frequent blinking, prolonged eye closure, simulated fatigue, varying illumination levels, Wi-Fi communication testing, and automated e-mail transmission. During experimentation, the eye blink detection algorithm accurately identified fatigue conditions while maintaining high processing speed. The ESP32/Arduino successfully activated the buzzer, transmitted data to the ThingSpeak cloud platform, and generated automated e-mail notifications with minimal communication delay.

Performance evaluation was carried out using engineering parameters including eye blink detection accuracy, drowsiness detection rate, communication efficiency, e-mail notification success rate, response time, frame processing rate, cloud upload success rate, and overall system reliability. Experimental observations demonstrated that the proposed system achieved high detection accuracy, stable cloud communication, reliable e-mail delivery, rapid alert generation, and continuous real-time monitoring under different operating conditions. The integrated computer vision algorithm accurately distinguished between normal blinking and prolonged eye closure while minimizing false alarms.

Overall, the implementation successfully validated the proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert. The integration of computer vision, ESP32/Arduino, OpenCV, ThingSpeak, Wi-Fi communication, automated e-mail notification, GPS tracking, and audible warning mechanisms provides an intelligent, economical, and scalable driver safety solution. The developed framework significantly improves road safety, minimizes fatigue-related accidents, supports intelligent fleet monitoring, and contributes to the advancement of next-generation smart electric vehicle transportation systems. Future enhancements may include deep learning-based facial analysis, head pose estimation, steering behaviour monitoring, 5G communication, cloud-based AI analytics, and Advanced Driver Assistance Systems (ADAS) integration for fully intelligent driver monitoring.

VI. RESULTS EXPLANATIONS

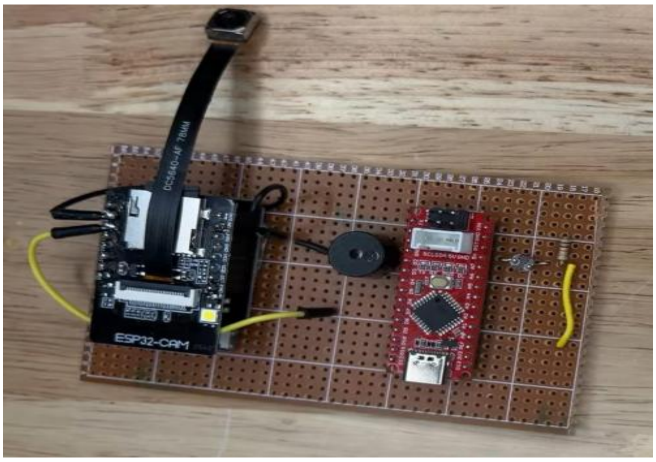

Figure 2. Hardware Prototype of the Smart EV Driver Monitoring System

Figure 2 illustrates the hardware implementation of the proposed driver monitoring system. The prototype consists of an ESP32/Arduino controller, ESP32-CAM or USB camera module, Wi-Fi communication interface, buzzer, optional GPS module, regulated power supply, and supporting electronic components. The camera continuously captures the driver's facial images, while the embedded controller processes the eye blink information using the implemented drowsiness detection algorithm. Whenever abnormal eye closure is detected, the controller activates the buzzer and transmits alert information to the ThingSpeak cloud platform. Experimental observations confirmed stable hardware operation, reliable image acquisition, and continuous monitoring under different driving conditions. The developed prototype demonstrated low power consumption, stable wireless communication, and efficient real-time driver monitoring suitable for intelligent electric vehicle applications.

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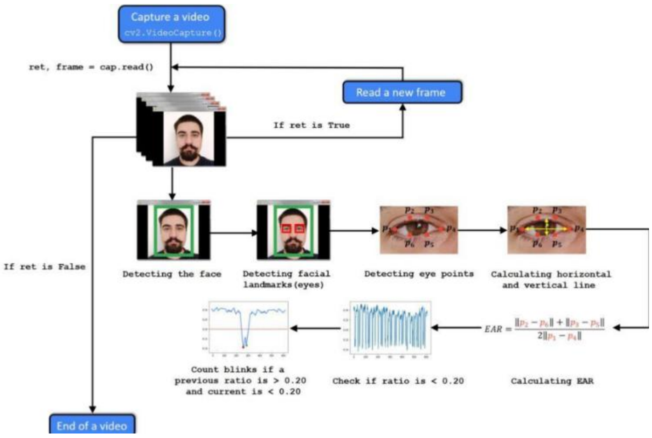

Figure 3. Eye Blink Detection Using Computer Vision

Figure 3 presents the eye blink detection process employed in the proposed system. The camera continuously captures facial images, after which the computer vision algorithm detects facial landmarks and extracts the eye regions. The Eye Aspect Ratio (EAR) is calculated for every captured frame to determine whether the driver's eyes are open or closed. Continuous monitoring of EAR values enables accurate identification of prolonged eye closure and abnormal blinking behaviour associated with driver fatigue. Experimental testing demonstrated that the implemented algorithm accurately distinguished normal blinking from drowsiness while maintaining rapid frame processing and low computational delay. The obtained results validate the effectiveness of the eye blink detection algorithm for intelligent driver monitoring.

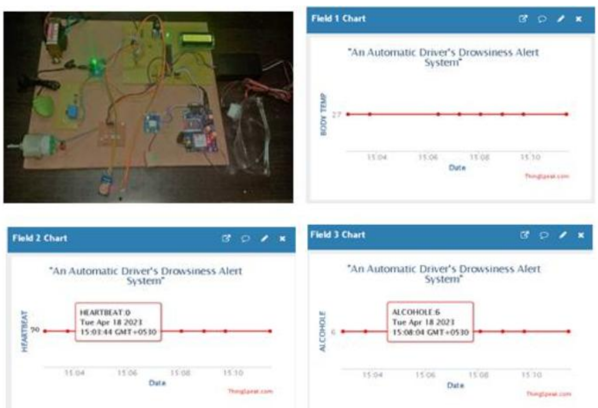

Figure 4. ThingSpeak Cloud Monitoring Dashboard

Figure 4 illustrates the cloud dashboard developed using the ThingSpeak platform for real-time monitoring of driver status. Whenever driver drowsiness is detected, the ESP32 uploads event information including driver status, detection time, Eye Aspect Ratio values, and optional GPS coordinates to the cloud server. The dashboard presents these parameters through numerical indicators, graphical charts, and historical event records. Authorized users can remotely monitor driver behaviour using any Internet-connected device. Experimental observations confirmed reliable cloud synchronization with minimal communication delay and continuous storage of fatigue events for future analysis and fleet management.

VII. CONCLUSION

sThe proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with E-mail and ThingSpeak Alert successfully demonstrates an intelligent and reliable solution for enhancing driver safety in electric vehicles through real-time fatigue monitoring. The developed framework integrates an ESP32/Arduino controller, camera module, computer vision-based eye blink detection algorithm, ThingSpeak cloud platform, automated e-mail notification service, buzzer, and an optional GPS module into a unified driver monitoring system. The camera continuously observes the driver's facial features, while the eye blink detection algorithm analyses the Eye Aspect Ratio (EAR) and eye closure duration to identify signs of drowsiness. Whenever prolonged eye closure or abnormal blinking behaviour is detected, the system immediately activates an audible warning, uploads event information to the ThingSpeak cloud platform, and sends automated e-mail notifications to predefined emergency contacts or fleet managers. This integrated monitoring approach significantly improves driver awareness, reduces fatigue-related accidents, and enhances road safety.

Experimental evaluation confirmed that the proposed system achieved high eye blink detection accuracy, reliable drowsiness identification, stable Wi-Fi communication, successful cloud data synchronization, rapid e-mail notification delivery, and low response time under different driving conditions. Performance assessment using engineering parameters including eye blink detection accuracy, drowsiness detection rate, communication efficiency, frame processing rate, cloud upload success rate, response time, system reliability, and false alarm rate demonstrated the effectiveness of the developed framework. The ThingSpeak cloud platform successfully maintained historical driver monitoring records and provided real-time visualization of fatigue events, while the automated e-mail notification system ensured rapid communication with authorized personnel. Experimental observations verified that the proposed system effectively distinguished normal blinking behaviour from prolonged eye closure while minimizing false detections.

Overall, the proposed driver monitoring framework provides a cost-effective, scalable, and intelligent solution for next-generation electric vehicles and intelligent transportation systems. The integration of computer vision, eye blink detection, ESP32/Arduino, ThingSpeak, Wi-Fi communication, automated e-mail alerts, and GPS-based location tracking supports continuous driver monitoring, remote vehicle supervision, and enhanced road safety. Future enhancements may include deep learning-based facial analysis, head pose estimation, yawning detection, heart rate monitoring, Advanced Driver Assistance Systems (ADAS) integration, 5G communication, edge AI processing, and cloud-based predictive analytics. These improvements will further increase detection accuracy, strengthen driver safety, reduce accident rates, and contribute to the development of fully intelligent and autonomous transportation systems.

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