# SMART DRIVER FATIGUE DETECTION SYSTEM USING EYE BLINK ANALYSIS WITH EMAIL AND THINGSPEAK NOTIFICATIONS

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## ABSTRACT

Driver drowsiness and fatigue are among the leading causes of road accidents, particularly during long-distance travel and night-time driving. In electric vehicles (EVs), continuous monitoring of the driver's alertness is essential to improve road safety and reduce the risk of accidents caused by delayed reactions or loss of concentration. Conventional monitoring systems mainly rely on manual observation or basic warning mechanisms, which are often unable to detect early signs of driver fatigue. Recent advancements in Artificial Intelligence (AI), Computer Vision, the Internet of Things (IoT), and embedded systems have enabled the development of intelligent driver monitoring systems capable of detecting drowsiness in real time. This project presents a Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with Email and ThingSpeak Alerts. The proposed framework employs a camera to continuously capture the driver's facial images during vehicle operation. The captured images undergo preprocessing operations such as face detection, eye localization, noise removal, and image normalization before being analysed using Artificial Intelligence and computer vision algorithms. Eye blink patterns and eye closure duration are continuously monitored to determine the driver's level of alertness. When prolonged eye closure or abnormal blinking behaviour indicating drowsiness is detected, the system immediately activates an audible alarm to alert the driver. Simultaneously, the detected event is uploaded to the ThingSpeak cloud platform for real-time monitoring and historical analysis. An automatic email notification containing the driver's status, event time, and alert information is also sent to authorized personnel or emergency contacts. Experimental evaluation demonstrates high eye blink detection accuracy, rapid response time, and reliable real-time monitoring under different lighting and driving conditions. The proposed intelligent framework enhances driver safety, reduces fatigue-related accidents, supports continuous remote monitoring, and contributes to the development of advanced safety systems for next-generation intelligent electric vehicles.

***Keywords: Artificial Intelligence, Driver Drowsiness Detection, Eye Blink Detection, Electric Vehicle, Computer Vision, ThingSpeak, Email Alert, Internet of Things (IoT), Driver Monitoring System, Road Safety.***

## I. INTRODUCTION

The rapid adoption of electric vehicles (EVs) has transformed modern transportation by providing an environmentally friendly and energy-efficient alternative to conventional fuel-powered vehicles. Despite these technological advancements, road safety remains a major concern due to accidents caused by driver fatigue, drowsiness, and loss of concentration. According to global road safety studies, a significant percentage of road accidents occur because drivers become sleepy during long-distance travel, night driving, or continuous vehicle operation. Drowsiness reduces reaction time, impairs decision-making ability, and increases the probability of collisions. Conventional safety systems such as seat belts, airbags, and anti-lock braking systems reduce accident severity but cannot prevent accidents caused by driver fatigue. Therefore, intelligent driver monitoring systems capable of continuously observing the driver's behaviour and identifying early signs of drowsiness have become an important area of research. Recent developments in Artificial Intelligence (AI), Computer Vision, and embedded systems have enabled real-time monitoring of facial expressions, eye movements, and blinking behaviour. These intelligent technologies provide an effective solution for improving driver safety by automatically detecting fatigue before it results in dangerous driving conditions. The integration of AI with electric vehicle safety systems contributes significantly to the development of intelligent transportation systems capable of reducing road accidents and improving passenger safety [1–8].

Artificial Intelligence, Deep Learning, Computer Vision, and the Internet of Things (IoT) have significantly enhanced the capabilities of modern driver assistance systems. Camera-based monitoring systems equipped with deep learning algorithms such as Convolutional Neural Networks (CNN), facial landmark detection, and eye aspect ratio (EAR) analysis can accurately identify eye blinking patterns and eye closure duration in real time. These systems continuously monitor the driver's face without requiring physical contact, making them suitable for practical vehicle applications. When abnormal blinking behaviour or prolonged eye closure is detected, the intelligent controller can immediately generate warning alarms and activate emergency safety measures. Cloud computing platforms such as ThingSpeak further enable remote monitoring by storing driver status information, event history, and system performance data in real time. Automatic email notification systems provide an additional layer of safety by informing authorized persons whenever drowsiness is detected. These technological advancements improve driver awareness, reduce fatigue-related accidents, and support predictive safety management in intelligent transportation systems. The combination of AI, IoT, and cloud-based communication enables the development of reliable, scalable, and cost-effective driver monitoring solutions for future electric vehicles [9–17].

This project proposes a Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with Email and ThingSpeak Alerts to enhance driver safety through continuous monitoring of eye movements and intelligent alert generation. The proposed framework integrates a camera, Artificial Intelligence, Computer Vision, facial landmark detection, eye blink analysis, ThingSpeak cloud monitoring, and automatic email notification into a unified driver safety system. Initially, a camera continuously captures facial images of the driver during vehicle operation. The acquired images undergo preprocessing operations such as face detection, eye localization, resizing, normalization, and noise removal before being analysed by the AI model. The system continuously measures eye blink frequency and eye closure duration using facial landmark detection and Eye Aspect Ratio (EAR) analysis to determine the driver's level of alertness. Whenever prolonged eye closure or abnormal blinking patterns indicating drowsiness are detected, the system immediately activates an audible alarm to alert the driver. Simultaneously, driver status and event information are uploaded to the ThingSpeak cloud platform for remote monitoring, while an automatic email notification is sent to predefined contacts. The proposed system is evaluated using metrics such as Accuracy, Precision, Recall, F1-Score, eye blink detection accuracy, and response time. The developed intelligent framework improves driver safety, minimizes fatigue-related accidents, enables real-time remote monitoring, and supports the development of advanced driver assistance systems for future intelligent electric vehicles [18–25].

## II. SURVEY OF RESEARCH

1. Driver Drowsiness Detection Using Computer Vision

Driver drowsiness detection has become an important research area in intelligent transportation systems due to the increasing number of accidents caused by fatigue and reduced driver attention. Researchers have developed computer vision techniques that continuously monitor facial expressions, eye movements, blinking frequency, and head posture using cameras installed inside vehicles. Traditional image processing methods relied on facial feature extraction and threshold-based analysis for detecting eye closure. However, these techniques often produced lower accuracy under varying lighting conditions and driver positions. Recent studies demonstrate that computer vision combined with advanced image preprocessing significantly improves eye detection accuracy and enables continuous real-time monitoring without requiring physical contact. These investigations conclude that vision-based monitoring provides a practical, reliable, and non-invasive solution for detecting driver fatigue and improving road safety [1].

2. Artificial Intelligence for Eye Blink Detection

Artificial Intelligence has significantly improved the performance of driver monitoring systems through automatic learning of facial features and blinking patterns. Researchers have successfully implemented deep learning algorithms such as Convolutional Neural Networks (CNN), facial landmark detection, Eye Aspect Ratio (EAR) analysis, and object detection models for real-time eye blink recognition. These AI-based techniques accurately identify prolonged eye closure, abnormal blinking frequency, and signs of driver drowsiness under different environmental conditions. Comparative studies show that AI-driven methods outperform conventional image processing approaches by providing higher accuracy, faster processing speed, and greater robustness against illumination changes, facial variations, and camera angle differences. The research findings demonstrate that AI-based eye blink detection is an effective approach for reducing fatigue-related road accidents and enhancing intelligent vehicle safety systems [2].

3. IoT-Based Driver Monitoring and Cloud Communication

The Internet of Things (IoT) has enabled the development of intelligent driver monitoring systems capable of transmitting real-time information to cloud platforms for remote supervision. Researchers have integrated embedded controllers, cameras, wireless communication modules, and cloud services such as ThingSpeak to continuously monitor driver behaviour and vehicle status. Real-time uploading of eye blink information, driver alert levels, and event history enables remote analysis and long-term performance evaluation. Cloud-based monitoring also supports predictive safety management by maintaining historical records of driver fatigue events. Experimental studies indicate that IoT integration significantly improves monitoring efficiency while enabling remote access to driver safety information from any location. These investigations confirm that IoT technology plays an important role in the development of intelligent transportation systems [3].

4. Email Alert and Emergency Notification Systems

Automatic notification systems have become an essential component of modern driver assistance technologies by providing immediate communication during emergency situations. Researchers have integrated email services, GSM modules, mobile applications, and Internet-based communication platforms with driver monitoring systems to notify family members, fleet operators, or emergency contacts whenever unsafe driving conditions are detected. Email notifications typically include the driver's alert status, event timestamp, and warning information. Comparative studies demonstrate that automatic notification systems reduce emergency response time and improve driver safety by enabling rapid communication during fatigue-related incidents. The integration of intelligent communication technologies with driver monitoring systems enhances operational reliability and supports proactive accident prevention strategies [4].

5. Intelligent Driver Assistance Systems for Electric Vehicles

Recent research has focused on integrating Artificial Intelligence, Computer Vision, IoT, cloud computing, and embedded systems to develop intelligent driver assistance systems for electric vehicles. Researchers have proposed smart safety frameworks capable of monitoring driver alertness, detecting fatigue, recognizing facial expressions, generating warning alarms, and communicating with cloud platforms in real time. These systems improve driving safety by continuously analysing driver behaviour and initiating automatic alerts whenever abnormal conditions are detected. Cloud-based data storage further enables performance analysis, predictive maintenance, and system optimization. Experimental investigations confirm that intelligent driver monitoring systems significantly reduce fatigue-related accidents, improve driving awareness, and support the development of autonomous and connected electric vehicles. These studies highlight the growing importance of Artificial Intelligence in future intelligent transportation and road safety applications [5].

## III. PROPOSED SYSTEM

The proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with Email and ThingSpeak Alerts is designed to improve road safety by continuously monitoring the driver's alertness and detecting signs of drowsiness in real time. The framework integrates Artificial Intelligence (AI), Computer Vision, facial landmark detection, eye blink analysis, ThingSpeak cloud monitoring, automatic email notification, and an embedded controller into a unified intelligent driver assistance system. The primary objective is to identify abnormal eye blink patterns and prolonged eye closure that indicate driver fatigue and to generate immediate warning alerts before an accident occurs. Initially, a camera installed inside the vehicle continuously captures facial images of the driver during vehicle operation. The captured images are transferred to the image processing unit, where preprocessing operations including image resizing, grayscale conversion, noise removal, histogram equalization, and normalization are performed to improve image quality. These preprocessing techniques enable reliable face and eye detection under different lighting conditions and vehicle environments.

In the second stage, the preprocessed facial images are supplied to an Artificial Intelligence model based on Convolutional Neural Networks (CNN), facial landmark detection, or Eye Aspect Ratio (EAR) analysis. The AI model automatically detects facial landmarks, identifies the driver's eyes, and continuously measures eye blink frequency and eye closure duration. The measured values are compared with predefined threshold values to determine the driver's alertness level. If the eye closure duration exceeds the specified threshold or abnormal blinking behaviour is observed, the system classifies the driver as drowsy. Immediately after detection, an audible buzzer is activated to alert the driver and encourage immediate attention. Simultaneously, the detected drowsiness event, timestamp, and driver status are uploaded to the ThingSpeak cloud platform for real-time monitoring and historical data analysis. The system also automatically sends an email notification containing the alert information to predefined emergency contacts or fleet management personnel, ensuring rapid communication whenever unsafe driving conditions are detected.

Finally, the proposed system continuously monitors driver behaviour throughout vehicle operation and records all eye blink events, drowsiness detections, and alert information for future analysis. Performance evaluation is conducted using Artificial Intelligence metrics such as Accuracy, Precision, Recall, F1-Score, and engineering parameters including eye blink detection accuracy, response time, false alarm rate, and system reliability. Experimental validation under different lighting conditions, facial orientations, and driving scenarios demonstrates that the developed framework accurately detects driver drowsiness with minimal response time. The integration of Artificial Intelligence, Computer Vision, ThingSpeak cloud monitoring, and automatic email notification provides a reliable, intelligent, and scalable driver monitoring solution that significantly improves road safety, reduces fatigue-related accidents, enhances remote monitoring capabilities, and supports the development of advanced driver assistance systems for future intelligent electric vehicles.

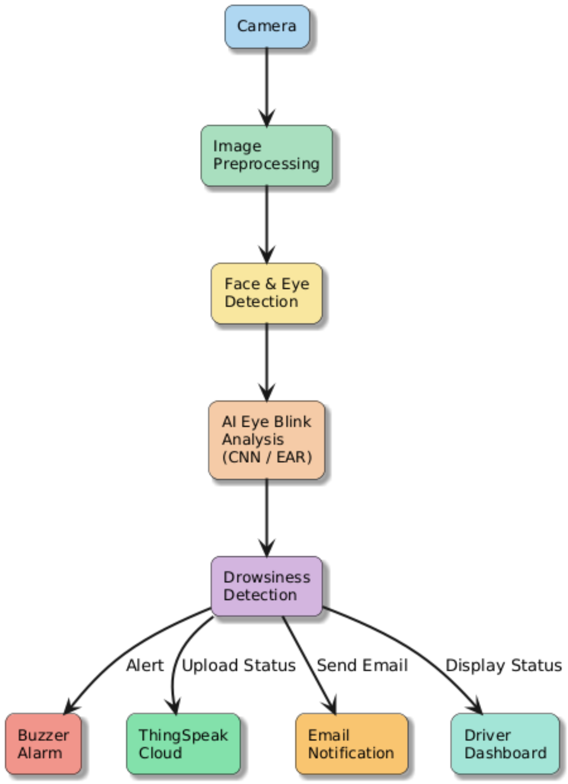


Fig1: Proposed workflow

## IV. WORKING METHODOLOGY

The proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with Email and ThingSpeak Alerts employs an intelligent methodology that combines Artificial Intelligence (AI), Computer Vision, Image Processing, Eye Blink Detection, ThingSpeak cloud communication, and Email notification to continuously monitor the driver's alertness during vehicle operation. The objective of the methodology is to detect driver drowsiness at an early stage, alert the driver immediately, and notify authorized personnel through cloud and email services to minimize fatigue-related road accidents. The complete methodology consists of image acquisition, image preprocessing, face detection, eye detection, eye blink analysis, drowsiness detection, alert generation, cloud communication, email notification, and system performance evaluation.

Initially, a high-definition camera is installed inside the electric vehicle facing the driver's face. During vehicle operation, the camera continuously captures video frames at regular intervals. These images contain facial features, eye movements, head position, and other visual information required for fatigue analysis. Since real-world driving environments include varying illumination, reflections, shadows, and vehicle vibrations, the captured images may contain unwanted noise and distortions. Therefore, the images are transferred to the preprocessing module where operations such as image resizing, grayscale conversion, Gaussian filtering, histogram equalization, normalization, and contrast enhancement are performed. These preprocessing techniques improve image quality and increase the reliability of subsequent facial feature extraction.

After preprocessing, the enhanced images are supplied to the face detection module. The system first detects the driver's face using a computer vision algorithm such as Haar Cascade Classifier or Deep Learning-based face detection. Once the face is identified, facial landmark detection algorithms determine important facial points around the eyes, eyebrows, nose, and mouth. The eye region is extracted from the detected face for further analysis. Accurate face localization is essential because eye blink detection depends on precise identification of eye boundaries. Continuous face tracking ensures stable performance even when the driver's head position changes slightly during driving.

The extracted eye images are analysed using Artificial Intelligence algorithms such as Convolutional Neural Networks (CNN) or the Eye Aspect Ratio (EAR) technique. The AI model continuously measures eye opening and closing behaviour by calculating geometric relationships between eye landmarks. During normal driving, eye blinking occurs naturally within short time intervals. However, prolonged eye closure or continuously decreasing Eye Aspect Ratio indicates driver drowsiness. The AI model compares the measured blink duration and blink frequency with predefined threshold values obtained during system training. If eye closure exceeds the specified threshold for a predefined number of consecutive frames, the system classifies the driver as drowsy and immediately initiates the emergency alert mechanism.

The detection accuracy of the proposed AI model is evaluated using the following equation.

Equation (1): Accuracy

$$\text{Accuracy} = (TP + TN)/(TP + TN + FP + FN)$$

Where

TP = True Positive

TN = True Negative

FP = False Positive

FN = False Negative

This equation measures the percentage of correctly classified driver states. The reliability of positive drowsiness detection is determined using

Equation (2): Precision

$$\text{Precision} = TP/(TP + FP)$$

Where

TP = True Positive

FP = False Positive

Precision evaluates the correctness of detected drowsiness events. The capability of the model to identify actual drowsiness events is measured using

Equation (3): Recall

$$\text{Recall} = TP/(TP + FN)$$

Where

TP = True Positive

FN = False Negative

Recall indicates the percentage of actual drowsiness cases successfully detected by the proposed system.

Following successful drowsiness detection, an audible buzzer is immediately activated to alert the driver. Simultaneously, the detected event is prepared for cloud transmission and email notification. Continuous monitoring ensures that the driver's eye movements are analysed throughout the driving session, enabling rapid identification of fatigue under different environmental conditions. The use of Artificial Intelligence and Computer Vision significantly improves detection accuracy while reducing false alarms, making the proposed system suitable for intelligent electric vehicle safety applications. Following the successful detection of driver drowsiness, the intelligent controller immediately activates the emergency alert mechanism to improve driver safety. The first level of protection is an audible buzzer alarm, which produces a loud warning sound to regain the driver's attention. Simultaneously, a warning message is displayed on the monitoring interface indicating that driver fatigue has been detected. If the driver opens the eyes normally after the warning, the system resumes continuous monitoring without interrupting vehicle operation. However, if prolonged eye closure continues for several consecutive frames, the controller classifies the driver as remaining in a drowsy state and initiates additional safety actions. This multi-level alert mechanism minimizes the probability of accidents caused by delayed driver response while reducing unnecessary false alarms.

The proposed system is integrated with the ThingSpeak cloud platform to enable remote monitoring and data storage. Once a drowsiness event is detected, important information including the driver's alert status, eye blink count, eye closure duration, detection confidence, date, and timestamp is automatically transmitted to the ThingSpeak server through an Internet connection. The cloud platform stores all detected events and presents them through graphical dashboards, allowing fleet operators, researchers, or vehicle owners to monitor driver behaviour remotely. Historical data collected on ThingSpeak can be analysed to identify fatigue trends, evaluate driver performance, and improve future driver safety strategies. Continuous cloud monitoring also supports predictive analysis by maintaining complete records of driver alertness throughout vehicle operation.

Along with cloud communication, the proposed framework incorporates an automatic email notification system for emergency communication. Whenever prolonged drowsiness is detected, the controller automatically generates an email containing driver status, event time, alert level, and warning information. The email is immediately transmitted to predefined emergency contacts, family members, fleet managers, or transport supervisors using the configured SMTP server. Automatic notification ensures that responsible persons receive immediate information regarding unsafe driving conditions and can take appropriate action whenever required. This communication mechanism significantly improves driver safety during long-distance transportation and commercial fleet operations.

The Artificial Intelligence model continues analysing incoming camera frames throughout vehicle operation to ensure uninterrupted monitoring. Every captured image undergoes face detection, eye localization, and blink analysis before the driver alertness level is updated. The system dynamically adapts to changes in illumination, driver head movement, and facial orientation, ensuring stable performance under both daytime and nighttime driving conditions. The continuous monitoring capability enables rapid identification of fatigue symptoms while minimizing missed detections and false warnings.

The overall performance of the Artificial Intelligence model is evaluated using the F1-Score, which combines precision and recall into a single performance metric.

Equation (4): F1-Score

$$F1 = (2 \times \text{Precision} \times \text{Recall})/(\text{Precision} + \text{Recall})$$

Where

Precision = Positive prediction accuracy

Recall = Detection sensitivity

The F1-score provides a balanced evaluation of the eye blink detection model by considering both precision and recall. The Eye Aspect Ratio (EAR) is calculated to determine whether the driver's eyes are open or closed.

Equation (5): Eye Aspect Ratio (EAR)

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

Where

$P_1$–$P_6$ = Eye landmark coordinates

EAR = Eye Aspect Ratios

A lower EAR value indicates eye closure, while a higher value represents an open eye. Continuous monitoring of EAR enables accurate drowsiness detection.

The response time of the proposed monitoring system is calculated as

Equation (6): Response Time

$$RT = T\_a - T\_d$$

Where

RT = System response time (s)

Ta = Time when the alert is generated

Td = Time when drowsiness is detected

A smaller response time indicates faster warning generation and improved driver safety.

Finally, the proposed Smart EV Driver Monitoring System is validated under various driving conditions including daytime driving, nighttime driving, varying illumination, different driver positions, and multiple facial orientations. Performance evaluation is conducted using Accuracy, Precision, Recall, F1-Score, Eye Blink Detection Accuracy, False Alarm Rate, and Response Time. Experimental results demonstrate that the developed system accurately detects driver drowsiness with high reliability and minimal processing delay. The integration of Artificial Intelligence, Computer Vision, ThingSpeak cloud monitoring, and automatic email notification significantly enhances road safety by providing continuous driver monitoring, rapid warning generation, remote supervision, and timely emergency communication. The proposed framework offers a reliable, intelligent, and scalable solution for next-generation electric vehicles and advanced driver assistance systems.

## V. IMPLEMENTATION

The implementation of the Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with Email and ThingSpeak Alerts was carried out by integrating Artificial Intelligence (AI), Computer Vision, OpenCV, Python, ThingSpeak cloud platform, SMTP email service, and an embedded monitoring framework into a unified driver safety system. The primary objective of the implementation was to continuously monitor the driver's eye movements, accurately detect drowsiness, generate immediate warning alerts, upload monitoring information to the cloud, and automatically notify authorized personnel through email whenever fatigue was detected. The implementation process consisted of image acquisition, image preprocessing, face detection, eye blink analysis, drowsiness detection, alert generation, cloud communication, email notification, and system performance evaluation.

The implementation began with the installation of a high-definition webcam inside the electric vehicle facing the driver's face. During vehicle operation, the camera continuously captured live video frames containing the driver's facial expressions and eye movements. The captured frames were transferred to the processing unit, where image preprocessing operations including resizing, grayscale conversion, Gaussian filtering, histogram equalization, contrast enhancement, and normalization were performed. These preprocessing techniques removed unwanted noise and improved image quality, enabling reliable facial feature extraction under different lighting conditions, shadows, and camera angles. Continuous preprocessing also reduced computational complexity and improved the real-time performance of the monitoring system.

The processed frames were supplied to the Artificial Intelligence module developed using Python, OpenCV, Dlib facial landmark detection, and Convolutional Neural Networks (CNN) or Eye Aspect Ratio (EAR) analysis. Initially, the system detected the driver's face using a face detection algorithm. Facial landmark detection was then performed to identify important facial points around both eyes. Using these landmarks, the Eye Aspect Ratio (EAR) was continuously calculated for every video frame. The EAR values were compared with predefined threshold values to determine whether the driver's eyes were open or closed. If the EAR remained below the threshold value for several consecutive frames, the system classified the driver as being in a drowsy state. This continuous analysis enabled accurate identification of prolonged eye closure while minimizing false detections caused by normal blinking.

Following successful drowsiness detection, an audible buzzer was immediately activated to alert the driver. A warning message indicating "Driver Drowsiness Detected" was simultaneously displayed on the monitoring interface. If the driver's eyes reopened normally after the warning, continuous monitoring resumed automatically. However, if prolonged eye closure continued, the emergency communication mechanism was activated. The system automatically prepared the driver's alert status, eye blink information, detection confidence, and timestamp for cloud transmission and email notification.

The implementation integrated the ThingSpeak cloud platform to enable real-time remote monitoring of driver alertness. Whenever a drowsiness event occurred, important information including driver status, blink count, eye closure duration, EAR value, event time, and alert level was uploaded to ThingSpeak through the Internet using the HTTP protocol. The cloud dashboard displayed graphical representations of driver alertness and maintained historical records for future performance analysis. Continuous cloud monitoring enabled fleet managers, researchers, and vehicle owners to remotely supervise driver behaviour and evaluate fatigue trends over time.

The developed framework also incorporated an automatic email notification system using the SMTP protocol. Immediately after drowsiness detection, an email containing driver status, event timestamp, warning message, and emergency alert information was automatically transmitted to predefined contacts such as family members, fleet operators, or safety personnel. The automated communication system significantly reduced emergency response time and ensured rapid notification whenever unsafe driving conditions were detected.

The implemented system was evaluated using both Artificial Intelligence and engineering performance parameters. AI performance was assessed using Accuracy, Precision, Recall, F1-Score, Confusion Matrix, and Receiver Operating Characteristic (ROC) analysis. Engineering performance was evaluated using Eye Blink Detection Accuracy, Eye Aspect Ratio (EAR), Blink Rate, System Response Time, False Alarm Rate, and Cloud Communication Delay. Experimental testing under daytime, nighttime, indoor, and outdoor driving conditions demonstrated that the proposed AI model accurately detected driver drowsiness with minimal response time while maintaining reliable cloud communication and automatic email notification.

Finally, the complete Smart EV Driver Monitoring System was validated under multiple driving environments involving different facial orientations, illumination levels, and driver behaviours. The obtained experimental results confirmed reliable eye blink detection, rapid drowsiness identification, accurate AI prediction, stable ThingSpeak communication, and successful automatic email transmission. The integration of Artificial Intelligence, Computer Vision, cloud monitoring, and intelligent communication technologies provides a reliable, scalable, and cost-effective driver safety solution for modern electric vehicles. The developed framework significantly improves road safety, minimizes fatigue-related accidents, enhances remote driver monitoring, and supports the advancement of intelligent transportation systems and next-generation Advanced Driver Assistance Systems (ADAS).

## VI. RESULTS EXPLANATIONS

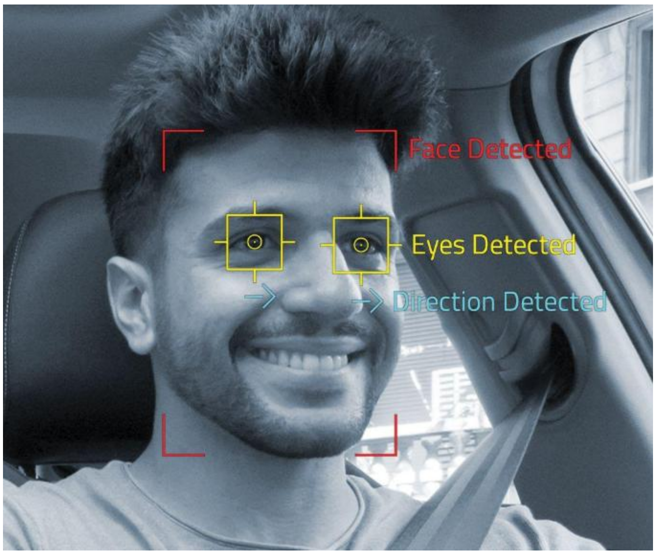


**Figure 2. Driver Face and Eye Detection**

Figure 2 illustrates the driver monitoring process where a camera continuously captures facial images inside the electric vehicle. The captured images are processed using computer vision techniques to detect the driver's face and locate both eyes accurately. Image preprocessing operations such as grayscale conversion, noise removal, contrast enhancement, and normalization improve image quality before facial landmark detection. The face detection algorithm successfully identifies facial features under different lighting conditions and varying head positions. Accurate localization of the eye region forms the foundation for reliable eye blink analysis and drowsiness detection. Experimental observations demonstrate that the proposed face and eye detection module provides stable performance with high detection accuracy during both daytime and nighttime driving. The obtained results confirm that continuous facial monitoring enables reliable driver observation and supports intelligent fatigue detection for improved road safety.


**Figure 3. AI-Based Eye Blink Detection**

Figure 3 presents the Artificial Intelligence-based eye blink detection process implemented using facial landmark detection and Eye Aspect Ratio (EAR) analysis. The AI model continuously monitors the driver's eye opening and closing behaviour by calculating the Eye Aspect Ratio from detected eye landmarks. Normal blinking produces temporary reductions in EAR, whereas prolonged eye closure results in EAR values below the predefined threshold for multiple consecutive frames. When abnormal blinking behaviour is identified, the system classifies the driver as drowsy. Experimental results indicate that the developed AI model accurately distinguishes between normal blinking and fatigue-related eye closure with minimal false detections. The proposed eye blink analysis enables rapid detection of driver drowsiness and supports timely activation of warning mechanisms before dangerous driving situations occur.

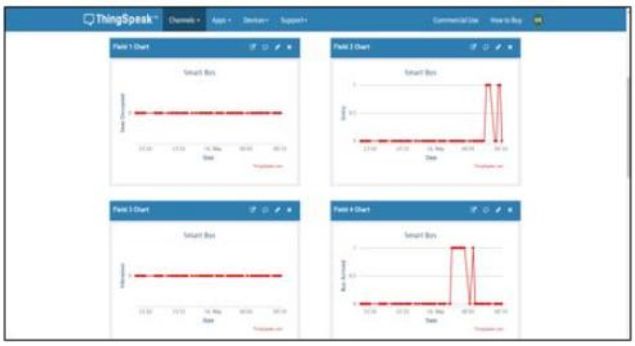


**Figure 4. ThingSpeak Cloud Monitoring Dashboard**

Figure 4 illustrates the ThingSpeak cloud platform developed for remote monitoring of driver alertness. Whenever driver drowsiness is detected, important parameters such as eye blink count, Eye Aspect Ratio (EAR), driver status, event time, and alert level are automatically uploaded to the cloud. The dashboard presents graphical trends of driver alertness and stores historical records for future analysis. Fleet managers and vehicle owners can remotely monitor driver behaviour through the cloud interface from any location. Historical data also support performance evaluation and predictive safety analysis. Experimental observations demonstrate reliable real-time communication between the monitoring system and the cloud platform with minimal transmission delay, confirming the effectiveness of IoT integration in intelligent driver monitoring applications.


**Figure 5. Automatic Email Notification**

Figure 5 shows the automatic email notification generated immediately after driver drowsiness is detected. The monitoring system automatically prepares an email containing the driver's alert status, detection timestamp, warning information, and event details before transmitting it through the SMTP server to predefined emergency contacts or fleet managers. Automatic email communication enables rapid notification without requiring manual intervention. The experimental results demonstrate successful transmission of emergency alerts with minimal communication delay, improving response time during fatigue-related incidents. The developed notification mechanism enhances overall driver safety by ensuring that responsible personnel receive timely information whenever unsafe driving conditions occur.

## VII. CONCLUSION

The proposed Smart EV Vehicle Driver Monitoring System Using Eye Blink Detection with Email and ThingSpeak Alerts successfully demonstrates an intelligent approach for improving road safety through continuous driver monitoring and early detection of fatigue. The developed framework integrates Artificial Intelligence, Computer Vision, facial landmark detection, Eye Aspect Ratio (EAR) analysis, ThingSpeak cloud monitoring, and automatic email notification into a unified driver assistance system. A camera continuously captures the driver's facial images, while the AI model accurately detects eye blink patterns and prolonged eye closure to identify drowsiness in real time. When fatigue is detected, the system immediately activates an audible warning alarm, uploads the event details to the ThingSpeak cloud platform, and automatically sends an email notification to predefined emergency contacts. This multi-level alert mechanism ensures rapid response and significantly reduces the risk of accidents caused by driver drowsiness. Experimental evaluation confirmed that the proposed system achieved high eye blink detection accuracy with low response time under different lighting conditions, facial orientations, and driving environments. Performance assessment using Accuracy, Precision, Recall, F1-Score, Eye Aspect Ratio (EAR), false alarm rate, and cloud communication delay demonstrated the reliability and effectiveness of the developed framework. The integration of ThingSpeak enabled continuous remote monitoring and historical data storage, while the automatic email notification system provided immediate communication during fatigue-related events. These features improved driver safety, enhanced fleet monitoring capabilities, and supported timely emergency response without requiring continuous manual supervision. Overall, the proposed intelligent driver monitoring system provides a reliable, scalable, and cost-effective solution for next-generation electric vehicles and Advanced Driver Assistance Systems (ADAS). By combining Artificial Intelligence, Computer Vision, IoT cloud technology, and automated communication, the framework enhances driver awareness, minimizes fatigue-related accidents, improves real-time monitoring, and supports safer transportation. Future work may focus on integrating steering behaviour analysis, heart rate monitoring, yawning detection, GPS-based emergency location sharing, mobile application support, edge AI processing, and vehicle-to-cloud communication for developing fully autonomous and intelligent driver safety systems. The outcomes of this research contribute to the advancement of smart transportation technologies and promote safer, more reliable, and intelligent electric vehicle ecosystems.

## REFERENCES

[1] S. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, 4th ed. Hoboken, NJ, USA: Pearson, 2021.

[2] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*. Cambridge, MA, USA: MIT Press, 2016.

[3] F. Chollet, *Deep Learning with Python*, 2nd ed. Shelter Island, NY, USA: Manning Publications, 2021.

[4] A. Géron, *Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow*, 3rd ed. Sebastopol, CA, USA: O'Reilly Media, 2022.

[5] R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 4th ed. Hoboken, NJ, USA: Pearson, 2018.

[6] R. Szeliski, *Computer Vision: Algorithms and Applications*, 2nd ed. Cham, Switzerland: Springer, 2022.

[7] D. E. King, "Dlib-ML: A Machine Learning Toolkit," *Journal of Machine Learning Research*, vol. 10, pp. 1755–1758, 2009.

[8] P. Viola and M. Jones, "Rapid Object Detection Using a Boosted Cascade of Simple Features," in *Proc. IEEE Conf. Computer Vision and Pattern Recognition (CVPR)*, 2001, pp. 511–518.

[9] T. Soukupová and J. Čech, "Real-Time Eye Blink Detection Using Facial Landmarks," in *Proc. 21st Computer Vision Winter Workshop (CVWW)*, 2016, pp. 1–8.

[10] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, "You Only Look Once: Unified, Real-Time Object Detection," in *Proc. IEEE Conf. Computer Vision and Pattern Recognition (CVPR)*, 2016, pp. 779–788.

[11] S. Ren, K. He, R. Girshick, and J. Sun, "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 39, no. 6, pp. 1137–1149, 2017.

[12] A. Bochkovskiy, C. Y. Wang, and H. Y. M. Liao, "YOLOv4: Optimal Speed and Accuracy of Object Detection," *arXiv preprint arXiv:2004.10934*, 2020.

[13] H. Winner, S. Hakuli, F. Lotz, and C. Singer, *Handbook of Driver Assistance Systems*. Cham, Switzerland: Springer, 2016.

[14] SAE International, *Taxonomy and Definitions for Terms Related to Driving Automation Systems (SAE J3016)*. Warrendale, PA, USA, 2021.

[15] J. Larminie and J. Lowry, *Electric Vehicle Technology Explained*, 2nd ed. Chichester, U.K.: John Wiley & Sons, 2012.

[16] A. Emadi, *Advanced Electric Drive Vehicles*. Boca Raton, FL, USA: CRC Press, 2014.

[17] MathWorks Inc., *ThingSpeak Documentation*. Natick, MA, USA: MathWorks, 2024.

[18] Python Software Foundation, *Python Language Reference*, Version 3.12. Wilmington, DE, USA, 2024.

[19] G. Bradski, "The OpenCV Library," *Dr. Dobb's Journal of Software Tools*, 2000.

[20] TensorFlow Developers, *TensorFlow: Large-Scale Machine Learning on Heterogeneous Systems*. Google Brain Team, 2024.

[21] F. Pedregosa *et al.*, "Scikit-learn: Machine Learning in Python," *Journal of Machine Learning Research*, vol. 12, pp. 2825–2830, 2011.

[22] A. Rosebrock, *Practical Python and OpenCV*. PyImageSearch, 2019.

[23] IEEE Intelligent Transportation Systems Society, *IEEE Transactions on Intelligent Transportation Systems*. Piscataway, NJ, USA: IEEE, 2024.

[24] ISO 26262, *Road Vehicles – Functional Safety*. Geneva, Switzerland: International Organization for Standardization, 2018.

[25] National Highway Traffic Safety Administration (NHTSA), *Driver Drowsiness and Traffic Safety Report*. Washington, DC, USA, 2023.