Passenger Safety System

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Abstract

The module integrates three advanced safety solutions designed to mitigate transportation risks. Firstly, the "Intelligent Child Safety System" combines CAM human detection and CO2 monitoring to prevent children from being locked in cars accidentally. Using CAM sensors and Python-integrated microcontrollers, it detects human presence and CO2 levels, triggering alarms and sending mobile alerts for timely intervention. Secondly, the module explores high-speed alerting systems' effectiveness in reducing speeding-related accidents. Through a comprehensive literature review and empirical evidence, it emphasizes integrating these systems into vehicles for enhanced road safety. Lastly, it introduces a novel "Driver Drowsiness Detection System" utilizing ESP32-CAM and OpenCV's Face Mesh model to analyze facial landmarks for drowsiness signs. By calculating blink frequency and yawning patterns and leveraging OpenCL for accelerated processing, it offers real-time assessments of driver alertness, contributing significantly to road safety. Through these innovative approaches, the module emphasizes the importance of technological advancements for safer transportation.

Keywords : Passenger safety , Speeding prevention , Tiny YOLO model , ESP32-CAM , Speed Tracker , Blink detection

1. Introduction

In today's rapidly evolving landscape of transportation, ensuring the safety of passengers, particularly vulnerable ones like children, is of utmost importance. Our project addresses this pressing concern through the introduction of three innovative safety systems designed to mitigate various risks on the road. Firstly, the "Intelligent Child Safety System" targets the alarming issue of children being accidentally locked inside cars, a scenario that can lead to tragic consequences, especially in extreme weather conditions. By integrating advanced technologies such as CAM human detection and CO2 monitoring, our system not only detects the presence of a child in a locked car but also assesses and responds to potential risks associated with elevated CO2 levels, ensuring a comprehensive approach to safety. Secondly, our research delves into the effectiveness of high-speed alerting systems in combatting speeding-related accidents, a significant contributor to road fatalities worldwide. Through an in-depth exploration of the technological foundations and socio-economic implications of these systems, we aim to provide insights into their potential to enhance driver awareness, promote adherence to speed limits, and ultimately improve road safety outcomes. Lastly, we focus on the development and implementation of the "Driver Drowsiness Detection System," recognizing the critical role of driver attentiveness in preventing accidents. Leveraging state-of-the-art technologies such as ESP32-CAM and OpenCV's Face Mesh model, our system analyzes facial landmarks and physiological indicators to assess driver alertness in real-time, offering a proactive approach to mitigating the risks associated with driver fatigue and inattention. By examining these three safety systems in detail, we contribute to the ongoing discourse on automotive safety, emphasizing the transformative potential of intelligent systems in reshaping the future of transportation and fostering a culture of safety-conscious driving. Through our interdisciplinary approach, we aim to inform policymakers, engineers, and stakeholders about the importance of integrating these systems into vehicles to promote safer mobility solutions for all.

2. LITERATURE SURVEY

In recent years, various innovative approaches have been proposed to address critical issues related to child safety in vehicles [1]. Grid-EYE sensors offer an alternative to conventional PIR sensors for human detection and tracking, utilizing infrared radiation emitted by humans for identification and temperature data collection [2]. IoT-based smart car systems integrate oxygen and motion sensors to mitigate the risk of heatstroke in locked vehicles, triggering alerts and notifications upon detecting low oxygen levels and movement inside the vehicle [3]. Machine learning algorithms integrated with Bluetooth and Raspberry Pi enable Child Presence Detection and Alerting Systems, categorizing a child's cry and notifying parents via SMS when the child is out of range [4]. Similarly, IoT-based surveillance and monitoring systems leverage various sensors to prevent tragic incidents such as pediatric vehicular heatstroke by providing remote monitoring and instant alerts to caregivers [5]. Feasibility studies on vehicular heatstroke avoidance systems and automated heatstroke detection systems using Grid-EYE sensors have shown promising results in enhancing child safety in vehicles [6]. Prototypes such as the Child Safety Car Alert System (SCCAS) utilize pressure and motion sensors to detect the presence of children in vehicles and send alerts to drivers via SMS, offering vital reminders to prevent vehicular heatstroke incidents [7]. High-speed alerting systems (HSAS) play a crucial role in enhancing road safety by mitigating speeding incidents and improving driver awareness of speed limits [8]. Systematic reviews and comparative studies have demonstrated the significant impact of HSAS on reducing speeding incidents through prompt alerts and reinforcement of speed limit compliance [9]. Additionally, research emphasizes the role of GPS technology in enhancing the accuracy and reliability of vehicle info-enhancement systems (VIES), particularly in providing real-time speed limit information to drivers [10]. The development of real-time driver drowsiness detection systems utilizing facial landmark analysis and machine learning algorithms has gained significant attention, offering a non-intrusive approach for monitoring driver alertness and promoting safer driving practices on the road [11]. Studies exploring drowsiness detection through facial landmarks and Support Vector Machines (SVM) demonstrate the efficacy of these systems in detecting and alerting drivers to drowsiness episodes [12]. These advancements collectively underscore the importance of integrating technology into vehicles to enhance child safety, mitigate risks associated with heatstroke incidents and promote safer driving practices overall.

3. PROPOSED METHODOLOGY & IMPLEMENTATION

A. Child locked inside car

- Methodology

This system combines human presence detection and CO2 monitoring to enhance in-car safety. It utilizes a Raspberry Pi as the central hub, controlling an ESP32 CAM that captures images for human detection via a Tiny-YOLO model. Meanwhile, a dedicated CO2 sensor continuously monitors air quality. When CO2 levels exceed a safe threshold or a human is identified inside a parked car, the system triggers an alarm. This alarm can include audible sounds, flashing hazard lights, and even sending notifications to the car owner for remote awareness.

The system prioritizes autonomous operation for user convenience. Once installed and configured, it should function seamlessly without needing constant manual intervention. To ensure reliability, the system's performance is evaluated under various environmental conditions. Additionally, a user-friendly interface allows for configuration adjustments and real-time monitoring of CO2 levels and human presence detection status.

- Implementation

The implementation of the Intelligent Child Safety System integrates a combination of hardware and software components to detect and address the critical issue of children being inadvertently locked inside cars. Hardware elements include a Raspberry Pi, CO2 Gas Sensor, IR Sensor, and ESP32 CAM with OV2640 Camera. The Raspberry Pi serves as the central controller, orchestrating the operation of all components. The CO2 Gas Sensor continuously monitors carbon dioxide levels within the car, while the IR Sensor detects human presence or movement. The ESP32 CAM captures images inside the car, which are then processed using the Tiny-YOLO model integrated with the Raspberry Pi for precise human detection. The software stack involves Python programming for system integration and algorithm implementation, utilizing the OpenCV2 library for image processing and analysis. The algorithmic approach includes initializing all sensors, monitoring the IR sensor for movement, capturing images upon detection, analyzing images for human presence, checking CO2 levels, and triggering an alarm if CO2 levels exceed a predefined threshold, indicating potential risk to the occupant. This multi-layered approach ensures comprehensive coverage and timely response to potential dangers inside locked cars.

Fig. 1: Human is detected

B. Speed Limit Tracker

- Methodology

The methodology adopted for the development of the Passenger Safety Module follows a structured and iterative approach, encompassing various stages from requirement analysis to deployment and maintenance. The process begins with a thorough Requirement Analysis, aiming to define the system's scope, objectives, and stakeholder needs. This phase involves gathering requirements related to speed limit detection, alert generation, and user interface design, laying the groundwork for subsequent development activities.

Following requirement analysis, the System Architecture Design phase takes center stage, focusing on creating a scalable and modular framework for the Passenger Safety Module. This phase involves delineating components such as speed sensors, data processing modules, alerting mechanisms, and user interfaces, alongside the selection of suitable technologies and frameworks for each aspect. The architecture design ensures flexibility, scalability, and compatibility with future enhancements and adaptations.

Subsequently, the integration of speed limit data from reliable sources and real-time speed monitoring functionalities is prioritized. This involves leveraging APIs from mapping services or databases to fetch and store speed limit information, ensuring accuracy and reliability. Real-time speed monitoring capabilities are implemented to track vehicle speed accurately, utilizing sensors or GPS data for timely updates. Violation detection algorithms and alert generation mechanisms are then developed to notify drivers promptly upon detecting speed limit violations, tailored to individual preferences.

User interface development follows suit, focusing on creating intuitive interfaces for system configuration and management. The interfaces are designed to optimize user experience across various display systems and input devices, ensuring ease of use and accessibility. Integration testing, performance optimization, quality assurance, and validation are conducted iteratively throughout the development process to ensure functionality, reliability, and usability. Finally, deployment and maintenance phases involve disseminating the system into vehicles and establishing a robust maintenance plan for ongoing updates and enhancements. Compliance with relevant regulations governing vehicle safety systems and data privacy is also ensured throughout the development lifecycle. Through this comprehensive methodology, the Passenger Safety Module is effectively realized, contributing to enhanced vehicle safety and driver awareness.

- Implementation

The Passenger Safety Module takes a multifaceted approach to data visualization and user interaction. At its core, the system utilizes Folium, a Python library known for its strength in data manipulation and interactive mapping. Folium excels at seamlessly integrating with Leaflet.js, a popular JavaScript library for creating web maps. This powerful combination allows developers to manipulate data in Python and effortlessly present it on interactive maps. From color-coded choropleth maps depicting risk zones to detailed vector graphics highlighting specific locations, Folium offers a range of visualization options. Additionally, Folium's compatibility with various map providers like OpenStreetMap or Google Maps grants flexibility and customization to tailor the maps to specific needs. This data visualization foundation fosters user engagement by presenting information in a clear and interactive format.

Furthermore, the Passenger Safety Module integrates a web browser module to provide a user-friendly interface. This module acts as a bridge, allowing users to access and interact with web-based resources seamlessly. It intelligently selects the most suitable browser based on the user's device and operating system, ensuring a smooth browsing experience. This eliminates technical hurdles and empowers users to readily access critical safety information presented on web pages. By incorporating this module, the Passenger Safety Module prioritizes user accessibility and fosters engagement, ultimately promoting passenger safety through informed decision-making.

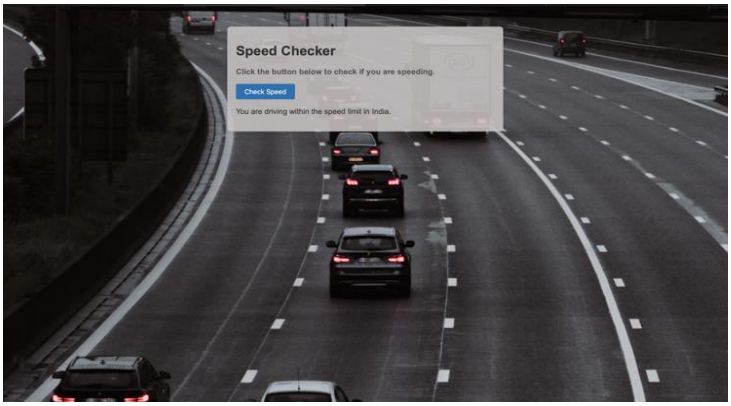

Fig. 2: Speed Tracer User Interface

C. Driver Sleeping During driving

- Methodology

There's a growing need for a system that monitors driver drowsiness to prevent accidents. This system would analyze facial features to assess alertness. It would use facial landmark detection, like the FaceMesh model, to pinpoint key features on the face such as eyes, mouth, and eyebrows. By tracking changes in these features, the system can detect blinks and yawns. Eyelid closure for a certain duration can indicate a blink, while changes in the distance between mouth corners can signal a yawn. These events would be used to infer the driver's drowsiness level.

To ensure smooth operation, the system would process video frames continuously in a separate thread, independent of the main program. This allows for real-time analysis without delays. Additionally, visual alerts would be displayed on the screen based on the detected drowsiness level. Frequent blinking or yawning would trigger warnings to alert the driver.

For enhanced performance, the system could leverage separate threads for video processing and utilize OpenCL, a framework for parallel processing. This would distribute tasks across multiple cores, speeding up image analysis and reducing response times, ultimately leading to a more reliable and responsive drowsiness detection system.

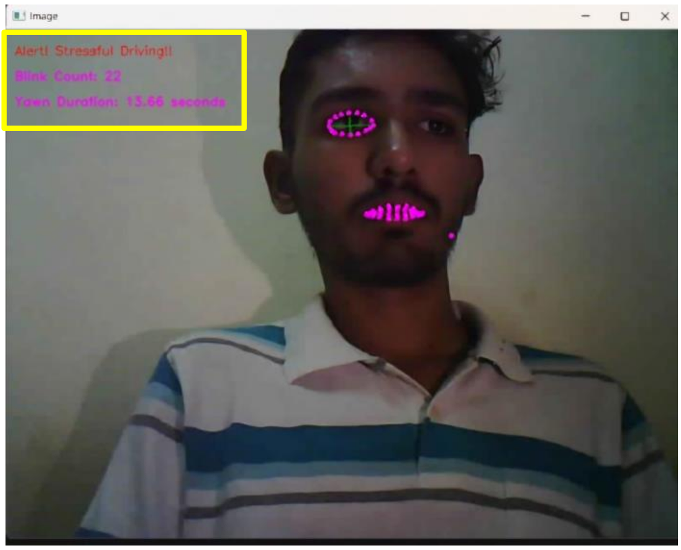

Fig. 3 : Detection of Stressful Driving

- Implementation

The system for tracking a driver's level of sleepiness by analyzing facial expressions and motions in a video feed is implemented using Python and several libraries, including OpenCV, NumPy, and requests. The system utilizes the ESP32-CAM microcontroller-based development board equipped with a camera module to capture the driver's facial expressions in real-time.

Facial landmarks are detected using the FaceMesh model, which accurately tracks key facial features like the eyes, nose, mouth, and eyebrows. Blink detection is achieved by calculating the aspect ratio of the eyes, while yawn detection is based on the distance between mouth landmarks. These features are continuously analyzed in a separate thread to ensure real-time responsiveness without blocking the main thread.

Visual alerts are provided on the video stream interface to indicate the driver's level of alertness based on detected patterns of blinks and yawns. The system dynamically adjusts its analysis based on changes in facial expressions and motions, allowing for accurate and timely detection of drowsiness or stress indicators.

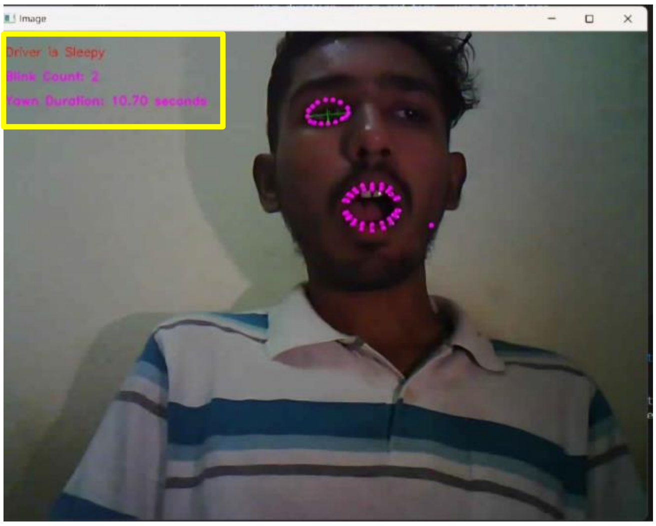

Fig. 4: Detection of sleepy or Drowsiness

4. Result and Discussion

In the realm of child safety, the model aims to mitigate the risks associated with leaving children unattended in vehicles, particularly during hot weather conditions. By leveraging weight sensors and alert systems, the model detects the presence of a child in the vehicle and promptly notifies caregivers to take action. This proactive approach is vital in preventing tragic incidents of heat-related injuries or fatalities among children left in cars. Integrated into car seats or vehicles themselves, this model serves as a critical safety feature, providing caregivers with peace of mind and safeguarding the well-being of children.

Moving on to the speed tracker model, its primary objective is to promote responsible driving behavior and enhance road safety by addressing instances of speeding. Through the utilization of high-speed alerting systems (HSAS), the model monitors vehicle speed in real-time and alerts drivers when they exceed speed limits. This proactive approach not only reduces the likelihood of accidents caused by speeding but also fosters greater awareness and adherence to speed regulations. Whether integrated into vehicles or deployed as standalone devices, the speed tracker model serves as a valuable tool in curbing speeding-related incidents and promoting safer driving practices on roadways.

Meanwhile, the drowsiness detection model represents a significant advancement in driver safety technology, particularly concerning the prevention of accidents caused by drowsy driving. By employing computer vision techniques, the model analyzes facial expressions and movements in a video feed to track a driver's level of alertness. It detects subtle indicators of drowsiness, such as blinks and yawns, and issues alerts when signs of fatigue or stress are detected. Integrated into vehicles or used in conjunction with existing driver assistance systems, this model plays a crucial role in mitigating the risks associated with drowsy driving and enhancing overall road safety. Its ability to provide real-time alerts based on driver behavior makes it an indispensable tool for preventing accidents and safeguarding lives on the road.

5. Conclusion

In conclusion, the models discussed in this paper represent significant advancements in vehicular safety technology, addressing various safety concerns with precision and effectiveness. The implementation of child safety measures, speed tracking systems, and drowsiness detection models demonstrates a proactive approach to mitigating risks associated with vehicle usage. Through the integration of innovative technologies such as weight sensors, high-speed alerting systems, and computer vision techniques, these models offer practical solutions to common safety challenges faced by drivers and passengers.

Furthermore, the successful implementation and deployment of these models underscore their potential to enhance road safety outcomes and save lives. By leveraging real-time data analysis and alert mechanisms, these models enable drivers to make informed decisions and respond promptly to potential hazards on the road. Whether integrated into vehicles or deployed as standalone devices, these safety solutions contribute to creating safer environments for all road users.

Looking ahead, continued research and development in the field of vehicular safety are essential to further advance these models and address emerging safety concerns. Additionally, collaboration between industry stakeholders, policymakers, and researchers is crucial to ensure the widespread adoption and implementation of these safety technologies. Through collective efforts, we can strive towards a future where accidents and injuries on the road are minimized, and road safety standards are upheld to the highest degree.
In summary, the models presented in this paper represent valuable contributions to the ongoing efforts to improve vehicular safety and reduce the incidence of preventable accidents on the roads. By leveraging cutting-edge technologies and proactive safety measures, these models pave the way for a safer and more secure transportation ecosystem for all stakeholders involved.

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