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Vehicle Authentication Using Face Recognition and an Accident Detection System

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ABSTRACT

Theft of vehicles and road mishaps have eventually become major problems that negatively affect the security of properties and the safety of the public, following the rapid development of the automobile industry. Conventional vehicle authentication methods such as physical keys, RFID cards, and password-based systems are prone to theft, duplication, and unauthorized access. Many accident identification systems do not have either automatic emergency response or real-time communication resulting in considerable delay in medical assistance. In an attempt to tackle these challenges, the project proposes a smart car authentication and accident detection system that relies on the Raspberry Pi platform to merge face recognition and Internet of Things-based safety technologies.

The system proposed will allow only authorized users to unlock the vehicle, as it captures the driver's face through a USB webcam for verification. Among the various sensors implemented to ensure safety are a MEMS accelerometer for crash detection, an alcohol sensor for preventing drunk driving, as well as heartbeat and temperature sensors for monitoring driver's health. The system automatically takes the vehicle's GPS position and uses a GSM module to send emergency messages to the pre-specified contacts whenever an accident or an unusual event is detected. The technology, according to experimental implementation, not only greatly improves vehicle security but also enables rapid emergency response and provides a low-cost, reliable solution for intelligent transportation safety systems.

INTRODUCTION

The rapid advancements in the automotive sector and the increase in the number of vehicles led to a significant increase in concerns over the security of vehicles and the safety of their occupants. Every year road accidents are responsible for a large number of injuries and deaths while the issue of vehicle theft still exists. Classic automotive identification methods such as PIN-based ignition systems, RFID cards, and mechanical keys are all open to stealing, duplication, and breaking in. Likewise, manual reporting is the most significant part of traditional accident response system that often leads to the delays in medical aid and consequently to the increased risk to human life [1].

Innovations in embedded systems, computer vision, and Internet of Things (IoT) technology have led to the creation of intelligent car safety solutions in recent years. Biometric authentication, particularly face recognition, has established a reliable and hassle-free method for securing cars. The driver's identity is confirmed using unique facial characteristics, thus eliminating the use of physical keys and reducing the chances of unauthorized entry. Studies have shown that the integration of computer vision techniques with low-cost embedded systems like Raspberry Pi can significantly enhance car security without increasing the cost factor [2].

Apart from auto theft, one of the major contributors to public safety concerns is traffic accidents caused by reckless, intoxicated drivers or sudden medical issues. MEMS accelerometers are among the sensors that are commonly used to detect accidents by monitoring sharp fluctuations in acceleration or tilt. Moreover, temperature sensors and heartbeat monitors are part of the driver's health surveillance system, which can reveal medical issues such as heat stress or cardiac arrest. When such systems are integrated with GPS and GSM modules, they offer the ability to dispatch emergency alerts and real-time location data to the specified contacts automatically. Consequently, this leads to faster responses and higher chances of survival [3].

The authentication of smart vehicle and accident detection system presented in this paper integrates real-time alarm systems, face recognition, accident detection, and driver health monitoring into one embedded platform. An integrated approach that employs a Raspberry Pi as the main controller, which ensures vehicle access to permitted users, rapidly detects accidents, monitors critical driver metrics, and sends emergency alerts with location information automatically. The overall strategy is to make road safety better, provide more security for vehicles and offer a reliable, low-cost solution that is suitable for the actual intelligent transportation systems in the world [4].

LITERATURE SURVEY

The limitations of traditional security systems have led to the wide acceptance of biometric vehicle authentication. Among the various biometric methods, face recognition has become the most successful solution due to its non-intrusive nature, ease of use, and difficulty of replication. It has been shown that installing embedded platforms like Raspberry Pi in a face recognition-based car entry system can effectively halt illegal activities [1]. Other studies have reported that real-time authentication accuracy is higher under controlled settings when OpenCV-based facial recognition is combined with IoT controllers [2]. Such systems require robust preprocessing and training models because they are highly susceptible to variations in light conditions and head positions.

One of the major factors contributing to traffic accidents around the world is driving under the influence. In order to mitigate this issue, embedding alcohol detection systems in car ignition systems has been proposed as a solution. Based on research [3], it was concluded that the car's starting process could be effectively blocked by alcohol sensor- controlled ignition lock systems if the detected alcohol content exceeded the permissible limit. Further studies combined alcohol detection with GSM modules to notify the authorities or the family members as a part of the safety measures [4]. The role of ambient conditions and sensor calibration in precise alcohol detection has been underscored in these studies.

Driving after drinking is considered to be one of the top reasons for road accidents all over the globe. It has been proposed that combining alcohol detection systems with car ignition systems could significantly reduce this issue. A study [3] has shown that one can effectively prohibit the start of the vehicle by using the alcohol sensor-controlled ignition lock systems if the measured alcohol concentration was above the permissible level. Linking alcohol detection with GSM modules to notify family or the police was another safety measure

suggested by the researchers [4]. The importance of environmental conditions and sensor adjustment in precise alcohol detection has been demonstrated through these studies.

MEMS sensors are one of the main topics in intelligent transportation systems and their application in the area of accident detection. MEMS accelerometers form the core technology frequently used in the detection of these abrupt shocks, tumbles, and vibrations that are characteristic of car accidents. A study has shown that MEMS-based accident detection, in combination with GPS tracking, automatically providing location-based alerts can help reduce emergency response times significantly [7]. Recent research, however, states that detection accuracy is higher when multi-axis accelerometer data is used, plus the number of false alarms, due to sudden brakes or road anomalies, is decreased [8].

The integration of GPS and GSM technologies has made automated emergency communication systems in vehicles a reality. The GPS module supplies the exact location coordinates, while the GSM module sends alarm notifications to the set contacts. Research states that the combination of GPS and GSM assures rapid accident notification even in remote or countryside areas [9]. Other studies say that GSM communication is the most suitable for real-world application as SMS-based alert systems are less prone to failure than internet-based systems in places with limited access.

In recent studies, integration of various security and safety measures in one embedded platform has been a topic of research. Such systems that integrate face recognition, accident detection, health monitoring, and IoT communication provide complete car safety solutions. Research finds that sensor fusion along with centralized control results in greater reliability for Raspberry Pi-based integrated smart car safety systems [10]. These multi-sensor IoT-based car systems are quite superior to the standalone alternatives in terms of safety, responsiveness, and scalability.

PROPOSED METHODOLOGY

The proposed system, which aims to be an integrated smart vehicle authentication and accident detection solution, uses the Raspberry Pi as the central processing unit. During the system initialization, the Raspberry Pi powers and interfaces all the hardware components like the USB web camera, MEMS sensor, alcohol sensor, heartbeat sensor, temperature sensor, GPS module, GSM module, relay, DC motor, and buzzer. The real-time communication is enabled by the simultaneous execution of the booting process of the operating system and the starting of the Python-based control programs for the different modules. The sensors are regularly checked to confirm proper operation prior to the driving of the vehicle. This centralized structure supports the seamless transitioning between authentication, safety monitoring, and emergency response service, thus assuring the system's reliable performance across a wide range of operating conditions.

The vehicle authentication procedure is based on facial recognition technology created using a USB webcam and image-processing algorithms. The camera captures the driver's face, and then computer vision techniques are used to process it when the user intends to start the car. The captured image is subjected to preprocessing to achieve consistency in lighting and facial features before it is compared to a pre- trained database of the authorized persons stored in the system. The Raspberry Pi activates the relay which, in turn, starts the DC motor simulating the car's engine, if a match is found. In case of a failed authentication, the technology promptly sounds a buzzer warning and prevents starting the car. This method offers reliable, secure, and no-contact vehicle access control.

The technology constantly examines driver safety metrics and vehicle condition after the vehicle is validated and operational. To avert driving under the influence, the system restricts the vehicle's functioning whenever the alcohol sensor indicates that the driver's breath contains more alcohol than the permissible limit. The temperature and heartbeat sensors simultaneously monitor the driver's physiological condition in real-time. Extremely high or low body temperatures and irregular heartbeats are among the atypical measurements that are treated as possible medical emergencies. Raspberry Pi is the one that continuously processes this sensor data, which ensures detection of dangerous driving situations and allows quick preventive measures to reduce the risk of accidents.

The final step of the proposed new method is detecting an accident and generating an emergency alert. To identify sudden impacts or movements that could indicate an accident, a MEMS accelerometer constantly

records the vehicle's acceleration and tilt in different directions. When these situations occur, the system automatically receives the current location data from the GPS module. The GSM module is then used to transmit the location data and an emergency alert message to the mobile numbers specified in advance. To attract nearby help, a buzzer makes an alarm sound at the vehicle's location. Due to its automatic response mechanism, which significantly reduces emergency reaction times and hence increases the chances of immediate medical intervention, the system is applicable to real-life safety scenarios.

A. System Architecture

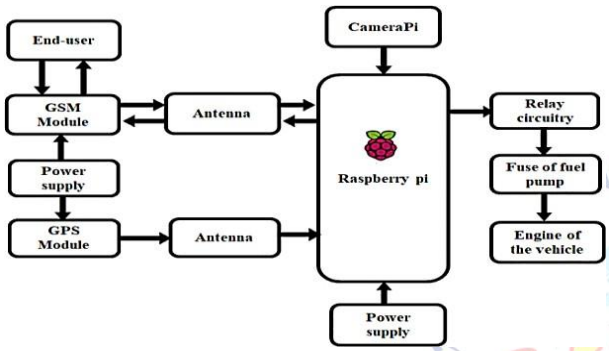

Fig.1 Architecture of Vehicle Authentication

B. Methodology

Framework of Data Procurement along with Multi-Sensor Monitoring

The proposed measure relies on the collection of data from different sensors constantly in order to ensure driver and vehicle security. A USB web camera is used to take the driver's face for authentication in real time. Critical information about the state of the driver and the movement of the vehicle is collected simultaneously by the MEMS accelerometer, alcohol sensor, heartbeat sensor and temperature sensor. These sensors are connected to the Raspberry Pi, which is the primary data collection unit. Each sensor operates within fixed sample periods in order to ensure that data is captured accurately and quickly without putting a lot of stress on the system processor.

The alcohol sensor incessantly assesses the driver's breath for liquor early and also during driving. The instrument keeps a check on the situation and prevents the car from starting if the alcohol level is more than the allowed one. The real-time tracking of the driver's physiological factors like temperature and heartbeat helps in the early trapping of unusual health conditions. The Raspberry Pi is capable of processing the data efficiently owing to the analog signals of these sensors, which are converted into digital data by using the right signal conditioning methods.

In the Vehicle dynamics the MEMS accelerometer plays a significant role through the constant monitoring of acceleration and tilt over different dimensions. The possibilities of an accident are indicated by abnormal tilt angles or sudden transformations in acceleration patterns. Time-stamping and real-time processing of all the gathered sensor data creates a complete surveillance framework that is capable of providing emergency response, safety monitoring, and authentication all in one system.

Design ofthe Embedded Processing Logic and Controlling System

Python programming on the Raspberry Pi platform is utilized to realize the embedded logic of the proposed system. The embedded software activates all the connected peripherals, sensors, and communication modules immediately when the system is powered up. Each subsystem—authentication, health monitoring, alcohol detection, and accident detection—functions separately but communicates through a centralized control loop due to the modular design of the control logic. This architecture not only guarantees system reliability but also simplifies debugging and upgrading processes.

The integrated logic applies computer vision techniques to facial images taken by the camera for car identification. The images captured are processed to get rid of noise and to rotate the face for easy readability before proceeding to feature extraction. The characteristics are compared with a database of approved users which is the source of the stored data. If the identification is successful, the system changes the control state to allow starting the car only. The control logic blocks unauthorized access by ringing the buzzer alarm immediately and also blocking the system to progress any further in case the identification fails.

One more part of the control architecture is the continuous monitoring logic that compares sensor data to the pre-set safety specifications. In extraordinary circumstances, like the detection of alcohol, health issues,

or sudden vehicle crash, the embedded unit gives the safety measures the top priority. The decision-making logic is built with the use of conditional statements and interrupt-driven mechanisms, which enable the system to run smoothly in the normal mode while responding immediately to emergency situations.

Self-actuation and protection mechanism for vehicles

Managing physical elements such as the relay, DC motor, and buzzer, the automated actuation mechanism takes responsibility for the enforcement of decisions in the system. The Raspberry Pi, when all safety conditions are met and the driver has been properly authenticated, activates the relay module which allows the current to go to the DC motor simulating the car ignition. Thus, this controlled actuation allows the car to be driven only in safe and authorized places.

Immediately, the actuation logic turns off the relay which cuts off the starting of the engine or stopping of the vehicle if the entry is illegal, there is alcohol detected, or the driver is unhealthy. The buzzer, at the same time, is activated to sound a warning and alert anyone close by about the security or safety issue. The manual involvement is minimized and thus, the automated protection system assures instant and dependable safety enforcement.

The actuation mechanism aids in emergency handling by maintaining system power and powering communication modules. The GSM module, on the other hand, sends out a signal to the already identified contacts in case of an emergency, while the GPS module gets the location data instantaneously. This safety measure ensures rapid emergency response, reduces rescue times, and elevates overall vehicle safety. The system is very effective for practical vehicle security and accident management scenarios as it provides automatic actuation along with smart decision logic.

RESULTS

The experimental implementation of the proposed vehicle authentication and accident detection system represents the reliability of security, safety monitoring, and emergency response functions. The system is a universal embedded platform that efficiently unites automatic alarm systems, multi-sensor surveillance, and facial recognition. Authorized access control, real-time driver condition monitoring, precise abnormal event detection, and timely emergency communication were all done with very little delay during the testing. The system is suitable for real-world intelligent transportation applications as the observed results indicate that it not only enhances the security of vehicles but also accelerates the response time in emergency situations.

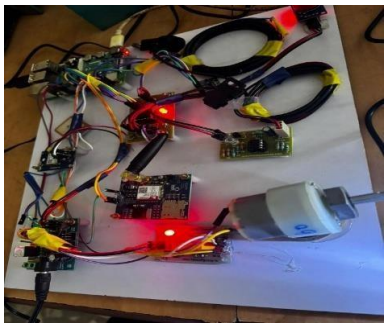

Fig .2 Overview of Vehicle Authentication

The effectiveness of facial verification for vehicle access control was to be evaluated. After matching recorded facial features to the database, the system accurately recognized authorized persons and allowed vehicle operation only after successful verification. Regularly denied access for unauthorized users and immediate activation of the alert system demonstrated the strength of biometric security. The speedy turnover of the authentication process provided user comfort along with security.

In addition, although there were many unsuccessful attempts to gain entry, the authentication module still worked steadily. The slight changes in light and different expressions on the face had no noticeable effect on the recognition accuracy which indicated very good preprocessing and feature extraction. Thus, it can be concluded that facial recognition is a secure and convenient alternative to traditional car verification methods using keys or cards.

Fig .3 Real-Time Face Recognition–Based Vehicle Authentication Interface Using Raspberry Pi

The compilation of results indicates that the system is capable of detecting abnormal vehicle movement and risky driving conditions. The MEMS sensor effectively recognized sudden impacts and irregular movements through constant observation of acceleration and tilt parameters. The system validated precise accident detection in test crash simulations by recognizing rapid motion parameter shifts and quickly starting safety actions.

Moreover, sensor data processing was capable to separate and mark out serious accidents and normal driving conditions as well. Thus, the normal car movements did not cause as many false alarms as before. The unchangingness of the abnormal motion identification has confirmed the dependability of MEMS-based sensors for accidents monitoring in embedded vehicle safety systems.

Fig .4 Face Recognition Authentication Module Execution on Raspberry Pi for Secure Vehicle Access

The primary results were real-time tracking and emergency communication. The technology utilized satellite-based positioning to accurately obtain the location coordinates whenever it sensed an accident or critical situation. The coordinates were sent to pre-arranged contacts, which enabled the incident location to be known quickly. Testing showed that the communication delay was very minimal, thus facilitating a quick emergency response.

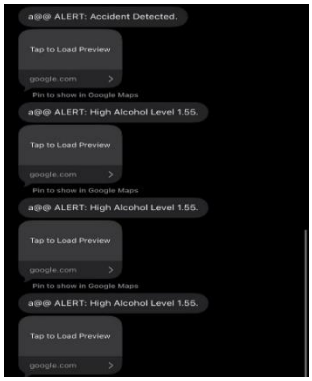

Fig .5 GSM-Based Emergency Alert and Alcohol Detection Notification with GPS Location

Alerts were always dispatched successfully during tests conducted in different environments and also location transmission. In addition, the cellular communication secured the operation in areas where the internet connection was very bad. The results indicate that the combination of automated messaging with real-time positioning significantly enhances the effectiveness of emergency notifications and reduces the time to get the response. The final results underscore the reliability of the whole system and performance of the integration. The embedded processor controlled the whole hardware and ensured continuous monitoring without any system crashes or data loss. The robustness of the hardware design was confirmed by the stability of the power management and sensor interfacing throughout the long operation.

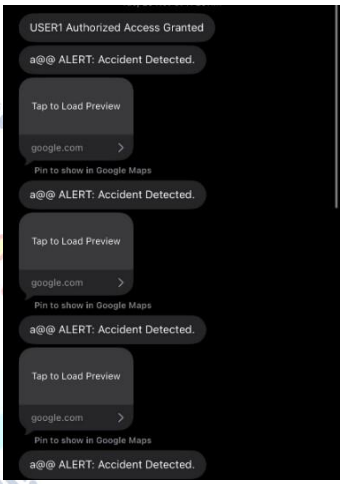

Fig .6 Accident Alert Notification

In the event of critical situations, alarm messages are automatically generated by the system, thus showcasing real- time emergency communication efficiency. Upon the successful identification of the driver or the detection of an unusual incident such as an accident or a high level of alcohol content, the system at once alerts the previously selected persons. To ensure a quick response, the alerts come with the exact location and a short description of the incident. Notifications are sent at all times which makes sure that the concerned parties are notified without delay and this also proves the reliability of the communication mechanism. This function reduces emergency response times considerably and keeps the situation enlightened instantly during accidents or dangerous driving conditions, thus contributing significantly to the safety of roads.

CONCLUSION

The combination of biometric security, real-time monitoring, and automated emergency response into a unified embedded platform is exemplified by the proposed vehicle authentication and accident detection system. The solution employs facial recognition for vehicle access management, which ensures that only authorized users can operate the car, thereby significantly reducing the risk of theft and illegal use. The constant monitoring of driver state and vehicle status made possible by the integration of several sensors allows for a safety-oriented approach. The experimental results confirm the system's reliability in different operating conditions while maintaining rapid response times and consistent performance.

The system, through continuous health and behavior monitoring, gives priority to driver safety along with vehicle security improvement. The prevention of hazardous driving situations and medical emergencies is achieved by the combination of temperature sensing, cardiac monitoring, and alcohol detection. The automated preventive measures such as restricting the operation of vehicles and dispatching notifications play a significant role in minimizing the risks before they escalate to serious accidents. The accident detection feature by sensing unusual vehicle movements and initiating emergency communication without human intervention adds more safety to the overall system.

Taking everything into account, the proposed system presents a solution that is both scalable and economical at the same time, which is very suitable for modern intelligent transportation applications. The modular architecture allows easy addition of more sensors, cloud connectivity, or sophisticated machine learning methods to the future applications. The system is a possible plan for practical implementation because it merges security, safety, and emergency response into one design that helps to improve road safety, reduce emergency response times, and secure both vehicles and occupants.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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