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A Smart Car Seat Belt Accident Detection and Emergency Services in A Smart City Environment

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Abstract: *Delay in the arrival of emergency services after road accidents significantly contributes to the increasing number of fatalities globally, including in Saudi Arabia. To address this problem, a cost-effective IoT-based system has been developed to detect accidents and send timely alerts. The system employs an MPU6050 sensor to monitor variations in a vehicle's angle, aiding in the identification of incidents such as rollovers or collisions. These readings are continuously analysed by an ESP32 microcontroller to assess whether an accident has occurred.*
Upon detecting an accident, the system automatically generates a notification to alert nearby emergency contacts or authorities, facilitating a quicker response. The Blynk platform is used to send these notifications through communication technologies such as Wi- Fi or Bluetooth. All hardware components are assembled using the Arduino platform, with programming carried out through the Arduino IDE. This solution is designed to minimize the critical time gap between an accident and the arrival of emergency help, ultimately aiming to save lives..

Keywords*:* ESP 32, MPU6050, Solenoid Lock, Servos

I. INTRODUCTION

As smart cities continue to evolve, enhancing road safety and ensuring rapid emergency response have become key priorities. With the increasing number of vehicles on the road, accidents remain a major concern, often leading to severe injuries or fatalities due to delayed medical attention. Traditional safety measures are largely reactive, emphasizing the need for intelligent systems that can detect accidents in real time and trigger immediate responses without depending on manual reporting.

The integration of Internet of Things (IoT) technology into accident detection systems offers a transformative approach to improving vehicle safety. IoT enables seamless communication between devices, allowing for real-time monitoring, data processing, and instant alert transmission. By incorporating IoT, accident detection systems can function autonomously, ensuring that critical information is relayed to emergency services or contacts within seconds of an incident. This drastically reduces the time between an accident and the arrival of assistance, significantly improving the chances of survival and minimizing the impact of injuries.

A smart accident detection and emergency service system, powered by IoT, contributes to the development of safer and more responsive urban environments. These systems not only enhance individual vehicle safety but also support the broader vision of connected, intelligent infrastructure within smart cities. By leveraging advanced technologies to address critical safety issues, such initiatives help create a transportation network that prioritizes human life and promotes proactive emergency management.

1.1 Project Outline:

The project titled "A Smart Car Seat Belt Accident Detection and Emergency Services in Smart City Environment" is designed to enhance road safety and reduce fatalities caused by delayed emergency responses. With the continuous growth of vehicle usage in smart cities, accidents have become a major concern, often leading to severe consequences

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due to the absence of immediate detection and communication with emergency services. This project addresses the issue by developing a smart system capable of automatically identifying accidents and promptly sending notifications to emergency contacts, ensuring quicker medical assistance.

By leveraging Internet of Things (IoT) technology, the system enables real-time monitoring and communication between the vehicle and external platforms. It continuously tracks motion and impact data to detect accidents and triggers alerts without requiring manual input. This not only shortens the critical response time but also enhances overall passenger safety through automated features like seat belt locking and audible alerts. The integration of smart sensors, microcontrollers, and cloud-based notification platforms creates a reliable and efficient safety solution aligned with the needs of modern urban transportation systems.

1.2 Project Objective:

The main objective of this project is to develop a smart car seat belt accident detection and emergency service system that utilizes IoT technology for real-time monitoring and immediate response. The system aims to automatically detect accidents by analyzing vehicle movement and impact data. Upon detecting an accident, the system triggers instant alerts to emergency contacts or services, reducing the time between the incident and the arrival of help. Additionally, it enhances passenger safety by locking the seat belt and providing audible alerts. By integrating various sensors, actuators, and IoT platforms, the system strives to improve road safety and ensure faster emergency response in a smart city environment. Ultimately, the project seeks to save lives and minimize the severity of injuries in accident scenarios.

II. LITERATURE SURVEY

S. Patil [1]: This study presents a system to automatically detect vehicular accidents and alert emergency services, hospitals, and family members. It employs an accelerometer to detect sudden acceleration changes and uses a GPS module to track the accident location. Alerts are sent through a GSM modem.

C. K. Gomathy [2]: This paper describes a system designed to detect vehicle accidents using an Arduino, GPS, and GSM module. The system detects sudden changes in a vehicle's axes through an accelerometer and sends an alert message with the vehicle's location and speed to pre-set mobile numbers via GSM.

Dr. R. Prasanthi [3]: The research in this paper focuses on developing an accident detection and alert system using an Arduino board. It integrates GPS and GSM technologies to locate the accident and notify emergency services quickly. The system is highlighted as particularly useful in developing countries with high traffic fatalities.

M. Ajay Kumar [4]: This research develops a system that uses Arduino, GPS, and GSM for accident detection and alert. It is aimed at rapidly increasing vehicle numbers in developing nations, intending to reduce accident response times and improve emergency medical services.

G. Siri [5]: This paper discusses a system that uses a combination of GPS, GSM, and additional sensors like vibration and alcohol detection sensors to improve road safety by automatically detecting accidents and alerting emergency services. The system also includes functionality to stop the vehicle if alcohol is detected, aiming to prevent accidents before they occur.

III. EXISTING SYSTEM

Most vehicles depend on drivers and passengers to manually wear seat belts, lacking automatic enforcement or monitoring. High-end vehicles may have airbag systems and crash sensors, but these don’t notify emergency services unless connected to costly proprietary services, which aren’t universally available. In accidents, bystanders or victims must contact emergency services manually, causing delays in medical help and worsening injury outcomes.

Moreover, existing safety systems are not designed to integrate with smart city infrastructures or IoT platforms for proactive emergency management. These systems work in isolation, unable to share vital accident data with emergency responders or connected networks. The lack of integration hampers response effectiveness, as critical data isn’t exchanged immediately between the vehicle, emergency services, and smart city infrastructure. Consequently, response times remain slow, and the potential of IoT in enhancing safety and emergency management is underutilized.

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IV. PROPOSED METHOD

The proposed system is an advanced IoT- based smart safety solution designed to ensure seat belt compliance and provide real-time detection of vehicle accidents. At the heart of the system is an ESP32 microcontroller, which acts as the central controller coordinating and managing all connected components. When a person occupies the seat, a level switch detects their presence and triggers the automatic engagement of a solenoid lock that fastens the seat belt securely. This automatic enforcement helps to ensure that seat belts are worn consistently, improving passenger safety. To continuously monitor the vehicle's motion, an MPU6050 sensor is employed, which tracks changes in acceleration and tilt angles. This sensor can detect unusual or sudden movements that indicate accidents such as collisions or vehicle rollovers.

Upon detecting such abnormal events, the system immediately responds by activating several safety measures. A buzzer sounds to alert occupants inside the vehicle, while a display on the LCD screen shows important warning messages to provide clear visual alerts. At the same time, the system sends instant notifications to pre-designated emergency contacts through the Blynk mobile application as well as email alerts, ensuring that help can be dispatched quickly. In addition to enforcing seat belt usage and accident detection, the system incorporates servo motors that automatically unlock the vehicle's doors in case of an emergency, allowing passengers to exit safely and without delay. A relay component is also integrated to manage power distribution safely, protecting the electronic circuit from any potential damage caused by power fluctuations. Overall, this smart safety system not only automates critical safety features but also facilitates rapid communication during emergencies, making it an excellent candidate for integration within smart city infrastructures. By enabling real-time detection and prompt emergency response, the system significantly enhances road safety and supports faster intervention during accidents.

Block Diagram:

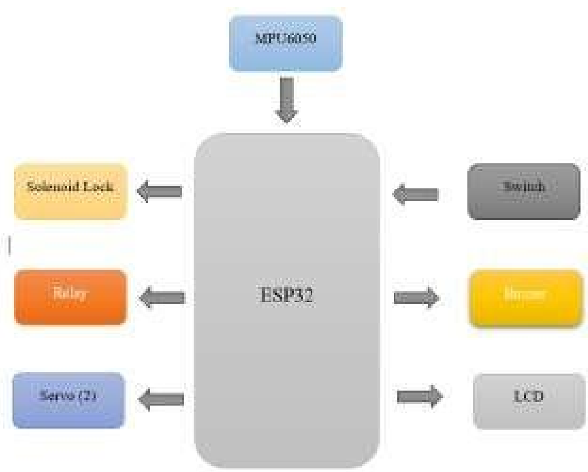

Fig : Block diagram for Smart Car Seat Belt Accident Detection

Working Principle:

The smart car seat belt accident detection system is designed to monitor vehicle dynamics and respond intelligently in the event of a crash. It uses two primary input sensors: the MPU6050 (a 6-axis accelerometer and gyroscope) and a level switch. The MPU6050 continuously measures the vehicle's motion and orientation to detect abnormal events like rollovers or sudden impacts. Simultaneously, the level switch monitors changes in fluid or tilt levels—serving as a secondary confirmation of a possible accident. These sensor readings are fed into the ESP32 microcontroller, which analyzes the data to determine whether an accident has occurred, based on predefined motion thresholds or tilt angles.

Upon detecting an accident, the ESP32 initiates a series of automated safety responses. It triggers a relay module to power the 12V solenoid lock, which controls the seat belt mechanism. This ensures that the seatbelt can be either

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locked during risky motion or released in a crash to aid escape. At the same time, the ESP32 activates servo motors connected to the vehicle doors, automatically unlocking them to allow for emergency exit or rescue—especially critical if occupants are injured or unconscious. A buzzer is also activated to produce an audible alert, and the LCD with I2C displays a warning message or system status.

Additionally, the ESP32 uses its Wi-Fi or Bluetooth capabilities to send real-time notifications through the Blynk IoT platform to emergency contacts or authorities. These alerts can be enhanced with GPS data (if included) for accurate location tracking. All components are programmed via the Arduino IDE, making the system low-cost, scalable, and ideal for smart city integration. The overall design reduces response time in emergencies and enhances passenger safety by automating critical actions such as seatbelt control and door unlocking.

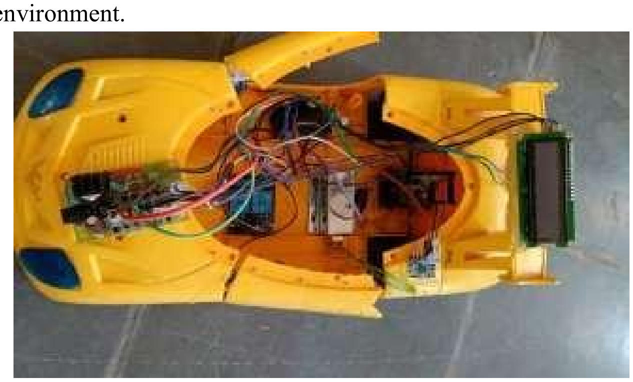
V. SOFTWARE EMPLOYED

In the project titled "A Smart Car Seat Belt Accident Detection and Emergency Services in a Smart City Environment", the software employed plays a crucial role in enabling smart detection, control, and communication functionalities. The primary software used is the Arduino IDE, which serves as the platform for programming the ESP32 microcontroller. Through the Arduino IDE, code written in Embedded C is uploaded to the microcontroller to control various sensors and actuators. Additionally, the project utilizes the Blynk IoT platform for remote monitoring and alert notifications, enabling real-time communication with emergency contacts via Wi-Fi or Bluetooth. For Android mobile integration, applications such as MIT App Inventor might have been used to create simple interfaces, although it is not explicitly mentioned. These software tools collectively ensure efficient data processing, user interface development, and remote connectivity essential for implementing the smart safety features in the vehicle.

VI. RESULTS & DISCUSSION

The system was successfully developed and tested using the ESP32 microcontroller along with sensors and actuators such as the MPU6050, level switch, solenoid lock, servo motors, buzzer, and LCD with I2C. During testing, the MPU6050 accurately detected rapid motion changes and rollovers, while the level switch provided additional confirmation in situations involving vehicle tilting. When an accident was detected, the relay efficiently powered the 12V solenoid lock, and the servo motors automatically unlocked the doors, simulating a real-world emergency response scenario.

Immediate audible alerts were generated through the buzzer, and real-time visual feedback was displayed on the LCD to confirm activation of the safety mechanisms. At the same time, emergency notifications were transmitted using the Blynk platform over Wi-Fi, successfully reaching preconfigured emergency contacts. Overall, the system demonstrated high responsiveness, reliability, and practicality, making it well-suited forintegration into smart vehicle safety frameworks in a smart city environment.



VII. CONCLUSION

The development of the Smart Car Seat Belt Accident Detection and Emergency Services System demonstrates significant potential for improving road safety and emergency response times in smart cities. By leveraging IoT

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technology, the system efficiently detects accidents using sensors such as the MPU6050, level switch, and GPS, allowing for rapid and automatic responses. Upon detecting an accident, the system triggers critical safety measures, including unlocking seat belts, opening vehicle doors with servo motors, and sending real-time emergency alerts through the Blynk platform. This timely communication with emergency contacts and services can significantly reduce the response time, ultimately saving lives.

The project successfully integrates various hardware components, such as the ESP32 microcontroller, solenoid lock, servo motors, and LCD with I2C, offering a reliable and effective solution for emergency situations. While there are certain challenges, including sensor accuracy, power consumption, and the reliance on network connectivity, these limitations can be addressed with further optimization. Overall, this project presents a scalable and cost-effective solution for enhancing vehicle safety and emergency services, contributing to the development of smart city infrastructures. Future improvements could further expand the system's capabilities, increasing its adoption in real-world applications.

VIII. FUTURE SCOPE

The Smart Car Seat Belt Accident Detection and Emergency Services System holds strong potential for future enhancement. Future upgrades could involve integrating more precise GPS for accurate location tracking and using machine learning to distinguish accident types, reducing false alarms. As autonomous vehicles become more common, the system could support fully automated emergency protocols, triggering immediate actions without human input. Integration with smart city infrastructure would enable real-time communication with traffic control systems, helping emergency vehicles navigate more efficiently during accidents.

The system could also monitor driver behavior, detecting signs of drowsiness, distraction, or unsafe driving, and providing alerts to prevent accidents. Cloud-based data storage would allow for detailed analysis of accident patterns and help identify high-risk zones for better urban planning. With advancements in 5G, communication speed and reliability would improve, enabling faster emergency responses, especially in busy city areas. As IoT hardware becomes more affordable, wider adoption in personal and commercial vehicles could significantly enhance road safety on a global scale.

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