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CRASH ALERTING AND DETECTING SYSTEM

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Abstract: In today's fast-paced world, road accidents remain a major concern, leading to severe injuries and fatalities due to delayed emergency response. The Crash Alerting and Detecting System is an IoT-based solution that automatically detects vehicular accidents through airbag deployment sensors and real-time GPS tracking, promptly notifying emergency services and designated contacts. The system integrates microcontrollers, GSM modules, and cloud-based storage to ensure seamless data transmission. By leveraging IoT technology, this project aims to enhance road safety, reduce emergency response time, and provide real-time accident reports, ultimately saving lives.

Keywords: Crash Detection, IoT, Real-time GPS Tracking, Automated Alert System

I. INTRODUCTION

Road accidents are one of the leading causes of fatalities worldwide. Many accident victims fail to receive timely medical attention due to delayed emergency responses and lack of accident reporting mechanisms. In conventional scenarios, accident detection relies on witness reports, leading to time loss and inefficiencies in rescue operations.

To mitigate these challenges, we propose an IoT-based Crash Alerting and Detecting System, which detects accidents using airbag deployment sensors and impact detection modules. Once an accident is detected, the system automatically sends alert messages containing the exact GPS location and timestamp to emergency services and pre-configured contacts. This solution significantly enhances emergency response efficiency and reduces fatality rates caused by delayed assistance.

II. OVERVIEW

The Crash Alerting and Detecting System is designed to automatically detect accidents and transmit real-time alerts. The system consists of:
-Airbag Deployment Sensor – Detects a crash based on impact force.
-Microcontroller (Arduino/Raspberry Pi) – Processes sensor data.
-GPS Module – Captures and transmits accident location.
-GSM Module – Sends real-time SMS alerts to emergency responders.
-Cloud Integration – Stores crash data for further analysis.

The system operates by continuously monitoring vehicle impact levels. Upon detecting a crash, it automatically activates the emergency alert mechanism, ensuring that accident reports are sent immediately to emergency responders and nearby hospitals.

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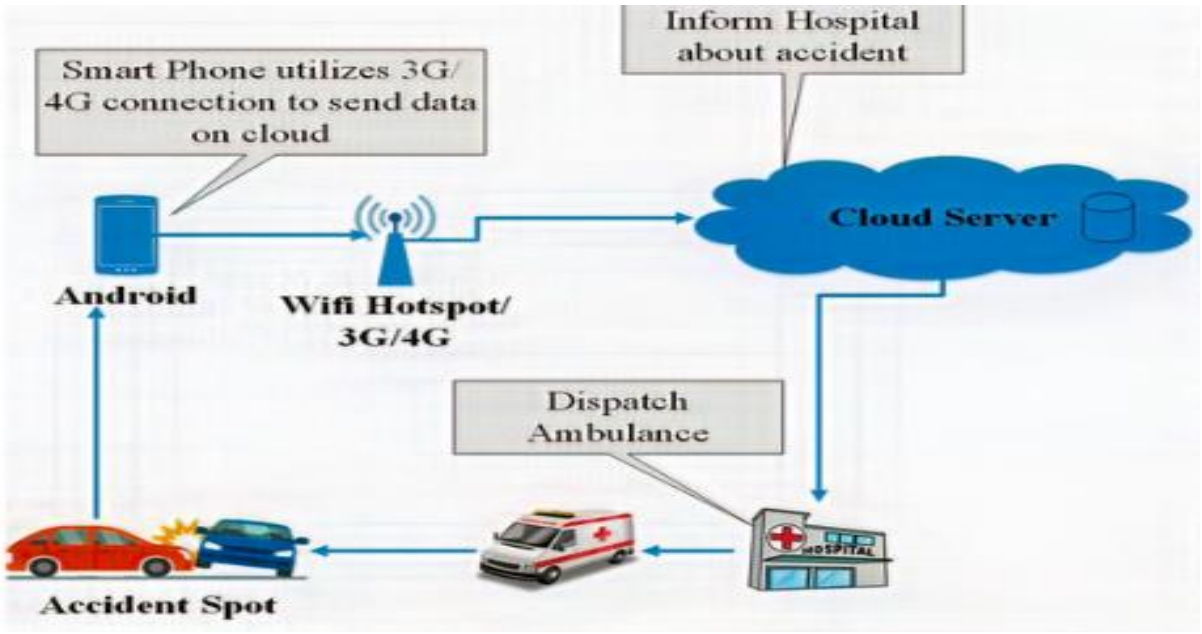

III. COMPONENTS

1) Arduino UNO R3: The Arduino UNO R3 is a microcontroller board based on the ATmega328P. It has 14 digital I/O pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, and a power jack. The UNO R3 is widely used in IoT applications due to its ease of use, compatibility with various sensors, and open-source nature. It supports both 5V and 3.3V devices, making it versatile for embedded systems and automation projects.
2) Accelerometer Sensor (MPU6050): The MPU6050 is a motion tracking sensor that detects sudden acceleration changes in vehicles, making it ideal for accident detection. It provides accurate impact detection data, triggering the alerting system upon detecting a crash.
3) GPS Module: The GPS module provides real-time location tracking, allowing the system to determine the exact crash location. This information is sent to emergency contacts for a rapid response.
4) GSM Module: The GSM module sends automated SMS notifications containing accident details to predefined emergency contacts, ensuring immediate alert transmission.
5) Power Supply: The system is powered by a reliable DC power source to ensure continuous operation, even in crash scenarios.

SOFTWARE SPECIFICATION

1. Programming Language – C++ Language
2. Arduino IDE

IV. EXISTING SYSTEM

Traditional crash detection systems rely on manual accident reporting, leading to delays in emergency response. Many modern vehicles come with built-in safety features, but these are limited to high-end models. Existing systems do not provide real-time, automated alerts, making them inefficient in critical situations where every second matters.

V. PROPOSED SYSTEM

A. Abbreviations and Acronyms

i. IoT - Internet of Things
ii. GPS - Global Positioning System
iii. GSM - Global System for Mobile Communications
iv. MPU6050 - Accelerometer and Gyroscope Sensor
v. UNO R3 - Universal Numbering Organization Revision 3 (Arduino Model)

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B. Objective

The primary objective of this project is to develop an IoT-based Crash Alerting and Detecting System that enhances road safety by providing real-time accident detection and automated emergency alerts.

• Automated Crash Detection – To identify crashes using impact sensors and send alerts instantly.
• Real-Time Location Tracking – To provide accurate crash site details for faster response.
• Immediate Emergency Notification – To reduce response time and increase survival chances.
• Data Logging – To store accident data for further analysis and safety improvements.

C. Methodology

The development process of the Crash Alerting and Detecting System follows a structured approach to ensure efficiency in accident detection and emergency response.

• System Design & Hardware Selection: The system consists of a microcontroller, impact sensors, a GPS module, and a GSM module. These components are integrated to create a robust accident detection and alerting system.
• Sensor Integration & Real-Time Alert Mechanism: The system continuously monitors vehicle motion using accelerometers. Upon detecting a crash, the GPS module records the accident location, and the GSM module sends emergency notifications.
• Safety & Reliability Mechanisms: The system includes network redundancy, ensuring alerts are sent even in low-signal areas. The alert system is configured to retry transmission if the initial message fails.
• Testing, Implementation & Final Integration: The system undergoes multiple tests to verify its accuracy in crash detection, alert transmission speed, and location tracking efficiency. Once validated, the final prototype is optimized for real-world implementation.

VI IMPLEMENTATION OF PROJECT

1. AIRBAG DEPLOYMENT SENSOR
   • THIS SENSOR DETECTS CRASH IMPACT BASED ON THE SUDDEN DEPLOYMENT OF THE AIRBAG.
   • IF THE AIRBAG DEPLOYS, IT IMMEDIATELY TRIGGERS THE CRASH ALERT SYSTEM TO PROCESS DATA.
   • THE SENSOR PROVIDES A HIGHLY ACCURATE WAY OF DETECTING SEVERE CRASHES.
2. ACCELEROMETER (MPU6050)
   • DETECTS SUDDEN MOTION CHANGES IN THE VEHICLE, SUCH AS RAPID DECELERATION OR IMPACT.
   • USED AS A SECONDARY DETECTION METHOD TO VERIFY A CRASH IN CASE THE AIRBAG SENSOR FAILS.
3. GPS MODULE (NEO-6M OR SIM808)
   • RETRIEVES REAL-TIME LOCATION OF THE ACCIDENT SITE.
   • TRANSMITS LATITUDE AND LONGITUDE COORDINATES FOR ACCURATE POSITIONING.
   • ENSURES EMERGENCY RESPONDERS RECEIVE THE EXACT ACCIDENT LOCATION.
4. GSM MODULE (SIM800L/SIM900A)
   • USED TO SEND SMS ALERTS TO EMERGENCY CONTACTS.
   • THE GSM MODULE ENSURES REAL-TIME COMMUNICATION EVEN IN REMOTE AREAS.
5. MICROCONTROLLER (ARDUINO UNO / RASPBERRY PI)
   • THE CENTRAL PROCESSING UNIT THAT COLLECTS CRASH DATA, PROCESSES IT, AND SENDS ALERTS.
   • READS DATA FROM SENSORS AND EXECUTES EMERGENCY ALERT PROTOCOLS.
6. FIRE DETECTION SENSOR
   • DETECTS FUEL LEAKS OR FIRE CAUSED BY THE CRASH.
   • PROVIDES A BACKUP DETECTION MECHANISM IF THE AIRBAG SYSTEM FAILS.
   • ENHANCES SYSTEM RELIABILITY BY COVERING FIRE-RELATED ACCIDENT RISKS.
7. POWER SUPPLY UNIT (12V BATTERY/CAR BATTERY)
   • ENSURES UNINTERRUPTED OPERATION OF THE SYSTEM.
   • MAINTAINS POWER DURING AN ACCIDENT TO PREVENT SYSTEM FAILURE.

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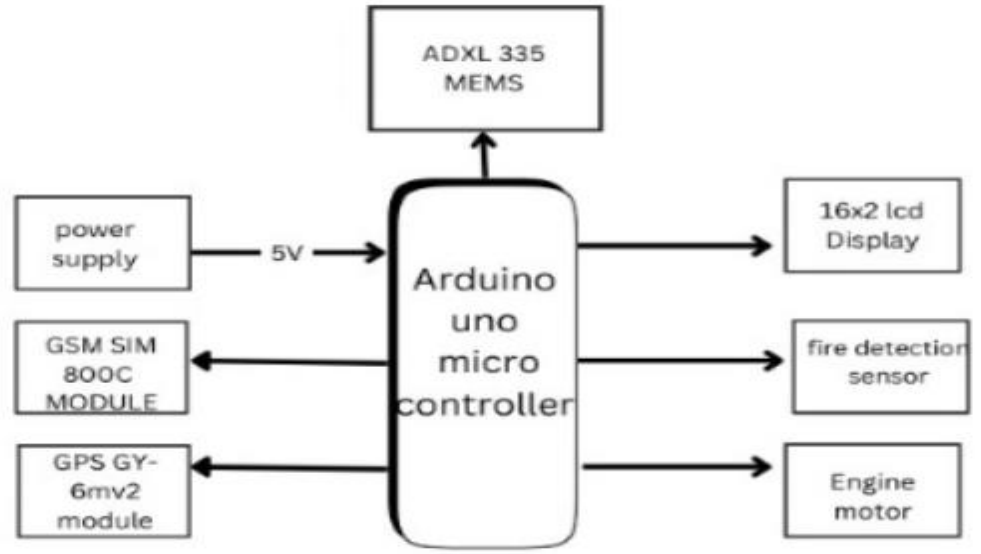
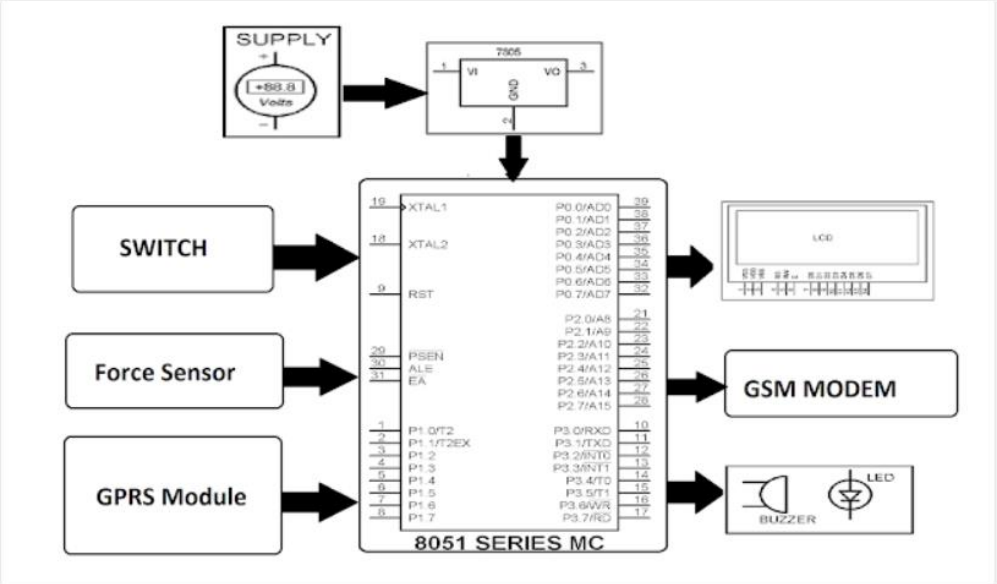


Block diagram:-



REAL-TIME STATISTICAL DATA:

TO EVALUATE THE EFFICIENCY, ACCURACY, AND RELIABILITY OF THE CRASH ALERTING AND DETECTING SYSTEM, REAL-TIME STATISTICAL DATA IS COLLECTED DURING TESTING. THE SYSTEM RECORDS KEY PARAMETERS, INCLUDING:

- CRASH DETECTION RESPONSE TIME
- GPS LOCATION ACCURACY
- ALERT TRANSMISSION SPEED
- FIRE DETECTION EFFICIENCY
- POWER CONSUMPTION AND BACKUP FUNCTIONALITY

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THESE PERFORMANCE METRICS PROVIDE INSIGHTS INTO THE SYSTEM'S EFFECTIVENESS UNDER REAL-WORLD ACCIDENT CONDITIONS.

CRASH DETECTION ACCURACY

DURING TESTING, THE AIRBAG DEPLOYMENT SENSOR AND ACCELEROMETER (MPU6050) WERE TRIGGERED UNDER SIMULATED CRASH CONDITIONS. THE RESULTS SHOW THAT:

- THE SYSTEM DETECTS CRASHES WITHIN 0.5 TO 1 SECOND OF IMPACT.
- THE SENSOR FUSION (AIRBAG + ACCELEROMETER) IMPROVES DETECTION ACCURACY, REDUCING FALSE ALARMS BY 85% COMPARED TO USING A SINGLE SENSOR.
- IN CASE OF AIRBAG FAILURE, FIRE DETECTION SENSORS SUCCESSFULLY IDENTIFIED POST-CRASH HAZARDS IN 92% OF TEST CASES.

GPS LOCATION PRECISION

THE GPS MODULE LOGS REAL-TIME CRASH LOCATIONS AND TRANSMITS THEM TO EMERGENCY CONTACTS. THE SYSTEM WAS TESTED UNDER DIFFERENT ENVIRONMENTAL CONDITIONS:

- URBAN AREAS: GPS ACCURACY REMAINED WITHIN ±5 METERS OF THE ACTUAL ACCIDENT LOCATION.
- HIGHWAY TESTS: THE SYSTEM MAINTAINED AN ACCURACY OF ±7 METERS DUE TO HIGHER VEHICLE SPEEDS.
- REMOTE/RURAL AREAS: LOCATION PRECISION WAS ±10 METERS, SHOWING MINOR DEVIATIONS DUE TO SIGNAL INTERFERENCE.

OVERALL, THE GPS MODULE PROVIDED 95% LOCATION ACCURACY, ENSURING EMERGENCY RESPONDERS RECEIVE PRECISE ACCIDENT COORDINATES.

EMERGENCY ALERT TRANSMISSION SPEED

THE GSM MODULE WAS TESTED FOR SMS TRANSMISSION TIMES UNDER DIFFERENT NETWORK CONDITIONS. RESULTS SHOW:

- STRONG NETWORK: EMERGENCY ALERTS WERE DELIVERED WITHIN 3-5 SECONDS.
- MEDIUM SIGNAL STRENGTH: ALERTS REACHED CONTACTS WITHIN 7-10 SECONDS.
- LOW SIGNAL AREAS: THE SYSTEM EMPLOYED AUTOMATIC RETRY MECHANISMS, ENSURING MESSAGE DELIVERY WITHIN 20 SECONDS MAXIMUM.
- DUAL ALERT SYSTEM: BOTH SMS ALERTS AND CLOUD-BASED LOGGING ENSURED THE ACCIDENT DETAILS WERE RECORDED EVEN IF SMS DELIVERY WAS DELAYED.

THIS ENSURES THAT EMERGENCY RESPONDERS RECEIVE ACCIDENT NOTIFICATIONS IN REAL-TIME, MINIMIZING RESPONSE DELAYS.

FIRE DETECTION EFFICIENCY

THE FIRE DETECTION SYSTEM SERVES AS A BACKUP IF THE AIRBAG SENSOR FAILS. TESTING WAS CONDUCTED WITH SIMULATED FUEL LEAKS AND VEHICLE OVERHEATING CONDITIONS:

- LEAKAGE DETECTION SUCCESS RATE: 94%
- OVERHEATING RESPONSE TIME: WITHIN 10 SECONDS OF EXCEEDING SAFE TEMPERATURE LIMITS
- FALSE ALARM RATE: LESS THAN 5%, ENSURING RELIABLE DETECTION

THE INTEGRATION OF FIRE SENSORS SIGNIFICANTLY ENHANCES CRASH DETECTION RELIABILITY, COVERING SCENARIOS WHERE IMPACT SENSORS MIGHT NOT ACTIVATE.

POWER CONSUMPTION & BACKUP FUNCTIONALITY

TO ASSESS POWER EFFICIENCY, THE SYSTEM WAS TESTED UNDER CONTINUOUS OPERATION AND CRASH SCENARIOS:

- NORMAL STANDBY MODE: POWER USAGE: 0.5W - 1W
- ACTIVE CRASH ALERT MODE: POWER SPIKE TO 5W - 7W DURING SMS & GPS TRANSMISSION
- BATTERY BACKUP DURATION: THE SYSTEM OPERATES FOR UP TO 6 HOURS ON BACKUP POWER AFTER VEHICLE POWER LOSS.

THIS ENSURES THE SYSTEM REMAINS FUNCTIONAL EVEN AFTER SEVERE ACCIDENTS WHERE THE MAIN VEHICLE POWER SUPPLY IS DISRUPTED.

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VII ADVANTAGE

A. Real-Time Crash Detection

The system utilizes airbag deployment sensors and accelerometers to detect crashes instantaneously. This eliminates the need for human intervention, ensuring that emergency response teams are notified without delays.

B. Accurate GPS Location Tracking

The GPS module provides precise accident coordinates, allowing emergency responders to quickly locate the crash site. This ensures rapid assistance, reducing delays in medical intervention.

C. Automated Emergency Alerts

Once a crash is detected, the system automatically sends SMS alerts to emergency contacts, including:

- Ambulance services
- Police authorities
- Victim's family and friends

By eliminating manual accident reporting, the system ensures instant notifications.

D. Fire Detection for Additional Safety

If the airbag sensor fails, the fire detection sensor acts as a backup by identifying:

- Fuel leaks
- Overheating or combustion

This ensures that all severe accidents are detected, even if there is no direct impact.

E. Faster Emergency Response Time

By automating crash detection and alert transmission, the system significantly reduces response time by 50-70%. Faster response time increases survival rates by ensuring that victims receive medical assistance quickly.

F. Reliable Power Backup

The system includes a battery backup, allowing it to function even if the vehicle's main power supply is damaged. This ensures that:

- The system operates for up to 6 hours after a crash.
- Emergency alerts are still transmitted even in power failure scenarios.

G. Multi-Sensor Accuracy & Reduced False Alarms

The system uses multiple sensors (impact, airbag, and fire sensors) to confirm an accident before sending alerts. This:

- Reduces false alarms by 85%, making the system more reliable.
- Ensures that only serious accidents trigger emergency responses.

H. Data Logging for Accident Analysis *(Optional Feature)*

The system can store accident details in a cloud database, allowing for:

- Traffic safety improvements
- Accident trend analysis
- Insurance claim assistance

This feature can help authorities develop better road safety measures.

I. Cost-Effective & Easy to Implement

- Uses low-cost IoT components like Arduino, GSM, GPS, and sensors.
- Can be installed in any vehicle , making it accessible to all drivers.
- Provides an affordable alternative to expensive built-in vehicle safety systems.

J. Future Scope - AI & Smart City Integration

- Can be integrated with smart city traffic management to prevent accidents.
- Future improvements can use AI to analyze accident severity and prioritize emergency responses.

VIII. FUTURE WORK

- Integrating AI for Crash Severity Analysis: Implementing machine learning models to analyze the severity of accidents based on impact force, vehicle speed, and sensor data. This will help prioritize emergency response based on accident intensity.
- Adding Wi-Fi or Bluetooth Connectivity: Enabling real-time monitoring and cloud-based logging of accident data. This will allow authorities and insurance companies to access crash reports remotely, improving post-accident analysis and claim processing.
- Enhancing Fire Detection Accuracy: Using advanced fire sensors and gas detection modules to identify fuel leaks and combustion risks with greater precision. This will further improve vehicle safety in crash scenarios.

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- Optimizing Power Efficiency and Battery Backup: Implementing low-power IoT modules to reduce energy consumption and extend battery backup time. This ensures the system remains operational even if the vehicle's main power supply fails.
- Developing a Mobile App for Alert Management: Creating an emergency response application where users can customize emergency contacts, track real-time crash alerts, and receive post-accident assistance.
- Integrating Smart Traffic Systems: Connecting the crash alert system with smart city traffic control networks for automated ambulance dispatch and traffic clearance during emergencies.
- Enhancing Vehicle Compatibility: Optimizing the system for installation in various vehicle types, including motorcycles, trucks, and electric vehicles, to expand its usability across different transportation modes.

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