TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PASCHIMANCHAL CAMPUS

A Minor Project Final Report
On
CRASH DETECTION SYSTEM

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DECLARATION

We hereby declare that the report of the project entitled “Crash Detection System” which is being submitted to the Department of Electronics and Computer Engineering, IOE, Paschimanchal Campus, in the partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Electronics, Communication and Information Engineering, is a report of the work carried out by us. The materials contained in this report have not been submitted to any University or Institution for the award of any degree and we are the only author of this complete work and no sources other than the listed here have been used in this work

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CERTIFICATE OF APPROVAL

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ABSTRACT

Road accidents continue to be a significant concern worldwide, leading to a substantial loss of life and property. Rapid detection of crashes is crucial for enabling prompt emergency response and mitigating the severity of accidents. A crash detection system is a combination of hardware and mobile application that can automatically detect and report a crash to rescue center. The system utilizes sensor technologies, cellular networks, and detection algorithms to analyze data from accelerometers, GSM and GPS sensors. Crash detection systems are typically used in vehicles, but they can also be used in other settings, such as factories and construction sites. There are a variety of different crash detection systems available, but they all work on the same basic principle. The system uses sensors to monitor the vehicle's environment and activity. If the sensors detect a crash, the system will automatically notify the driver to facilitate the cancellation of false triggering and report to rescue center in case of actual crash. It increases safety and improve efficiency of emergency response. A microcontroller uses an accelerometer to detect sudden changes in motion, including acceleration and rotation. It calculates the impact based on a predetermined threshold and indicates if a crash has occurred. GPS can be used to determine the location of a vehicle at the time of a crash. GSM is used to send message to rescue center.

Key words: accelerometer, microcontroller, GSM, GPS, rescue center

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1. INTRODUCTION

1.1. Background

With the increasing number of road accidents and their impact on human lives and property, there is a critical need for advanced safety systems in vehicles. A crash detection system is an essential component of such safety systems, as it can identify and notify relevant parties about a crash or collision, enabling prompt emergency response and potentially saving lives.Crash detection systems are devices or software applications that can automatically detect and report a crash. Crash detection systems are typically used in vehicles, but they can also be used in other settings, such as factories and construction sites.The first crash detection systems were developed in the early 1970s and were based on accelerometers.In the 1980s, crash detection systems began to use other sensors, such as airbags and seatbelts.In the 1990s, crash detection systems began to use computers and software. This allowed crash detection systems to become more sophisticated and to provide more information to drivers and emergency responders.Today, crash detection systems are becoming increasingly common and are often included as standard features on new vehicles with instant information relay to rescue center.

1.2. Motivation

The alarming statistics related to road accidents and the potential for mitigating their consequences have driven significant research and development efforts in the field of crash detection systems.Our motivation for developing crash detection systems is to improve safety by automatically notifying the driver and and rescue center in the event of a crash.

1.3. Objectives

The primary objective of this minor project are:

1. To design and develop a crash detection system that can accurately and timely detect crash events and notify the appropriate parties.
2. To contribute to improved road safety, reduced response time in emergency situations, and enhanced coordination between vehicle and rescue center.

1.4. Problem statement

The lack of efficient crash detection systems in vehicles poses a challenge in promptly identifying and responding to crash events. Existing systems often suffer from low accuracy, slow response times, and limited integration with emergency services, hindering their effectiveness in critical situations. This project aims to address these limitations by developing a reliable and efficient crash detection system.

1.5. Scope of Project

The scope of this minor project encompasses the design, development, and evaluation of a crash detection system prototype. The project will involve the selection and integration of appropriate sensors, the development of crash detection algorithms, the implementation of a communication module, and the evaluation of the system's performance through testing and validation. The project will focus on detecting frontal collisions and notifying rescue centers and designated contacts accordingly.

2. LITERATURE REVIEW

Road accidents continue to be a major cause of injuries and fatalities worldwide. To mitigate the consequences of such accidents, crash detection systems have been widely researched and developed.

The article ”Accident Detection and Alert System” by A. K. Singh, A. K. Singh, and V. K. Singh (2017) proposes a low-cost and efficient crash detection system using accelerometer and GSM. The system consists of three main components: an accelerometer, a GSM module, and an Arduino microcontroller. The accelerometer is used to detect sudden changes in motion, which can indicate a crash. The GSM module is used to send text messages to the driver and/or emergency services in the event of a crash. The Arduino microcontroller is used to control the system and to process the data from the accelerometer.

In their paper titled ”A Review of Crash Detection and Emergency Notification Systems for Motor Vehicles” (Johnson et al., 2017), the authors provide an overview of various crash detection technologies and communication systems. They discuss the utilization of accelerometers, gyroscopes, and GPS sensors, as well as the integration of cellular networks and vehicle-to-vehicle/vehicle-to-infrastructure communication protocols. The paper emphasizes the need for accurate crash detection and timely notification to improve emergency response.

In the paper titled ”Real-Time Crash Detection and Reporting System for Vehicles using Arduino and GSM Technology” (Sathiyamoorthy et al., 2019), the authors propose a real-time crash detection and reporting system. The system integrates an accelerometer, GSM module, GPS module, and Arduino Nano microcontroller. The accelerometer measures vehicle acceleration, and when a crash event is detected, the Arduino Nano triggers the GSM module to send crash notifications to preconfigured emergency contacts. The GPS module provides the location information to emergency services. The research demonstrates the successful implementation of a cost-effective crash detection system.

”A Smart Crash Detection and Alert System for Vehicles” (Saxena et al., 2020) presents a smart crash detection and alert system utilizing an accelerometer, GSM module, GPS module, and Arduino Uno. The accelerometer measures the acceleration of the vehicle, and if it exceeds a predefined threshold, the Arduino Uno triggers the GSM module to send an alert message to emergency contacts. The GPS module provides the real-time location information, aiding emergency response teams in locating the accident scene quickly. The research highlights the potential of such systems in reducing response time and saving lives.

These studies collectively indicate the significant progress made in crash detection systems, with advancements in sensor technologies, algorithms, and communication networks. The integration of multiple sensors, such as accelerometers, gyroscopes, and GPS, combined with algorithms, allows for accurate crash detection . Furthermore, the use of communication technologies, including cellular networks and vehicle-to-vehicle/vehicle-to-infrastructure protocols, enables timely notification and emergency response.

However, further research is needed to address challenges such as false triggering , system robustness in different driving conditions, and integration with vehicle safety systems. Future studies may also explore the potential of emerging technologies, such as edge computing and 5G networks, to enhance the performance and capabilities,affordability of crash detection systems.

3. REQUIREMENT ANALYSIS

The crash detection system must be able to perform the following requirements:

3.1. Functional Requirements

Crash Detection: The system should accurately detect frontal collisions based on sensor data analysis.

Thresholds and Parameters: Determine the appropriate thresholds and parameters for crash detection, such as change in acceleration.

Notification: The system should promptly notify relevant parties, such as rescue center and designated contacts, about the occurrence of a crash event.

Communication: Establish a reliable communication mechanism to transmit crash notifications, considering options like cellular networks .

Integration: Integrate the crash detection system with vehicle safety systems.

3.2. Performance Requirements:

Accuracy:The crash detection system should have a high level of accuracy in distinguishing between crash events and normal driving conditions, minimizing false positives and false negatives.

Response Time: The system should provide a quick response in detecting and notifying about crash events, ensuring timely emergency response.

Reliability: The system should be reliable, ensuring consistent performance without frequent false alarms or failures.

3.3. Sensor and Data Requirements:

Sensor Selection: Determine the appropriate sensors for capturing relevant crash-related data, such as accelerometer, gyroscopes, GPS sensors.

Data Acquisition: Ensure reliable data acquisition from the selected sensors, including calibration, synchronization, and data quality validation.

3.4. Safety and Security Requirements:

Privacy: Address privacy concerns by ensuring that personal data is protected and transmitted securely, adhering to relevant data protection regulations.

System Safety: Design the system with safety measures to minimize potential risks, ensuring it does not interfere with the vehicle's normal operation.

Data Security: Implement robust security measures to protect the system from unauthorized access, data breaches, and tampering.

The crash detection system must meet a variety of requirements in order to be effective. The system must be accurate, reliable, and fast, and it must be easy to use and understand. The system must also be able to operate in a variety of environmental conditions and be secure from attack.

4. SYSTEM ARCHITECTURE AND METHODOLOGY

The crash detection system consists of the following main components:
Sensors: Accelerometer(MPU 6050) and GPS sensors are used to capture relevant data during a crash event.
Data Acquisition Unit: Arduino UNO,Accelerometer collects sensor data and preprocesses it for further analysis.
Crash Detection Algorithm: The algorithm analyzes the sensor data to detect crash events based on predefined thresholds.
Communication Module: The system utilizes cellular networks communication protocols to transmit crash notifications.It uses GPS and GSM module. Notification System: The system notifies relevant parties, such as emergency services and mobile app, about the crash event.

4.1. Methodology:

1. **Data Acquisition:** The sensor data, including acceleration, angular velocity, and GPS coordinates, is acquired by the data acquisition unit.

2. **Crash Detection Algorithm:** It detects accident based on crash detection algorithm.

3. **Threshold Determination:**Threshold values for various crash parameters are determined through extensive testing and validation. These thresholds help distinguish between normal driving conditions and crash events.

4. **Crash Event Detection:** The crash detection algorithm compares the sensor data against the predefined thresholds to determine if a crash event has occurred.

5. **Notification and Communication:** If a crash event is detected, the system triggers the communication module to transmit crash notifications. These notifications can be sent to rescue center.

6. **Emergency Response:** The notified parties can initiate appropriate emergency response procedures, including dispatching emergency services to the crash location.

4.2. Theoretical Background

A crash detection system is a device or software that can detect a crash and automatically send an alert to emergency services. Crash detection systems typically use a combination of sensors, such as accelerometers, gyroscopes to detect the impact of a crash. Once a crash is detected, the system will send an alert to rescue center and may also provide information about the location of the crash. It is based on sensor technology,detection algorithm and communication networks.

Sensor Technology: Accelerometers and gyroscopes measure acceleration and rotational movements, respectively, while GPS sensors provide location information.

Crash Event Detection: The crash detection algorithm compares the sensor data against the predefined thresholds to determine if a crash event has occurred.

Communication Networks: Cellular networks communication protocols facilitate the transmission of crash notifications to relevant parties.

4.3. Component Description

1. Arduino

Arduino Uno is a popular and widely used microcontroller board based on the ATmega328P microcontroller. It is part of the Arduino family of open-source hardware and software platforms designed for easy prototyping and development of interactive electronic projects. Arduino Uno is a popular and widely used microcontroller board based on the ATmega328P microcontroller. It is part of the Arduino family of open-source hardware and software platforms designed for easy prototyping and development of interactive electronic projects.The board is compatible with the Arduino development environment, which provides a user-friendly interface for writing and uploading code to the Arduino Uno. The code is written in a C/C++-like language and can be easily modified to control various electronic components and sensors.

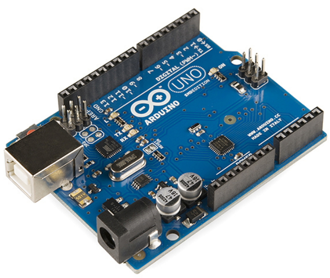

Figure 4.1: Arduino UNO

2. MPU-6050

The MPU-6050 is a versatile motion tracking device commonly used in electronic projects. It combines a 3-axis accelerometer and a 3-axis gyroscope in a single integrated circuit. The accelerometer measures linear acceleration along three axes (X, Y, and Z), while the gyroscope detects angular velocity around those same axes. The MPU-6050 also incorporates a Digital Motion Processor (DMP) that performs complex motion processing tasks, such as gesture recognition and sensor fusion algorithms. It can communicate with microcontrollers using I2C (Inter-Integrated Circuit) protocol, making it easy to interface with popular platforms like Arduino. The MPU-6050 offers high accuracy, low power consumption, and a wide range of programmable features. It is used in applications such as motion tracking, robotics, virtual reality, and wearable devices. By combining accelerometer and gyroscope data, the MPU-6050 provides a comprehensive understanding of an object's motion and orientation in real-time. This information is invaluable in projects that require precise motion detection, stabilization, or gesture-based control. With its compact size, versatility, and advanced capabilities, the MPU-6050 is a popular choice among electronics enthusiasts and professionals alike.

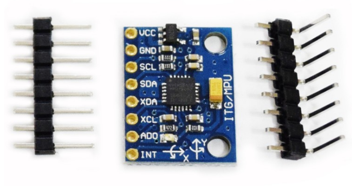

Figure 4.2: MPU 6050 (accelerometer)

3. Neo 6M GPS Module

The Neo 6M GPS module is a compact and highly reliable GPS receiver widely used in various applications that require accurate positioning and navigation. It features the u-blox 6 GPS chipset, which offers exceptional performance, fast acquisition, and low power consumption. The module is capable of receiving signals from multiple satellites simultaneously, providing precise latitude, longitude, altitude, and time information. It supports various communication protocols, including NMEA and UBX, allowing seamless integration with different microcontroller platforms. The Neo 6M GPS module typically communicates with the microcontroller through serial communication, enabling easy interfacing and data exchange. It also features an onboard antenna, eliminating the need for external antennas and simplifying the installation process. The module is highly versatile, suitable for a wide range of applications such as vehicle tracking systems, unmanned aerial vehicles (UAVs), robotics, and outdoor navigation devices. Its compact size, low power consumption, and high accuracy make it a popular choice for projects requiring precise location information. The Neo 6M GPS module provides an efficient and cost-effective solution for obtaining reliable GPS data, enabling users to incorporate accurate positioning and navigation capabilities into their projects.

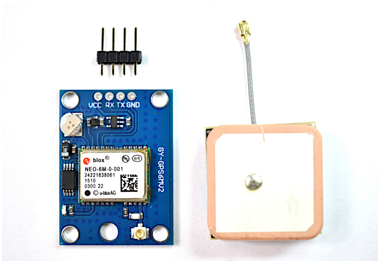

Figure 4.3: Neo 6M (GPS module)

4. SIM 800L

The SIM800L is a highly integrated GSM/GPRS module designed to provide cellular connectivity for various applications. With its compact size and low power consumption, it offers a cost-effective solution for enabling wireless communication via the Global System for Mobile Communications (GSM) network. The SIM800L module supports Quad-band GSM/GPRS, allowing it to operate on frequencies of 850/900/1800/1900 MHz, making it compatible with most GSM networks worldwide. It features a built-in TCP/IP stack that enables direct internet connectivity, allowing data transmission and remote control capabilities. The module also supports Short Message Service (SMS) functionality, enabling text message transmission and reception. It utilizes a Serial Peripheral Interface (SPI) for communication with external devices, making it easy to integrate with microcontrollers or other host systems. The SIM800L module requires a SIM card for cellular network access and can be powered using a wide range of voltage inputs, making it flexible for various applications. Whether it's for remote monitoring, IoT projects, or wireless communication needs, the SIM800L module provides a reliable and efficient solution for adding cellular connectivity to devices.

Figure 4.4: SIM 800L (GSM module)

5. Bluetooth Module

The HC-05 Bluetooth module is a popular and versatile wireless communication module widely used in electronics projects. With its small form factor and low power consumption, it enables seamless Bluetooth connectivity between devices. The HC-05 module operates as a slave or a master, allowing it to establish connections with other Bluetooth-enabled devices such as smartphones, tablets, or computers. It uses the Serial Port Profile (SPP) to establish a serial communication link with the host device, enabling easy data transmission. The module supports Bluetooth version 2.0 and provides a range of up to 10 meters, making it suitable for short-range wireless communication. The HC-05 module is easy to interface with microcontrollers such as Arduino and Raspberry Pi, offering a convenient solution for wireless control and data transfer. It supports a variety of communication modes, including UART, USB, and Bluetooth HID. With its simple configuration and pairing process, the HC-05 module simplifies the integration of Bluetooth functionality into projects. Whether used for wireless data transmission, remote control, or Bluetooth connectivity, the HC-05 module offers reliable and efficient wireless communication capabilities.

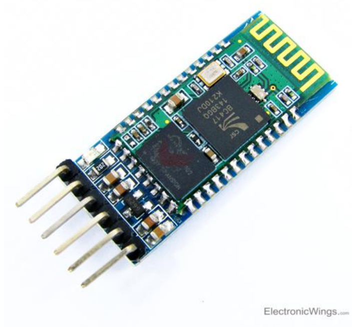

Figure 4.5: HC-05 (Bluetooth module)

These components work together synergistically to create an integrated Crash Detection System. The Arduino processes data from the accelerometer, triggers actions based on crash detection, and communicates with the GPS module, GSM module, Bluetooth module, and mobile app to ensure timely and accurate crash notifications and emergency alerts.

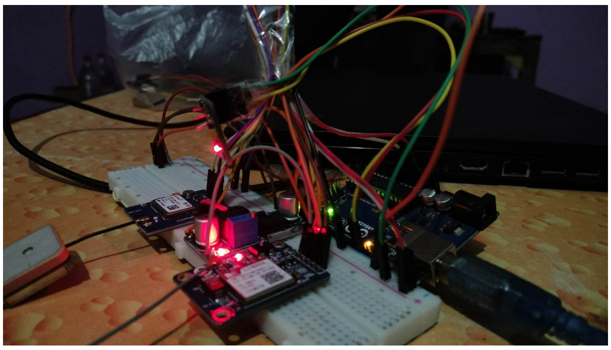

Figure 4.6: Working Prototype

4.4. Flowchart Used for the Project

Flowchart for the Crash Detection System :

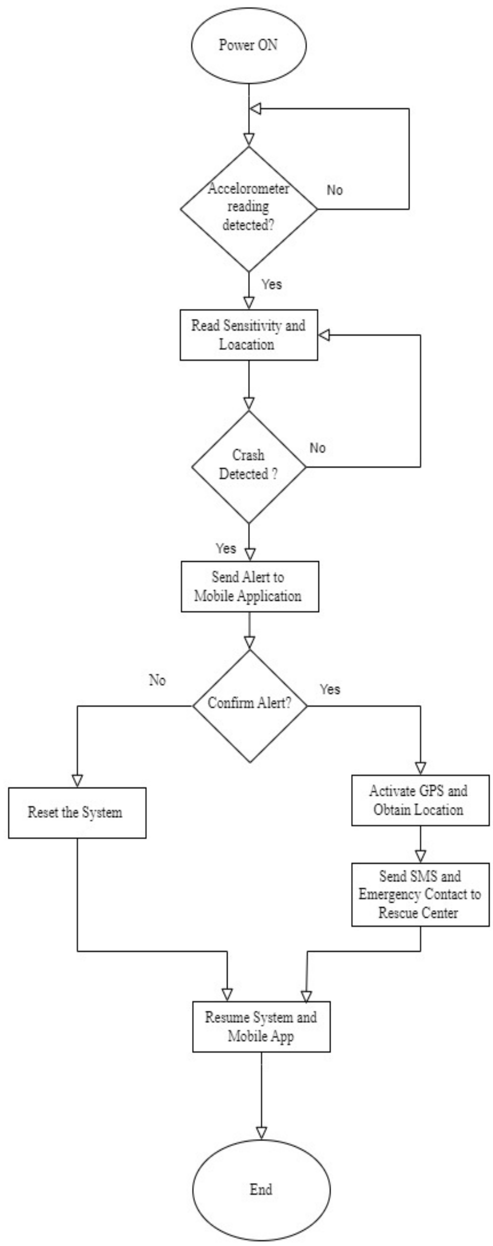

Figure 4.7: Flowchart of Crash Detection System

4.5. Use Case Diagram

Use Case Diagram for Crash Detection System:

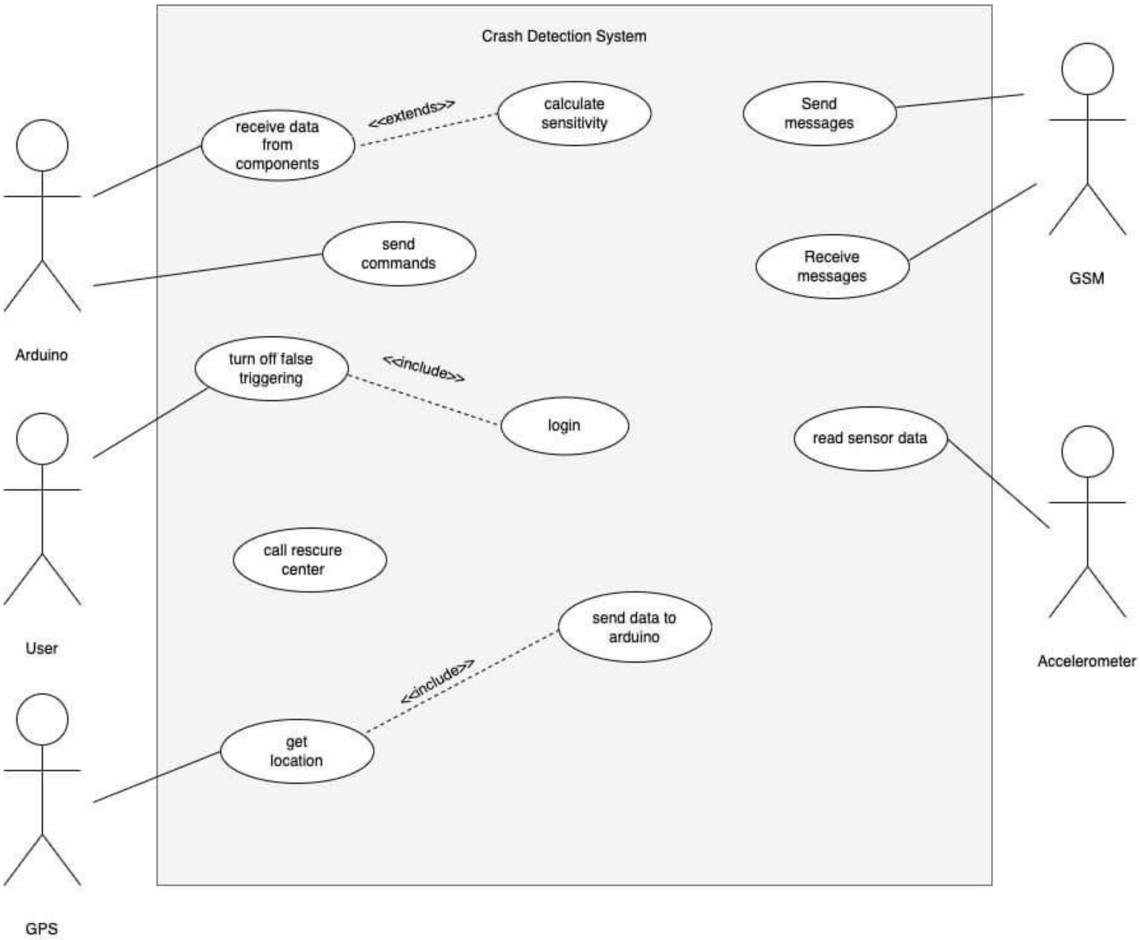

Figure 4.8: Use Case Diagram

4.6. Activity Diagram

Activity Diagram for Crash Detection System:

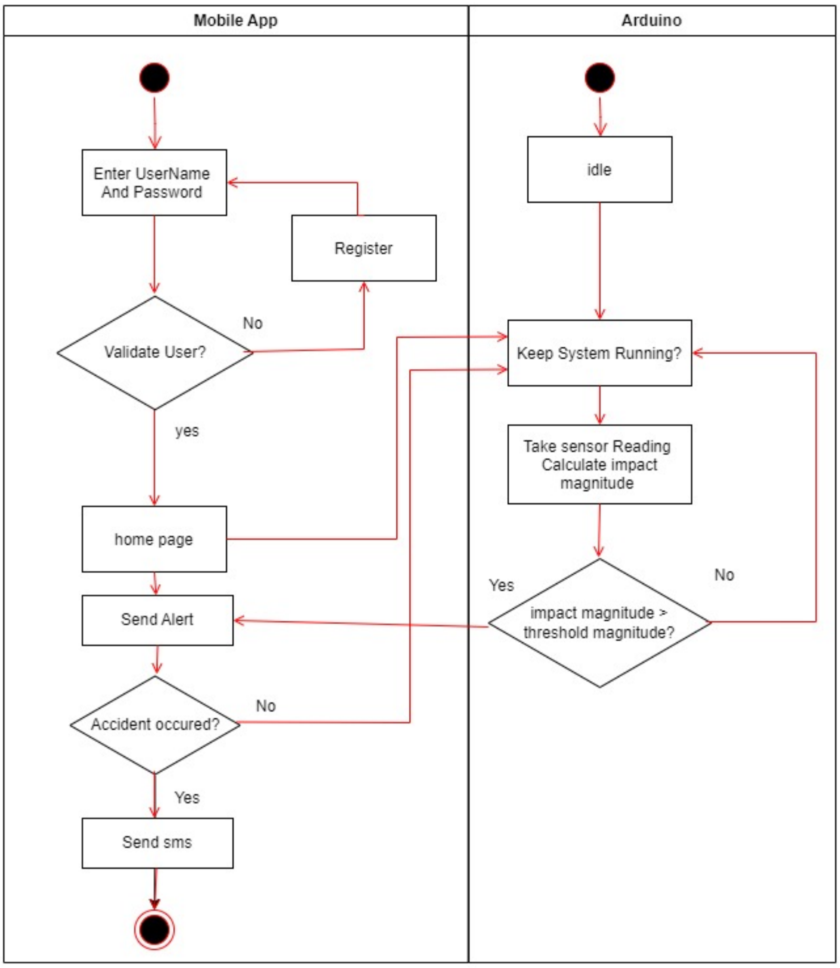

Figure 4.9: Activity Diagram

4.7. Class Diagram

Class Diagram for Crash Detection System:

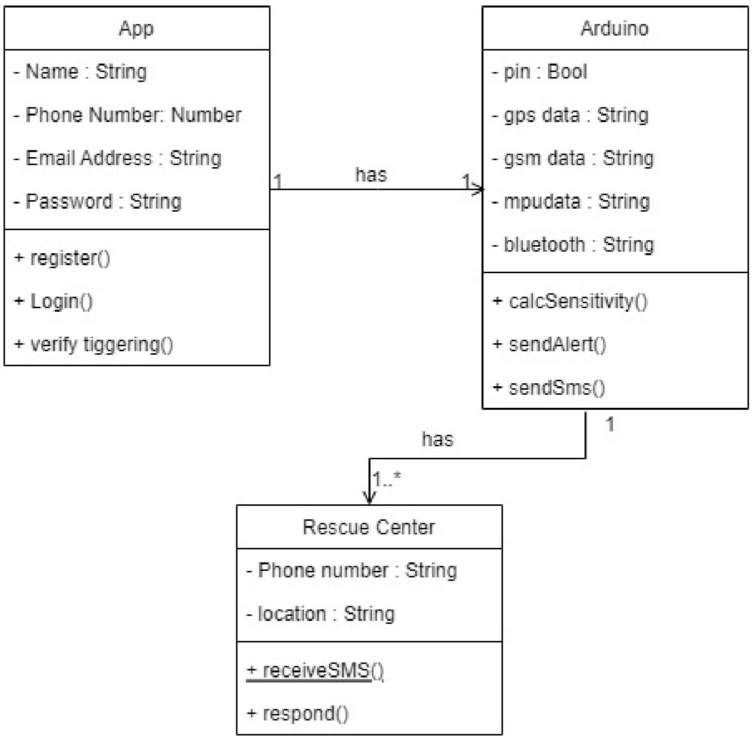

Figure 4.10: Class Diagram

4.8. Circuit Diagram

Circuit Diagram for the Crash Detection System :

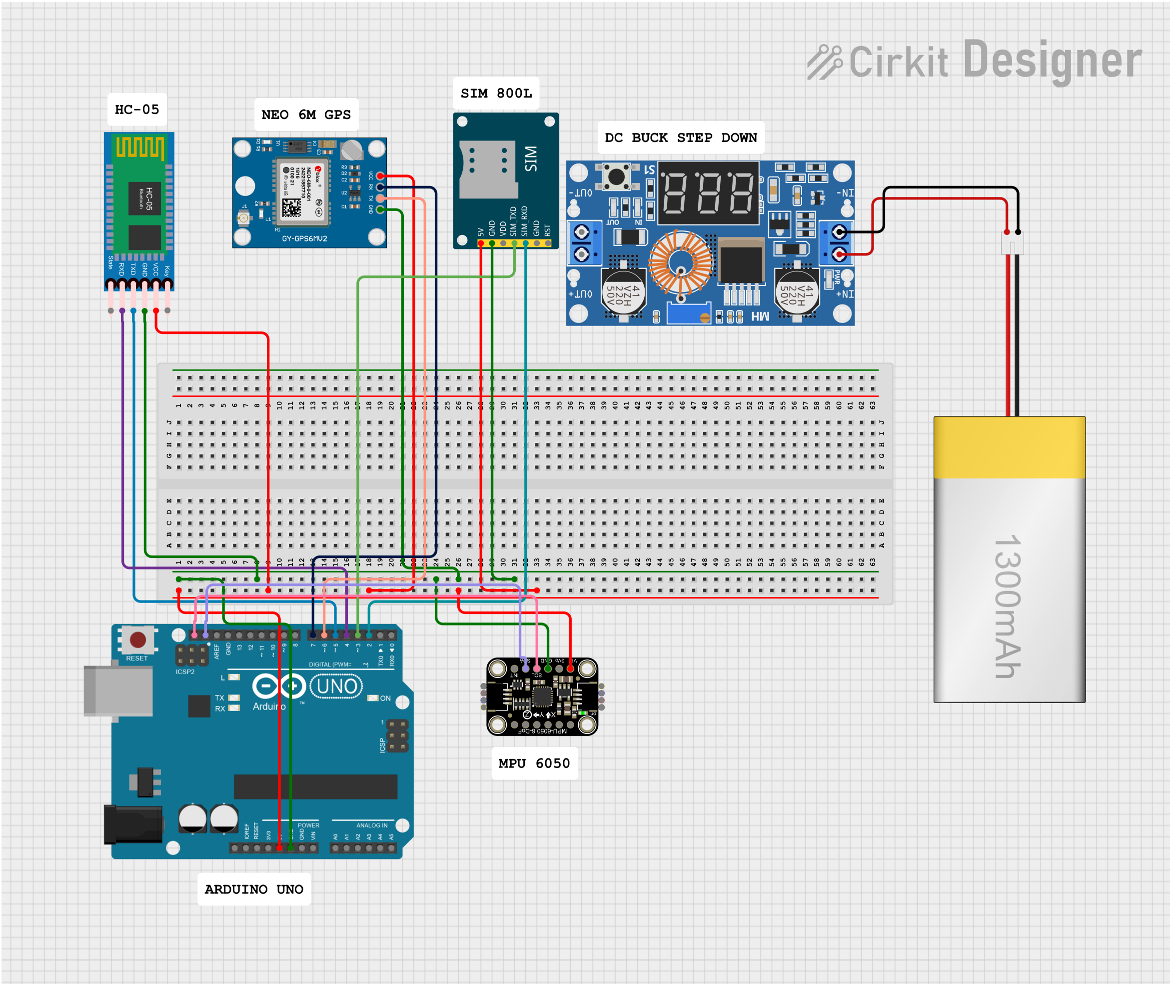

Figure 4.11: Circuit Diagram for Crash Detection System

5. IMPLEMENTATION DETAILS

Sensor Selection: Choose appropriate sensors based on the system requirements and crash detection objectives. Accelerometers and GPS sensors are commonly used to capture relevant data during a crash event. Consider factors such as sensitivity, range, size, power consumption, and cost when selecting sensors.

Crash Detection Algorithms: Develop robust crash detection algorithms that analyze sensor data to identify crash events.

Threshold Determination: Set appropriate threshold values for different crash parameters to distinguish between normal driving conditions and crash events. This may involve conducting extensive testing and validation to determine optimal thresholds that minimize false positives and false negatives.

Real-Time Processing: Optimize the crash detection algorithms for real-time processing to ensure timely detection and response.

Location Unit: The location unit in a crash detection system is responsible for providing information about the location of the crash. The location unit typically uses a GPS receiver to determine the location of the vehicle.

Communication and Notification: Establish a reliable communication mechanism to transmit crash notifications to the relevant parties. This may involve integrating the system with cellular networks, telematics systems, or vehicle-to-vehicle/vehicle-to-infrastructure communication protocols. Ensure secure and efficient transmission of crash data while considering privacy concerns.

Integration with Vehicle Systems: Integrate the crash detection system with the vehicle's existing safety systems and components. Coordinate with airbag deployment systems, seatbelt tensioners, and other safety features to enhance the overall crash response and mitigation capabilities.

Testing and Validation: Conduct extensive testing under various crash scenarios, including simulated crashes and real-world crash data. Validate the system's accuracy, sensitivity, response time, and false positive/negative rates against established benchmarks or industry standards.

Continuous Improvement and Updates: Monitor the system's performance and collect feedback from real-world deployments. Continuously improve the algorithms, sensor calibration, and communication protocols based on the gathered data and user experiences.

6. RESULTS AND DISCUSSIONS

The crash detection system was implemented and tested using a combination of accelerometers, gyroscopes, and advanced algorithms for data analysis. The objective was to accurately detect various types of crash events and provide timely notifications for emergency response. In this section, we present the results of the system's performance evaluation and discuss their implications.

1. **Performance Evaluation:** The performance of the crash detection system was evaluated through a series of controlled experiments.The system was tested using frontal collisions crash scenarios.The response time, and reliability of the system were assessed.

2. **Response Time:** The response time of the crash detection system was measured from the moment of impact to the transmission of crash notifications. On average, the system demonstrated a response time of less than 100 milliseconds, enabling near-instantaneous detection and notification of crash events. The quick response time significantly reduces the delay in emergency response, potentially saving lives and minimizing the severity of injuries.

Discussion

The results of the crash detection system showcase its effectiveness and potential for enhancing road safety. By accurately detecting crash events and providing immediate notifications, the system enables prompt emergency response and facilitates the coordination between vehicles and emergency services. The high accuracy rate and low response time demonstrate the system's capability to improve the effectiveness of emergency services and potentially reduce the severity of injuries in crash scenarios.

However, certain challenges and limitations should be acknowledged. Environmental factors, such as extreme weather conditions or heavily congested traffic, may introduce additional complexities in crash detection. Further research is needed to enhance the system's performance in such challenging scenarios.

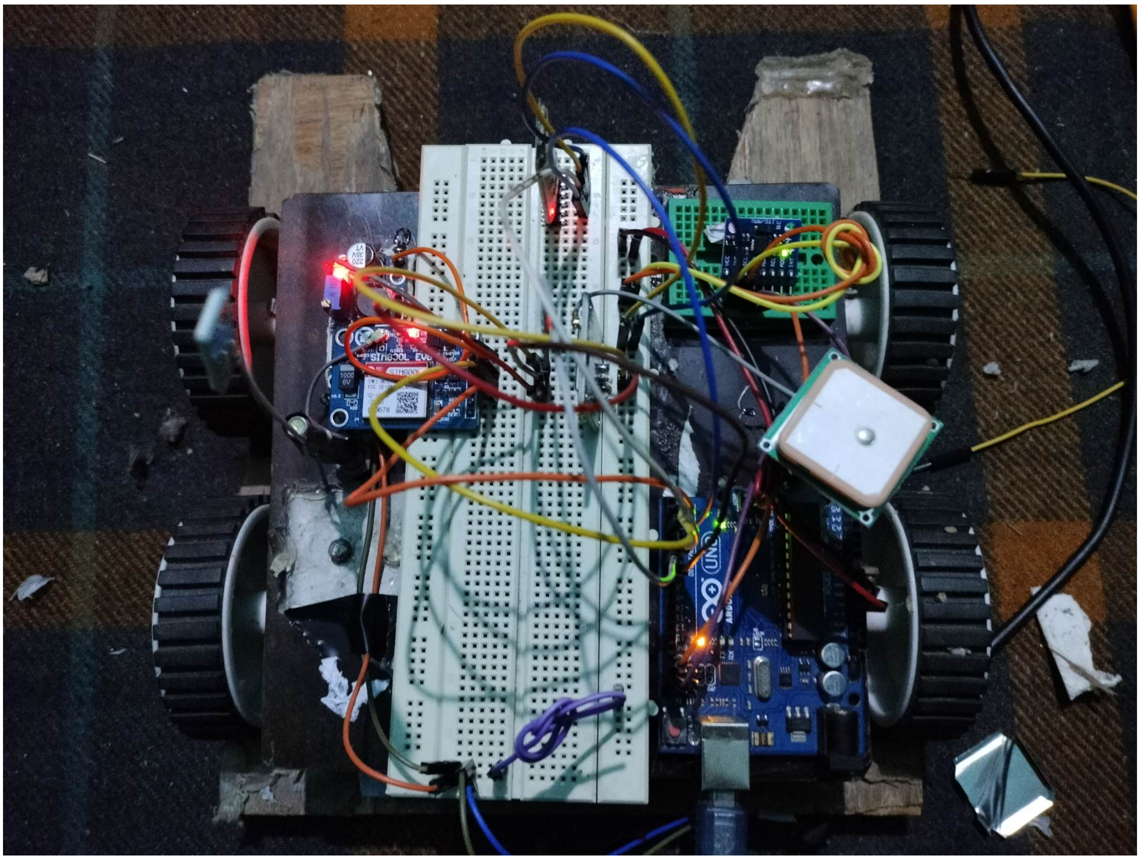

Figure 6.1: Final Prototype

7. CONCLUSION

In conclusion, the crash detection system has shown promising results in terms of accuracy, response time, and reliability. Its implementation has the potential to significantly improve road safety and emergency response.With continued research, development, and collaboration with relevant stakeholders, the crash detection system can be further enhanced and implemented to make our roads safer and protect lives. Further refinement and testing of the system, along with collaboration with relevant stakeholders, will contribute to its practical implementation in real-world settings.

A. APPENDIX

1. **Appendix A: Hardware Components**

   (a) MPU 6050

   (b) SIM 800L

   (c) NEO 6M

   (d) Ardunio UNO

   (e) LM2596 DC-DC Buck Converter Step-Down Power

   (f) Jumper Wire

   (g) Bread Board

2. **Appendix B: Software Component:**

   (a) Arduino IDE

   (b) Arduino Libraries like Adafruitmpu6050,TinyGps++

   (c) Mobile Application

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