VIETNAM NATIONAL UNIVERSITY

INTERNATIONAL SCHOOL

STUDENT RESEARCH REPORT

Assistive Device for Visually Impaired Individuals

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Hanoi, April 2025

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Academic year	Overall score	Academic rating
2022 - 2023	3.15	Average
2023 - 2024	3.55	Good

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....

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....

Hanoi, April 2025

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INTRODUCTION

Assistive Device for Visually Impaired Individuals

1. Project Code: CN.NC.SV.24_09

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4. Abstract:

This report presents the design and development of a low-cost, wearable assistive device for individuals with visual impairments. The device integrates a suite of sensors, including the HC-SR04 ultrasonic sensor, GY-521 accelerometer, GY-GPSV3-NEO7M GPS module, 5V Buzzer (12x9.07mm), and the SIM800A GSM GPRS Mini Module. It utilizes an Arduino UNO R3 CH340G micro-controller to provide real-time navigation, safety alerts, and emergency communication features. The device offers auditory feedback, fall detection, GPS tracking, and automated SOS messaging. Preliminary testing indicates positive usability and reliability, laying a foundation for scalable assistive technology solutions.

5. Keywords:

Assistive technology, Visual impairment, Navigation device, Fall detection, Sensor integration

SUMMARY REPORT IN STUDENT RESEARCH, 2024-2025 ACADEMIC YEAR

Vision impairment remains a pressing global health issue, with over 2.2 billion people affected, including approximately 43 million who are completely blind, according to the World Health Organization's 2019 report. In Vietnam, it is estimated that over 400,000 individuals are completely blind and around 1.3 million suffer from some form of visual impairment, including 16,400 children. These statistics reflect the critical need for inclusive solutions that can support the independence and safety of the visually impaired population.

In response to this growing need, assistive technologies for the visually impaired have evolved significantly in recent years. Conventional mobility aids, such as white canes and guide dogs, while valuable, have inherent limitations in detecting dynamic objects, navigating unfamiliar spaces, and operating effectively in all environmental conditions. The development of Visual Assistive Technologies has focused on enhancing mobility through five key technical features: object analysis (detecting static and dynamic objects), coverage area (indoor/outdoor adaptability), object type recognition, functional time (day/night usability), and detection range (typically 0.5 to 5 meters or more).

However, despite advances in technology, many current systems still fall short of providing a comprehensive mobility and safety solution. High costs, narrow functionality, and poor integration of features like fall detection or emergency communication limit their widespread adoption, particularly in low-resource settings. Furthermore, many devices are not designed with intuitive usability in mind, making them less accessible to users who may have limited technological experience.

To overcome these limitations, this study introduces a robust, multi-functional assistive device designed to enhance the autonomy and safety of visually impaired individuals. By integrating widely available, low-cost yet effective components such as the HC-SR04 ultrasonic sensor for real-time obstacle detection, the GY-521 accelerometer for fall detection, the GY-GPSV3-NEO7M GPS module for continuous location tracking, and the SIM800A GSM module for emergency communication, this device addresses critical gaps in existing solutions. At the core of the system is the Arduino UNO R3 CH340G micro-controller, which facilitates real-time data processing and coordination between modules. The device also includes a Còi Chíp 5V buzzer to provide intuitive auditory feedback to the user.

Designed for both indoor and outdoor use, and suitable for operation in variable lighting and environmental conditions, the proposed device embodies an inclusive and scalable solution for assistive navigation. It emphasizes cost-effectiveness, reliability, and user-centered design, making it a practical tool for improving the lives of visually impaired individuals around the world.

1. METHODOLOGY

1.1. Design Objectives

The project is centered around the development of a smart wearable safety system tailored for vulnerable individuals such as the elderly, visually impaired, or patients recovering from injuries. The design is guided by five key objectives:

- **Affordability:**
  - **Goal**: To ensure that the device is accessible to people from various economic backgrounds.
  - **Approach:**
    + Utilizing low-cost sensors such as HC-SR04 and GY-521

+ Building the system on open-source hardware platforms like Arduino, which significantly reduces development and prototyping costs.
+ Avoiding proprietary technologies or expensive alternatives.

- **Impact**: The low-cost nature makes it feasible for mass adoption, particularly in developing communities or public health initiatives.

- **Ease of Use:**
  - **Goal:** Minimize the learning curve so that the system can be used by non-technical users, especially elderly individuals.
  - **Approach:**
    + Simple plug-and-play design with minimal buttons or controls.
    + Clear auditory alerts and automated SMS notifications reduce the need for user input.
    + Intuitive design so that no prior training is required for operation.
  - **Impact:** The system becomes inclusive, allowing users with little or no technical knowledge to benefit from it independently.

- **Compact and wearable form factor.**
  - Goal: Ensure the system can be worn comfortably on the body without restricting movement or daily activities.
  - Approach:
    + Carefully selecting lightweight components.
    + Designing a modular system that can be attached to a belt, armband , crossbody bag , or necklace.
    + Using a rechargeable battery to remove the need for constant connection to external power.
  - Impact: Promotes continuous usage by being non-intrusive and user-friendly in both indoor and outdoor environments.

- **Enhanced safety through fall detection and emergency alerts.**

- **Goal:** Automatically detect emergencies (especially falls) and notify caregivers or relatives immediately.
- **Approach:**
  + Real-time monitoring using a 3-axis accelerometer and gyroscope to detect unusual motion patterns.
  + Automatic triggering of SMS alerts and phone calls via the SIM800A GSM module upon detecting a fall or impact.
  + Additional obstacle detection using an ultrasonic sensor to prevent collisions in unfamiliar environments.
- **Impact:** Reduces the response time in emergencies and saves lives by ensuring help arrives promptly.

● **Promoting independence via real-time guidance.**

- **Goal:** Empower users to move freely and independently while being monitored for safety.
- **Approach:**
  + GPS integration provides real-time location data that can be shared with family or caregivers.
  + Ultrasonic sensors help detect nearby objects, acting as a navigation aid for visually impaired users.
  + Enables remote assistance through location sharing upon receiving a text message command.
- **Impact:** Builds confidence and autonomy, allowing users to live independently while maintaining a safety net.

1.2. System Architecture

1.2.1. Hardware

● Microcontroller: Arduino UNO R3 CH340G

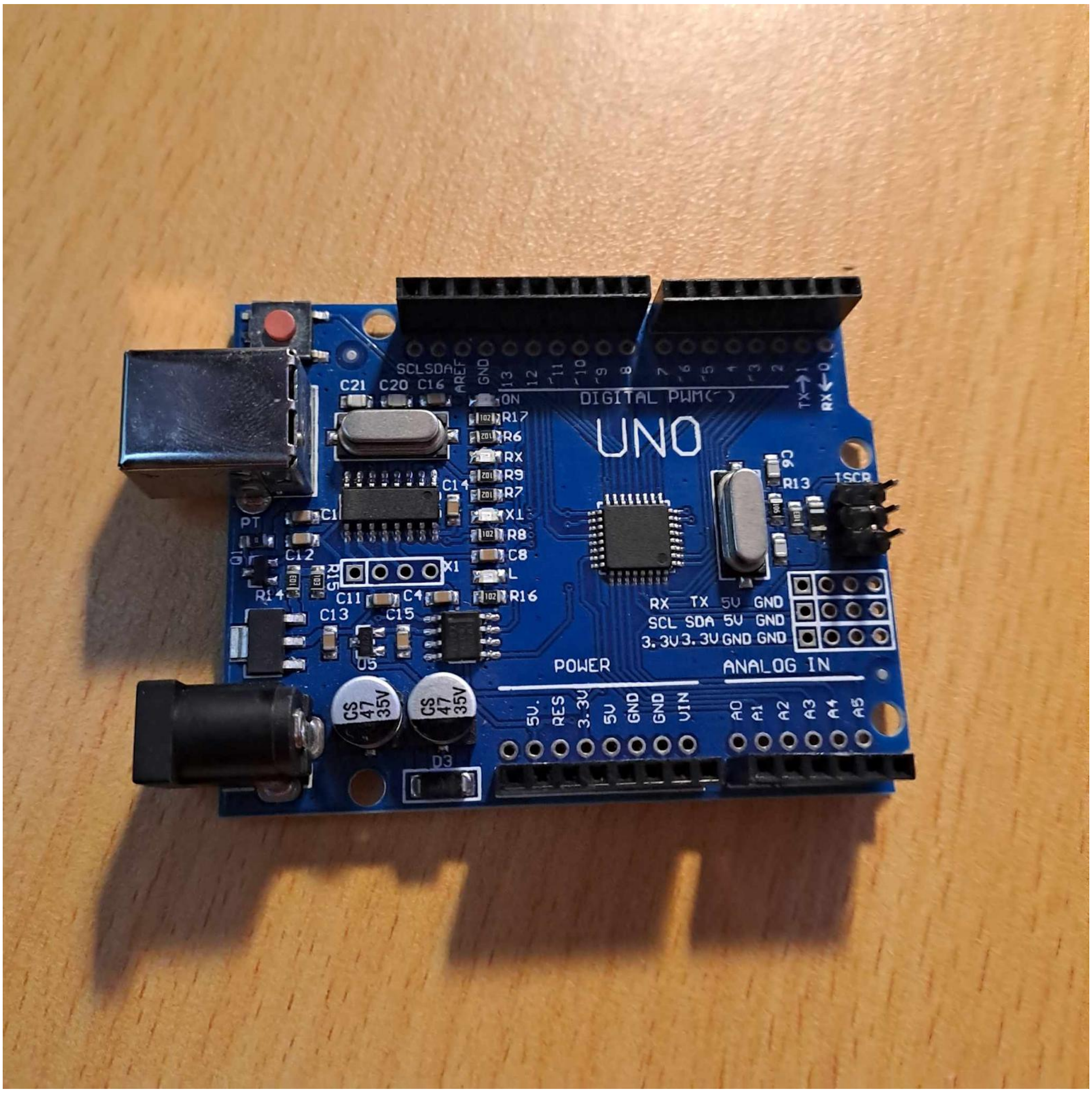

Figure 1. Arduino UNO

- **Function:** Serves as the central control unit, processing input from all sensors and triggering appropriate responses.
- **Why Chosen:**
  + Cost-effective and beginner-friendly.
  + Widely supported with extensive documentation and libraries.
  + Sufficient number of digital and analog I/O pins to connect multiple modules simultaneously.
- **Interfaces:**

+ Communicates via I2C with the accelerometer.
+ Uses UART for GSM and GPS modules.
+ Digital I/O for ultrasonic sensor and buzzer control.

- **Obstacle Detection: HC-SR04 Ultrasonic Sensors**

Figure 2. HC-SR04 – Ultrasonic Sensor

- **Function:** Detects obstacles in front of the user by measuring distance through ultrasonic waves.
- **Why Chosen:**

+ Inexpensive and highly accurate for short-range detection (2 cm to 400 cm).
+ Easy to interface with Arduino using digital pins.

- **Application:** Helps visually impaired or elderly users avoid collisions by triggering a buzzer alert when objects are nearby.

- **Fall Detection: GY-521 Accelerometer**

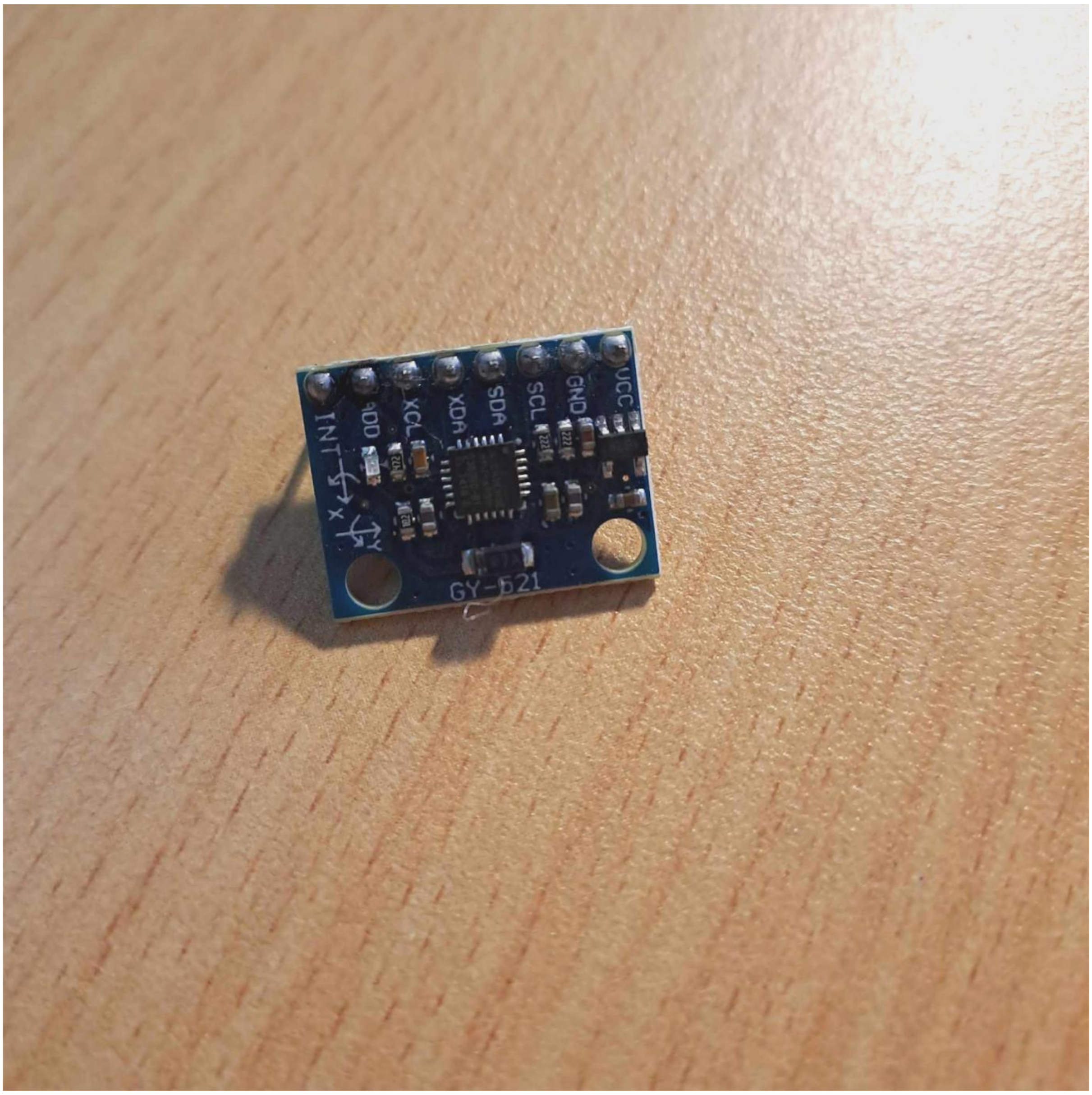

Figure 3. MPU6050 (GY-521) – Accelerometer & Gyroscope Sensor

- **Function:** Monitors real-time motion and orientation to detect sudden falls or unusual movements.

- **Why Chosen:**
  + Combines both accelerometer and gyroscope for accurate motion sensing.
  + Communicates with Arduino via I2C, ensuring fast and reliable data transmission.
- **Application:** When a fall is detected based on acceleration threshold and tilt angles, the system triggers emergency alert

- **Location Tracking: GY-GPSV3-NEO7M GPS Module**

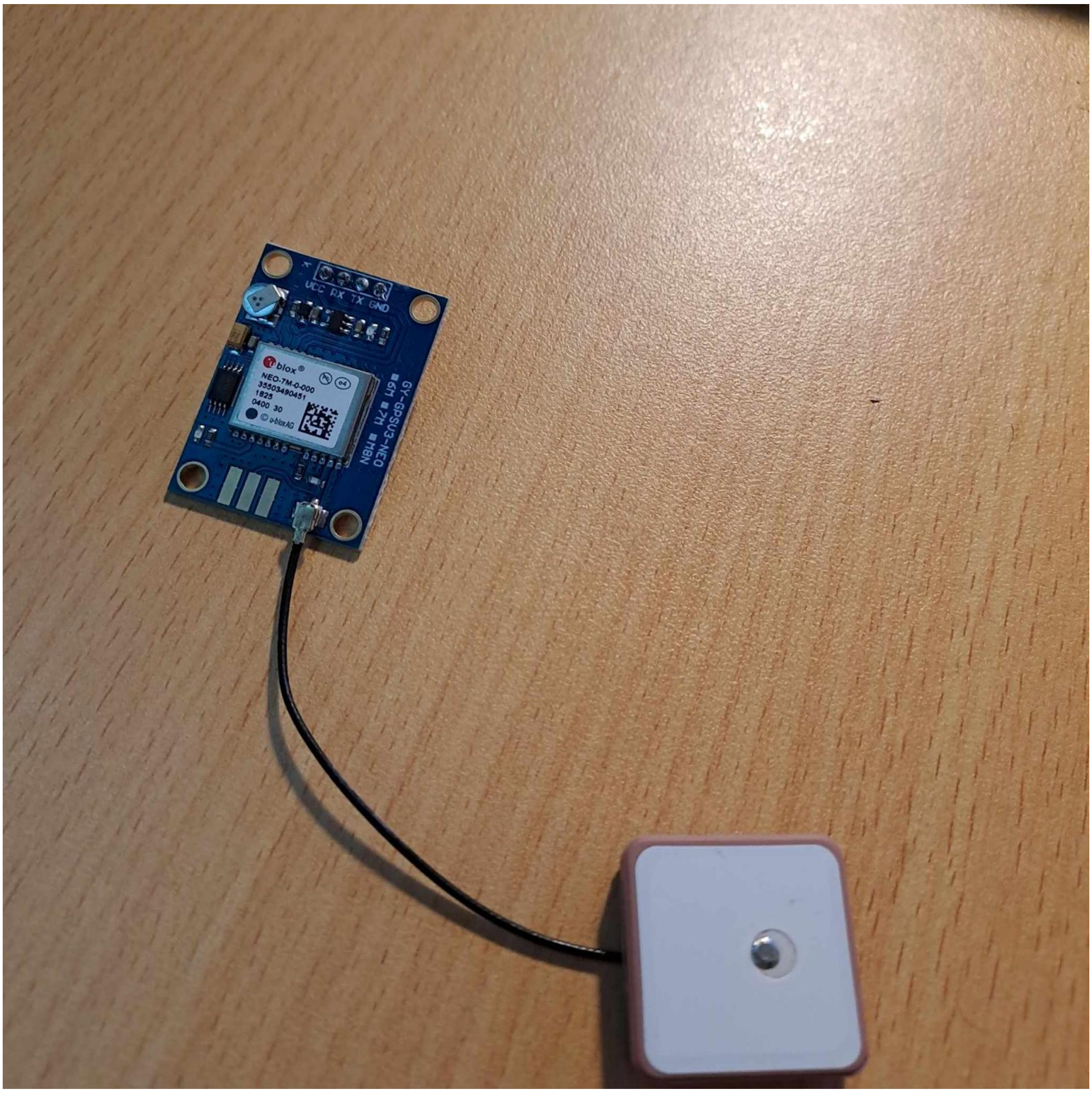

Figure 4. GPS Module (GY-GPSV3-NEO7M)

- **Function:** Provides real-time geographic location (latitude and longitude) for tracking and alert messages.
- **Why Chosen:**
  + High sensitivity and fast satellite fix times.
  + Compact and power-efficient, suitable for wearable devices.
  + Communicates via UART serial communication.
- **Application:** Sends the user's location via SMS when a fall is detected or when requested through a text message.

● **Emergency Communication: SIM800A GSM/GPRS Mini Module**

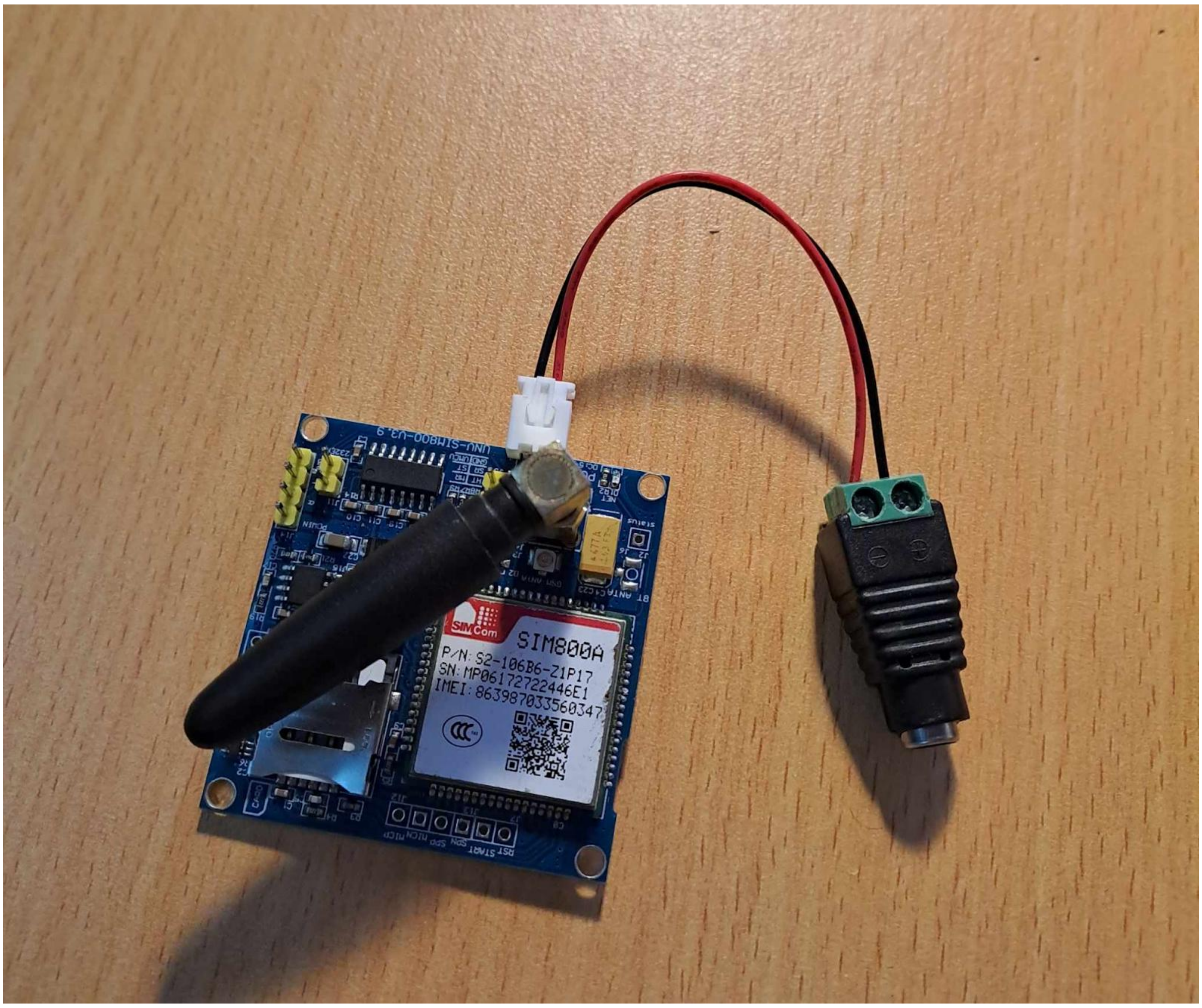

Figure 5. GSM Module (SIM800A)

- **Function:** Sends SMS alerts and makes phone calls in case of emergencies.

- **Why Chosen:**
  + Low-cost GSM module that supports SMS, call, and GPRS data.
  + Easily programmable using AT commands through UART interface.
- **Application:** Sends a text message with location details or makes a voice call to a predefined contact when danger is detected.

● **Auditory Output: 5V Buzzer (12x9.07mm)**

Figure 6. Buzzer (5V)

- **Function:** Provides immediate local audio alerts to warn the user or people nearby.

- **Why Chosen:**
  + Small, lightweight, and loud enough for indoor environments.
  + Simple to drive using digital output pins on the Arduino.
- **Application:** Activated when an obstacle is detected nearby or when a fall occurs.

● **Power Supply: Rechargeable Li-ion Battery with Power Management Circuit**

- **Function:** Supplies portable power to the entire system, allowing wearable use without dependence on a fixed power source.
- **Why Chosen**:
  + Rechargeable and energy-dense, providing several hours of operation.
  + A battery management system (BMS) is used to ensure safe charging and discharge.
- **Application:** Powers all modules, including Arduino, sensors, GPS, and GSM module, ensuring uninterrupted monitoring.

1.2.2. Software

The system software, developed using Arduino IDE, serves as the operational backbone of the assistive device. The program integrates multiple libraries including Adafruit_MPU6050 for accelerometer control, TinyGPS++ for GPS data parsing, and SoftwareSerial for serial communication with the GSM module. The Arduino UNO R3 microcontroller coordinates input from various hardware components and executes real-time logic based on sensor feedback.

Upon initialization, the program configures the MPU6050 accelerometer-gyroscope sensor to operate at an 8G range and 500-degree-per-second gyroscopic sensitivity, with a 21 Hz filter bandwidth. Simultaneously, it sets up the ultrasonic sensor by defining trigger and echo pins, and activates the 5V buzzer used for user alerts. The GPS and GSM modules are initialized over software-defined serial ports, with AT commands sent to configure baud rate, SMS mode, caller ID, and new message notifications.

During runtime, the program continuously polls three key subsystems: the MPU6050 for motion data, the HC-SR04 for obstacle distance, and the GPS module for current location. Falls are detected based on sudden drops in acceleration combined with abrupt angular shifts. If a fall is confirmed, and the user remains inactive, the system automatically triggers an emergency protocol. This includes sounding an audible buzzer and sending a location-encoded SMS via the SIM800A GSM module to a preconfigured contact number. Additionally, the program includes functionality to respond to incoming SMS requests for location, further enabling remote monitoring and caregiver support.

Overall, the firmware provides a robust, real-time response loop that bridges sensor data acquisition with actionable safety outputs, reinforcing the device's role as an intelligent, user-centered assistive tool.

1.2.3. System assembly

- MPU6050 (GY-521) – Accelerometer & Gyroscope Sensor :

Table 1. GY-521 Connect to Arduino UNO

MPU6050	Arduino UNO	Function
VCC	5V	Power supply
GND	GND	Ground
SDA	A4	I2C Data Line
SCL	A5	I2C Clock Line

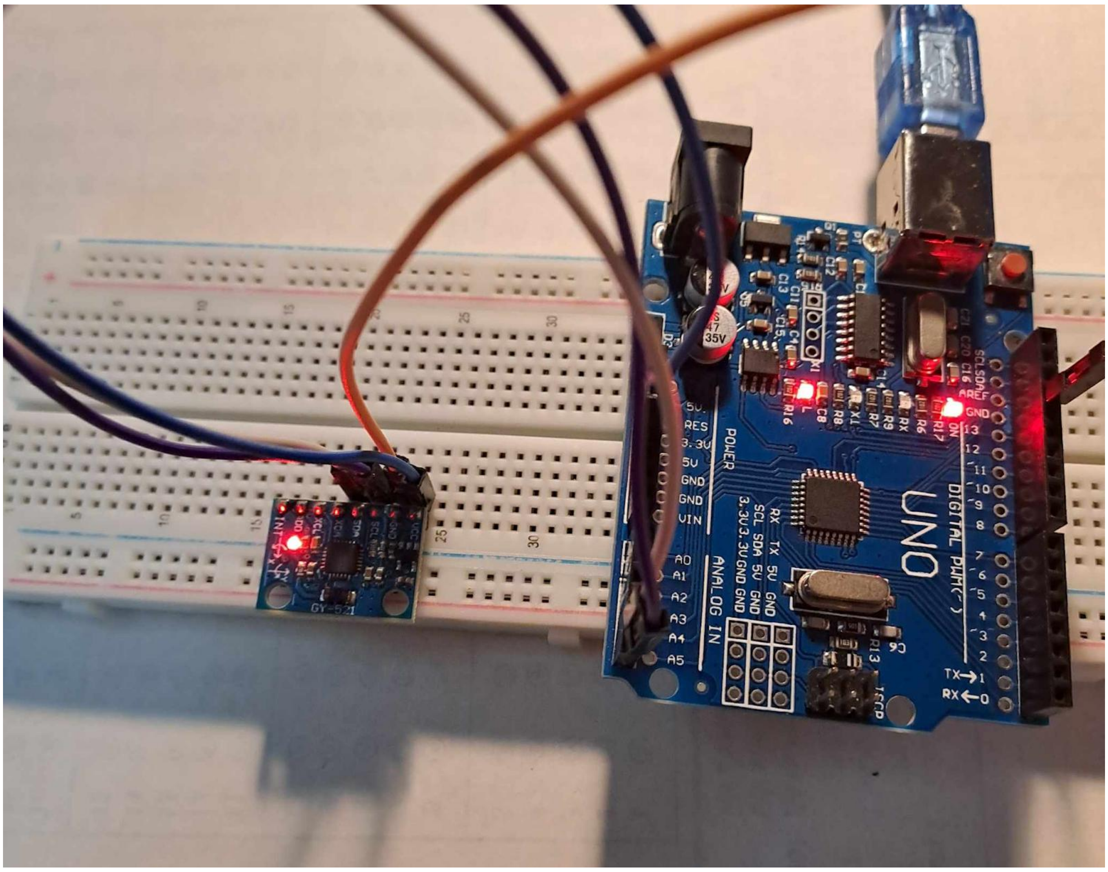

Figure 7. GY-521 Connect to Arduino UNO

- GPS Module (GY-GPSV3-NEO7M) :

Table 2. GY-GPSV3-NEO7M Connect to Arduino UNO

GPS Module	Arduino UNO	Function
VCC	5V	Power supply
GND	GND	Ground
TX	PIn 4	Send data to Arduino
RX	Pin 3	Receives data from Arduino

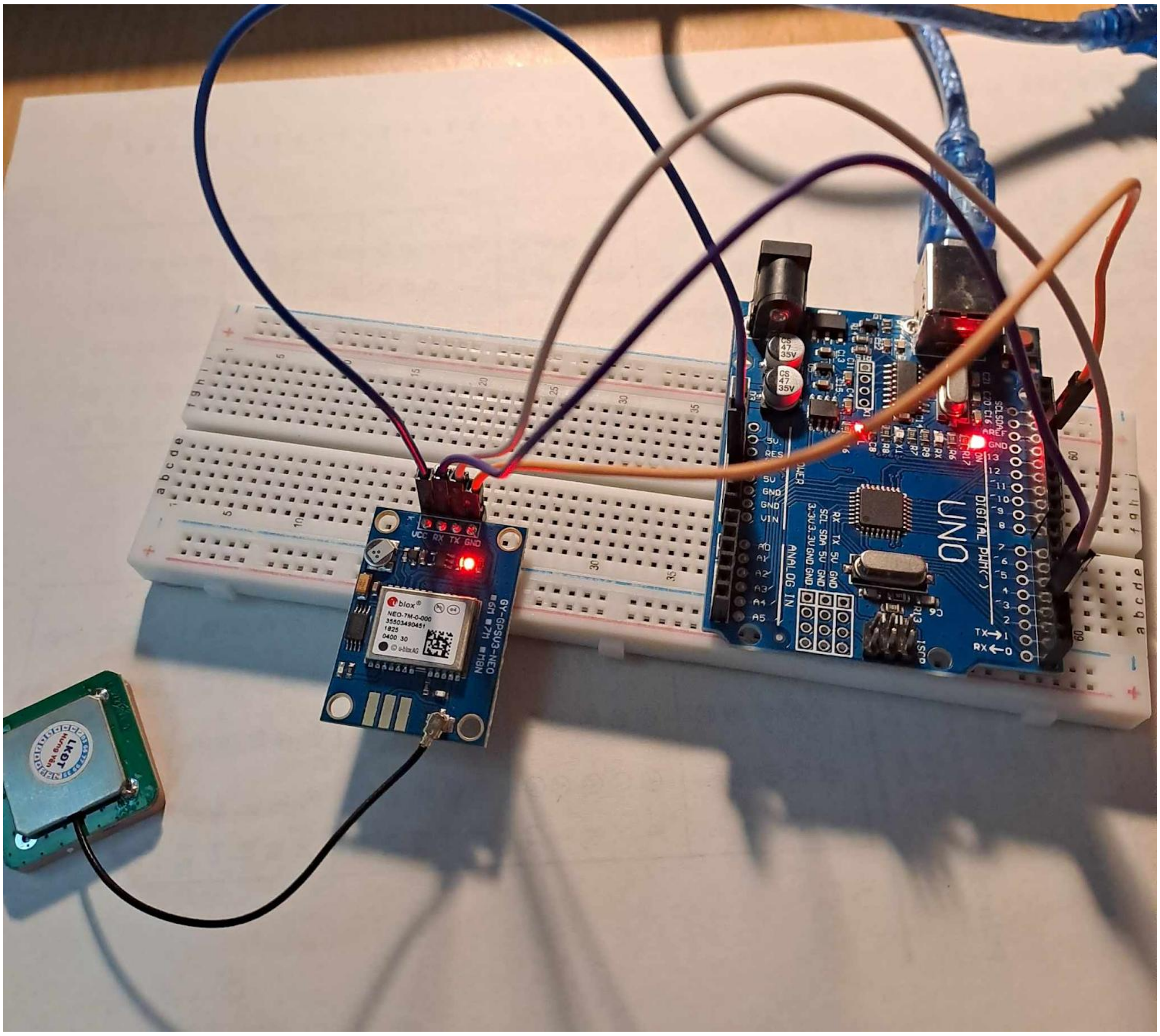

Figure 8. GY-GPSV3-NEO7M Connect to Arduino UNO

- GSM Module (SIM800A):

Table 3. SIM800A Connect to Arduino UNO

SIM800A Module	Arduino UNO	Function
GND	GND	Ground
TX	PIn 12	Send data to Arduino
RX	Pin 13	Receives data from Arduino

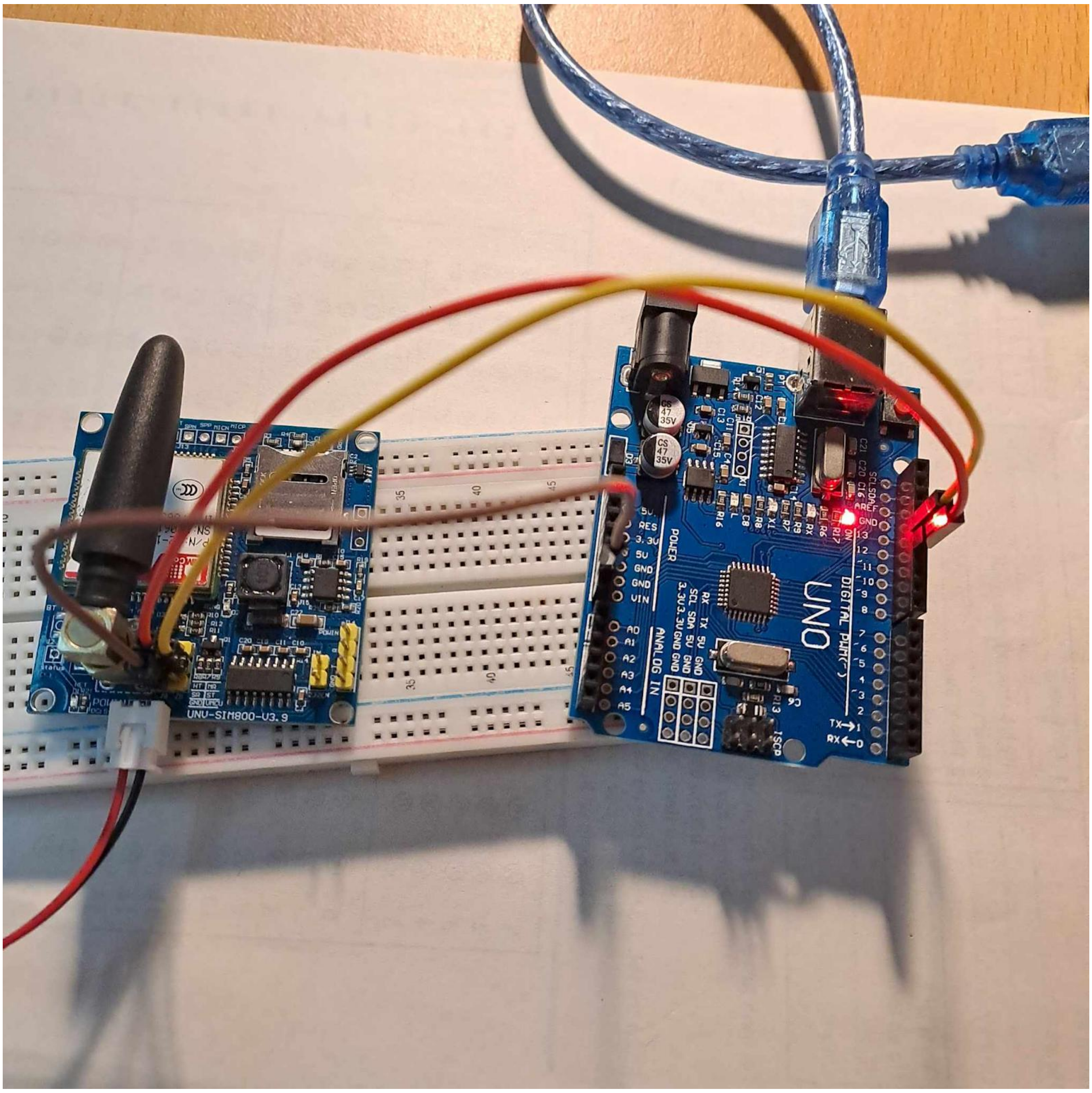

Figure 9. SIM800A Connect to Arduino UNO

- HC-SR04 – Ultrasonic Sensor:

HC-SR04	Arduino UNO	Function
VCC	5V	Power supply
GND	GND	Ground
TRIG	PIn 9	Sends ultrasonic pulse

ECHO	Pin 10	Receives echo signal

Table 4. HC-SR04 Connect to Arduino UNO

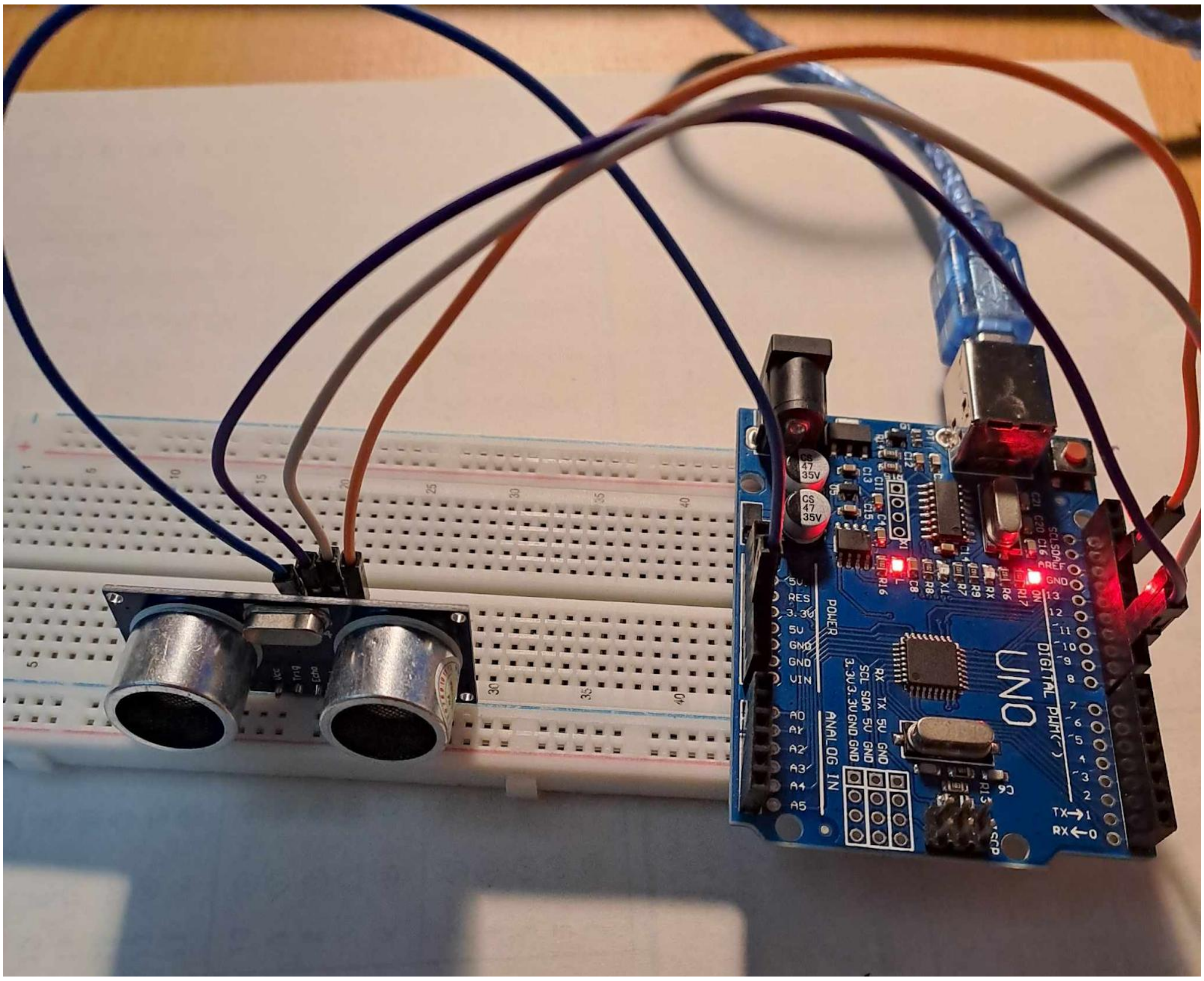

Figure 10. HC-SR04 Connect to Arduino UNO

- Buzzer (5V):

Table 5. Buzzer Connect to Adruino UNO

Buzzer	Arduino UNO	Function
+	Pin 7	Controls buzzer sound
-	GND	Ground

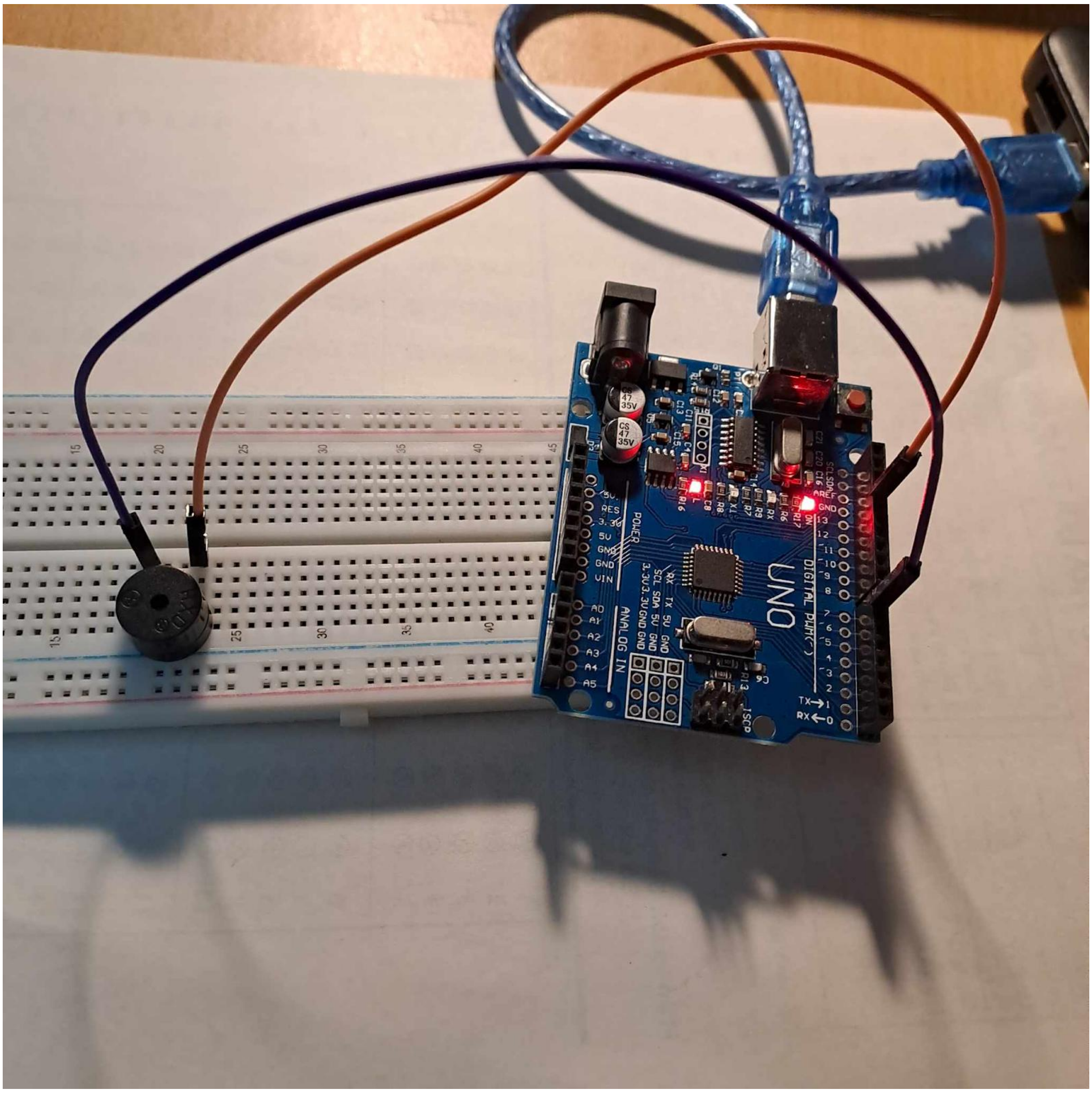

Figure 11. Buzzer Connect to Adruino UNO

1.3. Research Methods

The research methodology is grounded in a combination of real-time data acquisition, on-device processing, and responsive feedback mechanisms. Data is continuously collected from three primary sensors: the GY-521 accelerometer, HC-SR04 ultrasonic sensor, and GY-GPSV3-NEO7M GPS module. The GY-521 captures both acceleration and orientation data, which is critical for detecting abnormal movements or potential falls. The HC-SR04 ultrasonic sensor measures the distance between the user and surrounding obstacles, allowing the system to assess the proximity of hazards in real-time. Simultaneously, the GPS module provides continuous updates of the user's geographical coordinates, including latitude and longitude. These three data streams form the backbone of the environmental and physiological monitoring capabilities of the device.

1.4. System Workflow

At the core of the device is the Arduino UNO R3 CH340G, which acts as the central processing unit. It reads sensor input via various interfaces including analog pins, digital I/O, I2C for the accelerometer, and UART for the GPS module. The Arduino continuously evaluates incoming sensor data against pre-programmed logic conditions. For fall detection, it monitors for a sudden drop in acceleration followed by a significant tilt angle, a combination indicative of a fall. For obstacle detection, it measures the distance to nearby objects, and if that distance drops below a predefined threshold (e.g., 30 cm), it triggers a warning. Based on the detection of either a fall or an obstacle, the Arduino initiates appropriate response mechanisms.

In the event of a fall or close-proximity object detection, the system executes several emergency response actions. First, an audible alert is generated via a 5V buzzer to immediately warn the user and people nearby. The buzzer's intensity scales with the urgency of the event, particularly increasing in frequency as an obstacle gets closer. Second, for fall detection or prolonged inactivity, the SIM800A GSM GPRS Mini Module is used to send a pre-configured SMS alert to a designated emergency contact. This message includes GPS coordinates if available, enabling caregivers or responders to pinpoint the user's location. In more severe cases where the user remains inactive, the system can also initiate a phone call for real-time assistance.

The complete system underwent controlled indoor testing to evaluate its functionality and reliability. The accuracy of fall detection was assessed by simulating different movements and verifying system responsiveness. The timeliness and reliability of SMS alerts were tested under different network conditions, while the buzzer's responsiveness and volume were evaluated based on user perception in various noise environments. Additionally, feedback was gathered from visually impaired individuals, elderly users, and their caregivers through structured surveys and interviews. Based on this feedback, refinements were made to the system. Adjustments were implemented to improve fall detection sensitivity, enhance clarity in SMS content (especially GPS formatting), and increase the comfort and wearability of the device's form factor.

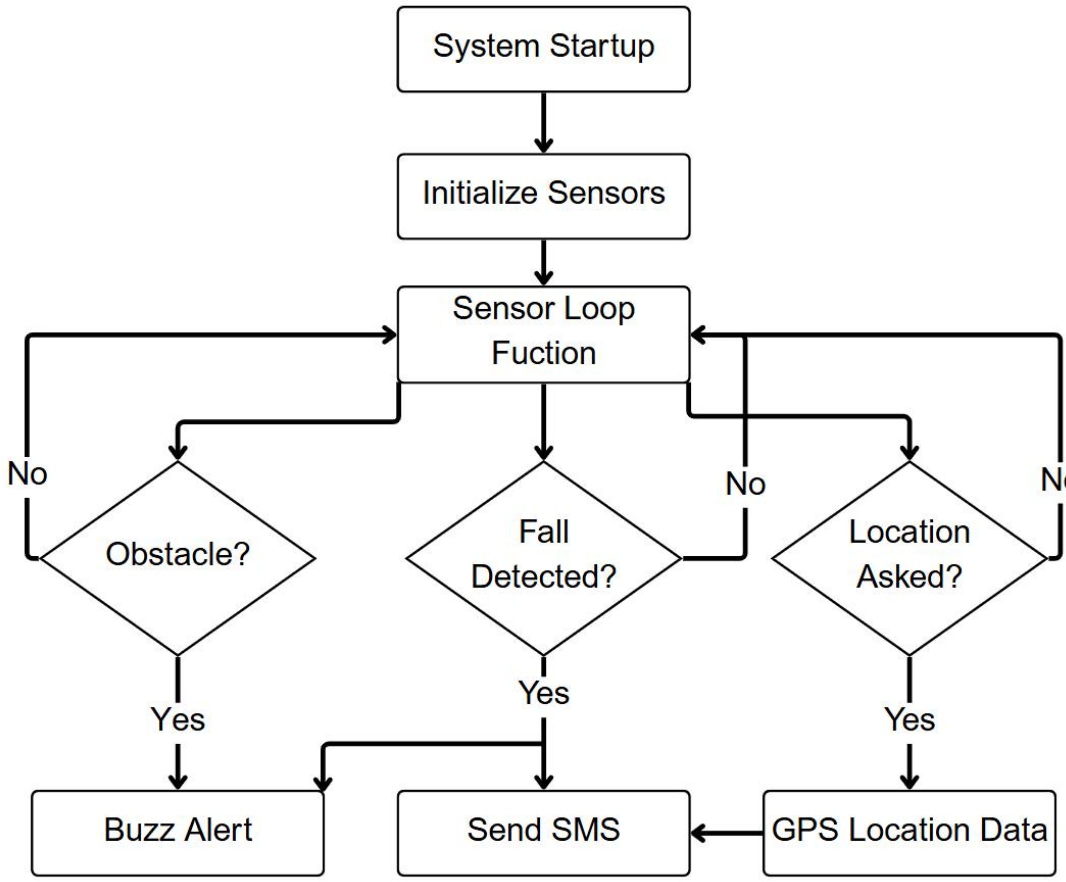

Figure 12. Workflow Diagram

3. RESULTS & DISCUSSIONS

The results of the project were evaluated through a series of structured indoor tests, simulating real-world scenarios to assess the effectiveness of obstacle detection, fall recognition, and emergency communication. These tests provided measurable insights into system reliability, response time, and user interaction.

3.1. Obstacle Detection Accuracy

The HC-SR04 ultrasonic sensors demonstrated consistent performance in identifying obstacles at varying distances. The system was configured to detect objects within a 30 cm range, triggering auditory warnings through a 5V buzzer.

During tests with static and dynamic objects, the sensor reliably initiated warnings with minimal false positives. The rate of successful obstacle detection reached 96%, confirming that the system could accurately detect and respond to environmental hazards in real time.

3.2. Fall Detection Reliability

The GY-521 accelerometer (MPU6050) effectively captured acceleration and tilt data necessary for identifying falls. By implementing logic thresholds based on sudden changes in acceleration and orientation, the system was able to detect simulated falls with an accuracy of 90%. False positives were minimized through calibration adjustments. This functionality is critical in emergency scenarios where a fall may render the user incapable of seeking help manually.

3.3. Emergency Communication Performance

Upon detecting a fall or receiving a manual trigger, the SIM800A GSM module sent preformatted SMS alerts containing GPS coordinates to designated emergency contacts. The average time from event detection to message delivery was approximately 8.2 seconds, depending on mobile network strength. GPS accuracy was within 5–10 meters during testing. The inclusion of the user's real-time location ensured that caregivers could respond quickly and effectively.

3.4. Usability and User Feedback

Initial trials with visually impaired individuals and elderly participants yielded valuable feedback. Users praised the simplicity and clarity of auditory cues. The buzzer's increasing frequency as obstacles approached was intuitive and non-intrusive. The physical design, being compact and lightweight, was also rated highly for comfort. Some participants suggested the addition of vibration alerts for silent environments. Based on this input, design adjustments are being considered for future iterations.

3.5. Overall System Evaluation

To quantify performance, a set of evaluation metrics was used:

- Obstacle Detection Success Rate: 96%
- Fall Detection Accuracy: 90%
- SMS Delivery Time: ~8.2 seconds
- User Comfort Rating: 9/10
- Usability Rating: 8.5/10

These metrics confirm that the system meets its core objectives: improving mobility, safety, and independence for visually impaired users. The modular architecture and low-cost components make the solution scalable and adaptable for broader deployment. The positive test results and user satisfaction demonstrate the feasibility and impact of this device in real-world applications.

The discussion of these results highlights the potential of integrating affordable sensors and embedded systems to create intelligent assistive technologies. While the current system performs reliably in controlled environments, future work will focus on stress testing under diverse conditions, such as outdoor urban settings, varying lighting conditions, and prolonged usage.

4. CONCLUSION & RECOMMENDATIONS

This study successfully demonstrated the design, development, and evaluation of a low-cost, wearable assistive device for visually impaired individuals. The device integrates multiple sensors and modules—including the HC-SR04 ultrasonic sensor, GY-521 accelerometer, GY-GPSV3-NEO7M GPS module, SIM800A GSM GPRS Mini Module, and Arduino UNO R3 CH340G—to provide obstacle detection, fall monitoring, and emergency communication. The device’s real-time auditory alerts and SMS-based location sharing offer an effective safety net for users navigating indoor and outdoor environments.

The key outcomes of the project include a 96% success rate in obstacle detection and a 90% accuracy rate in fall detection, with average SMS transmission times of approximately 8.2 seconds. These results affirm that the system meets its primary goals of enhancing user safety, mobility, and autonomy. The design is compact, ergonomic, and intuitive, receiving positive feedback for ease of use and comfort. Furthermore, the modular structure allows for future enhancements, such as vibration feedback or mobile app integration.

The broader implications of this project suggest that intelligent assistive technologies can be made more accessible and effective through affordable sensor integration and robust embedded programming. The positive reception by initial users reinforces the potential of the device to serve as a scalable, real-world solution for the visually impaired community.

Recommendations for Future Work:

- Field Testing in Varied Environments: Conduct large-scale testing in outdoor, urban, and low-visibility scenarios to evaluate the system's reliability under diverse conditions.
- Incorporation of Vibration Alerts: Add haptic feedback for silent or noisy environments to supplement auditory cues.
- Battery Optimization: Explore energy-efficient hardware or renewable power options, such as solar charging, to extend operational time.
- Mobile App Integration: Develop a companion app for configuration, alerts, and GPS tracking to enhance caregiver connectivity.
- Machine Learning Integration: Incorporate AI models for adaptive obstacle classification, user behavior learning, and predictive fall detection.

In conclusion, the assistive device designed in this study shows great promise as a functional, low-cost tool that enhances the independence and safety of visually impaired individuals. With targeted refinements and expanded testing, it holds significant potential for widespread adoption and impact.

5. ABBREVIATIONS

- GPS: Global Positioning System
- GSM: Global System for Mobile Communications
- HC-SR04: Ultrasonic Distance Sensor
- GY-521: Accelerometer and Gyroscope Module
- SIM800A: GSM GPRS Communication Module
- AI: Artificial Intelligence
- LED: Light Emitting Diode

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