Elderly Fall Detection & Alert System

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September– 2025

Embedded System Design

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Certificate

This is to certify that the Project titled "Elderly Fall Detection & Alert System" is a Bonafide work carried out by Ms. Simran Sah bearing in partial fulfilment of requirements of the award of the Certificate for the Program Embedded C & Microcontroller for Embedded Applications of Ramaiah Skill Academy.

September 2025

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Declaration

The project work is submitted in partial fulfilment of the training requirements for the award of the Certificate for having completed the training program in Embedded System Design at Ramaiah Skill Academy from July 30th 2025 to September 3rd 2025. The project report submitted herewith is a result of our own work and in conformance with the guidelines of Ramaiah Skill Academy.

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Date: 3 September 2025

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Summary

Embedded systems are at the core of modern technological advancements, powering a wide range of applications that demand efficiency, reliability, and real-time response. These systems combine microcontrollers, sensors, and actuators to perform specialized tasks, making them essential in fields such as healthcare, automation, safety, communication, and industrial control. With the continuous evolution of embedded technologies, there is a growing need for engineers and learners to acquire practical knowledge of system design, programming, and sensor integration.

This project report has focused on developing skills in C programming, embedded system design, and the STM32 microcontroller platform**.** Using the STM32Cube environment, the author has gained hands-on experience in hardware and software integration. As part of this journey, several sensors and modules have been explored and interfaced with microcontrollers, including buzzers, LEDs, soil moisture sensors, servo motors, infrared (IR) sensors, touch sensors, rain sensors, motion detectors, vibration sensors, sound sensors, heart rate sensors, accelerometers (GY-61), and LCD displays. These experiments provided valuable insights into the functioning of embedded systems and highlighted their role in developing real-time applications.

To apply these skills in a practical context, the author carried out a mini project titled "Elderly Fall Detection and Alert System." This project was designed to address a significant real-world problem: the safety and well-being of elderly individuals, especially those who live alone. Elderly people are highly vulnerable to sudden falls, which may lead to severe injuries or health complications. In such cases, timely detection and alert mechanisms are critical to prevent life-threatening situations.

The mini project utilized the Nucleo-F446ZE microcontroller board as the central processing unit. A GY-61 accelerometer was used to monitor body movements and detect sudden falls by analyzing changes in acceleration. Additionally, a heart rate sensor was integrated to monitor the physiological condition of the individual, as abnormal heart activity can often accompany or follow a fall. A buzzer was included in the system to generate immediate audible alerts, while an LCD display was used to present real-time data such as heart rate

and fall status. All components were connected through a breadboard to prototype the system effectively. The design of this system reflects the importance of embedded systems in healthcare applications**.** By combining sensor data with programmed logic, the project demonstrates how embedded devices can enhance safety and improve quality of life. In practice, such a system could be further developed to send wireless alerts to caregivers or healthcare professionals, ensuring timely assistance during emergencies. Through the development of this project, the author was able to strengthen technical expertise in. More importantly, the project highlights the societal impact of embedded technologies, as they can be applied to create affordable, practical, and life-saving solutions. This mini project serves as an example of how knowledge in embedded systems can be directed towards sensor interfacing, embedded C programming, and microcontroller-based system design solving real-world challenges, particularly in the domain of elderly care and safety.

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Abbreviation

1. **ADC** – Analog to Digital Converter
2. **BPM** – Beats Per Minute
3. **CPS** – Cycles Per Second
4. **DC** – Direct Current
5. **GY-61** – Accelerometer Sensor Module (based on ADXL335/ADXL345 family)
6. **HAL** – Hardware Abstraction Layer
7. **Hz** – Hertz
8. **IDE** – Integrated Development Environment
9. **IoT** – Internet of Things
10. **LCD** – Liquid Crystal Display
11. **LED** – Light Emitting Diode
12. **MCU** – Microcontroller Unit
13. **PCB** – Printed Circuit Board
14. **PWM** – Pulse Width Modulation
15. **RAM** – Random Access Memory
16. **ROM** – Read Only Memory
17. **STM32** – 32-bit Microcontroller Family by STMicroelectronics
18. **UART** – Universal Asynchronous Receiver Transmitter
19. **VCC** – Voltage Common Collector (Power Supply Voltage)

ABSTRACT

The rapid growth of embedded systems has enabled the development of intelligent devices capable of addressing critical issues in healthcare, safety, and automation. Elderly individuals, particularly those living alone, are highly vulnerable to accidental falls and sudden health complications, which may lead to severe injuries or even life-threatening conditions if timely assistance is not provided. This project focuses on the design and implementation of an Elderly Fall Detection and Alert System using an STM32 Nucleo-F446ZE microcontroller, aiming to provide a low-cost and reliable solution to ensure elderly safety.

The system integrates a GY-61 accelerometer to detect sudden changes in motion and orientation, which indicate a possible fall. A heart rate sensor is used to monitor the individual's pulse in real time, thereby enabling the detection of abnormal health conditions alongside fall events. A buzzer is included to generate immediate audible alerts, and an LCD display is employed to show the current system status, including heart rate and fall detection messages. The system was prototyped on a breadboard for testing and validation.

The project demonstrates how embedded C programming, STM32CubeIDE, and sensor interfacing can be combined to develop a practical healthcare application. Experimental results showed that the system successfully detected falls and abnormal conditions, generating timely alerts that could be extended to wireless communication systems for remote monitoring.

This work highlights the importance of embedded technologies in designing assistive devices that enhance safety, provide real-time monitoring, and improve the quality of life for the elderly population. The proposed system not only showcases technical proficiency in microcontroller-based design but also emphasizes the potential of embedded systems in creating impactful, real-world solutions in the healthcare domain.

CHAPTER 1

INTRODUCTION

Embedded systems form the foundation of numerous modern technologies, combining hardware and software to perform specific, real-time functions efficiently. Unlike general-purpose computing devices, embedded systems are designed for dedicated tasks, which makes them highly reliable, compact, and energy efficient. They have become a core part of applications in diverse fields such as industrial automation, communication, consumer electronics, defence, automotive systems, and healthcare monitoring. As technology continues to advance, the demand for embedded systems that can integrate multiple sensors and actuators has grown, paving the way for innovative solutions to real-world problems.

In recent years, the application of embedded systems in healthcare has gained significant importance. The elderly population, in particular, faces challenges such as falls, sudden health deteriorations, and the absence of immediate caregivers. Falls are one of the most common causes of injury among senior citizens and can lead to serious consequences if help is not provided quickly. Traditional monitoring systems often fail to address this problem effectively, which highlights the need for low-cost, reliable, and responsive solutions. Embedded systems, with their ability to process sensor data in real time, offer an efficient approach to tackling such challenges.

This project report has developed strong knowledge in C programming, embedded system design, and STM32 microcontrollers, particularly through the use of the STM32CubeIDE platform. This learning was reinforced through practical experience with a wide range of sensors and modules such as buzzers, LEDs, soil moisture sensors, servo motors, infrared (IR) sensors, touch sensors, rain sensors, motion detectors, vibration sensors, sound sensors, heart rate sensors, accelerometers (GY-61), and LCD displays. By experimenting with these devices and integrating them with microcontrollers, the author has gained the ability to design small-scale but effective projects that demonstrate the application of embedded technologies in solving real-world problems.

Building on this foundation, the author implemented a mini project titled "Elderly Fall Detection and Alert System." This project aimed to design a prototype capable of detecting falls and abnormal heart conditions among elderly individuals, thereby ensuring their safety through timely alerts. The system was built around the Nucleo-F446ZE microcontroller board. The GY-61 accelerometer was used to detect sudden changes in body orientation and acceleration, which indicate a fall. A heart rate sensor was integrated to continuously monitor the pulse of the individual. A buzzer served as an immediate alerting device in case of emergencies, while an LCD display presented real-time data such as heart rate and system status. The components were connected using a breadboard for prototyping and testing. The significance of this project lies in its contribution to healthcare monitoring through embedded technology. By successfully combining sensor data with microcontroller-based processing, the system demonstrates how embedded devices can enhance safety and quality of life, particularly for elderly individuals living alone.

CHAPTER 2

LITERATURE SURVEY

Papan et. al. highlights the increasing frequency and impact of falls among the elderly, emphasizing the significant health and mobility risks associated with such incidents. It discusses the importance of efficient detection and immediate response to reduce the severity of injuries and life-threatening complications from falls. The review notes the advancements in object detection technology, particularly the capabilities of YOLO v8, which offers high speed and accuracy for real-time monitoring. It addresses the multi-source approach for fall detection, incorporating video feeds, RTSP streams, static images, and wearable sensors to enhance adaptability in various environments. The review underscores the role of data-driven analytics in improving system accuracy over time and aiding caregivers in understanding fall patterns and risk factors [1].

Kalidas et. al. addresses the increasing risk of falls among elderly individuals living independently or distanced from family, highlighting the need for effective monitoring systems. It discusses the emergence of IoT-based solutions as crucial tools for caregivers, emphasizing their role in enhancing the safety of the elderly population. The use of accelerometer and gyroscope sensors is identified as a key technological advancement in fall detection, allowing for continuous movement monitoring and risk assessment. The system's dual-notification feature, which alerts both caregivers and the elderly individual, is presented as a significant improvement in response time and assistance during emergencies. The promising results of implementing this technology indicate a consensus on its effectiveness in reducing severe health consequences associated with undetected falls among seniors [2].

Fitriawan et. al. indicates that falls are a significant health issue for the elderly, with a high incidence rate among individuals aged 65 and older. It is noted that falls lead to a substantial number of fatalities, particularly in low- and middle-income countries, highlighting the global health concern. The research emphasizes the importance of prompt and accurate fall detection to mitigate risks associated with falls in the elderly population. Prior work suggests that integrating technology, such as sensors and communication modules, can enhance the effectiveness of fall detection systems. There is a consensus on the need for effective prevention strategies, including research, policy establishment, and education to create safer environments for the elderly [3].

C Padmaja et. al. highlights the increasing challenges faced by an aging population, particularly concerning the well-being of elderly individuals. It emphasizes the prevalence of falls among seniors, which poses significant risks to their physical health and independence. The review critiques conventional fall detection methods, noting their inadequacy in providing timely assistance to those in need. There is a consensus on the necessity for innovative solutions to enhance elderly care and ensure safety for seniors, especially those who are wheelchair-bound. The review underscores the importance of advanced technologies, such as the MPU6050 sensor module and sophisticated algorithms, in improving fall detection systems [4].

Vijith P R et. al. addresses the increasing risk of falls among elderly individuals living alone, highlighting the need for timely assistance. It proposes a system utilizing wall-mounted cameras and mmWave sensors to detect falls quickly and accurately. The system is designed to alert medical services and caregivers immediately upon detecting a fall, ensuring prompt assistance. Fall-related data is securely stored on a website, allowing access for medical professionals and family members for real-time monitoring. The integration of technology in care giving is emphasized as a means to enhance the safety of the elderly and provide peace of mind for their loved ones [5].

A review of existing research and related works is essential to understand the current state of development in fall detection and healthcare monitoring systems. Numerous studies have highlighted the importance of using embedded systems and sensor-based technologies to address challenges faced by the elderly population, particularly in fall detection, health monitoring, and emergency response.

Researchers have widely explored the use of accelerometer sensors for detecting falls. Accelerometers are capable of measuring sudden changes in body orientation and motion, which makes them suitable for identifying fall events. Several studies have proposed threshold-based algorithms, where acceleration values beyond a certain limit indicate a fall.

This method is simple, cost-effective, and reliable for basic fall detection applications. However, some works have also highlighted the limitations of false alarms caused by normal activities such as sitting abruptly or bending.

In addition to fall detection, heart rate monitoring has been recognized as a critical parameter for assessing the health condition of elderly individuals. Literature suggests that integrating physiological monitoring with fall detection increases the accuracy and reliability of such systems. For example, monitoring heart rate alongside body movement provides additional insights into whether a detected fall is accompanied by abnormal health conditions. This integration improves the overall effectiveness of alert systems, ensuring timely intervention.

Studies have also investigated various alert mechanisms. Traditional systems often relied on manual alarms or wearable devices requiring user interaction, which may not always be practical during emergencies. Recent research has emphasized automated alerting systems using buzzers, mobile notifications, or wireless communication modules (such as GSM, Bluetooth, or LoRa). These ensure that caregivers or medical professionals are notified immediately when a fall or abnormal condition is detected.

The role of microcontrollers in healthcare monitoring has been extensively studied. Platforms such as Arduino, Raspberry Pi, and STM32 have been commonly used in prototyping fall detection systems. Among these, STM32 microcontrollers are considered more reliable for real-time applications due to their high processing speed, low power consumption, and extensive peripheral support. Literature supports the use of STM32 boards for applications requiring efficient sensor interfacing and quick response times, making them highly suitable for healthcare-related projects.

Recent works have also explored the incorporation of LCDs and display modules for presenting real-time data to users. This allows elderly individuals or caregivers to monitor health conditions directly, thereby improving system usability. Furthermore, combining multiple sensors such as accelerometers, gyroscopes, and heart rate monitors has been found to enhance system accuracy and minimize false alarm.

CHAPTER 3

METHODOLOGY

The project employs a STM32 Nucleo-F446ZE microcontroller interfaced with a GY-61 accelerometer**,** heart rate sensor**,** buzzer**,** and LCD display. The system continuously monitors acceleration and heart rate data to detect falls and abnormal conditions. On detecting an event, the buzzer generates an alert, and the LCD displays real-time status. The methodology combines sensor data acquisition, embedded C programming, and real-time **processing** for effective elderly monitoring.

1.1 Block Diagram

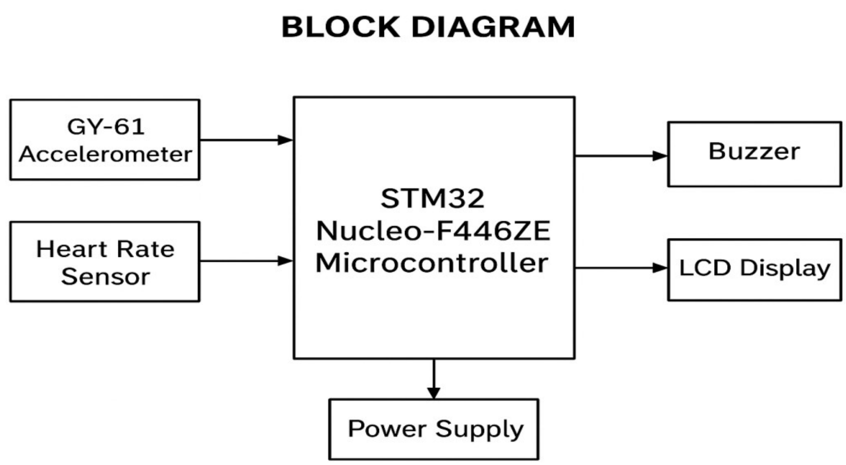


Figure1- Block Diagram

The Elderly Fall Detection and Alert System consist of the following main components, interconnected to perform continuous monitoring and alerting:

1. **STM32 Nucleo-F446ZE Microcontroller** – Serves as the central processing unit that receives data from sensors, processes it, and triggers alerts.
2. **GY-61 Accelerometer** – Detects sudden changes in motion and orientation to identify potential falls.

3. **Heart Rate Sensor** – Monitors the individual's pulse in real time for abnormal health conditions.
4. **Buzzer** – Generates an immediate audible alert when a fall or abnormal condition is detected.
5. **LCD Display** – Shows real-time data including heart rate and system status to the user.
6. **Power Supply** – Provides necessary voltage and current to all components for stable operation.

Flow of Operation:

- Sensors continuously send data to the microcontroller.
- The microcontroller analyzes acceleration and heart rate values.
- If a fall or abnormal condition is detected, the buzzer is activated, and the LCD displays the alert message.

1.2 Hardware Components

The "Elderly Fall Detection and Alert System" relies on a combination of microcontroller, sensors, and output devices, carefully selected to detect falls accurately and provide immediate alerts. The hardware components used in this project include:

1. **Nucleo-F446ZE Microcontroller Board**:

   Serving as the central processing unit, the Nucleo-F446ZE board is based on the STM32F446RE microcontroller. It provides sufficient computational power, multiple GPIO pins, ADC channels, and communication interfaces to support the integration of various sensors and peripherals. The STM32Cube development environment facilitates programming, debugging, and hardware abstraction.

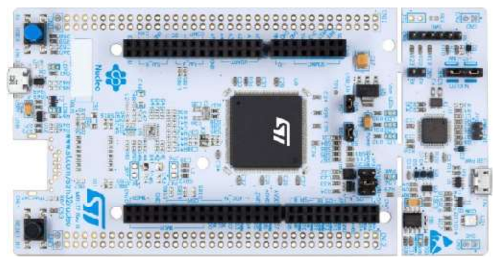


Figure 2- Nucleo-F446ZE Microcontroller Board

Hardware Specifications

Component	Specification/Model
Microcontroller	STM32F446ZE (Nucleo-F446ZE)
Accelerometer	GY-61 (ADXL335)
Heart Rate Sensor	Pulse Sensor / MAX30100
Buzzer	Active Buzzer Module
LCD Display	16x2 Character LCD with I2C
Power Supply	5V DC

2. **GY-61 (ADXL335) Accelerometer**:

The GY-61 accelerometer is a three-axis analog sensor used to monitor body movements. It detects sudden changes in acceleration, which allows the system to identify falls. By processing the sensor's X, Y, and Z-axis outputs, the microcontroller can determine whether a fall has occurred.

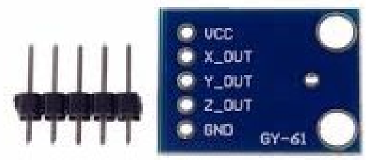


Figure 3- GY-61 (ADXL335) Accelerometer

3. **Heart Rate Sensor**:

   This sensor monitors the physiological condition of the individual, providing real-time heart rate data. Continuous monitoring is crucial because falls may be associated with abnormal heart activity, enabling the system to respond more effectively in emergencies.

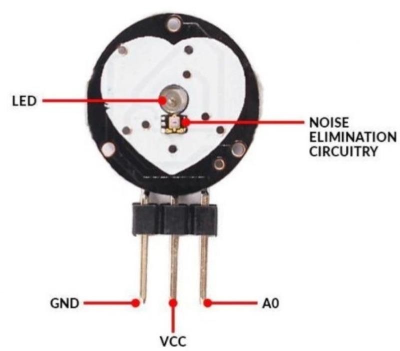


Figure 4- Heart Rate Sensor

4. **Buzzer:**

   A buzzer is used to generate audible alerts whenever a fall is detected. This immediate feedback not only alerts the elderly individual but also signals caregivers or nearby people to provide assistance.

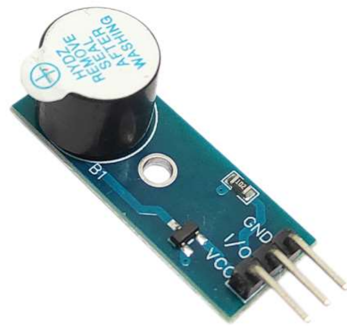


Figure 5- Buzzer

5. **LCD Display**:

   The LCD module displays vital information such as heart rate and fall status in real-time. This provides a clear visual interface for the user and aids in monitoring the system's functionality.

Figure 6- LCD

6. **Breadboard and Connecting Wires**:

   The breadboard allows for easy prototyping and testing of the circuit without soldering. Jumper wires facilitate connections between the microcontroller and sensors, ensuring flexibility during the development phase.

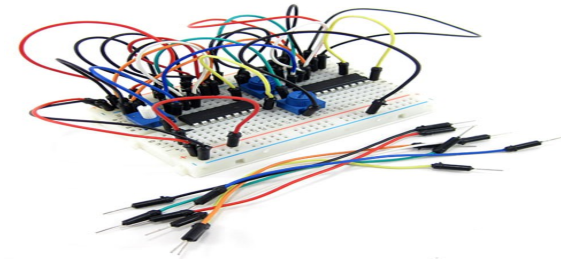


Figure 7- Breadboard and Connecting Wires

3.3 Software Requirement:

The “Elderly Fall Detection and Alert System” relies not only on robust hardware but also on an efficient software environment to process sensor data, detect falls, and generate alerts. The following software tools and platforms were used in the development of this project:

1. **STM32CubeIDE**

   STM32CubeIDE is an integrated development environment (IDE) provided by STMicroelectronics. It combines code editing, compiling, debugging, and project management features in a single platform. It supports the STM32 microcontroller family, providing hardware abstraction layers (HAL) that simplify peripheral configuration and sensor interfacing. STM32CubeIDE was used to write embedded C code, configure GPIOs, ADC channels, and timers, and debug the microcontroller program.

2. **STM32CubeMX**

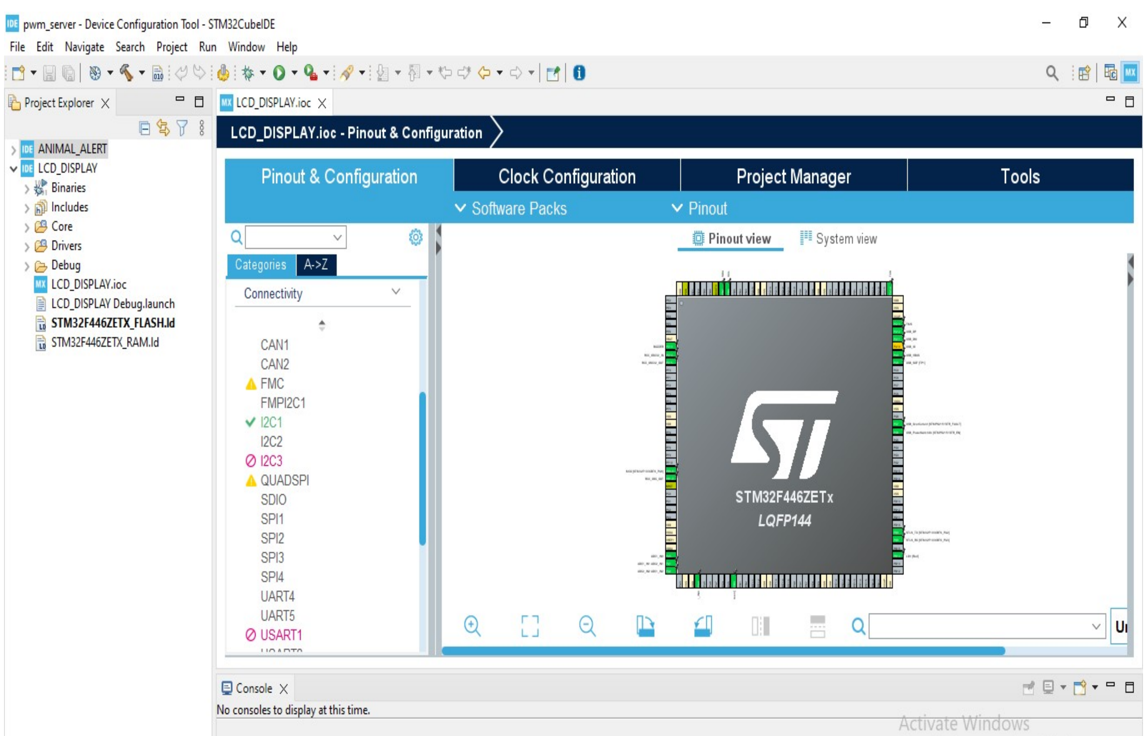
   STM32CubeMX is a graphical tool used for configuring STM32 microcontrollers and generating initialization code. In this project, STM32CubeMX helped in configuring the microcontroller’s peripherals, including ADC inputs for the accelerometer and heart rate sensor, I2C or SPI interfaces for the LCD, and GPIO pins for the buzzer and LEDs. It significantly reduced development time by providing a visual representation of hardware connections.

3. **Embedded C Programming**

Embedded C is the primary programming language used to develop firmware for the microcontroller. It enables precise control of hardware components, real-time data acquisition, and decision-making logic for fall detection. The project code includes algorithms for processing accelerometer data, detecting sudden changes in motion, monitoring heart rate, and controlling the buzzer and LCD display.

4. **Serial Monitor/Debugging Tools**

Debugging and monitoring tools such as the serial terminal in STM32CubeIDE were used to track real-time sensor data, validate fall detection thresholds, and ensure correct communication between components. These tools are essential for verifying the functionality and reliability of embedded systems before deployment.



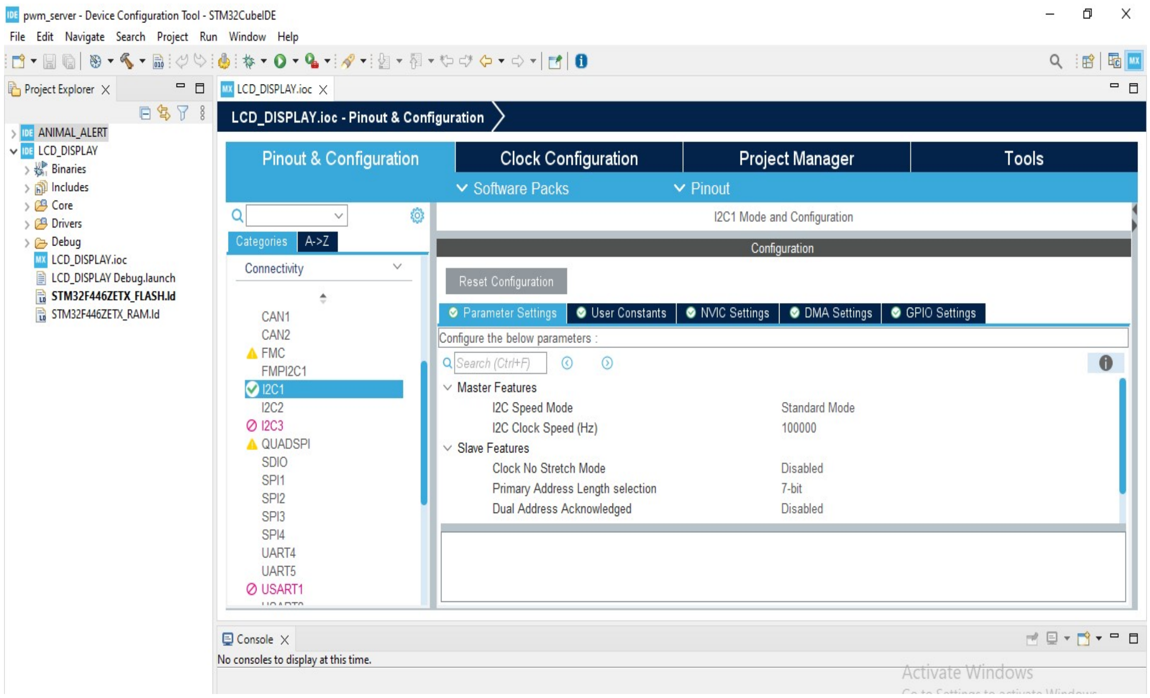


Figure 12 - STM32CubeIDE

Circuit Diagram

The circuit diagram of the “Elderly Fall Detection and Alert System” shows the connections between the Nucleo-F446ZE microcontroller, GY-61 accelerometer, heart rate sensor, buzzer, and LCD display. It illustrates proper GPIO usage, power supply connections, and data signal paths for prototyping on a breadboard.

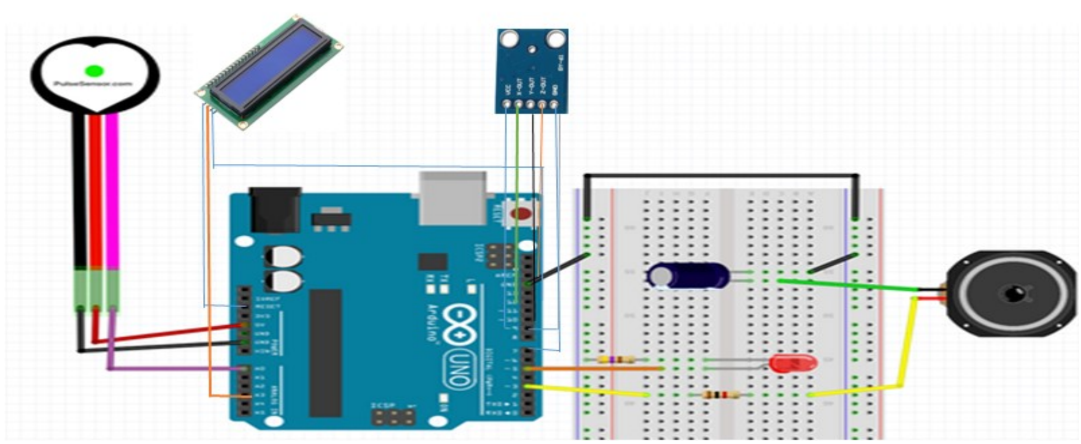
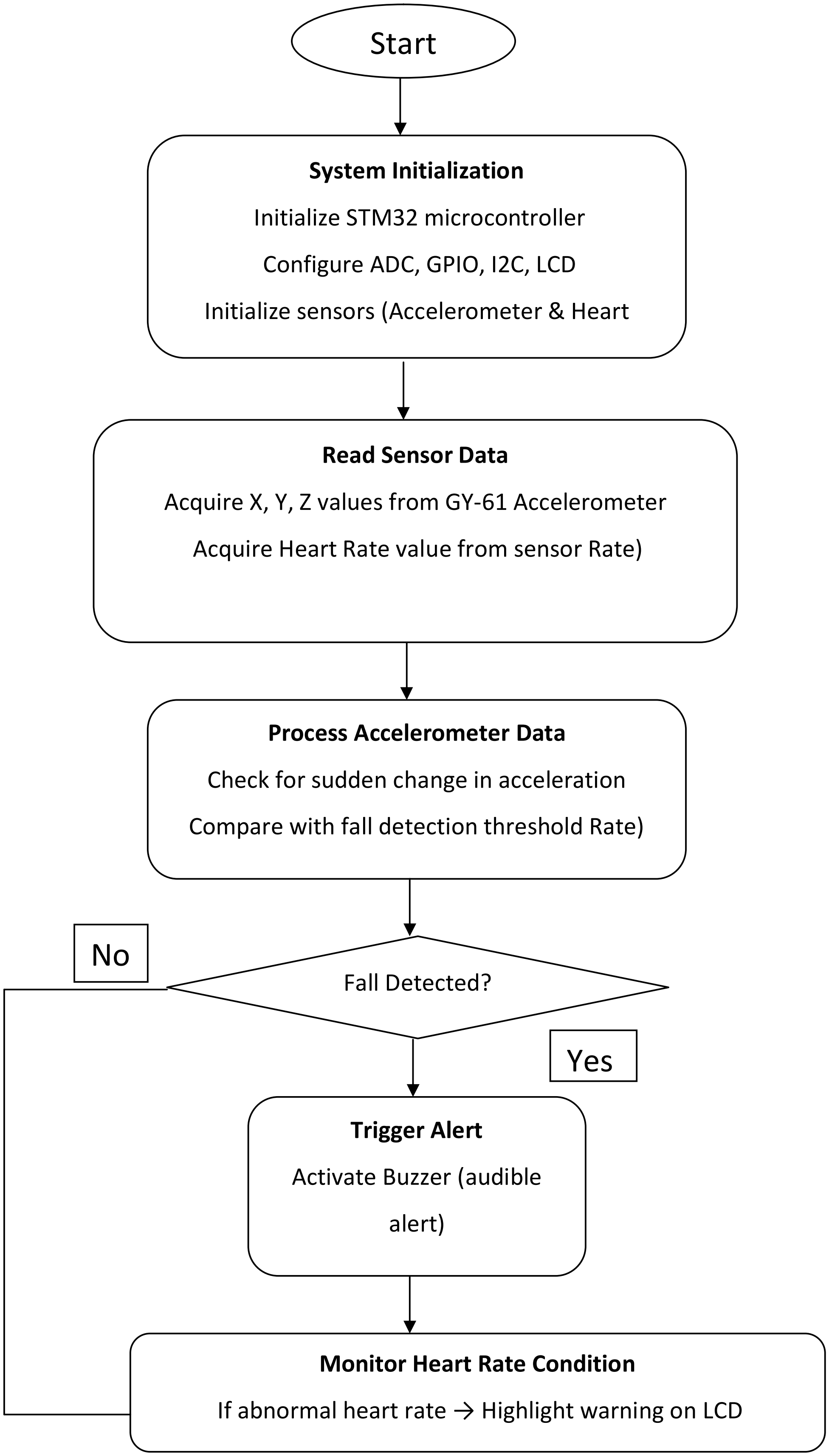


Figure 13 – Circuit Diagram

Flowchart of System Operation

The flowchart below explains the working sequence of the system, starting from initialization, sensor data acquisition, fall detection, and alert triggering.

Figure 9 – Flowchart of System Operation


Start
System Initialization
Initialize STM32 microcontroller
Configure ADC, GPIO, I2C, LCD
Initialize sensors (Accelerometer & Heart
Read Sensor Data
Acquire X, Y, Z values from GY-61 Accelerometer
Acquire Heart Rate value from sensor Rate)
Process Accelerometer Data
Check for sudden change in acceleration
Compare with fall detection threshold Rate)
No
Fall Detected?
Yes
Trigger Alert
Activate Buzzer (audible alert)
Monitor Heart Rate Condition
If abnormal heart rate → Highlight warning on LCD

CHAPTER 4

RESULT AND DISCUSSION

The “Elderly Fall Detection and Alert System” was successfully developed and tested using the Nucleo-F446ZE microcontroller, GY-61 accelerometer, heart rate sensor, buzzer, and LCD display. The system demonstrated accurate detection of falls by continuously monitoring changes in acceleration along the X, Y, and Z axes. When a sudden fall occurred, the system immediately triggered the buzzer and updated the LCD with the fall status, providing real-time alerts.

The heart rate sensor effectively monitored the physiological condition of the individual, allowing the system to detect abnormal heart activity that could accompany a fall. The integration of multiple sensors showcased the capability of embedded systems to process real-time data and respond to critical events without human intervention.

During testing, various scenarios were simulated, including normal movements, sitting, walking, and sudden falls. The system successfully differentiated between minor movements and actual falls, reducing false positives. The LCD provided clear visual feedback, displaying both fall status and heart rate, which enhanced usability for elderly individuals.

The project highlights the practicality of embedded systems in healthcare applications. By combining sensor data, microcontroller logic, and output devices, the system offers an affordable and reliable solution for elderly safety. Additionally, the modular design allows future expansion, such as adding wireless notifications to alert caregivers or integrating more physiological sensors for comprehensive health monitoring.

Overall, the project demonstrates that embedded systems can effectively improve quality of life, provide timely alerts, and potentially save lives by addressing the critical problem of falls among the elderly.

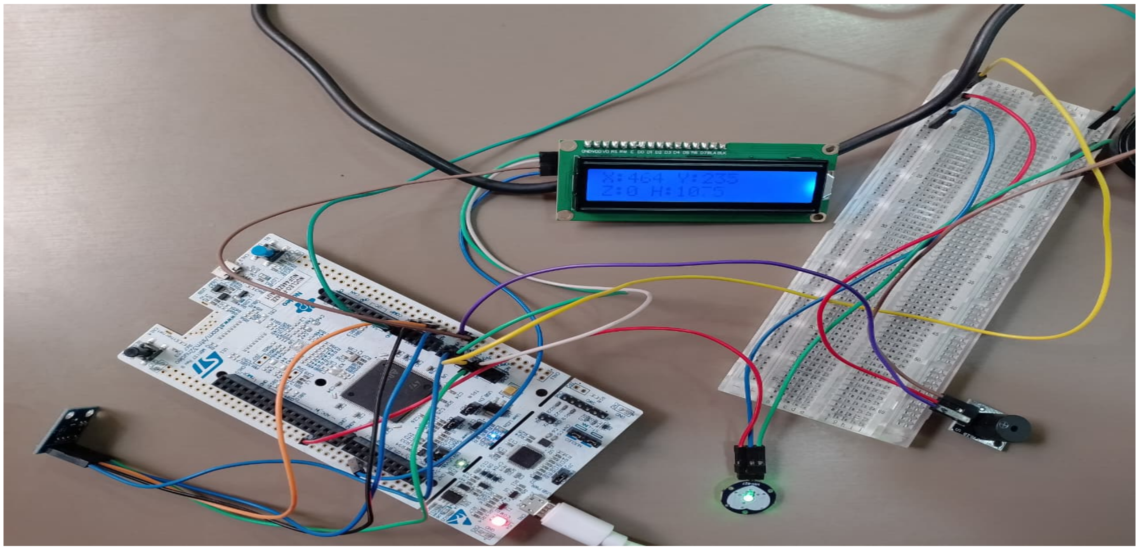


Figure 8 – Hardware Connections on Breadboard

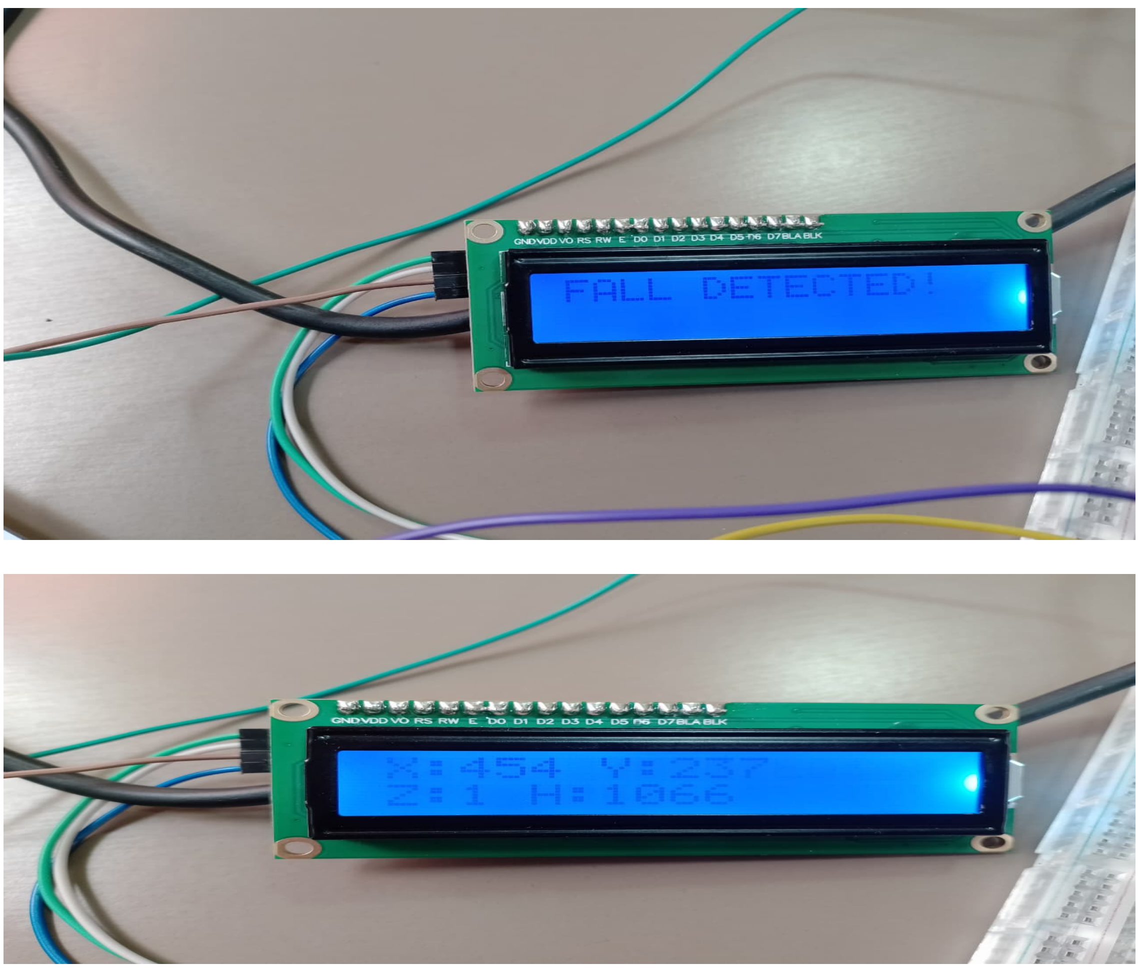


Figure 11 – Output Display on LCD

Test Results

Test Scenario	**Result**
Normal Walking	No false alert
Sitting / Standing	No false alert
Sudden Fall	Alert triggered, buzzer ON
Heart Rate Monitoring	Accurate real-time display

CHAPTER 5

CONCLUSION

The “Elderly Fall Detection and Alert System” successfully demonstrates the application of embedded systems in enhancing elderly safety and well-being. By integrating a Nucleo-F446ZE microcontroller with a GY-61 accelerometer, heart rate sensor, buzzer, and LCD display, the system accurately detects falls and provides real-time alerts.

The project highlights the importance of sensor interfacing, embedded C programming, and microcontroller-based system design in developing practical, real-world solutions. Testing confirmed that the system reliably differentiates between normal movements and actual falls, while continuously monitoring heart rate for added safety.

Moreover, the modular design of the system allows for future enhancements, such as wireless alerts to caregivers, cloud-based monitoring, integration of additional health sensors, wearable miniaturized designs, and smart detection using machine learning. These advancements can transform the system into a more proactive, reliable, and user-friendly healthcare solution, significantly improving elderly safety and quality of life.

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APPENDIX

Datasheets

A. GY-61 Accelerometer (ADXL335)

Parameter	Specification
Sensor Type	3-Axis Analog Accelerometer
Measurement Range	±3 g
Operating Voltage	1.8 – 3.6 V
Output Type	Analog (X, Y, Z)
Power Consumption	~350 µA
Datasheet	ADXL335 Datasheet

B. Heart Rate Sensor (MAX30100 / Pulse Sensor)

Parameter	Specification
Sensor Type	Optical Heart Rate + SpO_2
Operating Voltage	1.8 – 3.3 V (logic), 5 V (supply)
Communication	I^2C Interface
Features	Integrated LEDs & Photodiode
Applications	Heart rate & oxygen monitoring
Datasheet	MAX30100 Datasheet

C. Buzzer Module

Parameter	Specification
Type	Active Buzzer
Operating Voltage	3.3 – 5 V
Drive Mode	ON/OFF via GPIO
Sound Frequency	~2 kHz
Applications	Alert / Notification
Datasheet	Active Buzzer Datasheet

D. 16×2 LCD Display (with I²C Backpack)

Parameter	Specification
Display Format	16 Characters × 2 Lines
Controller IC	HD44780
Interface	I²C (via PCF8574)
Operating Voltage	5 V
Character Size	5 × 8 pixel matrix
Datasheet	HD44780 Datasheet