ASHESI UNIVERSITY

AN IoT FALL DETECTION AND ALERT SYSTEM FOR ELDERLY PERSONS WITH STROKE AND HEART ATTACK

CAPSTONE PROJECT

BSc Electrical and Electronics Engineering

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CAPSTONE PROJECT

Capstone Project submitted to the Department of Engineering, Ashesi University in partial fulfillment of the requirements for the award of Bachelor of Science degree in Electrical and Electronics Engineering.

Sharhan Alhassan Mohammed

2020

DECLARATION

I hereby declare that this capstone is the result of my original work and that no part of it has been presented for another degree in this university or elsewhere

Candidate's Signature:

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Candidate's Name:

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Date:

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I hereby declare that the preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of the capstone laid down by Ashesi University.

Supervisor's Signature:

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Supervisor's Name:

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Date:

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Acknowledgments

I extend my sincere appreciation to the Almighty God who gave me life and perseverance to finish this project. Also, to my supervisor Dr. Elena Rosca, whose supervision, guidance, and constant motivation supported me to deliver this project that meets all academic standards. My final acknowledgment to the entire Engineering faculty who helped me in diverse ways with knowledge and resources over the past four years of my bachelor's degree.

ABSTRACT

Abrupt falling of the aged population is a rising concern among other chronic sicknesses faced by older people in the world. Elderly patients are disposed to falling abruptly due to heart-related diseases, muscle weakness, high blood pressure, and balance-related diseases such as labyrinthitis – inflammation of the delicate balance regulating parts of the ear. This project focuses on the design and development of simple, low-cost fall detection, and smart alert system. The system detects the fall of a patient using the device's gyroscopes and accelerometers to send an alert message via mail to the caretaker for immediate intervention. The device also possesses a panic push button that can be used by the patient to call for urgent help. The device's buzzer is used to make an alert sound for caretakers who are around the patient's vicinity to respond urgently. Data collected from the device are stored in a database and further aggregated to give the patient's fall history in a web application. The web application displays the patient's fall history by showing the patient's name, age, state, time of fall, and their condition.

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LIST OF ABBREVIATIONS

UN – United Nations

IoT – Internet of things

GPS – Global Positioning System

SGPS/GPS – General Packet Radio Service and Global Positioning System

TB – Tuberculosis

WHO – World Health Organization

MOH – Ministry of Health

NCD – Noncommunicable disease

BAN – Body Area Network

EKG – Electrocardiogram

PCB – Printed Circuit Board

LED – Light emitting diode

I2C – Inter-Integrated Circuit

SPI – Serial Peripheral Interface

P2P – Point to Point

ISM – industrial, Scientific and Medical

MEMS – Micro Electro-Mechanical Systems

SOC – System-on-a-Chip

TCP – Transmission control protocol

UDP – User datagram protocol

HTTP – Hypertext transfer protocol

SMTP – Simple Mail Transfer Protocol

PHP – Hypertext Preprocessor

MAE – Mean absolute error

WLAN – Wireless local-area network

CHAPTER 1: Introduction

1.1 Background

The rapid growth of the aged population has caused an equivalent demand for health care services. According to the United Nations (UN) in its 2017 report of 'World Population Ageing,' the global population of the aged community of 60 years or over numbered nine-hundred and sixty-two million in 2017 [1]. This number is more than twice as large as the number that was recorded in 1980 when the population stood at three hundred and eighty-two million. Future projections by the UN indicates that this number would double by 2050 when the number would reach nearly 2.1 billion [1]. With this rapid growth of the aged population, developed countries are keen on maximizing the advancement of technology to address the problems that come with this aged population explosion. Older people are usually faced with unique challenges that come with varied complexities in solving these problems. Critical health issues such as chronic illness, sleeping disorders, falling, cardiac conditions, and inadequate means of maintaining them in independent-living situations call for immediate intervention to address these problems [2] [3]. With the emergence of technologies such as the internet of things (IoT), GPS services, phone applications, virtual/robot assistants, and implants, health care delivery in developed regions has seen drastic improvements. Aside from governmental and federal waivered-health care delivery systems, wearable technologies have emerged as another alternative that seeks to penetrate and add value to the healthcare industry. Wearable technologies have evolved in many forms; smart clothing, smartphones, smart glasses, SGPS/GPRS body control, and smart bracelets [4]. Developed countries have already adopted this technology into their healthcare delivery system. An integration of low-cost sensors with already existing microcontroller units will efficiently create an effective monitoring system that could easily be worn by a patient. With an embedded communication module, it will send data to caretakers via a web application to monitor the state of the patient. The emergence of the Internet of Things (IoT) has played a key role in the health care industry when it comes

to wearable technology. IoT solely deals with a system of interconnected computing devices, mechanical and digital machines, objects, and the vast amount of inanimate items that are provided with a unique identifier network connectivity that enables some physical components to collect and exchange data over the internet [4]. The connection of physical objects is supported by embedded technology for data communication and sensors to interact with both internal and external object states and the environment [5].

1.2 Problem Definition

The UN estimated that two-thirds of the world's population are living in developing regions [6]. By 2050, it is expected that eight in ten of the world's older persons would be living in developing areas [6]. A middle-income country like Ghana will contribute to the aged population of the UN's projected growth of older people. The doctor to patient ratio in Ghana currently stands at one doctor to eight thousand patients [7]. These statistics fall short to the World Health Organization's requirement of a ratio of one doctor is to one thousand patients. This means that more people in Ghana would not be able to access physicians to cater to their healthcare needs. Also, the general public health of Ghana is plagued with a high prevalence of infectious diseases such as tuberculosis (TB), malaria, HIV/Aids, and diarrhea as well as a rising incidence of noncommunicable diseases such as cancers, cardiovascular diseases, diabetes mellitus, respiratory disease, and sickle cell diseases [8]. The ministry of health (MOH) has identified the four Noncommunicable Diseases (NCD); cardiovascular disease, diabetes, cancers, and chronic respiratory diseases, and drafted a national policy to focus on their prevention and control. Although the National Health Insurance Scheme (NHIS) was introduced to cater to some of the NCD's inpatient and outpatient services, it failed to achieve one of its core aims; to meet the health needs of the poorest members of the society. According to the National Development Planning Commission [9], a survey taken in 2008 found out that fewer than 30% of those in the lowest socio-economic quintile were members of the scheme, compared with over 60% of the wealthiest. The main reason given for not belonging to the scheme was affordability [9]. The general problem of inadequate health care in Ghana is worst for the older generation who usually rely on family and friends to help them take care of their health needs. Aging-related sicknesses such as sudden rise in body temperature, blood pressure issues, falling, and cardiac conditions, instead, make the situation of the aged population worse. Unlike older people, the youth could still afford to endure the long ques and waiting time at hospitals and clinics. Among the numerous pressing issues that the aged population face is sudden falling. Some common reasons why older people are more susceptible to falling are chronic health conditions such as heart diseases, dementia, and low blood pressure. These can cause dizziness, impairments such as poor vision or muscle weakness, as well as other chronic illnesses that can affect the patient's balance, such as labyrinthitis – inflammation of the delicate balance regulating parts of the ear [10]. The outlined causes mentioned above, coupled with the personal experience I have with my grandmother, serve as the motivation for this project to design and develop a wearable technology that would focus on monitoring the state of a patient. The device is a fall detection IoT technology that would employ the use of accelerometer and gyroscope to monitor the patient's movement and balance and use an algorithm to measure a set threshold to determine if the patient has fallen or not. Patients would also have the ability to send a warning note to caretakers or primary care providers by pressing an emergency button. The button feature is useful for sudden heart attacks and stroke, where the patient would still have the ability to press the button to call for help. The caretaker or primary care provider via an urgent mail can receive queries from a patient and respond to that effect immediately. The caretaker can also visualize a fall history of the patient on a web application

1.3 Project Objectives

This project seeks to design and develop a device that can detect the state of an elderly patient. With the use of a robust algorithm, a sensor would determine whether the patient has fallen or not and communicate the data to a caretaker or primary care provider. A message in the form of an email is sent immediately to the caretaker who would have access to this information via a web application. The design process, planning, execution, and deployment of this project have several objectives that ought to be realized. These objectives are listed below:

1. **Development of a portable hardware system with sensors and integrated components**
    a. This objective will guide the design of the hardware system of this project to have all required components to fit on a sizeable printed circuit board (PCB). The hardware part of the project will feature the microcontroller unit, a communication module, a sensor, pushbutton, resistors, and a buzzer.
2. **Development of user-friendly and responsive web application to monitor the state of the patient.**
    a. This objective will guide the design process of this project to implement a web application that will display information taken from a database and indicate when thresholds are crossed from the users' end. The web application will also display records of the number of times a patient had fallen when a pushbutton pressed, or a false positive recorded.

CHAPTER 2: Literature Review

The adoption of wearable devices in the developed world is fast becoming an alternative to the improvement of efficiency in health care delivery. Wearable technologies come in different forms and types. They come in the form of implantable, smartwatches, smart jewelry, fitness trackers, smart clothing, and head-mounted displays [11].

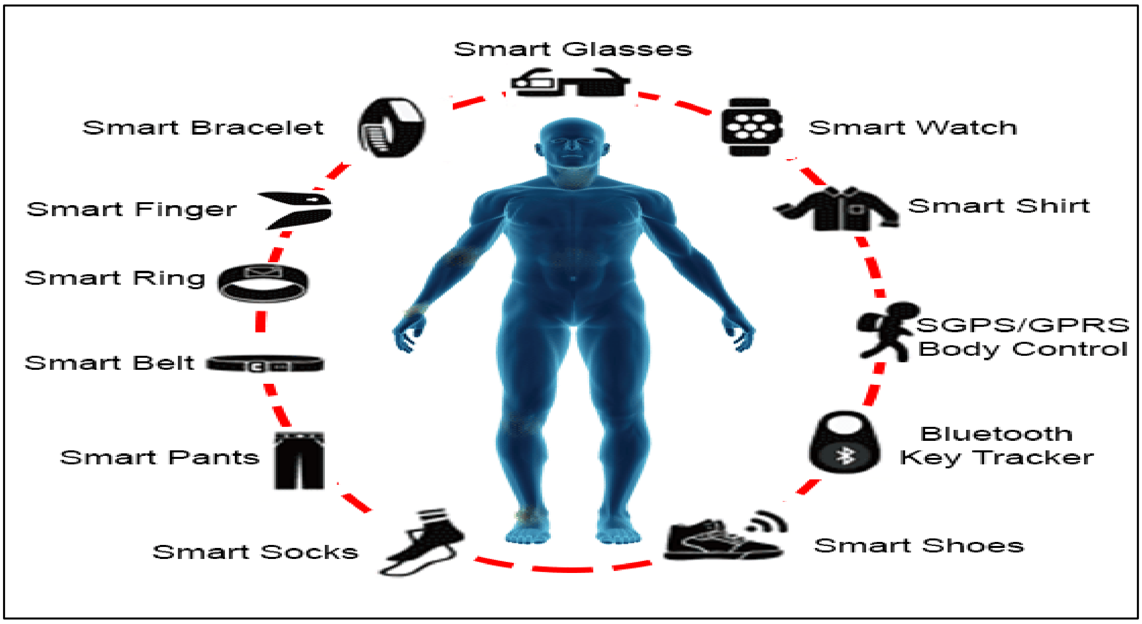


Figure 1. 1 List of some wearable technologies

Implantable among the different types of wearable technologies are devices that users carry with them all the time. Such devices could be implanted either through surgical operations, tattoos, defibrillators, or pacemakers [12]. Smartwatches are instead the most commonly known form of wearable technology. When synchronized with smartphones, real-time information, and vital parameters of a patient can be recorded and sent to a device. Existing works often focus on people who have a problem with independent living, such as older people with chronic diseases and age-related illnesses. For instance, Varatharajan et [13] presents a dynamic time warping algorithm-based early detection of Alzheimer’s disease using wearable sensors while Romero et al. [14] describe a system that diagnoses and monitor Parkinson’s disease. Nonetheless, it is impossible to develop a one-size-fits-all application that can address all the needs of various individuals; hence, several directions have been explored in this project, as demonstrated in the following paragraphs.

Mobile phones to personal healthcare: In the last couple of years, smartphones have become the centerpiece or social networking, surveillance monitoring, environmental analysis, weather, transportation, healthcare, and wellbeing. Smartphones are revolutionizing the core fabric of the economic and social sectors in the future. Today’s smartphones are embedded with a more vibrant range of sensor units such as accelerometer, microphone, gyroscope, digital compass, ambient light, and GPS. Besides, the fusion of faster communication modules such as 3G/4G/5G, Bluetooth radio, and WIFI enable networking and information sharing with other end terminals [15]. In recent years, research on smartphone-based healthcare systems have been attracting increasing attention in academia and the IoT industry with a countless number of applications already engineered.

Mobile phones with GPS: An integrated GPS in smartphones for tracking purposes is a critical area that has been explored and harnessed to develop applications. For instance, Pigadas et al. [11] [16] present an Android phone-based application that gathers GPS data, accelerometer information, and data from several wearable sensors. The data is transmitted to a remote base station. When hazardous situations are detected, it sends notifications for quick intervention.

Mobile phone with wearable sensors: In recent times, mobile phones serve as a gateway for gathering sensor signals, with or without processing, and sent them to an associated medical center or data processing center. Another area is the Body Area Network (BAN), which composes of series of interconnected wearable sensing devices to collect vital biomedical parameters such as body temperature, Electrocardiogram (EKG), and blood pressure, among many others. Such sensors use various communication protocols like Bluetooth, ZigBee, and WiFi. However, sensor nodes are often designed with limited memory and computing capacity;

thus, sensor data are typically transmitted to another processing server, where a mobile phone is commonly adopted [13].

Physical activity recognition with wearables: The idea of adopting sensors and communication protocols for activity monitoring and recognition has become prevalent for the last two decades [13] [17] [18]. Accelerometers and gyroscopes are among some of the sensors that capture the movement data of different parts of the body. Several motions can be determined by utilizing two-axis or three-axis accelerometer data such as standing, walking, running, sitting, cycling, and stretching. Another widespread use of accelerometer data is fall detection. Fall detection is essential for elderly health monitoring. Different systems of fall detection have been proposed by [13] [19] [20]. Berke et al. used an integrated feature for accelerometer-based activity recognition, while Catal et al. used an ensemble of classifiers or accelerometer-based activity recognition.

2.1 IoT Architecture

The concept of IoT, which describes the interconnection of smart devices with the physical environment to exchange data, necessitates the establishment of a structure and topology for the interoperability of devices. The fundamental block of every IoT technology includes several layers. *Figure 2.1* represents an overall framework for embedding IoT technologies for personalized healthcare.

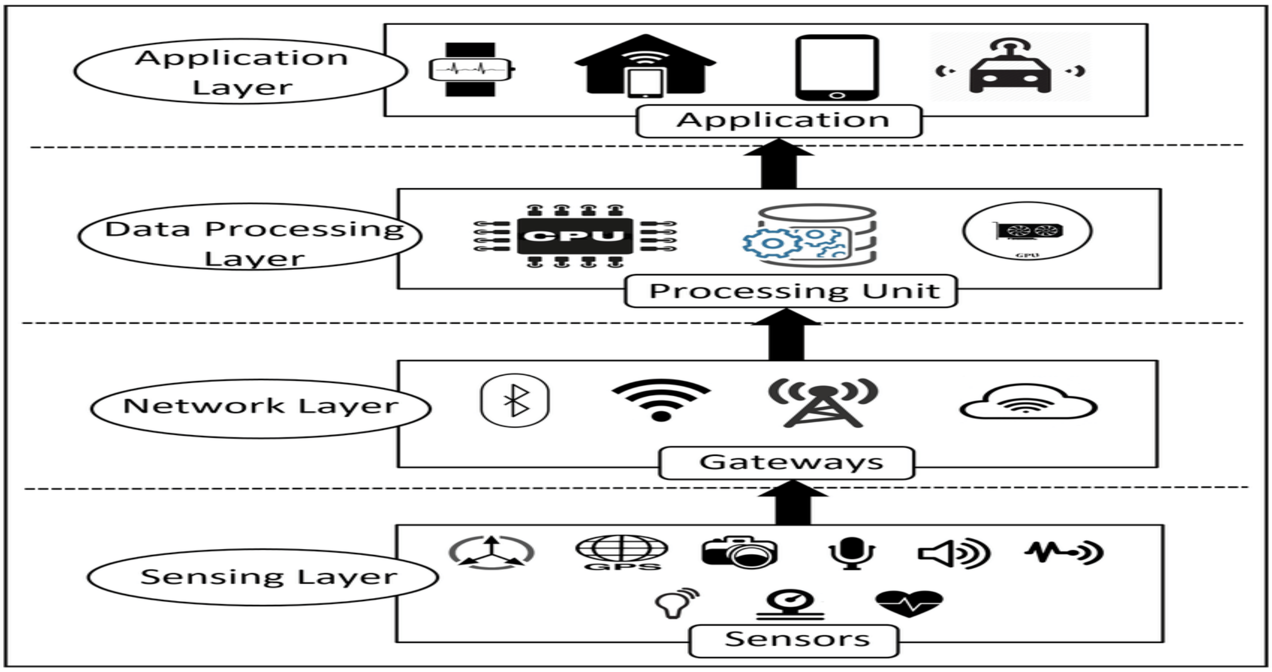


Figure 2. 1 IoT Architecture Layers and Components

Source: Adapted from Aksu, H. (2018). A Survey on Sensor-based Threats to IoT Devices and Applications [21]

Sensing Layer: The sensing layer, which is sometimes referred to as the ‘Things’ in the ‘Internet of Things’ are a range of smart devices and actuators. *Table 2.1* shows the different types of sensors and their description found in the sensing layer of the IoT architecture.

Sensor Type	Sensor Name	Description
Motion	Gyroscope	Measures rate change of angular momentum in all three axes
	Accelerometer	Measures changes in acceleration forces along x, y, and z-axis
Environment sensors	Camera	Deals with light intensity, device ambiance etc., to capture pictures and videos
	Light sensor	A photodiode which changes characteristics with a change in light intensity
	Temperature sensor	Measures temperature of device and ambient temperature
	Barometer	Measures a peripheral’s pressure
	Proximity sensor	Detects the presence of nearby objects
	Audio sensor	The microphone detects acoustic signal whiles speaker outputs it

Position sensors	Magnetic sensor	Measures device's magnetic field with respect to earth's magnetic field
	GPS	Infers device's location using a satellite's signal

Table 2. 1: Some of the sensors available in the IoT sensing layer

These sensors in the sensing are responsible for interfacing with the physical environment and carry data from their environments. More sensors used to carry out such processes to achieve more diverse data to measure different parameters of the physical environment. The connection of sensors usually requires sensor hub, which uses one of these transport mechanisms; Inter-Integrated Circuit (I2C) or Serial Peripheral Interface (SPI) for data to be communicated between sensors and applications [21].

Network Layer:

The network layer, which serves as the gateway between sensors' data and other layers, acts as a communication channel to transfer data to other connected peripherals in the architecture. In this layer, a wide variety of communication technologies are available to allow the flow of data among different sub-layers and devices. A choice of a type of communication technology for an IoT device is made from salient factors such as range, power consumption, frequency band, processing power, cost, and topology. *Table 2.3* shows the architectural considerations of communication technologies.

Technology	**Type and Range**
Ethernet	Wired, 100m maximum
WiFi (2.4 GHz, 5 GHz)	Wireless, 100m (multipoint) to a few kilometers (P2P)
802.11ah (Halo W, WiFi in sub-1 GHz	Wireless, 1.5 km (multipoint), 10 km (P2P)
WiMAX (802.16)	Wireless, several kilometers (last mile), up to 50km
Cellular (LTE)	Wireless, several kilometers

Table 2. 2: Different communication technologies and their ranges

There are also other few other wireless technologies for short-range communication such as Infrared Data Association (IrDA), Near field Communication (NFC), Radio Frequency

Identification (RFID), Ultra-Wide Band (UWB). Bluetooth is a popular technology that is popular for its low power. It uses the 2.4 GHz frequency band in the industrial, scientific, and medical (ISM) radio spectrum and transmits signals [22] [23]. Zigbee is another technology that is standard wireless for low power and low-cost communication within a short-range. It operates in the unlicensed 2.4GHz (worldwide), 915MHz (Americas and Australia), and 868MHz (Europe) frequency bands of the ISM spectrum and transmits data over sixteen, ten, and one channel, respectively [23]. *Table 2.4* gives a summary of wireless communication technologies.

Wireless technology	Frequency band	Range	Data rate	Power consumption	Security	Modulation
RFID	13.56MHz, 860-960MHz	0 – 3m	640kbps	200 mW	N/A	ASK, PSK, FSK
Bluetooth	2.4 – 2.5GHz	1–100m	1 – 3Mbps	25 – 100mW	56-128 bit key	GFSK
BLE	2.4 – 2.5GHz	1-100m	1Mbps	10mW	128-bit AES	GFSK
Zigbee	2.4 – 2.5GHz	10-100m	250kbps	35mW	128-bit key	OQPSK, BPSK
IrDA	38kHz	10cm	1Gbps	15mW	AES	ASK

Table 2. 3: *Some key features of currently available wireless technologies*

Data Processing Layer:

The data processing layer is the layer that houses the central data processing units of every IoT device. In most IoT devices, this layer saves and analyzes results to improve the user experience. This unit also functions as a sharing point of data with other connected devices via the network layer.

Application Layer:

The application layer is the last layer which implements and show the results of data processing from the data processing layer. It offers a user-friendly interaction to execute various tasks for the users. The application layer can go as far as performing data analytics of sensor data to create patterns that improve users' ability to maximize data utilization.

In an age of technological advancement in IoT, the design, development, and adoption of health care wearable technology are now beginning to penetrate Ghana, most of West Africa, and other low to middle-income countries. The absence of such technology in the presence of a low doctor to patient ratio and little coverage of NHIS establishes the need for a low-cost smart e-care fall detection system. The system will help monitor the state and condition of older people and communicate changes to a caretaker or associated primary care provider.

CHAPTER 3: Design

3.1 Requirements Specifications

The design, development, and successful implementation of every technology rely on a specific metric to gauge the achievement rate of the technology. The requirement specification is the key metric that outlines and guides the technology under study or development. The two major requirement specifications for this project are user requirement specification and system requirement specification. These two major requirements serve as the foundation for the design and development process of the proposed solution to make a wearable fall detection system for elderly patients. The core functionality of the system will align with the user requirement and system requirement specifications.

3.1.1 User Requirement

The user requirement is the set of all needs from the users' point of view that would determine the success of the proposed solution. At the end of the development of the system, the overall functionality of the system would be juxtaposed with the user requirement to map the device's outcome, and the users' expectations. This project has mainly two users; those who wear the device (patient) and the other who have access to the patients' data through a web application (caretaker or primary care provider). As such, the following serves as the user requirement from the users' perspective.

The patient expects the system to:

1. Fit as a wearable device that is comfortable with body contact.
2. Have easy access to device push buttons.
3. Be portable for the user
4. Be safe and user-friendly

The caretaker or primary care provider expects the system to:

1. Collect data on the balance of the patient

2. Store the data on a database
3. Receive a notification – an email – on the patient's state – whether they fell or not
4. Received notification on when an emergency push button is pressed.
5. Access analytics on data about the number of times the patient fell or pressed the push button.

3.1.2 System Requirement

The system requirement describes the operational and performance of the hardware system of the proposed project that aligns with the expectations of the user the requirement. The following description describes the system requirement of the project:

1. The hardware system must have the required sensors for measuring the acceleration and angle of the patient to detect their balance efficiently. The sensor must have a low error rate to collect such data for transmission
2. An efficient algorithm that goes with the threshold-based detection system to check whether a set parameter is above a set threshold value within a time interval.
3. The system should be energy efficient and rechargeable. The user (patient) should have the ability to plug and charge with a usual USB charger
4. The device must be able to send sensor data to a database for the accessible collection, analysis, and interpretation of a patient's balance and health status.
5. The system should be portable; thus, easy to be carried or worn around by the patient. Because the patient is old, this is crucial not to inconvenience them with a heavy-weight device

3.2 Design Specifications

This section of the project aims to combine the user requirements and system requirements stated earlier. The aim is to arrive at a technology that fits both of their expectations. The users who are the wearer (patient) and monitor (caretaker) both form a crucial part of the design architecture. The hardware aspect of the device will be in contact with the patient, whereas the software aspect is accessed by the caretaker or primary care provider.

3.2.1 System Design Architecture

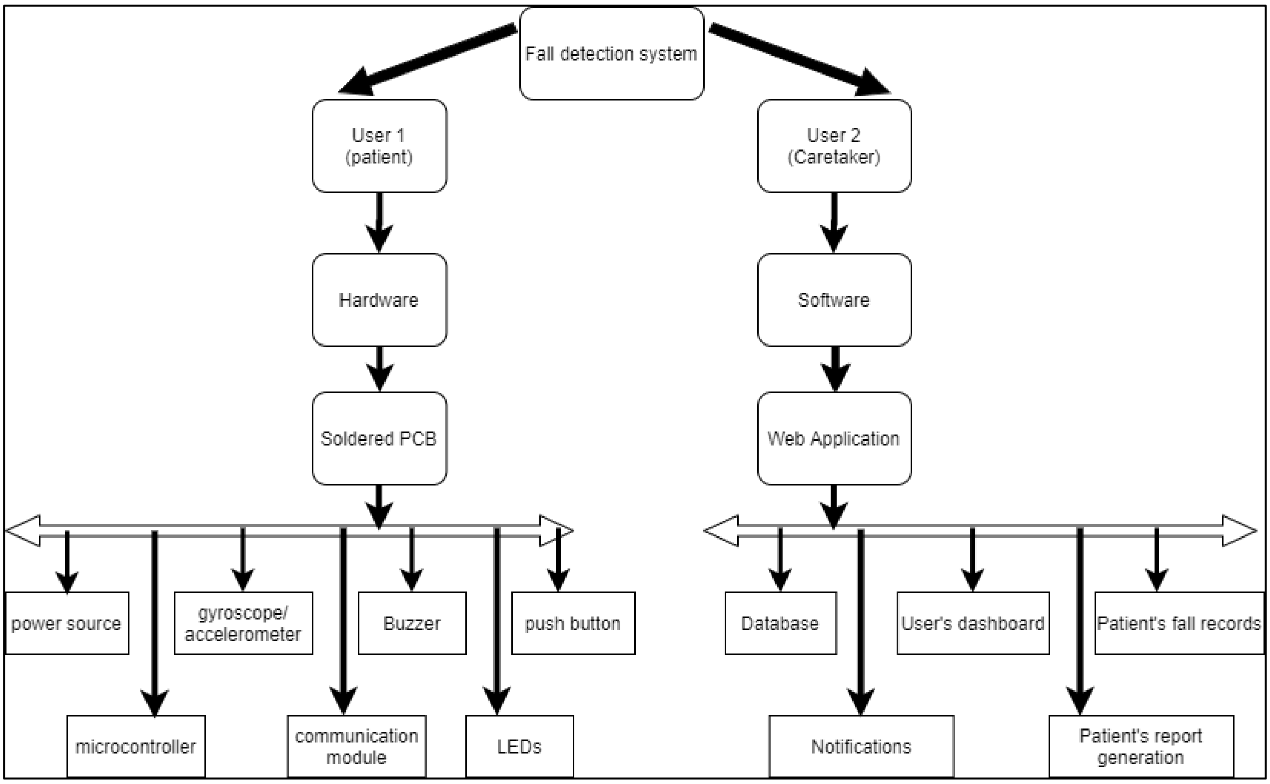


Figure 3. 1 Design architecture of a fall detection system.

The above system design architecture for fall detection shows all the indispensable part of the project that is crucial for the design implementation. The hardware part comes in bodily contact with the wearer. The hardware includes all the physical components and devices that come together to fulfill the system requirement. All relevant components are soldered onto a printed circuit board (PCB). A PCB mechanically supports and electrically connects electrical or electronics components using conductive pads, tracks, and other features etched from one or more sheet layers of copper laminated onto and between sheet layers of a non-conductive substrate. The system derives its power source from a rechargeable battery. The rechargeable battery can be charged for subsequent usage using a breakout charging board. The microcontroller is the main processing unit of the device, which contains memory, programmable input/output peripherals as well as a processor. It does the computation of the algorithm that uses acceleration in the x, y, and z-axis together with the gyroscope x, y, and z-axis to compare with the stipulated threshold to detect balance. The sensor for measurement consists of a 3-axis accelerometer and a 3-axis gyroscope inside it. This helps to measure acceleration, orientation, displacement, and motion-related parameter of the system. The communication module in the devices is responsible for sending the sensor's data to the cloud. A database fetches the data from the cloud for display. The buzzer is another electrical device that makes a buzzing noise to make signals when electrical current passes through it. The buzzer is synchronized the light-emitting diode (LED). Both the buzzer and LED are supplied power from the same output peripheral from the microcontroller to send sound and light signals, respectively. A pushbutton is electrically connected with other components on the PCB to serve as a manual route to send a message to the caretaker. It is useful to initiate this process when there is a situation like a heart attack or stroke.

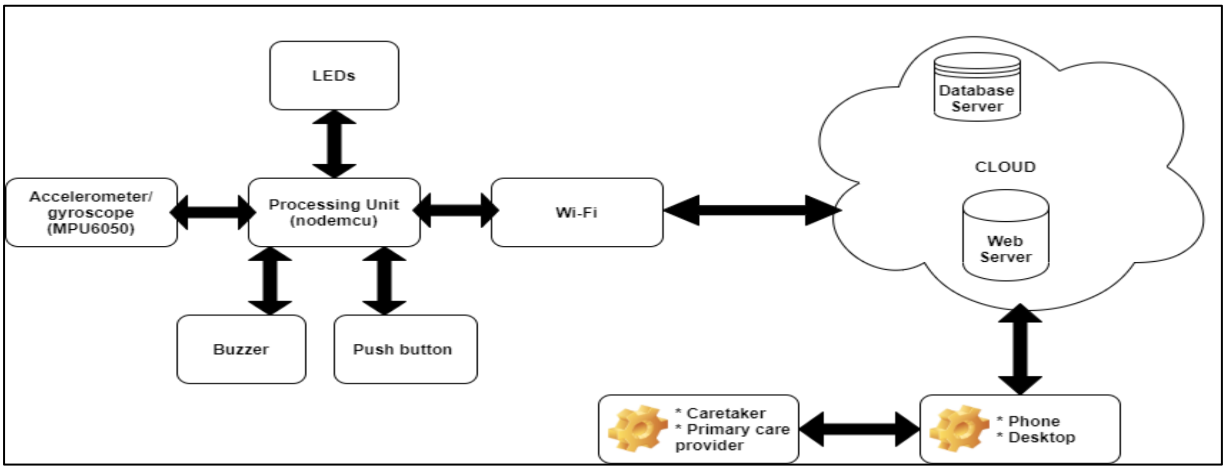


Figure 3. 2 General architecture of the fall detection system

The software component of the system deals with how the information gathered from sensors is stored in the MYSQL database and extracted with Hypertext Preprocessor (PHP) into a dashboard, which serves as the web application. The web application would have several features that highlight security, efficiency, and usability. A key aspect of the web application is to perform user authentication. This feature does that by verifying an active human-to-machine transfer of credentials required for a confirmation to grant access to the page. Unknown users who cannot be verified or recognized would be locked out of the system to secure users' data from intruders. If users are successfully logged in, they will have the chance to fill out a portion with their email addresses and phone numbers. This information would be used as the means of sending notifications to them when a fall is detected or when the emergency push button is pressed on the hardware device. The web application displays records of the status, condition, and biodata of the patient. This information can be used to determine the total number of falls of the patient in a week, month, or entire year.

3.2.2 Design Components

The design components of this project must be designed to satisfy all relevant aspects of the product requirements and all design structures of the product architecture. Pugh matrix is used in determining which items are potential components to be used for the design. The Pugh matrix is a scoring matrix for concept selection in which options are assigned scores relative to criteria. This matrix is used on salient components such as microcontroller unit, accelerometer/gyroscope sensor, and communication module for the design process.

3.2.2.1 MPU6050 sensor

The GY – 521 MPU6050 is a micro-electro-mechanical system (MEMS) that consists of a 3-axis accelerometer and a 3-axis Gyroscope inside it. This 6-point axis helps to measure acceleration, orientation, velocity, displacement, and many other motion-related parameters of a system. *Table 3.3* below shows the choice of selection for the GY-521 sensor.

		Pugh Chart									
Criteria	**Baseline**	**Weight**	**A**	**A1**	**B**	**B1**	**C**	**C1**	**D**	**D1**	
	BMP180		**DSP310**		**GY-521**		**GY-91**		**BME280**		
Availability	**0**	**7**	**0**	**0**	**1**	**7**	**0**	**0**	**-1**	**-7**	
Power consumption	**0**	**5**	**1**	**5**	**-1**	**-5**	**-1**	**-5**	**0**	**0**	
Efficiency	**0**	**3**	**1**	**3**	**1**	**3**	**1**	**3**	**1**	**3**	
Cost	**0**	**6**	**-1**	**-6**	**0**	**0**	**0**	**0**	**1**	**6**	
Complexity	**0**	**2**	**-1**	**-2**	**0**	**0**	**1**	**2**	**-1**	**-2**	
Coverage Area	**0**	**4**	**1**	**4**	**1**	**4**	**1**	**4**	**1**	**4**	
Safe	**0**	**1**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	
				0		**0**		**0**		**0**	
				0		**0**		**0**		**0**	
Total				**4**		**10**		**5**		**5**	
Chosen									**GY-521**		

Table 3. 1 *Some key features of currently available wireless technologies*

Its availability, low power consumption, and cost were the compelling factors that influenced the choice of selection. The axes of this sensor can give output through the 16-bit analog-to-digital (ADC) converter on the device.

Figure 3. 3 *MPU6050 GY-521 accelerometer/gyroscope sensor*

3.2.2.2 <u>ESP8266 (NodeMCU)</u>

The ESP8266 is Espressif's low-cost dual-purpose microcontroller unit and WiFi communication module, also referred to as the Node microcontroller unit (NodeMCU). The device delivers a highly integrated WiFi inexpensive system-on-a-chip (SOC) solution to meet projects that demand efficient power usage and reliable performance in the IoT industry.

Figure 3. 4 ESP8266 NodeMCU

The NodeMCU is an open-source firmware that runs on the ESP8266 WiFi SOC from Espressif systems. It has an operating voltage of 2.5V-3.6V, 802.11 b/g/n (HT20) WiFi, and a frequency range of 2.4 GHz-2.5 GHz, IPv4, and TCP/UDP/HTTP network protocols [24].

		Pugh Chart									
Criteria	**Baseline**	**Weight**	**A**	**A1**	**B**	**B1**	**C**	**C1**	**D**	**D1**	
	Zigbee		**GSM module**		**Esp8266 WiFi**		**LoraWan**		**LTE module**		
Availability	**0**	**7**	**1**	**7**	**1**	**7**	**1**	**7**	**0**	**0**	
Power consumption	**0**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**-1**	**-5**	
Efficiency	**0**	**3**	**-1**	**-3**	**1**	**3**	**1**	**3**	**1**	**3**	
Cost	**0**	**6**	**0**	**0**	**0**	**0**	**-1**	**-6**	**-1**	**-6**	
Complexity	**0**	**2**	**1**	**2**	**-1**	**-2**	**1**	**2**	**-1**	**-2**	
Coverage Area	**0**	**4**	**0**	**0**	**1**	**4**	**1**	**4**	**1**	**4**	
Safe	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	
				0		**0**		**0**		**0**	
				0		**0**		**0**		**0**	
Total				**7**		**13**		**11**		**-6**	
Chosen									**ESP8266 WiFi module**		

Table 3. 2: Pugh chart for microcontroller selection.

Availability and cost were some of the factors that influenced the choice of selection. Also, the fact that ESP8266 is a dual-purpose board with both a chip for processing and a WiFi communication module for data transmission was another factor that influenced the choice of this device. The size of the proposed device matters a lot because it will be crucial to have a small and portable device that can be carried around by an elderly patient. This feature is one of the key users' requirements that ought to be met in the design process.

3.2.2.3 Rechargeable LiPo battery

A 3.7V Lithium polymer rechargeable battery will power the proposed design. It has a nominal capacity of 750mAh, a charge temperature of 0~45 degrees Celcius, the maximum charge voltage of 4.2V with a size ratio of 5.2 * 34.5 * 55mm. This battery supplies power to the ESP8266 module for data processing as well as the power to the GY-521 sensor

Figure 3. 5: 3.7V LiPo rechargeable battery

3.2.2.4 TP4056 Charging module

The TP4056 is a standalone linear Lithium-ion battery charger module. The module is suitable for portable applications and can work with a wall adapter and USB. It will charge the 3.6v LiPo via a USB cable. It has a programmable charge current of up to 1000mA with a preset voltage of 4.2 with 1.5% accuracy. It has two charge status output pins with a trickle charge threshold of 2.9v. It has Pin 1 for temperature sense input, Pin 2 for constant charge current setting pin, Pin 3 for ground, Pin 4 for Vcc, Pin 5 for battery connection, standby Pin 6, and 7 for open-drain charge status output and Pin 8 for chip enable input.

:

Figure 3. 6: TP4056 charging module

3.2.2.5 <u>Push-Button</u>

The pushbutton is a simple switch mechanism used in completing an electric circuit by allowing current to pass through it. The one used in this project measures 12x12x7.5 mm with a contact rating of 0.05A at 12VDC. In this project, when the patient wants to send a panic message, the pushbutton will be pressed. It would also be used to cancel initiating a notification within a time frame of five seconds when a fall is detected.

Figure 3. 7: Push-button

3.2.2.6 <u>Buzzer</u>

The buzzer used in this project is an electromechanical device that has an alarm device for the confirmation of user input, such as pressing a pushbutton or keystroke. It gives a sound signal by contracting or expanding its ceramic disk when current is applied to it. The function of the buzzer is to provide an alarm signal to alert people around when the patient falls. This mechanism is a secondary alert system to compliment the use of light-emitting diodes to create alerts.

Figure 3. 8: Buzzer

Chapter 4: Design Implementation

4.1 Hardware implementation

This section of the project focuses on the hardware realization of the proposed design. It focuses on the integration of all sensors, actuators, and communication modules to effectively collect data and send it to a database for further storage and analysis. The hardware implementation uses the system requirement as a metric to gauge the design process of all deliverables. It has the TP4056 charging model connected to the 3.6v LiPo battery. The output ports of the charging module are connected to the voltage in (Vin) and Ground (GND) of the ESP8266 NodeMCU. The GY-521 sensor is connected to the NodeMCU by I2C connection using 3v power (3v3), ground (GND), serial data (SDA) for communication, and clock (SCL). The buzzer is connected to pin D7 of the NodeMCU via a resistor to limit the current. An LED is connected to pin D5 of the NodeMCU. The pushbutton is connected to D6. Pin D8 on the NodeMCU is grounded. *Figure 4.2* below shows a pictorial schematic of the various hardware connection using fritzing software.

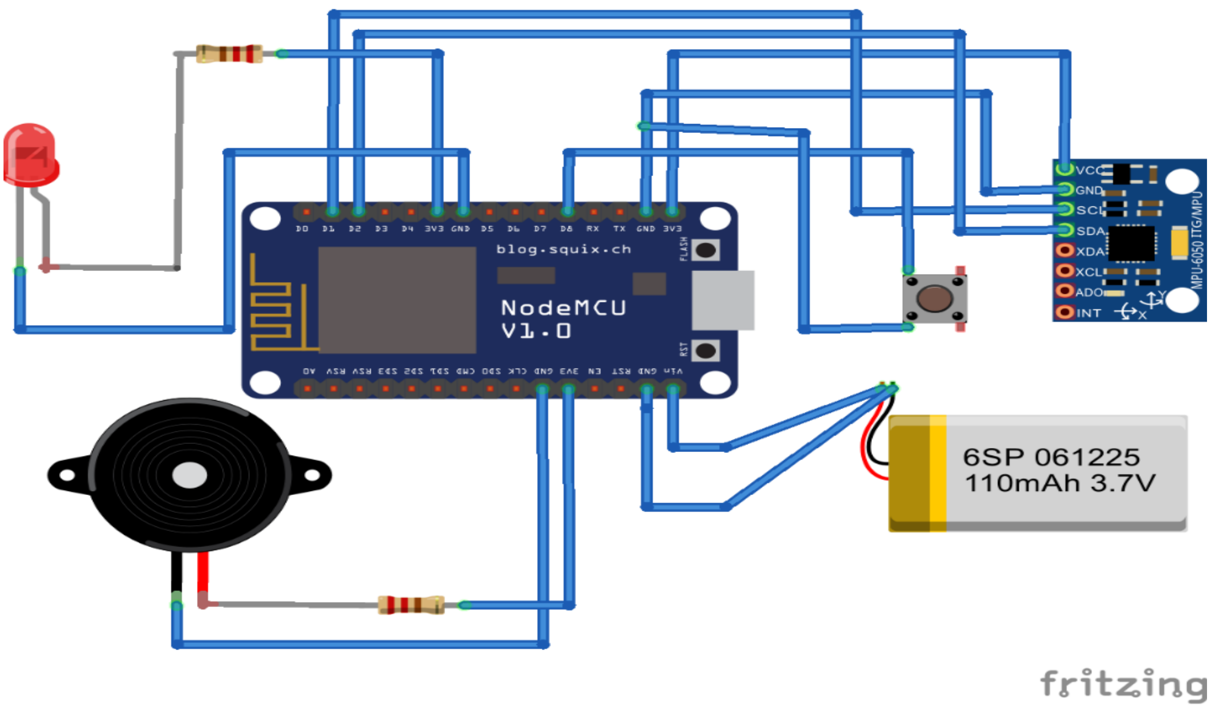


Figure 4. 1: Pictorial schematic connection of the various hardware components

4.1.1 Sensor calibration

The primary sensor used in this project is the MPU6050 GY-521 sensor. This sensor can sometimes be tricky to work with hence the need for it to be calibrated to note the offset values. Calibrating the sensor is a necessary procedure to improve the sensor's performance by removing structural errors. Structural errors are the differences between a measured output and the sensor's expected output. The circuity wiring for the sensor's connection with an Arduino nano is given below:

SCL __ D1

SDA __ D2

VCC __ 3.3V

GND __ GND

The fact that every sensor is different and unique makes it discreet to note the offset values of the sensor used in this project. An MPU6050 specific calibration library is run, and the offset values are recorded from the serial monitor. The expected optimum offsets for the X acceleration, Y acceleration, Z acceleration, X gyroscope, Y gyroscope, and Z gyroscope are recorded as -29, 774, 1591, -95, -115 and 90 respectively.

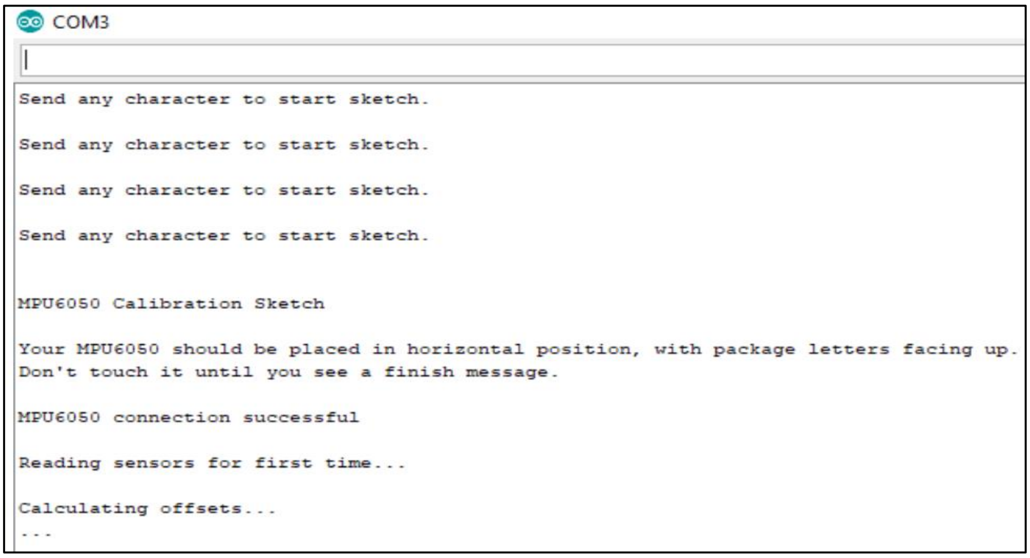


Figure 4. 2: Serial monitor showing the calibration process of the sensor

```
FINISHED!

Sensor readings with offsets:   0       9       16380   0       0       0
Your offsets:   -29     774     1591    -95     -115    90

Data is printed as: acelX acelY acelZ giroX giroY giroZ
Check that your sensor readings are close to 0 0 16384 0 0 0
If calibration was succesful write down your offsets so you can set them in your projects

Soft WDT reset

>>>stack>>>

ctx: cont
sp: 3ffffdf0 end: 3fffffc0 offset: 01b0
3fffffa0:  feefeffe 00000000 3ffee6f8 40202944
3fffffb0:  feefeffe feefeffe 3ffe84fc 40100ea1
<<<stack<<<

 ets Jan  8 2013,rst cause:2, boot mode:(3,6)

load 0x4010f000, len 1392, room 16
```

Figure 4. 3: Printed offset sensor values on the serial monitor of Arduino

4.1.2 Communication model setup

The Nodemcu or ESP8266 used in this project is a dual-purpose board with both a chip for processing and a WiFi communication module for data transmission. The Nodemcu is a station (STA), which makes it connect to any access point (AP) that would act as a hub for other stations. Any device that can connect to a WiFi network is termed as a station. To verify that the Nodemcu works, the WiFi Scan library is run to observe any available networks in the vicinity.

From the Arduino main interface: File -> Examples->ESP8266WiFi->WiFiScan

```
COM3

scan start
scan done
2 networks found
1: VodafoneMobileWiFi-FC0A07 (-77)*
2: me (-26)*

scan start
scan done
2 networks found
1: VodafoneMobileWiFi-FC0A07 (-78)*
2: me (-27)*

scan start
scan done
2 networks found
1: VodafoneMobileWiFi-FC0A07 (-76)*
2: me (-28)*
```

Figure 4. 4: Available networks scanned around the sensor's area

A summary of the working procedure of the Nodemcu when it is connected to an access point is as follows:

1. Nodemcu is powered and connected to all needed peripherals.
2. A router or access point is made available
3. The Nodemcu is connected to the WiFi
4. Values from the MPU6050 are attached to a URL
5. Sensor values by HTTP request send the values to a server and stored in a database
6. An alert message by Simple Mail Transfer Protocol (SMTP) sends an email to the caretaker
7. A success message is returned after the request is made successfully

4.1.3 System powering

The Nodemcu can either be powered with a 3.7V lithium polymer battery or a USB type B cable. For it to be powered with a 3.7 LiPo battery, an additional TP4056 charging peripheral is attached to it to allow the battery to be easily charged.

4.1.4 PCB design and assembling

The printed circuit board (PCB) was designed using the open-source Fritzing software. The software generated the schematic diagram and the PCB of the system.

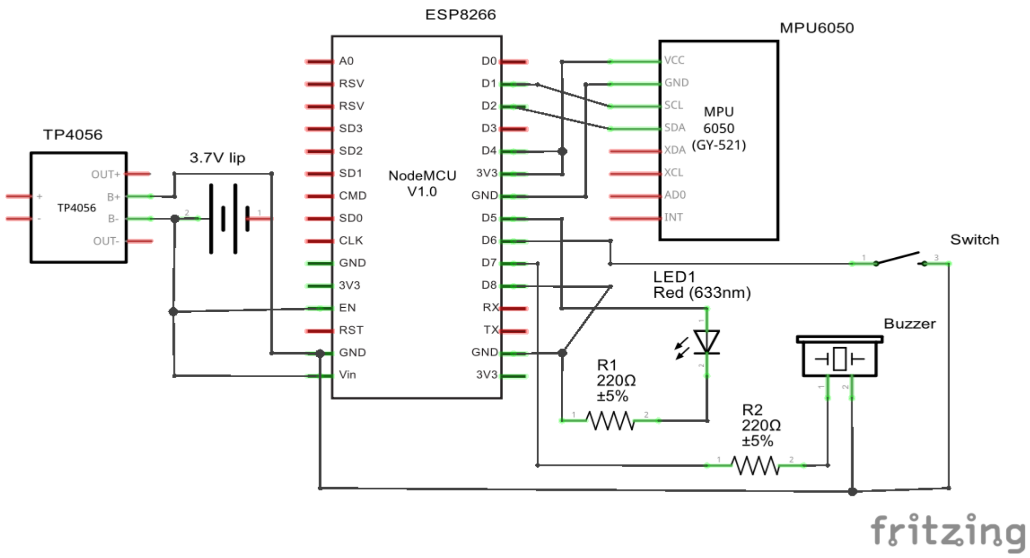


Figure 4. 5: A schematic diagram of the system

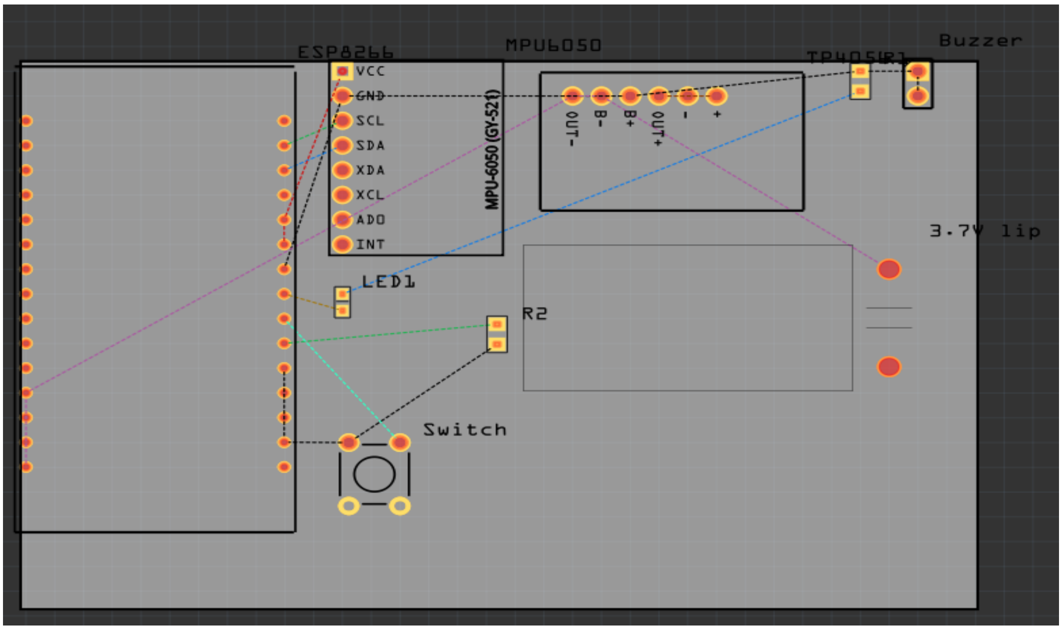


Figure 4. 6: Automatic generated PCB of the system

4.1.5 Soldering and Assembling

After testing all the individual components of the system were working correctly, as shown in chapter 3.2.2, they were assembled and soldered together.

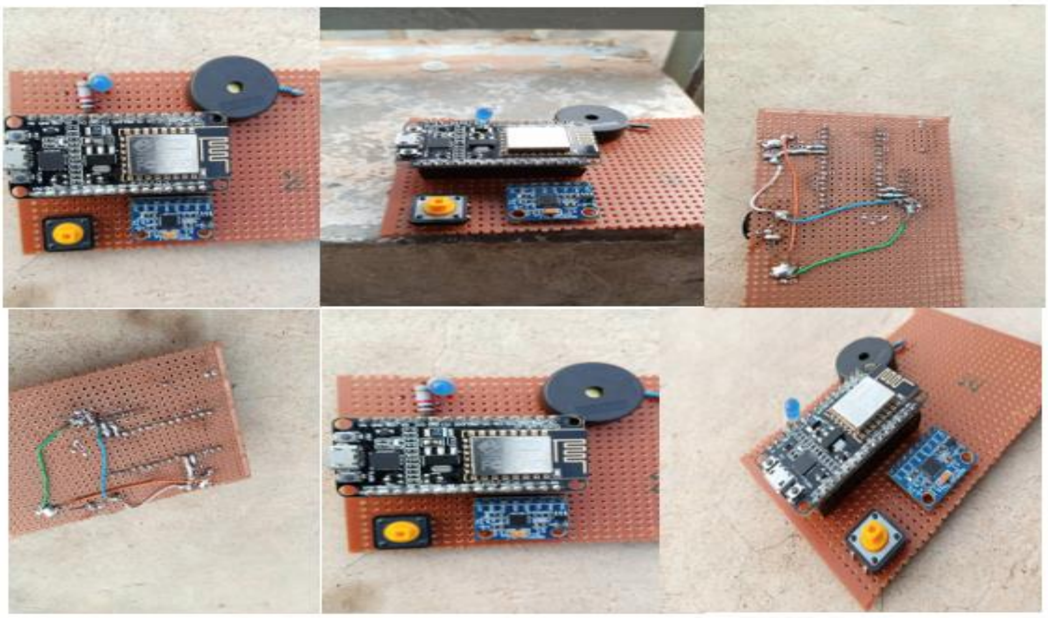


Figure 4. 7: Hardware system showing all integrated components

4.2 Software Implementation

The software implementation of this project deals with the server-side, database management, and software logic of the system's application. This section focuses on the application process of how sensor values are fetched into the database by the HTTP request, an alert message sent to a caretaker via an email, and a web application that displays the information.

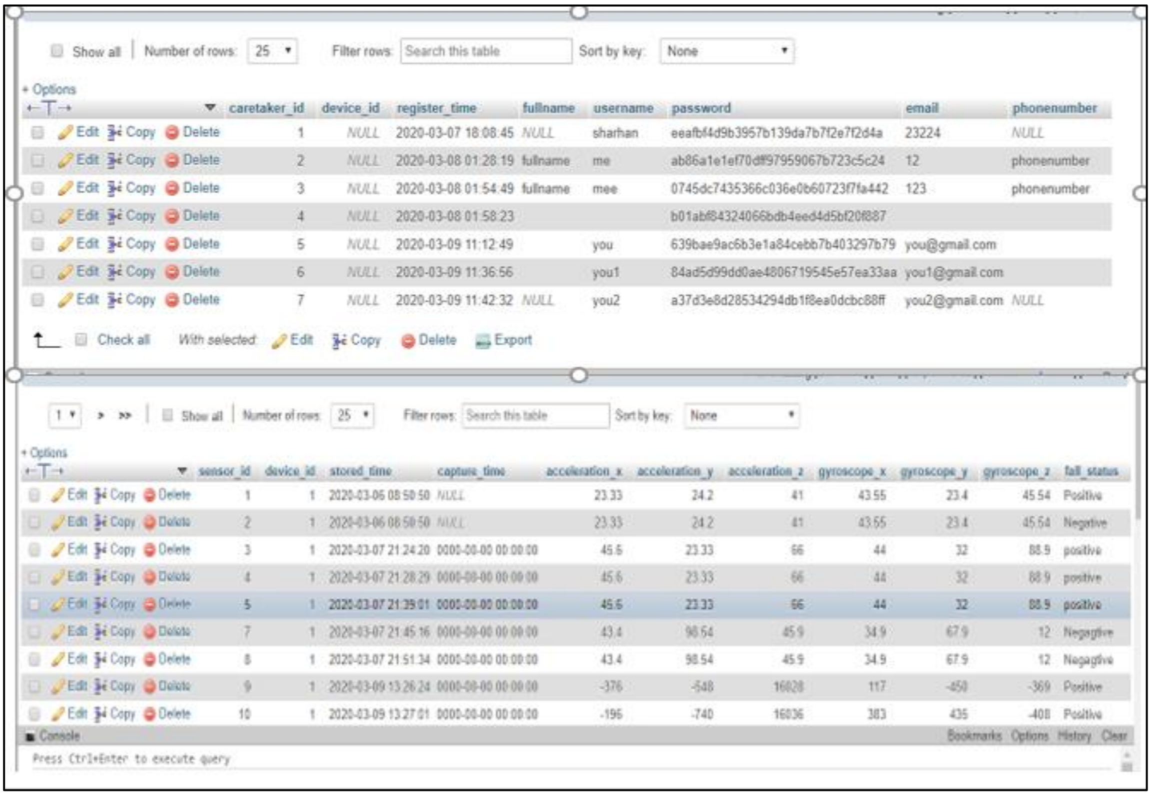
4.2.1 ESP8266 Libraries setup

Special ESP8266 libraries are installed to configure the processor to connect to available networks and allow sensor values to be sent to a remote database via an HTTP request. ESP8266 is added into the *Additional Board Manager URLs* field of the Arduino, and after that, Generic ESP9266 is selected from the *Tools* bar.

4.2.2 Database Setup

Before any sensor values could access and have analytics done on them from the web application, a database needs to be set up to receive the data values. The database has different categories that explain the different sections that would aid data collection and interpretation into useful information. Below is a summary of all the sections available in the database.

1. **Caretaker**: The caretaker is the person responsible for monitoring and taking immediate actions when they receive an email. Some columns available in the database for the caretaker are; *register time, full name, username, password, phone number, and email.* They can, therefore, receive an urgent email when a patient either falls or presses the panic button on the hardware device.
2. **Sensor:** The MPU6050 GY-521 sensor has specific parameters available in the database. Some of the parameters that are recorded are; *stored time, capture time, acceleration x, acceleration y, acceleration z, gyro x, gyro, y, gyro z, and fall status.*



caretaker_id	device_id	register_time	fullname	username	password	email	phonenumber
1	NULL	2020-03-07 18:08:45	NULL	sharhan	eeafbf4d9b3957b139da7b7f2e7f2d4a	23224	NULL
2	NULL	2020-03-08 01:28:19	fullname	me	ab86a1e1ef70df97959067b723c5c24	12	phonenumber
3	NULL	2020-03-08 01:54:49	fullname	mee	0745dc7435366c036e0b60723f7fa442	123	phonenumber
4	NULL	2020-03-08 01:58:23			b01abf84324066bdb4eed4d5bf20f887		
5	NULL	2020-03-09 11:12:49		you	639bae9ac6b3e1a84cebb7b403297b79	you@gmail.com	
6	NULL	2020-03-09 11:36:56		you1	84ad5d99dd0ae4806719545e57ea33aa	you1@gmail.com	
7	NULL	2020-03-09 11:42:32	NULL	you2	a37d3e8d28534294db1f8ea0dcbc88ff	you2@gmail.com	NULL

sensor_id	device_id	stored_time	capture_time	acceleration_x	acceleration_y	acceleration_z	gyroscope_x	gyroscope_y	gyroscope_z	fall_status
1	1	2020-03-06 08:50:50	NULL	23.33	24.2	41	43.55	23.4	45.54	Positive
2	1	2020-03-06 08:50:50	NULL	23.33	24.2	41	43.55	23.4	45.54	Negative
3	1	2020-03-07 21:24:20	0000-00-00 00:00:00	45.6	23.33	66	44	32	88.9	positive
4	1	2020-03-07 21:28:29	0000-00-00 00:00:00	45.6	23.33	66	44	32	88.9	positive
5	1	2020-03-07 21:39:01	0000-00-00 00:00:00	45.6	23.33	66	44	32	88.9	positive
7	1	2020-03-07 21:45:16	0000-00-00 00:00:00	43.4	98.54	45.9	34.9	67.9	12	Negagtive
8	1	2020-03-07 21:51:34	0000-00-00 00:00:00	43.4	98.54	45.9	34.9	67.9	12	Negagtive
9	1	2020-03-09 13:26:24	0000-00-00 00:00:00	-376	-548	16028	117	-450	-369	Positive
10	1	2020-03-09 13:27:01	0000-00-00 00:00:00	-196	-740	16036	383	435	-408	Positive

Figure 4. 8: Database of caretaker and device

4.2.3 Web Application

In developing the graphic user interface of this project, the CSS bootstrap framework was used together with PHP and JavaScript to create a dynamic, responsive, and user-friendly frontend web application. The bootstrap framework typically has good designs for tables, buttons, navigation, typography, forms, image carousels, and modals together with an easy to use JavaScript plugins. The frontend also displays the web application's login, sign up, and register pages. As per the user requirement and for security reasons, a new user – caretaker – would have to input in crucial details to be stored in the database. This would help the web administrator track the availability and biodata of caretakers.

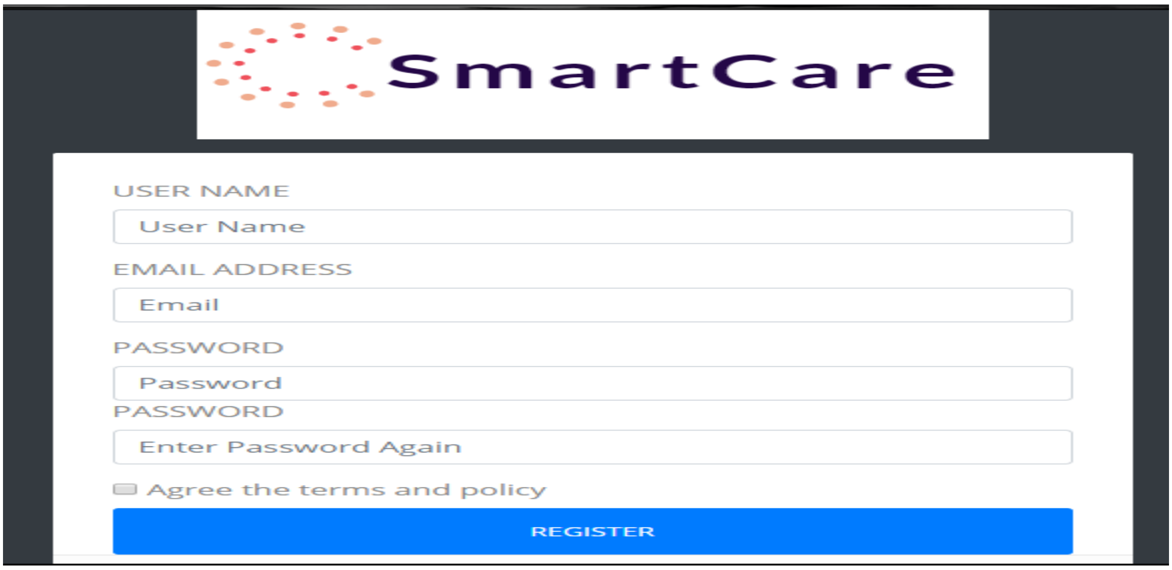
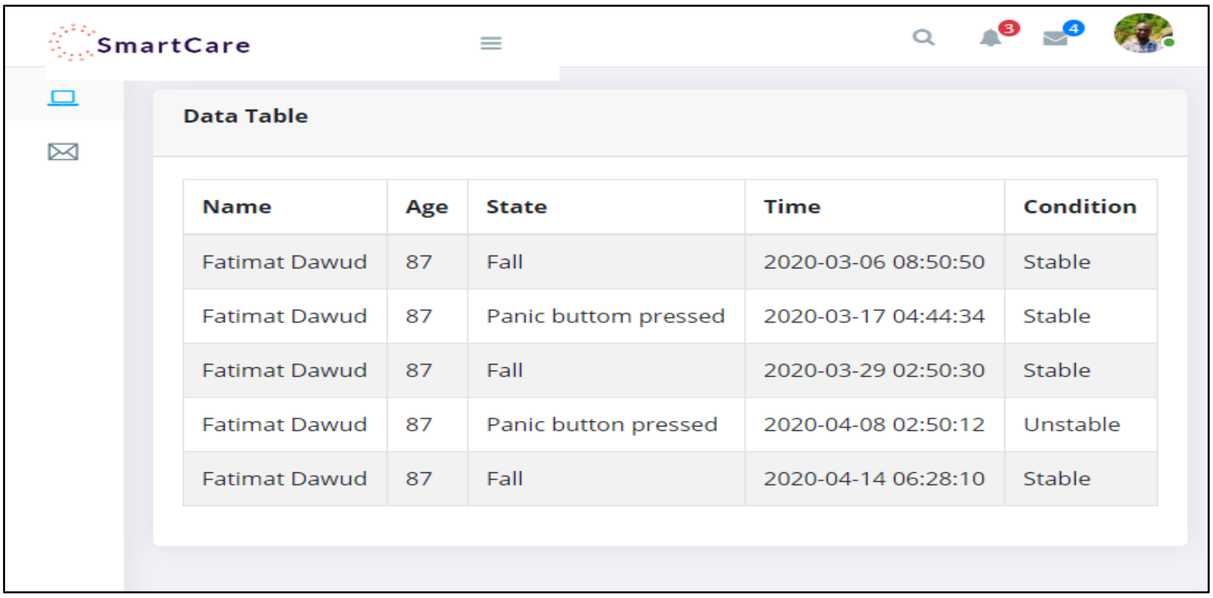


Figure 4. 9: Register page of the web application

A critical part of the web application is the dashboard. The dashboard summarizes information about the patient's fall records. The status of the patient is registered into the database with the use of a PHP file named *user-history.php file*. This allows the caretaker to visualize the numerical representation of the sensor values in an interactive, responsive, and user-friendly interface. From the dashboard, the patient's name, age, state, time of the recorded incident, and condition are shown in a tabular form.



Name	Age	State	Time	Condition
Fatimat Dawud	87	Fall	2020-03-06 08:50:50	Stable
Fatimat Dawud	87	Panic buttom pressed	2020-03-17 04:44:34	Stable
Fatimat Dawud	87	Fall	2020-03-29 02:50:30	Stable
Fatimat Dawud	87	Panic button pressed	2020-04-08 02:50:12	Unstable
Fatimat Dawud	87	Fall	2020-04-14 06:28:10	Stable

Figure 4. 10: A summary of a patient's fall details and status

4.2.3.1 Frontend code

The frontend code for this project includes the human interactive part of the web application. The frontend view includes buttons, navigation bar, image carousels, topography, tables, and forms styles. This was written in the CSS Bootstrap framework to make the front page less crowded with information but easy to navigate around. JavaScript is a powerful scripting tool used in the creation of dynamic content, fill forms and animated pictures. It was used in the frontend because of its versatility for client-side and server-side prowess.

4.2.3.2 Backend code

The backend was wholly written in PHP, a general-purpose scripting language that is good for server-side scripting. PHP was used in diverse ways in this project, and among them are the following:

1. Configure the connection between the database and the server
2. Insert sensor values into the database.
3. Create sessions for a user (caretaker)
4. Store biodata of a new user into the database.

4.2.4 Email notification

The core functionality of the hardware system is to be able to send an email notification to the caretaker to respond adequately. The email is sent when the patient falls, and the set threshold of the sensor is exceeded or when the patient deliberately presses on the push button to activate an emergency alarm for help. The protocol used in sending an email is the SMTP. This protocol is part of the application layer of the TCP/IP protocol. It uses the process of ‘store and forward’ where the SMTP moves an email on and across networks.

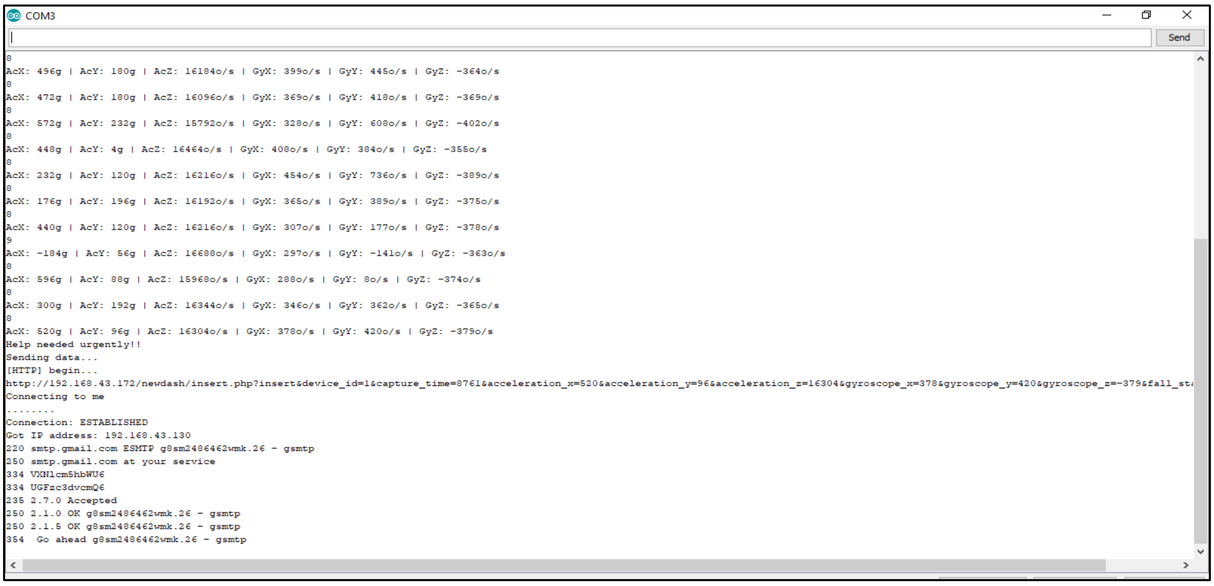


Figure 4. 11: SMTP connection with the server-side to send an email

The SMTP contacts the destination's SMTP server on its designated well-known port 25 to deliver the mail. Upon receipt of the 220-success message, the client sends the success command [25].

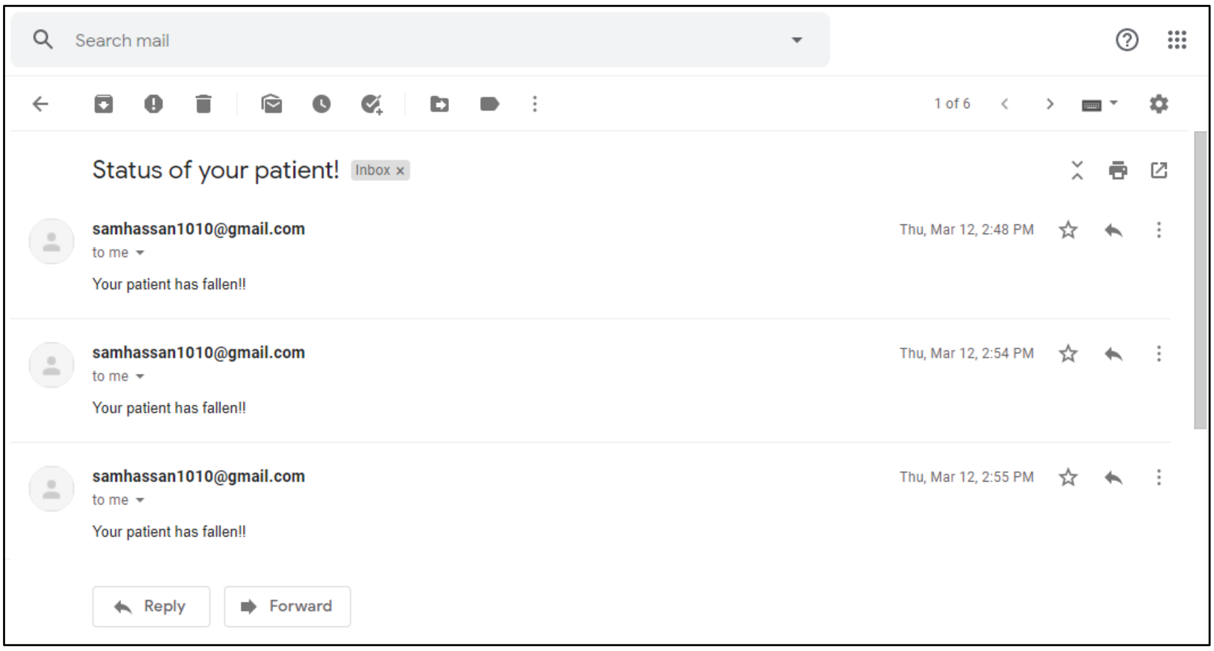


Figure 4. 12: An email notification

Chapter 5: Results and Analysis

5.1 Test Description

This section of the project focuses on some test cases of the hardware system and analysis of the data collected to make meaningful information from it. These tests were carried to find out the system's core functionality and performance. Three significant tasks were carried out. The test cases are as follows

1. Testing the time lag of the system's ability to send an email to a caretaker. This test case involves simulating different kinds of falls with the hardware systems from different angles and acceleration and allowing the falling threshold to exceed the set threshold. The time taken between SMTP to connect to the receiver's protocol and the caretaker to receive an email was recorded.
2. An independent T-Test with two tail distribution of two samples with an equal variant to infer the existence of any statistically significant difference between the means' of sensor data sent from the mobile hotspot and the Ashesi network.
3. Data analysis on the sensor's values to create a machine learning model using time series analysis and the sensor's threshold to determine an actual fall.

5.2 Test Results and Analysis

The first test measures the time it takes for an email to be sent to a caretaker. This test was performed using two different network access connections; a regular access point from Ashesi WiFi and a mobile phone hotspot via a wireless local-area network (WLAN). The assumption was made that the Ashesi network connection would be the ideal one. Four different falls were simulated, and the average time was taken for each of the mobile hotspot network and Ashesi network. The table below gives the time-difference (in seconds) of an email reception when a falling threshold is triggered.

Mobile hotspot					
Id	1st fall	2nd fall	3rd fall	4th fall	Average time
1	55	56	49	60	55
2	54	60	66	48	57
3	67	56	78	79	70
4	67	89	56	55	66.75
5	69	78	79	87	78.25
6	67	55	59	60	60.25
7	50	58	49	47	51
8	45	70	71	76	65.5
9	65	60	69	67	65.25

Ashesi network					
Id	1st fall	2nd fall	3rd fall	4th fall	Average time
1	45	40	45	48	44.5
2	37	46	38	39	40
3	40	46	47	40	43.25
4	58	49	50	49	51.5
5	47	49	55	50	50.25
6	45	39	36	42	40.5
7	46	50	57	48	50.25
8	45	49	57	45	49
9	46	49	39	50	46

	Average time (hostpost)	Average time (Ashesi network)	Absolute Deviation
	55	44.5	10.5
	57	40	17
	70	43.25	26.75
	66.75	51.5	15.25
	78.25	50.25	28
	60.25	40.5	19.75
	51	50.25	0.75
	65.5	49	16.5
	65.25	46	19.25
	Mean Absolute Dev		17.0833
Mean	63.22	46.14	
Stdev	8.35	4.35	
Variance	69.76	18.91	
CV	0.13	0.09	

Figure 5. 1: Analysis of time taken for an email to be sent to a caretaker

The mean absolute deviation is calculated using the formula **MAD = $\sum|x_i - \bar{x}|/n$**

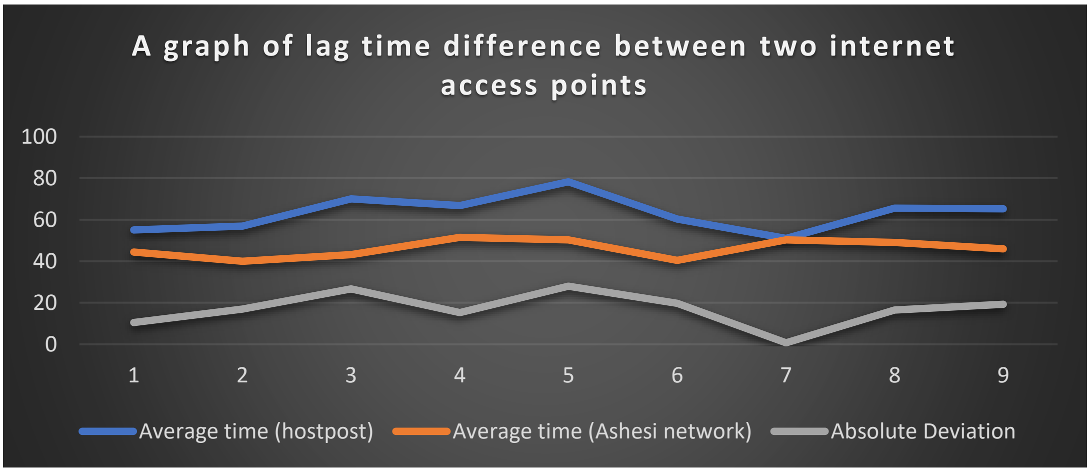
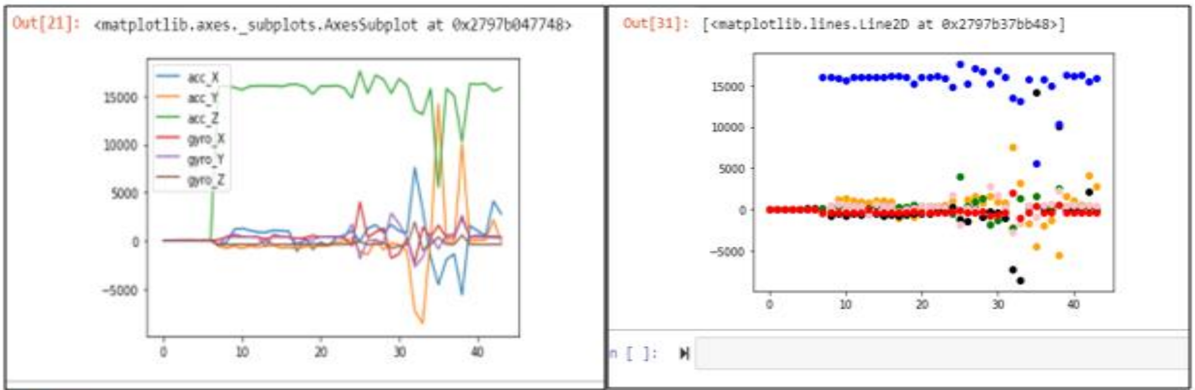


Figure 5. 2: Lag time graph between two internet access points and their absolute deviation

The Coefficient of variation (CV=standard deviation/mean) is estimated to find the difference between each data set sent from a mobile hotspot and Ashesi network. The results were interpreted using the general rule of thumb that a CV >=1 indicates a relatively high variation, while a CV<=1 indicates a relatively low variation. The analysis shows that data were relatively closer to the samples' mean. Also, a CV of **0.13 or 13%** and **0.09 or 9%** shows a lower level of dispersion around the mean for mobile hotspot and Ashesi network respectively. According to Ebrahimi, a CV<10 is very good 10-20 is good, and 20-30 is acceptable [26].

The second test is the T-Test assuming that the null hypothesis (there is no significant difference between the two groups) is true. After conducting the T-Test, the results came out with a P-value of **5.42087E-05.** The fact that **P < α (standard α = 0,05)** indicates there is a statistically significant difference between the observed groups and, therefore, the null hypothesis is rejected.

The third test results are data analysis on the sensor's data collected over a period to make a prediction and draw a pattern for what which values represent a fall. A CSV file of the fall data containing the acceleration and gyroscope values were downloaded from the database and uploaded onto Jupyter software. Python packages such as pandas, matplotlib, and sklearn were used for data cleaning, visualization, and model creation.



Out[7]:

	Sensor_id	device_id	acc_X	acc_Y	acc_Z	gyro_X	gyro_Y	gyro_Z
count	44.000000	44.0	44.000000	44.000000	44.000000	44.000000	44.000000	44.000000
mean	23.386364	1.0	470.778636	-71.921136	12969.904545	361.929545	240.331818	-212.959545
std	13.024513	0.0	1985.119800	3210.531521	5988.849311	944.446748	923.363481	429.278996
min	1.000000	1.0	-5580.000000	-8560.000000	41.000000	-2274.000000	-2698.000000	-975.000000
25%	12.750000	1.0	-64.000000	-646.000000	14476.000000	98.750000	30.000000	-374.000000
50%	23.500000	1.0	538.000000	-300.000000	15878.000000	362.500000	386.500000	-364.500000
75%	34.250000	1.0	1083.000000	24.200000	16081.000000	405.750000	461.500000	-49.500000
max	45.000000	1.0	7604.000000	14168.000000	17592.000000	4024.000000	2863.000000	1948.000000

Figure 5. 3: A scatter plot, linear graphs and statistical description of the MPU6050 sensor values

With the use of python packages, new columns of weekdays and months were included to create the model. The model is projected to be able to ascertain the falling value for acceleration in the X direction only. The below figure shows the outcome of the machine learning model.

For the same weekday and month, the predictions for acceleration in the X direction are given as 1556, 1032, 520, 4112, and 2764.

Out[56]:

	acc_X	weekday	month
count	44.000000	44.000000	44.0
mean	470.778636	1.704545	3.0
std	1985.119800	1.746485	0.0
min	-5580.000000	0.000000	3.0
25%	-64.000000	0.000000	3.0
50%	538.000000	1.000000	3.0
75%	1083.000000	3.000000	3.0
max	7604.000000	5.000000	3.0

```
Making predictions for the following 5 entries (given dow and wk day):
     acc_X  weekday  month
39  1556.0        3      3
40  1032.0        3      3
41   520.0        3      3
42  4112.0        3      3
43  2764.0        3      3
The predictions are
[1556. 1032.  520. 4112. 2764.]
```

Figure 5. 4: A model showing falls and statistical description of acceleration in the X direction

Chapter 6: Conclusion

The IoT fall detection and alarm system demonstrate how the state of older people who suffer from recurrent falls could provide a new paradigm of monitoring and support system. The hardware system is portable and low-cost for any use, which could be worn around the neck, waist, or used as a bracelet. The hardware system's set threshold, when exceeded, will automatically trigger an alert email that will be sent to the caretaker to respond immediately. An emergency push button could also be pressed at the convenience of the patient to call for help directly. The buzzer attached to the system will go on while an email is sent to the caretaker as well. An interactive web application allows the caretaker or primary care provider to see a summary of the patient's fall status. A predictive model could predict days in the week and month the type of values that the sensor could output from the acceleration X plane of the sensor. With this system, the caretaker would not be mandatory requested to stay all the time with the patient. They could spend their time a few kilometers away from their patients. Summary of patient's fall report could create insights and trends about the number of times a patient fell within a period. Although the system much helps elderly patients and caretakers, it has its own set of limitations.

6.1 Project Limitations:

The design process and implementation of this project anticipate addressing a serious health issue of the aging community, which is abrupt falling. However, there were certain limitations defined during the design and implementation stages, which could affect the full potential of the prototype. Some of the limitations are as follows.

1. Global Covid19 pandemic brought an abrupt end to classes and had school and classes closed. The prototype of the design could have better touches in soldering and assembling if resources were accessed from the school's laboratories.

2. Fewer prototypes had the design process less predictive to measure the robustness, efficiency, and performance of the system. With more and more prototypes, the efficiency and robustness of the hardware are projected to increase.
3. The lack of precision in the direction and angle of the fall of the device could affect the type of data collected. The fact that the device was not used on a human being but instead had a simulation using inanimate objects could have a certain degree of uncertainty in the collected data.
4. Lack of any data on an IoT-based fall detection system within my jurisdiction is a limitation since its availability could be used in comparing the developed system to identify similarities, trends, and differences in data to draw insights on predictive analysis.

6.2 Future works

The developed system for fall detection in elderly patients has more prospects in the future in terms of its betterment and performance to achieve the desired requirements. Among some of these possible improvements are as follows.

1. Implement a second monitor in addition to the caretaker. This could be a medical professional or primary care provider who could also have access to the fall data and status of the patient to make diagnosis and prediction from their end
2. The design could be developed to take care of other health care issues such as Alzheimer, depression, and blood pressure. This could be implemented to have a variety of other chronic health care issues that elderly patients face instead of a single health care problem.
3. Implement a better security feature for the hardware system. This could be implemented by giving each device a uniquely identifiable ID that would be assigned to a single

patient so that no other patient or person can have access to it if even they were lost or stolen.

4. Create a more efficient model that would use both train and test data samples together with decision tree regressor and random forest to predict the mean absolute error.

References

[1] U. Nations, "World Population Ageing," Department of Economic and Social Affairs, New York, 2017.

[2] K. N. Lohr, "Medicare: A strategy for Quality Assurance," vol. I, p. 468, 1990.

[3] M. Karasek, "Melatonin, human aging, and age-related diseases," November 2004.

[4] O. Nyarko-Boateng, "IoT: The Evolution of Smart Systems," Institute of ICT Professionals Ghana, 2020. [Online]. Available: https://iipgh.org/iot-the-evolution-smart-systems-part-one/. [Accessed 2020].

[5] M. Haghi, K. Thurow, D. I. Habil and R. Stoll, "Wearable Devices in Medical Internet of Things: Scientific Research and Commercially Available Devices," *The Korean Society of Medical Informatics,* 2017.

[6] U. Nations, "World Population Ageing," Department of Economic and Social Affairs, New York, 2019.

[7] G. H. Service, "The Health Sector in Ghana: Facts and Figures," Ministry of Health, Accra, 2017.

[8] R. U. Umanta, "Key Health Challenges in Ghana," Association of Chartered Certified Accountants, Accra, 2013.

[9] N. D. P. Commission, "2008 Citizen's Assessment of the National Health Insurance Scheme," Ministry of Health, 2009, 2009.

[10] H. Direct, "What causes fall?," Australian Health Advice, 2017. [Online]. Available: https://www.healthdirect.gov.au/what-causes-falls.

[11] K. Davis, "6 Forms of Wearable Technologies You Must Know," July 2015. [Online]. Available: https://www.42gears.com/blog/6-wearable-technologies-you-must-know-right-now/..

[12] A. Natarajan, "Implantables Devices Using Rechargeable Zero-volt Technology Lithium-ion," US patents, 2007. [Online].

[13] V. Ramachandran and G. Manogaran, "Wearable Sensor Devices for Early Detection of Alzheimer Disease Using Dynamic Time Wrapping Algorithm," pp. 1-10, 2017.

[14] L. E. Romero, P. Chatterjee and R. L. Armentano, "An IoT Approach for Integration of Computational Intelligence and Wearable Sensors for Parkinson's Disease Diagnosis and Monitoring," *Health and Technology,* pp. 167-172, 2016.

[15] J. Wan, M. A. A. H. Al-awlaqi, M. Li, M. O'Grady, X. Gu and J. Wang, "Wearable IoT Enabled Real-time Health Moniotoring System," *EURASIP,* pp. 1-10, 2018.

[16] V. Pigadas, C. Doukas, V. P. Plagianakos and I. Maglogiannis, "Enabling Constant Monitoring of Chronic Patient Using Android Smart Phones," *The 4th International Conference on Pervasive Technologies Related to Assistive Environments. ,* 2011.

[17] L. Chen, J. Hoey, C. Nugent, D. Cook and Z. Yu, "Sensor-based Activity Recognition," *IEEE,* pp. 1-9, 2012.

[18] R. Cheng, R. Xu and C. Cai, "An Abnormal Network Flow Feature Sequence Prediction Approach for DDoS Attacks Detection in Big Data Environment," 2018.

[19] C. B. Erdas, I. Atasoy and H. O. Koray Acici, "Integrating Features for Accelerometer-based Activity Recognition," *Procedia Computer Science,* pp. 522-527, 2016.

[20] C. Catal, S. Tufekci and G. Kocabag, "On The Use of Ensemble of Classifiers for Accelerometer-based Activity recognition," *Appl. Soft Computer,* pp. 1018-1022, 2015.

[21] A. K. Sikder, G. Petracca, H. Aksu, T. Jaeger and S. Uluagac, "A Survey on Sensor-based Threats to Internet of Things (IoT) Devices and Applications," *Reasearch Gate,* 2018.

[22] T. H. Laine, L. Chaewoo and S. Haejung, "Mobile Gateway for Ubiquitous Health Care System Using Zigbee and Bluetooth," *2014 Eighth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing,* pp. 139-145, 2014.

[23] M. Sumit, M. Tapas and M. J. Deen, "Wearable Sensors for Remote Health Monitoring," pp. 1-45, 2017.

[24] E. Systems, *ESP8266EX Datasheet,* Espressive Inc. , 2019.

[25] Omnisecu, "Simple Mail Transfer Protocol (SMTP) - How SMTP works?," [Online]. Available: https://www.omnisecu.com/tcpip/smtp-simple-mail-transfer-protocol-how-smtp-works.php.

[26] E. Ebrahimi, "What are the acceptable values for the percentage deviation (DEV%) and the coefficient of variation (CV)?," p. January, 2019.

[27] M. M. Rodgers, G. Alon, V. M. Pai and R. S. Conroy, "Wearable technologies for active living and rehabilitation: Current research challenges and future opportunities," *Journal of Rehabilitation and Assistive Technologies Engineering,* vol. 6, 2019.