International Journal of Trend in Research and Development, Volume 11(6), ISSN: 2394-9333
www.ijtrd.com

Fall Detection System Using IoT

[1]Nnamudi, Marcellinus Chukwudi, [2]Edith Omede, [3]Abel Efe Edje and [4]Debekeme Irene Alamarefa,
[1,2,3,4]Department of Computer Science, Faculty of Science, Delta State University, Abraka, Nigeria.

Abstract: Falling is among the major causes of medical problems that are faced by disabled people. They tend to injure themselves from falling when they are alone. When a falling event occurs, medical attention needs to be provided immediately to reduce the risk of severe injury to the disabled which may result in more injuries or even death. The current commercialized device is expensive and does not have a call-to-action button that sends a notification when the user feels uncomfortable and it also lacks accessibility through a web app. This research proposes an IoT-based fall detection system that has a high efficiency in alerting the surrounding with an alarm to notify the caregiver through an email and an SMS of a fall event. It affords the user the flexibility of requesting the attention of the caregiver when they feel uncomfortable. Additionally, a touch sensor, gyroscope, and GPS module were integrated into the nodeMCU, an open-source firmware, and a sim module, fused into the Arduino UNO microcontroller.

Keywords*: Open Source, SMS, GPS, nodeMCU, Sensor.*

I. INTRODUCTION

According to the World Health Organization (WHO), an estimated 1.3 billion people are living with one form of significant disability or another and this represents 16% of the world’s population, or 1 in 6 persons.Some persons with disabilities die up to 20 years earlier than those without disabilities because of the challenges they face. Persons with disabilities have twice the chance of developing ailments such as depression, asthma, diabetes, stroke, obesity, or poor oral health. Persons with disabilities face many health challenges. (Disability, 2023).

Every country on earth is focusing on developing its nation, and this increases the country’s population which leads to an increased number of people with various forms of deformity which rapidly increases the demand for healthcare services. The disabled are not fully in control of their body system and most times they are not able to walk, this gives rise to the need for a wheelchair.Wheelchair-bound patients are exposed to a higher risk of falls which can cause psychological or physical damage that may lead to severe injury or even death of the patient if there is no prompt medical attention. Therefore, a reliable fall detection system is needed to help and support the elderly and the sick. According to Hon et al. (2020), the wheelchair is broadly divided into two major types which are commercial wheelchairs and smart wheelchairs.

A commercial wheelchair is the regular and more common type of wheelchair that is operated manually,while a smart wheelchair consists of a controller unit that allows the user to provide input information through a joystick, voice command, etc, so that the wheelchair can automatically move to the desired destination. Usually, the smart wheelchair is not commonly used in families or hospitals because it is expensive to buy and maintain. Thus, a new system that can detect fall events needs to be designed and implemented for personal and commercial use with cost effectiveness. Disabled people are those who use wheelchairs in their daily life and there is a greater chance of them falling and getting injured. This can be disastrous because nobody is aware of this event.If these people live alone or their family members or caregivers are not around, this may lead to severe injuries. It is thus important to have a quick response if a falling event occurs (Hon et al., 2020),

Falls among individuals who use wheelchairs can lead to serious injuries, such as bruises, fractures, head trauma, and spinal cord damage. They can affect their health, independence, and quality of life. Despite the high incidence of falls, there is a lack of effective fall detection systems for wheelchairs, that can reliably notify the caregiver to provide prompt care and reduce the impact of falls as staying in an uncomfortable position for a long time can cause more damage or even lead to the death of the patient. (Hon et al., 2020).

Wheelchair fall detection is a technology designed to detect when a person using a wheelchair has fallen and trigger an alarm to alert caregivers or emergency services. The system typically uses sensors, such as accelerometers or gyroscopes, to detect changes in the position and orientation of the wheelchair, and uses algorithms to distinguish between normal movement and a fall. The detection data is then transmitted to a remote monitoring center or to an onboard device, such as a mobile phone, where an alarm can be triggered. Wheelchair fall detection aims to provide users with greater safety and independence and to ensure that prompt medical attention is available in the event of a fall (Dong, 2019).

A. Some examples of IoT applications include:

i. Smart homes, where IoT devices can be used to control lighting, temperature, security systems, and other household appliances
ii. Health monitoring devices, such as wearable fitness trackers collect data on a person's activity levels, sleep patterns, and heart rate
iii. Industrial IoT, where sensors and machines in factories and production facilities can be connected to optimize processes and increase efficiency.

The goal of IoT is to create a seamless, connected world where physical devices and objects can interact with each other and with the Internet, to improve efficiency, increase productivity, and enhance people's lives.

IoT devices can range from simple sensors and smart home appliances to complex industrial systems, and they can communicate with each other and with the internet using various wireless and wired communication technologies, such as Wi-Fi, Bluetooth, Zigbee, and cellular networks.

IoT also relies on cloud computing, big data, and artificial intelligence technologies, to store, process, and analyze the vast amounts of data generated by IoT devices, and to provide actionable insights and decision-making support to users and businesses.

The IoT ecosystem includes a variety of stakeholders, such as device manufacturers, software and service providers, network operators, integrators, and end-users, who collaborate to create, deploy, and operate IoT solutions that meet their needs and expectations.

i. Improved efficiency, productivity, and performance in various industries, such as manufacturing, healthcare, transportation, and energy.
ii. Enhanced convenience and comfort in daily life, such as smart homes, wearable devices, and connected cars.
iii. Increased safety, security, and sustainability, such as fall detection systems, smart city solutions, and smart energy systems.
iv. New business opportunities, revenue streams, and cost savings, such as predictive maintenance, remote monitoring, and asset tracking.

The architecture of a wheelchair fall detection system typically includes the following components:

i. Sensors: A range of sensors, such as accelerometers, gyroscopes, and pressure sensors, are used to detect changes in the position and orientation of the wheelchair, and to distinguish between normal movement and a fall.
ii. Data Collection Unit: The sensors collect data and send it to the data collection unit, which is responsible for processing the data and sending it to the next component.
iii. Algorithm Unit: This component uses algorithms to analyze the sensor data and determine if a fall has occurred. The algorithms may use machine learning techniques, such as decision trees or neural networks, to learn the characteristics of normal movement and fall, and to detect falls with high accuracy.
iv. Alert Unit: This component triggers an alarm in the event of a fall, and may send an alert to a remote monitoring center or an onboard device, such as a mobile phone. The alert may include the location of the user and the time of the fall and may be delivered by SMS, email, or voice call.
v. Communication Unit: This component handles the communication between the different components of the system and enables data to be transmitted between the sensors, the data collection unit, the algorithm unit, and the alert unit. The communication unit may use wireless technologies, such as Wi-Fi, Bluetooth, or cellular networks, to transmit the data.
vi. Power Supply: This component provides the power needed to operate the system, and may include a battery or a connection to an external power source.
vii. User Interface: The user interface allows users to interact with the system and may include a display, buttons, or touch controls. The user interface may also provide information on the status of the system, such as battery level and the number of falls detected.

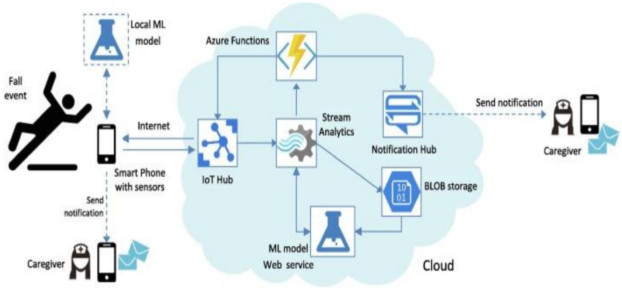

Figure 1: architecture structure of Wheelchair Fall Detection System (Source: https://ars.els-cdn.com/content/image/1-s2.0-S0020025520304886-gr3.jpg

B. IoT Roles in Building A Smart Wheelchair Fall Detection System

For a smart wheelchair fall detection system using IoT, the following roles are typically involved:

i. Sensors: These are the devices that detect and collect data on the movements and posture of the user and the wheelchair. They may include accelerometers, gyroscopes, and other types of sensors that can detect changes in orientation, velocity, and acceleration.
ii. Gateway: This is the device that connects the sensors to the internet, allowing the data to be transmitted to the cloud for processing. The gateway may also be responsible for performing some initial processing of the sensor's data, such as compression, encryption, and filtering.
iii. Cloud computing: This is the infrastructure that stores, processes, and analyzes the sensor data, and provides the intelligence and decision-making capabilities for the system. The cloud may use machine learning algorithms, data analytics, and other AI technologies to detect and respond to falls, and to provide notifications and alerts to the appropriate stakeholders.
iv. Mobile app: This is the user interface that allows the user and their caregiver to view and manage the system, and to receive alerts and notifications. The app may also allow the user to customize the system settings and preferences, such as the sensitivity of the fall detection, the types of alerts and notifications, and the response protocols.
v. Network: This is the communication infrastructure that connects the gateway, the cloud, and the mobile app, and enables the data to be transmitted securely and reliably between them. The network may use various communication technologies, such as Wi-Fi, Bluetooth, Zigbee, and cellular networks, depending on the requirements and constraints of the system.
vi. Stakeholders: These are the people and organizations that have a vested interest in the system, such as the user, their caregivers, health care providers, manufacturers, and regulators. They may interact with the system through the mobile app, or other means, such as email, SMS, or web portals, and they may provide feedback and input on the system's performance and functionality.

II. LITERATURE REVIEW

Amanda and Omar (2024). The primary contribution is that it's one of the few that addresses the possible impacts of utilizing the Internet of Things on accounting information systems in general and hospital accounting information systems. The study came to the following conclusions: First, errors will be reduced resulting from human data entry in the accounting information system's inputs. The accounting system receives enormous amounts of data that are entered quickly and accurately, in addition to data supplied to it instantly. Devices are no longer the only means of data entry. Not only is it intelligent, but thanks to sensors and other IoT-enabled devices.

Jones et al. (2024) say it is impossible to avoid using IoT-based health services, particularly in times of pandemic when a person's condition needs to be screened. It's a useful tool for doing preliminary health assessments, which are essential for choosing what treatments to do next in the healthcare system. IoT solutions focused on healthcare provide an affordable method of conducting remote health assessments, enabling them to reach remote and underserved areas. This procedure is made even better by the use of Safe Entry Stations (SES), which record basic health parameters like blood pressure, heart rate, and breathing rate. This article explores the factors that affect people's intentions to use Internet of Things (IoT) health-focused devices. The addition of new variables creates a new framework for the Technology Acceptance Model (TAM). The results obtained from the SmartPLS analysis validate the noteworthy influence on the adoption and assimilation of IoT devices with a health focus.

provides a thorough analysis of the Internet of Things (IoT) in healthcare, examining its applications, advantages, and drawbacks. Critical uses of IoT in clinical operations, medical supply chain management, telehealth services, and patient monitoring are identified by a thorough examination of a variety of sources, including white papers, journal articles, and conference proceedings. Our findings demonstrate how the Internet of Things is revolutionizing the healthcare industry by providing better patient care through early detection and personalized treatments, increased operational efficiency, and easier access to evidence-based decision-making. Notwithstanding the apparent advantages, problems with interoperability, privacy, and security still exist and call for more study and development of technology. The potential of IoT to transform healthcare delivery and make it more patient-centered, efficient, and accessible is highlighted in this review.

Kazi (2024). gives a comprehensive but succinct overview of the potential applications and difficulties of AI and IoT in the healthcare industry. An overview of AI and IoT, their applications, some observations on recent advancements, a look at the future, and challenges facing healthcare systems are also included. In healthcare organizations, the Web of Things is used for a variety of purposes, including medical device fusion, advanced sensors, and remote monitoring. In any case, it can make medical professionals' ideas more effectively communicated while maintaining patients' safety. By encouraging patients to work even closer with medical professionals, the Internet of Things, or IoT, can help human organizations achieve accountability and satisfaction.

Objectives of the Study

The objectives of this study are to:

i. to design and implement a microcontroller that detects the status of the patients
ii. to design and implement an interactive web application system for fall detection
iii. to test the functionality of the system in other to validate its performance with the support of Alpha test technique

The growth in the development of technology both in hardware and software, the increasing communication channels, and the development of advancement of tools for data analysis have all contributed to the rise of the Internet of Things (IoT) which is defined as a network of devices that are interconnected to monitor environmental variables, the idea behind IoT is to enable objects that are capable of collecting or generating data to interconnect using technologies such as Radio Frequency Identification (RFID), sensors, mobile phones, and actuators.

The Internet of Things (IoT) refers to the interconnected network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, and network connectivity, allowing them to collect and exchange data. IoT devices can communicate and coordinate with each other and with centralized systems, such as cloud services and databases, to automate tasks and make decisions based on data.

IoT has the potential to revolutionize a wide range of industries, such as healthcare, transportation, manufacturing, and home automation, by providing real-time monitoring and control, improving efficiency, and enabling new business models and applications. However, IoT also raises security and privacy concerns and requires the development of new technologies and standards to address these challenges (Shaheen et al., 2020)

III. MATERIALS AND METHOD

For the fall detection system, a touch sensor, MPU6050 (gyroscope and accelerometer), GPS module, SIM module, buzzer are implemented into the microcontrollers. The MPU6050 (gyroscope and accelerometer) detects and recognizes the orientation and movement of the user and the GPS checks for the location of the system as at the time of the fall and the Blynk IoT sends an email notification, then the sim module also sends an SMS notification and it is mostly relevant in the case of a bad internet connection while the touch sensor is used to seek the attention of the caregiver even before the fall event occurrs, these sensors work together to detect fall events which increases the accuracy and efficiency of the fall detection system while the buzzer notifies the surrounding. When a fall event occurs, all the data including the state of the chair will be sent to the Blynk IoT. This sound has to be turned off manually or with a mobile phone device or a PC. The sensor is connected to the Blynk IoT through the NodeMCU which is a microcontroller and it has a WIFI module embeded in it and an Arduino UNO which is a low-cost open source IoT platform.

A. Analysis of The Existing System

From analysis gathered from Khan *et al* (2022) worked on IoT Based Wheel Chair Fall detection. The system was developed for monitoring elder people using accelerometer sensors and RFID technology (radio frequency identification) operating through indoor and outdoor tracking using the embedded system with the thresholds. Falls can be detected by elderly people who are living alone in the home and the person who is handicapped can have certain incidents like falling. To monitor the elderly people's activities, the paper presents the accelerometer sensor and the RFID technology using this technology, the activities of the user can be identified and if they fall, an alert will be sent to the registered email for prompt medical attention.

B. Weakness of The Existing System

The following are some weaknesses of the existing system:

i. Likelihood of failure to notify caregiver of a fall event when internet connect fails since it has only one mode (email)alert system
ii. The system does not provide the possibility for the user to seek the attention of the caregiver before a fall event occurs.

C. Analysis of The Proposed System

The proposed system will be built to integrate Internet of Things architecture, where hardware devices will be built to provide security to disabled persons during emergencies. This essence of this research is to developed a fall detection system with IoT which is cost-effective and reliable to detect falls and alert surrounding for help. For the fall detection system, a touch sensor, MPU6050 (gyroscope and accelerometer), GPS module, SIM module, buzzer is implemented into the microcontrollers. The MPU6050 (gyroscope and accelerometer) detects and recognizes the orientation and movement of the user and the GPS checks for the location of the system as at the time of the fall and the Blynk IoT sends an email notification, then the sim module also sends an SMS notification and it is mostly relevant in the case of a bad internet connection while the touch sensor is used to seek the attention of the caregiver even before the fall event occurs, these sensors work together to detect fall events which increases the accuracy and efficiency of the fall detection system while the buzzer notifies the surrounding. When a fall event occurs, all the data including the state of the chair will be sent to the Blynk IoT. This sound has to be turned off manually or with a mobile phone device or a PC. The sensor is connected to the Blynk IoT through the NodeMCU which is a microcontroller and it has a WIFI module embeded in it and an Arduino UNO which is a low-cost open source IoT platform.

D. High-Level Model of the Proposed System

This high-level model represents the major components and interactions of a Student Transcript and Result Management System, highlighting the flow of data and the roles of different system users.

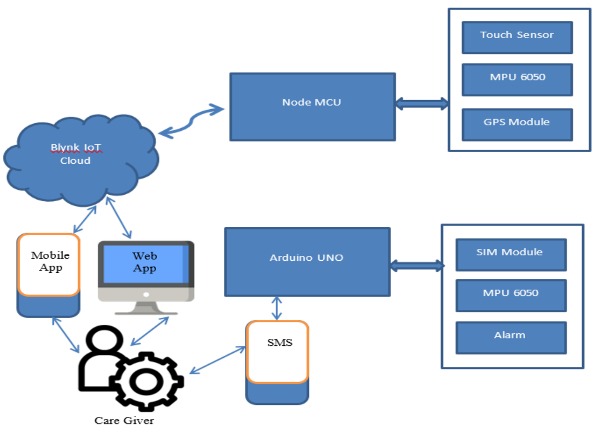

Figure 2. High Level Model

E. Hardware Components of Proposed System

i. MPU6050 (Gyroscope and Accelerometer): The MPU6050 accelerometer sensor captures acceleration data in three dimensions: X, Y, and Z, and it measures changes in acceleration, including those due to movement or impact.
ii. SIM Module: The SIM module sends an SMS notification and it is mostly relevant in the case of a bad internet connection.
iii. GPS Module: The NEO-6M GPS module receives signals from GPS satellites to determine the location (latitude and longitude) and other GPS-related data.
iv. Microcontroller (NodeMCU): The NodeMCU processes the accelerometer data received from the MPU6050, it calculates the angles of tilt or inclination using trigonometric functions.
v. Touch Sensor: The touch sensor is a panic button that the user uses to seek the attention of the caregiver, when a touch is detected, the touch sensor sends a signal to the NodeMCU.
vi. Arduino UNO: This microcontroller processes the data from the buzzer, SIM module, and MPU 6050 which are integrated into the Arduino Uno board.
vii. Buzzer also known as a sounder, alarm, or audio indicator, is an audio device that generates a sound from an incoming electrical signal.

System Interaction

i. Mobile App (Blynk): The Blynk mobile app is installed on a caregivers Android device where he can reliably monitor the affairs of the disabled patient, it communicates with the NodeMCU using the Blynk platform through Wi-Fi or cellular data and the app displays real-time GPS data, angles, and sensor status. It immediately receives notifications when a fall is detected or when the touch sensor is triggered.
ii. Web Application (Blynk Web Dashboard): - The Blynk web dashboard is accessed through a web browser on a computer, it communicates with the NodeMCU using the Blynk platform. The web dashboard displays real-time GPS data, angles, and sensor status, it also receives notifications when a fall is detected or the touch sensor is triggered and beeps alarms too.
iii. Communication: The NodeMCU sends data (GPS coordinates, angles, sensor statuses) to the Blynk cloud platform via the Blynk API., the Blynk handles the communication between the NodeMCU and both the mobile app and the web application.
iv. Notifications: When the fall detection algorithm is triggered or the touch sensor is activated, the NodeMCU sends notifications to both the mobile app and the web dashboard the notifications are displayed on the caregiver’s mobile device and in the web browser.
v. User Interaction: The caregiver receives notifications on their mobile devices and web browsers when a fall is detected or the touch sensor is triggered, they can respond to these notifications by accessing the mobile app or web dashboard to view the real-time status and location information.

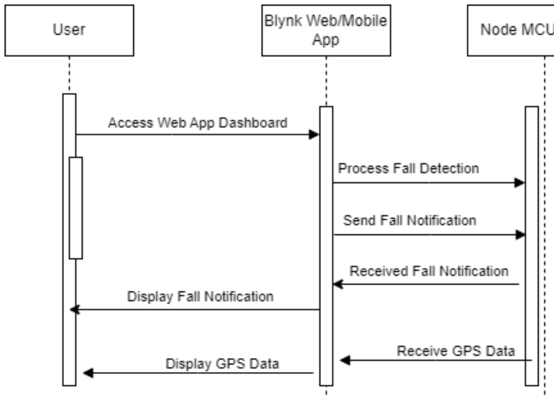

Figure 3.shows the sequential diagram

Algorithms

Start

Step 1: Log into the Blynk web dashboard using Blynk account credentials or create a new account if they don't have one.

Step 2: Create a new project on the web dashboard.

Step 3: Add virtual pins (V0-V8) for various widgets to be used (Map, Value Displays, Notifications, etc.).

Step 4: Add a Map widget to the dashboard and link it to a virtual pin (V0).

Step 5: Add Value Display widgets to display GPS data (lat, lon, speed, satellites,bearing), link these widgets to the appropriate virtual pins (V1-V5), add Value Display widgets (Gauge) to display MPU 6050 data (Angle-axis) and then link these widgets to the appropriate virtual pins (V6).

Step 6: Add a Notification widget to the dashboard.

Step 7: Click the "Play" button to run the project on the dashboard.

Step 8: The NodeMCU board sends data to the virtual pins (V0-V8) based on sensor readings. The web dashboard updates in real-time with GPS data and other information.

Step 9: The Map widget updates with the GPS location on the map as data is received from the NodeMCU.

Step 10: If the Y-axis angle crosses the threshold of 1400 i.e (Angle > 1400 or Angle < 450) or the touch sensor is triggered, then NodeMCU sends notifications and the Notification widget displays these notifications in the web dashboard.

Else, continue monitoring the Y-axis

End If

End.

IV. METHODOLOGY

IoT methodology was adopted in this work. This methodology is outlined in ten (10) steps:

i. Purpose and Requirements Specification
ii. Process Specification
iii. Domain Model Specification
iv. Information Model Specification
v. Service Specifications
vi. IoT Level Specification
vii. Functional View Specification
viii. Operational View Specification
ix. Device and Component Integration
x. Application Development

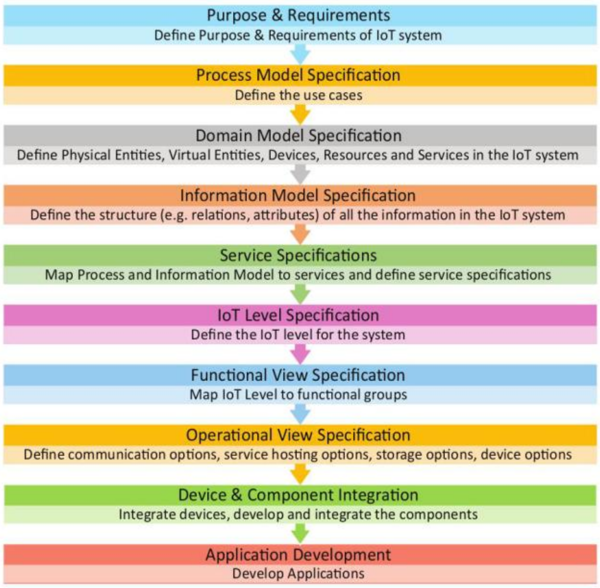

Figure 4: IoT Design Methodology (Bahga and Madisetti 2015)

Device & Component Integration

Integration of the devices and components design such as nodeMCU, Arduino UNO, and sensors, was done at this stage. The touch sensor, buzzer, GPS module, MPU6050 (gyroscope and accelerometer) are connected to the nodeMCU which serves as the brainbox of the system because of its ability to connect to WIFI technology, where Blynk IoT is implemented. The microcontroller and the sensors were programmed together on the Arduino IDE using C++ language. Figures4 and 5schematic diagram and high levelmodels of the proposed system respectively, which give more insight into how the various components are integrated to make up a complete system.

Component Specification

For the design of this system, the following components were used:

i. NodeMCU

NodeMCU is an open-source IoT platform. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware that is based on the ESP-12 module. The term "Node MCU" by default refers to the firmware rather than the development kits. Figure 5. shows the pictorial view of nodeMCU.

Figure 5: Node MCU

ii. Touch Sensor Module

The touch sensor here is a call-to-action button (a panic button) which the user uses to call the attention of the caregiver, it sends an email notification to the user to attend to the patient, this helps to avert the potential falls and damage that the user would have experienced. A touch sensor is shown in Figure 6.

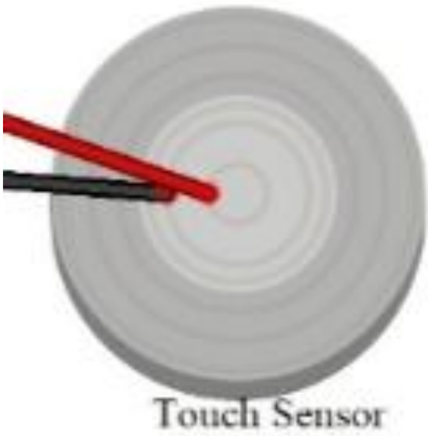

Figure 6: Touch Sensor Module

iii. Buzzer

A buzzer or beeper is an electromechanical audio signaling device. Typical uses of buzzers and beepers include alarm devices, timers, training, and confirmation of user input such as a mouse click or keystroke. A buzzer is shown in Figure 7.

Figure 7: buzzer

iv. Arduino Uno Board

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller, and developed by Arduino. cc and was initially released in 2010. The board is equipped with sets of digital and analog input/output pins that are interfaced with various expansion boards and other circuits. Figure 8; shows an Arduino Uno board.

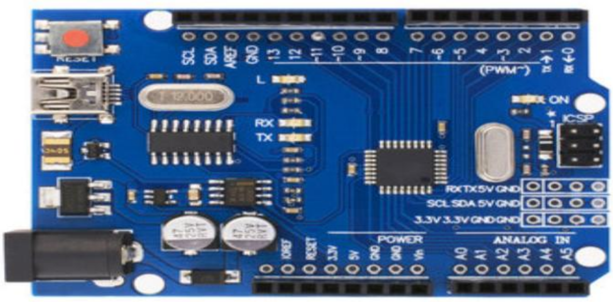

Figure 8: Arduino Uno Board

v. SIM module

The sim module allows communication in 3G / GSM standard and allows you to make voice calls, and send SMS messages. On the board, there are SIM card connector, a charging module for Li-Pol / Li-Ion batteries, and a RESET button. Version works with Arduino, Raspberry Pi, and BeagleBone, and has connectors for u.FL antennas. A sim module is shown in figure 9.

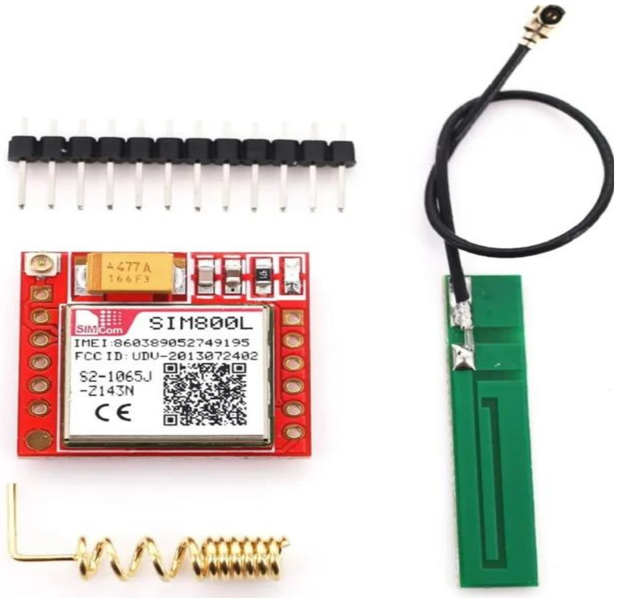

Figure 9: Module 3G/GSM - u-GSM shield 800L.

vi. MPU 6050 (Gyroscope and Accelerometer)

The gyroscope measures rotational velocity (rad/s), this is the change of the angular position over time along the X, Y and Z axis (roll, pitch and yaw). This allows us to determine the orientation of an object while the accelerometer measures acceleration (rate of change of the object's velocity). It senses static forces like gravity (9.8m/s2) or dynamic forces like vibrations or movement. The MPU-6050 measures acceleration over the X, Y and Z axis. Ideally, in a static object the acceleration over the Z axis is equal to the gravitational force, and it should be zero on the X and Y axis.

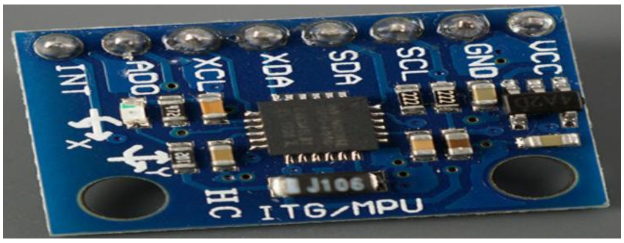

Figure 10: MPU 6050 (Gyroscope and Accelerometer)

V. RESULT AND DISCUSSION

System testing ensures that the system is error-free. It involves examining the system to ensure that it is logically and semantically correct. This system undergoes the three major tasks in system testing which are desk checking, program debugging, and Beta testing.

Steps for System Testing

i. Locate and launch the App
ii. Turn on the designed hardware
iii. It connects to electricity to power

a. Test Data

The system was first tested on the 17th of April, 2024, and was later tested on the 19th of April, 2024.

b. Test Plan

On the 17th of June, 2024, the test was conducted by:

i. Login to the Blynk IoT application
ii. The built hardware was powered ON and a handicap sat on a chair that it was fixed on
iii. iiiThen he intentionally fell down the prototyped wheelchair

c. Expected Result

The expected result is to get an SMS and email notification and the alarm was also expected to start buzzing.

d. Actual Result

The actual result gotten was that the system sent an email and SMS notification alert and made some alarms also.

e. Test Data

The test data used were physical objects.

System Implementation

Systems implementation is the process of defining how the information system should be built (i.e., physical system design), ensuring that the information system is operational and used, ensuring that the information system meets the quality standard (i.e., quality assurance)

Requirement for System Installation/Deployment

The following are the Requirements for System Installation/Deployment

i. An Operating System (Windows 10 Operating System)
ii. C++ language
iii. Arduino IDE
iv. Blynk Cloud Platform.

CONCLUSION

In conclusion, this study demonstrates the feasibility of using IoT technology to design and implement a fall detection system. The system showed promising results in terms of accurately detecting falls in real-time and has the potential to improve the safety and quality of life of people who rely on a daily basis. Further research and development are needed to refine and optimize the system, and to evaluate its effectiveness in real-world settings.

Suggestion for Further Research

One potential direction for further research on wheelchair fall detection systems using IoT is to investigate the system's effectiveness in real-world settings with a larger sample size of wheelchair users. This could involve conducting field tests in nursing homes or hospitals and evaluating the system's accuracy, reliability, and user acceptance. By collecting data on the system's performance in real-world scenarios, researchers could identify any limitations or challenges associated with the system and work to optimize its functionality and usability for wheelchair users.

Another potential area for future research is to develop a predictive fall detection model that can identify the factors that lead to falls in wheelchair users. This could be achieved by collecting and analyzing data from the sensors on the wheelchair and developing machine-learning algorithms to identify patterns and risk factors associated with falls. By identifying these factors, researchers could work to develop targeted interventions to prevent falls and improve the safety and quality of life of wheelchair users.

In addition, further research could explore the potential for integrating the fall detection system with other IoT-based healthcare technologies, such as remote monitoring systems and assistive devices. This could enhance the system's functionality and usability for wheelchair users, and could potentially lead to the development of a comprehensive IoT-based healthcare platform for individuals with mobility impairments.

Overall, further research is needed to optimize the design and implementation of IoT-based healthcare technologies for fall detection in wheelchair users and to evaluate the effectiveness of these technologies in real-world settings. By conducting rigorous research in this area, researchers can help to improve the safety, quality of life, and healthcare outcomes of individuals with mobility impairments.

References

[1] Abou, L., Fliflet, A., Hawari, L., Presti, P., Sosnoff, J.J., Mahajan, H.P., Rice, L.A. (2021). Sensitivity of Apple Watch fall detection feature among wheelchair users. Assistive Technology. 34(5): 619–625. https://doi.org/10.1080/10400435.2021.1923087

[2] Akoh, A., Toritsemogba, T. O., Oluwafunmi, A. E., Ifeoma, P. O., Andrew, I. D., and Oluwaseyi, R. O. (2024). Internet of Things (IoT) in healthcare: A systematic review of use cases and benefits, International Journal of Science and Research Archive, 2024, 11(01), 1511–1517. DOI: 10.30574/ijsra.2024.11.1.0243

[3] Alarifi, A., and Alwadain, A. (2021). Killer heuristic optimized convolution neural network-based fall detection with wearable IoT sensor devices. Measurement. 167(1): 108-258

[4] Babu, D. V., & Ramya, S. (2023). Wearable Device based Fall Prediction and Alert Mechanism for Aged People using IoT Technology. 2023 Third International Conference on Artificial Intelligence and Smart Energy (ICAIS). 50(1): 51-56

[5] Disability. (2023, March 7). Retrieved from https://www.who.int/news-room/fact-sheets/detail/disability-and-health#:~:text=Key%20facts,1%20in%206%20of%20us.

[6] Hamada, E. E., and Omar, I. T. (2024). The impact of using the Internet of Things on the development of the accounting information system in the health sector, In Information Technologies in Healthcare Industry, Artificial Intelligence, Big Data, Blockchain and 5G for the Digital Transformation of the Healthcare Industry, Academic Press, Pages 253-270, ISBN 9780443215988, https://doi.org/10.1016/B978-0-443-21598-8.00006-3.

[7] Hon, F.S., Abdulla, R., Selvaperumal, S.K., Nataraj, C., and Ratnadurai, D. (2020). Wheelchair-Person Fall Detection with Internet of Things. Solid State Technology. 63(1s): 258-294.

[8] https://www.premiumtimesng.com/news/more-news/288954-19-million-nigerians-living-with-disability-official.html. (n.d.). Retrieved from https://www.premiumtimesng.com/news/more-news/288954-19-million-nigerians-living-with-disability-official.html

[9] Hussain, F., Hussain, F., Ehatisham-ul-Haq, M., and Azam, M. A. (2019). Activity-Aware Fall Detection and Recognition Based on Wearable Sensors. IEEE Sensors Journal. 19(12): 4528–4536.

[10] Jonas, D., Maria, E., Sutarto, RatnaWidiasari, I. ., Rahardja, U., &Wellem, T. (2023). Design of a TAM Framework with Emotional Variables in the Acceptance of Health-based IoT in Indonesia. ADI Journal on Recent Innovation, 5(2), 146–154. https://doi.org/10.34306/ajri.v5i2.1005

[11] Kamble, S. M., Kawle, P.R., Mohile, S.S., Meshram, M.R., Mam, P.G.P., and Mam, N.G. (2022). IOT Based Person/Wheelchair Fall Detection System. International Journal for Research in Applied Science and Engineering Technology. 10(2): 258-263. https://doi.org/10.22214/ijraset.2022.40243

[12] Kazi, K. (2024). AI-Driven IoT (AIIoT) in Healthcare Monitoring. In T. Nguyen & N. Vo (Eds.), Using Traditional Design Methods to Enhance AI-Driven Decision Making (pp. 77-101). IGI Global. https://doi.org/10.4018/979-8-3693-0639-0.ch003

[13] Khan, M.H., Yogi, V.K., Kumawat, M.K., Khan, A., Kumar, M., and Kishor, I. (2022). Iot-Based Wheelchair Fall Detection. International Journal for Research Trends and Innovation. 7(6): 2456-3315.

[14] Khraief, C., Benzarti, F., and Amiri, H. (2020). Elderly fall detection based on multi-stream deep convolutional networks. Multimedia Tools and Applications. 79(27-28), 19537–19560. https://doi.org/10.1007/s11042-020-08812-x

[15] Maitre, J., Bouchard, K., and Gaboury, S. (2021). Fall Detection with UWB Radars and CNN-LSTM Architecture. IEEE Journal of Biomedical and Health Informatics. 25(4): 1273–1283.

[16] Meliá, S., Nasabeh, S., Luján-Mora, S., and Cachero, C. (2021). MoSIoT: Modeling and Simulating IoT Healthcare-Monitoring Systems for People with Disabilities. International Journal of Environmental Research and Public Health. 18(12): 6357. https://doi.org/10.3390/ijerph18126357

[17] Nissar, G., Khan, R.A., Mushtaq, S. et al. (2024). RETRACTED ARTICLE: IoT in healthcare: a review of services, applications, key technologies, security concerns, and emerging trends. Multimed Tools Appl (2024). https://doi.org/10.1007/s11042-024-18580-7

[18] Patel, I., Sethi, K., Kaul, S., and Jindal, S.K. (2022). Smart Wheelchair Management System for Disabled People. Lecture Notes in Electrical Engineering. https://doi.org/10.1007/978-981-19-1906-0_26

[19] Rahman, M.A., Ahsanuzzaman, S., Hasan, A., Rahman, I., Ahmed, T., and Kadir, M.M. (2020). Building A Wheelchair Controlling and Fall Detection System Using Mobile Application. 2020 2nd International Conference on Advanced Information and Communication Technology (ICAICT). 1022-1026

[20] Sadi, M.S., Alotaibi, M., Islam, M.R., Islam, M.S., Alhmiedat, T., and Bassfar, Z. (2022). Finger-Gesture Controlled Wheelchair with Enabling IoT. Sensors. 22(22): 18716. https://doi.org/10.3390/s22228716

[21] Shabibi, A.M.A.K., and Kesavan, S.M. (2021). IoT Based Smart Wheelchair for Disabled People. 2021 International Conference on System, Computation, Automation and Networking (ICSCAN). https://doi.org/10.1109/icscan53069.2021.9526427

[22] Sharmila, A., Saini, A., Choudhary, S., Yuvaraja, T., & Rahul, S. G. (2019). Solar Powered Multi-Controlled Smart Wheelchair for Disabled: Development and Features. Journal of Computational and Theoretical Nanoscience, 16(11). 4889-4900. https://doi.org/10.1166/jctn.2019.8401

[23] Shu, F., and Shu, J. (2021). An eight-camera fall detection system using human fall pattern recognition via machine learning by a low-cost android box. Scientific Reports. 11(1). https://doi.org/10.1038/s41598-021-81115-9

[24] Tshering, S., Biswa, D. R., Tshering, D., Rinchen, S., Rai, S., Bidha, R., &Lhayang, K. Y. (2023). Automated Wheelchair For Differently Abled Person With Fall Detection and Maneuverability. Journal of Applied Engineering, Technology and Management. 3(1): 39-47. https://doi.org/10.54417/jaetm.v 3i1.108

[25] Yousuf, S., and Kadri, M.B. (2023). A ubiquitous architecture for wheelchair fall anomaly detection using low-cost embedded sensors and isolation forest algorithm. Computers and Electrical Engineering. 105(1):108518. https://doi.org/10.1016/j.compeleceng.2022.1085 18

[26] Zaid Salah, O., Selvaperumal, S. K., and Abdulla, R. (2022). Accelerometer-based elderly fall detection system using edge artificial intelligence architecture. International Journal of Electrical and Computer Engineering (IJECE). 12(4): 4430-4438

[27] Zhao, D., Yang, J., Wang, Y., Yu, C., Jiang, Y., Wang, S., and Fukuda, T. (2018). Multiple Welfare-Robots Architecture of Smart House for Security Assistance of Daily Activities. 2018 IEEE International Conference on Intelligence and Safety for Robotics (ISR). https://doi.org/10.1109/iisr.2018.8535715

[28] Zurbuchen, N., Wilde, A., and Bruegger, P. (2021). A Machine Learning Multi-Class Approach for Fall Detection Systems Based on Wearable Sensors with a Study on Sampling Rates Selection. Sensors. 21(3): 938-958