

Wearable GPS Tracker for Monitoring Patient Movement in Rehab Centres

FYP 2 Report

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DECLARATION OF ORIGINALITY

I hereby declare that this research together with all its content is none other than that of my own work, with consideration of the exception of research-based information and relative materials that were adapted and extracted from other resources, which have evidently been quoted or stated respectively.

Signed,

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ABSTRACT

The increased demand for successful patient monitoring in the rehabilitation centers has drawn attention to the necessity of implementing the new technology and using its power in the sphere of patient safety and the efficiency of the working process in general. This project shows the progress of implementation of a wearable GPS tracker which will be used to track patients in real-time. The system also includes constant monitoring of the location, geofencing and occasional boundary violations, and maintaining an entire history of the motion, which is viewed through a database and an easy dashboard. The system can also make patient care more personalized and responsive as well as making the patients safer and minimizing the likelihood of wandering incidents by combining GPS technology with the modern, wireless communications systems and an easy-to-use interface. Moreover, the solution helps the healthcare provider make decisions based on data and improves the quality of the rehabilitation services on a general basis. Finally, the project will help in evolving the digital health tools considering some of the fundamental challenges facing patient management by using robust tracking technology.

Keywords: GPS Tracking, geofencing, movement tracking

ABSTRAK

Permintaan yang semakin meningkat terhadap pemantauan pesakit yang di pusat pemulihan telah menarik perhatian terhadap keperluan untuk melaksanakan teknologi baharu dan memanfaatkan potensinya dalam aspek keselamatan pesakit serta kecekapan proses kerja secara keseluruhan. Projek ini menunjukkan kemajuan pelaksanaan penjejak GPS boleh pakai yang akan digunakan untuk menjejak pesakit secara masa nyata. Sistem ini turut merangkumi pemantauan lokasi secara berterusan, *geofencing* dan pengesanan pelanggaran sempadan secara berkala, serta penyimpanan keseluruhan sejarah pergerakan yang boleh diakses melalui pangkalan data dan papan pemuka yang ringkas. Sistem ini juga dapat memperibadikan dan menjadikan penjagaan pesakit lebih responsif, di samping meningkatkan keselamatan pesakit dan mengurangkan kemungkinan insiden pesakit tersesat, dengan menggabungkan teknologi GPS bersama sistem komunikasi tanpa wayar yang mudah digunakan. Tambahan pula, penyelesaian ini membantu penyedia penjagaan kesihatan dalam membuat keputusan berdasarkan data dan memperbaiki kualiti perkhidmatan pemulihan secara keseluruhan. Akhir sekali, projek ini akan menyumbang kepada perkembangan alat kesihatan digital dengan menangani cabaran asas dalam pengurusan pesakit melalui penggunaan teknologi penjejukan yang kukuh dan boleh dipercayai.

Kata kunci: Penjejukan GPS, *geofencing*, penjejukan pergerakan

CHAPTER 1: INTRODUCTION

1.1 Introduction

Indeed, in today's tech-driven world, GPS (Global Positioning System) technology has revolutionized many aspects of life, including healthcare. Originally developed for military use, GPS now plays a crucial role in various civilian applications by providing accurate real-time location data. It is essential for navigation systems in vehicles, logistics and supply chain management, and personal safety devices, allowing for efficient route planning, shipment tracking, and real-time location sharing. Moreover, fitness enthusiasts benefit from GPS-enabled devices that track their activities, while healthcare professionals use GPS to improve patient care, such as guiding ambulances to emergencies and monitoring patients in rehabilitation centers. The integration of GPS into everyday life has enhanced efficiency, safety, and quality of life, and as technology advances, its applications will continue to expand, offering new opportunities for innovation and improvement (Pearson et al., 2023).

Due to the arrangement in most healthcare delivery facilities and especially in a rehabilitation facility systematic surveillance to retain patient movement is essential. People undergoing treatment are often unable to move freely, having to confine themselves to the so-called safe areas both to ensure their health, safety and general well-being (Firouraghi et al., 2022). Traditionally, this type of supervision required great vigilance and constant physical presence on the part of employees, but the advancement of information technologies brought about new tools, such as bed sensors and monitoring cameras, which can help to enhance this important activity. They serve as supportive monitoring devices, assisting personnel in their daily activities but allowing more productive and reliable control. Although personnel continue to play a crucial role in ensuring the safety of patients, these innovations improve the overall structure of monitoring, so that staff can direct their focus towards direct care and long-term care provider support of clients.

Even though there are new technologies, which are indeed designed to benefit the area of patient monitoring, namely, the bed sensors and surveillance cameras, there are grave drawbacks following them. The use of bed sensors requires that custom-made beds be purchased, a procedure that is quite expensive for most healthcare facilities making it impractical. Moreover, the continuous care of such specialized beds imposes a further financial burden on the rehabilitation facilities, most of which are working under critical financial constraints. Conversely, surveillance cameras, which are relatively cost effective, have the unintended skills of monitoring the approach of the personnel or the visitors that usually leads to false warnings or alert failure. These phenomena undermine the performance of the system and may disturb the functioning of the centers.

Furthermore, long-term monitoring of the movement of patients is a challenging operating need among the rehabilitation-center employees. The necessity to have continuous and regular monitoring means that it requires one to be especially attentive, the state which is stressful and exhausting after long shifts. Since the people have a wide range of obligations to attend to, they have a hard time attending to the patient on a regular basis, whether outside the establishment or inside. This persistent pressure of vigilance is linked to burnout and the possibility of human error thus threatening patient security. Although monitoring practices are strong, the existing practice of manual observation and the nature of technological constraints themselves render it impossible to actualize effective and reliable supervision, which explains the need to implement new approaches.

Therefore, considering the technological constraints exhibited by the current approaches of patient-monitoring in the rehabilitation centers, there is an urgent need for some efficient and affordable solution. The present proposal aims to make the use of GPS-based technology a part of a broader system with three key components to it, namely, a small and wearable GPS tracker providing precise location information and intended to be easy to implement and very affordable, a geofence created around the rehabilitation center to track the movements of patients to create alerts when any patient leaves that area, and then an automated Short Message Service (SMS) alert system sending the location and any other relevant information to specific staff members in order to help them to respond in time and protect the health of patients.

Ultimately, the proposed framework is expected to significantly improve the level of care quality and safety in a wide range of rehabilitation centers by continuously and accurately monitoring the patient movements and ensure they can be coordinated and measured accordingly being within the set parameters. The affordability and operational ease required in the project make the project viable in various institutional settings hence ensuring an improved efficiency in the entire patient monitoring process. The use of a wearable GPS tracker, geofencing, and the SMS alert system allows to achieve more efficient and trustworthy monitoring paradigm, which will ultimately culminate in the improvement of patient outcomes and bring both patients and staff members peace of mind.

1.2 Problem Statement

Monitoring patients in rehabilitation centers plays a central role in the protection of clinical outcomes, compliance with evidence-based procedures. During rehabilitation processes, patients are often expected to move within certain areas to resolve some health challenges. In the past, mankind supervision has been the major mission of monitoring such movements which require long periods of vigilance at the same time being emotionally and cognitively demanding. Sustained contact with this level of heightened alert can trigger employee burnout in addition to lowering the general quality of care provided.

To reduce this, bed sensors and surveillance cameras have been embraced to help in the technology. These plans will serve to support human supervision and therefore relax the burden subjected to personnel. However, all these modalities have certain drawbacks associated with them. Bed sensors are good at finding where the patient is but require purchase of bespoke beds, a cost which is not affordable by many centers. Transmission of the movements of all the individuals within the test field is instead recorded by surveillance cameras whenever they move, hence creating false intruder alarms or even omitting the most important movements at all (Latif et al., 2017). Such inaccuracy further makes it difficult to monitor patients correctly in expansive rehabilitation facilities where many people mix.

Although the use of highly developed technologies is a rather beneficial issue, it does not always help to address the necessity to monitor the movements of the patients in a constant and accurate way. When the activities of the patient are monitored incessantly both inside and outside the institutional settings, the members of the staff become subjected to an excessive cognitive load. As a result, any mistakes or break in detection can also cause negative results, such as patient exit of the facility and exposure to possible injuries. There is, therefore, an immediate necessity of a solution that is also more reliable, less expensive and less obtrusive. Wearable GPS tracker system promises a good solution as it would provide real-time positioning information and geofencing support to drive reliability and ensure optimal performance in rehabilitation applications (Latif, et al., 2017).

Ultimately, the current problem is a heavy burden on the health of the patients and the effectiveness of healthcare facilities. Poor monitoring systems place patients in a high-risk position for health and at the same time create more occupational stress and workload for the staff. This situation has the potential to lead to burnout and trigger the deterioration of the quality of care in general. An efficient and all-inclusive monitoring system would, not only, protect the patient's outcomes but also increase the efficiency of the rehabilitation programs by providing peace of mind to both the patients and the practitioners.

1.3 Scope

The current project aims at designing an Arduino-enabled central control unit (CCU) and a patient tracking system using GPS to track movement in rehabilitation centers to confine the patients to a treatment location. In case a patient crosses any boundary beyond this virtual boundary, real time SMS message is sent to rehabilitation staff. The developed workflow combines three elements: (1) a compact wearable GPS sensor; (2) a geofence program that keeps track of the location on a continuous basis; and (3) a cloud interface to facilitate the change of data and control alerts. The CCU keeps constant consistency between the patient location database and the dashboard hence enabling timely notification of personnel whenever there is an out-of-bound event. Together, these factors aim to enhance patient safety, guarantee their location within a safe zone, and allow early response by the rehabilitation staff that in the long-term will increase the overall efficacy of patient tracking systems in the rehabilitation hospital.

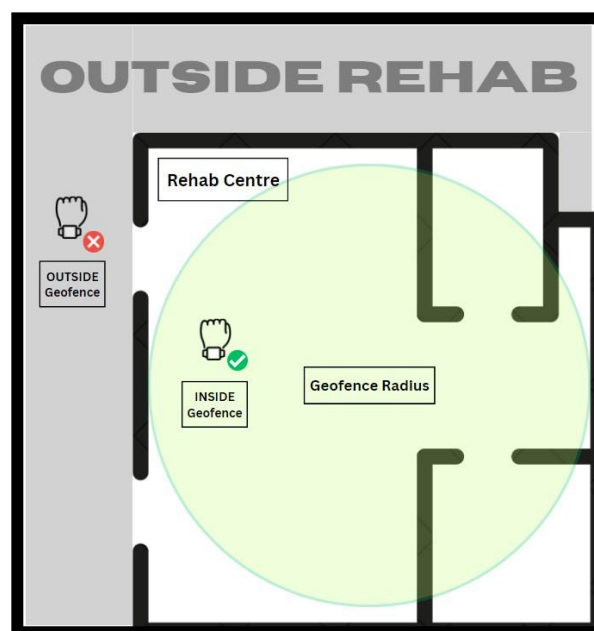


Figure 1.1: Floor plan with the geofence boundary for the GPS tracker.

1.4 Objectives

The objectives of this Wearable GPS Tracker for Monitoring Patient Movement in Rehab Centers project are:

- i. To develop a wearable GPS tracker system that is cost-effective and easy to implement.
- ii. To establish a geofence around the rehabilitation center to monitor patient movement.
- iii. To create a SMS alert system designed to notify staff when a patient crosses the established geofence boundary.

1.5 Brief Methodology

The methodology that is chosen for this project is Agile methodology.

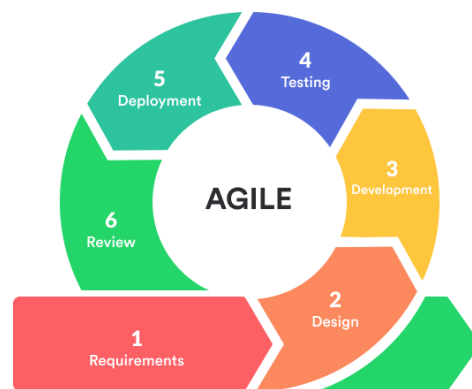


Figure 1.2: Agile Methodology (Jayathilaka, 2021).

Agile methodology is one of iterative and incremental approaches to project management and the development of systems, this paradigm emphasizes flexibility, teamwork, and continual advancement (Al-Saqqa et al., 2020). Unlike the conventional and linear approaches, Agile breaks down the project in small sprints of discrete units that are devoted to parts of the features shaped in a time-based boundary to allow proactive testing and flexible reordering. This modular structure makes Agile especially suitable for the Wearable GPS Tracker to monitor the movement of patients in rehab centers project in that it enables an orderly development through foreseeable phases where each must be systematically tested, polished, and meshed with each other before moving to the other. The iterative nature of Agile fosters feedback and changes to cover new needs all the time, which leads to project sustainability and user-orientation. To conclude, the framework of Agile is a rigid but not strict one which is highly effective in the implementation and successful design of the GPS tracking system which will serve to make a guarantee on the effective monitoring of patients in rehabilitation centers.

1.5.1 Research Planning

The initial processes of the endeavor include project initiation and project planning. At this stage it was decided to conduct a preliminary analysis of project needs-taking survey of the needs of a rehabilitation center, the analysis of the limits of GPS technologies and a choice of geofencing. The resultant information is used to determine the objectives of the project besides the technical feasibility. At the same time, the possible problems are also discovered and the methods of solving them are developed.

1.5.2 System Design

Design stage comes next, where a detailed plan of the Arduino-based central control unit (CCU) as well as the GPS tracker device, geofencing infrastructure, SMS alerting system and web-based dashboard are designed. To visualize the design, as well as the way the system will behave, the diagrams and flowcharts are created. The design must comply with technical specification and user expectations to create an easy integration.

1.5.3 Development

At the development stage, the parts of the project are developed in successive thrashings. Such activities are coding of the CCU, GPS module with a possibility to keep track of the locations, use of geofencing and setting up SMS and the dashboard version on the web. At the end of every sprint, unit tests are performed to ensure functionality and make subsequent steps.

1.5.4 Prototype Testing

Testing stage implies both unit testing of functions and full testing of the complete test prototype in customized environments. The reliability and the accuracy of geofencing, SMS alerts, and the dashboard are evaluated; identified flaws and/or limitations are solved.

1.5.5 Deployment

The application is then done in a natural setting at a center that practices rehabilitation. The CCU and GPS tracker devices are installed as well as the faultless communication between them, the database, and the dashboard are checked. Supplemental training or documentation is also availed on the end users to perform effectively.

1.5.6 Feedback Review and Monitor

The review and the retrospective stage involve gathering the responses of users most prominently the healthcare staff to assess how the system is performing. There is constant monitoring to detect the problems, periodic update being launched, and the improvements made functional. Constant re-analysis of statistics and input guarantees sustainability and extend usage of the system in the future.

1.6 Significance of Project

GPS tracking system forms one of the critical changes to patient safety in the rehabilitation centers through its real-time tracking of location and ability to set geo fences. Being a cost-effective intervention, it reduces the dependency on constant human intervention, which reduces the load on the staff and makes it possible to monitor the process continuously. The interventions take place as patients leave the pre-programmed zones automatically triggering the alerts and, thus, improving patient care. Additionally, this system provides information that could guide the treatment plans and enhance clinical outcomes at the same time, and the concept is not only flexible but also scalable to various rehabilitation environments.

1.7 Project Schedule

This final year project 1 (FYP 1) starts on 10th October 2024 and needs to be completed on 19th February 2025 which takes approximately 4 months. The details of the project are described below in the table and represented in the Gantt Chart.

Task Name	Start	End
▼ Final Year Project 1 (FYP1)	10 Oct 2024	19 Feb 2025
▼ Project Preparation	10 Oct 2024	14 Nov 2024
Project briefing	10 Oct 2024	10 Oct 2024
Prepare brief proposal	11 Oct 2024	19 Oct 2024
Approved brief proposal submission	20 Oct 2024	20 Oct 2024
Feedback from supervisor and examiner	20 Oct 2024	27 Oct 2024
Prepare full proposal	28 Oct 2024	13 Nov 2024
Full proposal submission	14 Nov 2024	14 Nov 2024

Table 1.1: Project Preparation phase

▼ Chapter 1: Introduction	14 Nov 2024	21 Nov 2024
Preparation and consultation for Chapter 1	14 Nov 2024	17 Nov 2024
Finalize Project Introduction	18 Nov 2024	21 Nov 2024
Chapter 1 Submission	21 Nov 2024	21 Nov 2024
▼ Chapter 2: Literature Review	22 Nov 2024	13 Dec 2024
Preparation and consultation for Chapter 2	22 Nov 2024	10 Dec 2024
Finalize Project Literature Review and Comparison	11 Dec 2024	13 Dec 2024
Chapter 2 Submission	13 Dec 2024	13 Dec 2024
▼ Chapter 3: Methodology	14 Dec 2024	05 Jan 2025
Preparation and consultation for Chapter 3	14 Dec 2024	31 Dec 2024
Finalize Project Methodology and System Diagram	01 Jan 2025	05 Jan 2025
Chapter 3 Submission	05 Jan 2025	05 Jan 2025

Table 1.2: Chapter 1,2, and 3 phase.

▼ Final Report	06 Jan 2025	19 Feb 2025
Finalize FYP1 Report	06 Jan 2025	16 Jan 2025
FYP1 Final Report and Paper for Assessment submission	17 Jan 2025	17 Jan 2025
Amendment and Modification Period	17 Jan 2025	10 Feb 2025
Reserved for Presentation (if any)	24 Jan 2025	25 Jan 2025
Final Date for Examiners comments and feedbacks	03 Feb 2025	03 Feb 2025
Final Report submission	19 Feb 2025	19 Feb 2025

Table 1.3: Final Report FYP1 phase.

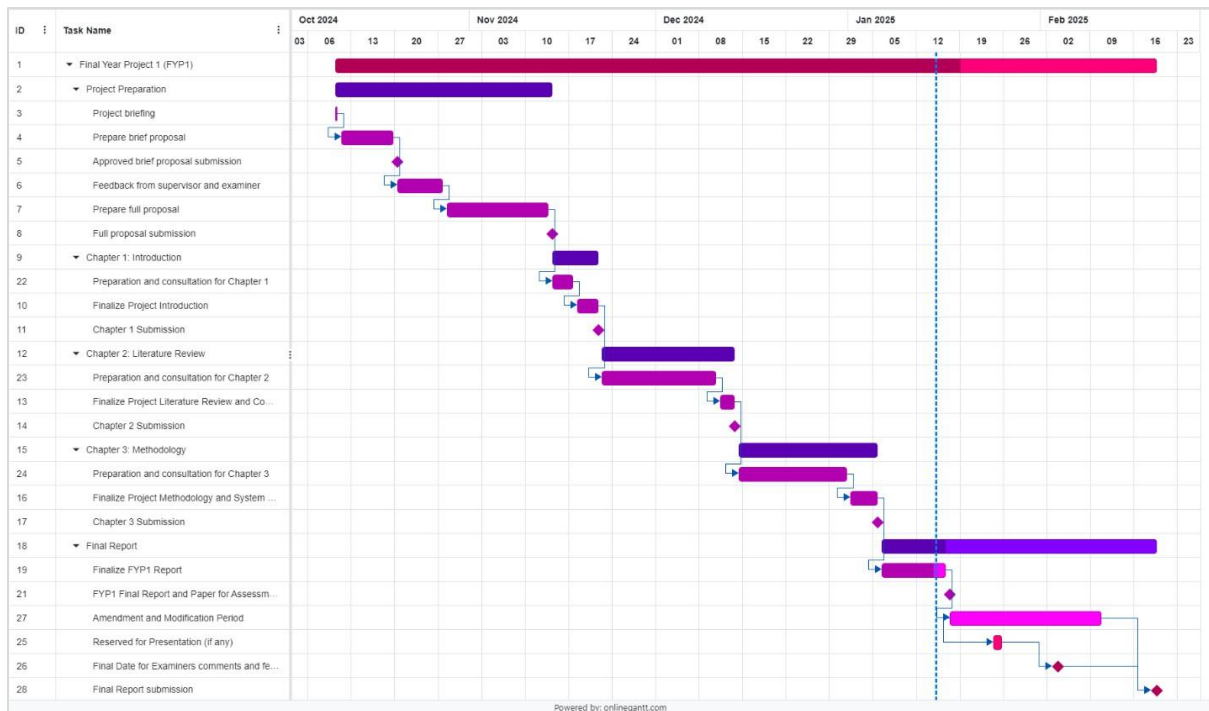


Figure 1.3: Final Year Project 1 Gantt Chart.

For Final Year Project 2 (FYP2), it is expected to start on 17th March 2025 and end on 2nd July 2025 which takes approximately 3 months. The details of the project are described below in the table and represented in the Gantt Chart.

Task Name	Start	End
Final Year Project 2 (FYP2)	2025-03-17	2025-07-02
Chapter 4: Implementation and Testing	2025-03-17	2025-05-03
Prototype testing phase	2025-03-17	2025-03-30
Build, demonstrate and refining prototype	2025-03-31	2025-04-19
Chapter 4 Submission	2025-04-20	2025-04-20
Deployment	2025-04-20	2025-05-03
Chapter 5: Conclusion	2025-05-04	2025-05-15
Refine project conclusion	2025-05-04	2025-05-14
Chapter 5 Submission	2025-05-15	2025-05-15
Finalize FYP2 report	2025-05-15	2025-06-23
FYP 2 Report Submission	2025-06-23	2025-06-23
FYP2 Symposium	2025-07-01	2025-07-02

Table 1.4: Final Year Project 2 phase.

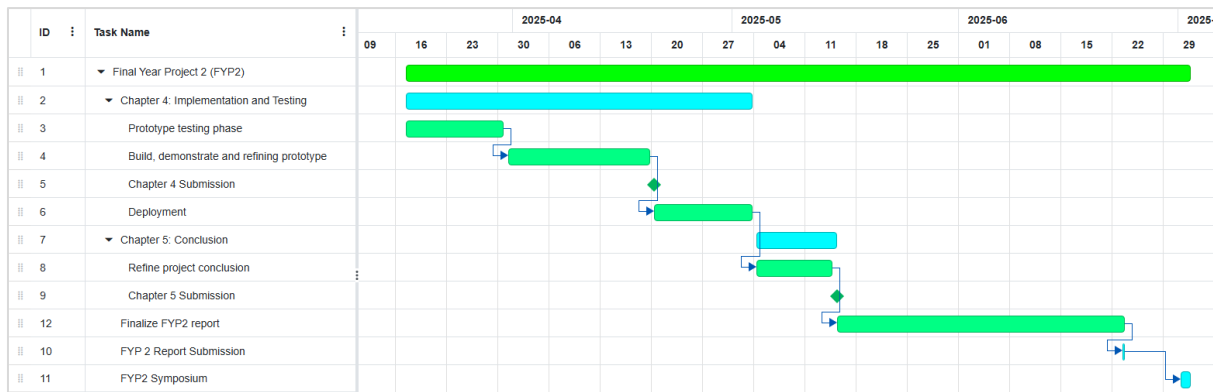


Figure 1.4: Final Year Project 2 Gantt Chart.

1.8 Expected Outcome

- i. GPS Tracker: Lightweight devices that can provide real-time location data to monitor their movements within and outside the rehabilitation center.
- ii. Designated Geofence: Virtual boundaries within the center, defined by GPS coordinates, allowing staff to easily track if a patient enters or exits these areas.
- iii. SMS Alert System: Integrated with the GPS trackers and geofencing, it sends notifications to staff when a patient leaves the designated area, ensuring prompt response and patient safety.

1.9 Summary

This chapter provides a brief description of the project and explains the aims that are planned to solve the difficulties outlined. To address these goals, the methodology, as well as the specific project schedule spanning over three months, is introduced. The importance of the project is highlighted, which proves its probability to increase safety levels, affordability of solutions, and reduction of risks and casualties. Moreover, Agile methodology is decided as the method of project development to guarantee positive results. The chapter therefore helps to set the significance of the project and how it will be organized, and the next chapter will go further to determine how the methodology will be conducted to give a comprehensive overview of what stages and procedures will be followed.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

To achieve desired project goals regarding the outlined project objectives, an optimal background check and analytical process are mandatory. The current chapter thus makes a comprehensive discussion of three current systems that are like the project topic. Based on this comparing, the crucial parameters and requirements of the offered system are separable and, thus, guidance with future design and implementation of the system is informed.

Moreover, the current chapter provides a brief description of the proposed system key characteristics and its expected operational features, thus providing a basis to the following identification of its design and operational scope. The literature review is founded on three academic journals that focus on such systems:

- i. Patient Monitoring using Geofencing (Gokhale, P et al., 2022).
- ii. Remote Patient Tracking and Monitoring System (Kamel, M et al., 2013).
- iii. Internet of Things Gateway Edge for Movement Monitoring in a Smart Healthcare System (Al-Naime, K et al., 2023).

The chapter undertakes an in-depth exploration of the existing body of knowledge on patient monitoring systems based on their methodology, technological aspects and outcomes of using patient monitoring systems. The results derived are then used in the designing process of the proposed system thus improving its architecture and functionality. Moreover, the research outlines any glaring deficiencies in existing systems which the proposed solution aims to rectify.

According to this comparative review, the research highlights the role of calculated dissection in understanding the existing ecosystem of patient monitoring systems and, in its turn, explains how the intended system can meet the needs of its users, guarantee their patient safety, and improve the rehabilitation operations.

2.2 Reviewed on Existing Systems

2.2.1 Patient Monitoring using Geofencing (Gokhale, P et al., 2022).

To begin with, the journal Patient Monitoring using Geofencing (2022) by Gokhale et al. is a systematic study explaining the ability of geofencing technology to support patient monitoring in hospitals with a specific focus on patients diagnosed with cognitive impairments, and dementia and Alzheimer s disease above all. The work answers an imperative of the modern healthcare practice: the necessity of trustworthy and extensible mechanism of patient-safety, which is exacerbated by the accelerating trend in the occurrence of these disabling disorders. The conclusions of the investigators also point out the requirement to incorporate innovative technological interventions that make it possible to increase not only the safety of the patients but also the general standards of the care offered in the medical institution.

Moreover, the authors present a strict explanation of the concept of geofencing which is a technique of creating an imaginary perimeter around the place of interest to allow tracking down individual movement. The mechanism utilizes the capability of the Global Positioning System (GPS) and hence offers real time location data for patients. This constant monitoring is a necessary constituent for avoiding cases of patients leaving areas that are not controllable and exposure to an unsafe environment. The debate goes further to highlight the great urgency of having effective monitoring tools, which is necessitated about increasing incidents of missing patients with dementia.

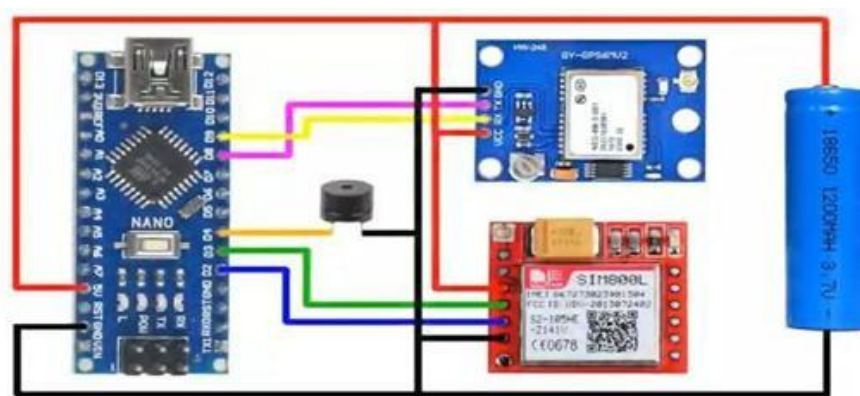


Figure 2.1: Circuit Diagram (Gokhale et al., 2022).

The effective implementation of the geofencing system, according to Figure 2.1 in Gokhale et al. (2022), presupposes a multiplicity of components, i.e., discrete but interdependent elements, such as GPS modules, GSM modules that send SMS, and Arduino boards that are essential in processing. The researchers illustrate the way these elements work together to provide caregivers with instant alert every time a patient leaves the pre-set

geofenced area. This rapidity is quite essential because rapid decisive corrective steps can be taken to maintain patient safety.

$$a = \sin^2(\Delta lat/2)\cos(lat1).\cos(lat2) \quad (1)$$

$$\sin^2(\Delta long/2) \quad (2)$$

$$c = 2.\operatorname{atan2}(\sqrt{a}, \sqrt{1 - a}) \quad (3)$$

$$d = R.c \quad (4)$$

Where:
 $\Delta long$ = Magnitude change in longitude (longitude)
 Δlat = Magnitude of change in latitude (latitude)
 Δlat = lat2 - lat1
 $\Delta long$ = long2 - long1
d = Distance (km)
c = Axis intersection calculations
R = Radius of earth 6371 (km)
1 degree = 0.0174532925 radian

Figure 2.2: Haversine formula used (1)-(4) (Gokhale et al., 2022).

In the given study, the field of analysis is the usage of the Haversine formula shown in Figure 2.2 in finding the shortest path between a patient and a caregiver. This mathematical model allows to significantly increase the accuracy of the monitoring system because caregivers can estimate more accurately to what extent a patient is outside of the safely set perimeter. The authors provide an illuminated explanation of the equation and its applicability to the geofencing technology under discussion and invoke in such a way an understanding of the practical applicability of the equation even in greater depth to the reader.

In conclusion, the paper on the topic by Gokhale et al. (2022): Patient Monitoring using Geofencing is a systematic investigation of the technology of geofencing in the field of healthcare. The research describes the benefits that such a method can deliver to the surveillance of cognitively impaired people, at the same time locating the challenges that should be overcome to ensure successful implementation. Through this, the study will be adding significantly to the existing body of increasing evidence that proposes innovative approaches to healthcare and this study can be seen as the foundation of future patient monitoring processes and thus illustrates the critical position of geofencing to the patient care framework.

2.2.2 Remote Patient Tracking and Monitoring System (Kamel, M et al., 2013).

The increasing need for constant patient care has created certain significant problems for healthcare providers. In this context, the traditional patient-monitoring modes of operating usually force the individuals to have to work within a limited area that is marked by the wireless transmitters, which limit mobility as well as independence. To this end, Kamel et al. (2013) introduce a Remote Patient Tracking and Monitoring (RPTM) system to which wireless medical sensors are incorporated to monitor vital signs yet provide the players with a sense of freedom of movement. This development avoids weaknesses of the existing systems by having the GPS installed into locating a patient, thus enhancing the ability of health personnel to respond to emergent cases quickly.

Additionally, Kamel et al. (2013) see the growing trend of the mobile healthcare applications industry driven by the development of wireless communications and increased interest of the masses in health problems. The empirical research shows that in 2015, it will have exceeded 100 million mobile healthcare application users, proving the importance of the solutions to modern health practice. However, the systems in the current generation, though very useful in observing patients in a limited area, do not offer required flexibility, allowing patients to continue with their daily life without compromising on health monitoring.

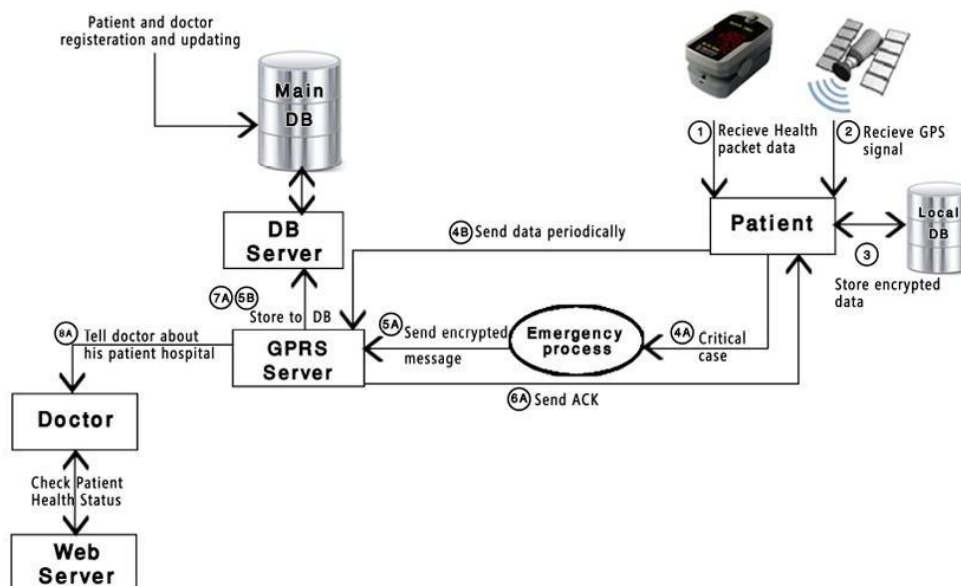


Figure 2.3: The proposed system workflow (Kamel et al., 2013).

As can be seen in Figure 2.3, provided earlier the very architecture of the Remote Patient Tracking and Monitoring (RPTM) system, described by Kamel et al. (2013) includes three key modules including medical sensors, data processing units, and communication media. The system is systematically designed in such a way that it can receive constant measurements of vital parameters such as temperature, heart rate, and blood pressure and in the meanwhile, it will be able to monitor the geographical location of the patient using GPS. The system triggers existing emergency procedures in case of a negative health situation and delivers notifications to medical personnel and ensures fast support. This is an advanced anticipatory system that is far better compared to traditional systems, which are likely to deal with emergent health events and not prevent them.

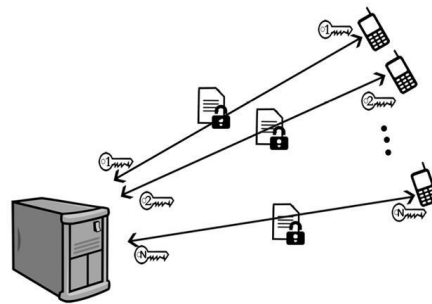


Figure 2.4: Message encryption scheme (Kamel et al., 2013).

Furthermore, Kamel et al. (2013) emphasize the central importance of data security in the setting of remote patient monitoring (RPTM). Health-related information is sensitive and thus it deserves rigorous protection. In that regard, the system incorporates the use of state-of-the-art encryption codes that secure patient information shared over the network. These security measures are unavoidable, since privacy infringement can jeopardize not only the confidentiality of patients, but also their confidence in healthcare technologies. As well, the authors outline roles and responsibilities of stake holders in the system, that is, patients, clinicians and system administrators, all of whom are needed in turning RPTM practices effective and reliable.

In conclusion, Kamel et al. (2013) presented the Remote Patient Tracking Model (RPTM) that represents a breakthrough in the field of remote patient monitoring. The integrated mobile technologies and capabilities of monitoring health in real-time and relaying emergencies via automated emergency-response systems makes the system not only useful in case of patient movement but also enhances the society-wide level of healthcare delivery. With the ongoing transformation of the healthcare environment, the further incorporation of innovative enhancements, such as the RPTM, is unavoidable in fulfilling the needs of both patients and the health providers. As a result, literature shows a decisive role of technological advancement on the path of patient care.

2.2.3 Internet of Things Gateway Edge for Movement Monitoring in a Smart Healthcare System (Al-Naime, K et al., 2023).

During the last 20 years, the role of applying the Internet of Things (IoT) to the world of healthcare has become one of the most relevant issues, as it promises to increase effectiveness and improve the effectiveness of healthcare services. Al-Naime et al. (2023) challenge this development, discussing movement monitoring in the scope of a smart healthcare framework, with the focus on pre-operative prehabilitation programs (PoPPs). The researchers stress the fact that IoT technologies such as Raspberry Pi (RPi) or even wearable devices can be used to solve the problems that patients with chronic diseases tend to face. In the current scenario, chronicity like cancer often happens to halt the gains to supervise exercise programs. The paper thus shows how these new tools can break such obstacles and, in the process, enhance the overall patient outcomes.

Moreover, Traditional healthcare delivery models have failed to be effective in long-term surveillance and interventions among the patients with chronic diseases. This weakness is most notable in patients with cancer who are on the waiting list to undergo an operation and thus are driven by physical deconditioning because of long waitlists and minimal interaction with care providers. There is an increasing amount of evidence that prehabilitation may significantly improve clinical outcomes of patients through physical conditioning and reduction of postoperative complications. However, it turns out that many of the patients are still not covered by the conventional supervised prehabilitation programs due to geographical isolation, long wait time, and travel costs. Based on this, the gap in care has led to the increased academic and clinical attention on home-based prehabilitation interventions. As promising as these models may be, in general, they have lower rates of adherence and poorer health-related outcomes as compared to structured, supervised programs.

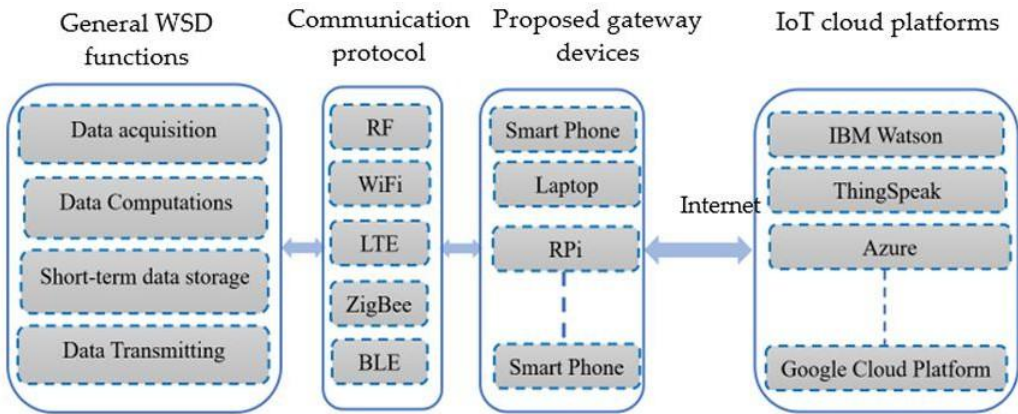


Figure 2.5: General organization of IoT system supporting the prehabilitation program (Al-Naime et al., 2023).

To overcome the above-mentioned challenges, Al-Naime et al. (2023) provides an IoT-based remote monitoring framework consisting of a Microduino wearable sensor and an RPi operating as the gateway to collect and analyze the data in real-time. The device will monitor the physical performance of the patients in prehabilitation activities, and as such, provide information to clinicians regarding improvements. Proper identification of specific physical activities and the levels of intensity have been known as key in verification of attainment of prescribed parameters of exercise.



Figure 2.6: a) RPi3B as a base station gateway, (b) RPiZW as a portable gateway (Al-Naime et al., 2023).

Furthermore, this paper is a critical assessment of the existing home-based monitoring systems and highlights their common deficiencies which are the necessity to use several devices and the impossibility to provide the comprehensive picture of exercise complexity and duration. To overcome these limitations, the proposal makes use of only one wearable sensor in combination with a comprehensive gateway, which makes it more streamlined to collect the data and maximizes the accuracy of the analysis of activities. The overall activity-monitoring success rate of 78 % evaluated by Al-Naime et al. (2023) also proves strong positive evidence that the implementation of IoT technologies may significantly improve the process of prehabilitation protocol management and, by extension, lead to enhanced patient outcomes.

In conclusion, Al-Naime et al. (2023) confirm that Internet-of-Things (IoT) technologies provide an excellent opportunity in the healthcare of the profession, but more specifically in cancer prehabilitation. They also emphasize the importance of the protection of the data of patients with a suggestion of applying unique device identifiers along with the secure transmission protocols. Bidirectional, devoid of two way communication between devices and servers is considered as an irreducible requirement of any strong data defense. The authors also suggest that the future research should investigate the idea of adding artificial intelligence to increase the accuracy and efficiency of remote monitoring systems.

2.3 Comparison of Existing Systems and the Proposed System

Feature	Patient Monitoring using Geofencing (Gokhale, P et al., 2022)	Remote Patient Tracking and Monitoring System (Kamel, M et al., 2013)	Internet of Things Gateway Edge for Movement Monitoring in a Smart Healthcare System (Al-Naime, K et al., 2023)	Wearable GPS Tracker for Monitoring Patient Movement in Rehab Centers (Proposed System)
Main Component	Arduino Nano.	Centralized server (unspecified components).	IoT gateway.	Arduino-based central control unit (CCU) and GPS tracker device.
Communication Modules	SMS for alert notifications.	GPRS server for encrypted message.	Wi-Fi for data transfer.	SMS and Wi-Fi for alerts and data management.
Sensors	GPS module (NEO-6M) for location tracking.	Basic sensors for monitoring (unspecified sensors).	“Wearable Sensor Device” for sensing the movement and capturing raw 3D movement data.	GPS module for location tracking and GSM module for SMS communication.
User Interactions	SMS alerts caregivers.	Mobile application for real-time monitoring.	Web-based dashboard and real-time analytics for healthcare providers.	Web-based dashboard and SMS alerts to healthcare staff.
Cloud Storage	Cloud storage unspecified.	Cloud storage unspecified.	Cloud-based IoT framework for real-time data processing and storage.	Cloud-hosted database storage for real-time data synchronization and web hosting.
Power Source	Battery-powered GPS devices.	Power sources unspecified.	Energy-efficient IoT modules, potentially battery-powered.	Cable-powered GPS and GSM devices.

Table 2.1: Comparison on Existing Systems and the Proposed System.

2.4 Brief Overview of the Proposed System

The suggested system can be a wearable GPS tracking device that would allow observing the patients of the rehabilitation centers. The device can not only serve to improve patient safety but also aid proper rehabilitation due to its capability to track their real-time location and send immediate notifications to health service personnel. The system puts to rest issues associated with monitoring of patients using modern technology thus making the rehabilitation process safer and effective.

The overall goal of this system is to design an inexpensive and simple to install wearable GPS tracker that can be easily included in the rehabilitation locations. In this direction, the system will create a geofence (type of geographical fencing) around the rehabilitation center to track the movement of patients and SMS will alert the staff when the patient breaches the given boundary. It is through this that safety matters are responded to quickly, hence a focus on enhancing rehabilitation is maintained.

The fundamental part of the system consists of Arduino-based central control unit (CCU) and a GPS tracking device that is portable and user friendly. The tracker, which can be worn comfortably without interfering with the patients is designed in such a way that during their rehabilitation activities the tracker remains unobtrusive. Moreover, the GPS block makes sure that the location is tracked accurately and GSM block implements reliable communication enabling real time notifications and smooth data transfer.

In order to manage the patient data in an effective way, the system takes the use of a cloud-hosted database, where the healthcare providers can securely store, access, and analyze the information about the movement of patients. Such information can be utilized in greater planning of rehabilitation measures as well as modifying them in accordance with the requirements of a patient. Also, the device runs on a chargeable battery making it easy to carry about and use all through the rehabilitation process.

To conclude, a wearable GPS tracker offered by this paper is a solution of combining real-time tracking, geofencing, and cloud-based data management to address patient safety and facilitate successful rehabilitation. Through its objectives this new system has the advantage of providing an effective and economical route to improving the rehabilitation centers in terms of taking better care of patients.

2.5 Summary

Analytical methodology A systemic review of modern patient-monitoring technologies is the basis of an offered wearable GPS tracker that can be used in the rehabilitation centers. Gokhale et al. (2022), Kamel et al. (2013) and Al-Naime et al. (2023) analyses are especially informative. Gokhale et al. use geofencing, together with GPS and GSM features to alert care providers when the patients with dementia have left designated safe areas, thus enhancing safety by providing high-resolution location information. The case of Kamel et al. can demonstrate important developments in emergency response work and communication features, offering a remote monitoring and tracking platform that provides real-time vital-sign operations and mobility conditions along with encrypted data collection to ensure patient privacy. In another study, Al-Naime et al. explored the field of IoT in prehabilitation of patients with chronic illnesses, where wearable devices and various IoT gateways are used to support remote monitoring of activities, and a particular focus is made on ensuring the security of data. The suggested wearable GPS-based tracking system incorporates geofencing, GPS location module, and text message alert at a price-conscious and user-friendly standard that values both economy and alertness and concomitantly delivers a better rehabilitation performance and patient security. Succinctly, a combination of those studies provides empirical evidence and theoretical frameworks to develop and install such a system.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The problem under construction Wearable GPS Tracker to Monitor Patient Movement in Rehabilitation Centers is devoted to a methodology chapter which charts the methods and methodologies used in the development of the solution. The discussion starts with the identification of the project methodology which is Agile Methodology followed with an argument as to why this framework is chosen. Sections that are next provide an in-depth analysis of the system requirements especially focusing both on hardware and software factors. The chapter ends by describing the system design and architecture in a very detailed manner, thus creating a good foundation upon which the implementation phase will be based.

3.2 Project Methodology (Agile)

The concept of Agile methodology represents a current, cyclical programming process and software development, which are quite different when compared to the former, linear style of project management characterized by a Waterfall model. Agile proponents depart from the idea of having work divided into one unified stage and instead follow the system of the project divided into small time-limited sprints of various durations between 1 and 4 weeks to enable project measurement progress, stakeholder feedback, and requirement changes. Focusing on these iterative steps of work, the Agile approach fosters teamwork, encourages constant improvement, and provides value over time and throughout the life cycle, which evenly spreads effort differently by focusing resources more on the actual delivery (rather than initial stages or planning) as traditional approaches in the field of project management.



Figure 3.1: Agile Software Development (D. Iddo, 2021).

By implementing an Agile framework, it can be said that a Wearable GPS Tracker with geofencing capabilities and the ability to send SMS notifications can be developed. The step called the Research Planning will help to define the aims of the project; in such a way, it

helps to explain how the core functionality like geofencing should be prioritized; the specific task list that aims to address the true real-world issues such as patient safety or the usability of the device will become clear.

The System Design step represents the phase during which the system architecture, a combination of both hardware implementation of the GPS tracker and a software framework of handling the GPS data, is painstakingly described. The use of the Agile methodology grants flexibility during this step, which allows a step-by-step improvement as the requirements change. The Development phase can be set when the design has been made. In this phase, the elements are being built and connected on an iterative basis: the tracker device can be assembled, the geofencing feature then programmed and the SMS alert mechanism implemented. After each step, the components are taken to the experiment stage to ensure that they are reliable and functional.

Next, the Prototype Testing stage checks the functionality of each part as well as the whole within its interaction. The use of the iterative framework offered by Agile gives future opportunities to optimize the system under development through the testing of its capability to accurately provide patient movement monitoring and send trigger messages in case a geofence line is crossed. After passing successful tests, the deployment phase is launched, which presupposes the systematized implementation of the system in a rehabilitation center. This phase concerns thorough personnel training and the gathering of preliminary user feedback. These in combination pave way to an efficient introduction of a system and facilitate optimum exploitation of the system wherein real-life situations are given consideration.

The sixth and the last phase would be the Feedback Review and Monitoring, which acts as feedback on system performance as well as providing feedback-based remedial adjustments to the staff and the patients. In this phase, agile methodology will allow an iterative release cycle, which in turn will allow enhancement of important details, such as enhancing the accuracy of the GPS and increasing the configurability of the alert system.

Agile methodology used in this project represents a systematic guide but flexible model of control of the project complexity. When embarking on such a course of action, one can be assured that the GPS tracker will meet both the technical requirements as well as the needs of the user, albeit it will be flexible enough to meet change. Agile enables the early realization of a stable and affordable solution with rigorous sustenance of the key phases of development, which support the efforts in patient safety and continued monitoring in the rehabilitation facilities.

3.3 Requirement Analysis

3.3.1 Identify the user

The primary users of the wearable GPS tracker system include healthcare staff, rehabilitation patients, and rehabilitation center administrators, as illustrated in Figure 3.2. Healthcare staff, such as nurses, doctors, and caregivers in rehabilitation centers, rely on the system to monitor patient movement effectively, ensuring timely interventions when needed. Rehabilitation patients, who wear the GPS tracker during their recovery, benefit from enhanced safety and monitoring, which supports their rehabilitation journey. Additionally, rehabilitation center administrators, including managers and operational staff, play a crucial role in overseeing the system's implementation and ensuring it is utilized effectively to optimize patient care and center operations.

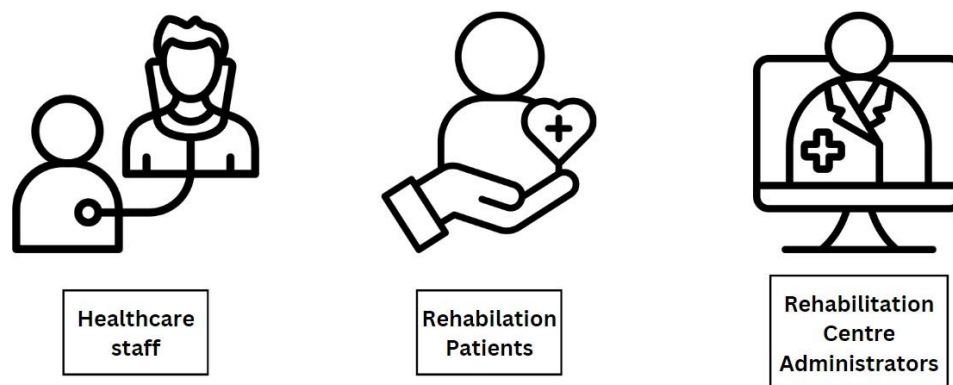


Figure 3.2: Users that will be involved with the proposed system.

3.3.2 Hardware Requirements

The Wearable GPS Tracker to Track Patient Movement in Rehab Centers entails a system that helps in monitoring patient movement in rehabilitating institutions thus constituting the elements of cost-effectiveness, easy implementation, and an effective monitoring system. The system integrates three central hardware elements, namely the Central Control Unit (CCU) and the GPS Tracker Device. All the components are essential to the achievement of the stipulated goals of the project.

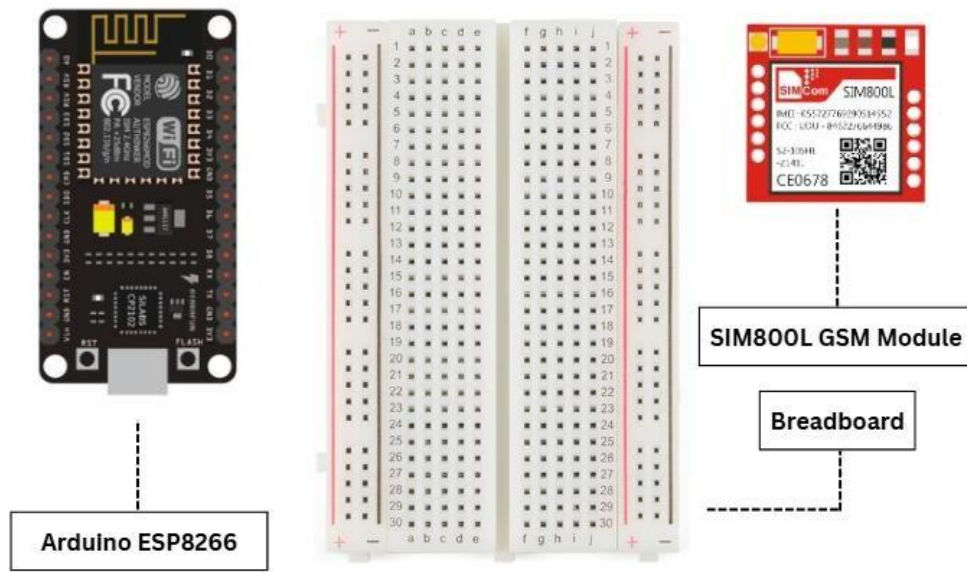


Figure 3.3: The Central Control Unit (CCU) board components.

As seen in the light of Figure 3.3, the Central Control Unit (CCU) is the single functional core of the system. The CCU uses the Arduino ESP8266 MCU microcontroller, which has inbuilt Wi-Fi enabling easy access to the internet. The system is complemented with the SIM800L GSM Module that enables messages in SMS format to be sent and the possibility to use GPRS in real time. In prototyping, breadboard makes it easier to assemble and test decoupled components. In addition to that, the power provided to the CCU is electric power, which is supplied with a power adapter, inserted into a standard electrical outlet, and thus maintaining an effective functional process. Operationally, the CCU can issue SMS messages, refresh a database, and update a dashboard, hence ensuring constant observation and spread of information relative to patient movements.

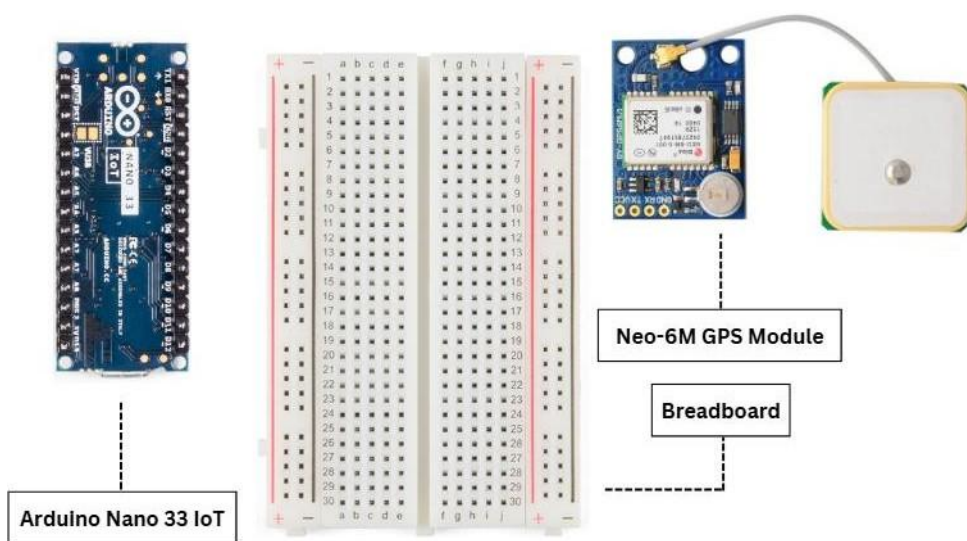


Figure 3.4: The GPS tracker device components.

In line with principles of simplicity, functionality, and user friendliness, the prototype of the GPS tracker shown in Figure 3.4 was designed. The real-time positioning information provided by the Neo-6M GPS Module is high-precise positioning information and the information is then further processed by the Arduino Nano 33 IoT microcontroller. Combined with the functionality of this microcontroller, it is fitted with Wi-Fi capability to transmit row-by-row changes in location to the Firebase Realtime Database without internet connection. In the present state of prototyping components get soldered on a breadboard, thus permitting testing (flexible, solderless). The final design goal will be to attain a small, portable form that patients continue rehabilitation therapy. This will be followed by an enclosure of the device inside a lightweight and comfortable casing; a housing in which the device can be used conveniently and on a day-to-day basis.

In summary, an analysis of the literature has revealed that the Wearable GPS Tracker for Monitoring Patient Movement in Rehabilitation Centers system incorporates advanced-level components of hardware to carry out a secure and convenient system of tracking the movement of patients. With synergy between the GPS board and CCU board, the system will allow efficiency of the system as well as accuracy, efficiency and comfort to the patients.

3.3.3 Software Requirements

When creating the system of Wearable GPS Tracker of Monitoring Patient Movement in Rehabilitation Centers, it is necessary to use multiple software tools and libraries that will help to make the work of the system seamless and make working with information convenient. This project utilizes the Arduino Integrated Development Environment (IDE) to code, many libraries to extend the features, and cloud-based programs like firebase to store all the data and host the web page. Using such resources, it is possible to build a strong system which is efficient in monitoring movements of patients in rehabilitation centers.

Arduino integrated Development Environment (IDE) is the main program used to enter code and to upload it in the Arduino Nano 33 IoT. Particularly, this user-friendly environment makes the process of coding simple, and it is easy to create and handle projects effectively. Specifically, the IDE can work with many libraries, and it is convenient to add one of them to add more features and make the development more comfortable. Moreover, IDE has facilities that allow debugging and real-time observation, which goes a long way in providing reliability of the system. To start development, it is possible to download Arduino IDE on the official Arduino site. Furthermore, the large base of documentation and community support offered to the Arduino IDE is also a great advantage to the development

environment, thus it can be easily accessible to both novices as well as the experienced developer.

To improve the functionality of the Wearable GPS Tracker project, one will require several open-source libraries. To start with, it helps to work with location data more easily as TinyGPS++ is specially designed to parse GPS data of NEO-6M GPS module. This library can be added through the Library Manager of Arduino IDE. Second, the WiFiNINA library deserves to be mentioned because it utilizes Wi-Fi connections on Arduino Nano 33 IoT. Distinguishingly, this library comes bundled with the Arduino IDE and does not need any additional installation process. Moreover, HTTPClient library will play an important role in sending HTTP requests to provide the data to the database and this library is also provided with the Arduino IDE. In general, all these libraries are open, and, thus, people can contribute to them and make changes.

Firebase is a NoSQL database offering a free level of service and is cloud based. It allows storing and retrieving GPS information in an efficient way. A firebase project should be set up and either a firestore or realtime database should be set up to use the Firebase effectively. Firestore is a mobile, Web, and server developer database. Advanced querying, and data synchronization through a flexible and scalable database. Otherwise, Realtime Database is the best choice to create collaborative apps, where it offers real-time data synchronization and offline data support. Using the powerful infrastructure of the Firebase, this project will be able to guarantee effective and safe data management.

Firebase Hosting is a service that provides an opportunity to host a free static site, so it is ideal to use it to create a web portal to present GPS information. To install the web application, Firebase CLI (Command Line Interface) may be applied to deploy the project easily. The CLI enables the launch of the project, deployment settings, and deploys files to Firebase Hosting servers. Moreover, the Firebase Hosting system uses HTTPS, and it provides secure experience on the web dashboard. It makes deployment easy to handle so that the web dashboard becomes amiable and well managed. Due to the deployment of Firebase Hosting, the developers can work to make the interface intuitive and convenient to make use of with no need to worry about the server maintenance and scalability.

In the development of web dashboard, HTML, CSS and JavaScript are a must. The provided text editor like Visual Studio Code is perfectly suited to this task because of its comprehensive functionality and the convenient interface. Moreover, it is possible to improve the design and functional use of the dashboard with the help of frameworks. As an example, Bootstrap will be the best solution to design responsive websites, so the dashboard becomes available on any device. Moreover, the Java script frameworks, that are currently trending,

are Vue.js and React, which help to create interfaces appropriately. With the help of these tools and frameworks, it is possible to conduct a much efficient development process, which makes the web dashboard look more attractive visually.

Serial Monitor is an inbuilt platform of Arduino Integrated Development Environment (IDE) that enables viewing of debug messages and data of the Arduino Nano 33 IoT. The tool is very useful in the troubleshooting of projects and the monitoring of the projects with real time feedback.

To summarize, the creation of the Wearable GPS Tracker System is possible to develop successfully with the help of key software tools and libraries. With the help of the application Arduino IDE, GPS and Wi-Fi management libraries, and Firebase data storage, an effective and complete system is developed. Such resources facilitate the development process, increase functionality, and monitoring of the patients in the rehabilitation centers.

3.4 System Design and General Architecture

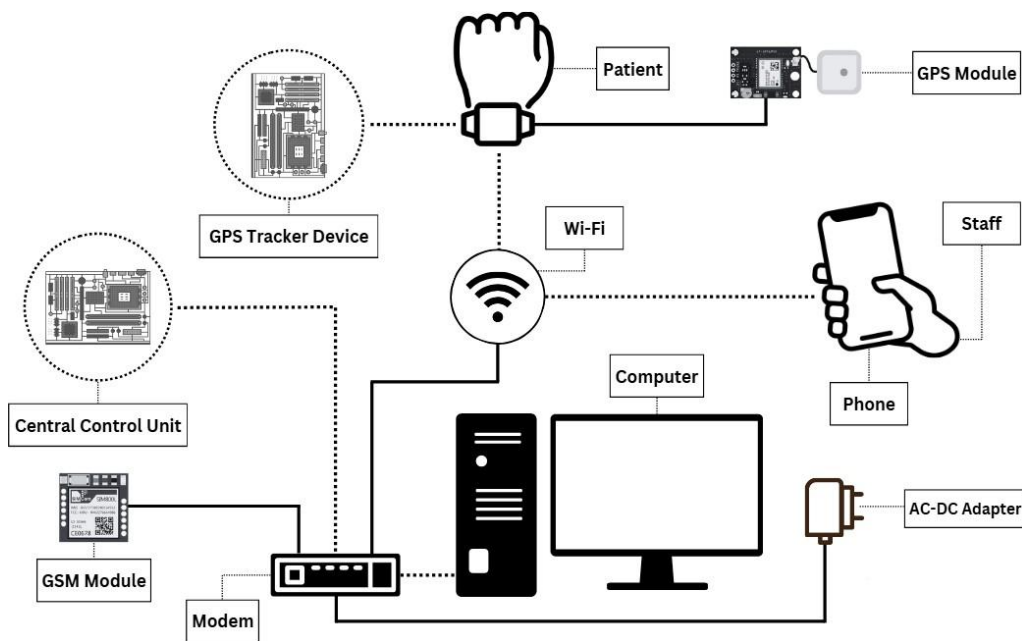


Figure 3.5: Connection Design for the proposed system.

Referring to Figure 3.5, the connections illustrate a well-structured design for the proposed system. In particular, the patient is outfitted with a GPS tracker gadget that interacts with Wi-Fi network. This is a network that links the GPS tracker that is attached to a GPS module to the Central Control Unit (CCU) that is packaged in a case to allow it to act as a modem. Also, the GSM module is linked with the CCU, and it can send SMS messages. Moreover, the Central Control Unit will communicate with the computer through Wi-Fi, thus creating a central point in terms of gathering information and tracking. The CCU is enjoyable with a power adapter which is plugged in the power socket, it will keep on working and it is

reliable. At the same time the Wi-Fi network is connected to a phone where SMS alerts are given out by the Central Control Unit. This solution will make sure that the location and information about the patients are always available, and exposed to the staff, wherever they are in their mobile phones, through SMS info.

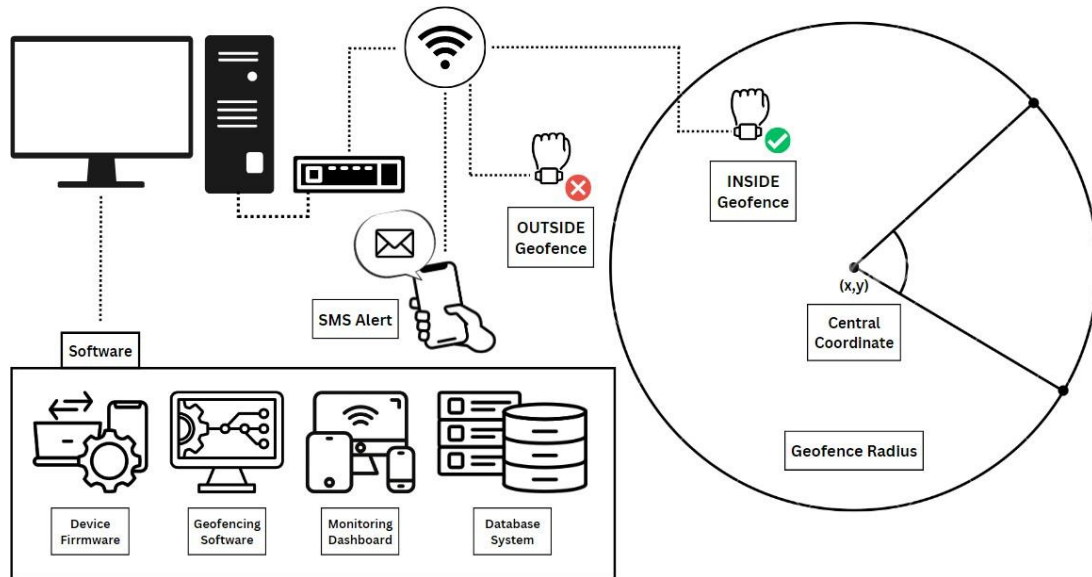


Figure 3.6: System Design for the proposed system.

The system design of the wearable GPS tracker as shown in Figure 3.6 can seamlessly combine both the hardware and the software part to offer efficient and reliable tracking of the patient during his/her movement within the rehabilitation centers. In particular, the hardware, that is the Central Control Unit (CCU) and the GPS tracker device, provides the correct location tracking and real-time communication. In addition, the software modules, including the firmware of the device, geofencing software, SMS notification system, monitoring dashboard, and database system, are combined to provide real-time notifications, map patients, and record patient information in a history to analyze it. Finally, this integration guarantees a wholesome monitoring tool.

The design would help promote patient safety through the geofence boundary around the rehabilitation center, which allows monitoring of the patients by the healthcare staff. In turn, when a patient goes outside the line, the alert is immediately delivered through the SMS to guarantee a rapid response and reduce possible risks. The system, in general, is easy to handle, trustworthy, and fast, which is an effective way to address and enhance patient care and safety in the rehabilitation setting.

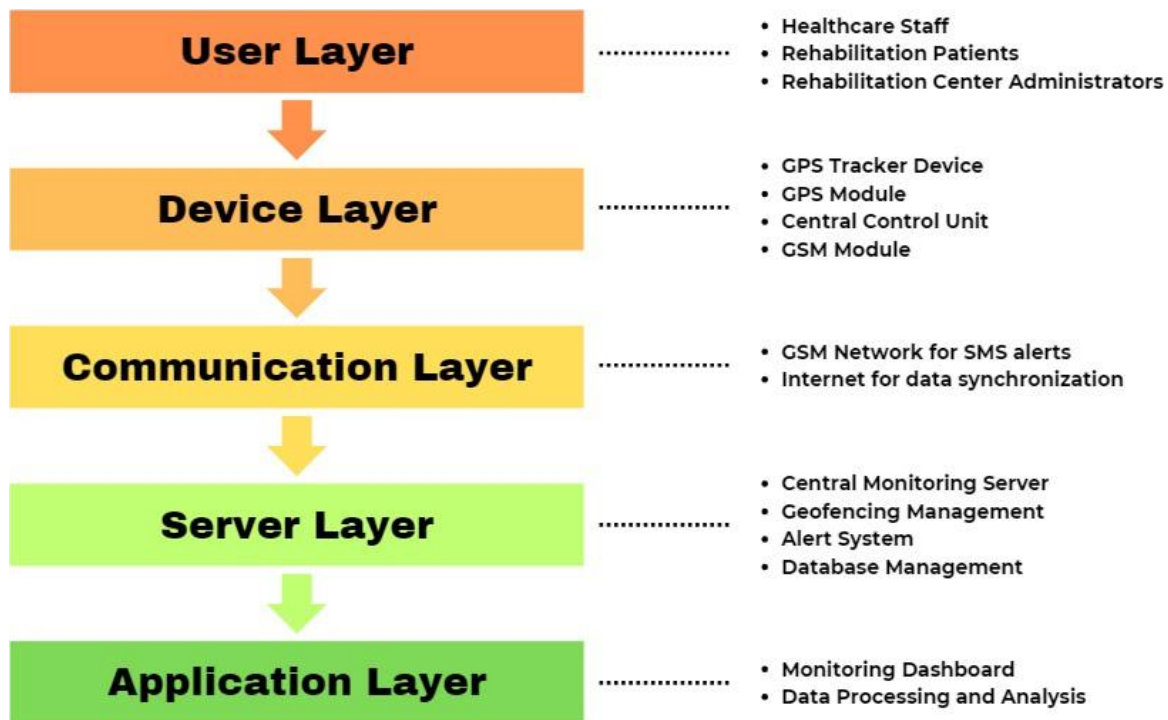


Figure 3.7: General Architecture Layers.

As can be observed in Figure 3.7, the basis of the wearable GPS tracking system is constructed with five fundamental layers that provide an easy running and simple to use operation. Firstly, the area of the User Layer consists of hospital personnel, patients, and administrators, which makes the system viable and operational. Secondly, within the Device Layer there is the GPS tracker device, the GPS module, the Central Control Unit (CCU) and GSM module, which does the real time tracking and data-taking. Thirdly, SMS alerts are conveyed with the use of GSM networks and the internet is used to convey real-time sorties which makes the flow of data seamless. Moreover, the Server Layer reads and writes the information to a central server, geofencing administration and the alerts system which provides effective monitoring and protection. Finally, to top it all off, the Application Layer offers a dashboard for real-time monitoring of location and historical data analysis in order to optimize the care of patients. The combination of the layers forms a stable and intuitive system that ensures that patients are safe, and staff minimize response time to emergencies.

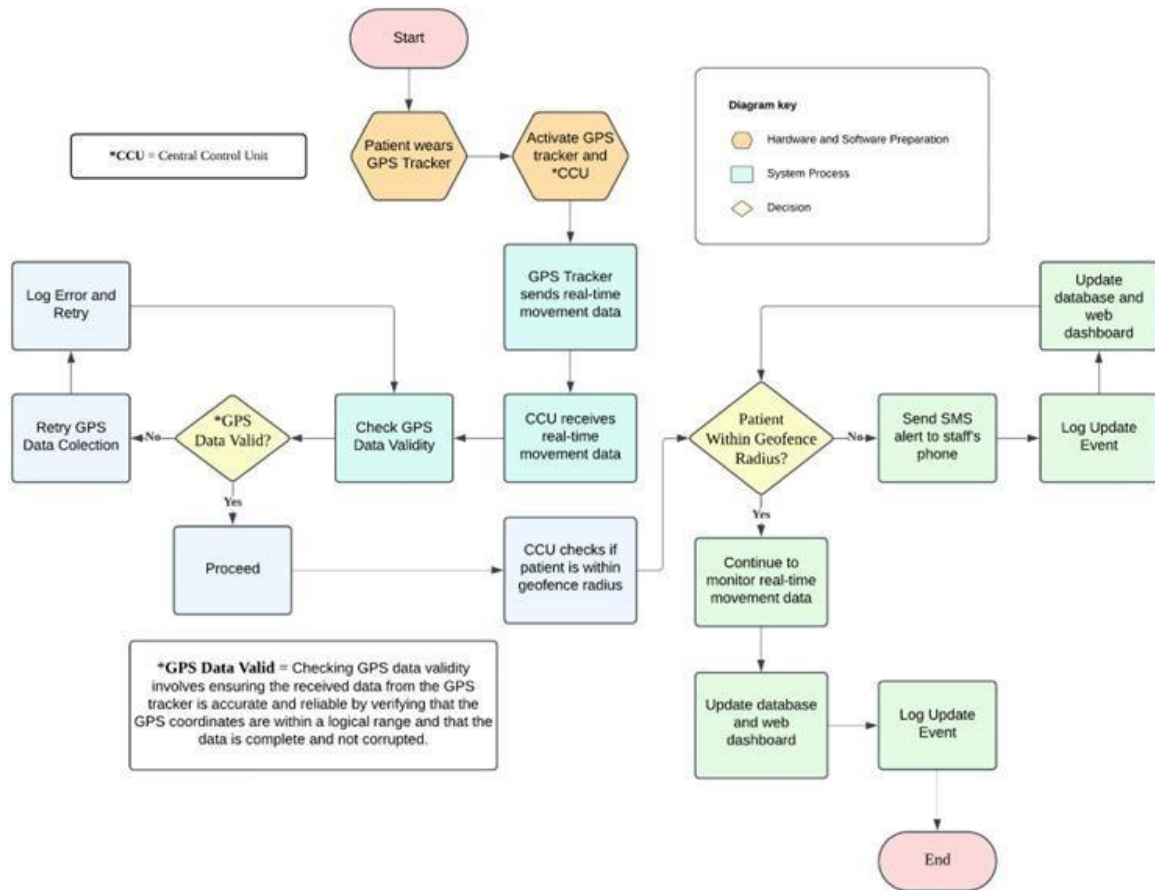


Figure 3.8: Flowchart of the Wearable GPS Tracker for Monitoring Patient Movement in Rehab Centers system.

During the proposed project as shown on the project flowchart in Figure 3.9, the patient will be equipped with a GPS tracker device that will stream the information on real-time movement. This kind of data is received and processed by the Central Control Unit (CCU) acting as a modem device to track the patient location area in terms of a given geofence radius.

As an example, when the patient goes beyond the radius of the geofence, the Central Control Unit (CCU) will realize it in real time and an SMS message is instantly sent to the phone of the staff, stating that the patient left the boundary. At the same time, the current location and status of the patient are uploaded to the central database and the web dashboard with the CCU. Any information that should be up to date is kept up to date.

As long as a patient is placed within the geofence radius, the modem keeps on receiving real-time movement data. In this scenario, however, the database and the web dashboard are basically updated every hour to verify that the patient is within the boundary. This plan will make sure that no SMS is sent to the phone unless it is crucial not to remind people often about minor violations and concentrate the attention on major boundary crossings.

The electronic monitoring system introduces the principle of constant monitoring of the patient location because it provides real-time notifications of the violation of the border and periodical updating of the database and web dashboard. As a result, it provides in-depth supervision and enhances patient safety due to the timely action of health-care workers.

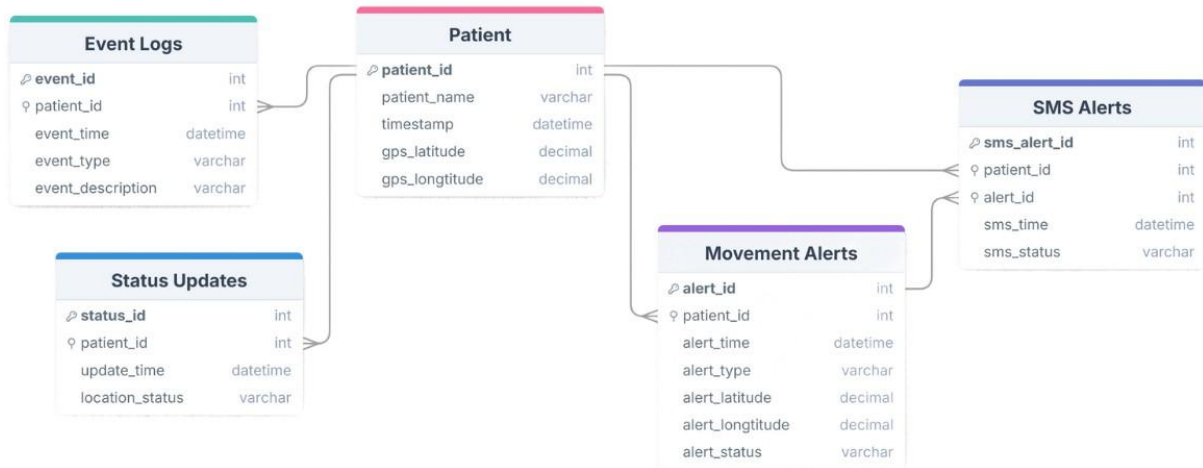


Figure 3.9: Database Diagram for the purposed system.

The database diagram of the patient monitoring system includes 5 tables as illustrated in Figure 3.9 including Patient, Movement Alerts, SMS Alerts, Status Updates, and Event Logs. The tables have their different roles in providing an excellent source of information on the patients.

The Patient table is discussed as the foundation of this database because it consists of the necessary information concerning individual patients. This has a patient unique identifier (`patient_id`), the name of the patient (`patient_name`), the time the record was made and their GPS coordinates (`gps_latitude` and `gps_longitude`).

Secondly, there is the Movement Alerts table containing details of alerts that are registered against patient movements. It comprises the alert ID (`alert_id`), the patient ID that has received the alert (`patient_id`), the alert time stamp (`alert_time`), a type of an alert (`alert_type`), coordinates of an alert (`alert_latitude` and `alert_longitude`) and the status of an alert (`alert_status`).

Second, the SMS Alerts table deals with SMS alert notifications. It has the SMS alert ID (`sms_alert_id`), the ID of the related patient (`patient_id`), the ID of the related alert (`alert_id`), the time of sending SMS (`sms_time`) and the SMS status (`sms_status`).

Also, the table of Status Updates is of great significance to provide information on patient status. It has the status ID (`status_id`), the related patient ID (`patient_id`), the date when it is updated (`update_time`), and the description of the location status (`location_status`).

Finally, Event Logs table traps patient related events. It also contains the event id (event_id) and the respective patient id (patient_id), the time of the event (event_time), the type of the event (event_type) and a report that gives an account as to what has taken place (event_description).

In addition, the schema ties up these tables so that data is consistent and germane. Patient table relates to the Event Log table, the Status Updates table, and the Alerts table with the column patient_id which means that each event, status updates and alert is dedicated to a particular patient. Moreover, the table of Alerts is related to SMS Alerts table through alert_id column as it demonstrates that every single SMS alert is related to a particular alert.

Conclusively, this database design provides an effective and properly organized method of handling the information about the patients, events, and status tracking, alerts, and SMS notifications delivery structure, therefore, enabling an extensive patient monitoring framework.

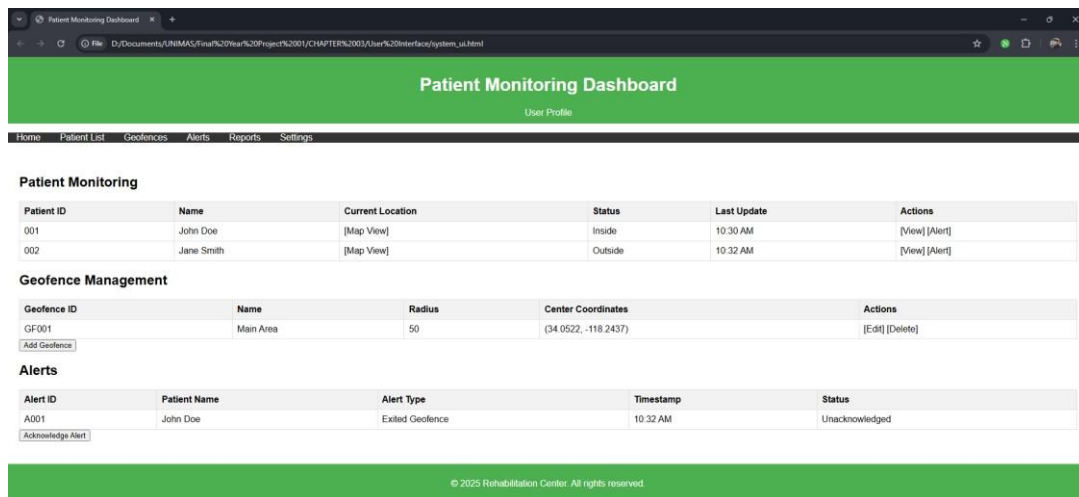


Figure 3.10: Patient Monitoring Dashboard user interface (Example).



Figure 3.11: SMS notification system when patient is outside the rehab center geofence.

According to Figures 3.10 and 3.11, Patient Monitoring Dashboard and SMS Notification System work together to guarantee effective monitoring and notify patients in the rehabilitation centers at the adequate time. The dashboard offers healthcare personnel with a user-friendly interface to monitor movements of patients in real time. This interface possesses three sections patients viewing, geofence viewing, and alert viewing. The ID, location, status and the last update of each patient is shown with the geofence (radius, center coordinates). Moreover, alerts are listed on the dashboard, providing such information as the name of the patient, alert type, the time of the issue, and the status so that the staff members could understand the problem and correct it immediately.

In addition, the SMS Notification System will enhance the effectiveness of the dashboard by providing prompt notification of staff members to patients who leave the geofence. These SMS alerts include vital information like the patient's ID, name, type of alert, as well as the time, and the message requests an immediate action. This, therefore, will make staff be able to respond in time to any problem that may occur, even when they are not on the dashboard, thus making the safety and care of patients a priority.

Also, the flow of these systems can provide complete control over the movements and conditions of patients. The system synchronizes data and pushes alerts in real time, thus keeping all members of healthcare staff informed and allowing them to act in case they are needed. Overall, the set of the Patient Monitoring Dashboard and the SMS Notification System is an effective and simple method of conducting the efficient work in the rehabilitation center connected with the issue of medical safety and care quality enhancement.

3.5 Summary

The use of the Wearable GPS Tracker in Rehabilitation Centers has been described in the current paper, using Agile methodology approach. The development lifecycles are organized as Research Planning, System Design, Development, Prototype Testing, Deployment and Feedback Review. These participants are healthcare staff, patients and administrators. The hardware arrangement includes the CCU and a GPS Tracker, whereas the software stack offers the deployment of Arduino IDE, TinyGPS++, WiFiNINA, and HTTPClient libraries and Firebase. The transmission of data is via wi-fi to ensure data transmission from the GPS tracker to the CCU, and it also creates SMS signals. This functionality is supported by an architectural model having five layers, namely, Device, User, Communication, Server, and Application. SMS alerts which are caused by boundary breaches make real-time monitoring possible and a specific database supports both patient and alert management. The Patient Monitoring Dashboard provides easy-to-use user experience to secure patients and patient care management.

CHAPTER 4: IMPLEMENTATION AND TESTING

4.1 Introduction

System implementation is that stage where a system is designed and finally developed to completion based on some predetermined requirements. It leaves the system functioning successfully and with regards to projected quality. The aspect of testing is also important in this phase since it aids in detecting errors or defects in the system. These are some of the issues that must be addressed to have perfect functioning of the final product and satisfaction by the user. The system without some tests can prove to be incomplete and not functional as required.

When working on the development of the Wearable GPS Tracker to Track Patient Movement in Rehabilitation Centers, the main attention is paid to the detail of the hardware component. The hardware is:

1. Arduino Nano 33 IoT
2. Arduino Nano ESP8266
3. Neo-6M GPS Module
4. SIM800L GSM Module
5. Jumper wires
6. USB cables

On the one hand, the software elements in this type of project are equally critical as the hardware elements. Such computer programs assist the machine to gather, transmit, and present data. These enable caregivers or staff to monitor the mobility of patients, store information safely, and interrelate with the system without difficulties. The programmed software features are:

1. Open-source Arduino Software (IDE)
2. Firebase Realtime Database
3. Firebase Hosting

4.2 System Implementation

The operationalization process requires the combination of various hardware and software elements to start tracking and alerting in real time. It consists of two key primary hardware units and a secondary web-based platform to monitor the data.

4.2.1 GPS Tracker (Board 1)

The central GPS tracking system comprises the Arduino Nano 33 IoT. It has built Wi-Fi and Bluetooth that enables it to communicate wirelessly using data easily. This board is linked to the Neo-6M GPS Module, and this module provides proper latitude and longitude locations as it picks the signals of multiple satellites.

The GPS information is recorded and sent through Wi-Fi to the Firebase Realtime Database. Also, there is a geofencing logic employed by the tracker. With the help of the Haversine formula, the distance between the current GPS position and a previously specified safe perimeter is computed by the system. With the help of this calculation, the tracker identifies whether the patient is located within or without the permitted zone and updates to Firebase.

4.2.2 Central Control Unit (Board 2)

The Control Unit is constructed with the ESP8266 microcontroller that also has Wi-Fi capability. It is used together with SIM800L GSM Module. Its primary purpose is to constantly check the Firebase data. The GSM module automatically issues an SMS alert to a pre-programmed phone number once the Control Unit sends a status update of a patient as being outside in the geofence. Integration-wise, this involves setting up serial communication between ESP8266 and SIM800L module, making use of AT commands in handling network connectivity and SMS capabilities.

4.2.3 Web Dashboard Interface

A web-based dashboard developed using modern web technologies was also built to support real-time monitoring. It is directly connected to the Firebase Realtime Database, and it shows current GPS positions of each patient and geofence status. It is possible to view the movement of patients through the dash and this interface is dynamic when the data changes which makes it easy to monitor the status of the system by staff using any device with internet connection.

4.3 Prototype Development

In the creation process of the prototype, the gathering of the hardware, the writing and uploading of the code in the microcontrollers, and the configuration of all system devices using the Firebase were undertaken. The objective was to develop a working prototype which successfully follows patient movement, identifies whether they are within geofence, and sends alert in case of it.

4.3.1 GPS Tracker Board

The steps have started with the GPS Tracker Board that encompasses Arduino Nano 33 IoT and Neo-6M GPS Module. Arduino IDE was used to program the board to connect to Wi-Fi, read GPS position, and calculate the state of geofence and the distance by calculating it. The information at these points was then sent to the Firebase Realtime Database regularly.

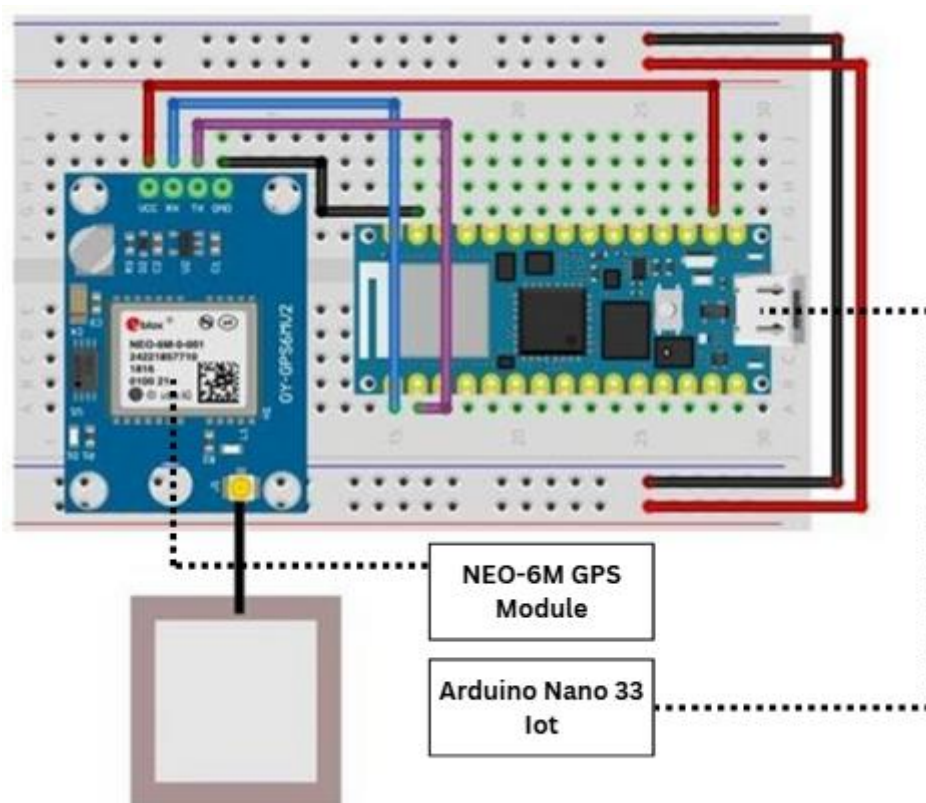


Figure 4.1: GPS Tracker Board diagram.

4.3.2 Control Unit board

Then a Control Unit was created based on the ESP8266 microcontroller and SIM800L GSM Module. The Control Unit used a Firebase database as source of information. In the case that after equipping a patient (who was wearing the GPS Tracker) left the radius within the defined geofence, the Control Unit sent out an alert over GSM. It required accurate AT commands and a continuous serial linkage between ESP8266 and SIM800L to guarantee successful transmission of messages.

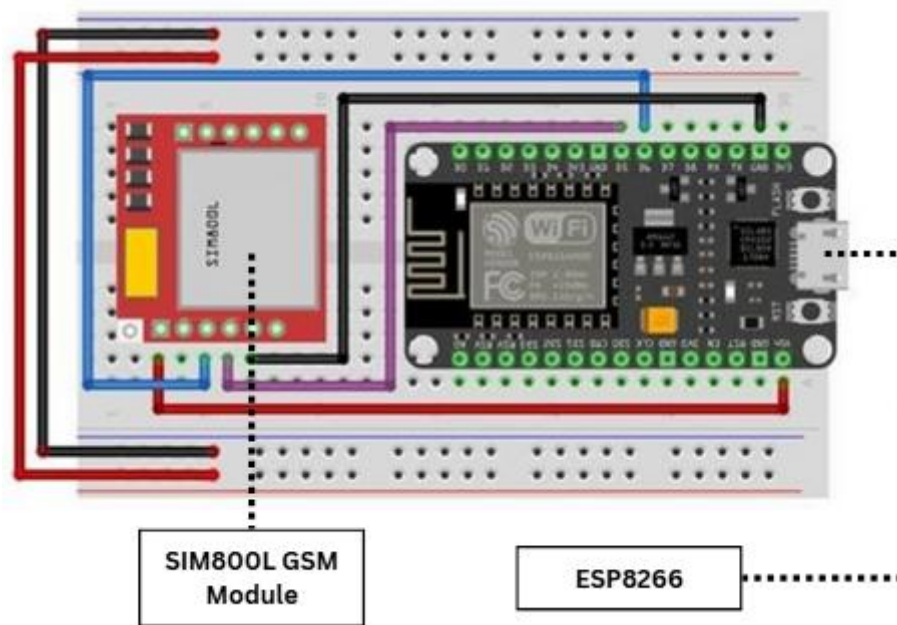


Figure 4.2: Control Unit Board diagram.

4.3.3 Dashboard Interface

At the testing and deployment, a Web-based dashboard interface was incorporated and developed. As a center of operations, the dashboard directly connects to the Firebase Realtime Database, thus providing real time information on the location of the patient as well as the status of the geofence. This is a graphical tool that takes advantage of the existing desktop and mobile browsers to allow staff to monitor the patients without getting to connect with the physical hardware, thereby giving a convenient way of monitoring the functioning of the system remotely in the field.

4.4 Prototype Modelling

Two prototypes are built to show how Wearable GPS Tracker for Monitoring Patient Movement in Rehab Centers works.

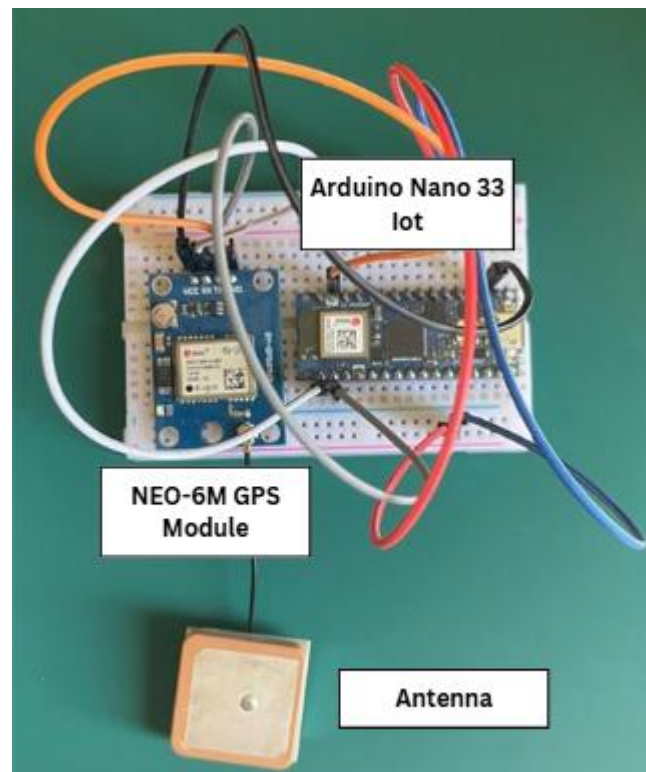


Figure 4.3: GPS Tracker Prototype.

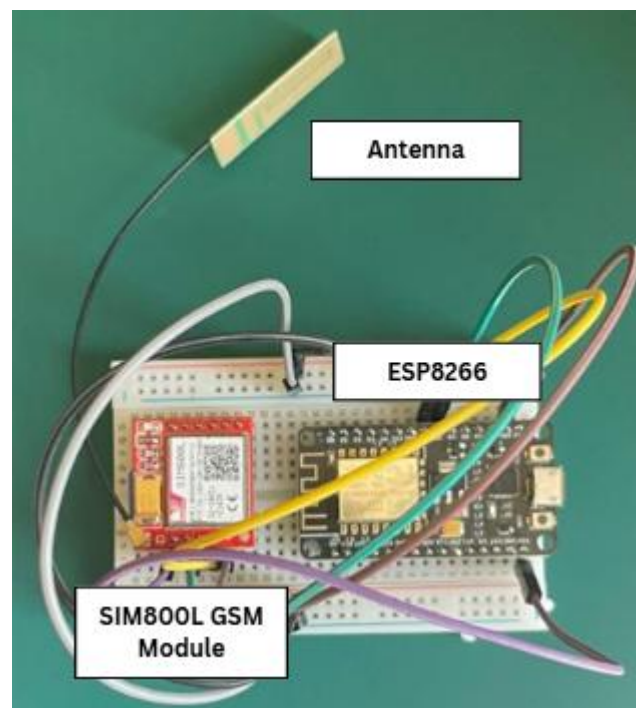


Figure 4.4: Control Unit Prototype.

4.5 Prototype Programming

All the implemented components need to be programmed first into the Arduino IDE to make the system work.

1. GPS Tracker board sketch.
 - (a) Library Includes & Object Initialization.

These are the necessary libraries and global objects used throughout the program.

```
#include "firebase_config.h" // Custom file for Firebase credentials
#include <WiFiNINA.h> // For Wi-Fi connectivity (Arduino Nano 33 IoT)
#include <Firebase_ESP_Client.h> // Firebase client library
#include <TinyGPS++.h> // For parsing GPS data

FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;
WiFiClient client;
TinyGPSPPlus gps;
```

- (b) Geofence Configuration.

Defines the center and radius of the geofenced area.

```
const float GEOFENCE_LAT = 1.4683577; // Rehab center latitude
const float GEOFENCE_LNG = 110.4284378; // Rehab center longitude
const float GEOFENCE_RADIUS = 100.0; // Radius in meters
```

- (c) Haversine Formula Function.

Calculates the distance between two GPS points (for geofencing logic).

```
float calculateDistance(float lat1, float lng1, float lat2, float lng2) {
    const float R = 6371000; // Earth's radius in meters
    float dLat = radians(lat2 - lat1);
    float dLng = radians(lng2 - lng1);
    float a = sin(dLat / 2) * sin(dLat / 2) +
              cos(radians(lat1)) * cos(radians(lat2)) *
              sin(dLng / 2) * sin(dLng / 2);
    float c = 2 * atan2(sqrt(a), sqrt(1 - a));
    return R * c;
}
```

(d) Setup Function.

Initializes serial communication, Wi-Fi, and Firebase.

```
void setup() {
  Serial.begin(115200);
  Serial1.begin(9600); // For GPS module
  delay(1000);

  // Connect to Wi-Fi
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
  unsigned long startTime = millis();
  while (WiFi.status() != WL_CONNECTED && millis() - startTime < 15000) {
    delay(500);
    Serial.print(".");
  }

  if (WiFi.status() == WL_CONNECTED) {
    Serial.println("\n✅ WiFi connected!");
    Serial.print("IP Address: ");
    Serial.println(WiFi.localIP());
  } else {
    Serial.println("\n❌ WiFi connection failed.");
    while (true); // Stop here if Wi-Fi fails
  }

  // Firebase configuration
  config.api_key = API_KEY;
  config.database_url = DATABASE_URL;
  auth.user.email = USER_EMAIL;
  auth.user.password = USER_PASSWORD;

  Firebase.begin(&config, &auth);
  Firebase.reconnectWiFi(true);
}
```

(e) Loop Function.

Continuously checks for GPS data and calls `sendToFirebase()` if location is updated.

```
void loop() {
  while (Serial1.available() > 0) {
    char c = Serial1.read();
    Serial.print(c); // For debugging raw GPS output
    gps.encode(c);

    if (gps.location.isUpdated()) {
      float lat = gps.location.lat();
      float lng = gps.location.lng();

      Serial.print("\n✅ GPS Fix!\nLatitude: ");
      Serial.println(lat, 6);
      Serial.print("Longitude: ");
      Serial.println(lng, 6);

      sendToFirebase(lat, lng);
    }
  }
}
```

(f) Firebase Upload Function.

Sends latitude, longitude, and geofence status to Firebase Realtime Database.

```
void sendToFirebase(float lat, float lng) {
    float distance = calculateDistance(lat, lng, GEOFENCE_LAT, GEOFENCE_LNG);
    String status = (distance <= GEOFENCE_RADIUS) ? "inside" : "outside";

    Serial.print("\ Distance from center: ");
    Serial.print(distance);
    Serial.println(" meters");
    Serial.print("★ Geofence status: ");
    Serial.println(status);

    // Prepare JSON object
    FirebaseJson json;
    json.set("latitude", lat);
    json.set("longitude", lng);
    json.set("status", status);

    String path = "/patients/patient_001/location";

    if (Firebase.RTDB.setJSON(&fbdo, path.c_str(), &json)) {
        Serial.println("✅ Location and status sent to Firebase!");
    } else {
        Serial.print("❌ Firebase Error: ");
        Serial.println(fbdo.errorReason());
    }

    delay(10000); // Wait 10 seconds before next update
}
```

2. Control Unit board sketch.

(a) Library Imports & Global Declarations.

Libraries used and hardware/software objects initialized.

```
#include <ESP8266WiFi.h>
#include <Firebase_ESP_Client.h>
#include <SoftwareSerial.h>

// SIM800L setup on GPIO pins
SoftwareSerial sim800l(D5, D6); // RX, TX
```

(b) Wifi and Firebase Credentials

```
// WiFi credentials
#define WIFI_SSID " "
#define WIFI_PASSWORD " "

// Firebase credentials
#define API_KEY " "
#define DATABASE_URL " "
#define USER_EMAIL " "
#define USER_PASSWORD " "
```

(c) Firebase and System Variables.

```
FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;

bool alertSent = false;
bool sim800lReady = false;
unsigned long lastNetworkCheck = 0;
const unsigned long networkCheckInterval = 30000;

// Target phone number
const char phoneNumber[] = "+601 ";
```

(d) setup() Function.

Initial system setup: serials, Wi-Fi, Firebase, SIM800L.

```
void setup() {
  Serial.begin(9600);
  sim800l.begin(9600);
  delay(1000);

  Serial.println("\n==== System Initialization =====");

  initializeWiFi();
  initializeFirebase();
  initializeSIM800L(true); // true = full initialization
}
```

(e) loop() Function.

Repeats checking Firebase and SIM800L status.

```
void loop() {
  if (millis() - lastNetworkCheck > networkCheckInterval) {
    checkNetworkStatus();
    lastNetworkCheck = millis();
  }

  if (Firebase.ready() && sim800lReady) {
    monitorPatientLocation();
  } else {
    if (!sim800lReady) {
      Serial.println("SIM800L not ready - attempting recovery...");
      initializeSIM800L(false); // partial recovery
    }
    delay(5000);
  }
}
```

(f) Wi-Fi Initialization.

Connects to Wi-Fi network.

```
void initializeWiFi() {
  Serial.print("Connecting to WiFi");
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);

  unsigned long startTime = millis();
  while (WiFi.status() != WL_CONNECTED && millis() - startTime < 30000) {
    delay(500);
    Serial.print(".");
  }

  if (WiFi.status() == WL_CONNECTED) {
    Serial.println("\nWiFi connected! IP: " + WiFi.localIP().toString());
  } else {
    Serial.println("\nWiFi connection failed!");
  }
}
```

(g) Firebase Initialization.

```
void initializeFirebase() {
  config.api_key = API_KEY;
  config.database_url = DATABASE_URL;
  auth.user.email = USER_EMAIL;
  auth.user.password = USER_PASSWORD;

  Firebase.begin(&config, &auth);
  Firebase.reconnectWiFi(true);
}
```

(h) SIM800L Initialization and Validation.

```
void initializeSIM800L(bool fullInit) {
    Serial.println("\nInitializing SIM800L...");

    if (!sendATCommand("AT", "OK", 2000, true)) {
        Serial.println("SIM800L not responding!");
        sim800lReady = false;
        return;
    }

    if (!checkSIMCard()) {
        sim800lReady = false;
        return;
    }

    if (fullInit && !configureSMS()) {
        sim800lReady = false;
        return;
    }

    if (!checkNetworkRegistration()) {
        sim800lReady = false;
        return;
    }

    sim800lReady = true;
    Serial.println("SIM800L ready for operation");
}
```

(i) SIM Card, SMS, Network Config Helpers.

```
bool checkSIMCard() { ... }
bool configureSMS() { ... }
bool checkNetworkRegistration() { ... }
```

(j) Network Status Checker.

```
void checkNetworkStatus() {
    ...
    sendATCommand("AT+CSQ", "OK", 2000, true);
}
```

(k) Patient Location Monitor (Firebase).

```
void monitorPatientLocation() {
    if (Firebase.RTDB.getString(&fbdo, "/patients/patient_001/location")) {
        processLocationData(fbdo.stringData());
    } else {
        Serial.println("Firebase read failed: " + fbdo.errorReason());
    }
    delay(5000);
}
```

(l) Location Processor.

```
void processLocationData(String jsonStr) {
    FirebaseJson json;
    json.setJsonData(jsonStr);

    FirebaseJsonData result;
    String status;
    json.get(result, "status");
    status = result.to<String>();

    if (status == "outside" && !alertSent) {
        sendAlert(json);
    } else if (status == "inside") {
        alertSent = false;
        Serial.println("Patient inside safe zone");
    }
}
```

(m) Alert via SMS.

```
void sendAlert(FirebaseJson& json) {
    FirebaseJsonData result;
    String latitude, longitude;

    json.get(result, "latitude");
    latitude = result.to<String>();
    json.get(result, "longitude");
    longitude = result.to<String>();

    String message = "ALERT: Patient outside!\n"
                    "Location: " + latitude + "," + longitude + "\n"
                    "Time: " + getTimestamp();

    if (sendSMS(phoneNumber, message)) {
        alertSent = true;
        Serial.println("Alert sent successfully");
    } else {
        Serial.println("Failed to send alert");
    }
}
```

(n) Timestamp Generator.

```
String getTimestamp() {
    return String(millis() / 1000); // Simplified time
}
```

(o) Send SMS Command.

```
bool sendSMS(const char* number, String message) {
    ...
    sim8001.write(26); // Ctrl+Z to send
    return checkSMSConfirmation(10000);
}
```

(p) SMS Helpers: Wait & Confirm.

```
bool waitForPrompt(unsigned long timeout) { ... }  
bool checkSMSConfirmation(unsigned long timeout) { ... }
```

(q) AT Command Sender.

```
bool sendATCommand(const char* cmd, const char* expected, unsigned long timeout, bool verbose) {  
    ...  
}
```

4.6 Prototype Testing

The process of testing prototypes forms an important step of ensuring that a wearable GPS tracker has been designed towards the necessary performance before actual deployment into the market. The main goal of the current experiment was the assessment of the operability of all modules, to be exact, the functionality of the GPS module, Firebase Realtime Database updates, GSM module to realize short Messages, to define whether they work according to the model or not.

4.6.1 Testing Setup

The hardware configuration was done on two primary boards of microcontrollers:

- Board 1 (GPS Tracker with Arduino Nano 33 Iot): This board will deal with the process of getting the GPS data and posting it on Firebase.
- Board 2 (Control Unit with Arduino ESP8266): It deals with reading data of patient location stored in Firebase and sending an SMS in case the patient moves out of the geofenced area.

The connection between the Arduino Nano 33 IoT and the GPS module was done with a small breadboard rig. The ESP8266 was connected to SIM 800L such that it is used to send the SMS messages with a valid SIM card inserted in SIM 800L module.

4.6.2 Testing Procedures

Several tests were conducted in stages:

1. GPS Location Test

- The GPS module was powered and connected to the Arduino Nano 33 IoT.
- The location data (latitude and longitude) were successfully read and displayed through the Arduino Serial Monitor.
- The GPS data was then uploaded to Firebase Realtime Database.

```
✅ WiFi connected!  
IP Address: 172.20.10.14  
,113830.00,A,A*66  
$GPRMC,113831.00,A,0126.87430,N,11027.23877,E,0.041,,150525,,A*7B  
✅ GPS Fix!  
Latitude: 1.447905  
Longitude: 110.453979  
✅ Location sent to Firebase!
```

Figure 4.5: Serial Monitor for GPS Tracker output.

2. Firebase Connection Test

- The Arduino Nano 33 IoT was connected to Wi-Fi.
- A real-time connection to Firebase was established.
- The Firebase Realtime Database was updated with the latest patient location and geofence status (e.g., “inside” or “outside”).

```
https://rehab-dashboard-b37d8-default-rtdb.asia-southeast1.firebaseio.com/  
├── locations  
│   └── uniqueID  
│       ├── latitude: 1.44791  
│       └── longitude: 110.45399  
├── patients  
│   └── patient_001  
│       └── location  
│           ├── latitude: 1.46861  
│           ├── longitude: 110.42848  
│           └── status: "inside"
```

Figure 4.6: Firebase Realtime Database with latest patient location and geofence status.

3. Geofence Detection Test

- A center point and radius were set as geofence.
- During testing, the GPS module was moved beyond the defined radius to simulate the patient leaving the safe zone.
- The status in Firebase automatically changed from “inside” to “outside” based on distance calculation.

```
✓ WiFi connected!
IP Address: 172.20.10.14
> ERROR.mRunUntil: SSL internals timed out!
> ERROR.mConnectSSL: Failed to initialize the SSL layer.
> ERROR.mConnectSSL: Unknown error code.
Y4,2,13,13,65,036,09,15,67,266,18,19,09,146,,20,17,027,13*7F
$GPGSV,4,3,13,21,12,029,,23,06,269,,24,28,187,14,25,17,252,13*7C
$GPGSV,4,4,13,29,26,322,33*47
$GPGLL,0128.10775,N,11025.70405,E,065543.00,A,A*66
$GPRMC,065544.00,A,0128.10808,N,11025.70401,E,11,35,067,13,12,29,218,24*72
$GPGSV,4,2,13,13,64,036,13,15,67,268,21,19,09,146,,20,17,027,08*7B
$GPGSV,4,3,13,21,12,030,,23,06,269,,24,28,187,,25,16,251,*71
$GPGSV,4,4,13,29,26,321,33*44
$GPGLL,0128.10909,N,11025.70679,E,065653.00,A,A*68
$GPRMC,065654.00,A,0128.10907,N,11025.70654,E,0.111,,100625,,A*76
✓ GPS Fix!
Latitude: 1.468485
Longitude: 110.428444
📏 Distance from center: 14.13 meters
★ Geofence status: inside
✓ Location and status sent to Firebase!
```

Figure 4.7: GPS Module results when the board is inside geofence radius.

4. SMS Alert Test

- The ESP8266 read the patient’s geofence status from Firebase.
- When the status changed to “outside,” it triggered the SIM800L module to send an SMS to a preset phone number.
- The SMS contained the patient’s location coordinates and an alert message.
- The test was considered successful when the message was received on the phone.

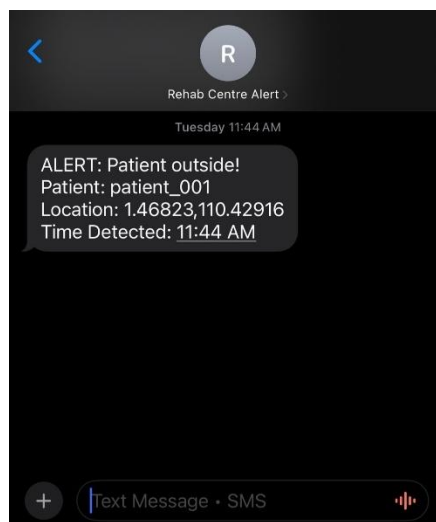


Figure 4.8: SMS sent from Control Unit if patient is outside geofence.

5. Dashboard Update Test

- The web-based dashboard was on a browser and connected to the Firebase Hosting.
- To confirm the real-time updates, the GPS tracker was moved to new locations.
- Whether it was a left or a right movement the dashboard updated the coordinates and the status of the geofence without having to refresh a page of the browser.
- When the patient gets out of the geofenced zone, the dashboard showed the alert condition in clear marking to make sure that the patient has been successfully synchronized with Firebase.
- This was confirmed during this test that care givers can see the movement of the patients live in any device with access to the internet.

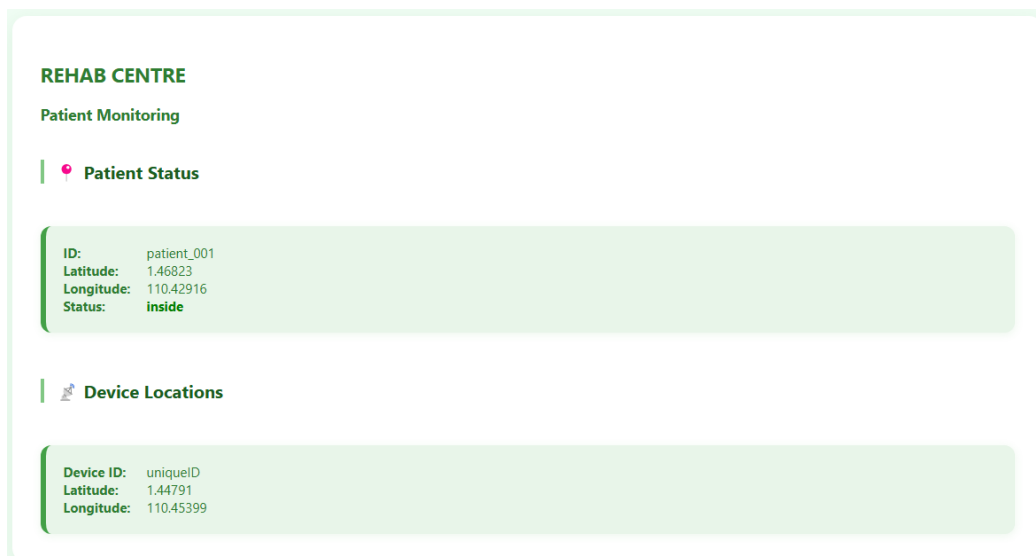


Figure 4.9.1: Dashboard user interface displayed while the device remains within the geofence radius.

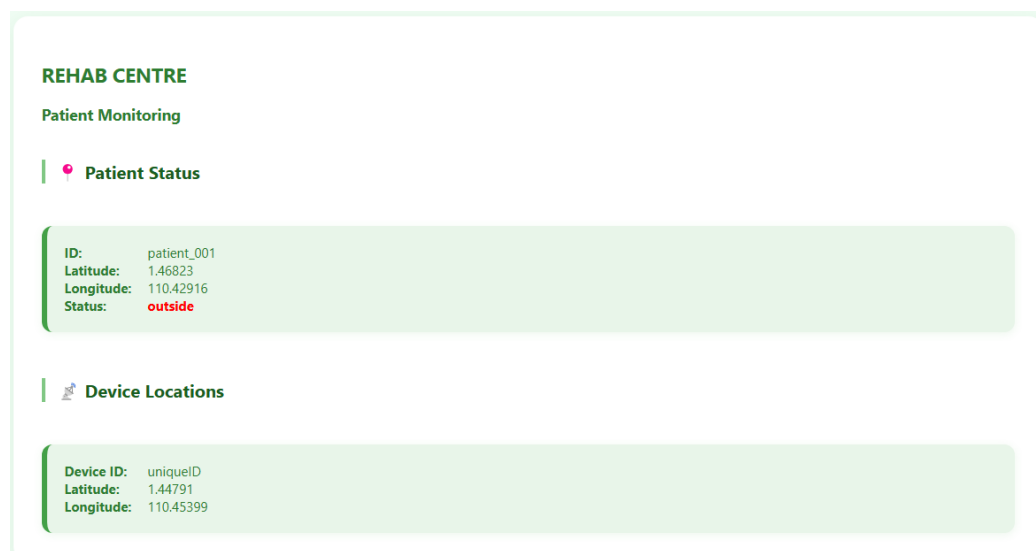


Figure 4.9.2: Dashboard user interface displayed while the device is moving beyond the geofence radius.

4.7 Summary

In this chapter, the entire implementation process and testing steps of the wearable GPS tracking system were discussed. Choosing and connecting hardware, building the system with the help of functional sketches and connecting with Firebase, every step was taken to make the system reliable. Geofencing worked succinctly and the position boundaries were measured accurately. The Control Unit was able to send SMS warnings when patients were out of the allocated areas. Moreover, the web-based dashboard gave the staff real-time location data, improving the level of situational awareness and response time.

CHAPTER 5: RESULT

5.1 Introduction


This chapter provides the findings of the development, testing as well as implementation of Wearable GPS Tracker to Monitor Patient Movement in Rehabilitation Centers. The primary goal of the system is to care about real-time location tracking and safety alerting of patients with the help of an IoT solution made on the integrated system consisting of a GPS module, Firebase Realtime Database, and GSM-based SMS notification system.

The following chapter presents the results derived due to the testing of the system on real testing conditions. These are correctness of the GPS location tracking, timeliness of transmitted data to the Firebase, efficacy of geofence detectives and the succinct transmission of the SMS notifications to the patient in the event of exiting the predetermined safe zone.


Comparing these results, this chapter draws an evaluation concerning the fulfillment of the given system along with its functional and non-functional requirements, the applicability to possible improvements, or prospective real-life conditions at a rehabilitation center.

5.2 Functional Testing


Functional testing is a kind of software testing which tests to ascertain the efficiency of the system to operate as per the desired specifications or requirements. It seeks to do the input testing of each functionality of the software by providing the right input and ensuring that the output is as per the expectation as stipulated by the objectives of the system.

Device	Board 1 (Neo-6M GPS Module and Arduino Nano 33 IoT)					
Test Objective	To verify that the board correctly detects and displays coordinate if placed outdoor.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GPS01	Identify GPS Module Outdoor	<ol style="list-style-type: none"> 1. Enter the current GPS coordinates into the Arduino IDE code. 2. Position Board 1 near a window or in an open space to ensure a clear signal. 3. Upload and run the code, then observe the sensor readings and confirm the output on the Serial Monitor. 	Serial Monitor displays “  GPS Fix!” and shows coordinate.	Test: 10 times Pass: 10 Failure: 0		

Ten tests were undertaken to determine the capacity of the GPS module to obtain coordinates in the outdoors environment. Arduino Nano 33 IoT was set up facing a window or outside; on every trial the Serial Monitor showed GPS fix and coordinates. The findings suggest that there is a consistent signal reception by the satellite and functionality guaranteed outdoors.

Device	Board 1 (Neo-6M GPS Module and Arduino Nano 33 IoT)					
Test Objective	To verify that the board correctly detects and displays coordinate if placed indoor.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GPS02	Identify GPS Module Indoor	<ol style="list-style-type: none"> 1. Enter the current GPS coordinates into the Arduino IDE code. 2. Position Board 1 inside a room to receive a signal. 3. Upload and run the code, then observe the sensor readings and confirm the output on the Serial Monitor. 	Serial Monitor displays “  GPS Fix!” and shows coordinate.	Test: 10 times Pass: 7 Failure: 3	Initially, set the coordinates for Board 1 outside the room with a radius of 100 meters. Once the board is successfully detected and brought back inside, adjust the radius to 30 meters.	

Indoor operation may be erratic depending on the quality of signal indoors, mainly in enclosed spaces. Indoors in the trial, the experiment portrayed success seven of ten times. The module was cold started outdoors and later its detection radius was set in the indoor environment to reduce the variance.

Device	Board 1 (Neo-6M GPS Module and Arduino Nano 33 IoT)					
Test Objective	To verify that the board correctly send coordinate to Firebase Realtime Database.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GPS03	Identify GPS Module and Firebase Connection	<ol style="list-style-type: none"> 1. Enter the current GPS coordinates into the Arduino IDE code. 2. Upload and run the code, then observe the sensor readings and confirm the output on the Serial Monitor. 3. Check and confirm that the coordinates have been successfully updated in the Firebase Realtime Database. 	Serial Monitor displays “  Location and status sent to Firebase!”, and Firebase Realtime Database receives the coordinate.	Test: 5 times. Pass: 5 Failure: 0		

This was aimed at getting the GPS Tracker board and Firebase Realtime Database connected. Effective readings were sent into firebase, and updates about geofence status were provided, which proves cloud connectivity to be steady.

Device	Board 1 (Neo-6M GPS Module and Arduino Nano 33 IoT)					
Test Objective	To verify that the board correctly send status inside geofence to Firebase Realtime Database.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GPS04	Identify GPS Module and Firebase Connection inside radius	1. Power on the device using a power bank while it is located within the geofence area. 2. Monitor the Realtime Database to check for any status updates.	Firestore updates status to "inside".	Test: 5 times. Pass: 5 Failure: 0		

Device	Board 1 (Neo-6M GPS Module and Arduino Nano 33 IoT)					
Test Objective	To verify that the board correctly sends status outside geofence to Firebase Realtime Database.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GPS05	Identify GPS Module and Firebase Connection outside radius	1. Power on the device while it is located outside the defined geofence radius. 2. Monitor the Realtime Database to check for any status updates.	Firestore updates status to "outside".	Test: 5 times. Pass: 5 Failure: 0		

In five tests, the behavior of the geofence mode of the system was set to be an inside state when the tracker did not move further than the specified radius. Coordinates were stored on Firebase and the status of the geofence was the same. In the cases when the tracker was above the geofence, the relevant coordinates had been sent, and all the five trials were reflected as being outside, which proved effective detection of geofence and calculation of Haversine formula.

Device	Board 2 (SIM800L GSM Module and Arduino ESP8266)					
Test Objective	To verify that the board correctly detects sim card signal outdoor.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GSM01	Identify GSM Module outdoor.	<ol style="list-style-type: none"> 1. Power on the device while it is located outside the building. 2. Position Board 2 near a window or in an open space to ensure a clear signal. 3. Upload and run the code, then observe the sensor readings and confirm the output on the Serial Monitor. 	Serial Monitor displays “GPS JSON received” with coordinate.	Test: 10 times. Pass: 9 Failure: 1	The GSM module requires approximately 30 to 50 seconds to initialize, detect, and establish a signal connection.	

The GSM module was seen to work well outdoors to check its signal detection. The module started successfully after about 30-50 seconds start time in 9 out of 10 trials and provided valid information at the Serial Monitor, thus confirming its functionality in open outdoor tests.

Device	Board 2 (SIM800L GSM Module and Arduino ESP8266)					
Test Objective	To verify that the board correctly detect sim card signal indoor.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GSM02	Identify GSM Module indoor.	<ol style="list-style-type: none"> 1. Power on the device while it is located inside the building. 2. Position Board 2 inside a room to receive signal. 3. Upload and run the code, then observe the sensor readings and confirm the output on the Serial Monitor. 	Serial Monitor displays “GPS JSON received” with coordinate.	Test: 10 times. Pass: 5 Failure: 5	The device should initially be used in an open area, such as near a window or outside a building, to ensure it successfully receives a signal. Once the signal is established, it can then be used as intended.	

The test results inside were mixed as only five successful connections out of ten were achieved. The module would not work in the absence of a preliminary signal lock when the module is indoors. After gaining a signal outside, the performance rose.

Device	Board 2 (SIM800L GSM Module and Arduino ESP8266)					
Test Objective	To verify that the board correctly reads Firebase Realtime Database data if Board 1 inside geofence radius.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GSM03	Identify GSM Module and Firebase connection.	1. Power on the device while it is located inside the building. 2. Upload and run the code, then observe the sensor readings and confirm the output on the Serial Monitor.	Serial Monitor displays “GPS JSON received”, coordinate and “status: inside”.	Test: 5 times. Pass: 5 Failure: 0		

A preliminary test proved that the module was able to read the Firebase data when the GPS signal showed that it was inside. The coordinates and the inside status were properly in the Serial Monitor in five iterations.

Device	Board 2 (SIM800L GSM Module and Arduino ESP8266)					
Test Objective	To verify that the board correctly reads Firebase Realtime Database data if Board 1 outside geofence radius.					
Test ID	Test Case	Test Procedure	Result	Status (Pass/Fail)	Summary	Comment
GSM04	Identify GSM Module and Firebase connection.	1. Power on the device while it is located inside the building. 2. Upload and run the code, then observe the sensor readings and confirm the output on the Serial Monitor.	Serial Monitor displays: - GPS JSON received. - Coordinate. - status: outside - sending SMS... - SMS sent successfully. The assigned phone number will receive the SMS with coordinate.	Test: 5 times. Pass: 5 Failure: 0		

The last exercise was used to test the complete alert process in case the tracker has left the geofenced region. The state of the system was recognized as an outside system and a SMS was transmitted by the SIM800L GSM module with coordinates and a warning that reliable notification took place.

5.3 Issues Encountered

Regardless of successful development and laboratory testing of the wearable GPS tracker, some difficulties appeared. The most notable one was that of the GPS module. The GPS signal was unreliable during indoor testing; sometimes it could be detected and in other times it could never be detected. To avoid such an issue, the original coordinates of Board 1 were retrieved by a location called not in the room and the radius used was 100 meters to acquire the signals. After the GPS connection had been established and preventing any loss of the board by means of relocating it to the inside, the radius had been set at 30 meters to offer more valuable geofencing.

The same signal-related problems took place with the GSM module. The module had to be in the open space (near the window, out of the building) to get a stable signal in the cellular network. Once the signal was assured of the device was able to operate as usual. This was also important to make sure that the SIM800L module that would be sending SMS alerts would not fail when the patient stepped out of the predefined geofenced zone.

5.4 Summary

To conclude, wearable GPS tracker served its purpose and achieved operational standards. It precisely traced the location of patient, updated information in real-time to Firebase, and prompted SMS notifications when the patient breached the geofenced area. The system was reliable during testing but still there were minor issues with the signals.

CHAPTER 6: CONCLUSION AND FUTURE NETWORK

6.1 Introduction

The current chapter marks the culmination of the development of the wearable GPS tracker to help observe the movement of the patient inside rehabilitation centers. It considers the project results, determines how well the set goals were achieved, and gives recommendations on how the project can be improved in the future and possible updates in the system.

6.2 Objective Achievement

The original set of aims of the current project has been achieved to satisfaction. All the features suggested in the system have been tested and found to work properly. There was an efficacy between the hardware and software components, and it showed that the prototype was ready to be deployed in the real world, as part of a rehabilitation unit at a patient-safety monitoring process. The objectives fulfilled and the features verified (Tables 6.1) include a synopsis of the goals attained and nature confirmed in the process of prototype development.

Objective	Achievement
Develop a wearable GPS tracker system that is cost-effective and easy to implement.	The tracking device was constructed of cheap parts such as the Arduino, GPS, and GSM modules. Design was straightforward, thus simple to assemble and could be applied in the real world.
Establish a geofence around the rehabilitation center to monitor patient movement.	The working system was developed in the form of a geofence, which was able to sense the position of the patient within or outside an established geographic area during the test.
Create an SMS alert system designed to notify staff when a patient crosses the established geofence boundary.	The system also managed to send SMS notifications of the patient's location whenever the patient went out of the geofence.

Table 6.1: Objectives and achievements.

6.3 Future Work

Despite the current prototype presenting a usable and reliable GPS tracking platform to be used in wearable devices, significant possibilities to polish both the user experience and system performance are available.

The most common way forward relates to the physical layout of the hardware part. Further versions should be more focused on miniaturization, weight reduction and ergonomic integration to eventually integrate the gadget into other accessories like wrist bands, belts or even wearable clips. These design changes would raise the ease of the patients, reduce the risk of being removed or lost and hence increase user compliance.

The system would also be enhanced to provide location mapping together with semantic labels as opposed to the continuous GPS coordinates. Position data being mapped to updated descriptors, such as, “Operating Room,” “Emergency Department,” or “Therapy Hall” allows the caregivers to find out quickly the location of a patient without the overhead of interpreting raw positioning data. The accomplishment of this would necessitate the correlation of global positioning system (GPS) locations with predetermined areas that are programmed in a digital map of a facility.

The other important enhancement would be in boosting the performance of the GPS receiver and GSM modem. An upgrade to modules with a higher signal sensitivity, reduction of acquisition time and better connectivity would significantly increase dependability of the system - especially in more difficult indoor or urban environments.

Moreover, the dashboard interface also deserves to be systematized. An improved, user-friendly interface might optimize the level of effectiveness of interaction between the caregivers and the platform. The suggested changes are live embedded maps, custom patient filtering, search options and custom alert settings. Adding a possibility to adjust the parameters of the systems we are talking about, (the radius of the geofence or the frequency of the notifications, etc.), through the dashboard itself would both improve flexibility and usability.

An observation of battery-status tracking and energy optimization is also appropriate. Real-time battery-level display and optional low-power modes that could be switched between during the working day would then allow the staff to act before the device runs out of charge. This would extend the time further without the need to manually intervene in possible techniques such as solar charging or wireless charging.

Finally, the use of indoor positioning technologies that may include Bluetooth Low Energy beacons or Wi-Fi Positioning Systems (WPS) could be proposed as the subject of further development. The trick of GPS, together with these add-on interior mechanisms would provide a more accurate to track the location of the medical facility with numerical rigor.

6.4 Summary

The research analyzed the opportunity of using the Internet of Things (IoT) technologies in patient monitoring in the healthcare setting and found that this integration comes with immense value. The prototype achieved the set goals and worked within the evaluation period. This system can be deployed in the real world with specific changes, and, perhaps, it can be generalized to the general application of medical objectives and safety areas.

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