ENHANCE IOT INTEGRATED DESIGN FOR RAPID ADVANCE FUTURE LIGHT WEIGHT PROSTHETIC LEG

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**A thesis submitted
in fulfillment of the requirements for the degree of
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DEDICATION

I hereby dedicate this here piece of work to my precious parents and my trusty supervisor, Dr. Muhammad Ilman Hakimi Chua bin Abdullah. They have been my rock, offering me love and support through thick and thin. I couldn't have done it without them. Much obliged for giving me the grit to wrap up my Final Year Project.

ABSTRACT

In recent years, there has been a rise in the use of IoT-based prosthetics, which allow for continuous feedback on the effectiveness of the prosthetic leg. IoT technology can potentially enhance the prosthetic leg's functionality, performance, and convenience. However, conventional prosthetic legs are expensive in terms of development and manufacturing. There is also a need for more awareness among healthcare providers and patients regarding the advantages of implementing IoT in prosthetic legs. This study aimed to integrate the Internet of Things (IoT) into a prosthetic leg by building a temperature sensor, a step tracker, and GPS coordinates. Integration into a smartphone app had been built using Arduino Cloud software that connect to IoT Remote application to synchronize all the sensors involved. With this invention, it is expected that the data can be analyzed by the user. This system excels at detecting the user's location, tracking steps, and measuring temperature with remarkable accuracy and minimal power consumption. The system enables users to conveniently view the location on their smartphones using IoT Remote. The system can be easily attached to the prosthetic leg thanks to its compact size. Ultimately, this system has the potential to greatly enhance the quality of life for amputees. It offers real-time feedback and the ability to personalize the experience, resulting in a more tailored and beneficial outcome.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, terdapat peningkatan penggunaan kaki palsu berasaskan IoT, yang membolehkan maklum balas berterusan mengenai keberkesanan anggota buatan. Teknologi IoT boleh meningkatkan fungsi, prestasi dan kemudahan kaki palsu. Walau bagaimanapun, kaki palsu konvensional amatlah mahal dari segi pembuatan dan pengeluaran. Terdapat juga keperluan untuk kesedaran yang lebih besar di kalangan penjaga dan pesakit mengenai kelebihan melaksanakan IoT dalam kaki palsu. Kajian ini bertujuan untuk mengintegrasikan Internet of Things (IoT) ke dalam kaki palsu dengan membina sensor suhu, pengesan langkah, dan koordinat GPS. Integrasi ke dalam aplikasi telefon pintar akan dibina menggunakan perisian Arduino Cloud yang menyambung ke aplikasi IoT Remote untuk menyegerakkan semua sensor yang terlibat. Dengan penemuan ini, pengguna akan dapat menganalisa data dengan mudah. Sistem ini unggul dalam mengesan lokasi pengguna, menjejaki langkah-langkah, dan mengukur suhu dengan ketepatan yang luar biasa dan penggunaan kuasa minimum. Sistem ini membolehkan pengguna melihat lokasi dengan mudah pada telefon pintar mereka menggunakan IoT Remote. Sistem ini boleh disambungkan dengan mudah kepada kaki protetik berkat saiz kompaknya. Pada akhirnya, sistem ini mempunyai potensi untuk meningkatkan kualiti hidup bagi amputasi. Ia menawarkan umpan balik masa nyata dan keupayaan untuk menyesuaikan pengalaman, yang membawa kepada hasil yang lebih disesuaikannya dan bermanfaat.

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LIST OF ABBBREVIATIONS

IoT	**-**	INTERNET Of Things
GPS	**-**	Global Positioning System
WHO	**-**	World Health Organization
UAI	**-**	User Accessible Interface
WiFi	**-**	Wireless Fidelity
GPIO	**-**	General Purpose Input Output
SPI FLASH	**-**	Serial Peripheral Interface Flash
UART	**-**	Universal Asynchronous Receiver Transmitter
GNSS	**-**	Global Navigation Sattelite System
MIT	**-**	Massachusetts Institude of Technology
APK	**-**	Android Package
IDE	**-**	Integrated Development Environment
UI	**-**	User Interface
CPU	**-**	Central Processing Unit
SDK	**-**	Software Development Kit
USB	**-**	Universal Serial Bus
SPI	**-**	Serial Peripheral Interface
LNA	**-**	Low-Noise Amplifier
TTFF	**-**	Time To Time First Fix
SBAS	**-**	Satellite Based Augmentation System
QZSS	**-**	Quasi-Zenith Satellite System
AGPS	**-**	Assisted Global Positioning System
ROM		Read Only Memory
RAM		Random Access Memory

CHAPTER 1

INTRODUCTION

1.1 Background

With improvements in technology and materials, prosthetic legs have advanced significantly over the past few decades, giving amputees more capability and movement (Perez et al., 2023). Many amputees still struggle with their prosthetic legs, however, and report discomfort, a restricted range of motion, and trouble doing jobs (Kim et al., 2020). To increase the usefulness and utility of prosthetic legs, there has been an increase in interest in the application of Internet of Things (IoT) technology in prosthetics in recent years. The collection of data that can be utilized to enhancethe design and performance of prosthetics is made possible by IoT, which enables real-time monitoring of the leg's movements and performance. It is possible to significantly improve amputees' quality of life and provide them more independence and movement by incorporatingIoT into prosthetic limbs.

In order to offer real-time feedback on the leg's functioning, this project created an IoT in prosthetic leg that includes a range of sensors and data collection techniques. The prosthetic leg includes an accelerometer sensor and temperature sensor. These sensors work together to collect data on the leg`s movements, including step count and temperature. The data is then transmitted to a mobile app via Arduino Cloud where it can be analyzing by the user or their healthcare provider. Thus, the prosthetic leg will include a Global Positioning System (GPS) sensor, which can be used to track the user`s location (Jayaraman et al., 2014).

The focus of this project is to address the issue of limited mobility and discomfort that many amputees face when using traditional prosthetic legs. The integration of IoT technology in prosthetic leg can greatly improve the user experience by providing real-time feedback and allowing for greater customization. To develop a prosthetic leg that not only function well, but also feels comfortable and natural by the user is the main goal of this project. In addition, the importance of a personalized approach to prosthetic leg design, as every individual`s needs and preferences are unique are being recognized.

With all the findings, the aim of this project includes to develop an IoT system equipt into prosthetic leg, determine the control unit required to monitor gps, step tracker and temperature also to test and evaluate the effectiveness of development IoT.

1.2 Problem Statement

According to World Health Organization (WHO), approximately 1.3 billion individuals are reported to encounter significant disability. This figure denotes 16% of the global populace, which is equivalent to one out of every six individuals (Disability, 2023). Among the populace of Malaysia, which amounts to 33.2 million individuals in total. Out of the total population, 218,219 individuals are identified as having physical disabilities. In Malaysia the avaibility of the Internet of Things in prosthetic legs is still limited and not widely accessible. One of the main reasons is the high cost of development and manufacturing. This is because IoT in prosthetic legs involve the use of specialized sensors, wireless connectivity and advanced computing capabilities. These technologies are relatively new and epensive to integrate, which can increase the cost of the prosthetic leg significantly. Then, these devices may not be affordable for many people who need them.

One major challenge in making prosthetic legs more widely available is the integration of IoT technology into their design and functionality (Hobara et al., 2012). To excel in various fields, one must possess technical expertise in multiple areas such as sensor technology, wireless communication protocols, programming, and user interface design. It's no secret that our country is facing a shortage of individuals with technical skills. This poses a significant challenge as we strive to keep up with the constantly changing technological landscape. It's crucial that we address this issue in order to stay competitive and ensure that we have the talentwe need to succeed.

Currently, it seems that there is a lack of awareness among healthcare providers and patients regarding the advantages of incorporating IoT technology into prosthetic legs. It's possible that healthcare providers aren't up to date on the latest advancements in prosthetic leg technology, including the use of IoT. As a result, they may not be aware of the exciting benefits that these devices can offer. Patients may have valid concerns about the safety and privacy of IoT in prosthetic legs. They may worry about cyber-attacks or the collection of sensitive personal data. It's important to address these concerns and ensure that patients feel secure and protected when using these advanced technologies.

1.3 Objectives

The objectives of this project are stated as below:

1. To develop an IoT system equipt into prosthetic leg with digitalization monitoring.
2. To determine the control unit required to monitor global positioning system (gps), step tracker and humidity.
3. To test and evaluate the effectiveness of the development Internet of Things (IoT).

1.4 Scope of Research

The scope of this research are as follows:

1. Developing an IoT system equipt into prosthetic leg using Arduino Cloud IoT.
2. Determining the control unit by using microcontroller equipt with simple algorithm to monitor global positioning system(gps), step tracker and temperature.
3. Testing and evaluating the effectiveness of the development IoT in prosthetic leg on patient with leg amputation.

CHAPTER 2

LITERATURE REVIEW

2.1 Internet of Things

Today, more than two billion individuals utilise the Internet for a variety of purposes, including sending and receiving emails, accessing websites, utilising social networking sites, and doing many other tasks. As time goes on, more and more people will have access to an incredible amount of information thanks to the internet. This will lead to a new era where our gadgets and smart devices will be able to connect, communicate, compute, and coordinate with each other like never before. It's fascinating to think about how the Internet will continue to expand and connect an ever-growing number of networks and devices in the coming years. As we continue to have access to valuable information and services, it becomes easier to create innovative applications and adopt new ways of working, communicating, and entertaining ourselves. This ultimately leads to exciting new ways of living our lives (Mehta et al., 2018). Manufacturing companies also can greatly benefit from the IoT as it presents an endless number of growth opportunities for their business models. By incorporating IoT, companies can enhance their productivity, reduce costs, and establish a more resilient business framework.

2.1.1 Implementing of Iot in Healthcare Domain

Thanks to the latest advancements in the IoT, the healthcare industry has been able to make significant progress in a short amount of time (Rejeb et al., 2023). The IoT has the potential to revolutionise the healthcare industry by transforming the way healthcare is delivered, monitored, and managed. The IoT also has revolutionised the healthcare industry by linking medical devices, wearables, and healthcare systems. This interconnected network has resulted in a more efficient and effective patient care system, improved business operations, and a platform for innovation. With the help of real-time data analysis, healthcare providers can now offer more personalised and proactive care to their patients. This means that they can gather, analyse, and utilise data in real-time, which ultimately leads to better health outcomes for individuals. The healthcare industry is facing a significant challenge when it comes to keeping confidential medical documents secure. With the increasing number of IoT devices and a vast amount of healthcare data, ensuring the privacy and security of sensitive information has become a major concern (Sharma et al., 2023).

Figure 2.1 Understanding the Impact of IoT in Healthcare

2.1.2 Application of Iot In Smart Home

The world of IoT is expanding rapidly and has given rise to a numerous of innovative applications that are being referred to as "smart". These include smart cities, smart agriculture, smart education, smart healthcare, smart waste management, smart surveillance, logistics, supply chains, and many more (León et al., 2010; Nayak & Swapna, 2023). The term "smart home" refers to a residential structure that makes use of a variety of IoT technologies and gadgets in order to automate and improve day-to-day life. Imagine being able to control all of your devices from the comfort of your couch or even when you're away from home. With a home network, you can connect all of your devices and control them remotely using your smartphone, tablet, or even your voice assistant. It's like having your own personal assistant at your fingertips.

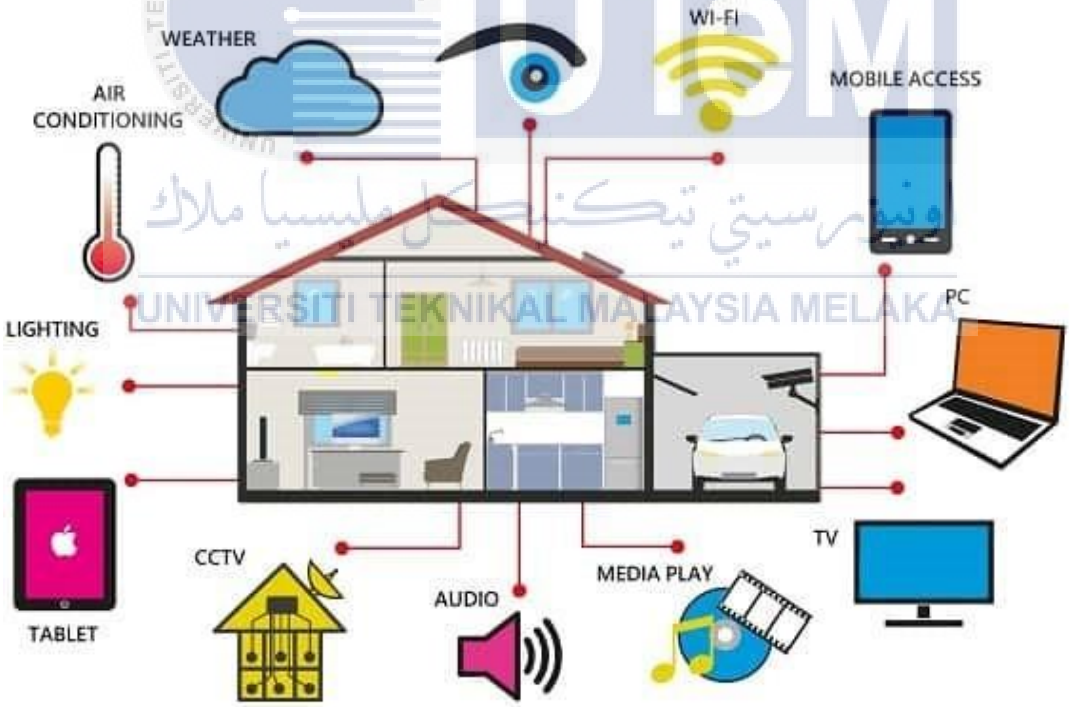


Figure 2.2 Example of Smart Home Application

2.1.3 Potential Advantage of Iot Integrated with Prosthetic Leg

IoT in prosthetic legs has many exciting benefits. Collecting data in real-time helps to personalise changes for each individual, enhancing their comfort and walking abilities. Remote tracking helps doctors and nurses monitor patients and make personalised changes without frequent visits. Analysing data helps improve design and device performance. Users can adjust settings to control their artificial leg's functionality. IoT integration improves safety by sending real-time alerts to prevent discomfort or skin problems. Improved device connectivity simplifies daily usage. IoT-connected artificial legs are more useful, comfortable, and connected. Table 2.1 below shows the example of prosthetic leg with IoT integration that available in the market.

Table 2.1 The example of prosthetic leg with IoT Integration

Prosthetic Leg Model	**IoT Features**	**Connectivity Options**	**Data Collection Capabilities**
Model X	Real-time gait analysis and personalized feedback	Bluetooth, Wi-Fi	Motion sensors for gait analysis, force sensors for pressure data
Model Y	Remote monitoring and adjustment	Cellular, Wi-Fi	Activity tracking, socket pressure monitoring

2.2 Prosthetic Leg

Prosthetic legs are amazing artificial devices that can replace body parts that are missing due to injury, disease, or birth defects. They are designed to help people regain their mobility and independence, and they can make a huge difference in their quality of life. Prosthetic legs are amazing devices that can help people who have lost limbs to get back to their normal routines and activities. They are designed to mimic the function of the missing limb, allowing amputees to perform tasks that they might have thought were impossible (Arifin et al., 2017; Hoque et al., 2023).

2.2.1 Type of Prosthetic Leg

There are three groups of prosthetic leg which are inactive prosthetic, semi-active prosthetic, and active prosthetic. For people with lower limb amputations, inactive prosthetic is intended to offer the bare minimum of stability and support. Their movement capabilities are quite limited since they do not have any articulating joints or dynamic components. Although these prosthetics can help with walking and supporting weight, they do not provide much freedom of movement. These devices are perfect for people who have a less active lifestyle or those who do not need advanced features. Prosthetics that are not in use have a limited range of adjustments available to them, and they usually require less maintenance because they have a more straightforward design.

Compared to non-active prosthetics, semi-active prosthetics provide greater mobility and more natural movement. By integrating mechanical components and joints, these devices are able to perform a wider range of functions with greater ease and efficiency. These prosthetics are designed to offer a greater level of mobility and mimic the natural walking patterns of humans more accurately. These shoes are designed to cater to your unique preferences and walking style with adjustable alignment, foot angle, and stiffness settings. Prosthetics that are semi-active are pretty cool, but they do require some maintenance. This is because they have mechanical parts that might need some modification or even replacing every now and then.

Active prosthetics are designed to offer top-notch functionality and advanced features, providing users with the best possible experience. These devices are cool because they combine both mechanical and electronic parts, which allows them to perform a variety of movements and functions. Prosthetics that are active can greatly improve mobility and imitate the movement of a natural leg, making walking feel more natural and effortless (Hobara et al., 2012). These devices usually come with adjustable alignment, foot angle, and stiffness settings, giving you the freedom to customise them according to your preferences(Naseri et al., 2022). Additionally, they offer advanced control options that allow for even more personalization. On the other hand, active prosthetics are quite intricate with electronic and mechanical parts, which means they may need more attention and care. This could involve regular maintenance and tweaks to ensure they function optimally.

2.2.2 Evolution of Prosthetic Leg

As technology advances, so does the evolution of prosthetic leg technology. Materials science, robotics, sensor technology, and artificial intelligence are all driving forces behind this progress. It's exciting to see how far we've come and where we'll go next. Researchers and innovators are constantly striving to improve the lives of individuals with limb loss by developing new technologies that enhance functionality, comfort, and overall quality of life. Their efforts are pushing the boundaries of what is possible in the field of prosthetics, offering hope and new possibilities for those in need (Arango-gonzález et al., 2022; García et al., 2022).

Table 2.2 The Evolution of Prosthetic Leg

Evolution of Prosthetic Leg Technology	Features
Ancient civilizations	Basic prosthetics using wood, leather, and metal.
Industrial Revolution	Advancements in manufacturing techniques and materials.
World War I and II	Adjustable sockets, articulated joints, improved foot mechanisms.
Advancements in Materials	Introduction of lightweight and durable materials like plastics, polypropylene, and carbon fiber.
Microprocessor-Controlled Prostheses	Integration of microprocessors and sensors for real-time movement monitoring and adjustment.
Bionic Prostheses	Utilization of advanced robotics and artificial intelligence for more natural limb movement simulation.
Customization and Personalization	CAD and 3D printing technologies for highly individualized prosthetic limbs.
Integration with IoT and Wearable Technologies	Incorporation of IoT and wearable technologies for remote monitoring and real-time adjustments.

2.3 Mobile App

Throughout the history of the Information Technology industry, a diverse range of software programmes have been revolutionising the way individuals perceive and interact with the world. We have noticed that many of the tasks we used to do manually are now being automated and managed by computer systems. The world of Software Development is a fascinating one. It is a broad term that involves the creation and delivery of all sorts of software, from websites to standalone applications. It is a complex process that involves a lot of hard work and dedication. To create these apps, you typically need a personal computer with decent specs to get started. This is usually the minimum hardware requirement. Back in the day when software was just starting to take over the world, only those who were fortunate enough to own a computer and had the financial resources to buy one were able to utilise it to its full potential. There was a time when cybercafés were the only way for people to access the internet. Although laptops and personal computers are becoming increasingly common, the number of people who have access to them is still relatively low compared to the overall population.

After the introduction of mobile phones that were essentially hand-held computers, there has been a significant increase in the number of people purchasing these devices (C. G. & Devi, 2021). Moreover, the advent of mobile phones has led to a surge in the number of individuals who can comprehend and utilise apps. It is fascinating to see how people of all ages are becoming proficient in using mobile apps. It is safe to say that today, everyone is learning how to navigate through these applications with ease. This holds true for individuals of all ages,whether they are young or old. Ever since then, the world of app development has been thrivingand taking full advantage of this opportunity.

2.3.1 Mobile App Development

The development of mobile applications involves the creation of software that is primarily designed to operate on mobile phones and other portable digital devices (C. G. & Devi, 2021). The industry in question has experienced significant growth and has emerged as a crucial component of virtually all types of businesses. The dominance of Android and iOS is evident in the vast array of mobile phones available on the market.

Table 2.3 The Global OS Market Share

Mobile operating system	Percentage
Android	71.81%
iOS	27.43%
Samsung	0.38%
KaiOS	0.14%
Unknown	0.14%
Linux	0.02%

2.3.2 MIT App Inventor

The present study highlights the potential of MIT App Inventor as a web-based development environment that enables individuals with limited or no programming experience to create their own mobile applications for Android devices. The tool is noted for its powerful features that facilitate the development of mobile applications. The utilisation of a block-based, user-friendly visual programming language sets MIT App Inventor apart from conventional coding environments (Labusch et al., 2019). The approach discussed herein obviates the necessity of composing intricate code lines, thereby rendering app development more inclusive to a wider demographic.

The component-based development model of MIT App Inventor is a significant advantage. The platform offers a diverse selection of pre-built components, including buttons, labels, text boxes, sensors, and other items, that can be conveniently placed onto a canvas through a simple drag-and-drop process. The present interface is designed to enable users to create and organise the user interface components of their application, without the need for extensive coding knowledge.

The programming paradigm employed by MIT App Inventor is event-driven. The ability to define events and specify corresponding app responses is a feature available to users. An event can be created to activate upon the click of a button or the detection of a particular motion by the device's accelerometer. The desired behaviour of an app can be constructed by users through the visual connection of blocks that represent event-handling functions.

The significance of the Blocks Editor in MIT App Inventor cannot be overstated. The platform offers a graphical interface that enables users to construct the operational framework of their application through the interconnection of distinct blocks(Mathematics, 2016). The Blocks Editor provides a diverse range of blocks that symbolise different commands and functions. These blocks can be utilised by users to incorporate various functionalities, including but not limited to data manipulation, user input management, multimedia playback, and other features. The utilisation of a visual approach in programming enables users to visually perceive and comprehend the progression of their application's logic.

The live testing capability of MIT App Inventor is a notable feature. The real-time viewing and interaction of the app during development can be achieved by users through the connection of their Android device or utilisation of an emulator. The ability to rapidly iterate through an immediate feedback loop enhances user efficiency and enjoyment in the development process.

MIT App Inventor facilitates the generation and exportation of an APK (Android Package) file upon completion of an app. The present file is capable of being installed on Android devices and subsequently shared with other users. MIT App Inventor offers the possibility of expanding one's audience reach by enabling the publication of apps on the Google Play Store. This feature allows users to disseminate their creations to a global audience.

The primary objective of MIT App Inventor is to facilitate the integration of coding and creativity through the provision of a user-friendly platform for the development of mobile applications. The tool under consideration is an excellent option for individuals who wish to bring their app ideas to life without requiring extensive coding knowledge. This is due to its visual programming approach, component-based development, and live testing capabilities. As a result, it is highly recommended for students, educators, and hobbyists alike.

2.3.3 Android Studio

The integrated development environment (IDE) known as Android Studio is tailored tothe creation of applications for the Android platform. The platform provides an extensive array of functionalities and resources that aid programmers in constructing Android applications with proficiency and efficacy.The user interface (UI) designer is a significant characteristic of Android Studio. The provision of a visual editor by the UI designer facilitates the process of designing and customising the user interface of applications for developers. The utilisation of drag-and-drop functionality and layout adjustment options enables developers to expeditiously generate visually captivating interfaces. The provision of a preview feature by the UI designer enables developers to visualise the appearance of their application on diverse screen sizes and orientations (Esmaeel & Esmaeel, 2015; Thamizharasi, 2016).

The Android Studio's code editor is a potent tool that developers can exploit. The provision of code completion, syntax highlighting, and code refactoring features enhances coding productivity and accuracy. The debugging capabilities integrated within the code editor facilitate the identification and resolution of coding issues by developers.The utilisation of Gradle build system by Android Studio streamlines the build process of Android applications.

Gradle enables developers to specify build configurations, handle dependencies, and automate diverse tasks, simplifying the process of constructing and sustaining intricate Android projects. Android Studio offers a simulation tool in the form of an emulator, which enables developers to test various Android devices. The ability to test applications on multiple screen sizes, resolutions, and Android versions without the requirement of physical devices is madepossible. The ability to connect physical devices to Android Studio for testing and debugging purposes are available to developers.

Android Studio provides performance analysis tools for the purpose of optimising app performance. The tools facilitate the process of profiling applications, scrutinising CPU and memory consumption, monitoring method execution, and detecting performance hindrances for developers. The identification and resolution of performance issues by developers is crucial to ensuring the smooth and efficient operation of their applications.The integration of Android Studio with version control systems like Git facilitates source code management and team collaboration for developers. The benefits of this include improved code organisation, version tracking, and enhanced team collaboration.

The Android Studio is equipped with the Android SDK Manager, enabling developersto acquire and regulate the essential Android SDK constituents. The aforementioned encompasses the essential components, namely system images, libraries, and tools, that are necessary for the development of applications. By managing the SDK components directly within Android Studio, developers can ensure that they have the latest updates and resources for building Android apps. Android Studio facilitates the creation of applications for diverse platforms, beyond smartphones and tablets. The aforementioned are the three distinct Android operating systems, namely Wear OS, Android TV, and Android Auto, which cater to smartwatches, television devices, and in-car infotainment systems, respectively. Android

Studio enables developers to utilise their pre-existing knowledge and expertise to design applications for various platforms, thereby broadening the scope of their app's accessibility.

Android Studio is widely considered as the primary Integrated Development Environment (IDE) for the creation of Android applications. The Android platform is a robust tool for constructing top-notch applications, thanks to its extensive range of features, potent tools, and seamless integration capabilities. Android Studio offers a comprehensive set of tools and resources that facilitate the app development process for both novice and seasoned developers. With these tools, developers can efficiently bring their ideas to fruition on the Android platform.

2.3.4 Arduino Cloud Iot

The Arduino Cloud IoT platform is a powerful tool that enables users to easily incorporate Internet of Things (IoT) features into their Arduino projects to provide a more seamless experience. It streamlines the process of connecting Arduino boards to the internet by providing a web-based interface that is easy to use. This makes it possible to remotely monitor and control Internet of Things devices. Data visualization in real time, the creation of individualized dashboards, and the programming of Arduino devices can all be done straight from the cloud. The platform places an emphasis on accessibility, which makes it acceptable for those with varied degrees of technological expertise. Because it is compatible with a wide variety of Arduino boards, it enables greater flexibility in the construction of projects. In addition, Arduino Cloud IoT improves security by encrypting communication and provides advanced capabilities such as automation rules, which together provide a comprehensive and effective Internet of Things experience. Arduino Cloud IoT offers a scalable solution for realizing the potential of connected devices, and it can be used for projects ranging from those undertaken by hobbyists to those implemented in industrial settings.

Figure 2.3 Arduino Cloud widget

2.4 Hardware

The term hardware describes to the physical components that constitute a computer system. The system comprises various components such as the central processing unit (CPU), memory, storage devices, input and output devices, and networking equipment. The central processing unit (CPU) serves as the computational and operational hub of a computer system, executing instructions and performing mathematical computations. The concept of memory encompasses two distinct types of storage: Random Access Memory (RAM) for temporary data retention and Read-Only Memory (ROM) for permanent instructions. The term hardware refers to the measurable and observable constituents which make up a computer system. The fundamental components of a computer system comprise the central processing unit (CPU), memory, storage devices, input and output devices, and networking equipment. Every constituent element plays a distinct role in guaranteeing the operational efficacy of thecomputer system, enabling it to execute data processing, retain data, and facilitate userengagement.

2.4.1 Esp32 Microcontroller

There are many types of Esp32 Microcontroller board on the market today. Adafruit Huzzah32, Esp32 DevKitC, NodeMCU-32S and Wemos D1 Mini ESP32 are the microcontroller that popular among the engineers and hobbyists.

In (Vega-Luna et al., 2020), Huzzah32 card had been used as the resources required for the design of the slave nodes, thus reducing their size and cost. The Adafruit Huzzah32 is an ESP32-based development board produced by Adafruit Industries. The Huzzah32 board is designed to provide an easy-to-use and convenient platform for IoT development using the ESP32 microcontroller. It features the ESP32 chip, which includes dual-core processors, Wi-Fi and Bluetooth connectivity, a rich set of peripheral interfaces, and ample memory resources.

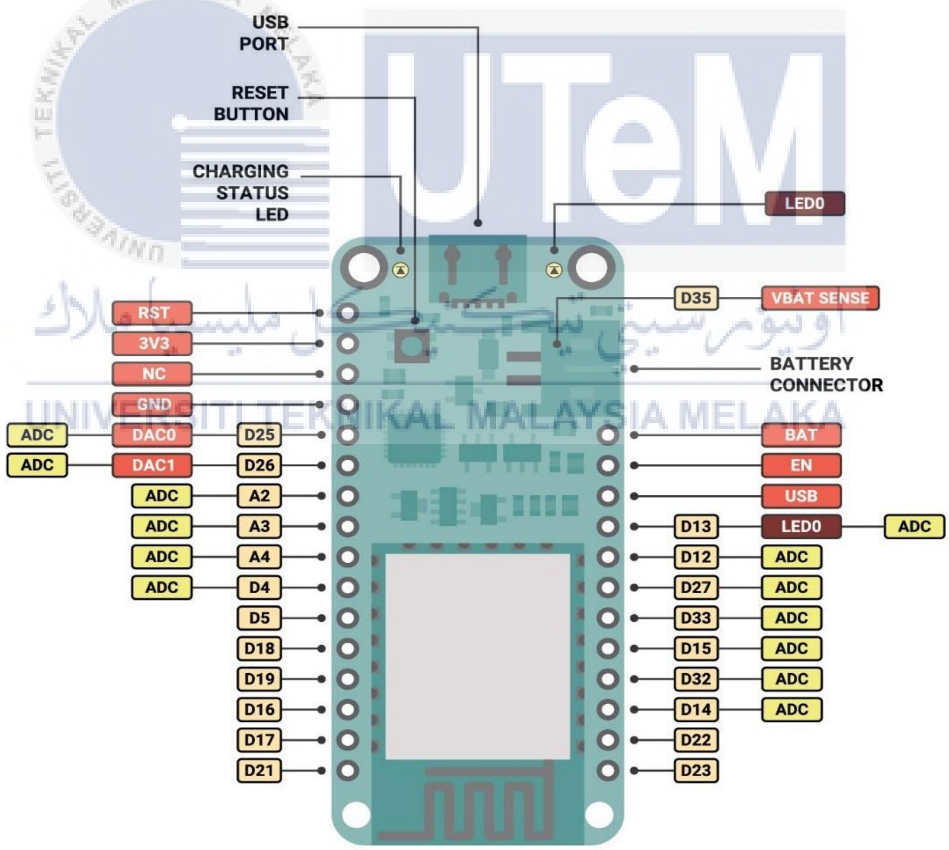


Figure 2.4 Huzzah32

The NodeMCU-32S and Huzzah32 share comparable functionalities, although differing in size and packaging (Homolak et al., 2022). The device is equipped with the ESP32 microcontroller chip, which boasts dual-core processors, integrated Wi-Fi and Bluetooth capabilities, and a sufficient number of GPIO pins for interfacing with external components. The compatibility of the board with the Arduino Integrated Development Environment and its support for Lua scripting are noteworthy features.

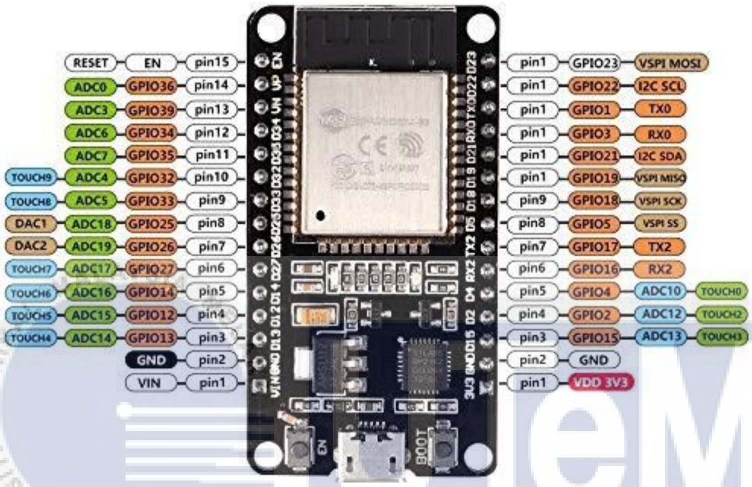


Figure 2.5 NodeMCU-32S

The ESP32 DevKitC is a development board that is based on ESP32 and is extensively utilised for prototyping and IoT applications. The ESP32 microcontroller chip is equipped with dual-core processors and integrated Wi-Fi and Bluetooth connectivity. This board offers a multitude of GPIO pins to facilitate external device interfacing, is compatible with the Arduino IDE for programming, and features a user-friendly USB-to-serial interface for seamless programming and debugging. The ESP32 has built in Bluetooth and Wi-Fi with good number of GPIO pins and communication protocols (Ismail et al., 2020). The ESP32 DevKitC is a highly favoured device due to its extensive range of features and compatibility with the Arduino ecosystem.

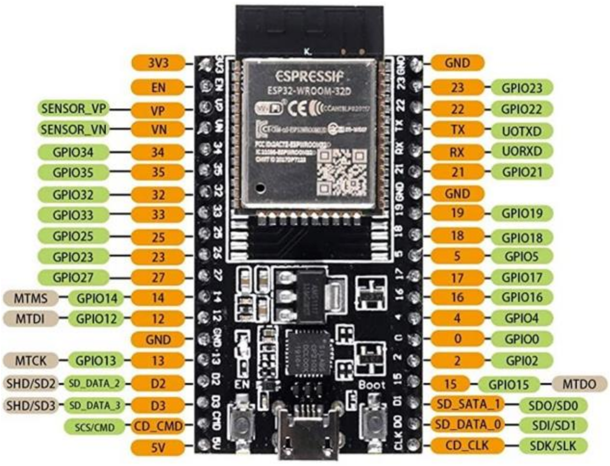


Figure 2.6 ESP32 DevKitC

The compact development board, Wemos D1 Mini ESP32, is founded on the ESP32 microcontroller chip. The device's inherent Wi-Fi and Bluetooth functionalities render it appropriate for Internet of Things (IoT) endeavours (Ganesh et al., 2022). The board offers GPIO pins that facilitate the connection of external components and interfaces, including SPI and I2C. The device is equipped with a USB interface that enables programming and debugging functionalities. Its compact size renders it suitable for projects that have limited space availability. The popularity of the Wemos D1 Mini ESP32 among makers and developers can be attributed to its user-friendly nature, compatibility with the Arduino IDE, and cost-effectiveness, which make it a preferred option for prototyping and developing connected projects.

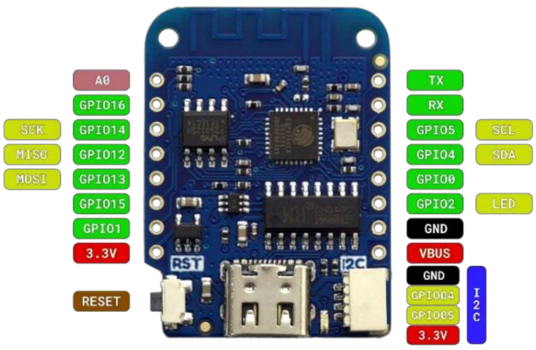


Figure 2.7 Wemos D1 Mini ESP32

Table 2.4 Comparison Between ESP32 Microcontroller

	HUZZAH32	ESP32 DevKitC	NodeMCU-32S	Wemos D1 Mini ESP32
Size	56mm x 26mm (2.2" x 1.0")	53mm x 28.5mm (2.1" x 1.1")	49mm x 25mm (1.9" x 1.0")	34.2mm x 25.6mm (1.3" x 1.0")
Operating Voltage	3.3V	3.3V	3.3V	3.3V
Clock Speed	Up to 240MHz	Up to 240MHz	Up to 240MHz	Up to 240MHz
Power Supply Options	USB, External Power Jack	USB, External Power Jack	USB, VIN Pin	USB, External Power Jack

The microcontroller utilised in this project is the Adafruit Huzzah32. The Adafruit board, due to its small size and low cost in comparison to other ESP32 boards, is deemed more appropriate for implementation within the system.

2.4.2 Tracking System

The primary objective of a tracking system is to ascertain the location or direction of a target in a nearly uninterrupted manner. The optimal tracking system should ensure consistent communication and real-time updates of the target's azimuth, range, and elevation. The present study highlights that the output generated by the tracking system has the potential to be transmitted to a fire control system. This system is capable of storing the received information and subsequently deducing the motion of the target, thereby enabling the prediction of its future position. This paper will demonstrate that tracking systems offer not only automated target following capabilities, but also precise target positioning for effective tools delivery.

2.4.2.1 Global Positioning System (GPS)

The navigational system known as the global positioning system (GPS) was initially created by the American Department of Defence for military purposes (Ystems et al., 2015). However, it has since been made available to the public and commercialised. The system comprises of a constellation of 27 satellites that are equipped with atomic clocks and are positioned in the Earth's orbit. The continuous transmission of data from satellites to GPS receivers enables the latter to determine the distance to the former through signal analysis. There are many types of the GPS module. Neo-6M and Neo-m8n are the GPS module that commonly used by engineers and hobbyists.

The implementation of the L86-M33 GNSS module from Quectel has been carried out for the navigation system (Picallo et al., 2023). The device features an integrated antenna and low-noise amplifier (LNA). The integration of multiple advanced features yields benefits in terms of expediting Time to First Fix (TTFF), enhancing sensitivity, and reducing power consumption. The device is capable of supporting a range of positioning, navigation, and industrial applications, such as autonomous GPS, GLONASS, SBAS, QZSS, and AGPS.

Figure 2.8 L86-M33

The GPS Module Neo 6M enables access to location coordinates and facilitates transmission of said information through the channel location (Pandu Maulana1, Ucuk Darusalam2, 2020). Upon obtaining the coordinate data from the GPS Module Neo 6M, users proceeded to utilise the channel location coordinates. This module is ideal for battery-powered devices with limited cost and space, as it features optimised architecture, power, and memory. The suitability of the product for use on CanSat is highly evident (Satria et al., 2017). The utilisation of 50 channels of positioning engines results in a Time-To-First Fix (TTFF) acceleration of less than 1 second.

Figure 2.9 NEO 6M

Although the NEO-6M GPS module and the LM86 M33 GPS module both fulfill the aim of giving accurate location data, the NEO-6M GPS module stands out as the solution that is more suitable for the situation. Because of its small size, low power consumption, and ease of integration, it has gained significant popularity throughout the world. This is because it is a versatile solution that can be used for a variety of applications. The NEO-6M's extensive use in both do-it-yourself projects and commercial applications can be attributed to its compatibility with a wide variety of microcontrollers, its uncomplicated communication through a serial interface, and its cost-effectiveness. The NEO-6M GPS module delivers a compelling combination of characteristics, including dependable performance, user-friendly setup options, and a proven track record. As a result, it is the ideal choice for individuals who are looking for a GPS solution that is both reliable and efficient.

2.4.2.2 Step Tracker

The application of an accelerometer sensor is for the purpose of sensing capacitance, whereby the acceleration is associated with the modification of capacitance of a moving mass. The accelerometer is an automated instrument utilised for the measurement of acceleration, detection and quantification of vibration, and assessment of bodily acceleration (Arun

Faisal et al., 2019). The accelerometer is a sensor that is capable of measuring acceleration or modifications in motion. The detection and monitoring of movements are widely employed in diverse applications. The accelerometer operates on the principle of inertia and employs minute microstructures or MEMS (Micro-Electro-Mechanical Systems) that react to acceleration forces. The electrical signal that is proportional to the applied force is generatedby the deflection of microstructures when subjected to acceleration. Accelerometers are capable of providing significant insights into the motion and positioning of an individual or object by gauging the intensity and orientation of the acceleration. Accelerometers have become ubiquitous in modern electronic devices, including but not limited to smartphones, fitness trackers, and game controllers. Their primary functions include step counting, motion detection, screen rotation, and gesture recognition.

Figure 2.10 Accelerometer

The present statement highlights the fundamental concept of a piezoelectric sensor, which is a transducer that converts mechanical stress or pressure into an electrical charge. The operational principle of the device is based on the piezoelectric effect, a phenomenon observed in specific materials that possess the ability to produce an electrical charge in response to an externally applied force. The conversion of mechanical energy into electrical energy is facilitated by the piezoelectric element in the sensor. The deformation of the sensor under the influence of pressure or impact results in the generation of an electrical signal that is directly proportional to the magnitude of the applied force. Piezoelectric sensors find common application in diverse applications, such as step trackers. In this context, they are typically situated within footwear or insoles to discern the impact force produced during each step. The measurement and analysis of electrical signals enables the calculation of step count, stride length, and cadence, among other parameters. This data is of great value for both activity tracking and gait analysis purposes.

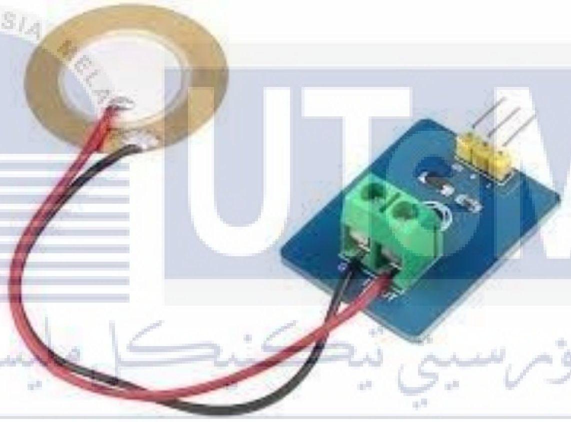


Figure 2.11 Piezoelectric Sensor

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describe the approach used to complete this project successfully. This chaper shows the flow process starting from survey until assembling component to the prosthetic leg. This chapter includes the project planning flow chart, the process of selecting component and testing the circuit, and the final product outcome. This chapter also includes a detailed process for each section. Detailed procedure on how selecting component is made, design a comprehensive and detailed circuit, simulation modelling in term of development and performance, and testing of the product.

The first stage of this project is to gather information through research prior to project development to enhance the knowledge required to develop the project. It is essential for the development of this project to investigate the problem statement and outline the objectives based on the problem statement. Then, analyses and identifies the information. The information collected from the journal, newspaper, or reliable website and make analysis in the Literature Review section. The comparison between the hardware and method is that done in the Literature Review section help to understand the functionality of the components.

In step 2, making the decision on the use of hardware component. The comparison of the hardware and method use in the previous step has helped to improve the understanding of the component and method use. Indirectly, the decision making about the use of components and programming language will be easier. The development the hardware will be done in the third step. After the choose the suitable component use in this project, the development of the hardware can be started. Testing and modifying the project is repeated until the project's result reach the desired goal.

3.1 Flow Chart

The general setup used in this project is being discussed in the section. The figure 3.1 shows the general flow chart of this project.

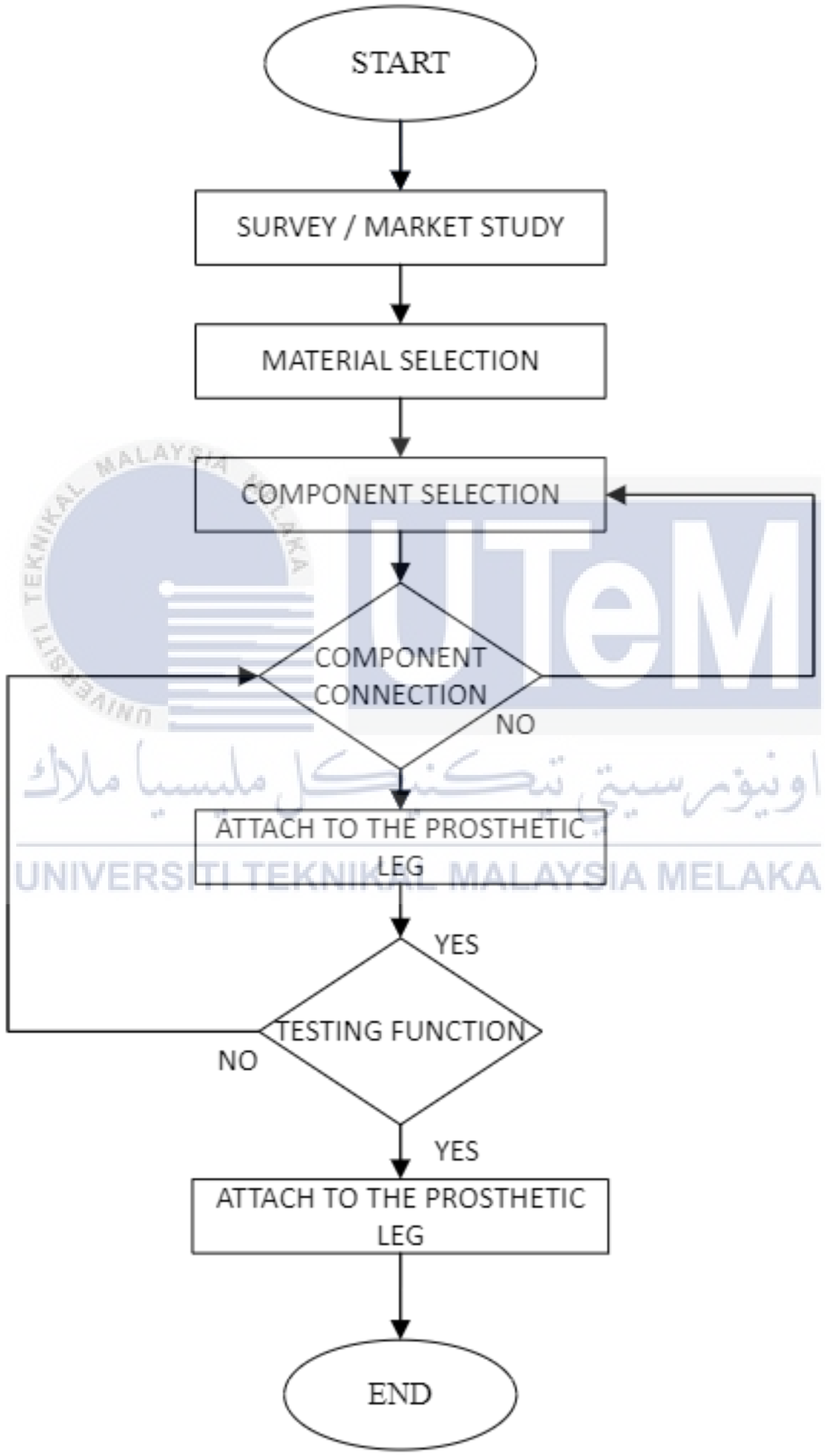
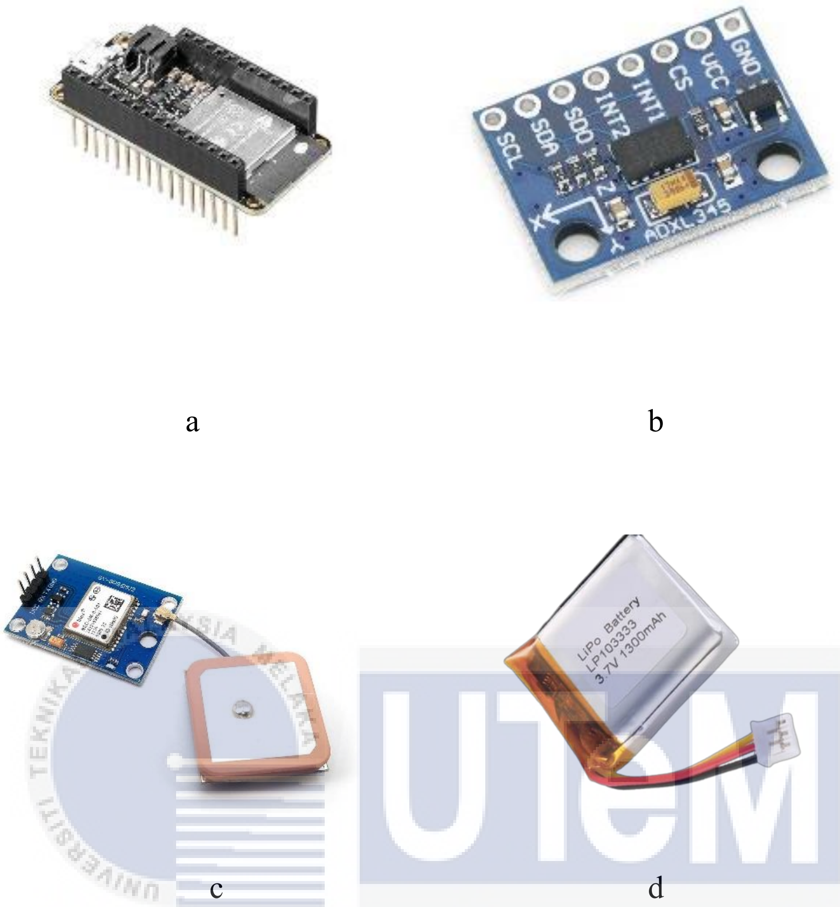


Figure 3.1 Overall Flow Chart for This Project

3.2 Specific IoT

The Internet of Things (IoT) can be defined as a self-governing network of devices that are integrated into a physical entity and possess the ability to detect internal or external alterations, modify their state, and communicate through the Internet without any time constraints. This definition remains applicable irrespective of the system's intended function (Negash et al., 2017) (Minn et al., 2015). The application of IoT technology enables prostheticlegs to acquire and transmit instantaneous data, thereby enhancing their operational efficiency and management. The integration of sensors within prosthetic legs enables the monitoring of crucial characteristics, including movement and location, thereby providing essential feedbackto both the user and healthcare providers. This study explores the potential of IoT prosthetic legs to transmit data wirelessly to a user interface or application, providing users with access to valuable information on their gait patterns, prosthetic utilisation, and health-related metrics. The previous data holds potential to facilitate progress tracking, performance optimisation, andidentification of opportunities for improvement. The utilisation of IoT technology has the potential to enhance the functionality, performance, and convenience of prosthetic legs. IoT- enabled prosthetic legs offer enhanced connectivity and data-driven insights that facilitate improved mobility management, progress monitoring, and overall optimisation of the prosthetic experience for users.



a b

c d

Figure 3.2: IoT Sensor
a Huzzah32, b Accelerometer, c gps L86-M33, d LiPo battery

3.2.1 User Accessible Interface

The seamless interaction between IoT consumers and devices is dependent upon the criticality of the User Accessible Interface (UAI). The market currently offers a selection of UAI, as portrayed in Figure 3.2. This paper discusses the various interfaces, applications, and platforms that facilitate user control, monitoring, and management of IoT devices and their functionalities. The utilization of the UAI facilitates the retrieval and manipulation of copious amounts of data generated by IoT devices, thereby empowering users to make well-informed decisions and execute suitable measures. The UAI enables remote control and configuration of IoT devices, establishment of preferences, and receipt of notifications or alerts based on predefined conditions. The ability to monitor the status, performance, and health of IoT devices is a crucial aspect that enables users to engage in proactive maintenance and enhances the overall user experience. The UAI facilitates effective communication and offers a user-friendly interface, thereby unlocking the full potential of IoT devices. This results in increased accessibility and empowers users to leverage IoT technology in their daily routines.

Figure 3.3: a Smart Home Automation, b Agriculture, c Wearable

3.2.2 Device Integration

The integration of devices is a crucial aspect in the development of a prosthetic leg that is integrated with the IoT. The process involves the careful selection, configuration, and integration of diverse components into a prosthetic leg, with the aim of enhancing its functionality and connectivity. The accurate detection and measurement of leg movements, angles, and orientation through the integration of motion sensors, including accelerometers and gyroscopes, is a crucial aspect of device incorporation. The sensors offer significant insights into the user's gait patterns, facilitating accurate monitoring and analysis of their motion. The establishment of connectivity between external devices or systems and prosthetic limbs is reliant on communication modules, such as Bluetooth or Wi-Fi. The modules described herein facilitate real-time monitoring, analysis, and control by enabling the transmission of sensor data to a centralised system or user interface. The integration of devices is a critical aspect in the development of an IoT-integrated prosthetic limb that can provide improved functionality, data-driven insights, and enhanced user experiences.

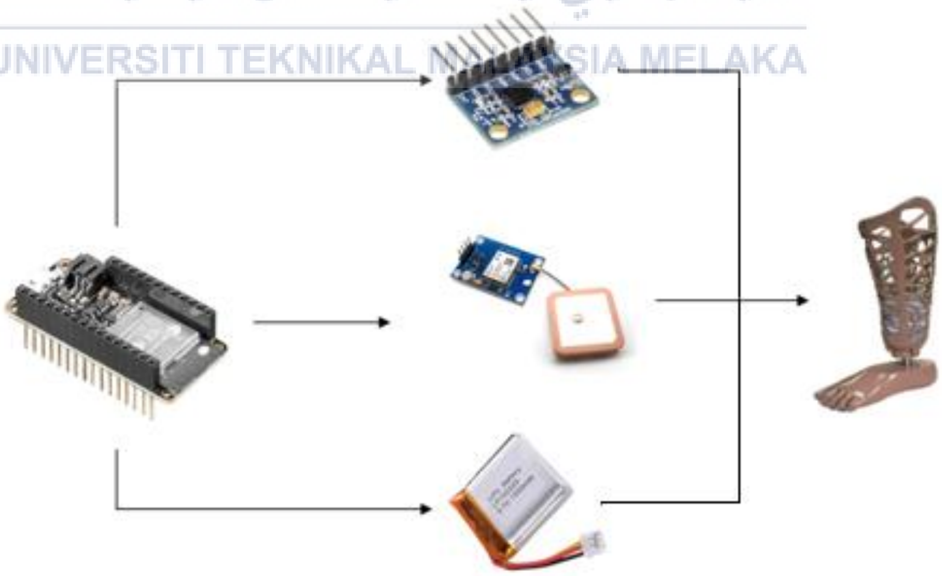


Figure 3.4 How the Device Develop

3.3 Component Selection

The selection of suitable components is a crucial step in the development of a prosthetic leg that is integrated with IoT technology. The selection of components for prosthetic legs is crucial in ensuring optimal comfort, flexibility, and performance, as well as structural integrity and durability. At this stage of the project, it is imperative to meticulously consider the distinct requirements of the prosthetic leg, encompassing factors such as weight, strength, biocompatibility, and resistance to environmental conditions. The selection of materials for the socket, frame, joint mechanisms, and covering of a prosthetic leg should align with the desired functionality and objectives of the device, with the ultimate goal of providing optimal support, natural mobility, and user satisfaction. By carefully evaluating and selecting the appropriate materials, the integration of IoT technology into prosthetic legs can achieve a balance between structural integrity, functionality, and user comfort. This can ultimately lead to an improvement in the mobility and quality of life for individuals utilising the prosthetic device.

3.3.1 Microcontroller

The HUZZAH32 is an ESP32-based Feather that utilises the official WROOM32 module. The device under consideration encompasses all the desirable features of Feathers, including a pre-installed USB-to-Serial converter, an automatic bootloader reset mechanism, a charger for Lithium Ion/Polymer, and nearly all the GPIOs exposed to enable compatibility with any of the FeatherWings.

The Feather's final module comprises a dual-core ESP32 chip, 4 MB of SPI Flash, a tuned antenna, and the necessary passives to harness the full potential of this robust processor. The ESP32 is equipped with support for both WiFi and Bluetooth Classic/LE. The versatility of the product makes it suitable for a wide range of wireless or Internet-based projects.

The ESP32 is an ideal advancement from the widely favoured ESP8266. The ESP32 boasts a significantly greater number of GPIO, ample analogue inputs, dual analogue outputs, and a plethora of supplementary peripherals, including an additional UART. With the added benefit of dual cores, the device obviates the need to relinquish control to the WiFi manager, while also featuring a substantially faster processor.

Table 3.1 Comparison of ESP32 Microcontroller

Type	Userbility	Feature	Price
Arduino uno	User friendly	Using microcontroler ATmega328P running at 16 MHz	Estimated price RM 20 – RM 30
Arduino nano	Beginner-friendly	USB connection for programming and communication	Estimated price RM 50 - RM 80
Esp32	Beginner-friendly with added IoT capabilities	Wi-Fi and Bluetooth built-in, USB connection for programming and communication	Estimated price RM 60 - RM 100
Huzzah32	Beginner-friendly with added IoT capabilities	Comes with power socket for LiPo battery	Estimated price RM 80 - RM 120

3.3.2 Sensor

The device known as a sensor is designed to detect and quantify physical stimuli within its surroundings, subsequently transforming this information into a format that can be comprehended by either a human or a machine. The majority of sensors operate through electronic means, whereby the collected data is converted into electronic format. However, there exist simpler sensors, such as a glass thermometer, which provide visual data. Sensors are utilised for a multitude of purposes, including but not limited to temperature measurement, distance estimation, smoke detection, and pressure regulation.

3.3.2.1 Step Tracker

The accelerometer is a device utilised for measuring the vibration or acceleration of motion of a structure. The piezoelectric material generates an electrical charge that is directly proportional to the force applied to it. This force is typically induced by vibration or acceleration, which causes the mass to compress the material and produce the electrical charge. The accelerometer is a device that utilises an electromechanical sensor to quantify static or dynamic acceleration. The concept of static acceleration pertains to the consistent application of force on an object, such as the effects of gravity or friction. The predictability and uniformity of these forces are extensive.

Gyroscopes are sensors that detect and quantify the angular motion of an object. The rotational velocity of an object is determined by measuring its rotation around a specific axis, namely the 1-axis, 2-axis, and 3-axis. The utilisation of these technologies has expanded from high-cost military applications to include low-cost commercial applications. In this project, accelerometer is chosen because of the accelerometer's popularity stems from its capacity to detect changes in motion activity rates.

3.3.2.2 Global Positioning System (GPS)

Over the past few years, there has been a growing interest in the utilization of tracking devices for a variety of purposes, including the monitoring of patients, athletes, and children, as well as applications involving cars and robotics. Devices that are low-cost and use the Global Positioning System (GPS) have become increasingly popular as a result of the increased accuracy of this system as well as the overall improvement in affordability.(Bujang et al., 2020)

U-blox is a Swiss company that excels in positioning and wireless communication technologies. The company has gained recognition for its diverse product portfolio, which encompasses Global Navigation Satellite System (GNSS) receivers, wireless modules, and chips designed for various applications like GPS, Galileo, GLONASS, BeiDou, and cellular communication. u-blox's solutions have gained significant traction across a range of industries, such as automotive, industrial, consumer electronics, and Internet of Things (IoT) devices.

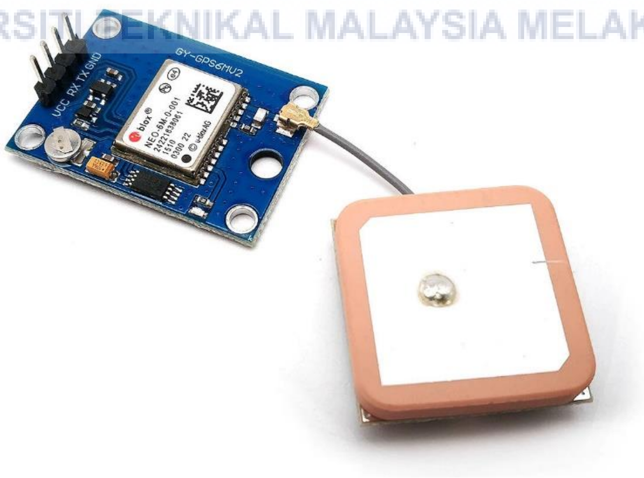


Figure 3.5 Neo 6M GPS module

3.4 Circuit Testing

The validation of functionality, identification of errors and defects, and assurance of product quality are critical aspects of IoT-integrated prosthetic leg development, all of which are made possible through circuit testing. The evaluation of the circuit's efficacy through rigorous testing is crucial to ascertain its intended functionality and compliance with the specified requirements. The process of circuit testing serves to enhance the dependability and security of the electronic system of a prosthetic leg by detecting and resolving any inconsistencies or problems. This, in turn, mitigates the likelihood of malfunctions and instills a greater sense of assurance in the end product. In accordance with the guidelines presented in Figure 3.4, the proper procedure for conducting circuit testing is demonstrated.

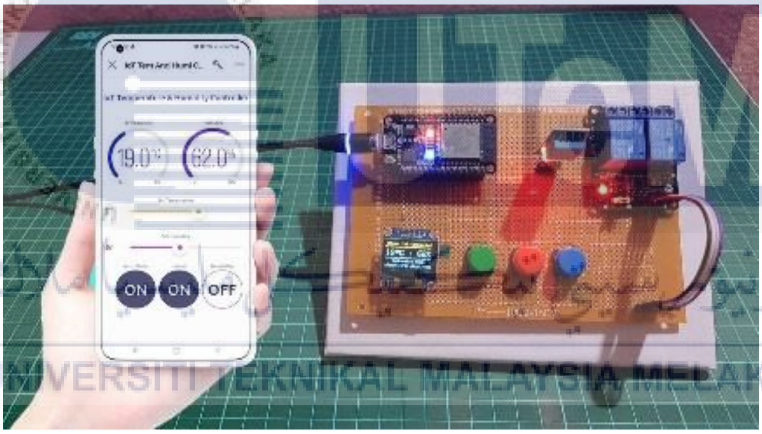


Figure 3.6 Circuit Testing

3.4.1 Develop a Circuit

The thorough review of the design and schematic diagram was integral in the development of the circuit for IoT integration in the prosthetic leg. During the circuit design process, the selection of components such as accelerometers, GPS modules, and temperature sensors was based on the specific needs of the project. The circuit created using EasyEda software is illustrated in Figure 3.7. The schematic diagram presented a clear illustration of the accurate interconnections and associations among the said components, guaranteeing their appropriate integration into the circuit. The design prioritised user safety by incorporating safety measures,including insulation and grounding. This study presents the integration of IoT capabilities into a prosthetic leg through meticulous circuit design and a detailed schematic diagram. The integration resulted in enhanced functionality, personalised control, and an improved user experience.

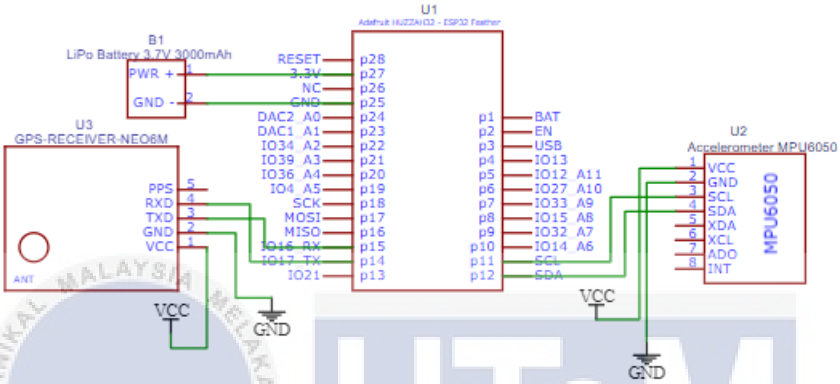


Figure 3.7 Schematic Diagram

3.5 Software implementation

Arduino IoT Cloud is a platform created by Arduino to simplify the integration of Internet of Things (IoT) capabilities into Arduino projects. It is designed to accommodate users with different levels of technical knowledge, offering a simple and accessible web interface that doesn't require advanced programming or networking skills. Designed to work seamlessly with various Arduino boards, including well-known models such as Arduino Uno and MKR series, this cloud platform empowers users to effortlessly establish internet connectivity for their devices. This enables convenient remote monitoring and control capabilities.

The platform offers a customizable dashboard with a range of widgets for visualizing data, the convenience of programming Arduino devices directly from the cloud interface, and the flexibility to establish automation rules for triggering actions based on specific conditions. Security is a top priority for Arduino IoT Cloud, with a strong focus on implementing measures to protect communication between devices and the cloud using secure protocols. In addition, users can take advantage of integration capabilities with other cloud services and APIs to enhance functionality. Arduino offers comprehensive documentation and a helpful community to support users in developing, managing, and enhancing their IoT projects. Various subscription plans are on offer, including a free tier with basic features and paid options for those seeking more advanced functionalities. For the most up-to-date information on Arduino IoT Cloud, it's recommended to visit the official Arduino website. As technology continues to advance, staying informed is crucial.

An IoT remote application designed to connect with Arduino IoT Cloud allows users to remotely monitor and control their Arduino-based IoT projects. Through this application, users can access real-time data, visualize project metrics, and trigger actions on connected devices from anywhere with an internet connection. Leveraging the connectivity provided by Arduino IoT Cloud, the application enables seamless interaction with Arduino boards, facilitating a user-friendly and intuitive interface for managing IoT projects remotely.

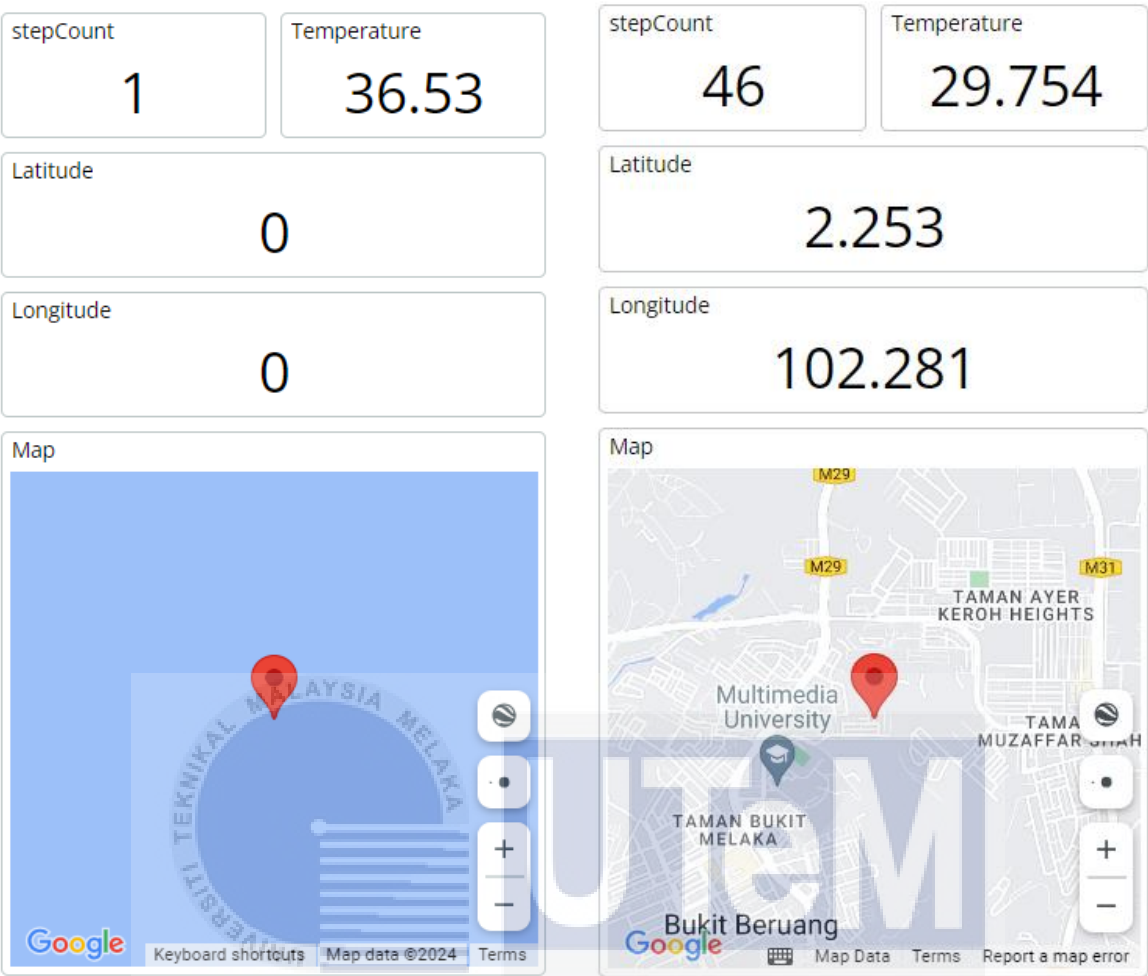


Figure 3.8 Dashboard of Arduino Cloud and IoT Remote

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter explores the finer points of creating and putting into practice an innovative Internet of Things (IoT) prosthetic leg system that is precisely calibrated to track user steps, deliver accurate GPS positioning, and continuously monitor the user's temperature. With the goal of bridging the gap between technological advancements and human limitations, as well as improving the overall adaptability and integration of assistive technologies into the daily lives of individuals with limb prosthesis, this ground-breaking project is a testament to the intersection of healthcare and technology. The chapter provides a thorough examination of the techniques used in developing a coherent and responsive prosthetic limb system by carefully navigating through the hardware architecture and design complexities. In addition to restoring mobility, our exploration aims to contribute to the ongoing conversation about the symbiosis between IoT and healthcare by imagining a future in which prosthetic limbs seamlessly integrate into the digital landscape, giving users unprecedented control and connectivity. The following sections explore the historical development of prosthetic legs, emphasizing significant turning points that led to their IoT integration and underlining the significant influence that these developments have on the assistive technology landscape as a whole.

4.2 The development of Rapid Advance Future Prosthetic Lightweight Leg system

The design of the Rapid Advance Future Prosthetic Lightweight Leg system had been discussed in this section. Figure 4.1 show the prototype of the prototype project in Rapid Advance Future Prosthetic Lighweight Leg system. A Rapid Advance Future Prosthetic Lightweight Leg system is constructed by using Huzzah32 Adafruit Feather as the microcontroller, Neo 6M GPS module as the tracking system and MPU6050 Accelerometer as the communication device for step tracker and temperature. Arduino Cloud IOT app is used to show the step, location and temperature when the data transmission is successful. Figure 4.3 show the interface of the Arduino Cloud IOT app. It includes the step counter, temperature and location of the prosthetic leg.

Figure 4.1 The Prototype

4.3 Result Analysis

This section is to discuss about the performance on the tracking system and accelerometer. The results are recorded and analyzed in this section. The time response of tracking system and accelerometer had been analyzed and illustrated in the plotted graph.

4.3.1 Response Time for Tracking System

The data for response time in the tracking system using the NEO-6M GPS sensor has been gathered. This is based on the time it takes to appear on serial monitor through the Arduino Cloud IoT platform once a location change is detected by the GPS sensor. In this scenario, a location change is considered when the GPS sensor measure a distance that falls within the specified tracking range. A graph illustrating the response time for the location detection versus tracking distance has been plotted as per Figure 4.2.

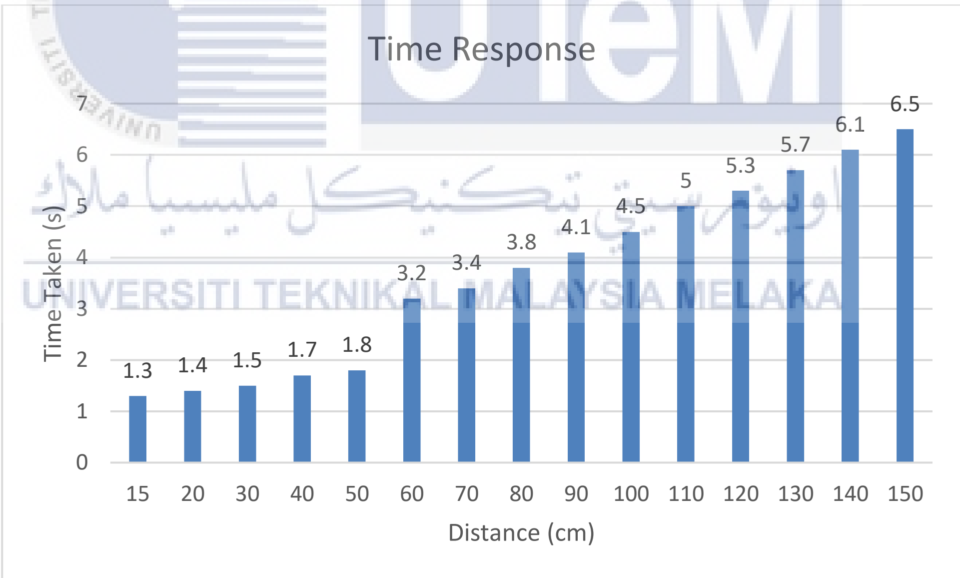


Figure 4.2 Response Time for Tracking System

Table 4.1 Pin Cofiguration

Distance	Average Time Respond
<10 cm	Data obtain unstable
10 cm-50 cm	1.5 s
50 cm-100 cm	3.5 s
100 cm-150 cm	5.5 s

Figure 4.2 shows the distance between the sensor and the avaibility of Wifi application against time taken receive data. The time taken to receive data had been recorded from distance 15 cm to 150 cm. It is difficult to compare the distance between the GPS sensor and Wifi transmitter when the distance was smaller than 10 cm due to low accuracy of GPS. According to the Figure 4.2, the average time taken for data receive was about 1.5 s when the distance was in the range of 15 cm to 50 cm. Furthermore, the average time taken for data receive was around 3.5 s when the distance between the GPS sensor and Wifi transmitter was in the range of 50 cm to 100 cm. The results showed that the average time respond increased by 2 s when every estimated 50 m further from the source. Besides, the average time taken for data receive was about 5.5 s when the distance went up to the range of 100 cm to 150 cm. It increased about 4 s by compare with the initial average time respond for the distance range of 10 m to 50 m. This graph illustrates the distance between GPS sensor and Wifi transmitter increase, the time taken to receive data increases. Average time respond increase 2 s each 50 cm as per Table 4-1 mentioned above. This conclude that the time respond was stable.

4.3.2 Step Count Accuracy

The MPU605 accelerometer sensor measures step and send data to the microcontroller to display in Arduino Cloud IoT. This controlled test where manually count a specific number of steps while wearing the step tracker. Then, compared the recorded step count on the device with manual count. It repeated with various walking speed and condition.

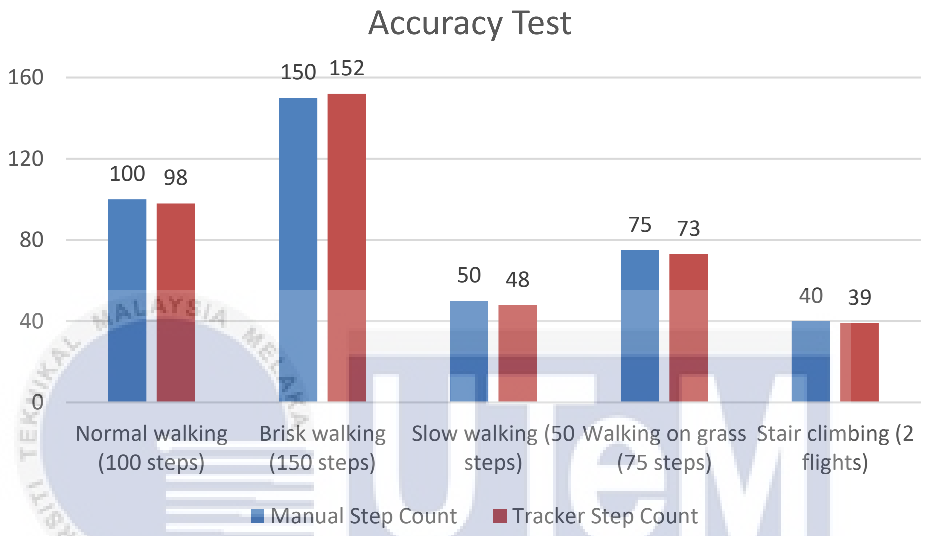


Figure 4.3 Step Count Accuracy

Table 4.2 Data Observed

Test Condition	Manual Step Count	Tracker Step Count	Discrepancy
Normal walking (100 steps)	100	98	-2
Brisk walking (150 steps)	150	152	+2
Slow walking (50 steps)	50	48	-2
Walking on grass (75 steps)	75	73	-2
Stair climbing (2 flights)	40	39	-1

Figure 4.3 presents a comparison of the steps counted manually and those tracked by the tracking system under various walking conditions. The graph displays various walking conditions on the x-axis, such as normal walking, brisk walking, slow walking, walking on grass, and stair climbing. On the y-axis, the graph represents the difference in step count, whether it is a positive or negative value. According to the findings in Table 4-2, it is evident that the data collected consistently indicate a pattern of undercounting steps by the tracking device. This conclusion is based on the negative values observed in the discrepancy column for normal walking, slow walking, walking on grass, and stair climbing. In addition, the findings indicate that the tracker may slightly overestimate the number of steps taken during more intense physical activity, as suggested by the positive difference in brisk walking.

4.3.3 Functional Test for Temperature

The purpose of this section is to examine the functionality of temperature sensors and their subsequent performance. The purpose of this test was to evaluate the effectiveness of a temperature-triggered fan system that was designed to maximize the user's level of comfort. A comparison of the time, temperature, and fan status was performed in order to examine the functional test for the RAF Lightweight Leg prosthetic leg.

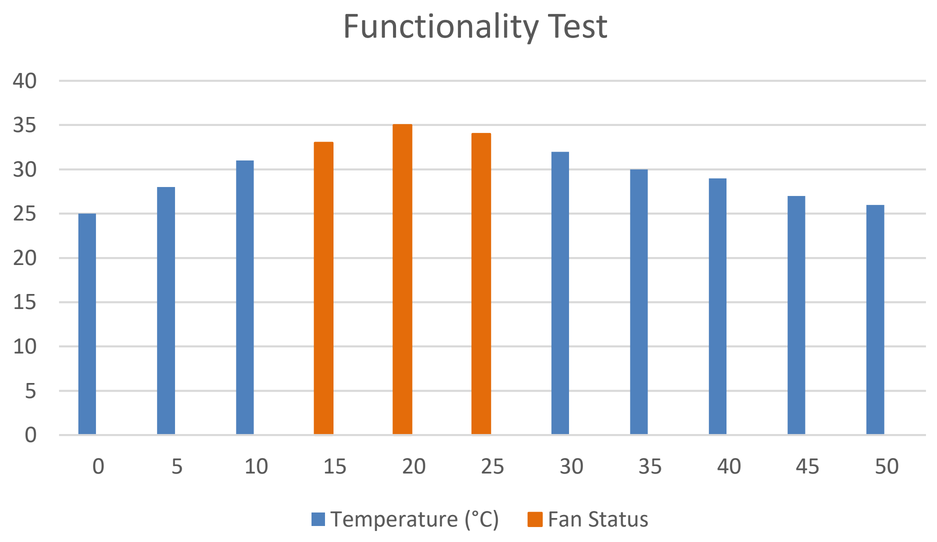


Figure 4.4 Functional Test

Table 4-3: Pin configuration

Time (minutes)	Temperature (°C)	Fan Status
0	25	Off
5	28	Off
10	31	Off
15	33	On
20	35	On
25	34	On
30	32	Off
35	30	Off
40	29	Off
45	27	Off
50	26	Off

The time series of temperature readings at defined intervals are shown by the graph, which is based on figure 4.4. Additionally, the graph displays the state of a fan that corresponds to each reading. In the range of 0 to 50 minutes, the amount of time that was spent recording the temperature. Among the key goals are the verification of the system's reactivity to changes in temperature, the evaluation of the accuracy of activation and deactivation thresholds, and the evaluation of the stability of fan operation under a variety of environmental conditions. As can be seen in Figure 4.4, the starting temperature for the test was 25 degrees Celsius, and the fan was not turned on during the experiment. Over the course of time, the temperature progressively rose to a higher threshold. The fan started operating as soon as the temperature reached 32 degrees Celsius at the 15-minute mark, and it continued to do so as long as the temperature stayed over the threshold. Around the thirty-minute mark, when the temperature had dropped to 32 degrees Celsius, the fan was turned off. The information demonstrates that the temperature-triggered fan system is capable of functioning effectively, demonstrating that it is able to react correctly to changes in the temperature of the surrounding environment by activating and deactivating the fan in the manner that was intended. The outcome makes it possible to recognize patterns, such as the sequence of events that occurs when the fan is turned on in response to changes in temperature. In the other hand, the data is restricted that make it tough to draw definitive judgments regarding the broader context. The graph most likely depicts a change in temperature over the course of time, with the fan turning on when the temperature hits a particular threshold and turning off when the temperature drops below that threshold.

4.4 Display of The Result

The results for the development of this Rapid Advance Future Light Weight Prosthetic Leg are outlined in this section.

4.4.1 Arduino Cloud IoT

Arduino Cloud IoT is crucial to create a GPS system tracker with temperature monitoring and step tracking. This research uses Arduino Cloud IoT to manage and aggregate data from Arduino-based GPS, temperature, and step-tracking devices. This IoT platform allows real-time monitoring and control through an easy interface, improving GPS system tracker operational efficiency and user-centricity. Arduino Cloud IoT's secure communication protocols and configurable dashboards help it handle varied data streams due to its complexity, according to the research. The platform's over-the-air (OTA) updates enable seamless remote maintenance and augmentation, improving GPS, temperature, and step-tracking capabilities. Thus, Arduino Cloud IoT improves connectivity, management, and usefulness of this composite IoT project.

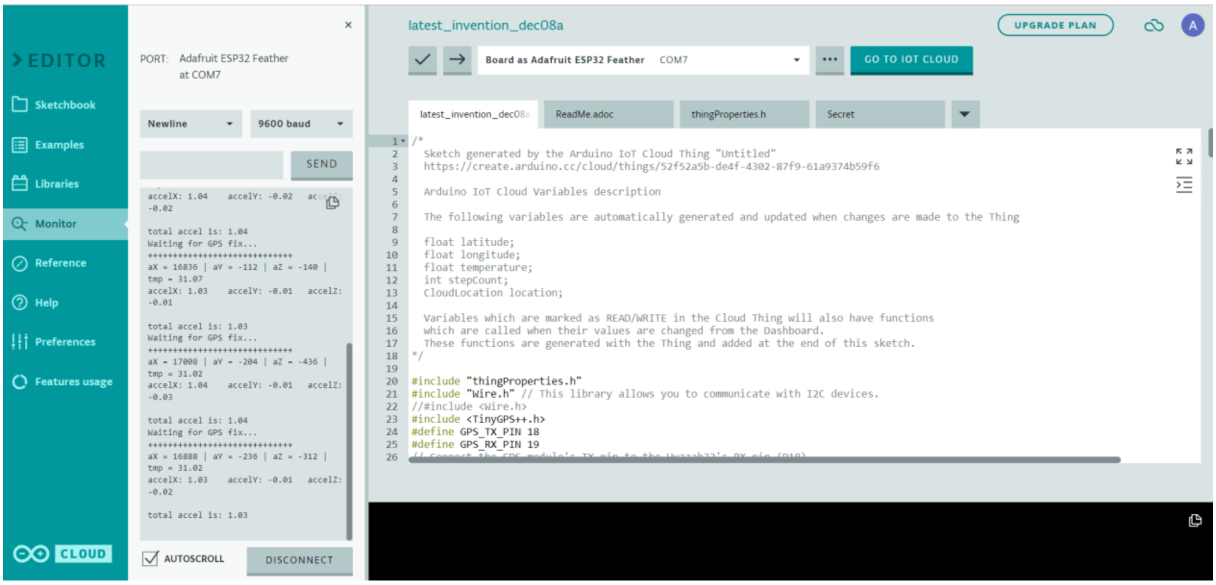


Figure 4.5 The Serial Monitor toll of Arduino Cloud IoT

Figure 4.5 show the Serial Monitor tool of the Arduino Cloud IoT. The baud rate is set to 115200. The result in the serial monitor has shown that the GPS Module, step tracker and temperature are works as expected. Code for the Arduino-based GPS system tracker with temperature and step tracking is essential to the project. Initialization sets up Arduino Cloud IoT libraries, variables, and connections. Data acquisition and processing portions retrieve GPS, temperature, and step-tracking sensor data accurately through pre-processing. Code segments for secure data transmission, real-time dashboard building, and user-friendly interfaces enable Arduino Cloud IoT communication. The code smoothly integrates Arduino Cloud IoT functionalities for real-time monitoring and control. Remote firmware updates via OTA are available for greater flexibility. System robustness and error-handling and security safeguards let this composite IoT project succeed. Code orchestrates the connection between components and Arduino Cloud IoT to create an efficient, user-centric, and flawlessly integrated GPS tracking system with temperature monitoring and step tracking.

4.4.2 Dashboard of Arduino Cloud IoT

The iOS IoT remote app is powerful and easy to use, allowing Apple mobile devices to control and monitor connected devices. This app lets users remotely control smart devices including home automation systems, security cameras, and others using the IoT framework. Regardless of their location, iOS users may execute commands, receive real-time information, and adjust settings for their linked devices. Users may engage with their IoT ecosystem on a single platform, improving efficiency and user experience. The iOS app's easy UI lets users monitor data, receive warnings, and operate IoT devices. Thus, the iOS IoT remote app helps integrate smart technologies into daily life by making it easy for users to control and interact with their connected devices remotely.

Figure 4.6 The Result

The marker represents of the position of the prosthetic leg to move around. From the Figure 4.9, it shows location of the prosthetic leg moving from one place to another. This is a real time tracking system. The user`s guardian can obtain the location of the user immediately from their Arduino Cloud IoT mobile application due to the identity of this real time tracking system.

4.5 Summary

Fom this chapter, the analysis of this project has been obtained in order to calculate the time respond for tracking system, step count accurancy and functionality of the fan`s temperature. The time taken to receive data for the tracking system will increase when the distance of Wifi to the sensor increase. This illustrate that the shorter the time taken for the sensor to receive data, the more accuracy of the tracking system. The data for the step tracker shows that it has varying level of accuracy under different conditions, with discrepancies eanging from -2 to +2 steps. a negative value indicates an undercount, while a positive value indicates an overcount. The data for temperature fan illustrated how the fan system responds to changes in temperature over time during the functional test. Arduino Cloud IoT is chosen as the IoT platform for this project. Maps widget is added in the application in order to display the location of the prosthetic leg. As a result, the probability of lost tracking of the user will reduce since the awareness of the guardian`s user improved due to the guardian can see the location of the user.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter explores the conclusion and future prospects for the Rapid Advance future Light Weight Prosthetic leg. The chapter concludes with the evaluation of the performance of the Rapid Advance Future Light Weight Prosthetic Leg and the subsequent recommendations for the project.

5.2 Conclusion

The development of both hardware and software includes both aspects of this project. The Huzzah32 Adafruit Feather, the Neo 6m GPS module, the mpu6050 accelerometer, the 3.7v cooling fan, and the 3.7v LiPo battery were the components that were engaged in the hardware side of the application. The C++ programming language is the one that is being utilized for the software component of this project. Utilizing the Arduino Cloud Internet of Things platform, the Huzzah32 is controlled in order to display the user's position, step tracker, and temperature measurements. The Rapid Advance Future Light Weight Prosthetic Leg system is a real-time tracking system that can trace the location of the user on a map, calculate the user's step count, and determine the user's current temperature.

In addition, the project has been demonstrated through the utilization of three distinct methods, including the reaction time for the tracking system, the functionality test for the temperature, and the accuracy test for the step tracker. There was no failure in any of the three tests that were carried out. As a result, the goal that was the main objective of this project had been successfully accomplished.

5.3 Recommendation and Future Work

In this section, the proposals for developing this Rapid Advanced Future Light Weight Prosthetic Leg system are determined.

5.3.1 Tracking System

The neo 6M GPS module is being utilized for this project. Due to its limitations, it is unable to determine the location of the prosthetic limb when it is brought inside. In the event that the user loses their prosthetic leg in an area where the satellite cannot be identified, this will cause them to experience considerable difficulties. It is recommended that the Global Navigation Satellite System (GNSS) module be replaced with the Global Positioning System (GPS) module in order to resolve this issue. The exceptional sensitivity of GNSS receivers makes it possible for them to pick up satellite signals in the majority of indoor environments.

5.3.2 Power Supply

One variety of battery that is capable of being recharged is known as lithium polymer batteries, or LiPo batteries. There are a lot of consumer electronics gadgets that make use of the LiPo battery because of its characteristics of being tiny in size, having a thin thickness, and being lightweight. It was decided to use a LiPo battery that has 3.7 volts and 1300 milliamperes for this project. The battery of this type, on the other hand, barely lasts for about six hours. Therefore, the user is unable to go outside for a longer period of time than the battery is able to last.In order to find a solution to this issue, the power supply for this project might be a battery that has the attribute of having a large current capacity but is relatively small in size.

5.4 Project Potential

The tracking of any object other than a prosthetic leg is possible with the help of this research. It is possible to utilize it to keep track of patients and children who have dementia. It is always possible for the guardian of the user to keep track of their existence in order to ensure that they have not strayed too far from their sight. The positioning of the object can be determined and shown on the Arduino Cloud Internet of Things in a mobile phone, making it a simple process.

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APPENDICES

APPENDIX A – Coding for Arduino Cloud IoT

```
#include "thingProperties.h"
#include "Wire.h" // This library allows you to communicate with I2C devices.
//#include <Wire.h>
#include <TinyGPS++.h>
#define GPS_TX_PIN 18
#define GPS_RX_PIN 19

TinyGPSPlus gps;

bool locationDetected = false;

const uint8_t MPU_ADDR=0x68;

int16_t accelerometer_x, accelerometer_y, accelerometer_z;
int16_t gyro_x, gyro_y, gyro_z;
int16_t temp;

char tmp_str[7];

char* convert_int16_to_str(int16_t i) {
  sprintf(tmp_str, "%6d", i);
  return tmp_str;
}

const int threshold = 1;
bool isStepDetected = false;

float totalAccel;

unsigned long lastResetTime = 0;
const unsigned long resetInterval = 86400000;  // 24 hours in milliseconds (24 * 60 * 60 * 1000)

int fanpin = 13;

void setup() {
  Serial.begin(115200);
  Serial1.begin(9600);

  pinMode(fanpin, OUTPUT);

  pinMode(LED_BUILTIN, OUTPUT);

  WiFi.begin(SECRET_SSID, SECRET_OPTIONAL_PASS);
    Serial.println("\nConnecting");

    while(WiFi.status() != WL_CONNECTED){
        Serial.print(".");
        delay(100);
        digitalWrite(LED_BUILTIN, HIGH);
    }

    digitalWrite(LED_BUILTIN, LOW);

    Serial.println("\nConnected to the WiFi network");
    Serial.print("Local ESP32 IP: ");
    Serial.println(WiFi.localIP());


  Wire.begin();
  Wire.beginTransmission(MPU_ADDR);
  Wire.write(0x6B);
  Wire.write(0);
  Wire.endTransmission(true);

  delay(500);

  initProperties();

  ArduinoCloud.begin(ArduinoIoTPreferredConnection);
}
```

```
void loop() {
  ArduinoCloud.update();

    unsigned long currentTime = millis();
  if (currentTime - lastResetTime >= resetInterval) {
    stepCount = 0;

    lastResetTime = currentTime;
  }



  Wire.beginTransmission(MPU_ADDR);
  Wire.write(0x3B);
  Wire.endTransmission(false);
  Wire.requestFrom(MPU_ADDR, 7*2, true);

  accelerometer_x = Wire.read()<<8 | Wire.read();
  accelerometer_y = Wire.read()<<8 | Wire.read();
  accelerometer_z = Wire.read()<<8 | Wire.read();
  temp = Wire.read()<<8 | Wire.read();
  gyro_x = Wire.read()<<8 | Wire.read();
  gyro_y = Wire.read()<<8 | Wire.read();
  gyro_z = Wire.read()<<8 | Wire.read();

  Serial.println("+++++++++++++++++++++++++++++");
  Serial.print("aX = "); //Serial.print(convert_int16_to_str(accelerometer_x));
  Serial.print(accelerometer_x);
  Serial.print(" | aY = "); //Serial.print(convert_int16_to_str(accelerometer_y));
  Serial.print(accelerometer_y);
   Serial.print(" | aZ = "); //Serial.print(convert_int16_to_str(accelerometer_z));
   Serial.print(accelerometer_z);

  Serial.print(" | tmp = ");
  temperature=temp/340.00+36.53;
  Serial.print(temperature);

  Serial.println();

  if (temperature > 32.0){
    digitalWrite(fanpin, HIGH);
  } else{
    digitalWrite(fanpin, LOW);
  }


  float accelX = accelerometer_x / 16384.0;
  float accelY = accelerometer_y / 16384.0;
  float accelZ = accelerometer_z / 16384.0;

Serial.print("accelX: ");
Serial.print(accelX);
Serial.print("\taccelY: ");
Serial.print(accelY);
Serial.print("\taccelZ: ");
Serial.print(accelZ);

Serial.println();
Serial.println();


  totalAccel = sqrt(accelX * accelX + accelY * accelY + accelZ * accelZ);
  Serial.print("total accel is: ");
  Serial.print(totalAccel);

Serial.println();
```

```
  if (totalAccel > threshold && !isStepDetected) {
    stepCount++;
    isStepDetected = true;
    Serial.println("Step Detected!");
    Serial.print("Current steps: ");
    Serial.println(stepCount);


  } else if (totalAccel < threshold) {
    // If the acceleration falls below the threshold, reset the step detection flag
    isStepDetected = false;
    Serial.println("Step not Detected!");
  }
// Serial.println();
// Serial.println();
  // delay
  delay(500);


while (Serial1.available() > 0) {
    char c = Serial1.read();
    gps.encode(c);
}

 // Check if a fix is available
if (gps.location.isUpdated()) {

    latitude = gps.location.lat();
    longitude = gps.location.lng();

    Serial.print("Location coordinates: ");
    Serial.print(latitude, 6);
    Serial.print(", ");
    Serial.println(longitude, 6);

    //coordinates = Location(latitude, longitude);
    location = Location(gps.location.lat(), gps.location.lng());

} else {
    if (locationDetected) {
      // The component was previously able to detect a location, but can no longer do so
      Serial.println("Location detection lost. Check the GPS connection or satellite signal.");
      locationDetected = false;
      delay(200);
    } else {
      Serial.println("Waiting for GPS fix...");
      delay(200);
    }
}
}
```