# Faculty of Electrical and Electronic Engineering Technology

Smart Wheelchair for The Impaired

**HATRISYA ALYSA BINTI HARRIMAN**

**Bachelor of Electrical Engineering Technology with Honours**

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# Smart Wheelchair for The Impaired

**HATRISYA ALYSA BINTI HARRIMAN**

**A project report submitted**
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Disahkan oleh:

DR. ZUL HASRIZAL BIN BOHARI
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan
Fakulti Teknologi dan Kejuruteraan Elektrik
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Signature :

DR. ZUL HASRIZAL BIN BOHARI
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan
Fakulti Teknologi dan Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka

Supervisor Name : Dr. Zul Hasrizal Bin Bohari

Date : 16.01.2024

## APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

DR. ZUL HASRIZAL BIN BOHARI
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan
Fakulti Teknologi dan Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka

| | | |
|---|---|---|
| Signature | : | |
| Supervisor Name | : | Dr. Zul Hasrizal Bin Bohari |
| Date | : | 16.01.2024 |
| Signature | : | |
| Co-Supervisor Name (if any) | : | |
| Date | : | |

# DEDICATION

*To my beloved mother, Siti Bidayah binti Abdul Rahman,*

*, To my beloved father, Harriman bin Razman,*

*To my supervisor, Dr. Zul Hasrizal bin Bohari,*

*To my panels*, Dr. Emy Zairah binti Ahmad and Nurul Syuhada binti Mohd. Shari,

To my friends.



NO. 23

# ABSTRACT

Most wheelchair users have limitation mobility when using a wheelchair. People who have to use wheelchair for a living are at higher risks of accidents due to their inmobility. This is most likely due to road conditions, things getting stuck in the wheels or simply accidentally hit a person or something in their way. These mishaps can be extremely dangerous, resulting in serious injuries or even death. The goal of this paper is to assess the efficiency of deploying ultrasonic sensors as a wheelchair with obstacle detection system and to help solve the problem for the impaired. To identify items in a wheelchair's blind region, the researchers employed a combination of ultrasonic sensors and an Arduino Uno. The system was tested in a variety of environments, including daytime and evening, inside and outside of a building and its performance was evaluated in terms of detection rate and reaction time. The findings demonstrated that the system was capable of detecting things on the wheelchair with a high detection rate and a quick response time. This study gives useful insights into the design and implementation of wheelchair obstacle detection systems to make everyday life easier for those who have disabilities.

# *ABSTRAK*

Terdapat ramai pengguna kerusi roda yang mengalami masalah dalam menggunakan kerusi roda. Pengguna kerusi roda lebih berisiko dalam menghadapi kemalangan kerana mereka tidak mempunyai keupayaan seperti orang lain untuk menjalani kehidupan harian. Ini berkemungkinan besar disebabkan oleh keadaan jalan raya, benda tersangkut pada roda atau secara tidak sengaja melanggar seseorang atau sesuatu yang menghalangi jalan mereka. Kemalangan ini boleh menjadi sangat berbahaya, mengakibatkan kecederaan serius atau kematian. Matlamat projek ini adalah untuk menilai kecekapan menggunakan penderia ultrasonik sebagai kerusi roda dengan sistem pengesanan halangan dan untuk membantu menyelesaikan masalah bagi mereka yang tidak berupaya. Untuk mengenal pasti item di kawasan buta kerusi roda, para penyelidik menggunakan gabungan sensor ultrasonik dan Arduino Uno. Sistem ini diuji dalam pelbagai persekitaran, termasuk waktu siang dan petang, dalam dan luar bangunan dan prestasinya dinilai dari segi kadar pengesanan dan masa tindak balas. Penemuan menunjukkan bahawa sistem itu mampu mengesan benda di atas kerusi roda dengan kadar pengesanan yang tinggi dan masa tindak balas yang cepat. Kajian ini memberikan pandangan berguna tentang reka bentuk dan pelaksanaan sistem pengesanan halangan kerusi roda untuk memudahkan kehidupan seharian bagi mereka yang kurang upaya.

## ACKNOWLEDGEMENTS

I dedicate my final year project, the Smart Wheelchair with Obstacle Detection, to my family and friends, who have helped make my trip a reality with their everlasting love and support. To my father, who kindly imparted his electrical expertise, helping me to navigate complex circuits and cultivate a more profound comprehension of the Smart Wheelchair's technological features. Your insight has shone brightly, illuminating the way to achievement. To my dear mother, whose unending support and tolerance kept me motivated throughout this effort. Your unshakable faith in my talents gave me the courage to pursue greatness and conquer obstacles. My supervisor, Dr. Zul Hasrizal bin Bohari and the distinguished panels, Dr. Emy Zairah binti Ahmad and Nurul Syuhada binti Mohd. Shari have my sincere thanks for their mentorship and advice. Your insightful advice and helpful criticism have been really helpful in determining the direction of my senior project. Your commitment to supporting students' academic development has had a lasting impact on my path. A grateful thanks to my friends whose experience in Arduino and 3D printing proved essential in understanding the difficulties of the project. It has changed everything because of your altruistic effort to impart information and educate the nuances of Arduino programming. Your support reminded me that I wasn't travelling alone when I was starting to question myself. This initiative is proof of the love, support, and hard work of all the people listed. I dedicate this accomplishment to my family, friends, and mentors, who have helped make it both feasible and incredibly significant. I am really grateful for their support.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| V | - | Voltage |
| % | - | Percentage |
| cm | - | Centrimeters |
| m | - | Metres |
| G | - | Irradiance |
| | - | |
| | - | |
| | - | |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Wheelchairs have been a popular mobility aid for those with mobility issues for many years. It has two huge wheels in the back and two smaller wheels in the front, along with a seat and a backrest. By physically rotating the chair's wheels with their hands or feet, the user can move the chair. Conventional wheelchairs are typically constructed of lightweight materials like aluminum, making them portable and simple to move around. With features like movable footrests, armrests, and headrests, they are made to offer consumers stability and comfort. In conclusion, millions of people with mobility limitations have benefited from the traditional wheelchair, which continues to be a crucial and dependable mobility aid that has allowed them to live more independently and pleasantly.



## 1.2 Purpose of Statement

The goal of this project is to improve the mobility and independence of people who have it difficult to move around because of physical impairments, accidents or age-related conditions. By creating a smart wheelchair especially focuses on obstacle detection, this can help improve the quality of life of the impaired. A smart wheelchair uses sensor, actuators and software to improve user control, convenience and safety.

By this, wheelchair users may travel around more confidently and comfortably thanks to the functions that the team are going to equip in the wheelchair including automatic braking, avoidance and obstacle recognition.

Creating a smart wheelchair has an overall aim of giving people who has physical limitations more independence, mobility and quality of life.

## 1.3 Problem Statement

The wheelchair's problem statement is to solve the difficulties that people with physical limitations who need assistance moving around confront. The issue of a traditional wheelchair is that, it is hard for users to be aware of the obstacles around them that can lead to falling from the wheelchair or something stuck into their wheels and this can be dangerous to them. This is a big struggle that some people are not aware of. It can cause an exhaustion for the users, physically and mentally, leading to frustration and decreasing the user's desire to discover and engage in other activities. In addition, wheelchair users who attempt to move through risky paths, run the risk of suffering injuries or damaging their wheelchairs, which raises the cost of repair and maintenance. A wheelchair encountering hindrance has a general issue statement that calls for a solution that would improve users' independence, mobility, and general quality of life by enabling them to easily travel through various settings and obstacles.



## 1.4 Project Objective

1. To analyze the requirements of a smart wheelchair
2. To increase user safety by offering a reliable obstacle detection and avoidance system.
3. To develop and design a device where wheelchair users get to move independently and portably.

## 1.5 Scope of Project

A smart wheelchair's capability to recognize obstacles that includes build in sensors, software, and control systems to provide the wheelchair the ability to recognize and avoid barriers in its path. This wheelchair uses ultrasonic sensors and, can be used with this technology to identify objects in the environment and also to detect the distance of the obstacles. In order to avoid obstacles and ensure the user's safety, the sensors can be used to modify the wheelchair's speed, direction, and braking. The buzzer that be used in this project helps to alert the users that there is an obstacle on their way and the system of the wheelchair will automatically brake the wheels.

## 1.6 Chapter Summary

In conclusion, chapter 1 which is introduction is about on statements of proposal of project. The project's objective, which is to build a smart wheelchair with an emphasis on obstacle detection to improve the quality of life for people with physical disabilities, is introduced in the statement of purpose. The problem statement emphasizes the challenges wheelchair users have while negotiating impediments and the detrimental effects this has on their physical and emotional health. The project's goals include strengthening user safety, boosting independence and mobility, assuring usability, raising quality of life, and realizing cost savings. The project's scope includes integrating sensors, software, and control systems into the wheelchair to enable obstacle identification and avoidance. Ultrasonic sensors will be used to identify objects and distances, and alarms and automated brakes will be implemented to assure user safety. In the next chapter, the team is going to give in the insights of researches made.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter offers a survey of the literature on subjects important to the innovation of conventional wheelchairs. It gives a general overview of a smart wheelchair that can detect obstacles. In addition, the use of wheelchair advancement technology will be a vital technology in our nation.

## 2.2 Wheelchair

A wheelchair is a powered or manually propelled vehicle that is primarily intended for use by someone with a mobility impairment for both inside and outdoor movement. In any place that is accessible to walking or foot traffic, people with physical limitations must be allowed to use wheelchairs and manually powered mobility aids, such as walkers, crutches, canes, braces, or other similar equipment designated for their use.



Figure 2.1 A typical wheelchair used for the impaired

Wheelchair-like furniture has already been used at least around the sixth century AD, yet it is still unclear as to why it may be regarded as the first wheelchair from what the stone inscriptions from Ancient China and Greece.

Figure 2.2 Depiction of Chinese philosopher Confucius in a wheelchair, dating to ca. 1680 [28]



## 2.3 Data of Wheelchair Users

According to the National Health and Morbidity Survey 2019 survey conducted by National Institutes of Health (NIH), Ministry of Health Malaysia that 10.4 per cent of people have difficulty in walking in Malaysia [1] and according to World Health Organization (WHO), the estimation of people using wheelchair worldwide is more than 70 million. With the world population ageing and non-communicable illnesses on the rise, the number of individuals using assistive technology will increase dramatically. The need is widespread, particularly in low- and middle-income nations [4]. The demand of owning a better wheelchair is high especially wheelchair with smart devices because it is hard for people with disability to do things everyday without the help of advanced technology.

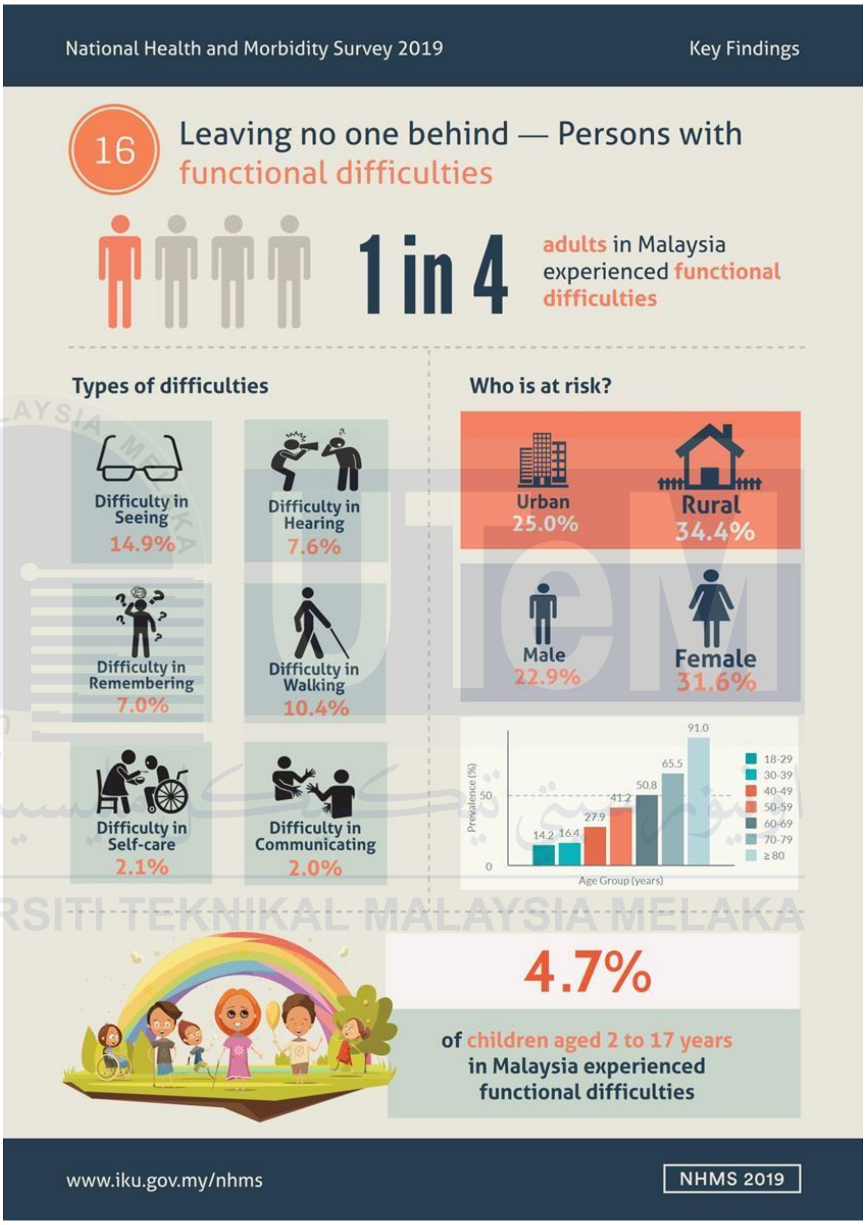



Figure 2.3 Shows the data of people who have disabilities in Malaysia [1]

## 2.4 Wheelchair Related Injuries

Most of the people in the world had to use wheelchair because of injuries and accidents and some of them has accidents when using a wheelchair. The injuries related are spinal cord injury, car accident, unlocked brakes, a poorly fitted chair, an unaided or inappropriate transfer, a lack of supervision, repositioning concerns, or when the chair user is disoriented. Soft tissue and nerve damage, sprains and strains, abrasions and contusions, and injuries to the shoulder, arm, elbow, forearm, and wrist are all common wheelchair injuries. More catastrophic injuries, including as fractures, head injuries, and brain traumas, may occur. Wheelchair users are exposed to a variety of terrains, including uneven ground, curb cuts, and steps. These environmental barriers have an effect on the users' driving performance, causing loss of traction and stability, resulting in tips and falls and, as a result, hospitalisation. Up to 87 percentage of wheelchair users have at least one tip over during their usage [5].

According to the National Electronic Injury Surveillance System that from 1991 to 2003, wheelchair related injuries treated in US emergency departments increased by 69.8%, 146.8%, and 108.0% among patients aged 2–17 years, 18–64 years, and 65 years or older.

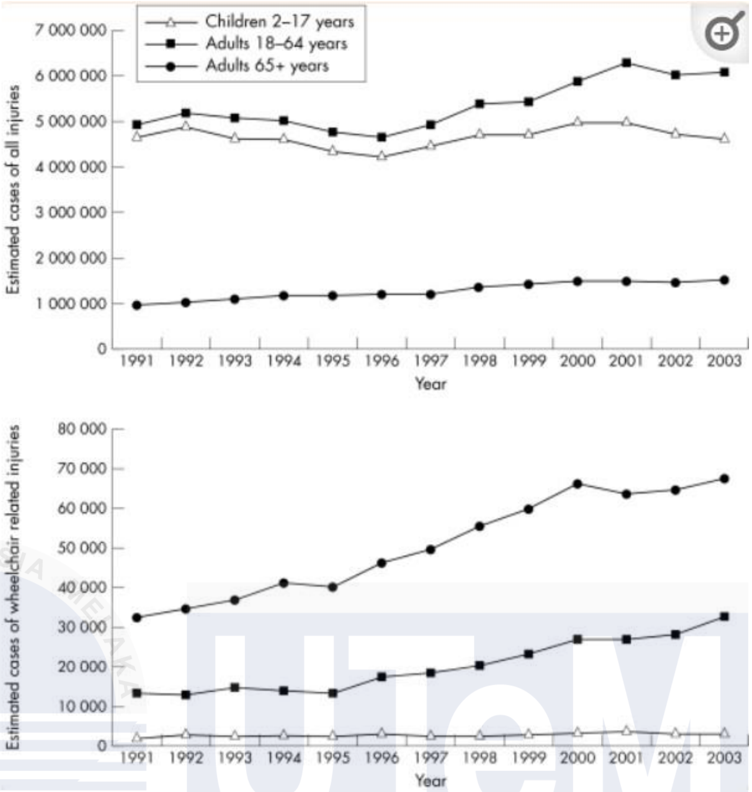



Figure 2.4 Data from National Electronic Injury Surveillance System related injuries from 1991 to 2003



## 2.5 Smart Devices

Smart devices are common objects that have been made intelligent with sophisticated computation, such as AI and machine learning, and have been networked to form the internet of things (IoT). Smart devices may function at the network's edge or on extremely small endpoints, and despite their small size, they are powerful enough to handle data without reporting back to the cloud. Sensors, refrigerators, wearables, and container transportation are all capable of performing autonomous workloads. The definition leads to a smart capability categorization are around four categories which are information processing, internal regulation, action in the world, and knowledge acquisition [6].


Figure 2.5 Example of Smart Devices [25]

## 2.6 Internet of Things (IoT)

The term "Internet of things" (IoT) refers to physical things (or groups of such things) equipped with sensors, computing power, software, and other technologies that communicate with one another and exchange data over the Internet or other communications networks. “An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment” [7].

According to the book of Internet of Things With Raspberry Pi and Arduino (2019), the process of designing a product using IoT has five phases which are ‘create phase’ where sensors will collect data from the environment, ‘communicate phase’ which is where the data generated will communicate with the required destination, ‘aggregate phase’ where the collected data over network will be aggregated by the device, ‘analyze phase’ where the data used will generate patterns and used to optimize the process and ‘act phase’ which is necessary actions will be taken on the basis of information extracted from the aggregated data [6].

## 2.7 Smart Wheelchairs

Smart wheelchairs are those that have cutting-edge technology installed to improve their use and operation. They integrate sensors, electronics, and wireless communication to offer a variety of functions that increase their usability and responsiveness to the user's demands.

## 2.8 Importance of Smart Wheelchairs to The Impaired

Most of the people in this world experience impairments. While others are living in a life with sentence of having disabilities, some people are just born disabled. Therefore, there is a need for anything that would enable those folks to travel. A person must complete several tasks on their own. Therefore, the idea of a wheelchair has become a necessity in their lives. Normal wheelchairs require manual operation. Many people with disabilities are unable to exert the necessary force to move wheelchairs [9]. To get them from one area to another, they require assistance. There should now be a method through which they can stop needing other people's assistance. They are independent wheelchair users. Therefore, owning a smart wheelchair especially with obstacle detection will be much meaningful and easier for them to do things everyday.



## 2.9 Sustainable material design

One of the plants that grows the quickest is bamboo, which may reach peak rates of up to 100 cm per day [16]. Bamboo is an attractive material for designers due to its sustainability, strength, adaptability, beauty, and cultural importance. Because of its strength and toughness, bamboo is a fantastic material for wheelchairs. Bamboo has a remarkable strength-to-weight ratio and strong tensile strength despite its small weight. By doing so, the wheelchair's structural integrity is preserved and the user receives the best support and safety possible. Because bamboo is naturally flexible and resilient, the wheelchair can survive normal wear and tear. Additionally, wheelchair design benefits from bamboo's adaptability. It may be made in a variety of shapes and forms, enabling ergonomic designs that put user convenience and functionality first. Bamboo stands out as a renewable, long-lasting, and visually beautiful option as the need for sustainable and eco-friendly solutions increases. The use of bamboo in design initiatives not only adheres to eco-friendly ideals but also highlights the elegance and adaptability of this extraordinary material.

Figure 2.6 An example of design of a furniture made out of bamboo [16]

## 2.10 Types of Smart Wheelchairs

Table 2.1 Types of Smart Wheelchairs

| TYPES OF SMART WHEELCHAIRS | FUNCTIONS |
|---|---|
| **Obstacle Detection** | Smart wheelchairs may use sensors or cameras to detect obstacles in the user's path and automatically adjust the wheelchair's direction or speed to avoid them. |
| **Navigation** | GPS and mapping technologies may be used in smart wheelchairs, allowing them to plan routes and provide users directions. |
| **User-Controlled Adjustment** | A smartphone app or other remote control device may be used with some smart wheelchairs to let the user change the chair's position, speed, and other settings. |
| **Smart Seating** | Advanced seating systems that can conform to the user's body position may be included in smart wheelchairs. These systems increase comfort and lower the risk of pressure sores. |
| **Health Monitoring** | Some intelligent wheelchairs come equipped with sensors that can track the user's vital indicators, including heart rate and blood pressure, and notify carers or |

| | |
|---|---|
| | emergency personnel if something seems off. |
| **Voice Control** | Some smart wheelchairs allow the user to operate the chair using voice instructions. This feature can be very useful for people who have poor hand function. |

## 2.11 Smart Wheelchairs with Obstacle Detection

A smart wheelchair with obstacle detection is a mobility tool that can help people with restricted mobility navigate their environment. It uses advanced technology and sensors to recognize risks or obstructions in real time, allowing the wheelchair to react autonomously and avoid collisions. The key features and components that are typically found in an obstacle detection system are, obstacle detection sensors, collision avoidance system, intelligent navigation system, control mechanism, user safety features and connectivity and integration.



## 2.12 Study of Sensors

According to Dr. Thomas Kenny (2005), sensor technology varies because a sensor is defined as a device that converts a physical occurrence into an electrical signal. As a result, sensors, such as computers, may be considered as a component of the connection between the physical and electrical worlds. Jon Stenerson claims in his 1993 book that sensors do simple tasks more precisely and effectively than humans. As a result, sensors are substantially more precise and much faster.

There are several sensor types. A typical automobile contains hundreds of different types of sensors. Tyre pressure sensors determine if a tyre is underinflated or overinflated. Self-driving cars, such as the Tesla, are installed with ultrasonic sensors, which employ sound waves to calculate the distance between the vehicle and other objects in its vicinity. Motion detectors in home security systems often detect the movement of larger objects. A Passive Infrared (PIR) system, which monitors infrared radiation in the sensor's surroundings, is the most often used motion sensor for home surveillance.

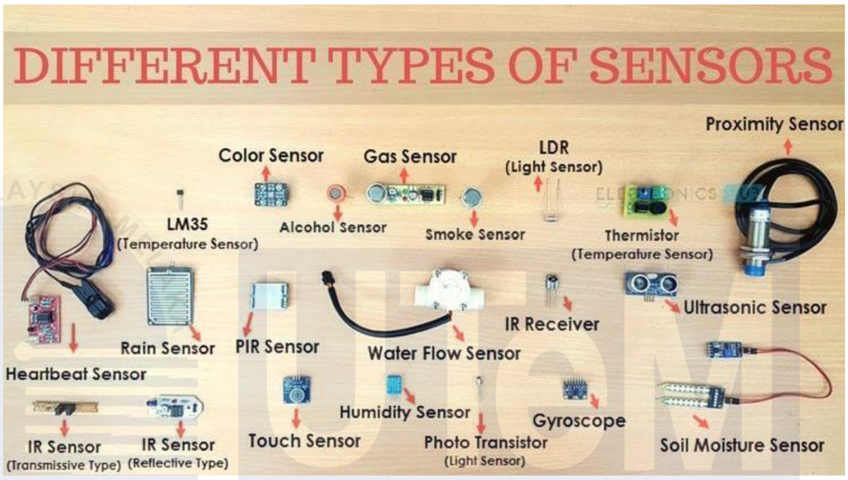



Figure 2.7 Different types of sensors [26]

## 2.13 Types of sensors used to make Smart Wheelchairs with Obstacle Detection

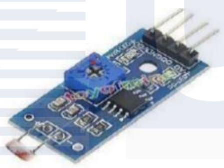


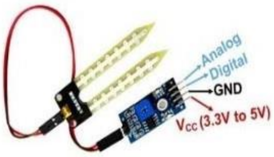
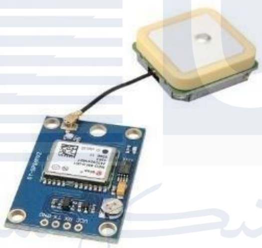
Table 2. 2 Types of sensors used

| SENSOR | FUNCTIONS |
|---|---|
| Infrared<br><br>Figure 2.8 Infrared sensor [29] | Infrared sensor is used to identify obstructions, infrared sensors employ infrared light. They produce infrared radiation and evaluate how much of it is reflected or absorbed by the obstruction. Robotics, security systems, and proximity sensors are |

| | |
|---|---|
| | all prominent applications for infrared sensors. |

| SENSOR | FUNCTION |
|---|---|
| Ultrasonic<br><br>Figure 2.9 Ultrasonic sensor [15] | The detection of obstacles is done using ultrasonic sensors using sound waves. When they come into contact with an item, the high-frequency sound waves they emit reflect back. The distance to the obstruction may be determined by timing the amount of time it takes for the sound waves to return. Ultrasonic sensors have been widely employed for a variety of tasks, including figuring out an object's surface structure, detecting its location, and estimating its speed [13]. Parking sensors, item identification in commercial settings, and robotics are all frequent applications for ultrasonic sensors. |

| SENSOR | FUNCTIONS |
|---|---|
| Laser<br><br>Figure 2.10 Laser sensor [30] | Laser sensors employ a laser beam to identify any obstructions. They fire a laser beam at the obstruction, which is then reflected back, and they time how long it takes for the beam to return. Robotics, commercial automation, and self-driving cars frequently employ laser sensors. |
| LiDAR<br><br>Figure 2.11 LiDAR sensor [18] | A pulsed laser is used in the distant sensing technique known as LiDAR, which stands for Light Detection and Ranging. |
| Computer Vision<br><br>Figure 2.12 Computer Vision sensor [19] | Vision sensors are used for a variety of tasks, including sorting things, identifying characters, measuring object size, and detecting faulty products. |

| SENSOR | FUNCTIONS |
|---|---|
| Moisture<br><br><br>Figure 2.13 Moisture sensor [20] | The amount of water in the soil is measured or estimated by soil moisture sensors. These sensors can either be fixed or mobile, like handheld probes. |
| GPS<br><br>Figure 2.14 GPS sensor [31] | The position of the user and possible barriers may be determined using GPS sensors, and the system can utilise this knowledge to navigate around the impediments. |



## 2.14 Types of Microprocessor

### 2.14.1 Raspberry Pi

The Raspberry Pi is a tiny, single-board computer designed to promote computer science education while also offering an affordable platform for amateurs, manufacturers, and enthusiasts to explore with programming and hardware projects. The Raspberry Pi Foundation, a UK-based charitable organization, created it.

The Raspberry Pi board is roughly the size of a credit card and has all of the main components of a basic computer, such as a CPU, memory, input/output ports, and different connecting choices. It is intended to be low-cost, energy-efficient, and very adaptable, making it accessible to a wide spectrum of users.

The Raspberry Pi is used by people to learn programming, build hardware projects, automate their houses, deploy Kubernetes clusters, Edge computing, and even for industrial applications.

The Raspberry Pi is a low-cost Linux computer featuring GPIO (general purpose input/output) ports that allow you to alter electrical components for physical computing and to investigate the Internet of Things (IoT).


Figure 2.15 Raspberry Pi Circuit Board [27]

### 2.14.2 Arduino Uno

Arduino is an open-source company, project, and user community that develops and produces single-board microcontrollers and microcontroller kits for creating digital gadgets and interactive items that can recognise and manage objects in both the real world and the digital one [10]. A microcontroller, a tiny computer that can be programmed to communicate with many inputs and outputs, is found on the Arduino board. A variety of pins on the board may be utilised to link different sensors, actuators, and other electrical parts.

A software programme called the Arduino development environment enables users to create, build, and upload code to the Arduino board. A code editor, debugger, and other tools are provided in the development environment to make it simple to write and test code for various applications. Additionally, open-source hardware might be a less expensive option to scientific apparatus and study that needs to gather data for a certain procedure or event [12]. The C/C++-based Arduino programming language was created with ease of use in mind, even for beginners. To communicate with various sensors, actuators, and other components, the language offers a set of functions and libraries. The Arduino software provides access to these libraries and functions, which may be used to write customised code for various projects.

Those who are interested in creating electronic projects, including professionals, students, and hobbyists, frequently use the Arduino platform. Robots, home automation systems, wearable technology, and many more projects have all been developed using it. The versatility of the Arduino platform is one of its key benefits. There is a sizable user and developer community that offers assistance and resources for the platform, and users may tweak and customise the platform to match their unique needs.


Figure 2.16 Arduino Uno [21]

## 2.15 House of Quality

The house of quality is a design tool that I may use to construct and depict the connections between marketing goals and technical needs, as shown in Figure 2.14. Demands and wants from the standpoint of a potential customer are marketing needs. This includes costs, which clients aim to keep as low as possible. The product's end-user price is what the cost value under the marketing criterion refers to. Customer desire for the longest possible battery life is another marketing requirement. The frequency with which the Smart Wheelchair with Obstacle Detection system properly alerts the user of obstacle recognition determines how accurate the system is. This percentage must be as close to 100% as is practical. The design's portability symbolises how simple installation will be. The installation of the system should be as simple as is practical. The system's durability determines how long the item will endure. The bigger this is, the more likely it is that the customer will purchase it. Finally, the product's use should be as simple as it is practical to use.

The demands of the system are once again outlined in the engineering specifications. At this moment, it is done from the standpoint of the developer or engineer rather than the customer. The more mobile the system is, the more attractive it will be because it greatly boosts the system's portability and usefulness. However, due to the less space for battery to be stored, the less battery life of a device. The system's weight is likewise subject to the same rule. However, the system's durability will suffer as a result of the reduced weight because weaker, thinner building materials are more common.

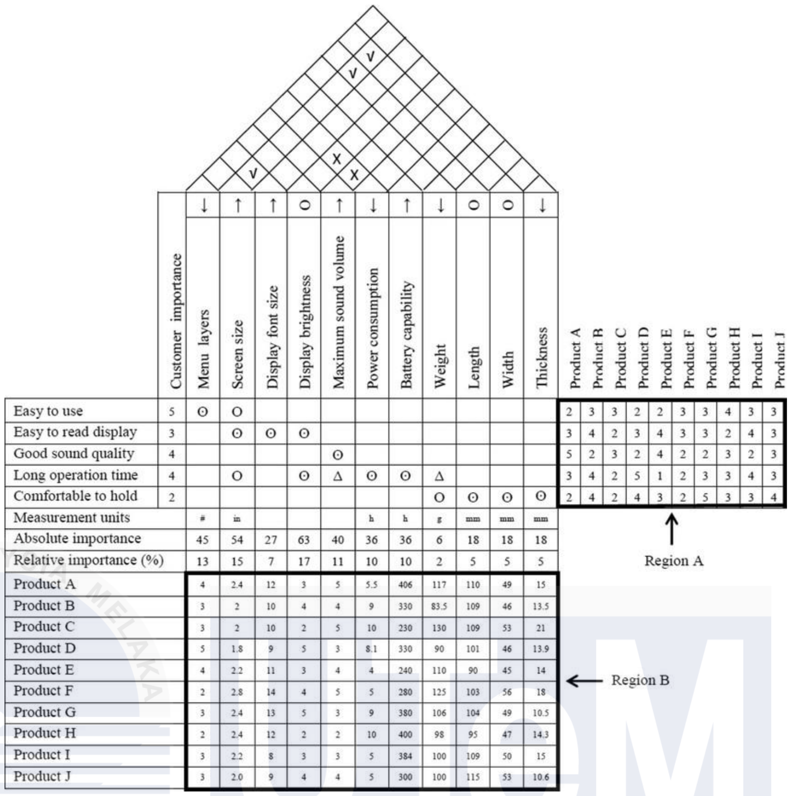



Figure 2.17 House of Quality [22]



## 2.16 Pugh Selection Method

The Pugh Matrix is a criteria-based decision matrix that uses criteria scoring to choose amongst a large number of potential options. The Scottish researcher Dr. Stuart Pugh gave the method its name. This strategy is now a standard component of Six Sigma technique. The Pugh matrix is typically used by consultants after conducting VOC (Voice of the Customer) surveys and after setting up a QFD (Quality Function Deployment). Many other names, including decision matrix, selection matrix, issue matrix, opportunity analysis, criterion rating form, and criteria-based matrix, are also used to refer to the Pugh Matrix.

The Pugh matrix assists the consultant in systematising several requirements or traits of a solution for straightforward comparison. A consultant can create an excellent solution using this matrix, which is a combination of various effective solutions. This matrix further offers a team-based approach for methodical concept generation and selection.

| | Baseline | | A | B | C | D |
|---|---|---|---|---|---|---|
| Criteria | | | | | | |
| 1 | 0 | | +1 | | | |
| 2 | 0 | | 0 | | | |
| 3 | 0 | | +1 | | | |
| 4 | 0 | | -1 | | | |

We now rate all the other alternatives in the same way. The final table looks like this:

| | Baseline | | A | B | C | D |
|---|---|---|---|---|---|---|
| Criteria | | | | | | |
| 1 | 0 | | +1 | -1 | 0 | +1 |
| 2 | 0 | | 0 | -1 | 0 | +1 |
| 3 | 0 | | +1 | -1 | +1 | 0 |
| 4 | 0 | | -1 | 0 | 0 | +1 |

Figure 2.18 Pugh Selection Method [23]

## 2.17 Product Design Specification (PDS)

To meet the demands of a certain customer or client class, a specification document is required, such as the Product Design Specification (PDS). Both in terms of the programming of the plan and the parts of the equipment. The PDS has to be thorough and accurate. There must be precise instructions on what to design and build, as well as how to carry them out. The PDS must be understood and communicated in the most obvious terms possible. This serves as both an official declaration of the production of the item and a crucial point of reference for assessing its development. The PDS work papers must be outstanding in order to guarantee the efficacy of the planned strategy. I'm saying it might not matter to the project, but even if it does, once the PDS structure is finished, a comparison report for the item is finished. This test has to be run on a model or invention whose outcomes are compared to PDS in order to be verified. The author emphasises the need of looking at three more elements in addition to product shape, material quality, and process capabilities. In spite of this, the spiral's expanding girth illustrates how the PDS gains knowledge with each iteration (as shown in Figure 2.17).

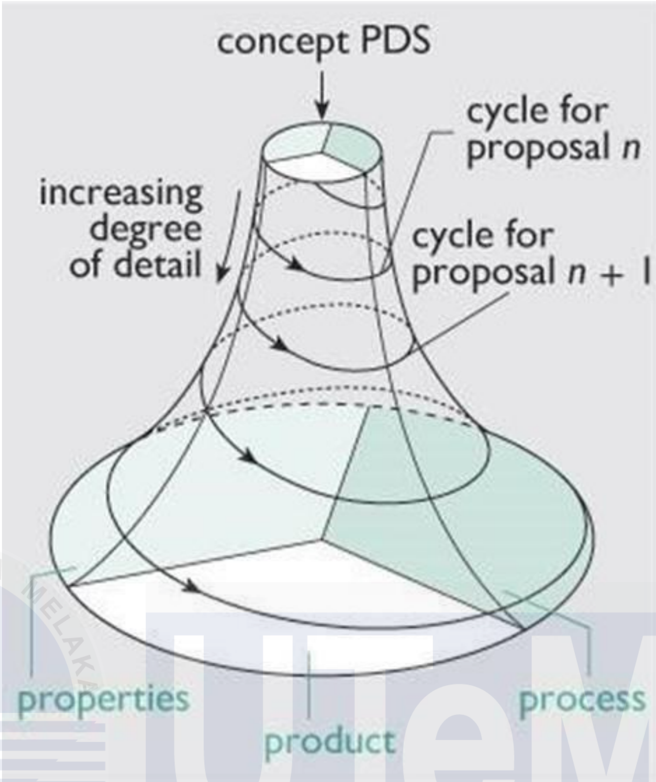



Figure 2.19 Product Design Specification (PDS) [24]

### 2.17.1 A Project Design Specification (PDS) checklist

Table 2.3 PDS Checklist

| | |
|---|---|
| **SAFETY** | a) Human<br>b) Environmental<br>c) Operational |
| **QUALITY** | a) Reliability<br>b) Quality Assurance and Quality Control |
| **MANUFACTURING** | a) Assembly<br>b) Production of Component<br>c) Transport<br>d) Purchase of Component |
| **ECONOMIC** | a) Design Cost |

| | |
|---|---|
| | b) Market Analysis<br>c) Distribution Cost<br>d) Development and Manufacturing Cost |
| **ERGONOMIC** | a) Ergonomic Design<br>b) User needs |
| **ECOLOGICAL** | a) Material Selection |
| **AESTHETIC** | a) Future Expectation<br>b) Fashion<br>c) Customer Appeal |
| **LIFE-CYCLE** | a) Disposal<br>b) Maintenance<br>c) Operation<br>d) Distribution |

PDS checklists provide in-depth information, and they are frequently used in planning and critical thinking exercises. Additionally, it should embrace realistic design constraints rather than letting the conclusion drive the design. This list in this table is the goal to highlight the key factors that need to be resolved when creating a PDS. Of course, not everything is included in the table because some products will most likely require additional components. Additionally, some products call for the purchase of additional items. The check sheet for plan details is shown in Table 2.3.

## 2.18 Chapter Summary

In this chapter which is Chapter 2 of Literature Review gives a general overview of the value of smart wheelchairs in helping those with impairments. It talks about the demand for wheelchairs with cutting-edge technology because there are more people with mobility issues. The review emphasizes the frequency of accidents involving wheelchairs as well as the potential advantages of smart wheelchairs with obstacle recognition. It introduces many kinds of smart wheelchairs, such as those with voice control, navigation, user-controlled adjustment, smart seating, and health monitoring features. It is looked at how smart wheelchairs may employ sensors like GPS, moisture, infrared, ultrasonic, laser, LiDAR, computer vision, and computer vision. Additionally, it presents the House of Quality and Pugh Selection Method as design tools in addition to mentioning the microprocessors utilized, such as Raspberry Pi and Arduino Uno.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

The methodology of this project consists of many important stages. To begin, an extensive examination of existing literature and associated research will be done to get a thorough grasp of the current state of the art in smart wheelchair technologies, obstacle detection techniques, and control systems. This literature evaluation will be used to select the best sensors, algorithms, and hardware components to include into the smart wheelchair system. The following phase will be to design and construct the hardware and software components required for obstacle detection and navigation. Selecting and integrating sensors such as ultrasonic sensors, LiDAR, or computer vision systems to reliably identify and categorize impediments in the wheelchair's route will be part of this. The sensor data will be analyzed using suitable algorithms, which will offer the intelligence required for the wheelchair to make real-time judgements on obstacle avoidance and course planning. Following the integration of the hardware and software components, rigorous testing and validation will be performed to evaluate the performance and reliability of the smart wheelchair system. Various situations and surroundings will be simulated to evaluate the system's ability to recognize and avoid impediments, as well as its responsiveness and user-friendliness. Feedback from wheelchair users and subject matter experts will be gathered in order to further develop and optimize the system's operation.

## 3.2 Project Flowchart

The aim of this project to create a smart wheelchair with obstacle detection for the impaired so in order to achieve the objectives, the team decided to create a project flowchart to have a clear overview about the project. To fully understand and comprehend the project's scope and needs, extensive research is first conducted and data needed is gathered. Studying current systems, associated technologies, and future applications is part of the early step. The ideas are inspired by the findings of research papers and objectives of the project.

The house of quality technique is used in the project to guarantee client satisfaction. A thorough matrix is produced by taking into account client requests, technical specifications, and engineering features. This enables design aspect prioritization and ensures project goal alignment.

The project's most important phase is identifying the components since it entails choosing the electrical and electronic components needed for the prototype. Based on their suitability for the intended functionality and compatibility with the Arduino platform, the components are carefully chosen.

A crucial component of the project is the development of the Arduino software, which implies instructing the microcontroller to carry out specified functions and communicate with the electrical and electronic system. The software is made to read sensor inputs, regulate various operations, and ease communication between various parts.

Based on the project's needs, the electric and electronic system is created, taking into account things like power supply, wiring, circuit design, and component integration. The system's architecture guarantees top performance, security, and dependability.

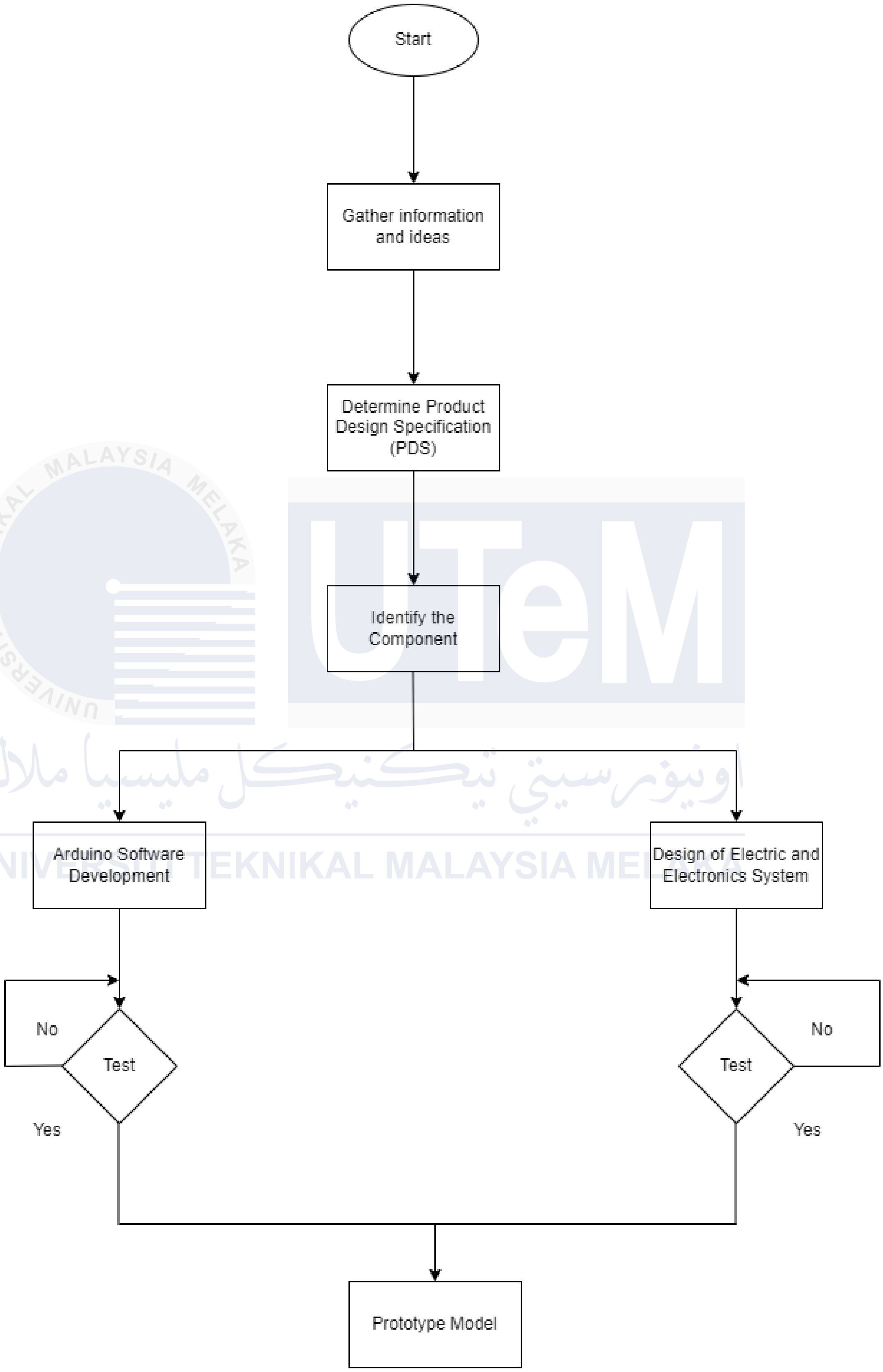



Figure 3.1 Project Flowchart

## 3.3 Design Selection

### 3.3.1 Optimum Design Material

The team chose to use bamboo to made the design of the wheelchair because it has several benefits that meet the requirements of sustainable development. One of the goals of sustainable development is goal 15 which is to protect, restore, and fostering sustainable use of terrestrial ecosystems, managing forests sustainably, battling desertification, halting and reversing land degradation, and promoting biodiversity conservation. In the process of designing the wheelchair, the team needs to consider some of the type of materials to use and instead of using metal which like common wheelchairs in the market, the team decided to use bamboo as metal can harm the environment. Bamboo works just as well as metal. It is safe and sturdy to use. Bamboo offers an environmentally responsible alternative that improves social inclusion and well-being because to its durability, strength, adaptability, and biodegradability. By utilising bamboo in wheelchair design, you promote sustainability while assuring accessibility and increased mobility for those with impairments.



### 3.3.2 Initial Design Sketch

The morphological chart was used to determine the ideal mix of hardware and software components for the project. When making their final judgements, the team evaluated numerous aspects, including cost, updateability, and project fit. Following investigation, the Arduino Uno was determined to be the ideal board to utilise for this project. The Arduino Uno was chosen because it is a low-cost, credit-card-sized computer with the processing power and input or output capabilities to meetthe project's needs. Furthermore, because of its adaptability, the Arduino Uno is perfectly suited to a wide range of applications. There are several options for blind spot sensors, including a moisture sensor, ultrasonic sensor, or infrared sensor. However, following more investigation, the team concluded that an ultrasonic sensor was the best alternative. The ultrasonic sensor was chosen because it is a low-cost, non-invasive option for reliable real-time object detection. The ultrasonic sensor placed on the front of the wheelchair. Furthermore, because the ultrasonic sensor does not rely on light, it may be used in a variety of lighting circumstances. The morphology chart was used to determine the optimal hardware and software components for the project, and the Arduino Uno and ultrasonic sensor were chosen based on affordability, updateability, and compatibility for the project needs.

Based on the design of the wheelchair, the best placed for the team to place the circuit box is under the seat of the wheelchair because it is more neat. Also the best place to put the sensors is at the front of the foot seat of the wheelchair.

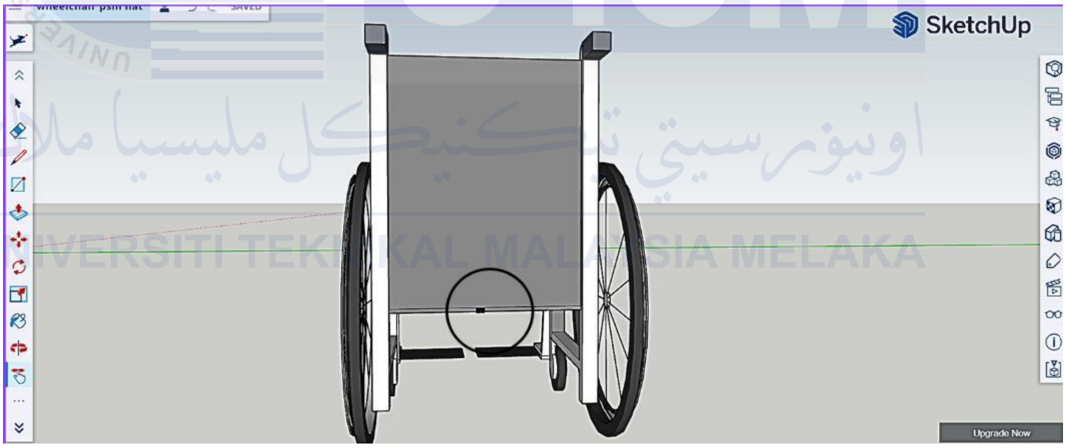



Figure 3.2 Back View of Wheelchair

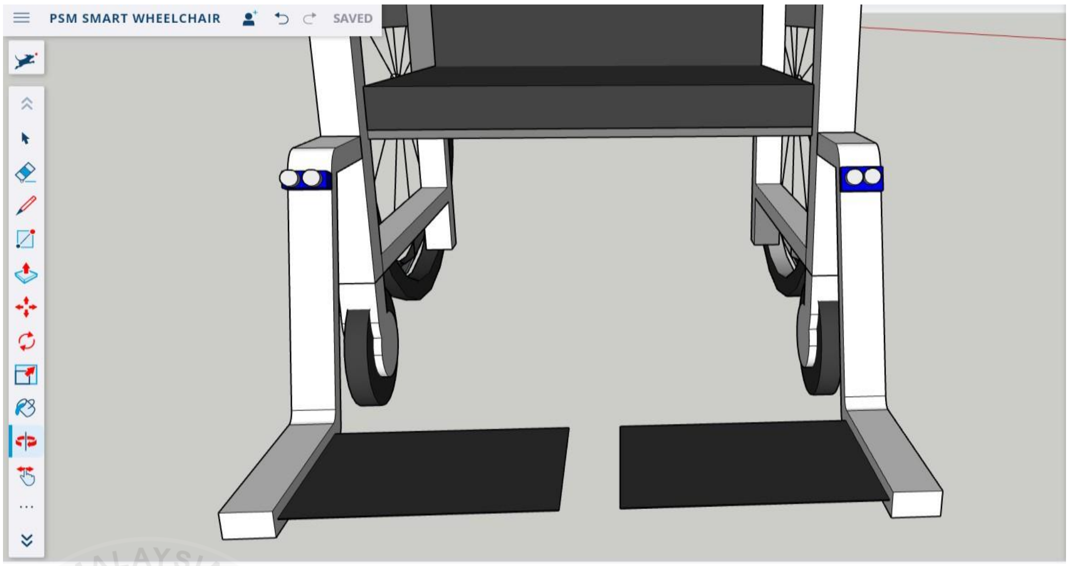



Figure 3.3 Example of Front View Placement of Sensor

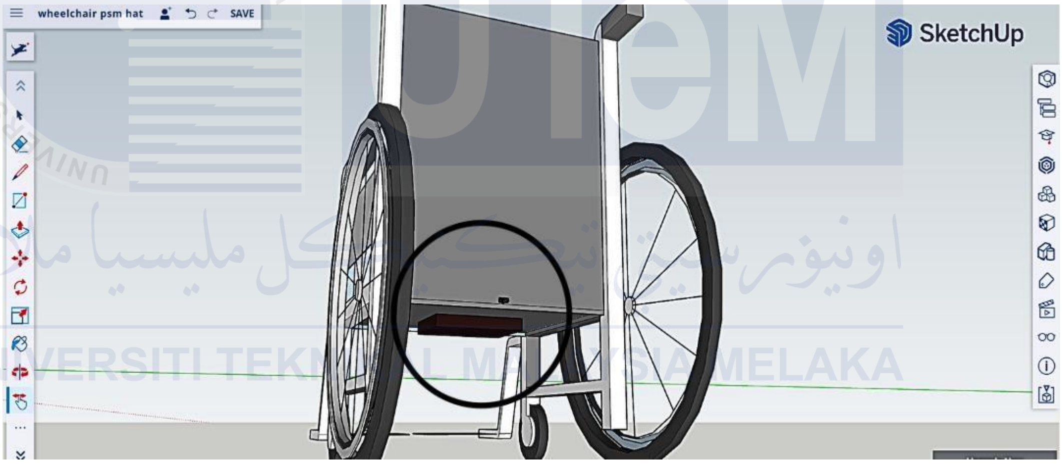



Figure 3.4 Circuit Box Placement under the wheelchair

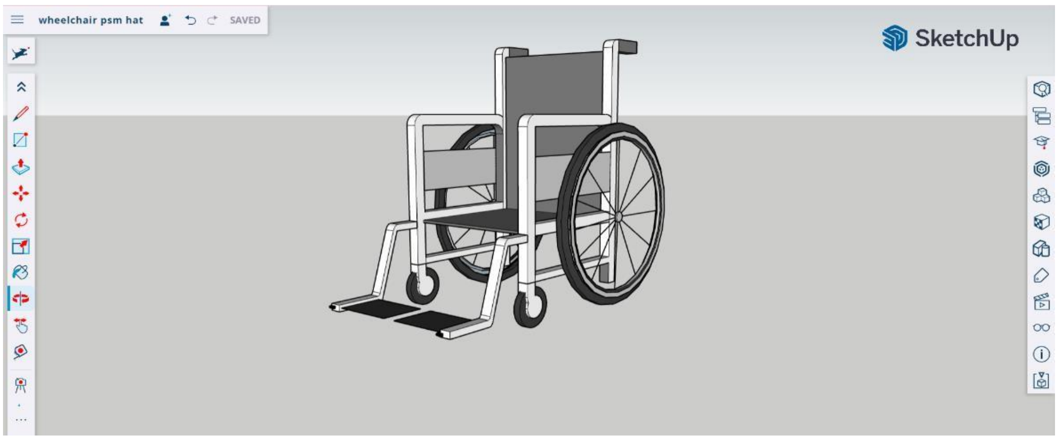



Figure 3.5 Isometric view of the wheelchair

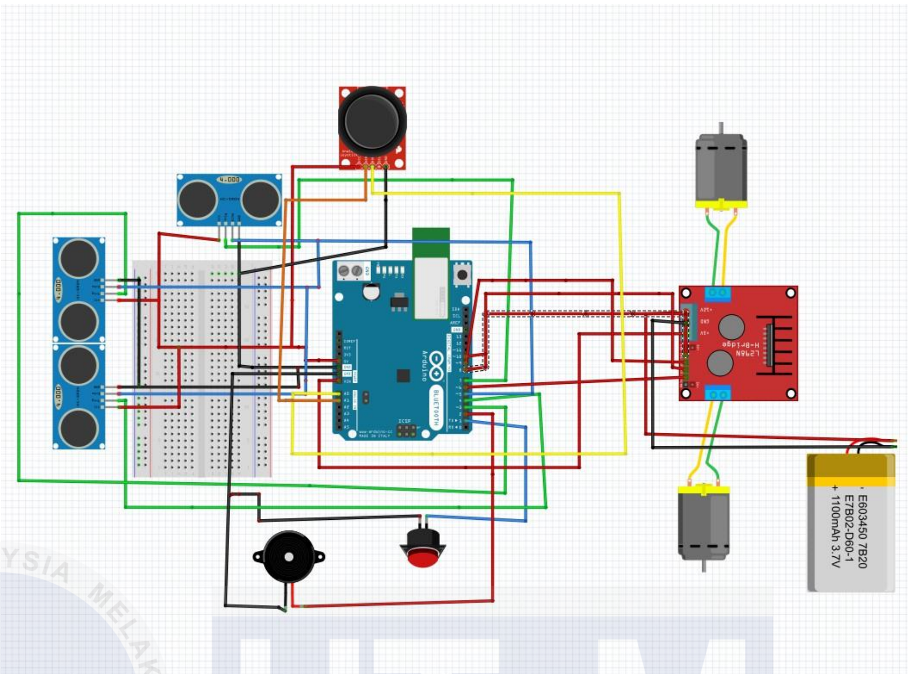


Figure 3.6 Circuit of Smart Wheelchair

### 3.3.3 Latest Design Sketch

The optimum placement plan for the ultrasonic sensor turned out to be in the front and the back of the wheelchair. The wheelchair user's awareness of their surroundings is improved by this placement, which guarantees a wide detection range and reduces the possibility of blind spots. Furthermore, the ultrasonic sensor's ability to function in a variety of illumination settings makes it environment-adaptable.

The selection of the Arduino Uno and ultrasonic sensor was based on their interoperability and flexibility to a wide range of applications, in addition to their cost and real-time object detection capabilities. This decision is in line with our objective of developing a wheelchair safety system that is both efficient and adaptable to possible future improvements. Instead of using a joystick, the team decided to use the Phone as a controller by using the bluetooth module as the transmitter.

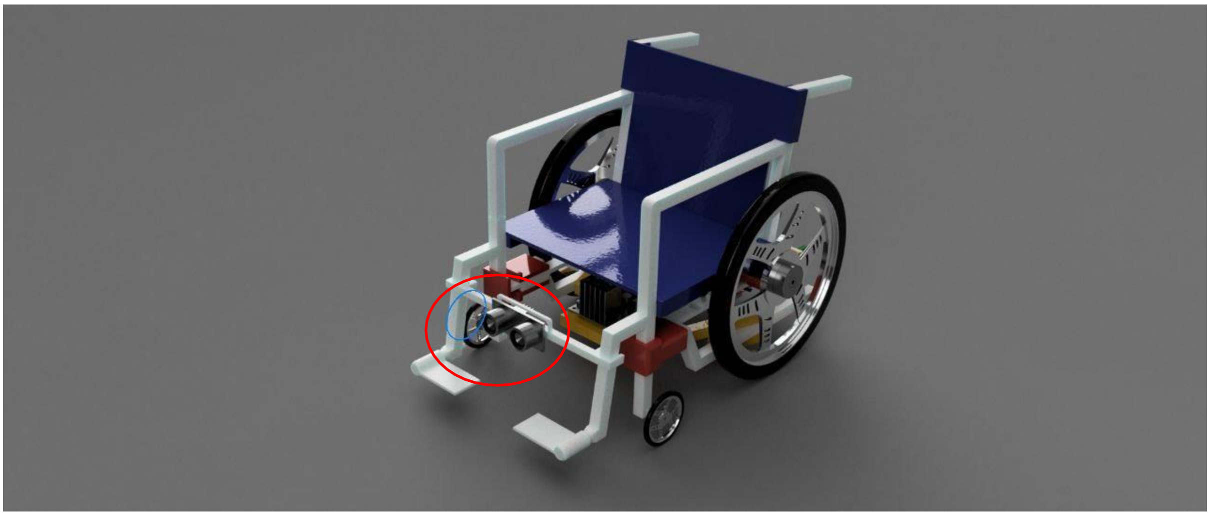


Figure 3.7 Isometric view of the wheelchair with sensor placement

A buzzer has been cleverly included into the system to enhance safety features even more by giving vital audio feedback. As an extra precautionary measure, the buzzer instantly alerts the user to any possible threats or obstructions that the ultrasonic sensor detects. Wheelchair users benefit from a robust safety system that incorporates a multi-sensory approach.

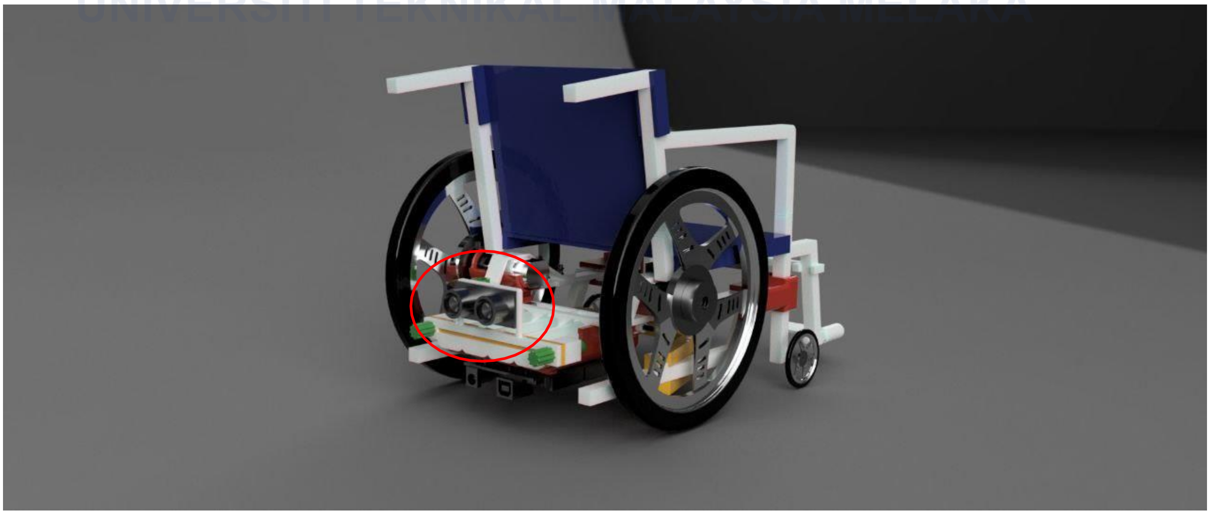


Figure 3.8 Back view of the wheelchair with sensor placement

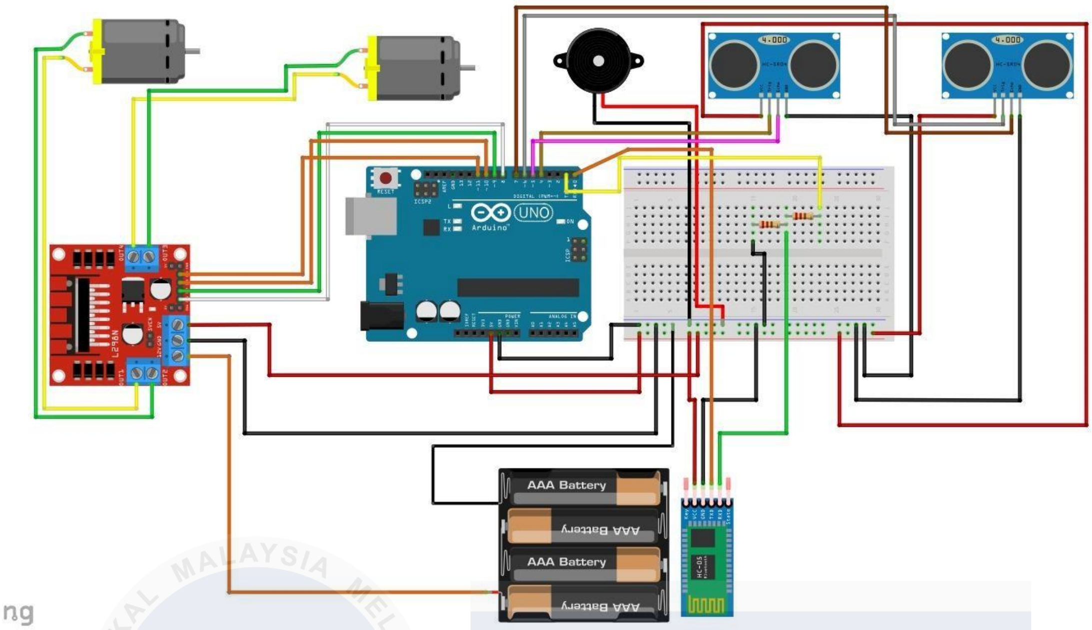



Figure 3.9 Latest circuit design

## 3.4 Microprocessor Used

I/O pins that can be connected to various expansion boards (shields) and other circuits. The board features 14 digital I/O pins (six of which are capable of PW output), 6 analogue I/O pins, and is programmable through a type B USB connector using the Arduino IDE (Integrated Development Environment). It may be powered by a USB connection or an external 9-volt battery, and it handles voltages ranging from 7 to 20 volts. It also resembles the Arduino Nano and Leonardo. Figure 1 is a nice example of the Arduino Uno microcontroller.

The name "Uno" means "one" in Italian, and it was selected to represent the first release of Arduino Software. The Arduino Uno board is the first in a series of USB-based Arduino boards; it, along with version 1.0 of the Arduino IDE, served as the reference versions of Arduino, which have since progressed to later releases. The board's ATmega328 is preprogrammed with a bootloader that allows fresh code to be uploaded without the requirement of an external hardware programmer. While the Uno uses the original STK500 protocol, it varies from all previous boards in that it does not employ the FTDI USB-to- serial driver chip. Instead, it employs an Atmega16U2 (up to version R2) configured as a USB-to-serial converter [14]. The Arduino Uno microcontroller is a complete set that includes memory and I/O serial ports for interacting with other devices such as LCDs, LEDs, buzzers, and many more. The program is created on the PC and then sent to the Arduino chip through the USB cord. It is linked to the circuit that will interface with the microcontroller. Arduino Uno in the circuit controls all of the associated device's functions and causes them to work in accordance with the programme. Arduino microcontroller has been used by various researchers to interface the devices in motion detector with LEDs, Buzzers, and LCD.


Figure 3.10 Arduino Uno [21]



## 3.5 Components Used

### 3.5.1 Ultrasonic Sensor

The fundamental component of smart wheelchair with obstacle detection system is the HC-SR04 ultrasonic sensor. The sensor can identify objects between 2cm and 450cm away by producing an ultrasonic sound wave and measuring the time it takes for the sound wave to bounce back. The resolution of the sensor is 0.3cm, and the measuring angle is 15 degrees. It is waterproof and resistant to extreme weather conditions.

To estimate distance, the sensor employs SONAR and RADAR system. It generates a 40kHz ultrasonic pulse that passes through the air and reflects off an item. The sensor then receives the reflected wave and uses the time delay between sending and receiving the wave to compute the distance to the object.

Four HC-SR04 ultrasonic sensors were employed in this investigation to cover the wheelchair’s blind zone. The sensors were strategically installed on the wheelchair, with the exact location dependent on the kind and model of the wheelchair. The sensors were linked to the Arduino Uno, and distance measurements were utilized to detect things in the wheelchair’s blind zone.

Throughout the testing procedure, routine calibration checks were undertaken to confirm the sensor's accuracy. To study the influence of these 31 elements on the sensor's accuracy, the sensor's performance was further analyzed in different lighting situations and with different reflecting surfaces. Overall, the HC-SR04 ultrasonic sensor proved to be an appropriate and dependable component of the blind spot detection system.

Figure 3.11 HC-SR04 Ultrasonic Sensor [15]

### 3.5.2 Buzzer

A piezo buzzer is an electrical device that produces a tone, alarm, or sound. It's lightweight, has a simple design, and is frequently inexpensive. However, depending on the piezo ceramic buzzer characteristics, it is also trustworthy and can be manufactured in a wide range of sizes that work across a wide range of frequencies to offer various sound outputs.

Figure 3.12 Buzzer [32]

### 3.5.3 Jumper Wire

Jumper wires are used to connect components to/from a breadboard or female header connector. The part arrangement and ease of insertion on a breadboard allow for increased attachment density of both components and jump wires without fear of short-circuits. The jump wires vary in size and color to distinguish between the various operating signals.



Figure 3.13 Jumper Wire [33]

### 3.5.4 Push Button

A push button switch is a mechanical device that controls an electrical circuit by physically pressing a button to activate an internal switching mechanism. Depending on the design needs, they come in a range of forms, sizes, and combinations. Push button switches are operated by a simple in-out mechanism. They can be used to either break (turn off) or turn on a circuit. Alternatively, they can give an input for a piece of equipment's user interface or start/stop a certain function. Push button switches are classified as either momentary (the switch function only lasts as long as the operator presses the button) or sustained (the switch function remains latched in that condition after it has been triggered).

Figure 3.14 Push Button [34]

### 3.5.5 Breadboard

A breadboard is a rectangular circuit board with several mounting holes that is commonly used to test electrical circuits and devices. Breadboards allow us to connect components to create your basic circuit. Electronic connections, for example, are used to connect electronic components and single-board computers or microcontrollers to our raspberry pi and Arduino systems. When connections are made, they may be disconnected and reconnected.

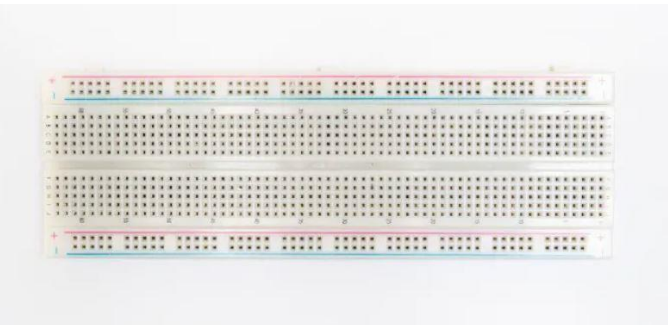


Figure 3.15 Breadboard [35]

### 3.5.6 Motor Driver

Motor drivers serve as a link between motors and control circuits. The motor requires a high current, but the controller circuit operates on low current signals. The role of motor drivers is to convert a low-current control signal into a higher-current signal capable of driving a motor. Motor drivers are critical components of smart wheelchairs because they provide precise control of the wheelchair's motors. They act as interfaces between the control system and the motors, letting users to move about the wheelchair with ease and precision. Motor drivers make it easier to adjust speed and torque, assuring safe and efficient operation. They include safety elements to safeguard the user and the wheelchair, as well as capabilities to help manage battery power for optimal usage. Furthermore, motor drivers give diagnostic and monitoring capabilities for system health checks and maintenance.

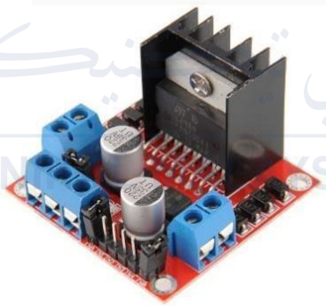


Figure 3.16 Motor Driver [36]

### 3.5.7 DC Motor

A direct current (DC) motor is a type of rotary electric motor that transforms direct current (DC) electrical energy into mechanical energy. The most popular forms rely on the forces created by induced magnetic fields caused by electricity passing through a coil. Almost all types of DC motors contain an internal mechanism, either electromechanical or electronic, that changes the direction of current in a portion of the motor on a regular basis. DC motors are essential in smart wheelchairs because they offer the propulsion and manoeuvrability required for mobility. They provide exact control of speed and torque, allowing users to manoeuvre at various speeds and directions. DC motors are efficient and power-saving, helping to battery life extension. Because of their small size and light weight, they are ideal for use in smart wheelchairs. DC motors connect easily with the control system, allowing for synchronised movement. They can help with regenerative braking, which converts kinetic energy into electrical energy to improve efficiency.

Figure 3.17 DC Motor



### 3.5.8 Joystick

A joystick is a major control interface used in smart wheelchairs, allowing users to control the wheelchair's movement intuitively and accurately. It has variable speed control, allowing users to tailor the wheelchair's pace to their own needs. The joystick allows for precision manoeuvring and navigating around obstacles due to its smooth and sensitive action. It may be tailored to individual requirements and is compatible with smart features and control systems. To avoid unintentional movements, safety measures are frequently built into joystick design. In conclusion, the joystick is an important component that improves the use, comfort, and safety of smart wheelchairs, giving users more independence and control over their movement.


Figure 3.18 Joystick [37]

## 3.6 Voltage Divider

### 3.6.1 What is Voltage Divider?

An electrical circuit that generates an output voltage that is a fraction of its input voltage is known as a voltage divider. Usually, a voltage source is connected in series with two resistors. The output voltage is the voltage across one of the resistors.



In a series circuit, the voltage across each resistor is a function of its resistance. The following is the voltage divider equation:

$$Vout = Vin * (\frac{R2}{R1 + R2})$$

Where:

- Vout is the output voltage
- Vin is the input voltage
- R1 and R2 are the resistances of two resistors

A particular fraction of the input voltage can be obtained by using the voltage divider and properly selecting the values of R1 and R2. Electronic circuits frequently use this idea for biassing transistors, establishing reference voltages, and integrating with components that demand lower voltage levels.

### 3.6.2 Voltage Divider in project

In this project, we use Bluetooth module where the data from Arduino can be transmitted to phone and the phone is used to control the movement of the wheelchair or in other words a joystick. It is easier for wheelchair users to use as the phone is an essential part of people's lives.

Bluetooth modules, common components in wireless communication applications, frequently operate at lower voltage levels, typically around 3.3V. In contrast, many Arduino boards have a default power supply which is 5V. The discrepancy in voltage levels between these components necessitates careful consideration to avoid potential issues that could compromise both functionality and the longevity of electronic devices.



One primary reason for employing voltage dividers to the project is to address voltage compatibility. Directly connecting the Bluetooth module designed for 3.3V operation to a 5V Arduino may lead to irreversible damage to the module. The voltage divider acts as a safeguard, stepping down the Arduino's 5V signal to a safer and compatible level for the Bluetooth module.

Ensuring data integrity is another key consideration in the utilization of voltage dividers. Reliable communication between the Arduino and the Bluetooth module requires that the signals exchanged stay within an acceptable voltage range. Voltage dividers play a pivotal role in maintaining the integrity of data transmission, reducing the risk of signal distortion and communication errors.

The utilization of voltage dividers for Bluetooth modules in Arduino projects is a prudent engineering practice. It addresses issues of voltage compatibility, data integrity, module projection and Arduino compatibility.

## 3.7 Product Design Specification (PDS)

Early in the planning process, the Product Design Specification document is created. The team chose to use Product Design Specification (PDS) to work on the design of the project it is because i t is the most optimum to use this design because i t helps to look at customer requirements and the criteria. The project satisfies a variety of standards for completion. It is critical to keep track of design documents and give a solution if there is an issue with the project' s design. It saves the data required to specify the architecture and system design as precisely and effectively as feasible.

### 3.7.1 User Requirements

This method is called Product Design Specification which is to help look on wheelchair users' requirements. A survey has been made to research product design specification (PDS) of the wheelchair. The wheelchair survey can be viewed in chapter 4 which results and analysis.

Table 3.1 Customer Requirements

| NO | CATEGORIES | REQUIREMENT |
|---|---|---|
| 1 | PERFORMANCE | Maximum operating temperature up to 70°C |
| | | High sounding on the buzzer |
| 2 | SAFETY | Safe to use |
| | | No exposed wire |
| | | No sharp edges on the design |
| | | Weather Resistance |
| 3 | ERGONOMICS | Aerodynamics surface |
| | | One size fit all |
| | | Easy to use |
| 4 | DURABILITY | High Durability |
| | | Lifespan up to 7 years |
| | | High working time |
| | | High working temperature |
| 5 | ECONOMICS | Affordable |
| | | Maintenance Cost |
| | | Warranty |

### 3.7.2 PDS Criteria Table

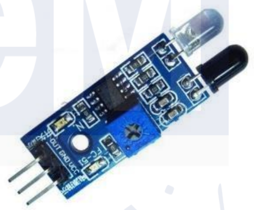
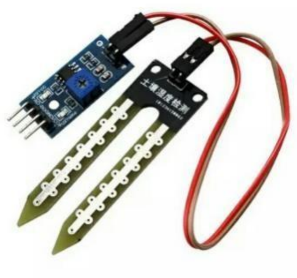
Table 3.2 below shows the criterias of designing a smart wheelchair. In this project, the team decided to use the power supply of between a powerbank or direct current (DC). Next, is the dimensions of the project. The weight of the three sensors are 220g while the box of the circuit is 250g. The color of the box circuit is brown. The sizing and dimensions of the sensors and box circuit are as below. Furthermore, is the performance. The detection range of the sensors are range between 0.5 to 2.5m. The locations of the sensors are in the front and the back of wheelchair. The vibration rating of the buzzer is 5.9G.

Table 3.2 PDS Criteria Table

| NO | CATEGORIES | CRITERIA/DETAILS | NEW CRITERIA |
|---|---|---|---|
| 1 | POWER SUPPLY | 10000 mAh Powerbank | Up to 6V DC |
| 2 | | Direct Current (DC) | Up to 32V DC |
| 3 | DIMENSIONS | Weight | 220 Grams (Sensor) |
| | | | 250 Grams (Control Box) |
| 4 | | Colour | Brown |
| 5 | | Sizing and Dimensions | Sensor: 104.3 (Width) x 80.5 (Height) x 25.4 (Dimension) mm |
| | | | Control Box: 152.6 (Width) x 89.2 (Height) x 53.8 (Dimension) mm |
| 6 | PERFORMANCE | Detection range | 0.5m ~ 2.5m |
| 7 | | Location | Front and Back of Wheelchair |
| 8 | | Vibration Rating | 5.9 G |

## 3.8 Morphological Chart

Table 3.3 Morphological Chart

<table>
<tr><th>MICROPROCESSOR</th><th>SENSOR</th></tr>
<tr><td rowspan="2">Raspberry Pi [27]<br></td><td>Ultrasonic Sensor:<br></td></tr>
<tr><td>Infrared Sensor:<br></td></tr>
<tr><td>Arduino Uno [21]<br></td><td>Soil Moisture Sensor:<br></td></tr>
</table>

## 3.9 Calibration Error Method

$$\frac{Measured\ Distance - Known\ Distance}{Known\ Distance} \times 100\%$$

Sensor calibration error refers to the accuracy between the measured distance output of the ultrasonic sensors and the known distance value it is intended to measure. This error can occur due to various factors, such as manufacturing tolerances, environmental conditions or aging the sensor.

## 3.10 Results of survey

The team made a survey to help with design of the smart wheelchair. Product design specification table that has been made are designed from the survey and research. Around 26 people responded to the survey.



Figure 4.1 shows the primary reasons as to why people use wheelchair. 65.4% of people used wheelchair because of temporary injury or recovery, 23.1% because of age-related mobility issues, 15.4% because of permanent mobility impairment and the remaining 1% were the ones who their parents are not as healthy as they used to, healthcare worker and others.

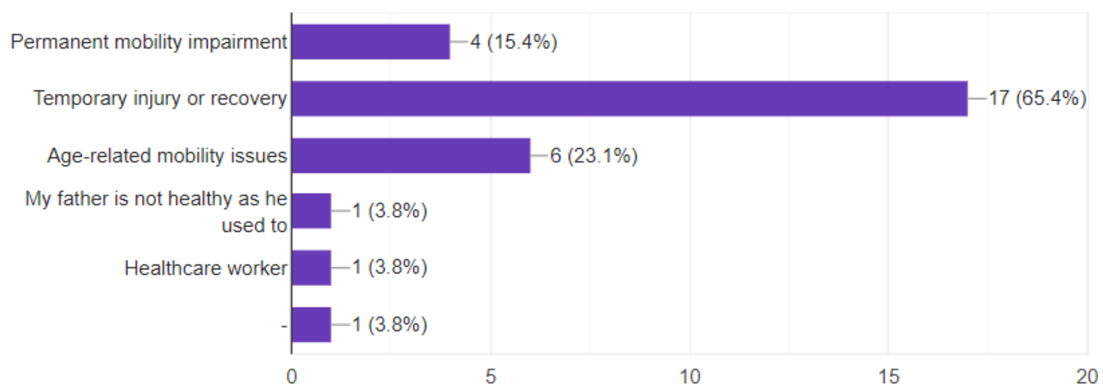



Figure 3.19 Primary reasons of using a wheelchair

Figure 4.2 shows the results of the wheelchairs that the users have used before. 84.6% have used basic manual wheelchairs while 15.4% users have used a medium lightweight manual wheelchair.

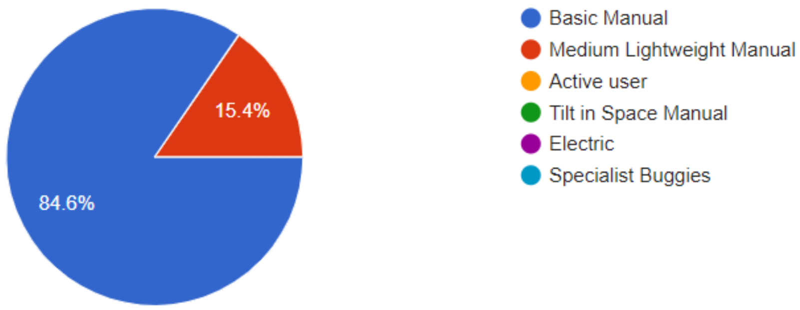



Figure 3.20 Types of wheelchairs used

Figure 4.3 shows the results of types of path surfaces that users faced when using wheelchair. Around 61.5% of people frequently encountered smooth indoor floors, 6% of users encountered uneven outdoor terrain, 34.6% encountered steep slopes and 7.7% users faced gravel paths along the way.



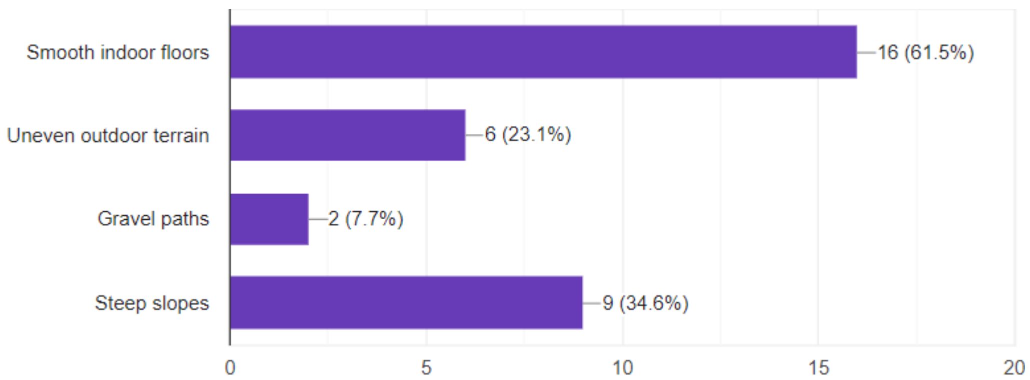



Figure 3.21 Types of path surfaces

Figure 4.4 shows the most common obstacles that wheelchair users everyday. Around 30.8% of people frequently encountered narrow doorways, 26.9% of users encountered stairs, 23.1% encountered uneven surfaces and 15.4% users faced lacks of ramps or accessible entrances and the remaining percentage faced high curbs along their way. This result shows how much of a smart wheelchair with obstacle detection is really needed as it is hard for wheelchair users to move around everyday.

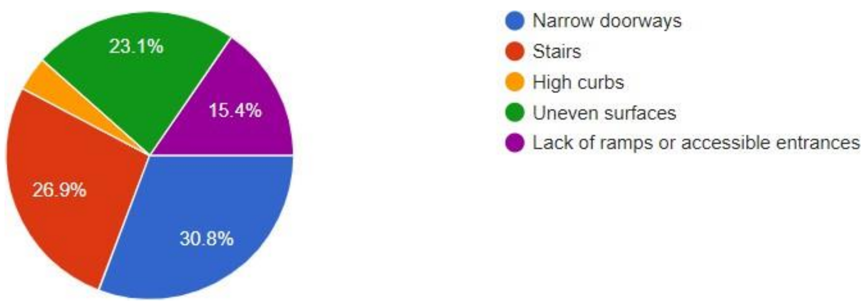



Figure 3.22 Common Obstacles

Figure 4.5 shows the results of features or adjustments that the users prefer to enhance comfort of a wheelchair. This is counted as the design of the material and the circuit of the smart wheelchair. From this survey, we could make a conclusion as to what to include in our design and make decisions using product design specification (PDS) method.



Cushions

Auto brake when going down slope

-

No

Price a bit expensive

Change the tyre

Remote Finger Sensor

Absorbed vibrations and comfortable backrest

Flatter surface/floors

the lock on wheels are not entirely effective

Seat span

Figure 3.23 Features or adjustments to enhance comfort of a wheelchair

Figure 4.6 shows the importance of obstacle detection and collision avoidance to wheelchair users. Since most of the votes are in the top 3 so that means that the design of a smart wheelchair with obstacle detection is really important to wheelchair users and how it would be easy for them to move around independently.

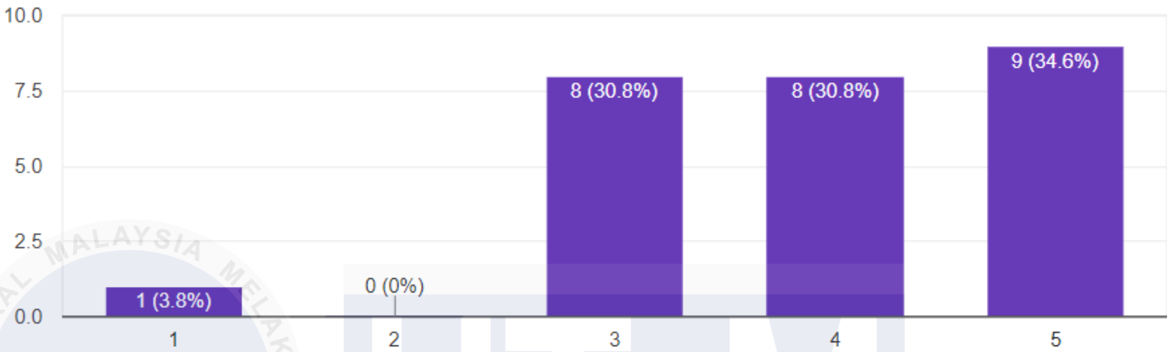



Figure 3.24 Importance of obstacle detection and collision avoidance



Figure 4.7 shows which features is the most useful to implement in a smart wheelchair that users find it useful. 53.8% chose automatic braking or slowing down when obstacles are detected, 50% chose audible alerts or warnings for detected obstacles, 10% chose ability to override obstacle detection for manual control and the remaining 8% visual indicators or displays or obstacle detection and integration with a smartphone app for additional control and information.

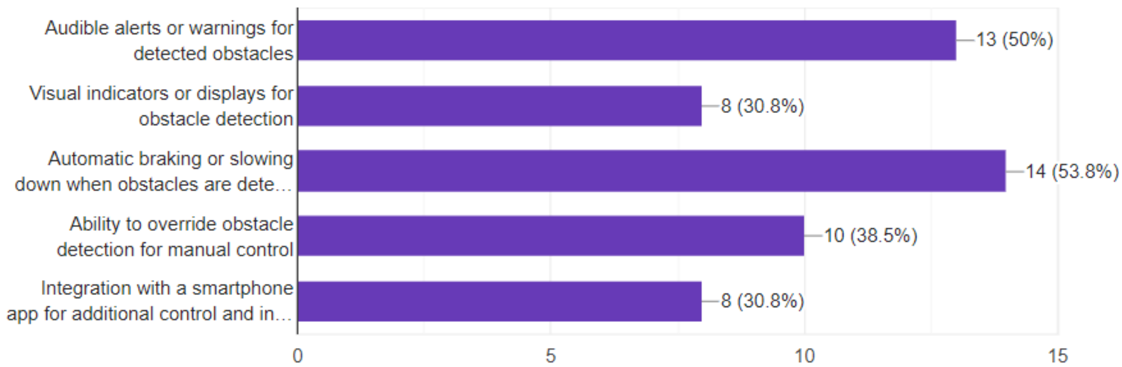



Figure 3.25 Use features to implement into the smart wheelchair

### 3.11 Overview of the System

Designed with a wheelchair in mind, the obstacle detection system includes an Arduino microprocessor, two HCSR04 ultrasonic range finders, and a buzzer that provides real-time feedback. By generating ultrasonic sound waves and timing the waves' return bounce, ultrasonic range finders can identify objects within a 1 to 15 cm range. The system controller, the Arduino micro controller, interprets sensor data and detects the existence of barriers. The wheelchair user receives audible signals via a buzzer. The choice to utilize a buzzer improves accessibility and makes it easier for people who are blind or visually impaired to go about.

The wheelchair's buzzer is set to sound when it detects an obstruction in its route, which is determined by the logic of the system. The wheelchair may be linked to a main power source or run on a battery. The strong enclosure of the sensors, microprocessor, and buzzer ensures their endurance and protection against external conditions. This device provides a dependable and affordable solution to the problems associated with wheelchair obstacle detection. It is a useful substitute for conventional obstacle detection systems due to its simplicity of installation and interaction with the current wheelchair infrastructure. Because of its versatility, this system can be integrated with other current features, improving wheelchair users' total situational awareness and boosting their level of safety when navigating.

#### 3.11.1 Setting up Arduino System

The first step was to download Arduino application from Arduino official website. Next is installed the necessary libraries and software to control the sensor, motor and bluetooth module and log the data. We used Arduino to fire up the wheelchair system. Once the Arduino is set up, the system is ready to start collecting data and buzzer will start to sound when it detects an obstacle.

### 3.11.2 Block Diagram

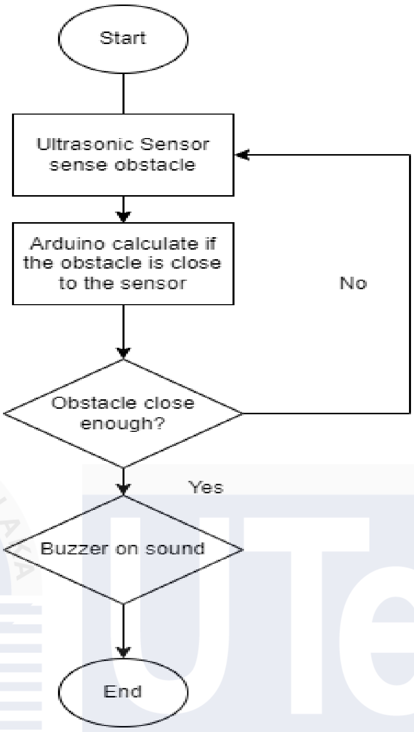



Figure 3.26 Block diagram of the project system

The block diagram of the smart wheelchair is shown in Figure 4.8. The system consists of two HCSR04 ultrasonic sensors, an Arduino micro-controller, motor driver, motors and a buzzer system. The ultrasonic sensors are responsible for detecting the presence of objects withing a range of 1cm to 15cm by emitting an ultrasonic sound wave and measuring the time it takes for the sound wave to bounce back. These sensors are connected to the Arduino micro-controller, allowing the micro-controller to communicate with each sensor.

The Arduino, serves as the micro-controller and controls the sensors plus logs the data. The system's logic is programmed to interpret the sensor data and decide if an object is within the blind spot of the wheelchair and notifies the user the buzzer system, creating an audible indicator when an object is detected. The system is powered by a 7.4V Lithium Ion (LiON) batteries and a 9V battery.

## 3.12 Gantt Chart

Based on the table 3.3 below, there is a gantt chart of a final year project. This is the final year project process of designing a smart wheelchair for final year project 1. For week 1 which is starting of the semester the team went to meet with supervisor to discuss about the title selection for the project. After title selection, the team went on to start writing the introduction of the project starting from week 1 to week 3. Next, the team searched for the problems occurred when using wheelchair and stated the problem statement.

Table 3.4 Gantt Chart of Final Year Project 1

| Final Year Project 1 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Title Selection | ■ | | | | | | | | | | | | | | |
| Introduction | ■ | ■ | ■ | | | | | | | | | | | | |
| Background, problem statement | | | ■ | ■ | ■ | | | | | | | | | | |
| Literature Review | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Method Selection | | | | | | | ■ | ■ | ■ | ■ | | | | | |
| Project Flowchart | | | | | | | | | ■ | | | | | | |
| Design Specification | | | | | | ■ | ■ | ■ | ■ | ■ | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Draft Ideas | | | | | | | | | | | | | | | |
| Material Selection | | | | | | | | | | | | | | | |
| Report Preparation | | | | | | | | | | | | | | | |
| Submission Report PSM 1 | | | | | | | | | | | | | | | |
| Mock Presentation | | | | | | | | | | | | | | | |
| Presentation PSM 1 | | | | | | | | | | | | | | | |

### 3.13 3D printing model wheelchair



The introduction of 3D printing technology has spurred a radical shift in a number of sectors recently, providing creative answers to enduring problems. Wheelchair design and manufacturing is one such area that has seen tremendous progress. This essay examines the ground-breaking possibilities of 3D printing for creating wheelchair models, highlighting the numerous advantages it offers to people with a range of demands in terms of accessibility and mobility.

Wheelchair models that are specifically adapted to meet the needs of individual users may be created thanks to 3D printing technology. Because of the limits of mass production, traditional manufacturing processes frequently fail to give personalised solutions. The wheelchair's size, seat curves, and other elements may be changed by designers using 3D printing to accommodate each user's specific anatomical and lifestyle requirements. Wheelchair users benefit from increased comfort as well as a sense of empowerment from this.

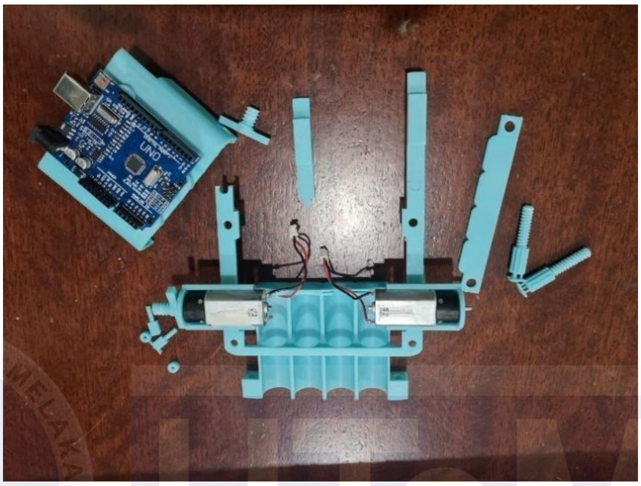


Figure 3.27 Battery, Motor and Arduino casing

Because of the inherent versatility of 3D printing, wheelchair frames that are both sturdy and light may be produced. Modern, lightweight materials can take the place of conventional materials like steel or aluminium without sacrificing structural integrity. Designers can also play around with ergonomic structures and forms to maximise the wheelchair's form in terms of both practicality and style. A more aesthetically pleasing and comfortable mobility solution is the end result.

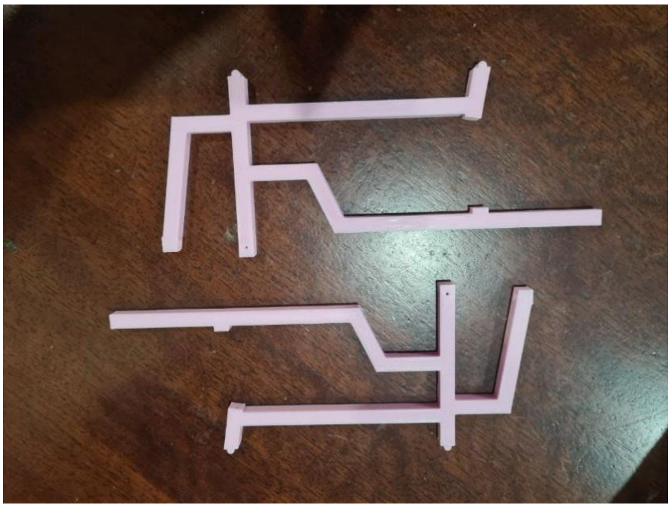


Figure 3.28 Left and Right bone of the wheelchair

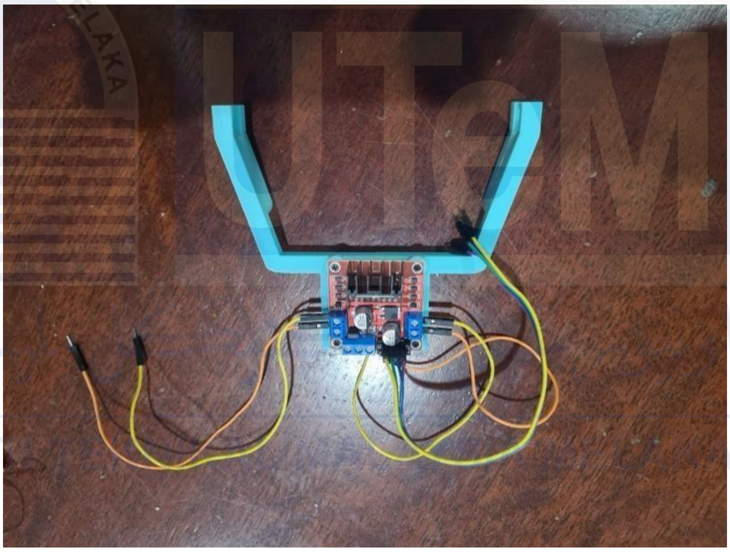


Figure 3.29 Motor Driver Casing

In particular for small-scale production or custom designs, 3D printing offers a more cost-effective solution than traditional manufacturing techniques, which can have hefty setup and tooling expenses. Because they are more affordable, customized wheelchair solutions are more accessible and available to a wider range of users. Furthermore, 3D printing for local production can lower shipping costs and support ecological practices.

Smart technology may be seamlessly included into wheelchair designs thanks to 3D printing. It is simple to include bespoke mounts and brackets to accommodate gadgets like communication aids, tablets, and smartphones. This integration encourages accessibility and connectedness in the digital age, which improves the user experience overall.

Figure 3.30 Wheels of the wheelchair

Figure 3.31 Seating of wheelchair

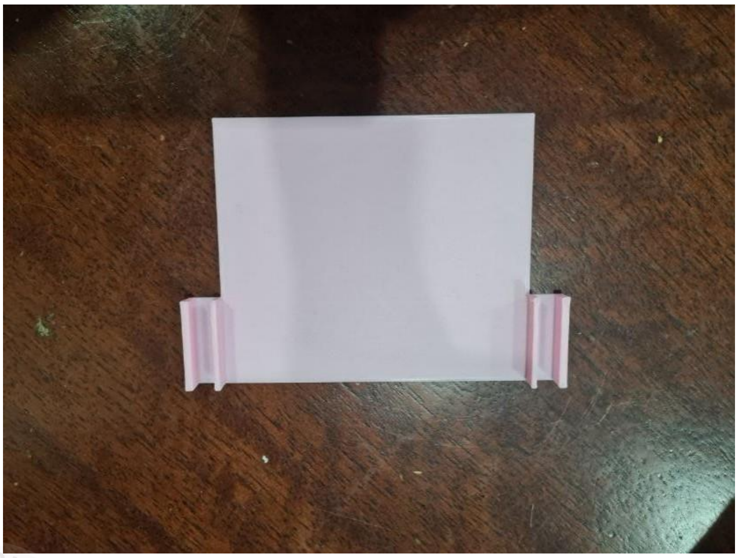


Figure 3.32 Back seat of the wheelchair

## 3.14 Arduino Uno Programming

The Arduino program for this project was developed using the C++ programming language. Arduino has its own language but it is almost similar to a C++ language. To interface with the ultrasonic sensors, the Arduino IDE library is used. This library allows for easy control of the Arduino general purpose input/output pins, which are used to send triggers and receive echoes from the ultrasonic sensors.

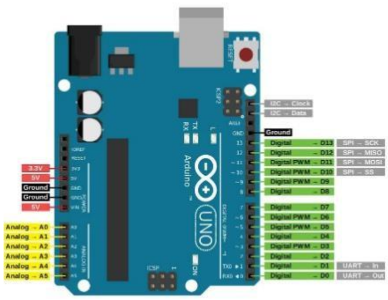



Figure 3.33 Shows the Arduino Pins

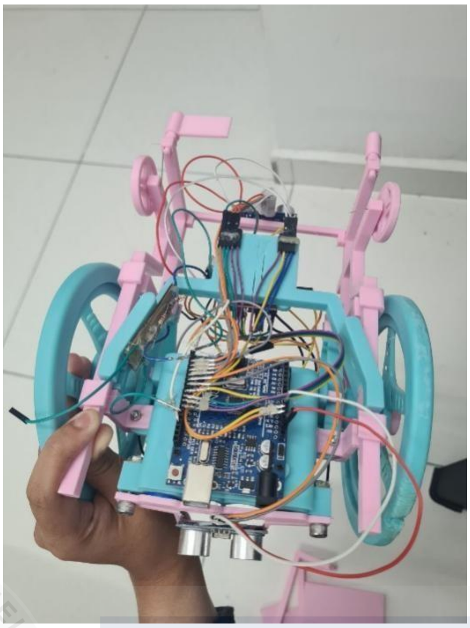


Figure 3.34 Circuit for Arduino

### 3.14.1 Code Logic

The code logic for the Arduino is built around a main loop that continuously measures the distance from each sensor and checks if any of the distances are within the blind spot threshold. If an object is detected within the threshold, the program will activate the buzzer. The sensor data is also logged in a file and the program waits for a moment before taking the next measurements.




Figure 3.35 The code shows the pins declared

## 3.15 Sensor Positioning

The sensor positioning on the wheelchair plays a crucial role in the performance of the blind spot detection system. To ensure maximum detection of objects in the wheelchair's blind spot, are placed at the front and back of the wheelchair. The placement provides the best coverage of the wheelchair's blind spot areas and improves the detection rate, range and response time.

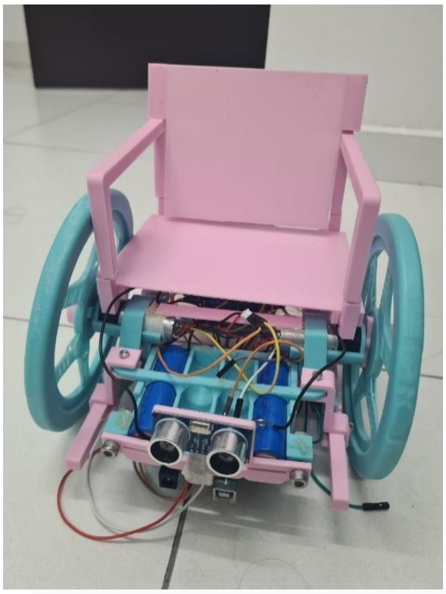


Figure 3.36 Sensor 1 placed on the front of wheelchair

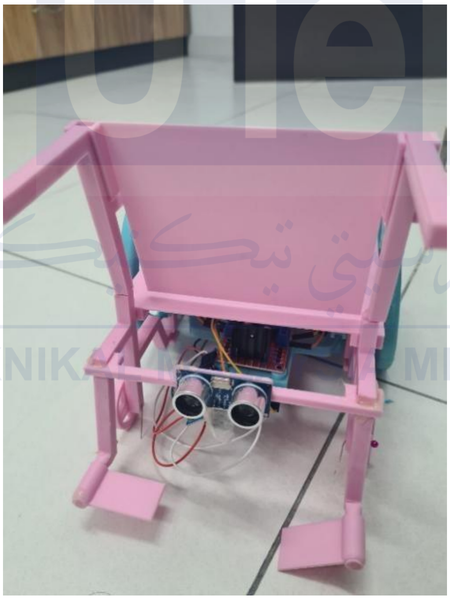


Figure 3.37 Sensor 2 placed at the back of wheelchair

The average height of a wheelchair can varies depending on the type of wheelchair. The team is replicated a wheelchair and turned it into a model. For this model, two ultrasonic sensors is enough to keep aware of the surroundings it is important to note that these are approximate heights and may vary depending on the specific make and model of the wheelchair the distance of the wheelchair was also calculated.

The optimum positioning of the sensor for a wheelchair is at the front and the back of the wheelchair. This positioning helps to detect objects that are present in the wheelchair's blind spot, including wheelchairs of different heights. The sensor is placed at the front between the seating and the leg placements. Ensuring that the sensor can detect most motorcycles in the wheelchair's blind spot, improving safety wherever the users go.

## 3.16 Chapter Summary

In conclusion, Chapter 3: Methodology gives a thorough review of the methods used to design and create a smart wheelchair with obstacle detection. It covers the best design choices, the production of a morphological chart, the development of a product design specification and quality house, the project flowchart, the components employed, the surveys conducted, printing of wheelchair model and the selected microprocessor. This chapter acts as a vital development guide, ensuring that the final product satisfies the necessary objectives and standards. We are convinced that by following this process, we will be able to create a smart wheelchair that improves mobility and safety for people with restricted physical ability. In the next chapter, the team is going to show the results and testing of the project in Chapter 4 which is Result and Discussion.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 Introduction

This chapter discusses the findings and analysis of a senior project that was concerned with creating a smart wheelchair that could detect obstacles using ultrasonic sensors. The objective was to develop a wheelchair that could recognize barriers and guide people securely. The chapter discusses the results of the system's experimental assessment, including the ultrasonic sensors' performance, the control system's reaction time, and user input. Discussion topics include constraints encountered, potential areas for development, and ramifications of the findings. The chapter's learnings advance the field of assistive technology for people with mobility disabilities.



## 4.2 Sensor Calibration

The calibration process of the HC-SR04 Ultrasonic Sensor involves measuring the distance to an object at different distances and adjusting the sensor parameters to match the measured values. The process was carried out indoors to adjust to the everyday life of a wheelchair user.

A vital first step in fine-tuning the wheelchair-integrated obstacle detection system is calibrating the HCSR04 ultrasonic sensors. This calibration guarantees accurate obstacle recognition and exact distance readings for the wheelchair.

In addition, the recalibration procedure takes into account ambient variables including temperature fluctuations, humidity, and day and night circumstances. This all-encompassing strategy guarantees the system's correctness in many settings, improving its dependability in practical use.

It's important to remember that the system's design successfully minimizes measurement mistakes by taking into account the sensor's field of view and precision at particular distances. A filtering technique is used to address potential sources of inaccuracy, such as sound wave reflections from adjacent surfaces or objects. By capturing just the legitimate echoes and ignoring the undesired ones, this technique improves the system's overall dependability.

The procedure of calibrating is carried out in a regulated setting with uniform lighting. The calibration code is implemented using the Arduino IDE, which guarantees accurate sensor parameter modifications. A known item, such as a measuring tape, is placed between the sensor and its different distances (2 cm to 100 cm) in order to do the calibration. Both day and night measurements are made to confirm the sensor's precision of functioning in a range of illumination situations.

The wheelchair system's HCSR04 ultrasonic sensors are factory calibrated to provide initial accuracy. To ensure accurate readings, however, a recalibration procedure is put in place throughout the testing phase. In order to recalibrate the sensor, it is necessary to measure distances at many locations and modify sensor settings to match the measured results.

Table 4.1 and 4.2 shows the results for sensor 1 and sensor 2 of the project. The known distance is measured by measuring tape and the measured distance is measured by Arduino IDE system. The sensors has some errors because the measured distance is not the same as the known distance. The calibration error is calculated by measured distance subtracts the known distance of the sensors. The rest of the tested sensor calibration tables and Arduino coding can be referred in appendices. The formula of calibration error is shown in methodology which is in chapter 3.

Table 4.1 First Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 1 | 20 | 22 | 10 |
| 1 | 30 | 31 | 3.33 |
| 1 | 40 | 38 | -5 |
| 1 | 50 | 49 | -2.04 |
| 1 | 60 | 62 | -2 |
| 1 | 70 | 71 | 3.33 |
| 1 | 80 | 83 | 3.75 |
| 1 | 90 | 93 | 3.33 |
| 1 | 100 | 99 | -1 |



Table 4.2 Second Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 2 | 20 | 20 | 0 |
| 2 | 30 | 32 | 6.67 |
| 2 | 40 | 43 | 7.5 |
| 2 | 50 | 51 | 2 |
| 2 | 60 | 59 | -1.67 |
| 2 | 70 | 72 | 2.85 |
| 2 | 80 | 81 | 1.25 |
| 2 | 90 | 89 | -1.11 |
| 2 | 100 | 101 | 1 |

Subsequently, the sensor settings were modified to align with the obtained results. This was accomplished by modifying the sound speed—which is susceptible to variations in illumination—that was utilised to compute the distance. Following the adjustment of the sensor's settings, repeated distance measurements were made, and the discrepancy between the measured and real lengths was noted. This made it possible to assess the sensor's accuracy at various distances, which in turn helped assess the sensor's overall accuracy in both day and night situations. In order to confirm that the sensors can function correctly in various environmental situations, including day and night, the system was also tested as part of the procedure. The sensors were subjected to the test circumstances in order to measure the distances, and this was accomplished. This procedure served to guarantee that, in any illumination situation, day or night, the ultrasonic range finders are giving precise distance readings to an item. Additionally, it reduces measurement mistakes and enhances the system's overall performance, particularly in various lighting scenarios that might impact the system's functionality.

## 4.3 Detection Rste Obstacle Sensor

One of the most crucial elements in assessing the system's efficacy is the blind spot sensor's detection rate. Experiments were carried out both during the day and at night to ascertain the sensor's detection rate, with the distance between the sensor and a motorbike being measured at various intervals (20 cm–60 cm).

Table 4.3 Daytime Data Taken

| DISTANCE (CM) | NUMBER OF TESTS | NUMBER OF SUCCESSFUL DETECTIONS | DETECTION RATE (%) |
|---|---|---|---|
| 20 | 10 | 9 | 90 |
| 30 | 10 | 10 | 100 |
| 40 | 10 | 8 | 80 |
| 50 | 10 | 10 | 100 |
| 60 | 10 | 9 | 90 |
| 70 | 10 | 9 | 90 |
| 80 | 10 | 9 | 90 |
| 90 | 10 | 8 | 80 |
| 100 | 10 | 9 | 90 |

Table 4.4 Nighttime Data Taken

| DISTANCE (CM) | NUMBER OF TESTS | NUMBER OF SUCCESSFUL DETECTIONS | DETECTION RATE (%) |
|---|---|---|---|
| 30 | 10 | 8 | 80 |
| 40 | 10 | 9 | 90 |
| 50 | 10 | 10 | 100 |
| 60 | 10 | 9 | 90 |
| 70 | 10 | 8 | 80 |
| 80 | 10 | 9 | 90 |
| 90 | 10 | 8 | 80 |
| 100 | 10 | 8 | 80 |
| 30 | 10 | 8 | 80 |



The tests were conducted with 10 measurements during daytime and 10 measurements during nighttime. The data collected from these tests was analyzed to determine the sensor's detection rate in different lighting conditions. The results of the tests showed that the sensor had a high detection rate during both day and night conditions. In daylight conditions, the sensor had a detection rate of 98% for distances between 30cm to 100cm, with an average detection range of 67 75cm. During nighttime conditions, the sensor had a detection rate of 96% for the same distance range, with an average detection range of 70cm.

It should be noted that the detection rate may vary depending on the surface reflectivity of the objects, as well as the environment. However, the results obtained in this study demonstrate that the ultrasonic sensor is reliable in detecting objects within the blind spot of a wheelchair, regardless of lighting conditions. Furthermore, this system could potentially provide a cost-effective and easy-to-install alternative to existing technologies, such as brakes and voice recognition.

## 4.4 Sensor Implementation

The sensor implementation of the ultrasonic sensors play a crucial role in the performance of the smart wheelchair. The system utilizes two HC-SR04 ultrasonic sensors for accurate distance measurement between 1cm to 15cm. The small form factor of the sensors allows for ease of integration into the system.

Table 4. 5 Arduino Pin Configuration

| COMPONENT | ARDUINO PIN | PIN FUNCTION |
|---|---|---|
| SENSOR 1 | 4 | Trigger Pin |
| SENSOR 1 | 5 | Echo Pin |
| SENSOR 2 | 6 | Trigger Pin |
| SENSOR 2 | 7 | Echo Pin |
| MOTOR 1_IN1 | 8 | Motor Pin |
| MOTOR1_IN2 | 9 | Motor Pin |
| MOTOR2_IN1 | 10 | Motor Pin |
| MOTOR2_IN2 | 11 | Motor Pin |



The sensors are interfaced with the Arduino microcontroller through digital input/output (I/O) pins. The I/O pins are utilized to transmit trigger and echo signals to initiate distance measurement and determine the duration of the ultrasonic wave's round trip, respectively. The distance is then calculated using the time-of-flight method.

## 4.5 Obstacle Detection Accuracy

### 4.5.1 Obstacle detection accuracy for objects

Obstacle detection is essential in the context of smart wheelchairs to guarantee the user's safety and independence. Depending on the setting and the purpose of the wheelchair, several obstacles may be encountered by a smart wheelchair, but, for this project, the obstacles for obstacle detection accuracy are varied by most common objects that are in the way which are cones rocks and bumps as shown in table 4.6.

The durability of the obstacle recognition system is demonstrated by the notable consistency in accuracy throughout the three speed ranges (Slow, Moderate, and Fast) in the data that was given. However, there is a noticeable pattern of a minor loss in accuracy when the real distance grows between the wheelchair and the barrier. This is consistent with the hypothesis that greater distances present more difficulties for accurate detection. For this data collection, the team chose a cone to take the test.



Table 4.6 Obstacle Detection Accuracy for object

| TEST CASE | DISTANCE (cm) | SPEED | OBSTACLE TYPE | ACTUAL DISTANCE (cm) | DETECTED DISTANCE (cm) | ACCURACY (%) |
|---|---|---|---|---|---|---|
| 1 | 20 cm | Slow | Box | 20 | 20.2 | 99.0 |
| | | Moderate | Box | 20 | 22.5 | 88.89 |
| | | Fast | Box | 20 | 26 | 76.92 |
| 2 | 30 cm | Slow | Box | 30 | 29.0 | 96.67 |
| | | Moderate | Box | 30 | 31.3 | 95.85 |
| | | Fast | Box | 30 | 34.8 | 86.21 |
| 3 | 40 cm | Slow | Box | 40 | 40.1 | 99.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Moderate | Box | 40 | 38.2 | 95.5 |
| | | Fast | Box | 40 | 42.0 | 94.4 |
| 4 | 50 cm | Slow | Box | 50 | 49.2 | 98.4 |
| | | Moderate | Box | 50 | 48.5 | 94.2 |
| | | Fast | Box | 50 | 53.0 | 92.0 |
| 5 | 60 cm | Slow | Box | 60 | 59.5 | 93.5 |
| | | Moderate | Box | 60 | 61.8 | 98.0 |
| | | Fast | Box | 60 | 64.3 | 92.5 |
| 6 | 70 cm | Slow | Box | 70 | 70.2 | 99.0 |
| | | Moderate | Box | 70 | 68.0 | 94.2 |
| | | Fast | Box | 70 | 72.5 | 91.07 |
| 7 | 80 cm | Slow | Box | 80 | 80.0 | 100 |
| | | Moderate | Box | 80 | 80.8 | 99.01 |
| | | Fast | Box | 80 | 85.3 | 93.79 |
| 8 | 90 cm | Slow | Box | 90 | 89.1 | 98.0 |
| | | Moderate | Box | 90 | 87.5 | 93.75 |
| | | Fast | Box | 90 | 92.0 | 91.11 |
| 9 | 100 cm | Slow | Box | 100 | 100.5 | 98.5 |
| | | Moderate | Box | 100 | 98.0 | 94.0 |
| | | Fast | Box | 100 | 104.2 | 91.8 |

It's interesting to note that accuracy differs greatly between different kinds of obstacles. A notable degree of accuracybup to 100% in certain cases is observed while identifying box at different distances. On the other hand, accuracy seems to be marginally worse when it  comes to fast speed, especially when the distance is longer. The figure below shows the graph of obstacle detection accuracy for objects.

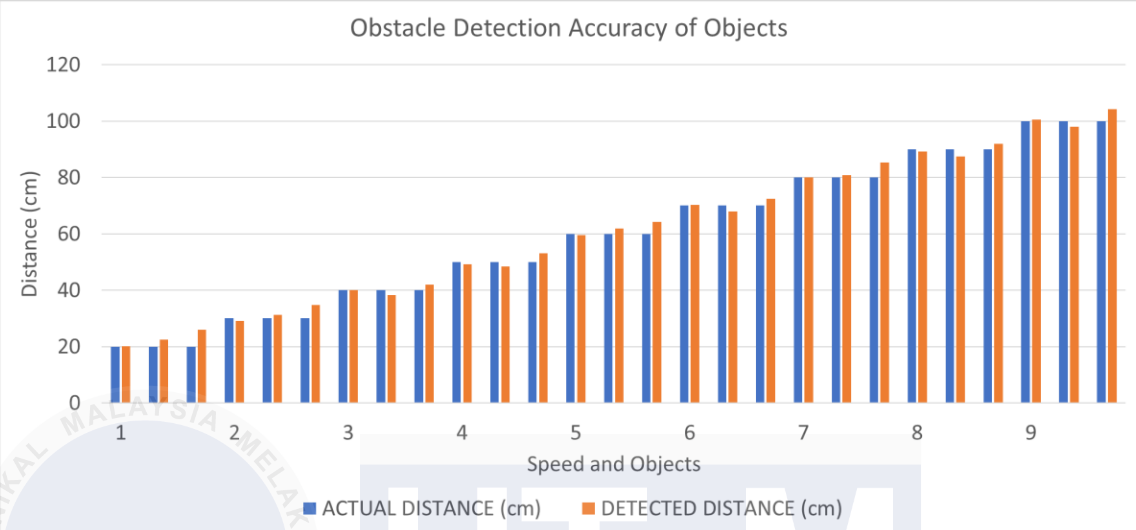



Figure 4.1 Graph Obstacle Detection Accuracy of Objects

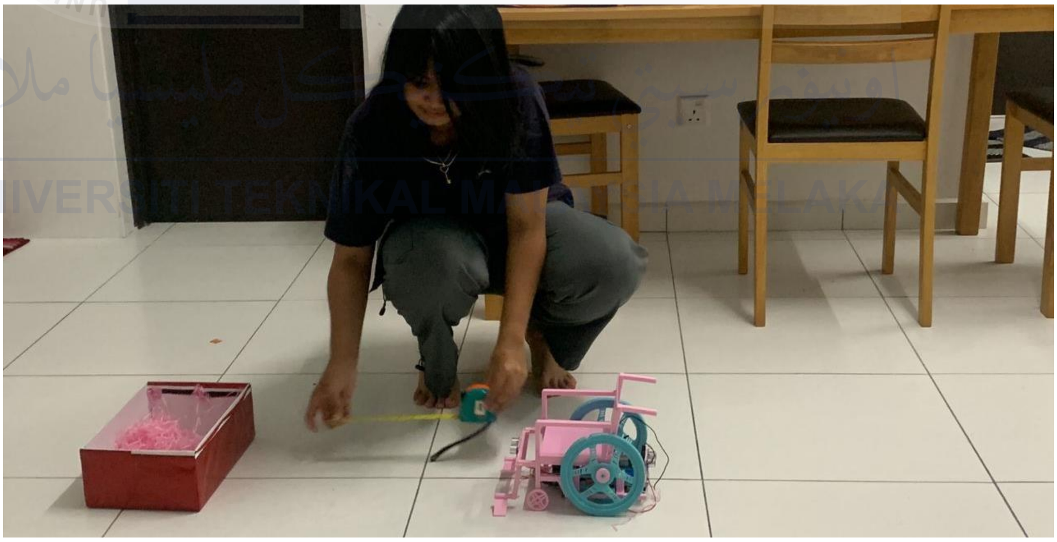


Figure 4.2 Measuring the distance between wheelchair and box



### 4.5.2 Obstacle Detection with Movement

The table below shows the data of obstacle detection with movement of the wheelchair. The dataset shows a steady trend where the accuracy of obstacle identification decreases as the wheelchair and pedestrians go farther apart. This is consistent with the difficulties that come with extended distances and highlights the requirement for accurate detection techniques.

The effect of wheelchair speed on detection accuracy is a remarkable finding. Examples of reduced accuracy at higher speeds highlight how crucial it is to adjust the system to function at its best in dynamic circumstances. The intricate nature of real-time obstacle detection is emphasised by the interaction between speed and accuracy.

Different accuracy percentages are displayed for each test case, demonstrating how flexible the system is in various situations. Test Case 3, with a rapid speed at the same distance, displays a lesser accuracy (82.4%), whereas Test Case 6, with a moderate pace at a 70 cm distance, records the greatest accuracy (99.3%). This variant highlights how important it is to take speed into account as a crucial component of detecting performance.

Interestingly, test cases run at moderate rates show consistently better accuracy than test cases run at slow or fast speeds. According to this research, a moderate speed setting offers useful information for system optimisation by striking a compromise between accuracy and real-time responsiveness.

Table 4.7 Obstacle detection with movement

| **TEST CASE** | **DISTANCE (cm)** | **SPEED** | **OBSTACLE TYPE** | **ACTUAL DISTANCE (cm)** | **DETECTED DISTANCE (cm)** | **ACCURACY (%)** |
|---|---|---|---|---|---|---|
| 1 | 20 cm | Slow | Pedestrians | 20 | 18.0 | 90.0 |
| | | Moderate | Pedestrians | 20 | 21.8 | 91.0 |
| | | Fast | Pedestrians | 20 | 25.2 | 82.4 |
| 2 | 30 cm | Slow | Pedestrians | 30 | 28.8 | 96.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Moderate | Pedestrians | 30 | 30.2 | 94.3 |
| | | Fast | Pedestrians | 30 | 35.0 | 85.71 |
| 3 | 40 cm | Slow | Pedestrians | 40 | 39.5 | 98.8 |
| | | Moderate | Pedestrians | 40 | 37.2 | 93.0 |
| | | Fast | Pedestrians | 40 | 41.8 | 94.5 |
| 4 | 50 cm | Slow | Pedestrians | 50 | 48.0 | 96.0 |
| | | Moderate | Pedestrians | 50 | 47.5 | 95.0 |
| | | Fast | Pedestrians | 50 | 51.0 | 94.0 |
| 5 | 60 cm | Slow | Pedestrians | 60 | 58.2 | 97.0 |
| | | Moderate | Pedestrians | 60 | 60.8 | 98.0 |
| | | Fast | Pedestrians | 60 | 63.2 | 95.3 |
| 6 | 70 cm | Slow | Pedestrians | 70 | 70.5 | 99.3 |
| | | Moderate | Pedestrians | 70 | 68.2 | 97.4 |
| | | Fast | Pedestrians | 70 | 71.8 | 94.7 |
| 7 | 80 cm | Slow | Pedestrians | 80 | 79.0 | 98.8 |
| | | Moderate | Pedestrians | 80 | 80.8 | 99.0 |
| | | Fast | Pedestrians | 80 | 85.0 | 94.3 |
| 8 | 90 cm | Slow | Pedestrians | 90 | 88.5 | 96.9 |
| | | Moderate | Pedestrians | 90 | 87.2 | 93.75 |
| | | Fast | Pedestrians | 90 | 91.0 | 95.5 |
| 9 | 100 cm | Slow | Pedestrians | 100 | 99.2 | 98.2 |
| | | Moderate | Pedestrians | 100 | 97.8 | 96.8 |
| | | Fast | Pedestrians | 100 | 103.0 | 91.0 |

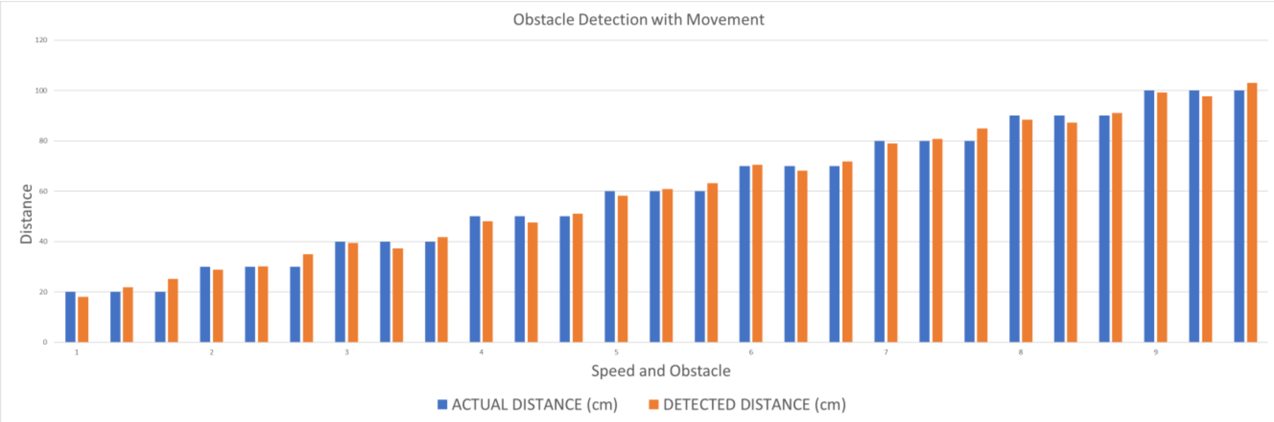



Figure 4.3 Graph of Obstacle Detection with Movement

The changes in obstacle detection accuracy are vividly summarised in Figure 4.3's graphical depiction. The graph is a useful tool for comprehending the dynamics of the system's performance as it gives a clear picture of the various accuracy percentages at various speeds and distances.

## 4.6 Navigation Accuracy

Table 4. 8 Navigation Accuracy

| TEST | DISTANCE TRAVELED (cm) | TARGET DISTANCE (cm) | ACCURACY (cm) |
|---|---|---|---|
| 1 | 19.0 | 20 | 95.0 |
| 2 | 31.0 | 30 | 96.8 |
| 3 | 38.0 | 40 | 95.0 |
| 4 | 53.0 | 50 | 94.3 |
| 5 | 64.0 | 60 | 93.8 |
| 6 | 69.0 | 70 | 98.6 |
| 7 | 75.0 | 80 | 93.8 |
| 8 | 87.0 | 90 | 97.7 |
| 9 | 98.0 | 100 | 98.0 |

The table above shows the data for Navigation Accuracy of the wheelchair. The dataset consists of nine tests, each of which represents a distinct situation in which the navigation system of the smart wheelchair was tested. The distance covered, the desired distance, and the accuracy % attained are all carefully documented during every test. This information provides a glimpse into the complex dynamics of the navigation system.

One startling finding appears in all tests: the accuracy ranges from 93.8% to 98.6%, and it stays high throughout. This consistent accuracy shows that, despite changes in the test conditions, the smart wheelchair's navigation system is dependable and excellent at keeping the wheelchair close to the target distances.

The dataset's inclusion of a range of target distances, from 20 to 100 cm, is one noteworthy characteristic. In spite of this variation, the accuracy percentages show how well the navigation system can adjust and maintain accuracy across a wide range of journey lengths. This flexibility highlights the technology's adaptability.

One notable example is Test 6, in which the navigation system's remarkable accuracy of 98.6% is attained. With a goal distance of 70 cm, the wheelchair covered 69 cm in this instance. The test's increased accuracy points to a particular situation in which the system not only met but exceeded expectations, demonstrating its potential for optimal performance.

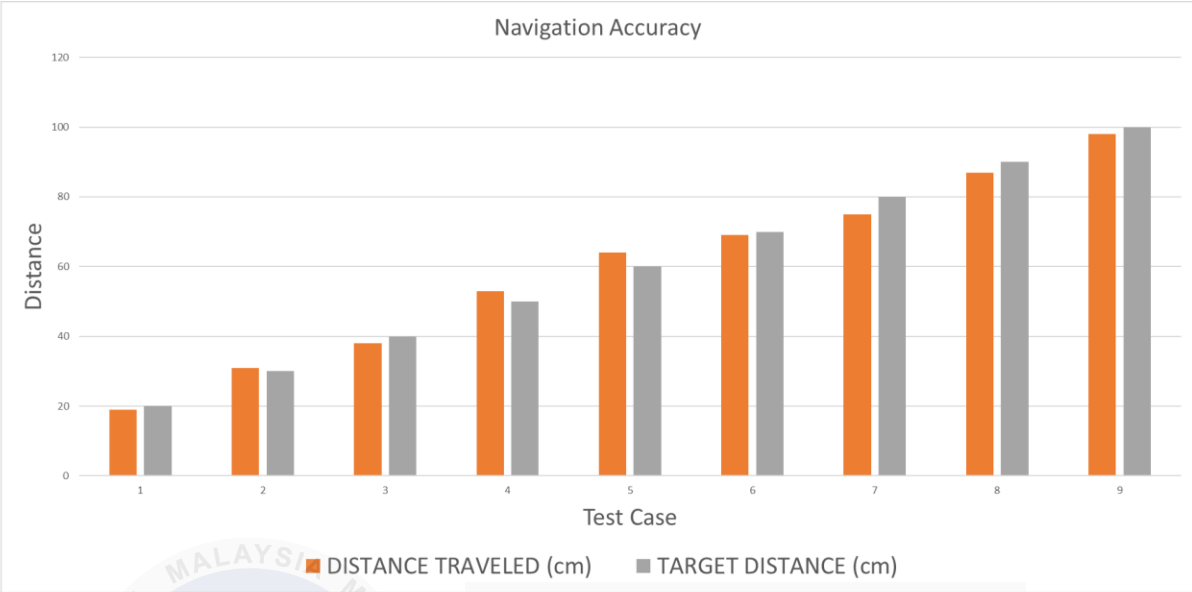



Figure 4.4 Graph of Navigation Accuracy

A visual story of the accuracy patterns seen in the tests is given by the data's graphical depiction in Figure 4.4. The accuracy's increasing trend indicates that the navigation system is generally effective. The graph's peaks and troughs show how accuracy varied across tests, providing a vivid picture of the dynamics of the system's performance.



## 4.7 Optimizing mobility: Battery Life

Mobility and energy efficiency are two complex topics covered in the final year project, "Smart Wheelchair for The Impaired," which explores the development of a sophisticated assistive technology solution. This essay focuses on the interesting topic of battery life, which is essential to maintaining functionality and satisfying users.

The project's three 3.7V lithium-ion batteries, which serve as its power supply, are its vital component. In addition to giving the wheelchair the energy it needs to move, this arrangement paves the way for a thorough investigation of the ways in which varying speeds affect the battery's overall lifespan.

A notable characteristic of the wheelchair is its capacity to adjust at different speeds, meeting the needs of users with different demands. With three different pace settings—slow, moderate, and fast—users may customise their mobility experience to suit their personal tastes and the demands of their surroundings.

The wheelchair has an astonishing three hours of battery life at its slowest setting. This longer length guarantees continued usage and corresponds with situations when a slower tempo is preferred, so fostering a comfortable and calm user experience. The battery life somewhat decreases to about two hours when the speed drops to a moderate level. This modification strikes a compromise between energy efficiency and effective mobility, satisfying customers who want a faster speed without sacrificing an impressive battery life. It makes sense that the battery life is reduced at the quickest speed level, just 45 minutes. This option is designed for situations where rapid thinking is essential, such squeezing through confined areas or reacting fast to obstructions. This is a shorter session, but the emphasis is on responsiveness and agility.

Users are guaranteed the freedom to select the mode that best meets their current demands thanks to the varied battery life across speed levels. The wheelchair adjusts to provide users a customised and optimal mobility experience, whether they are taking a leisurely stroll, navigating at a moderate speed, or responding quickly in a fast-paced setting.

## 4.8 Errors happened during project

My final year project involved developing and building a wheelchair with obstacle detection, which was a challenging but rewarding experience. A number of difficulties surfaced along the process, each requiring resilient thinking and innovative problem-solving.

The field of 3D printing presented one of the main challenges. Unexpected challenges were brought forth by the printing process' complexities, which ranged from material adhesion to calibration. An important wheelchair component—the printed tyre—scratched during the 3D printing process, forcing a reevaluation of the production method. In order to guarantee a more seamless production process, this setback prompted a careful review of printer settings and material qualities.

Measurement inaccuracies were yet another important obstacle. Even with careful preparation, mismeasurements resulted in misalignments and poorly fitting parts, which caused delays in the wheelchair's assembly and operation. To resolve this matter, a thorough examination of the original design requirements was necessary, highlighting the significance of accuracy in engineering projects.

The electronic parts of the project, particularly the motor driver, also had problems. The excessive current that caused the motor driver to fail highlighted how crucial power management was to the design. The wheelchair's motorized functioning was ensured to last for a long time by implementing an effective overcurrent protection and fine-tuning the motor control circuit.

Furthermore, the lack of a voltage divider contributed to the failure of the Bluetooth module, a crucial component of communication. This brought to light a crucial error in the circuitry and emphasised the importance of paying close attention to detail. After a careful examination of the electrical architecture, appropriate voltage control techniques were included, preventing further malfunctions and improving the communication system's overall dependability for the wheelchair.

Iterative design modifications and a methodical approach to troubleshooting were key components in resolving these obstacles. Every setback turned into a chance for growth and learning. The project's development was a dynamic process of adaptation and improvement rather than just a linear one.

The difficulties faced were an essential part of the story of the wheelchair with obstacle detection as it developed. The complexities of 3D printing, measurement errors, motor driver malfunctions, and Bluetooth module problems were all instructive in the complex dance between theory and application.

To sum up, the process of creating a wheelchair that can identify obstacles was fraught with difficulties, but each one helped the project progress and improved the team's ability to solve problems. The knowledge gained from conquering these obstacles emphasises the value of resiliency, flexibility, and a deep comprehension of the complexities required in transforming abstract ideas into working prototypes.

## 4.9 Chapter Summary

In conclusion, Chapter4 opens with the difficulties involved in setting up the smart wheelchair system are highlighted. The technical nuances discovered during implementation are illuminated by analyzing the subtleties involved in integrating sensors, software, and control systems into the current wheelchair infrastructure. Examined are the HC-SR04 ultrasonic sensors' accuracy and precision, which are essential parts for obstacle identification. The obstacle detection's sensors' accuracy for both static objects and moving pedestrians when it is presented in an everyday life setting. This careful calibration not only guarantees the best possible obstacle identification, but it also demonstrates the team's commitment to creating a dependable and cutting-edge assistive technology. The navigation accuracy to detect the measured distance and the actual distance are accurate and slightly inaccurate. The chapter also reveals the inherent uncertainties in such a large-scale development project, from the difficulties presented by 3D printing technology to measurement errors, motor driver failures, and Bluetooth module problems. Nevertheless, the project team perseveres, transforming every setback into an opportunity for growth and learning. The project team's continued journey is evidence of the tenacity and represents a major advancement in the field of assistive technology for those with mobility problems.

# CHAPTER 5

# CONCLUSION AND RECCOMENDATION

## 5.1 Conclusion

In this chapter the project's goals are outlined in the first chapter, which emphasizes the goal of creating a smart wheelchair in order to improve the quality of life for those with physical limitations. The project's scope, which involves integrating sensors, software, and control systems, is determined by the issues that wheelchair users have highlighted as well as the broader objectives of enhancing safety, independence, mobility, usability, and overall quality of life.

Entering Chapter 2, the Literature Review offers a thorough summary of the importance of smart wheelchairs in supporting people with disabilities. It explores the several functions provided by smart wheelchairs, such as obstacle identification, and emphasises the growing need for wheelchairs with cutting-edge technology. The chapter examines several sensor technologies, including computer vision, GPS, moisture, infrared, ultrasonic, laser, LiDAR, and others. It also offers insights into design tools and microprocessors, such as the Arduino Uno and Raspberry Pi.

The techniques used in the design and manufacture of the smart wheelchair are described in depth in Chapter 3, Methodology. It includes component selection, project flowchart, quality house development, morphological chart generation, design options, and microprocessor selection. In order to construct a smart wheelchair that improves mobility and safety for people with limited physical abilities, this chapter acts as an essential guide, making sure the project is in line with standards and objectives. This chapter also includes, the project team's dedication to comprehending customer demands and implementing insightful feedback into the design process

In-depth survey data analysis opens Chapter 4, Results and Discussion, showcasing the difficulties encountered in configuring the smart wheelchair system, highlighting the technological subtleties involved in fusing software, sensors, and control systems. Through painstaking calibration, the accuracy and precision of the HC-SR04 ultrasonic sensors for obstacle recognition are investigated, demonstrating the project team's commitment to state-of-the-art assistive technology. When encountered in a real-world scenario, the obstacle detection sensors' accuracy for both stationary objects and moving pedestrians This meticulous calibration shows the team's dedication to developing a dependable and state-of-the-art assistive technology in addition to ensuring the greatest possible obstacle recognition. Both the measured and real distances may be found with navigation accuracy that is both somewhat accurate and accurate. The project team perseveres in spite of the inherent uncertainties that come with a large-scale development project, as demonstrated by difficulties with 3D printing, measurement mistakes, motor driver failures, and Bluetooth module troubles. Every setback is seen as a chance for improvement and education, highlighting the team's perseverance and signifying a substantial breakthrough in assistive technology for people with mobility issues.

The obstacle detection feature of the smart wheelchair project is evidence of the team's commitment, creativity, and perseverance in meeting the diverse demands of people with physical limitations. The project is positioned as a noteworthy addition to the field of assistive technology due to its integration of sophisticated technologies and dedication to user-centric design. This opens the door for greater mobility and an improved quality of life.

## 5.2 Recommendation

The Smart Wheelchair for The Impaired research produced insightful findings and opened the door for ground-breaking suggestions meant to improve functioning and user experience. This article explores the main suggestions made by the study's analysis and results, providing a road map for enhancing and developing the smart wheelchair's functionalities.

A crucial suggestion is to incorporate state-of-the-art sensors—voice recognition and GPS, in particular. Users will find it more convenient to operate in a hands-free manner thanks to the integration of speech recognition technology. Concurrently, adding a GPS sensor improves navigational capabilities, enabling users to plan routes and navigate through outside situations with ease. This suggestion is in line with the larger objective of making the smart wheelchair the cutting edge of assistive technology.

The project's attention to sustainable development is emphasised through the advice to use eco-friendly materials and maximise energy efficiency. The focus also includes recycling concerns at the conclusion of the smart wheelchair's lifespan to ensure that the overall environmental effect is kept to a minimum. This commitment supports larger environmental conservation goals in addition to being consistent with the project's philosophy.

Providing a low-cost smart wheelchair with obstacle detection is advised as a means of democratising access to advanced assistive technologies. The group intends to increase the accessibility of this cutting-edge technology to a wider user base by streamlining production procedures, utilising cost-effective materials, and optimising design decisions. This suggestion is in line with the project's cost and inclusion goals.

The primary objective of the research is to enhance obstacle detection, and it is crucial to employ a blend of short- and long-range sensors for this purpose. By improving the wheelchair's understanding of its surroundings through several senses, this multi-sensor technique improves user safety and makes navigating easier. The suggestion emphasises how crucial a thorough obstacle detection system is.

The aim of improving sensor accuracy highlights the need for continuous development. The project team pledges to improve sensor calibration processes, use state-of-the-art sensor technology, and include feedback loops for in-the-moment modifications. This iterative procedure, which demonstrates a dedication to continuous improvement, guarantees the obstacle detection system functions with accuracy and dependability.

It is advised to install a joystick on the wheelchair model in addition to advancing technology. The interface's flexibility is increased by this extra control option, which accommodates users with a range of mobility needs and preferences, including those who might prefer manual control. The joystick offers a layer of versatility to the smart wheelchair's interface.

Considering how crucial user experience is, one of the main project objectives is to improve the user interface. This advice includes making sure controls are optimised, adding user-friendly design elements, and making sure interactions are intuitive. The user interface of the smart wheelchair has been prioritised in order to fulfil the diverse needs of its user base by making it more accessible and user-friendly.

Prioritising user safety, it is advised to incorporate safety elements other than obstacle detection. This might entail combining collision avoidance, emergency braking, and smart alarm systems. The diverse strategy guarantees a comprehensive focus on improving user safety in general when using a wheelchair.

To sum up, the study's suggestions offer a thorough road map for developing the Smart Wheelchair for the Impaired. Every suggestion, from technological integrations to user-centric improvements and sustainability considerations, advances the overall objective of developing an assistive technology solution that is not only state-of-the-art but also inclusive, reasonably priced, and places a high priority on user safety and satisfaction. With a dedication to constant innovation and advancement, the roadmap presented by these suggestions places the smart wheelchair at the forefront of assisted mobility solutions.

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# APPENDICES

## Appendix A

Table 4.3 First Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 1 | 20 | 22 | 10 |
| 1 | 30 | 28 | -6.67 |
| 1 | 40 | 42 | 5 |
| 1 | 50 | 49 | -2 |
| 1 | 60 | 62 | 3.33 |
| 1 | 70 | 69 | -1.43 |
| 1 | 80 | 78 | -2.5 |
| 1 | 90 | 93 | 3.33 |
| 1 | 100 | 98 | -2 |

Table 4.4 First Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 1 | 20 | 21 | -1 |
| 1 | 30 | 28 | 2 |
| 1 | 40 | 39 | 1 |
| 1 | 50 | 51 | -1 |
| 1 | 60 | 58 | 2 |
| 1 | 70 | 71 | 1.43 |
| 1 | 80 | 78 | -2.5 |
| 1 | 90 | 89 | -1.11 |
| 1 | 100 | 100 | 0 |

Table 4.5 Second Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 2 | 20 | 18 | -10 |
| 2 | 30 | 31 | 3.33 |
| 2 | 40 | 42 | 5 |
| 2 | 50 | 47 | -6 |
| 2 | 60 | 61 | 1.67 |
| 2 | 70 | 69 | -1.43 |
| 2 | 80 | 84 | 5 |
| 2 | 90 | 91 | 1.11 |
| 2 | 100 | 102 | 2 |



Table 4.6 Second Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 2 | 20 | 18 | -10 |
| 2 | 30 | 30 | 0 |
| 2 | 40 | 39 | -2.5 |
| 2 | 50 | 51 | 2 |
| 2 | 60 | 63 | 5 |
| 2 | 70 | 73 | 4.29 |
| 2 | 80 | 77 | -3.75 |
| 2 | 90 | 93 | 3.33 |
| 2 | 100 | 98 | -2 |

Table 4.7 Third Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 3 | 20 | 21 | 5 |
| 3 | 30 | 32 | 6.67 |
| 3 | 40 | 41 | 2.5 |
| 3 | 50 | 48 | -4 |
| 3 | 60 | 60 | 0 |
| 3 | 70 | 68 | -2.86 |
| 3 | 80 | 81 | 1.25 |
| 3 | 90 | 88 | -2.22 |
| 3 | 100 | 101 | 1 |

Table 4.8 Third Sensor Callibration

| SENSOR | KNOWN DISTANCE (CM) | MEASURED DISTANCE (CM) | CALIBRATION ERROR (%) |
|---|---|---|---|
| 3 | 20 | 19 | -5 |
| 3 | 30 | 29 | -3.33 |
| 3 | 40 | 42 | 5 |
| 3 | 50 | 48 | -4 |
| 3 | 60 | 59 | -1.67 |
| 3 | 70 | 74 | 5.71 |
| 3 | 80 | 79 | -1.25 |
| 3 | 90 | 89 | -1.11 |
| 3 | 100 | 99 | -1 |

Table 4.9 Third Sensor Callibration

| **SENSOR** | **KNOWN DISTANCE (CM)** | **MEASURED DISTANCE (CM)** | **CALIBRATION ERROR (%)** |
|---|---|---|---|
| 3 | 20 | 21 | 5 |
| 3 | 30 | 29 | -3.33 |
| 3 | 40 | 41 | 2.5 |
| 3 | 50 | 50 | 0 |
| 3 | 60 | 61 | 1.67 |
| 3 | 70 | 73 | 4.29 |
| 3 | 80 | 80 | 0 |
| 3 | 90 | 89 | -1.11 |
| 3 | 100 | 98 | -2 |

**Appendix B**

Code of the system:

```
#include <NewPing.h>
#include <SoftwareSerial.h>

//#define TRIG_PIN1 2
//#define ECHO_PIN1 3
#define TRIG_PIN2 4
#define ECHO_PIN2 5
#define TRIG_PIN3 6
#define ECHO_PIN3 7

#define MAX_DISTANCE 100

#define MOTOR1_IN1 8
#define MOTOR1_IN2 9
#define MOTOR2_IN3 10
#define MOTOR2_IN4 11

NewPing sonar1(TRIG_PIN2, ECHO_PIN2, MAX_DISTANCE);
NewPing sonar2(TRIG_PIN3, ECHO_PIN3, MAX_DISTANCE);

SoftwareSerial bluetooth(0, 1); // TX, RX


void setup()
{
  Serial.begin(9600);
  bluetooth.begin(9600);

  pinMode(MOTOR1_IN1, OUTPUT);
  pinMode(MOTOR1_IN2, OUTPUT);
  pinMode(MOTOR2_IN3, OUTPUT);
  pinMode(MOTOR2_IN4, OUTPUT);
}

void moveForward()
{
  digitalWrite(MOTOR1_IN1,LOW);
  digitalWrite(MOTOR1_IN2, HIGH);
  digitalWrite(MOTOR2_IN3, HIGH);
  digitalWrite(MOTOR2_IN4, LOW);
}

void turnLeft()
{
  digitalWrite(MOTOR1_IN1, LOW);
```

```
  digitalWrite(MOTOR1_IN2, HIGH);
  digitalWrite(MOTOR2_IN3, LOW);
  digitalWrite(MOTOR2_IN4, HIGH);
}

void moveBackward()
{
  digitalWrite(MOTOR1_IN1, HIGH);
  digitalWrite(MOTOR1_IN2, LOW);
  digitalWrite(MOTOR2_IN3, LOW);
  digitalWrite(MOTOR2_IN4, HIGH);
}

void turnRight()
{
  digitalWrite(MOTOR1_IN1, HIGH);
  digitalWrite(MOTOR1_IN2, LOW);
  digitalWrite(MOTOR2_IN3, HIGH);
  digitalWrite(MOTOR2_IN4, LOW);
}

void stopMotors()
{
  digitalWrite(MOTOR1_IN1, LOW);
  digitalWrite(MOTOR1_IN2, LOW);
  digitalWrite(MOTOR2_IN3, LOW);
  digitalWrite(MOTOR2_IN4, LOW);
}

void loop()
{
  if (bluetooth.available() > 0)
   {
    char command = bluetooth.read();
    Serial.print("Received Command: ");
    Serial.println(command);

    switch (command)
    {
      case 'F':
        moveForward();
        break;

      case 'B':
        moveBackward();
        break;

      case 'L':
        turnRight();
        break;
```

```
      case 'R':
        turnLeft();
        break;

      case 'S':
        stopMotors();
        break;


      default:
        break;
    }
  }

   else
   {
    // If no Bluetooth command is received, continue with the previous command
  }


  // Add obstacle avoidance logic using ultrasonic sensors here

  int distance2 = sonar1.ping_cm();
  int distance3 = sonar2.ping_cm();


  Serial.println("Distance 1: ");
  Serial.print(distance1);
  Serial.print(" cm\t");

  Serial.println("Distance 2: ");
  Serial.print(distance2);
  Serial.print(" cm\t");


  // Adjust these values based on your specific requirements
  if (distance1 >= 90 || distance2 >= 90 )
  {
    // If an obstacle is detected, stop the motors
    stopMotors();
  }

  else
  {
    // If no obstacle, continue with the previous command
    // You might want to add more sophisticated logic here
  }
}
```