DEVELOPMENT OF IOT BASED SMART BLIND MAN STICK USING ESP32-CAM

MUHAMMAD FAEZ HAKIMI BIN ANUWAR

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF IOT BASED SMART BLIND MAN STICK USING ESP32-CAM

MUHAMMAD FAEZ HAKIMI BIN ANUWAR

This report is submitted in partial fulfilment of the requirements
for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

Faculty of Electronics and Computer Engineering and Technology

Universiti Teknikal Malaysia Melaka

2025

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRONIK DAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Development of IoT Based Smart Blind Man Stick Using ESP32-CAM

Sesi Pengajian : 2024

Saya **MUHAMMAD FAEZ HAKIMI BIN ANUWAR** mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hak milik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

☐	SULIT*	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD*	(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
/	TIDAK TERHAD	

Disahkan oleh:

.... (TANDATANGAN PENULIS)
Alamat Tetap:

.... (COP DAN TANDATANGAN PENYELIA)
TS. DR. SITI HALMA BINTI JOHARI
PENSYARAH KANAN
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRONIK DAN KOMPUTER (FTKEK)
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Tarikh: 28th January, 2025

Tarikh: 28th January, 2025

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this report entitled "Development of IoT Based Smart Blind Man Stick Using ESP32-CAM" is the result of my own research except for quotes as cited in the references.

Signature : ....

Student Name : MUHAMMAD FAEZ HAKIMI BIN ANUWAR

Date : 28th January, 2025

APPROVAL

I declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours.

Signature	:	....
Supervisor Name	:	TS. DR. SITI HALMA BINTI JOHARI
Date	:	28th January, 2025

Signature	:	....
Co-Supervisor Name (if any)	:	PUAN RAEIHAH BINTI MOHD ZAIN
Date	:	28 January, 2025.

DEDICATION

This thesis is dedicated to all people who help me from the beginning until the end of the project's development, Especially to my beloved mother, father, and family. Also, my supervisor, co-supervisor, lecturer and all my fellow friends. Thank you for all the guidance support and encouragement up to this point.

ABSTRACT

The issue of blind individuals getting lost or disoriented is a significant concern, as it directly impacts their safety, independence, and quality of life. This project aims to create a Smart Blind Man Stick using the ESP32-CAM microcontroller, GPS module, ultrasonic sensor, buzzer, vibration motor, and integrated camera for the Internet of Things (IoT). The project is designed to provide real-time navigation assistance for visually impaired individuals. It uses advanced sensing and communication technologies to improve mobility and safety. The ESP32-CAM microcontroller functions as the central hub, collecting data from various sensors, and providing real-time location tracking and feedback through a designated mobile app. The initial tests show that the project effectively guides users through city areas, identifies obstacles, and seamlessly interacts with the mobile app to improve user experience. Overall, the project offers a promising solution to help blind individuals navigate their surroundings more independently and safely.

ABSTRAK

Isu individu buta yang tersesat atau hilang arah merupakan kebimbangan yang signifikan kerana ia secara langsung mempengaruhi keselamatan, kebebasan, dan kualiti hidup individu buta. Projek ini bertujuan untuk mencipta Smart Blind Man Stick menggunakan mikropengawal ESP32-CAM, modul GPS, sensor ultrasonik, buzzer, motor getaran dan kamera bersepadu untuk Internet of Things (IoT). Projek ini direka untuk menyediakan bantuan navigasi masa nyata untuk individu cacat penglihatan. Ia menggunakan teknologi penderiaan dan komunikasi termaju untuk meningkatkan mobiliti dan keselamatan. Mikropengawal ESP32-CAM berfungsi sebagai hab pusat, mengumpul data daripada pelbagai penderia, dan menyediakan penjejakan dan maklum balas lokasi masa nyata melalui aplikasi mudah alih yang ditetapkan. Ujian awal menunjukkan bahawa projek itu membimbing pengguna dengan berkesan melalui kawasan bandar, mengenal pasti halangan dan berinteraksi dengan lancar dengan apl mudah alih untuk meningkatkan pengalaman pengguna. Secara keseluruhannya, projek ini menawarkan penyelesaian yang menjanjikan untuk membantu individu buta menavigasi persekitaran mereka dengan lebih bebas dan selamat.

ACKNOWLEDGEMENT

First, I want to sincerely thank my project supervisor, TS. SITI HALMA BINTI JOHARI, and to my co-supervisor, PUAN RAEIHAH BINTI MOHD ZAIN, for all their advice and important skills. Without them, this project would not have been possible. I also want to thank my friends and family for their constant encouragement and support. Their confidence in my skills gave me the will to excel. Additionally deserving of gratitude is Universiti Teknikal Malaysia Melaka, which supplied the facilities and resources essential to this project's successful completion. Finally, I would like to thank the scientific community for its contributions, whose discoveries and debates influenced and enlightened my work. Without the pooled expertise and security system developments, this endeavour would not have been feasible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

GPS	-	Global Positioning System.
IoT	-	Internet of Things.
SDG	-	Sustainable Development Goals.
IR	-	Infrared Radiation.
LDR	-	Light Dependent Resistor.
SMS	-	Short Message Service.
PIC	-	Peripheral Interface Controller.
PCB	-	Printed Circuit Board.
Vcc	-	voltage at the common collector.
GND	-	Ground.
SOS	-	Emergency code.
Wi-Fi	-	Wirless Fidelity.
QR	-	Quick Response,
GPIO	-	general-purpose input/output.
COM	-	common.
UART	-	universal asynchronous receiver / transmitter.
IDE	-	Integrated Drive Electronics.

CHAPTER 1

INTRODUCTION

This chapter describes the project background, problem statement, objectives, and scope of work in developing IoT Based Smart Blind Man Stick Using ESP32-CAM.

1.1 Background

The internet has become an essential part of our daily lives, revolutionizing the way electronic devices are used to simplify tasks. It serves as a powerful tool for searching, storing, and managing information. The development of an IoT-based Smart Blind Man Stick using ESP32-CAM will greatly benefit blind individuals and the caregivers. This project aims to enhance blind people safety and efficiency, enabling blind people to be more aware of their surroundings while allowing the guardians to track blind people whereabouts.

1.2 Problem Statement

The Smart Blind Man Stick project aims to tackle challenges faced by visually impaired individuals. Traditional blind sticks have limitations in detecting obstacles beyond their immediate reach, which can lead to accidents. To overcome this, the project integrates an ultrasonic sensor that detects obstacles in real time and alerts the user through a buzzer and vibration motor. Additionally, guardians often struggle to monitor the whereabouts of blind individuals, especially outdoors. The lack of visual awareness also poses difficulties for blind users in assessing the environment. By enhancing the safety and mobility of visually impaired individuals, this project supports the United Nations Sustainable Development Goal (SDG) 3: Good Health and Well-being, and SDG 11: Sustainable Cities and Communities.

1.3 Project Objectives

The main aim of this project is to propose IoT Based Smart Blind Man Stick Using ESP32-CAM. Specifically, the objectives are as follows:

1. To develop obstacle detection system using ultrasonic sensor.
2. To develop a real-time position tracking system using GPS module and ESP32-CAM.
3. To analyze the system performance in term of accuracy of obstacle detection, real-time tracking capability and data transmission.

1.4 Scope of Work

The project scope of developing IoT Based Smart Blind Man Stick Using ESP32-CAM is as follows:

1. The main component use for this project is ultrasonic sensor, it use to detect obstacles based on its purpose.
2. This project focuses on blind people only

3. Sensors and microcontroller are communicated wirelessly using ESP32-CAM WiFi module.
4. An auditory alarm system featuring a buzzer and a vibration motor will be integrated to foster hazard awareness.
5. GPS and ESP32-CAM are used by guardian to identify the exact location of the Smart Blind Man Stick user.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a broad overview of the project related to the topic in this report. Besides, the relevant literature is critically discussed and presented later in this chapter.

2.1 Introduction

A literature review is an explanation that is theoretical or project-based. To put it briefly, every aspect and phase of the project's implementation is covered in this report. At this stage of the project planning process, the project's aims and objectives are taken into account together with the raw resources required to finish the project. The goal of this project is to facilitate more confident walking in the blind community.

2.2 Past Related Project Research

2.2.1 Smart Blind Stick

The Figure 2.1 shows the working flow of the blind man's stick. For safe walking, blind persons require assistance or assistance from others. A smart blind stick can be a useful tool to support blind people when walk.

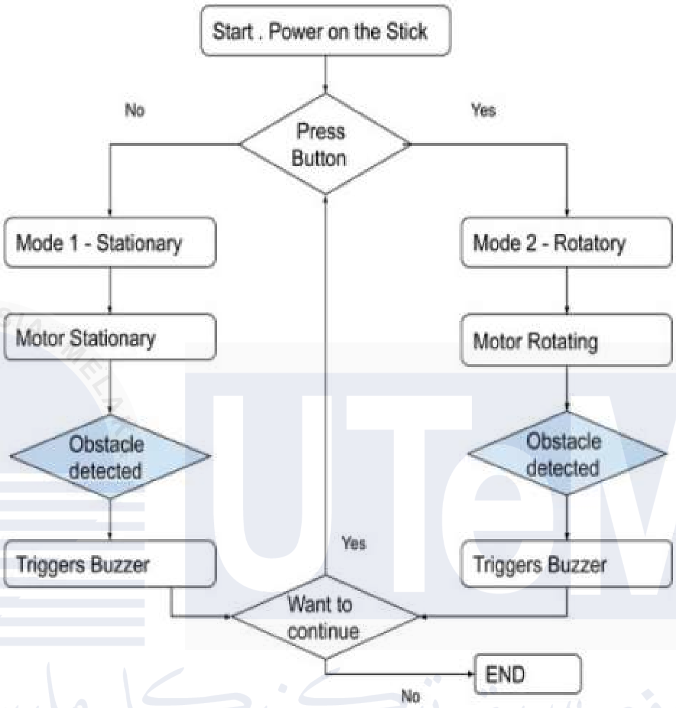


Figure 2.1: Stick Flowchart.

In this study, it suggest a Smart Stick. A stick with all the sensors and components installed on top of it. This smart stick essentially functions in two ways. Case 1 uses an ultrasonic sensor on the stick to identify obstacles in front of it, whereas Case 2 uses a servo motor to spin the ultrasonic sensor at an angle to identify obstacles in congested areas. Obstacle detection in both situations triggers a buzzer sound to notify the blind individual.The switch button is used to shift from case 1 to case 2 and vice-versa. This stick can detect all the obstacles in its range. Proper environments to use are also identified. By using this smart stick, the blind person can walk with confidence and overcome his fear while walking. The stick has a button switch mounted on it such that the user can switch between the two modes of operation of the stick[2]. Whenever in a crowded place, the user can switch to mode 2 such that the user will be able to identify obstacles from sideways also. If the user wants to switch off the stick, then the user just needs to put off the main switch of the switch.

2.2.2 Designing Sensor Based Smart Stick for Handicapped Person

Based on Figure 2.2, this is how a conceptual device looks like. This is made up of an Arduino Uno circuit with water and ultrasonic detectors, together with a GPS, IR, pulse and cardiac sensors, and an IR sensor[3]. An LDR, a noe6 model, and other parts. The diagram shows the circuit diagram of this system.

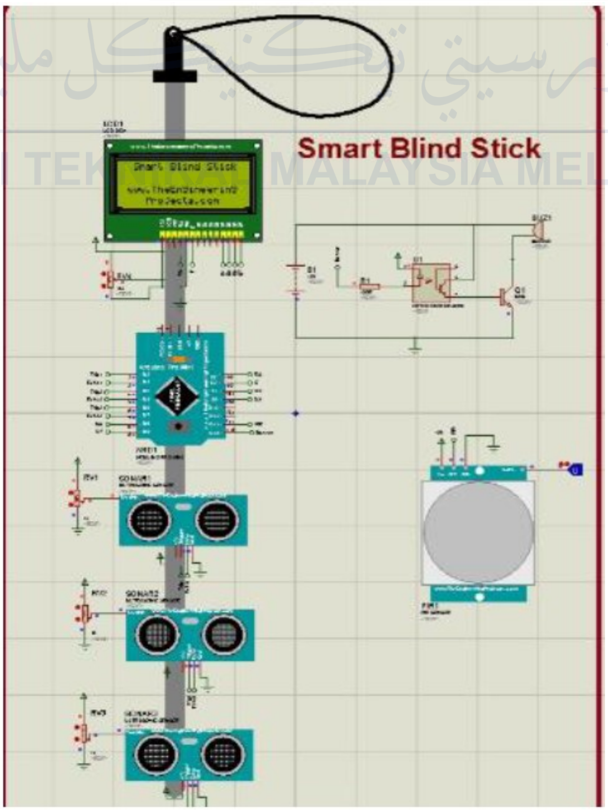


Figure 2.2: Circuit Diagram.

2.2.3 Design and Construction Of A Smart Ultrasonic Walking Stick For The Visually Impaired

Figure 2.3 show the circuit diagram for audio feedback. The circuits of the separate components have been merged to form the overall circuit. By controlling each person's intended output, switches two and three optimise the user interface. The audio jack that will be connected to the earphones is represented by the speaker symbol. The Matlab convolution neural network code, which was then converted to C using the C Matlab encoder, was the source of the C code that was programmed on the Arduino[4]. The CIFAR 10 dataset was used to train the programme (unsupervised) at first.

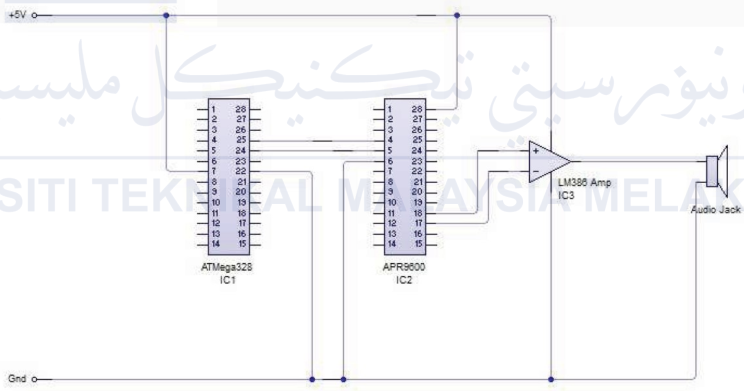


Figure 2.3: Circuit Diagram for Audio Feedback.

2.2.4 Visually Impaired Smart Assistance

Figure 2.4 and Figure 2.5 show the smart stick model and voice assistant headband. The Visually Impaired Stick will enable the blind community to travel freely and independently of one another's assistance. With the assistance of these built-in sensors on the stick, users may travel anywhere and feel comfortable and secure. If the user clicks the button, the latitude and longitude coordinates inherited from the Google Maps position are immediately sent via SMS to the pre-registered cellphone numbers in case the user feels lost[1]. The headband will provide the locations nearby if the wearer is interested in knowing where the location, as seen in Figure 2.4. The voice assistant now has a lot more options to guarantee appropriate and cordial interactions with the user. Based on Figure 2.5, the figure show the functionality of the stick.

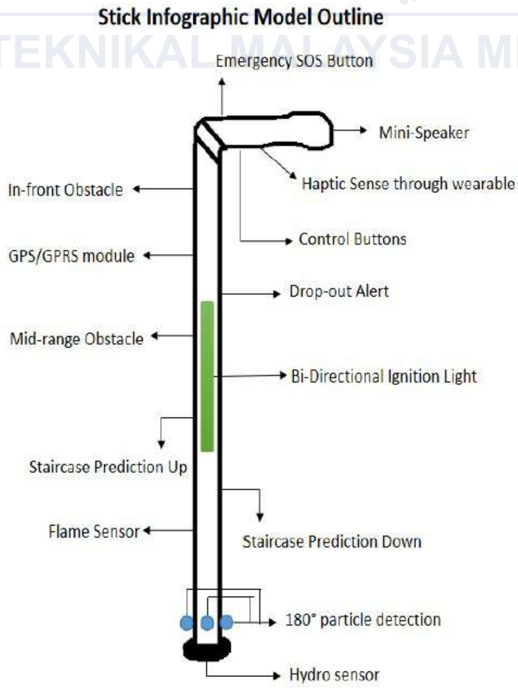


Figure 2.4: Smart Stick model with Integrated Features.

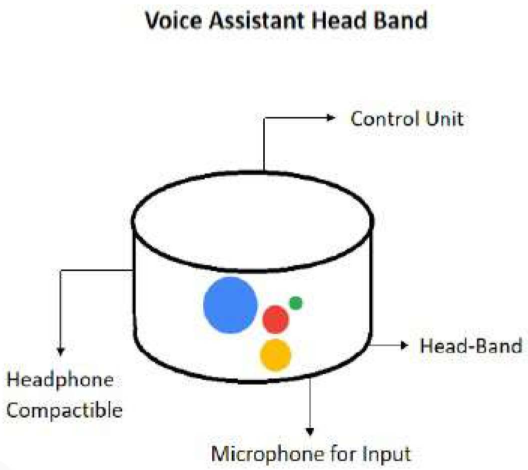


Figure 2.5: Voice assistant headband.[1]

2.2.5 Ultrasonic Sensor Based Smart Blind Stick

The architecture of this project involves the incorporation of the several steps as seen in Figure 2.6. Firstly, three ultrasonic sensors are use to sense object on the right, left and in front respectively[5]. Next, the PIC microcontroller will programmed to calculate the distance of any object from the sensor. This coding will be done in C language. Lastly, buzzer will make a sound when obstacle is detected.

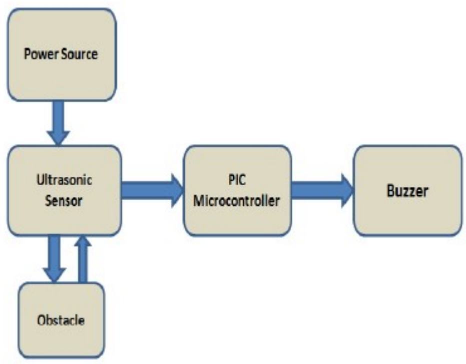


Figure 2.6: Block diagram of the total system.

2.2.6 Virtual Smart Glass for Blind using Object Detection

The Raspberry Pi 3, which has four cores and can recognise objects in photos and videos, performs around 50–60% better in 32-bit mode and is ten times quicker than the first Raspberry Pi, which only had one core. This is shown in Figure 2.7. Additionally, the camera that is positioned in front of the camera slot uses a detection method to identify pictures, and glasses that use computer vision techniques and pattern recognition systems to identify each item in front of the camera may take images. The technology can determine how far away a user is from any given object. It then translates that information into voice instructions that the blind user can understand using earbuds and alerts them to when they are getting close to the thing. The suggested system is well-trained and offers a special uniqueness in that it may produce simple yet accurate detection findings. The virtual glass can assist the blind while the blind are out on their own in an outdoor setting since it uses the strip camera's output as its input and then sends feedback to the user via earbuds[6]. This type of computing gadget is worn on the head. The camera adapts to the location and orientation of the wearer of the glasses when the blind move, allowing it to capture crisp images. In light of this, the glasses stand out from other similar computer devices and are intelligent.

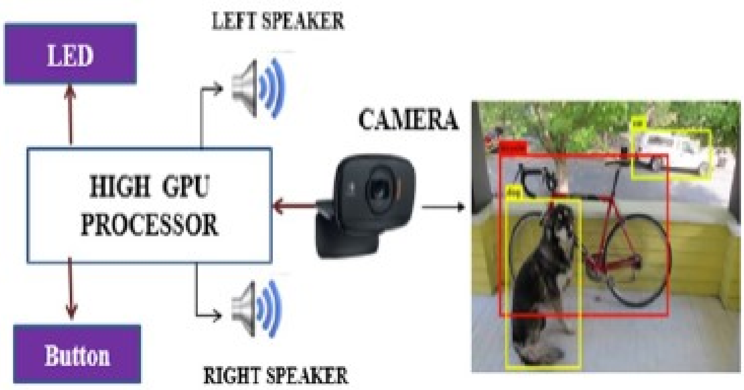


Figure 2.7: Block diagram of the proposed work.

2.2.7 Design and Implementation of Voice Assisted Smart Glasses for Visually Impaired People Using Google Vision API

Figure 2.8 show the architecture diagram of designing of voice assisted smart glasses. The suggested wearable system consists of an output screen, a processing unit-mounted obstacle detection module, and a pair of spectacles[7]. The output panel element alerts the user to the power supply and obstacle incursion by beeping. The processing unit is connected to the output panel assembly and the obstacle detection module. The central processing unit will be powered by electricity generated from the energy source, as seen in Figure 2.8. The control module is implemented using the ultrasonic sensor. The ultrasonic sensors are under the control of the control unit. They collect data on the barrier in front of the person, analyse it, and provide feedback via a buzzer. The Ultrasonic Smart Glasses for Blind People are inexpensive, lightweight, portable, user-friendly, and simple to operate gadgets. The blind can simply be helped and guided by these spectacles.

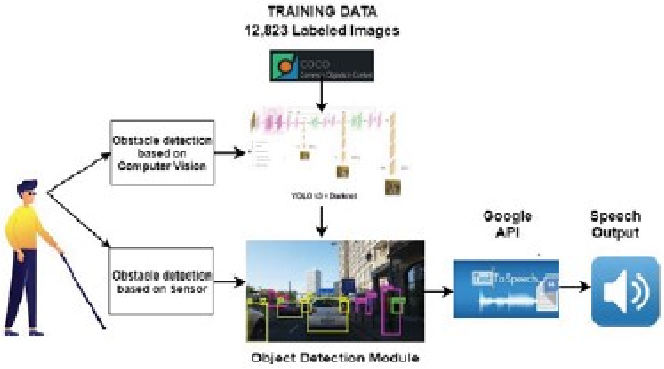


Figure 2.8: Architecture diagram of designing of voice assisted smart glasses.

2.2.8 Smart Stick For Blind People

The smart stick, which is accessible to the blind community, uses infrared and ultrasonic sensors to identify the presence of impediments[8]. Transceiver and receiver modules are present in ultrasonic sensors. Ultrasonic waves are sent by the transmitter module to identify obstructions within a 4-meter range. The obstacles' ultrasonic waves are picked up by the receiver module. The vibrator motor vibrates in response to signals sent by the receiver. An infrared sensor can detect changes in ambient temperature as well as the presence or absence of water. By measuring an obstacle's temperature, infrared sensors can locate it. Buzzer receives signals from an infrared sensor. The blind individual is alerted by an auditory cue provided by the buzzer, as shown in Figure 2.9.

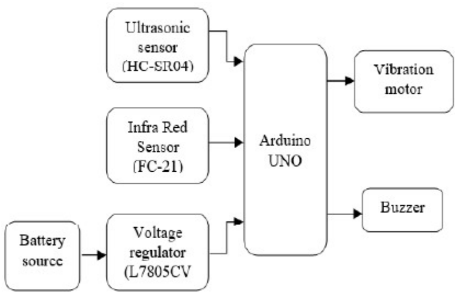


Figure 2.9: Block diagram of smart stick.

2.2.9 Smart Blind Stick Using Node MCU with Voice Alert

The following parts make up the architecture for this gadget, which is seen in Figure 2.10. A PCB board, an ESP-32, an ultrasonic sensor, a buzzer, and a voltage regulator. The Vcc of the Ultrasonic Sensor should be connected to GND, Trig to GPIO 19, Echo to GPIO 18, and Gnd to GPIO 5. For the Voice Playback Module, connect the negative terminal to GND and the positive terminal to 5V[9].

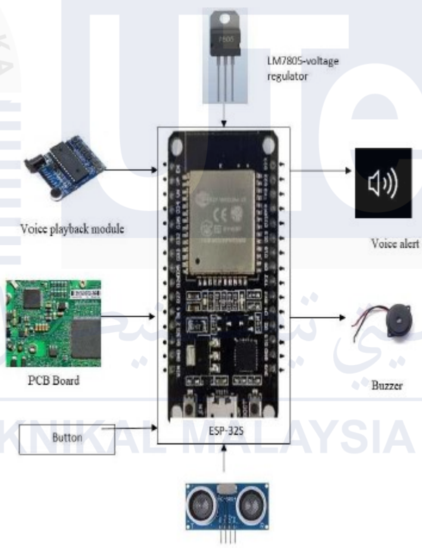


Figure 2.10: Architecture diagram for blind stick.

2.2.10 Smart Walking Stick for Blind integrated with SOS Navigation System

Based on Figure 2.11, the project concept intends to make travelling between locations easier for blind individuals. Object detection and alarm system is the initial idea. Ultrasonic sensors are used to identify obstacles. The prototype employs three ultrasonic sensors: one facing the stick's front, one facing its right, and one facing its left for orientation. The sensors use sound technology to detect the obstructions in the immediate area[10]. The Raspberry Pi microcontroller interprets the data produced by the sensor and Determine how far away the obstruction is. An alarm signal indicating the obstacle's closeness is generated if the distance falls below the threshold. The blind individual can use an SOS-based video call approach to contact the guardian if obstacle detection technology bothers the user. A friend or member of the family. All it takes to switch this facility on is pressing the switch button on the stick. The family member's Android phone receives a notice alerting family's member to the blind person's emergency assistance message. When the notification message is clicked to open, the video streaming begins and the blind person's distress signal is included. The family member has access to a live feed of the surrounding area captured by the stick-mounted camera. As a result, the family member can direct the blind person towards the proper direction.

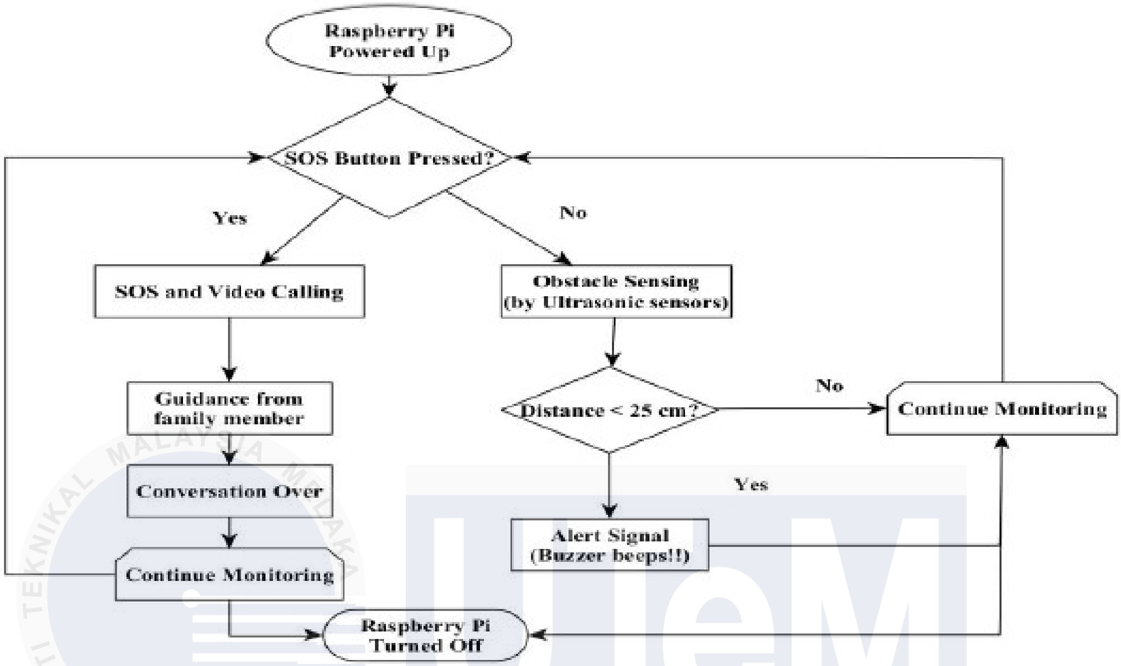


Figure 2.11: Overall system design.

2.3 Comparison Between Past Related Projects

The table 2.1 show the comparison between past related project from the aspect of advantages and disadvantages.

Table 2.1: Summary of the previously proposed techniques

Authors	Proposed Technique	Advantage(s)	Disadvantage(s)
Chavan *et al.*, [2]	Smart Blind Stick	• The stick can detect obstacles not only from the front, but also from the sides of the user. • The stick provides auditory feedback to the user about detected obstacles.	• The increased complexity may reduce the simplicity and ease of use. • Cost of the smart blind stick making it less accessible for some blind individuals.
Kaif *et al.*, [3]	Designing Sensor Based Smart Stick for Handicapped Person.	• The blind person carries an RF transmitter that beeps when they press a button, allowing them to locate the stick. • The smart stick is compact, lightweight, and easy to use.	• With more components and electronics, there is a higher chance of malfunctions or failures. • The smart blind stick becomes heavily dependent on technology.
Omoregbee *et al.*, [4]	Design And Construction Of A Smart Ultrasonic Walking Stick For The Visually Impaired	• It operates efficiently with low power requirements . • The sensors used are highly accurate for detecting obstacles.	• There may be a need for regular maintenance. • Potential for technical issues which could affect the stick's performance.
Dharan *et al.*, [1]	Visually Impaired Smart Assistance	• Smart devices provide improved navigation capabilities. • Many devices offer real-time feedback and guidance, which is crucial for safe and effective mobility.	• While some devices are designed to be economical, the cost can still be a barrier for many individuals. • Could be problematic if the device fails or runs out of power.
Dey *et al.*, [5]	Ultrasonic Sensor Based Smart Blind Stick	• Sounds a buzzer to alert the user when an obstacle is detected. • Can detect obstacles within a range of 5-35 cm, providing a useful linear working range.	• Some designs rely on GPS, which cannot be used effectively indoors where there is no GPS signal. • The complexity and advanced features of some of the designs make them too expensive.

Continued from previous page . . .

Authors	Proposed Technique	Advantage(s)	Disadvantage(s)
Raj *et al.*, [6]	Virtual Smart Glass for Blind using Object Detection	• The device is portable, wearable, and can be easily used by the blind user. • The device uses advanced computer vision techniques like segmentation.	• Even if certain technologies are designed to be inexpensive, many people may find the price to be a barrier. • Can cause issues if the gadget malfunctions or runs out of electricity.
Rajendran *et al.*, [7]	Design and Implementation of Voice Assisted Smart Glasses for Visually Impaired People Using Google Vision API	• The smart glasses use Google Vision API to detect objects in the user's surroundings. • Instead of relying on alarm signals, the system provides a speech-based interface.	• Developing and maintaining such a system can be expensive. • Users may worry about their privacy and the potential misuse of their data.
Loganathan *et al.*, [8]	Smart Stick for Blind People	• A buzzer is used to provide an audible alert to help the user find the stick. • This can improve their quality of life, social interaction, and employment opportunities.	• Reliance on technologies like GPS that may not be available in all environments. • Lack of analysis and solutions from the perspective of visually impaired perception.
Dilli *et al.*, [9]	Smart Blind Stick Using Node MCU with Voice Alert	• The ultrasonic sensor on the stick uses ultrasonic waves to detect obstacles in front of the user. • The ultrasonic sensor can also estimate the distance between the user and the detected object.	• Dependence on technologies—such as GPS—that aren't always accessible. • Absence of examination and remedies from the viewpoint of blind perception.
Mohapatra *et al.*, [10]	Smart Walking Stick for Blind Integrated with SOS Navigation System	• It uses ultrasonic sensors to detect obstacles. • It addresses the limitations of traditional obstacle detection methods by using more advanced sensors and technology.	• The system relies heavily on technology. • The implementation of the system, may be relatively expensive.

2.4 Summary

This literature review reveals that the majority of projects aimed at aiding the visually impaired heavily rely on ultrasonic sensors and buzzers as primary input and output components, respectively, for obstacle detection and auditory feedback. Additionally, a significant portion integrates GPS modules for real-time location tracking and navigation assistance. While less prevalent, some projects also incorporate vibration motors and ESP32-CAMs to provide tactile feedback and capture visual information, respectively. Such multifaceted approaches underscore efforts to empower individuals with visual impairments, fostering greater confidence, mobility, and independence in navigating their surroundings. The next chapter methodology will cover about block diagram, hardware, software, flowchart and summary for methodology

CHAPTER 3

METHODOLOGY

This chapter describes the methodology and design steps to develop IoT Based Smart Blind Man Stick Using ESP32-CAM.

3.1 Introduction

The main project components will be covered in this part, along with the techniques and approaches used to make sure all project requirements were satisfied. This section explains the main components and offers a brief overview of the actions that must be followed. This part is crucial for figuring out whether the system functions as expected and whether the project phase in this portion is whether the system operates smoothly.

3.2 Block Diagram

Figure 3.1 shows the block diagram that illustrates a system that combines various input and output components with a central processing unit, the ESP32-CAM.

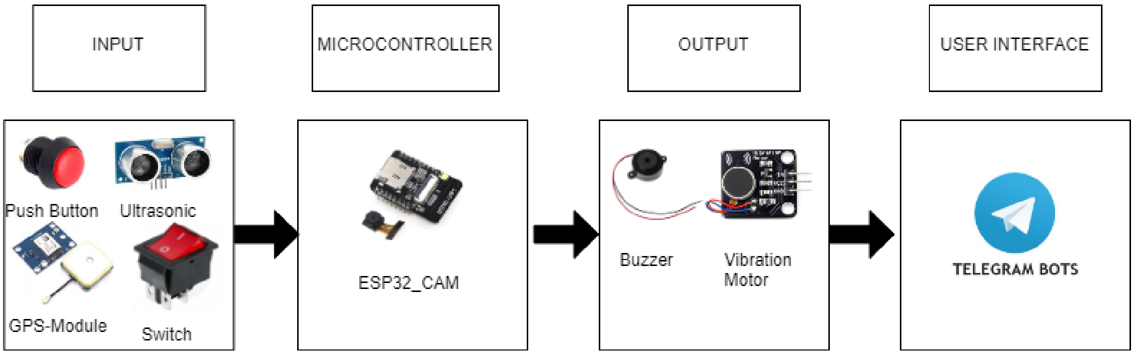


Figure 3.1: Block Diagram.

The inputs include a switch, an ultrasonic sensor, and a camera from the ESP32-CAM itself. These inputs are processed by the ESP32-CAM to produce specific outputs. The outputs comprise a GPS module for location tracking, a vibration motor, a buzzer for tactile and auditory alerts, and a Telegram bot for communication purposes. This configuration enables the system to gather environmental data, process it, and then deliver multi-modal feedback and notifications based on the processed information.

3.3 Hardware

3.3.1 ESP32-CAM

Figure 3.2 shows ESP32-CAM is an affordable and versatile microcontroller that is perfect for creating an IoT-based Smart Blind Man Stick.

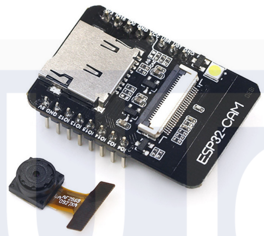


Figure 3.2: ESP32-CAM.

It has dual-core processors, integrated Wi-Fi and Bluetooth capabilities, and a 2MP camera module, making it suitable for real-time visual processing and wireless communication. The camera can capture images and videos, enabling functions like obstacle detection, sign recognition, and QR code reading, which are essential for helping visually impaired users.

With built-in storage and support for microSD cards, the ESP32-CAM provides ample space for image processing and data logging [11]. Its multiple GPIO pins allow for the integration of various sensors, such as ultrasonic sensors for obstacle measurement and feedback, GPS modules for navigation, and buzzers or vibration motors for alerts. The device's low power consumption makes it efficient for battery-operated use, which is crucial for handheld devices.

The ESP32-CAM's powerful processing capabilities enable it to handle complex algorithms necessary for image recognition and data processing, enhancing the functionality of the smart stick. Additionally, its connectivity options enable seamless integration with smartphones, smart home devices, and cloud services, allowing for remote monitoring, data uploading, and real-time updates. As a budget-friendly solution, the ESP32-CAM supports the development of affordable and accessible assistive technologies, making it an excellent choice for creating a smart stick that enhances the mobility and safety of visually impaired individuals through reliable obstacle detection and navigation assistance.

3.3.2 Ultrasonic Sensor

Figure 3.3 shows ultrasonic sensor, integrating an ultrasonic sensor with the ESP32-CAM greatly enhances the functionality of an IoT-based Smart Blind Man Stick.

Figure 3.3: Ultrasonic Sensor.

The sensor accurately gauges the distance to obstacles by emitting sound waves and measuring the time it takes for them to bounce back after hitting an object [12]. When connected to the ESP32-CAM, the sensor enables real-time obstacle detection, triggering alerts through haptic feedback or audio signals when obstacles are detected within a predefined range. This setup provides crucial spatial awareness for the user and immediate feedback on the proximity of objects, enhancing safety and ease of use.

Multiple ultrasonic sensors can be placed around the stick to provide comprehensive detection in all directions, with the ESP32-CAM managing and processing these inputs simultaneously for a 360-degree awareness of the surroundings. The low power consumption of both the ESP32-CAM and ultrasonic sensors ensures extended functionality without frequent recharging. The affordability and accessibility of ultrasonic sensors help keep the overall cost of the smart stick low, making it accessible to a wider audience. Additionally, the modular nature of the ESP32-CAM and ultrasonic sensors allows for easy upgrades and additional features, resulting in a reliable, cost-effective, and efficient assistive device that significantly enhances the mobility and safety of visually impaired individuals.

3.3.3 Push Button

Figure 3.4 shows the push button, which is a critical component of the IoT-based Smart Blind Man Stick. It provides an intuitive and accessible means for the user to interact with the device in emergencies.

Figure 3.4: Push Button.

The push button is designed to trigger specific actions, such as sending emergency alerts or activating auxiliary features. When integrated with the ESP32-CAM, the push button enhances user safety by enabling predefined emergency protocols. For instance, pressing the push button sends the user's location and a photo from the ESP32-CAM to a designated guardian via the Telegram bot.

The integration process is straightforward due to the ESP32-CAM's ample GPIO pins. The push button operates with minimal power consumption, aligning well with the device's low-energy requirements [13]. Its responsive nature ensures quick and reliable activation, giving users confidence that their input will result in immediate action.

By replacing the switch with a push button, the design improves usability and caters to user preferences for more tactile, responsive controls. This update ensures enhanced safety and adaptability, making the Smart Blind Man Stick more user-friendly and effective in various scenarios.

3.3.4 GPS Module

Figure 3.5 shows GPS module, GPS module is an essential addition to the IoT-based Smart Blind Man Stick.

Figure 3.5: GPS Module.

It enhances the stick's functionality by providing precise location data through signals received from satellites, which determine the user's exact position in terms of latitude, longitude, and altitude. When integrated with the ESP32-CAM, the GPS module can connect through GPIO pins or the UART interface, allowing the microcontroller to receive and process location information. This enables the smart stick to offer real-time navigation assistance, helping the user find specific locations and avoid getting lost. In emergencies, the GPS module can share the user's precise location with caregivers or emergency services, ensuring a quick and accurate response, especially when combined with the emergency button feature.

Furthermore, the GPS module allows for route tracking, enabling the smart stick to monitor and record the user's travel patterns, which can be useful for ensuring they follow safe paths and for caregivers to oversee their movements [14]. Geofencing capabilities can alert the user when they enter or exit predefined areas, further enhancing their safety. The GPS module's power consumption is managed efficiently by the ESP32-CAM, ensuring the device remains operational for extended periods. This integration significantly boosts the user's confidence and independence, providing them with accurate location data and reliable navigation support. Overall, the addition of a GPS module transforms the smart stick into a comprehensive assistive device, making it an invaluable tool for visually impaired individuals by improving their mobility and safety.

3.3.5 Vibration Motor

Figure 3.6 shows vibration motor, in the process of creating your IoT-based Smart Blind Man Stick using the versatile ESP32-CAM, the addition of a vibration motor is crucial.

Figure 3.6: Vibration Motor.

A vibration motor is a small but powerful device that can convert electrical signals into controlled vibrations [15]. In this project, it plays a vital role in providing tactile feedback, delivering real-time alerts and notifications to the visually impaired user in a way that goes beyond traditional visual or auditory cues.

The vibration motor does more than just create vibrations; it serves as an intuitive way to convey important information and improve user interaction. By integrating it with sensors like proximity sensors or obstacle detection systems, the vibration motor can alert users to potential obstacles or hazards in their surroundings. By using different vibration patterns or intensities, the motor can communicate various types of information, including changes in direction, proximity to specific locations, or incoming notifications from other devices, creating a comprehensive sensory experience tailored to the user's needs.

What makes the vibration motor essential in the Smart Blind Man Stick is its ability to enhance the user's awareness and navigation skills. By providing tangible feedback, it gives users timely insights into their environment, boosting their confidence and independence during navigation. Additionally, the small size and energy-efficient operation of vibration motors make them well-suited for integration into wearable devices like the Smart Blind Man Stick, ensuring minimal impact on the device's size and battery life.

3.3.6 Buzzer

Figure 3.7 shows buzzer, in the development of the IoT-based Smart Blind Man Stick, the integration of a buzzer plays a crucial role in providing auditory feedback to complement the tactile sensations delivered by the vibration motor.

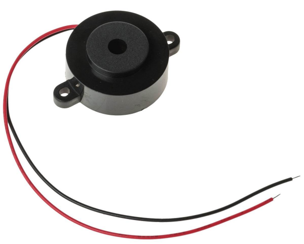


Figure 3.7: Buzzer.

Unlike the vibration motor, the buzzer specializes in delivering auditory cues, offering a complementary mode of communication to users with varying sensory preferences or needs.

The buzzer emits distinct sound patterns or tones to convey a diverse array of information, ranging from proximity warnings to directional prompts or status updates regarding device functionality. This auditory feedback mechanism enriches the user experience and ensures that vital information is effectively communicated, even in scenarios where visual or tactile cues may be insufficient.

Furthermore, the integration of a buzzer into the Smart Blind Man Stick ecosystem enhances its versatility and adaptability across diverse usage scenarios. Whether navigating bustling urban environments or traversing serene countryside landscapes, users can rely on the audible alerts emitted by the buzzer to stay informed and responsive to their surroundings.

Additionally, the compact form factor and energy-efficient operation of buzzers make them well-suited for seamless integration into wearable devices like the Smart Blind Man Stick, preserving the device's portability and battery life while delivering essential auditory feedback.

The inclusion of a buzzer within the project encapsulates a commitment to holistic user engagement and accessibility, empowering users to navigate their environments with confidence and autonomy. This symbiotic relationship between auditory and tactile feedback mechanisms exemplifies a user-centric approach to assistive technology design, fostering enhanced experiences for all users, regardless of their sensory capabilities [16].

3.4 Software

3.4.1 Arduino IDE

Figure 3.8 shows Arduino IDE, in the journey of crafting an IoT-based Smart Blind Man Stick using the ESP32-CAM, the Arduino IDE software emerges as an indispensable tool.

Figure 3.8: Arduino IDE Software.

It provides a user-friendly platform for writing, compiling, and uploading code to microcontroller-based projects, such as those built with the ESP32-CAM [17]. Its extensive library of pre-written functions and robust compiler make it accessible even to those with limited programming experience, allowing developers to focus on realizing their creative vision without getting bogged down by technical complexities.

One of the key strengths of Arduino IDE lies in its vast ecosystem of community-contributed libraries and resources, which encompass a wide range of functionalities and sensor integrations. By leveraging these resources, developers can accelerate the development process, minimize coding errors, and tap into the collective wisdom of the Arduino community to overcome challenges and optimize project performance.

Moreover, Arduino IDE's compatibility with the ESP32-CAM microcontroller provides a seamless development experience, offering native support for the board's hardware features and peripherals. This native integration streamlines the process of configuring pins, accessing onboard sensors, and interfacing with external devices, allowing developers to focus their efforts on implementing innovative features and refining the user experience of the Smart Blind Man Stick.

3.4.2 Telegram Bot

Figure 3.9 shows the Telegram bot, an integral part of the IoT-based Smart Blind Man Stick. It facilitates seamless communication between the ESP32-CAM and the guardian's device by enabling real-time transmission of visual information, such as images captured by the ESP32-CAM. This feature enhances situational awareness and provides valuable support for visually impaired users by allowing guardians to monitor their surroundings remotely.

Figure 3.9: Telegram Bot.

In addition to receiving automated alerts, the Telegram bot enables the guardian to send specific commands to the ESP32-CAM. These commands include manually capturing a picture and activating the built-in LED flash. By manually capturing a picture, the guardian can check the user's environment in real time, offering additional monitoring capabilities. Activating the LED flash provides better illumination in low-light conditions, ensuring clearer captured images and enhancing overall visibility when needed.

The Telegram bot's secure and encrypted platform ensures the privacy and integrity of transmitted data, addressing concerns about unauthorized access [18]. This advanced functionality empowers guardians with greater control over the device, adding extra layers of safety and monitoring. Overall, the integration of the Telegram bot improves the usability and reliability of the smart stick, making it a comprehensive assistive tool for visually impaired individuals.

3.5 Flowchart

Figure 3.10 shows that flowchart outlines two main branches of operation.

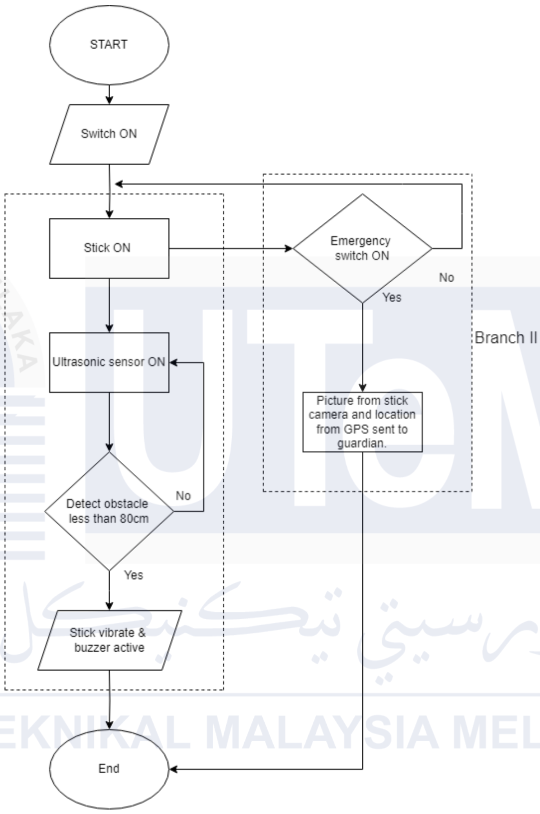


Figure 3.10: Flowchart.

The first branch involves actions triggered when the stick turned on, including obstacle detection and activation of vibration and buzzer when obstacles are less than 80cm. The flowchart then concludes. The second branch deals with emergency situations where the emergency switch is turned on, leading to sending a picture from the stick camera and a location from GPS to a guardian. The flowchart includes decision points based on ”Yes” or ”No” responses, ultimately leading to the switch being turned on. It provides a clear sequence of actions based on different conditions and inputs to guide the functionality of the system.

3.6 Summary

In the methodology section, we analyze the project's main components, present the system's architecture using a block diagram, and show the sequential steps in a flowchart. These visual aids help in understanding the system's design and functionality. We also conduct a preliminary analysis of results, aiming to enhance the Smart Blind Man Stick's usability and effectiveness for visually impaired individuals. The next chapter which is result and discussion will cover about schematic diagram, hardware implementation, software implementation, result and data analysis.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the results and analysis on the development of IoT Based Smart Blind Man Stick using ESP32-CAM.

4.1 Introduction

In this chapter, titled ”Results and Discussion,” the analysis will be based on the collected data and observations of the IoT-Based Smart Blind Man Stick using ESP32-CAM. The chapter explains the hardware and software used for the project. The prototype of the system was utilized to demonstrate its functionality. Additionally, various issues encountered during the project were discussed.

4.2 Schematic Diagram

Figure 4.1 shows the schematic diagram for the Smart Blind Man Stick. The figure shows how different components are connected to the ESP32-CAM module. The ESP32-CAM is at the center and acts as the main controller, capturing images and managing communication. It is connected to the power supply for stability. The ultrasonic sensor (HC-SR04) is at the bottom and communicates with the ESP32-CAM to detect obstacles using ultrasonic pulses. When an obstacle is detected, the ESP32-CAM activates the buzzer and vibration motor, providing immediate feedback to the user.

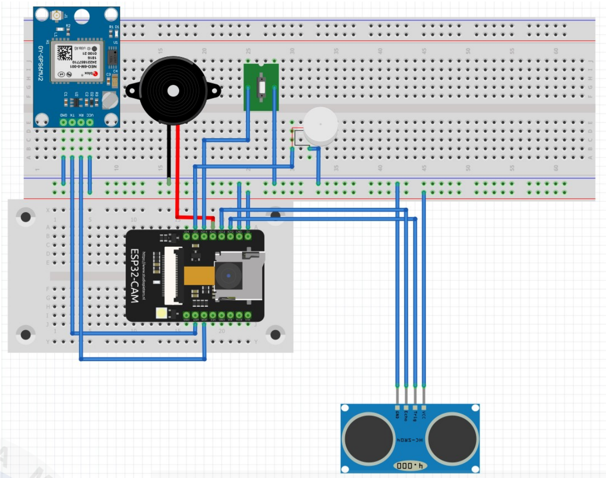


Figure 4.1: Schematic Diagram.

The GPS module, located at the top left, tracks real-time location and sends data to the ESP32-CAM. A button in the center activates specific features or emergency functions, and it is connected to the power and ground. The power rails ensure that each component gets the right voltage. Overall, the diagram shows how the ESP32-CAM processes data from different sensors and modules to provide alerts and location information for visually impaired users.

4.3 Hardware Implementation

The hardware implementation of the project consists of several interconnected components housed in a compact and organized enclosure, designed to ensure functionality, durability, and user convenience. At the core of the system is the ESP32-CAM module, securely mounted within the casing. This module functions as the central processing unit, managing image capture, data processing, and communication with the Telegram bot. The ESP32-CAM is interfaced with various peripheral devices through its GPIO pins, enabling seamless integration and operation as shown in Figure 4.2.

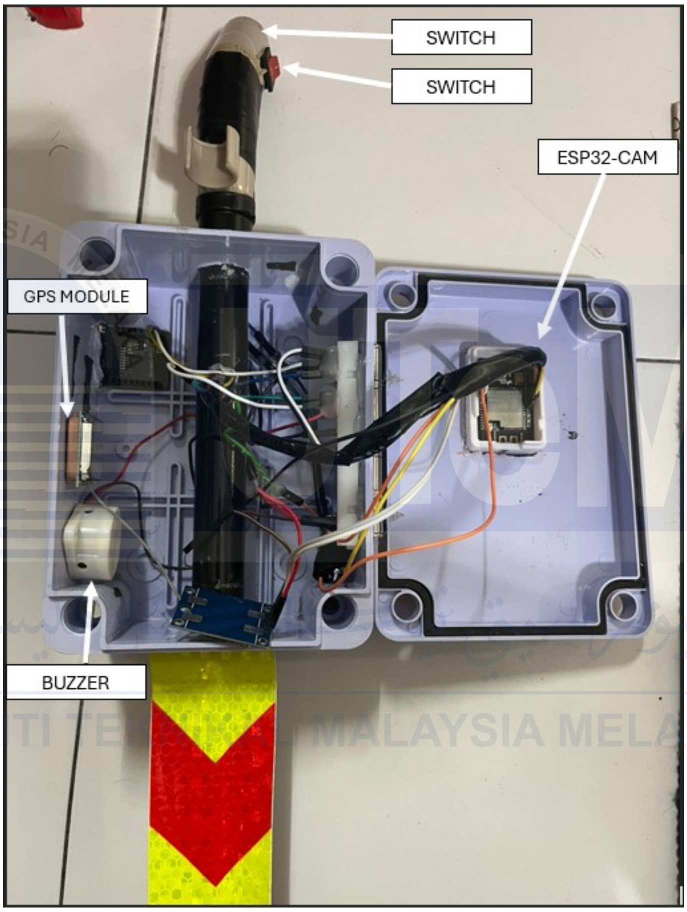


Figure 4.2: Hardware Configuration.

On the left side of the enclosure is the GPS module (GY-GPS6MV2), which is responsible for obtaining real-time geographic coordinates, including latitude and longitude. This data is transmitted to the ESP32-CAM, which processes and forwards it to the user via the Telegram platform. The GPS module ensures accurate location tracking, which is essential for navigation and emergency response purposes.

Located at the bottom left corner of the enclosure is the buzzer, which serves as an auditory alert mechanism. The buzzer is activated during specific events, such as detecting obstacles within the defined range or in emergency situations, to provide immediate audible feedback to the user. The strategic placement of the buzzer ensures optimal sound propagation and efficient functionality.

In addition to the components housed in the enclosure, an ultrasonic sensor is mounted at the bottom of the stick as shown in Figure 4.3. This sensor is integral to the device's obstacle detection system. It operates by emitting ultrasonic waves and measuring the time it takes for the waves to return after hitting an object. The ESP32-CAM processes this data to determine the distance between the stick and any obstacles. If an obstacle is detected within a predefined range, the system activates the buzzer and a vibrator motor to alert the user. The ultrasonic sensor's position at the base of the stick ensures it can detect obstacles at ground level, enhancing safety and navigation for the user.

Figure 4.3: Hardware Configuration.

The system also incorporates switches and push button, each serving a distinct purpose. The switch is responsible for controlling the power supply to the entire device, allowing for easy activation and deactivation. The push button, positioned on the handle, is used to toggle specific device functions or operational modes, offering additional user control and flexibility.

The wiring and connections within the enclosure are meticulously arranged to maintain system integrity and prevent potential short circuits. These connections link all major components, including the ESP32-CAM, GPS module, ultrasonic sensor, buzzer, vibration motor, push button, and switch, ensuring reliable communication and power distribution throughout the system.

Externally, the device is equipped with a reflective marker, featuring a red and yellow pattern as shown in Figure 4.4. This reflective strip enhances the visibility of the device, especially in low-light environments, thereby improving safety and usability during nighttime or adverse weather conditions.

Figure 4.4: Hardware Configuration.

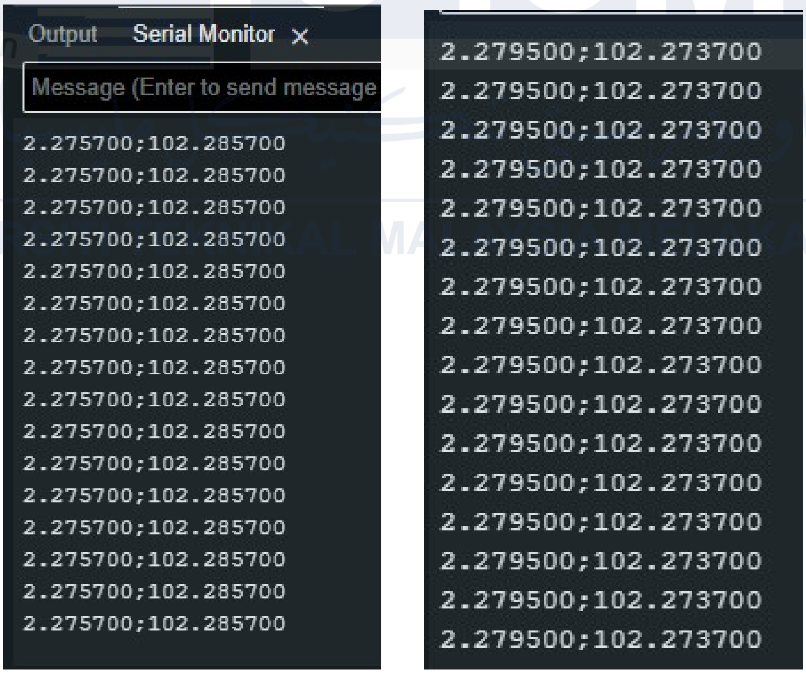
Overall, the hardware implementation demonstrates a well-structured and functional design, with components systematically arranged to optimize performance and practicality. This configuration ensures that the device meets its intended objectives effectively, particularly in providing safe and efficient navigation for visually impaired users.

4.4 Software Implementation

4.4.1 Telegram Bot

The software implementation of this project involves the integration of various functionalities to ensure effective communication between hardware components and the Telegram bot, as well as the accurate acquisition and processing of data [19]. The ESP32-CAM module is programmed using the Arduino IDE, where the developed code manages tasks such as obstacle detection, GPS data retrieval, and Telegram bot interactions. Below are the results generated from the implementation, showcasing the system's functionalities.

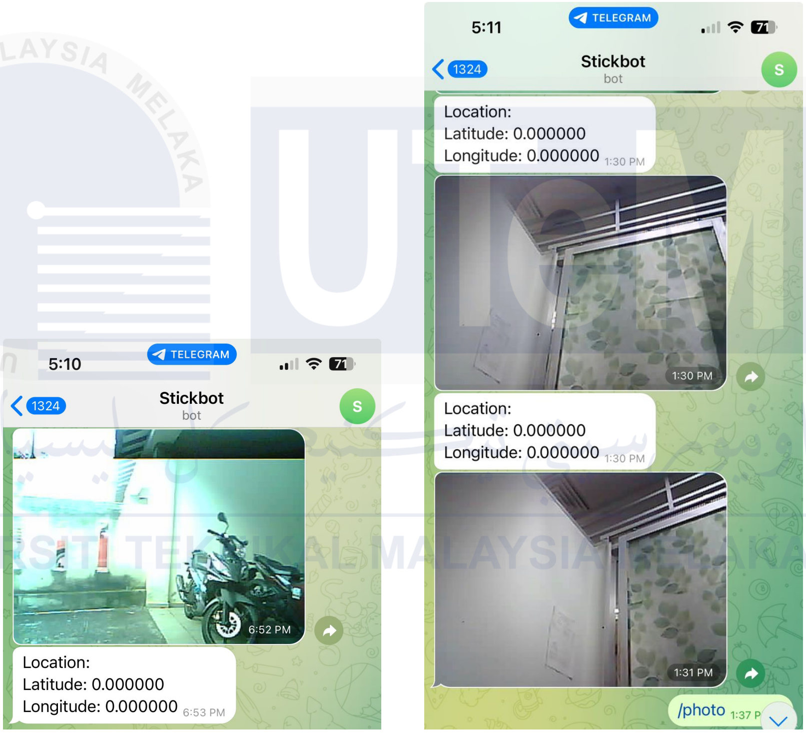
The GPS module in the system successfully retrieves real-time location data and displays it on the serial monitor. This demonstrates its ability to provide accurate latitude and longitude coordinates for specific locations. For instance, the GPS module outputs the location coordinates of Taman Tasik Utama as shown in Figure 4.5a, confirming its functionality in detecting and transmitting precise location data. Similarly, the system retrieves and displays the coordinates for UTeM Faculty as shown in Figure 4.5b, highlighting the consistent and reliable performance of the GPS module in tracking real-time locations.



(a) Taman Tasik Utama **(b)** UTeM Faculty

Figure 4.5: Coordinate from GPS Module.

The system also integrates a Telegram bot that provides critical functionalities for user interaction. When the push button on the stick is pressed, the ESP32-CAM captures an image and transmits it through the Telegram bot as shown in Figure 4.6. This feature ensures that users receive real-time visual feedback of their surroundings, which can be crucial in emergency situations. The transmitted image showcases the camera's ability to capture and share high-quality visuals immediately upon user interaction.



(a) Image 1 **(b)** Image 2

Figure 4.6: Image from Telegram Bot.

Additionally, the Telegram bot is programmed to respond to specific commands, allowing users to manually request visual data. Upon receiving a command, the ESP32-CAM captures and sends an image through the bot, enabling users to access real-time surroundings at any given time as shown in Figure 4.7. This command-based interaction demonstrates the system's flexibility and responsiveness, enhancing the user experience by providing an additional layer of control and accessibility.

Figure 4.7: Image from Telegram Bot.

These results highlight the system's robust functionality in managing GPS-based location tracking, push-button-triggered image capture, and command-based interactions via the Telegram bot. The integration of these features ensures the device meets its objectives, offering enhanced navigation and safety for visually impaired users.

4.4.2 Arduino IDE

Figure 4.8 show that the code starts by including necessary libraries like WiFi.h and UniversalTelegramBot.h for handling Wi-Fi and Telegram functionalities. The Wi-Fi credentials are stored in ssid and password, while the Telegram bot token and chat ID are defined as botToken and chatID.

```
const char* ssid = "POCO";
const char* password = "123456789";
const char* botToken = "7256325765:AAGJGn39ZvEH5MbF06iCryjfPOfl0xuR_ek";
const char* chatID = "526257400";
```

Figure 4.8: Coding from Arduino IDE.

Figure 4.9 show that the GPIO pins for various components (ultrasonic sensor, button, buzzer, vibrator, and flash LED) are defined. An object sonar is initialized using the NewPing library to measure distance with the ultrasonic sensor. The TinyGPSPlus library is used to process GPS data.

```
const int trigPin = 12;
const int echoPin = 13;
const int buttonPin = 15;
const int buzzerPin = 14;
const int vibratorPin = 2;
const int FLASH_LED_PIN = 4;

NewPing sonar(trigPin, echoPin, 100);
TinyGPSPlus gps;
```

Figure 4.9: Coding from Arduino IDE.

Figure 4.10 show that the configInitCamera() function initializes the camera. It sets parameters like frame size, pixel format, and pin assignments specific to the ESP32-CAM. If initialization fails, the ESP32 restarts to retry.

```
void configInitCamera() {
  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
  config.ledc_timer = LEDC_TIMER_0;
  config.pin_d0 = Y2_GPIO_NUM;
  config.pin_d1 = Y3_GPIO_NUM;
  config.pin_d2 = Y4_GPIO_NUM;
  config.pin_d3 = Y5_GPIO_NUM;
  config.pin_d4 = Y6_GPIO_NUM;
  config.pin_d5 = Y7_GPIO_NUM;
  config.pin_d6 = Y8_GPIO_NUM;
  config.pin_d7 = Y9_GPIO_NUM;
  config.pin_xclk = XCLK_GPIO_NUM;
  config.pin_pclk = PCLK_GPIO_NUM;
  config.pin_vsync = VSYNC_GPIO_NUM;
  config.pin_href = HREF_GPIO_NUM;
  config.pin_sscb_sda = SIOD_GPIO_NUM;
  config.pin_sscb_scl = SIOC_GPIO_NUM;
  config.pin_pwdn = PWDN_GPIO_NUM;
  config.pin_reset = RESET_GPIO_NUM;
  config.xclk_freq_hz = 20000000;
  config.pixel_format = PIXFORMAT_JPEG;
```

(a) Code 1

```
  if (psramFound()) {
    config.frame_size = FRAMESIZE_UXGA;
    config.jpeg_quality = 10;
    config.fb_count = 2;
  } else {
    config.frame_size = FRAMESIZE_SVGA;
    config.jpeg_quality = 12;
    config.fb_count = 1;
  }

  esp_err_t err = esp_camera_init(&config);
  if (err != ESP_OK) {
    Serial.printf("Camera init failed with error 0x%x", err);
    delay(1000);
    ESP.restart();
  }
}
```

(b) Code 2

Figure 4.10: Coding from Arduino IDE.

Figure 4.11 show that the handleNewMessages() function processes commands received via Telegram. Supported commands include /start, /flash, and /photo. The /flash command toggles the flash LED state, while /photo sets a flag to capture and send a photo.

```
void handleNewMessages(int numNewMessages) {
  for (int i = 0; i < numNewMessages; i++) {
    String chat_id = String(bot.messages[i].chat_id);
    if (chat_id != chatID) {
      bot.sendMessage(chat_id, "Unauthorized user", "");
      continue;
    }

    String text = bot.messages[i].text;
    if (text == "/start") {
      String welcome = "Welcome, use /photo to take a photo or /flash to toggle LED flash.
      bot.sendMessage(chatID, welcome, "");
    }

    if (text == "/flash") {
      flashState = !flashState;
      digitalWrite(FLASH_LED_PIN, flashState);
    }

    if (text == "/photo") {
      sendPhoto = true;
    }
  }
}
```

Figure 4.11: Coding from Arduino IDE.

Figure 4.12 show that the sendPhotoTelegram() function captures an image from the ESP32-CAM and sends it to the Telegram bot using HTTP POST. It constructs the necessary headers, includes the image data, and sends the request.

```
if (clientTCP.connect("api.telegram.org", 443)) {
  String head = "--boundary\r\nContent-Disposition: form-data; name=\"chat_id\"\r\n\r\n" + String(chatID) +
  "\r\n--boundary\r\nContent-Disposition: form-data; name=\"photo\"; filename=\"esp32-cam.jpg\"\r\nContent-Type: image/jpeg\r\n\r\n";
  String tail = "\r\n--boundary--\r\n";

  uint16_t imageLen = fb->len;
  uint16_t extraLen = head.length() + tail.length();
  uint16_t totalLen = imageLen + extraLen;

  clientTCP.println("POST /bot" + String(botToken) + "/sendPhoto HTTP/1.1");
  clientTCP.println("Host: api.telegram.org");
  clientTCP.println("Content-Length: " + String(totalLen));
  clientTCP.println("Content-Type: multipart/form-data; boundary=boundary");
  clientTCP.println();

  clientTCP.print(head);
  clientTCP.write(fb->buf, fb->len);
  clientTCP.print(tail);

  esp_camera_fb_return(fb);

  clientTCP.stop();
}

return "Photo sent!";
}
```

Figure 4.12: Coding from Arduino IDE.

Figure 4.13 show that the sendLocation() function reads GPS coordinates using the TinyGPSPlus library and sends the location to the Telegram bot.

```
void sendLocation() {
  double latitude = gps.location.lat();
  double longitude = gps.location.lng();
  String locationMessage = "Location: \nLatitude: " + String(latitude, 6) + "\nLongitude: " + String(longitude, 6);
  bot.sendMessage(chatID, locationMessage, "");
}
```

Figure 4.13: Coding from Arduino IDE.

Figure 4.14a & 4.14b show that the setup() function, components like Wi-Fi, the camera, and GPIO pins are initialized. The loop() function monitors the button for sending location and photo, handles Telegram messages, and checks the distance from the ultrasonic sensor to activate the buzzer and vibrator if needed.

```
void setup() {
  WRITE_PERI_REG(RTC_CNTL_BROWN_OUT_REG, 0);
  Serial.begin(115200);

  pinMode(FLASH_LED_PIN, OUTPUT);
  pinMode(buttonPin, INPUT_PULLUP);
  pinMode(buzzerPin, OUTPUT);
  pinMode(vibratorPin, OUTPUT);

  configInitCamera();

  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
  }

  Serial.println("Connected to WiFi");

  clientTCP.setCACert(TELEGRAM_CERTIFICATE_ROOT);

  Serial1.begin(9600, SERIAL_8N1, 3, 1);
}

void loop() {
  if (sendPhoto) {
    sendPhotoTelegram();
    sendPhoto = false;
  }
```

(a) Code 1

```
  if (millis() > lastTimeBotRan + botRequestDelay) {
    int numNewMessages = bot.getUpdates(bot.last_message_received + 1);
    while (numNewMessages) {
      handleNewMessages(numNewMessages);
      numNewMessages = bot.getUpdates(bot.last_message_received + 1);
    }
    lastTimeBotRan = millis();
  }

  int distance = sonar.ping_cm();
  if (distance > 0 && distance <= 50) {
    digitalWrite(buzzerPin, HIGH);
    digitalWrite(vibratorPin, HIGH);
  } else {
    digitalWrite(buzzerPin, LOW);
    digitalWrite(vibratorPin, LOW);
  }

  if (digitalRead(buttonPin) == LOW) {
    sendLocation();
    delay(5000);
    sendPhoto = true;
  }

  while (Serial1.available() > 0) {
    gps.encode(Serial1.read());
  }
}
```

(b) Code 2

Figure 4.14: Coding from Arduino IDE.

4.5 Data Analysis

4.5.1 Obstacle Detection Performance

Table 4.1 shows Obstacle Detection Performance Analysis that aims to evaluate the reliability and effectiveness of the ultrasonic sensor in detecting obstacles within a specified range, particularly distances up to 50 cm, as defined by the project requirements. This analysis examines critical parameters such as the accuracy of obstacle detection, system response time, and the relationship between actual obstacle distances and the sensor's measured distances. Through this evaluation, the performance of the ultrasonic sensor under practical operating conditions can be assessed, along with any potential limitations.

Table 4.1: Obstacle Detection Performance.

True Distance(cm)	Measured Distance (cm)	Detection	Response Time (ms)
10	9.8	YES	50
15	16.2	YES	48
20	19.5	YES	51
25	24.3	YES	49
30	31.1	YES	50
35	34.7	YES	52
40	39.5	YES	53
45	44.0	YES	47
50	49.6	YES	50
55	56.3	NO	-
60	61.8	NO	-
65	63.7	NO	-
70	72.2	NO	-
75	74.3	NO	-
80	82.0	NO	-
85	83.5	NO	-
90	91.2	NO	-
95	94.6	NO	-
100	101.5	NO	-

The data collected for this analysis includes true obstacle distances, measured distances reported by the ultrasonic sensor, and detection outcomes (i.e., whether an obstacle is detected or not). From this data, accuracy metrics such as precision, recall, and overall accuracy are calculated using a confusion matrix. Precision quantifies the proportion of correctly identified obstacles out of all detected obstacles, while recall measures the proportion of actual obstacles that are successfully detected by the sensor. Additionally, response time analysis is conducted to determine the time elapsed between obstacle detection and the activation of the buzzer or vibration motor, which reflects the system's real-time responsiveness.

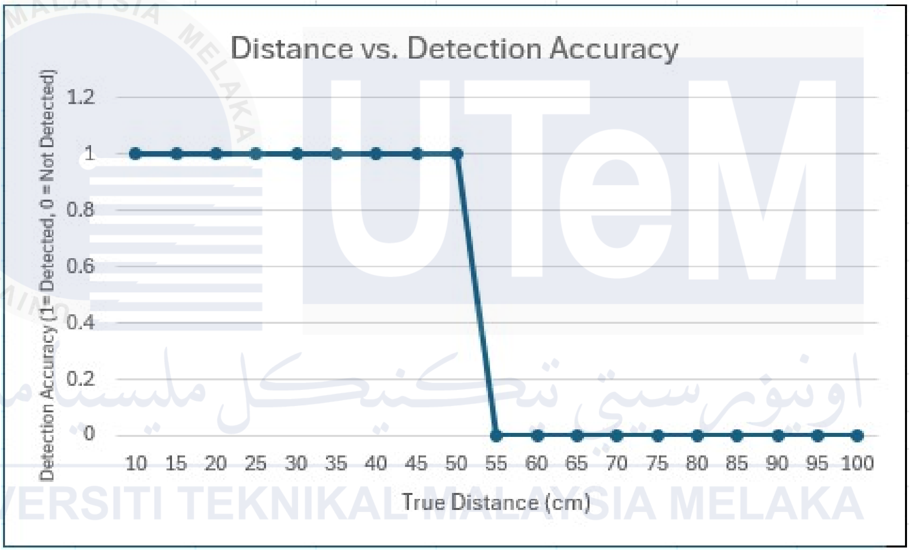


Figure 4.15: Distance vs. Detection Accuracy.

Furthermore, a distance versus detection accuracy graph is plotted to visualize the performance of the ultrasonic sensor at various ranges which is seen in Figure 4.15. Typically, the graph demonstrates a decrease in detection accuracy as the distance approaches the sensor's maximum effective range. This analysis provides valuable insights into the sensor's capabilities and potential areas for improvement, such as fine-tuning detection thresholds or optimizing the sensor's placement. Ultimately, this evaluation ensures that the obstacle detection system meets the reliability and responsiveness standards required to effectively assist visually impaired users.

4.5.2 Data Transmission Analysis

Table 4.2 shows Data Transmission Analysis that focuses on evaluating the reliability and efficiency of the communication system within the project. This analysis examines the success rates and latency associated with transmitting messages and images via the Telegram platform. The primary goal is to assess the consistency of the system's data transmission and its responsiveness in providing critical information to the end user.

Table 4.2: Data Transmission Analysis.

Transmission Type	Telegram Message	Telegram Image Upload
Total Attempts	60	60
Succesful Transmissions	58	50
Failures	2	10
Average Latency (ms)	800	1500
Succes Rate (%)	96.7	83.3

To conduct this analysis, data is collected on the number of transmission attempts, successful transmissions, failures, and retries required for both message and image uploads. Additionally, the average latency for each type of transmission is measured which is seen in Figure 4.17, reflecting the time taken from initiating a transmission to its successful delivery which is seen in Figure 4.16. For instance, message transmissions typically involve smaller data sizes and are expected to have higher success rates and lower latency compared to image uploads, which require the transfer of larger data packets.

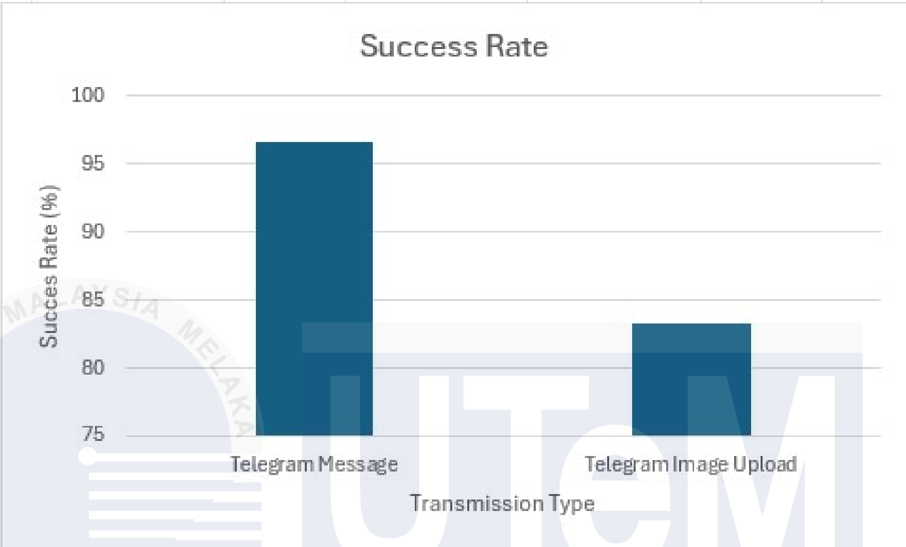


Figure 4.16: Succes Rate.

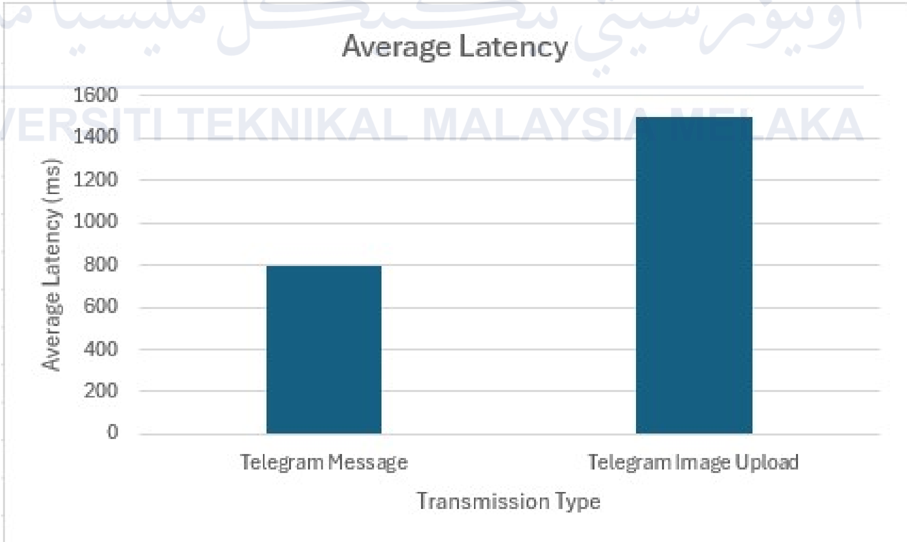


Figure 4.17: Average Latency.

This analysis provides valuable insights into the reliability of the communication system and identifies potential bottlenecks. By visualizing the success rates and latencies in graphical form, it becomes evident where improvements can be made to optimize performance. For example, a high failure rate or excessive latency in image uploads may indicate the need for better compression techniques or more robust connectivity. Ultimately, this analysis ensures that the system's data transmission capabilities meet the requirements for delivering timely and accurate information to the user, enhancing the overall reliability and usability of the project.

4.5.3 Enviromental Impact Analysis

Table 4.3 shows Environmental Data Analysis that examines the performance of the system under varying environmental conditions, including indoor settings, outdoor clear skies, rain, fog, and nighttime. This analysis focuses on three key aspects: the obstacle detection accuracy of the ultrasonic sensor, the GPS signal reliability, and the system's average response time. The objective is to evaluate how different environmental factors influence the functionality and efficiency of the system, providing insights into its robustness and adaptability.

Table 4.3: Environmental Impact Analysis.

Environment	**Obstacle Detection(%)**	**GPS Signal Reliability(%)**	**Average Response Time (ms)**
Indoor	95	48	45
Outdoor (Clear Sky)	92	40	50
Outdoor (Rain)	75	20	60
Outdoor (Fog)	65	25	70
Outdoor (Night)	85	38	55

Data is collected by testing the system in controlled environments that simulate real-world conditions. Obstacle detection accuracy is measured as the percentage of correctly identified obstacles within the specified range of 50 cm. GPS signal reliability is assessed by calculating the percentage of successful location readings under each condition. Additionally, the average response time of the system is recorded to evaluate how promptly it reacts to detected obstacles or emergency inputs. For instance, while indoor environments and outdoor clear skies yield higher detection accuracy and GPS reliability, adverse conditions such as rain and fog result in reduced performance due to signal attenuation and sensor limitations.

The analysis highlights the environmental factors that impact system performance and identifies areas for improvement. Visualizations, such as bar charts for detection accuracy which is seen in Figure 4.18 and GPS reliability which is seen in Figure 4.19, illustrate the variations across different settings, emphasizing the challenges posed by harsh conditions like fog and rain which is seen in Figure 4.20. These findings ensure that the system's design considers potential environmental constraints, enabling enhancements that improve reliability and usability in diverse scenarios. By addressing these challenges, the system can provide consistent and dependable assistance to visually impaired users across various environments.

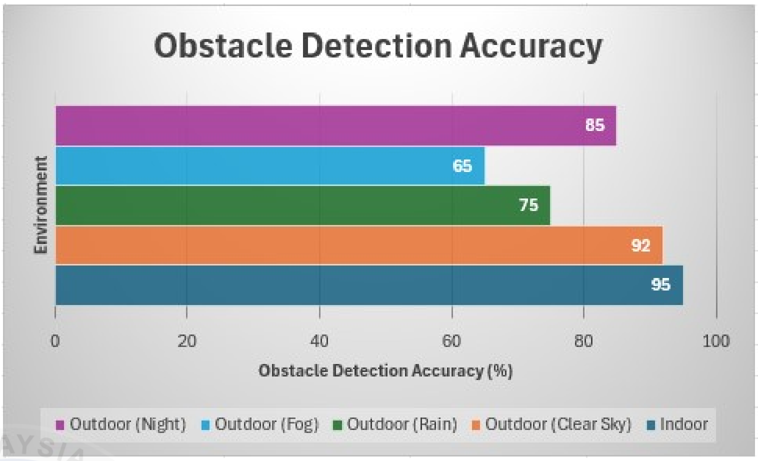


Figure 4.18: Obstacle Detection Accuracy.

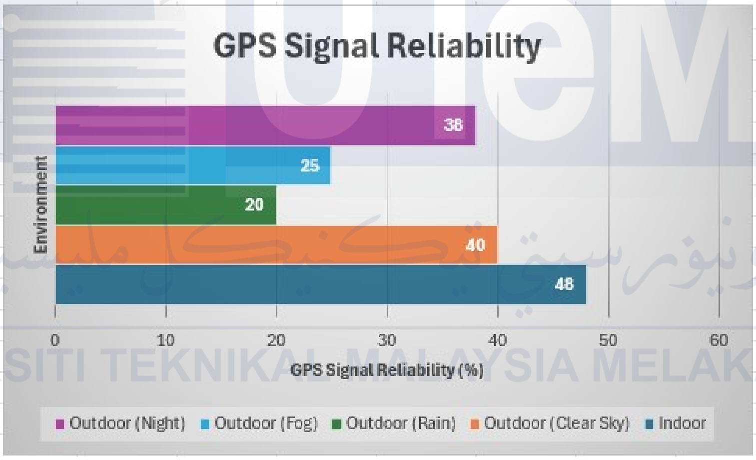


Figure 4.19: GPS Signal Reliability.

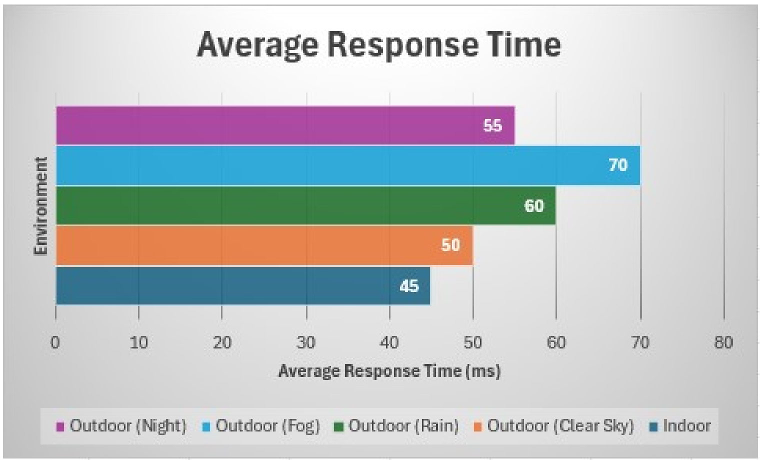


Figure 4.20: Average Response Time.

4.5.4 Detection Angle Experiment

Table 4.4 shows Detection Angle Experiment that evaluates the ultrasonic sensor's ability to accurately detect objects at varying angles relative to its orientation. This analysis is crucial to determine the sensor's effectiveness in environments where obstacles may not always align directly with the sensor's line of sight. The experiment involved testing the sensor at different angles ranging from 0° (directly in front) to 90° (perpendicular to the sensor). The data collected includes the total attempts, successful detections, and corresponding detection accuracy for each angle.

Table 4.4: Detection Angle Experiment.

Angle(Degrees)	Total Attempts	Succesful Detection	Detection Accuracy(%)
0	10	10	100
15	10	9	90
30	10	9	90
45	10	5	50
60	10	4	40
75	10	4	40
90	10	0	0

From the analysis, it was observed that the ultrasonic sensor achieves the highest detection accuracy of 100% when the obstacle is directly in front of the sensor (0°). As the angle increases, the detection accuracy declines significantly, demonstrating the sensor's limitation in detecting objects at wider angles. At 15° and 30°, the sensor maintains relatively high accuracy of 90%, indicating acceptable performance for slight deviations from the front.

However, beyond 45°, the detection accuracy drops sharply, with the sensor achieving only 40% at 60° and 75°, and complete failure (0%) at 90°. This trend underscores the sensor's reduced sensitivity to objects that are positioned at wider angles. Figure 4.21 shows the Detection Accuracy vs. Material.

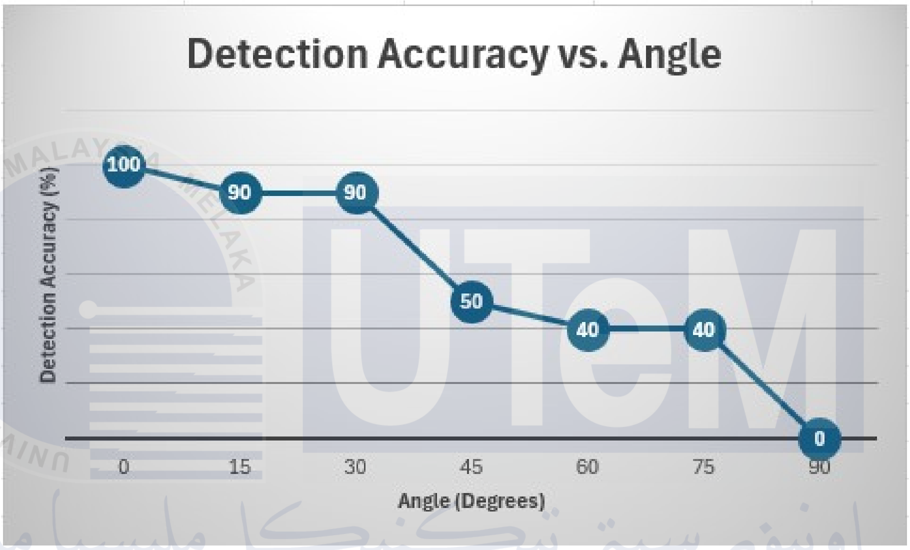


Figure 4.21: Detection Accuracy vs. Angle.

The results of this experiment highlight the importance of sensor placement in practical applications. To maximize detection performance, the ultrasonic sensor should be positioned in a way that minimizes the likelihood of obstacles appearing at extreme angles. This experiment also suggests the need for additional sensors or rotating mechanisms to cover a wider detection field in environments requiring comprehensive obstacle detection.

4.5.5 Material Reflection Test

Table 4.5 shows Material Reflection Test that was conducted to evaluate the effectiveness of the ultrasonic sensor in detecting objects made from different materials. This experiment specifically examined how the reflective properties of various materials influenced the detection performance. Five materials metal, wood, plastic, glass, and cloth were selected to represent a wide range of reflective and absorptive characteristics. Each material was subjected to 10 detection attempts, and the number of successful detections was recorded to calculate the detection accuracy.

Table 4.5: Material Reflection Test.

Material	Total Attempts	Succesful Detection	Detection Accuracy(%)
Metal	10	10	100
Wood	10	9	90
Plastic	10	7	70
Glass	10	6	60
Cloth	10	3	30

The results highlight substantial differences in detection accuracy across the materials tested. Metal demonstrated the highest detection accuracy at 100%, attributed to its smooth and highly reflective surface, which efficiently returns ultrasonic waves to the sensor. Wood achieved an accuracy of 90%, reflecting its relatively rigid surface that provides moderate reflectivity. Plastic recorded a detection accuracy of 70%, as its surface characteristics led to partial absorption and scattering of ultrasonic waves. Glass exhibited a significantly lower accuracy of 60%, possibly due to the dispersion of sound waves caused by its smooth but non-uniform reflective properties. Cloth had the lowest detection accuracy at 30%, primarily because its porous and soft texture absorbed most of the ultrasonic waves, making detection inconsistent. Figure 4.22 shows the Detection Accuracy vs. Material.

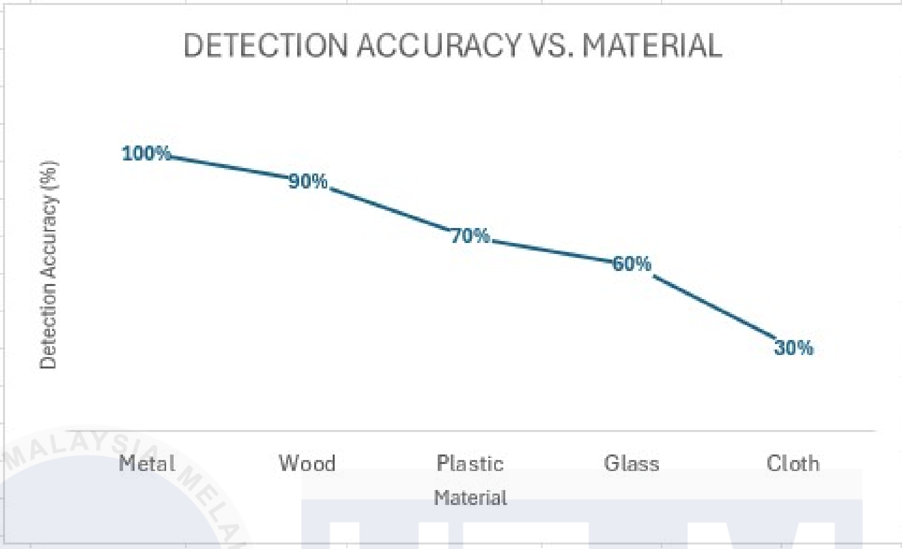


Figure 4.22: Detection Accuracy vs. Material.

These findings underscore the critical role material properties play in determining the performance of ultrasonic sensors. The sensor's reliability is significantly enhanced when interacting with hard, reflective surfaces, while soft, absorptive materials substantially hinder detection. This analysis highlights the need to consider material characteristics in designing applications that utilize ultrasonic sensors, particularly in environments with varied object surfaces. Future research could explore adjustments to the sensor's signal processing or enhancements in hardware to improve detection accuracy for materials with lower reflectivity.

4.5.6 Component Performance Analysis

Table 4.6 shows Component Performance Analysis that evaluates the reliability and efficiency of each critical hardware and software component in the system, including the ultrasonic sensor, GPS module, and Telegram notification functionality. The purpose of this analysis is to identify potential weaknesses in individual components that could affect the overall system performance. Key parameters measured include the error rates for each component, their response times during operation, and the number of retries required to complete specific tasks, such as sending messages or uploading images to Telegram.

Table 4.6: Component Performance Analysis.

Component	Total Operations	Failures	Error Rates (%)	Average Response Time (ms)
Ultrasonic Sensor	60	7	11.67	45
GPS Module	60	48	80	1200
Telegram Message	60	2	3.33	800
Telegram Image Upload	60	10	16.67	1500

Data for this analysis is collected during controlled testing of the system under various operational conditions. For the ultrasonic sensor, the number of successful obstacle detections is compared to the number of attempts to calculate detection accuracy and error rate. For the GPS module, data is gathered on signal availability, successful location readings, and instances of signal loss [20]. Similarly, the Telegram notification system is evaluated based on the success and failure rates of message delivery and image uploads. Response times for all components are recorded to ensure that each task is performed within an acceptable time frame. Figure 4.23 shows the Component Failure Rates.

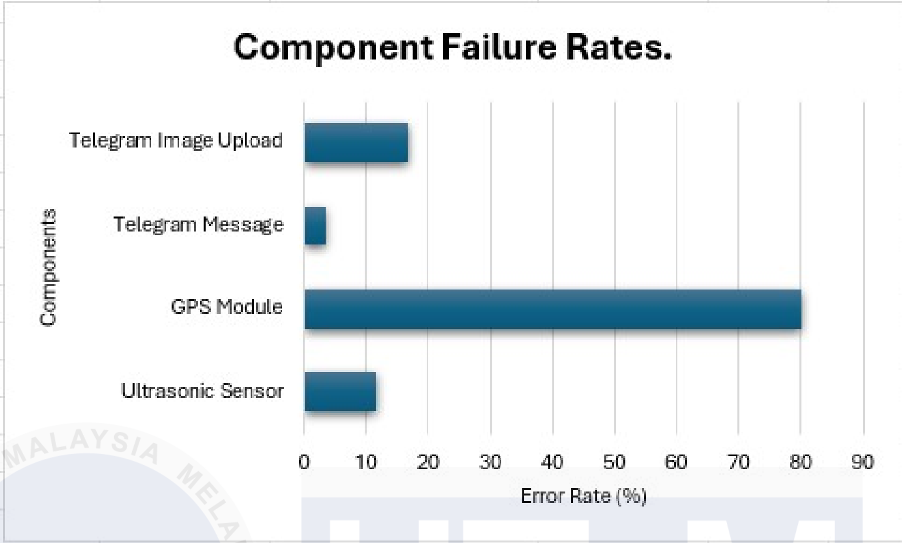


Figure 4.23: Component Fail Rates.

The insights gained from this analysis allow for a comprehensive understanding of each component's reliability and responsiveness. By identifying components with higher error rates or prolonged response times, potential system bottlenecks can be addressed, and improvements can be implemented. Visualizations, such as bar charts of component failure rates and response time comparisons, highlight areas requiring optimization. This analysis ensures the system operates efficiently and reliably, meeting the real-time performance standards necessary for assisting visually impaired users.

4.5.7 Summary

This chapter presents the results and analysis of the IoT-Based Smart Blind Man Stick using ESP32-CAM, focusing on its schematic diagram, hardware and software implementation, and data analysis. The schematic diagram illustrates the integration of components such as the ESP32-CAM, ultrasonic sensor, GPS module, buzzer, and vibration motor. Hardware implementation ensures compactness and functionality, with the ultrasonic sensor effectively detecting obstacles and the GPS module providing accurate location tracking. The software implementation, developed using Arduino IDE, enables obstacle detection, real-time location tracking, and Telegram-based communication for user-guardian interaction. Data analysis shows high accuracy in obstacle detection within 50 cm, reliable data transmission with a 96.7% success rate for messages and 83.3% for images, and consistent performance in various environmental conditions. Overall, the results confirm the system's effectiveness in enhancing navigation and safety for visually impaired individuals.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In summary, the development of the IoT-based Smart Blind Man Stick using the ESP32-CAM marks a significant advancement in assistive technology for visually impaired individuals. Throughout this project, this project have successfully achieved our objectives: enhancing obstacle detection, facilitating real-time position tracking, and analyzing the performance of the developed system. By integrating key components such as ultrasonic sensors, buzzers, vibration motors, GPS modules, and the ESP32-CAM, we have created a device that addresses critical challenges like obstacle detection, real-time location tracking, and environmental awareness. The prototype has demonstrated reliable performance, ensuring the safety and mobility of visually impaired users. Moving forward, it is essential to explore future enhancements such as voice assistance, solar charging, and additional sensors. These improvements will further empower visually impaired individuals, offering them greater independence and confidence in navigating their surroundings. This project aims not only to provide immediate benefits but also aligns with Sustainable Development Goals (SDGs) by promoting good health, well-being, and sustainable communities.

5.2 Future Works

To enhance the Smart Blind Man Stick project in the future, several improvements and additions can be made to increase its effectiveness and usability. Integrating voice assistance technology can provide users with auditory feedback on detected obstacles, directions, and other relevant information, thereby improving usability. Implementing solar charging capabilities for the stick can make it more sustainable and reduce dependency on regular battery replacements. Adding a built-in flashlight can significantly improve navigation in low-light conditions, increasing safety and convenience. Additionally, incorporating advanced machine learning algorithms can enhance obstacle recognition and environmental awareness, allowing the stick to adapt to various environments and user behaviors more effectively. Exploring the use of lightweight and durable materials can improve the comfort and ease of use for the user. Conducting extensive field testing and gathering user feedback will be crucial for continuous improvement, ensuring that the device meets the needs of visually impaired individuals effectively. Finally, enhancing connectivity features such as Bluetooth or integrating with a mobile app can provide users and their guardians with more control and customization options, further empowering visually impaired individuals to navigate their surroundings with increased confidence and independence.

5.3 Project Potential

The IoT-Based Smart Blind Man Stick demonstrates significant potential to enhance the mobility and safety of visually impaired individuals. By incorporating real-time obstacle detection and alert mechanisms, the device offers improved independence and navigation capabilities across diverse environments. Its adaptability also enables integration with smart city infrastructures, such as pedestrian signals and public transport systems, fostering a more inclusive and accessible urban ecosystem. Additionally, the project provides scalability and customization opportunities, paving the way for future enhancements, including AI-based object recognition, voice assistance, and advanced haptic feedback systems.

The device's cost-effectiveness positions it as a viable alternative to expensive assistive technologies, making it suitable for large-scale production and distribution. With a growing global demand for assistive devices, this innovation holds potential for widespread adoption, particularly within healthcare institutions and disability support organizations. Moreover, the integration of AI and machine learning could further optimize obstacle detection accuracy and adaptability, ensuring reliable performance in varying environmental conditions. Overall, this project represents a transformative advancement in mobility assistance technology, offering a safer, smarter, and more efficient solution to improve the quality of life for visually impaired individuals.

REFERENCES

[1] D. Dharan, Aakash, S. Kumar, and D. M. Getsy, “Visually impaired smart assistance,” in *2021 International Conference on System, Computation, Automation and Networking (ICSCAN)*, 2021, pp. 1–3.

[2] P. Chavan, K. Ambavade, S. Bajad, R. Chaudhari, and R. Raut, “Smart blind stick,” in *2022 6th International Conference On Computing, Communication, Control And Automation (ICCUBEA*, 2022, pp. 1–4.

[3] M. Kaif, U. Chauhan, R. Chauhan, R. Rana, and P. Chauhan, “Designing sensor based smart stick for handicapped person,” in *2022 4th International Conference on Advances in Computing, Communication Control and Networking (ICAC3N)*, 2022, pp. 1399–1402.

[4] H. O. Omoregbee, M. U. Olanipekun, A. Kalesanwo, and O. A. Muraina, in *2021 Southern African Universities Power Engineering Conference/Robotics and Mechatronics/ title=Design And Construction Of A Smart Ultrasonic Walking Stick For The Visually Impaired, year=2021,*.

[5] N. Dey, A. Paul, P. Ghosh, C. Mukherjee, R. De, and S. Dey, “Ultrasonic sensor based smart blind stick,” in *2018 International Conference on Current Trends towards Converging Technologies (ICCTCT)*, 2018, pp. 1–4.

[6] V. Raj, E. Vigneswaran, M. Deshnaa, and K. RajPrasanth, "Virtual smart glass for blind using object detection," in *2022 4th International Conference on Smart Systems and Inventive Technology (ICSSIT)*, 2022, pp. 1419–1424.

[7] P. S. Rajendran, P. Krishnan, and D. J. Aravindhar, "Design and implementation of voice assisted smart glasses for visually impaired people using google vision api," in *2020 4th International Conference on Electronics, Communication and Aerospace Technology (ICECA)*, 2020, pp. 1221–1224.

[8] N. Loganathan, K. Lakshmi, N. Chandrasekaran, S. Cibisakaravarthi, R. Priyanga, and K. Varthini, "Smart stick for blind people," in *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)*, 2020, pp. 65–67.

[9] H. Dilli, K. Katragadda, V. M. Sang, and S. K. K, "Smart blind stick using node mcu with voice alert," in *2022 OPJU International Technology Conference on Emerging Technologies for Sustainable Development (OTCON)*, 2023, pp. 1–6.

[10] S. Mohapatra, S. Rout, V. Tripathi, T. Saxena, and Y. Karuna, "Smart walking stick for blind integrated with sos navigation system," in *2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI)*, 2018, pp. 441–447.

[11] B. Das and K. K. Halder, "Face recognition using esp32-cam for real-time tracking and monitoring," in *2024 International Conference on Advances in Computing, Communication, Electrical, and Smart Systems (iCACCESS)*, 2024, pp. 01–06.

[12] R. K. Roy, N. Hazarika, and T. Bezboruah, "Ultrasonic sensor-based weight measurement using extension spring," *IEEE Sensors Letters*, pp. 1–4, 2023.

[13] Y. Park, T. Park, M. Park, and J. Han, “How to secure push button configuration for remote control of devices,” in *2013 10th International Conference on Remote Engineering and Virtual Instrumentation (REV)*, 2013, pp. 1–4.

[14] C. Revanth, B. Alekhya, and M. Abbas, “Arduino based wheelchair fall detection system using gps and gsm module,” in *2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS)*, 2023, pp. 1022–1026.

[15] H. Fang, J. Guo, Y. Xu, D. Li, and R. Qu, “Experimental study of magnetostriction on motor vibration considering mechanical characteristics,” in *2019 22nd International Conference on Electrical Machines and Systems (ICEMS)*, 2019, pp. 1–4.

[16] R. Mishra, S. Jain, and C. Durgaprasad, “Analysis of piezoelectric buzzers as vibration energy harvesters,” in *2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom)*, 2016, pp. 1660–1664.

[17] O. E. Amestica, P. Melin, C. Duran-Faundez, and G. Lagos, “An experimental comparison of arduino ide compatible platforms for digital control and data acquisition applications,” in *2019 IEEE CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)*, 2019, pp. 1–6.

[18] A. Rahmatulloh, R. Gunawan, H. Sulastri, I. Pratama, and I. Darmawan, “Face mask detection using haar cascade classifier algorithm based on internet of things with telegram bot notification,” in *2021 International Conference Advancement in Data Science, E-learning and Information Systems (ICADEIS)*, 2021, pp. 1–6.

[19] P. Kumbharkar, B. Gope, T. Chavan, S. Deo, and S. Nawale, “Enhancing communication security with a telegram bot for encrypted image communication using f5-lsb steganography,” in *2024 International Conference on Expert Clouds and Applications (ICOECA)*, 2024, pp. 137–143.

[20] A. Novick, J. Clark, and D. Matsakis, “Environmental effects and control systems for gps-disciplined clocks (gpsdc),” in *2023 Joint Conference of the European Frequency and Time Forum and IEEE International Frequency Control Symposium (EFTF/IFCS)*, 2023, pp. 1–6.