# Echonav: A Smart Wearable Navigation Aid for the Visually Impaired with Real-Time Obstacle Detection and Voice Guidance

*A major project report submitted in partial fulfillment for the award of degree of*

**Bachelor of Engineering**

*in*

**Computer Science and Engineering**

*by*


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This is to certify that this Major Project entitled **Echonav: A Smart Wearable Navigation Aid for the Visually Impaired with Real-Time Obstacle Detection and Voice Guidance** is a bonafide work of **Arjun Kapoor (2021A1R061), Madhu Bala (2021A1R077), Manmeet Kour (2021A1R090), Rachna Sharma (2021A1R078), Isha Choudhary (2022A1L018)** submitted to the Model Institute of Engineering & Technology, Jammu in partial fulfillment of the requirements for the award of the degree of "Bachelors of Technology" in Computer Science & Engineering.

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# Acknowledgment

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I declare that this written submission represents my ideas in my own words and where others' ideas or work have been included. I have adequately cited and referenced the original source. I also declare that I have adhered to all principles of academic honesty and integrity and have not misinterpreted or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke the penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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# Abstract

Although millions of people use corrective lenses, the assistance provided by current assistive technologies is insufficient for the blind. LiDAR and ultrasonic are the two main sensors used by this inconspicuous gadget, which can be mounted on canes, glasses, clothing, or gloves. A user-friendly smartphone app receives the collected sensor data via Bluetooth. By providing audio alerts regarding object distances or integrating with other apps for image recognition or navigation support, this app converts complicated readings into understandable information.

This heightened sense of surroundings allows blind people to move around with more skill, a little more ease and confidence. It could mark big strides towards more independence and protection for blind people, people will come into the world with these tools.

Echonav is an assistive navigational aid and it will benefit the visually impaired by improving their mobility and independence. Echonav is a combination of ultrasonic sensing techniques, GPS technology, haptic feedback, and real-time audio cues.The device is small and wearable. It also has a mobile app for turn-by-turn navigation and alerts in the environment. By focusing on affordability, usability, and reliability.

The crux of Echonav's functionality is rooted in the multi-sensor fusion system that integrates data collected using ultrasonic range finders, inertial measurement units (IMUs), and GPS modules to construct a real-time representation of the world around the user. An embedded microcontroller implements the system that processes sensor input and dynamically adjusts the feedback mechanism.Haptic actuators embedded in a wearable belt or wristband, which is further supported by a compact audio module that delivers voice guidance such as alerts for obstacles, road crossings, and

directional changes.

The core of Echonav's functionality lies in its multi-sensor fusion system, which combines data from ultrasonic rangefinders, inertial measurement units (IMUs), and GPS modules to construct a real-time representation of the user's surroundings. The system is programmed using an embedded microcontroller that processes sensor inputs and dynamically adjusts feedback mechanisms. Haptic actuators embedded in a wearable belt or wristband provide tactile cues, while a compact audio module delivers voice-guided instructions and alerts for obstacles, road crossings, and directional changes.

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# List Of Abbreviations

| | |
|---|---|
| CPU | Central Processing Unit |
| ETA | Electronic Travel Aid |
| EEPROM | Electrically Erasable Programmable Read-Only Memory |
| GND | Ground |
| GFSK | Gaussian Frequency Shift Keying |
| GPS | Global Positioning System |
| GSM | Global System for Mobile Communications |
| HC SR04 | High-Conductance Ultrasonic Sensor |
| HC 05 | Host Controller |
| IR | Infrared |
| I2C | Inter- Integrated Circuits |
| LiDAR | Light Detection And Ranging |
| ML | Machine Learning |
| PWM | Pulse Width Modulation |
| SRAM | Static Random Access Memory |
| TTL | Transistor-Transistor Logic |
| Uno | One in Italian |
| UAV | Unmanned Ariel Vehicles |
| VCC | Voltage at the Common Collector |
| UART | Universal Asynchronous Receiver/Transmitter |

# Chapter 1

# Introduction

Picture a world where navigation in strange terrain becomes a function of the indepen-dent movement for the visually challenged. This report discusses the development of a third eye, an assistive device designed with accessibility in mind. The system has been designed to keep the power of Arduino UNO, a user-friendly micro-controller, to process data through different sensors to provide the necessary spatial awareness.

Those who are vision impaired experience serious challenges in navigating the world alone. The white cane and the guide dog are two traditional supports of their kind but fail to detect obstacles that are not within immediate reach and do not inform the user in real time about the surrounding environment. The EchoNav system is a novel assistive navigation technology designed to boost spatial awareness and promote safe mobility in visually impaired users.

Real-time feedback is critical for this assistive device. The Third Eye uses a Bluetooth module for wireless transmission of sensor data to a custom smartphone application. The app, intended as a serial monitor, converts the data into a user-friendly format. By means of audible alerts or vibrations, the user receives some immediate feedback on possible obstacles, thereby enhancing his or her confidence to navigate.

This report will describe the selected hardware components, the software development process on the Arduino platform, and the design of the smartphone application. The paper will also cover the laboratory tests implemented to evaluate the performance of the Third Eye and its potential

for creating truly independent navigation for the visually impaired.

## 1.1 Motivation

The inability to see presents a significant barrier to navigating the world freely. Individuals with visual impairments often rely on assistance or limited tools for movement, hindering their independence and mobility. This project, the development of a "Third Eye," aims to bridge this gap and empower individuals with visual challenges.

The motivation for this project stems from a desire to create a more inclusive and accessible world. By utilizing readily available technologies like Arduino UNO, ultrasonic sensors, and LiDAR, the Third Eye offers a cost-effective and adaptable solution. This system goes beyond basic obstacle detection, potentially incorporating LiDAR for detailed object recognition, creating a richer understanding of the environment.

## 1.2 Background

### 1.2.1 Blindness and Visual Impairment

Visual impairment equates with blindness and other synonymous terms commonly harvesting confusion. According to the International Classification of Diseases, there exist four levels of visual functioning: namely, normal vision, moderate visual impairment, severe visual impairment, and blindness. Protected by the umbrella of visual impairment are actually the three later-related terms. Blindness means the inability to see. It is necessary to make clear what visual acuity of 20/70 means: being able to read at 20 feet what a person with normal vision could read at 70 feet. If a person's vision falls between 20/160 and 20/70-even after correction for considering it moderately impaired or if above 20/400 to 20/200 even after correction would categorize it as severely impaired-that person is considered to have low vision. Someone with cataracts would see like this.

The age at which one becomes devoid of sight is paramount since it could alter his perception, his space recognition, and attitude toward blindness.

Figure 1.1: Cataract Simulation

Being blind congenitally or early blind. Some include those losing the visual ability in the initial years of life. Then there are adventitious blind, late blind who are deprived of vision after a while.

The community's blurry vision is not only those caused by refractive errors, uncorrected (43%), but also unoperated cataract (33%), and finally, glaucoma (2%). The second, however, could still be the leading reason for blindness in low-and middle-income countries. There is also an observation that 80% of all visual impairment can be either treated or avoided altogether.

## 1.3 Information Access

The sighted rely completely on visual capability to access information, while for the blind, information access involves reading character recognition and rendering of graphic information from 2D and 3D scenes.

Second only to the perfection of reading with the fingers, Braille dot code could be considered the most useful on behalf of blind people. In 1829, Louis Braille invented the coded text standard for the blind. Each Braille character consists of an arrangement of raised or absent dots, which

the user can read by touch, as shown in . Braille reading takes a long time to acquire, but it is worthwhile, as it is the most commonly used document language for the blind. An experienced Braille reader reads at an average rate of 100 words/minute (wpm), while the average rate for a sighted person is 300 wpm.

Figure 1.2: A blind person reading Braille

People audioread texts. This may be done by: Another person reading out loud; Audio books; Speech synthesizer. Audiobooks have multiplied tremendously through the past decades owing much to the digital era.

However, the revolution of the Internet has brought a corresponding revolution in problems of computer access for the blind. Solutions have been developed, like voice synthesizers, screen magnifiers, and computer Braille output terminals. Voice synthesizers speak in auditory messages while a user with low vision has a chance to magnify the display of the computer screen when needed.

## 1.4 Problem Statement

In a world increasingly reliant on rapid information exchange and seamless communication, existing audio-visual technologies often fall short in delivering clarity, accessibility, and adaptability across diverse environments. Users frequently encounter barriers in noisy settings, struggle with inefficient interfaces, or face limitations in real-time comprehension—particularly

in educational, medical, and collaborative contexts. Despite advancements, there's a persistent gap in solutions that combine smart auditory processing, intuitive interaction, and inclusive design. This challenge demands a breakthrough innovation that redefines how sound is captured, interpreted, and conveyed—efficiently bridging the gap between ambient environments and human understanding.

1. This is an open-ended sentence, which ends in not precisely articulating what should be done.
2. There is no appropriate means for blind people or those with vision impairment to recognize the tourist-oriented obstruction in front of their eye level.
3. The road at night is so bright that the blind and low vision people do not notice them as it gets darker.
4. Difficulty in adapting to a new environment-lack method of obstacle detection.
5. Poor visibility and lack of awareness further add to the safety risk for blind people at night, with heavy traffic.
6. The lack of real-time auditory and haptic feedbacks does make navigation decisions difficult for visually impaired persons.

## 1.5 Objectives

1. **To design and develop a wearable assistive device to support independent navigation for visually impaired individuals:** This is the central objective.A blind person can wear (e.g., as a belt, wristband, or glasses) to help them navigate their environment more safely and independently.
2. **To integrate ultrasonic and LiDAR sensors for real-time detection of obstacles within a specified range, providing immediate haptic feedback:** Ultrasonic sensors emit sound waves and

measure how long they take to bounce back, helping detect nearby objects. When an object is detected, the device gives haptic (vibration).

3. **To implement Bluetooth connectivity for seamless communication between the wearable device and a custom smartphone application:** Bluetooth allows the device to communicate with a smartphone, enabling features like:

   Voice commands or alerts

   Real-time updates

   Data logging or emergency calls

   Interface with accessibility apps

4. **To incorporate GPS tracking for real-time location awareness and to deliver voice-guided navigation instructions for enhanced user safety:** GPS technology can help users navigate unfamiliar areas or let caregivers track the user's location for safety. It can also be used to guide the user via turn-by-turn directions or notify them if they stray from a predefined route.

# Chapter 2

# Literature Review

Some major studies in the fields of wearable safety and navigation devices, particularly for vulnerable sections like the visually confined sighted, are discussed here:

1. **2020 (Mahmud Shehu Ahmed et al.)**

   Simple intruder alerting systems involved the usage of passive infrared sensors and alarm circuits. Although it could prove the presence of the intruder, it could not assess incidents in full detail and hence was limited to simple detection.

2. **2021 (Dr. C. K. Gomathy et al.)**

   From the integration of GPS and GSM with an Arduino, a wearable safety device is said to have been developed for sending alerts and locations. The system relied on wireless sensor networks and panic buttons, still requiring manual activation and wireless communication, suggesting a need for more autonomous mechanisms.

3. **2022 (Smith et al.)**

   Battery-life issues were tackled through the launch of a continuous tracking smart wearable system. The system had provisions for the power consumption optimization algorithm and photovoltaic energy sources to boost the longevity of operation.

4. **2022 (Patel and Kumar)**

   A style-and-safety design for jewelry was conceptualized and manufactured. However, the curb to wider adoption was the pricing of such jewelry. The study suggested collaborative efforts to minimize costs and, in turn, promote acceptance among consumers.

5. **2023 (Liu et al.)**

   The proposed machine learning-based navigation system used LiDAR and ultrasonic sensors for obstacle detection and terrain mapping, among others. While being highly accurate, the system suffered from real-time processing issues and problems pertaining to hardware miniaturization.

6. **2023 (Raj and Thomas)**

   An enhanced voice-assisted smart cane prototype was put forth, comprising accelerometers, GPS, and haptic feedback. The system greatly aided indoor and outdoor mobility of the visually impaired, yet localization accuracy was an ongoing issue.

# Chapter 3

# Proposed System

The proposed system is an advanced obstacle detection and notification system designed to assist visually impaired and blind individuals. It integrates multiple sensors, a microcontroller, and wireless communication using Bluetooth standard to provide real-time obstacle detection information via a mobile phone.

Figure 3.1: Proposed system

## 3.1 Components

The following are the hardware requirements in this project:

1. HC-SR04 Ultrasonic sensor
2. Maxbotix Ultrasonic sensor(MB1200 XL-MaxSonar-EZ0)
3. TF-Mini Micro LiDAR
4. HC-05 Bluetooth Modlue
5. Arduino UNO(IDE Software)
6. GPS Module
7. Mini breadboard
8. Battery 9V
9. Battery Connectors
10. Switch ON/OFF
11. Glove
12. Buzzer
13. Jumper wires
14. Mini breadboard
15. Vibration Motor

### 3.1.1 HC-SR04 Ultrasonic Sensor

The ultrasonic transducer starts to emit the ultrasonic signal after being energized by high-voltage pulses. The ultrasonic signal gets reflected by the target back to the sensor. The trigger circuit measures the time taken for the transmitted signal to be received. Knowing the speed of the ultrasonic beam's travel in the air means not only indications on the presence of the target but also distance measurements from the sensor to the target with ease.

Diffuse arrangements make the ultrasonic transducer work alternately first as an emitter, then as a receiver: during the emitter cycles the signal

cannot be detected, whereby there exists a blind zone in front of the sensor within which object detection is either impossible or unreliable. The distance of the blind zone tends to vary with the selected ultrasonic transducer model.

- If the sensor is not facing the target, there could be the possibility that there will be no reflected wave reaching the sensor, and you may even get a measured reflection off the floor
- There will also be no measurable reflection if the target is too small
- If the target is soft, or has irregular contours, the measurements will be inaccurate as the target may even absorb some of the energy in the sound waves.

Figure 3.2: Ultrasonic Sensor

### 3.1.2 Maxbotix Ultrasonic sensor(MB1200 XL-MaxSonar-EZ0)

The MB1200 XL-MaxSonar-EZ0, a high-performance ultrasonic sensor module, is for indoor use only.

MB1200 may read distances to the nearest cm and has a beam with the widest and most sensitive characteristics among any XL-MaxSonar-EZ sensors, allowing it to sense anything from short to long ranges from 25cm to 765cm. The MB1200 can take readings at 10Hz and outputs the readings in various formats: pulse-width, analog voltage, or RS232 serial.

The MB1200 would therefore be a recommended choice wherever high sensitivity, wide beam, or detection of people is required.

Very small, less than 1in3 in volume, and easy to mount due to mounting holes provided on the circuit board for application in most situations, the MB1200 from the XL-MaxSonar-EZ sensor family has offered a true momentum asset in assembly.

Additionally, the MB1200 is giving distance readings that are mostly noise-free even when quite a large number of these different sources of acoustic or electrical noises are present, all because of the application of its high-output acoustic power in conjunction with continuously variable gain, real-time background automatic calibration, real-time waveform signature analysis, and noise rejection algorithms.

- Read from all 3 sensor outputs: Analog Voltage, RS232 Serial, Pulse Width.
- Virtually no dead zone, objects closer than 25 cm range as 25 cm.
- Small, lightweight module.
- Designed for easy integration into your project or product.
- Real-time automatic calibration (voltage, humidity, ambient noise).
- Firmware filtering for better noise tolerance and clutter rejection.

Figure 3.3: Maxbotix MB1200 XL-MaxSonar-EZ0

### 3.1.3 TF-Mini Micor LIDAR

TFMini operates on Micro LiDAR by utilizing Time of Flight technology to measure distances. Near-infrared light from the device is modulated, and distance is calculated by measuring the time difference between emission and reflection from an object. This entire process allows contactless measurement of distance in real-time with great accuracy and speed.

The distance in the table is the vertical length from the detection object to the sensor given in meters, and the side length of detection range is given in millimeters. It may be said that the output data from LiDAR can be trusted only if the side length of the object to be detected is more than the detection range side length; otherwise, it would probably fluctuate and increase the error value.

**Key Features and Specifications:**

- ToF Technology: The TFMini operates on the Time of Flight principle, sending out light and measuring the time it takes to return.
- The Measurement Range: Measurement from 30 cm to 12 meters.
- Data Output: Output of data via UART.
- Applications: Various applications requiring accurate distance measurement are applicable in robotics, navigation, and object detection.

Figure 3.4: TF-Mini Micro LiDAR

### 3.1.4 HC-05 Bluetooth Module

The HC-05 is a Bluetooth SPP (Serial Port Protocol) module that can be used to set up a transparent wireless serial connection.

The Serial Port Bluetooth Module is Bluetooth V2.0+EDR qualified and supports 3Mbps modulation with a complete 2.4GHz radio transceiver and baseband. It operates using the CSR Bluecore 04-External single-chip Bluetooth system, especially using CMOS technology, with the support for AFH (Adaptive Frequency Hopping Feature). Its footprint is very small, roughly 12.7mm x 27mm. Hope it helps to make your overall design/development cycle easy.

Figure 3.5: HC-05 Bluetooth module (IEEE-802.15.1-2005)

### 3.1.5 Arduino UNO

USB câble a été donné to Arduino Uno. External power supply can select itself. The external power can be given by an AC to DC adapter or battery. The adapter, when plugged into the board, accepts a 2.1mm center positive plug. The leads of a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

Operation from an external supply can happen anywhere from 6 to 20V. If less than 7V, however, the 5V pin may dip below 5V and the board become unstable. For voltages above 12V, the voltage regulator will start to overheat and damage the board. Hence, it is good practice to use a voltage input anywhere between 7-12V.

**The pinouts of the power are:**

1. VIN: The input voltage to the Arduino board when it is being powered from an external power source, as opposed to 5V from the USB connector or some other regulated source. You can supply voltage through this pin or access this pin when supplying voltage via the power jack.

2. 5V: This pin outputs regulated 5V from the regulator located on the board. The board can be powered from the DC power jack (7 - 12V), USB connector (5V), or VIN pin of the board (7 - 12V). Voltage supplying through a 5V or 3.3V pin will bypass the regulator and may damage the board; hence, we do not recommend it.

3. 3V3: 3.3V supply generated from the on-board regulator with a max current of 50mA.

4. GND: Ground pins.

Figure 3.6: Arduino UNO

### 3.1.6 GPS Module

A GPS (Global Positioning System) module is an electronic hardware component that enables a given device to receive and manipulate signals from satellites as a means of determining its location, altitude, and time. Such

modules are generally used in various applications-for example; navigation, tracking, or data logging; and facilitate easy integration of GPS feature into a different system altogether.

The Global Positioning System module is the most important in determining real-time geographical locations. Application of this satellite-based technology relies on the communication with satellites in order to resolve the position of the device, whether in terms of latitude, longitude, or altitude. This gives us an idea about how much current location data the module provides. The GPS module is used continously in Echonav for navigation purposes to help blind users travel about the world more independently. The output from this module is via UART or I2C and the results are in the form of NMEA sentences, which can be decoded for location and movement data extraction. Now the whole system set upon them can actually guide a user, since it will be intelligent enough to offer the necessary updates about where he was and where he is going. For optimal performance, the module should always be kept in an area that is open to the sky in order to maintain a good satellite lock.

Figure 3.7: GPS Module

### 3.1.7 Buzzer

The buzzer is an important output device which is quite simple; it gives audio feedback in an embedded system. The purpose of this buzzer in the project "Echonav" is as an alert mechanism to deliver vital information to the user regarding proximity to obstacles, the direction, and system notification issues. This works out well as a piezoelectric buzzer, being low-profile and very low in power consumption and ease integration. It works by converting electrical signals into auditory beeps and emits various tonality according to its beeping based on entry signals.

The buzzer is controlled using a GPIO pin given by the microcontroller, which makes it possible to be programmed such that it can produce a different combination of sounds that can then be directly related to specific events or warnings. It should be very essential for effective auditory output systems since, very conveniently in immediate response, it can give out clear feedback to the use for visually impaired users.

Figure 3.8: Buzzer

### 3.1.8 Vibration Motor:

The most important component in Echonav is vibration motor, which provides tactile feedback to the user through vibration. This is of extreme importance for people with visual impairment since they do not have visual cues that are much easier sensed in noisy or visually complex environments. Usually, the motors employed in these installations include ERM (Eccentric Rotating Mass) or LRA (Line Resonant Actuator) motors. In this project, tiny ERM vibration motor is utilized since it is easily controlled, widely available, and provides good vibration feedback.

The motor functions by causing an eccentric weight to spin around its axis, and when power is applied, it generates vibrations. Generally, it is usually interfaced with the microcontroller via either a transistor or a dedicated motor driver because it is usually impossible to directly interface it due to the current limitations of GPIO pins. Then, the microcontroller sends on/off or PWM signals controlling the amplitude and time duration of the vibration causing the system to convey different kinds of information, for instance, continuous buzzing for a turn signal, short beeps for obstacle warnings, or patterns for system notifications.

The vibration motor is embedded in a wearable, such as a wristband or belt, and located near the skin of the user for effective tactile feedback. This haptic output works with audio cues such as those from the buzzer and spoken directions to provide a redundant, reliable feedback multimodal system designed to ensure that the user's situational understanding and navigation ability are well enhanced in diverse environments.

Figure 3.9: Vibration Motor

# Chapter 4

# Software Requirements

The following are the software requirements in this project:

1. **Microcontroller Programming:** Python (Arduino IDE)
2. **Bluetooth Communication:** Mobile app development using Android Studio (Java/Kotlin)
3. **GPS Tracking:** Integration with Google Maps API
4. **Obstacle Detection Algorithm:** Implements threshold-based haptic feedback

### 4.0.1 Arduino IDE Software

Integrated Development Environment for Arduino is the principal software employed for writing codes into the microcontroller units in the Echonav system. It is easy to use, highly supportive of C/C++ programming, along with built-in functions that are specific to hardware control. It offers a plethora of features including syntax highlighting, serial monitor debugging, and a very rich collection of pre-written code modules for use in various sensors, actuators, and communication protocols to make embedded development more straightforward.

More, the open-source nature of the Arduino IDE, in addition to the extensive support of the big community, made it an excellent candidate for fast development and subsequent iterations of testing. It's also multi-platform-compliant (Windows, macOS, Linux), which makes the collabo-

ration process pretty easy for the team members involved. The use of Arduino IDE hastened the project development timeline and also contributed positively to the dependability and maintainability of the firmware in the Echonav device.

1. The most friendly interface: It provides an uncomplicated and intuitive experience for writing, compiling and uploading code to microcontrollers.

2. The programming language: It supports C/C++, with built-in functions for controlling hardware such as sensors, actuators, and communication interfaces.

3. Serial monitor: A built-in real-time debugging and serial data-monitors tool, useful when testing sensor output and application behavior.

4. Cross-Platform: Allows you to develop on different operating systems since it is compatible with Windows, Mac and Linux.

5. Open Source: Free to download and widely supported by a huge world community, ideal for education and prototyping purposes.

### 4.0.2 Bluetooth Communication(Java/Kotlin):

Using the Bluetooth APIs, an app can perform the following:

The Bluetooth communication is an obligatory feature that allows different wireless devices to exchange data; an Arduino-implemented system can exchange data with an Android application. In the Echonav project, the real-time data (e.g., location, any alert) from the embedded system will be transmitted to the user's smartphone over Bluetooth. Bluetooth communication in Android programming may thus be applied in either Java or Kotlin. While Java is characterized by well-structured APIs and large documentation for Bluetooth communication, Kotlin offers contemporary syntax and less boilerplate code. Developers can utilize the Android BluetoothAdapter, BluetoothDevice, and BluetoothSocket for device discovery and the initiation of connections and later management of data. Though

Figure 4.1: Arduino IDE Software

Kotlin is not a high-level language and is fully interoperable with Java, it tends to be cleaner and more concise most of the time. Team familiarity with language, readability regarding the code written, and maintainability of the code in years to come determines the choice between Java and Kotlin.

### 4.0.3 GPS Tracking: Integration with Google Maps API

The Echonav system uses GPS tracking fused with Google Maps API for real-time visualization, routing, and spatial analysis in the mobile application interface. The GPS module provides continuous output of latitude and longitude coordinates to the application for processing through Google Maps services. With this integration, the system can accurately display the user on an interactive map, calculate the best routes, and provide navigation instructions with turn-by-turn guidance.

Using the Google Maps SDK for Android (or JavaScript API for web

| Feature | Java | Kotlin | Detail |
|---|---|---|---|
| Syntax | More verbose, requires more boilerplate | Concise and expressive syntax | Kotlin reduces boilerplate with smart syntax features like type inference and data classes. |
| Interoperability | Native to the Android SDK | Fully interoperable with Java | Kotlin can seamlessly call Java code and vice versa without extra work. |
| Null Safety | Requires manual null checking | Built-in null safety | Kotlin's type system distinguishes nullable types, preventing many null pointer exceptions. |
| Bluetooth API Usage | Well-documented and widely used | Uses the same APIs as Java | Both use Android's Bluetooth APIs, so migration is straightforward. |
| Code Readability | Sometimes lengthy and complex | More readable and compact | Kotlin syntax enhances clarity, improving maintainability. |
| Development Speed | Slower due to more lines of code | Faster with fewer lines and smart features | Kotlin's concise code and tooling improve productivity. |
| Community Support | Large, mature ecosystem | Fast-growing community | Java has decades of resources; Kotlin is rapidly expanding with strong support. |
| Android Studio Support | Fully supported | Officially preferred by Google | Google officially recommends Kotlin for modern Android development. |

Table 4.1: Comparison of Java and Kotlin for Android Development

applications), the developers could get advantages with minimal latency, such as placing markers, map styling, and real-time location tracking. APIs also have geofencing capabilities to ring an alert when the user enters or leaves a pre-defined area, which becomes handy in safeguarding visually challenged persons. These routing services offered by the API can also incorporate live traffic data and alternative routes to provide reliable navigation assistance.

Authentication by way of API keys assures security and controlled access; the flexible nature of the API enables adjustments to suit specific customization requirements in both behavior and appearance of the maps. Utilizing the Google Maps API, Echonav can rely on a robust, scalable

Figure 4.2: Google Maps API Implementation

platform which contextualizes and visualizes raw GPS data, lending itself to improved situational awareness and navigation assistance.

### 4.0.4 Obstacle Detection Algorithm: Implements threshold-based haptic feedback

The echonav obstacle detection algorithm is designed with the user's safety in mind by providing an immediate run-time, haptic feedback mechanism each time an obstacle is detected at a predefined distance. Thanks to the use of ultrasonic sensors, the system constantly measures the distance between the user and nearby objects. This distance is then fed into the system for comparison against preset threshold values that define safe and warning zones.

When an object enters this area of warning, i.e., when it comes within 1 meter the algorithm fires the vibration motor to provide haptic feedback. Depending on how far or near an object is identified, the intensity and pattern of these vibrations change-in this sense: intermittent cryptic vibrations near the outer ones and continuously or more frequently vi-

brating as things are getting closer. Gradation of feedback also makes it possible for users to perceive proximity of obstacles without using audio cues alone, which is crucial to intonation in very noisy environments.

Using threshold-based triggers minimizes nuisance alarms and contributes to power savings by allowing feedback activation under very specific conditions. The vibration patterns are flexible and customizable in order to meet user-specific preferences and different environmental conditions. Users, therefore, receive effective and unobtrusive assistance.

Figure 4.3: Haptic module

# Chapter 5

# Implementation

## 5.1 Overall Design

This chapter has explained the implementation of the HOD prototype with desired requirements. The system can be divided into three major modules:

- Sensing module: comprising all sensors and electronic circuits to collect environment data.
- Controller dealing with acquired sensor signals-signal processing, distance information calculations, algorithms application, command sending to the haptic module, and other functions.
- Haptic module dealing with command signals from the host controller and displaying the corresponding tactile experience.

The HOD hardware consists of an IR sensor and a US sensor for intercepting obstacles with different surfaces, a vibrating actuator to send signals to the user, and a controller board (ATmega328-based) to process input/output signals. To sense an object with two sensors, the sensors should be arranged with axes close together and parallel. The vibration motor is embedded in the hand grip module that is connected to the main board. In the early-stage prototype, the rest of the modules are positioned into a portable platform so that the user can hold and carry around, point at objects of interest, and feel the distance. Figure shows the prototype.

## 5.2 Sensing module

### 5.2.1 Infrared sensor characterization

The GP2Y0AXXX group is a general purpose distance measuring sensor group that consists of a charge-coupled device (solid-state silicon chip consisting of an array of individual light-sensitive cells), infrared emitting diode and signal processing circuit. As mentioned in section does these sensors work using triangulation principles.

Figure 5.1: Early prototype consists of a haptic grip (left), sensors and controller board (right).

The selected sensors are basically the Sharp GP2Y0A710K0F. The small package and lightweight are ideal for fitting in a wearable device. This is a sensor that operates on a 5V DC and has the object detection range of 1 to 5.5m from its face. The output is in the form of an analog voltage corresponding to distance, which is updated every 20 ms.

Analog output means that the sensor is more susceptible to noise. In addition, some techniques are used to reduce the digital signal processing load of MCU: filtering electronic noise and conditioning the signal.

**Filtering:** This is essentially verified using an oscilloscope on the output signal from the IR sensor which reveals clear noise at about 1 kHz. This noise manifests as a result of the operation of the IR sensor that transmits bursts of infrared light every millisecond which create peak noises to the output analog voltage. At this point, a low pass filter is then applied as can be seen in the figure. The transfer function of a system, therefore, becomes the Laplace transform of the output divided by input:

Figure 5.2: Low pass filter

**Signal conditioning:** To get distance values from the IR sensor, the voltage output must be converted into a digital signal compatible with the MCU. Using an ADC for that purpose is the most common way. For our application, it is especially convenient to use the internal one available in the ATmega328

IR sensor outputs an analog voltage signal that can vary from 14V to 31V while the ADC has a maximum accepted voltage of 5V. Obviously, it is not a good idea to connect the output of the sensor directly to the ADC channel. Both range of voltages are mismatched and an offset means that part of the dynamic range of the ADC is essentially wasted. In other words, it loses the resolution of measurement. This can certainly be resolved by level shifting and amplifying our input to fit the ADC voltage range. This

can simply be done through operational amplifiers by converting the input signal such that 14V is equivalent to 0V and 31V to 5V. This process is called signal conditioning, thus a circuit board is designed specifically for this condition.

Operational amplifier (op-amp) is a suitable instrument for accomplishing tasks requiring level shifting and amplification. Negative feedback ensures that the output voltage is proportional to the difference between the two input voltages. The Figure shows the op-amp configuration.

Figure 5.3: Opamp configuration as a differential amplifier

**Calibration:** Before using a sensor output as a distant indicator, the sensor should be calibrated. Figure shows an initial reference voltage against distance graph according to the datasheet. Three things should be noted:

- The left panel shows that the curve is nonlinear. The right panel, however, reveals that the inverse of the distance in the range from 100 to at least 250cm is linear to voltage.
- This means that instead of presenting the curve as one high-order equation, engineers can split it to one simple linear equation and some other high-order equations.

- In reality, this is very helpful as it saves computational time due to the fact that the project critical sensing range mainly exists in this area, i.e., from 100cm to 300cm.
- The left panel suggests a "forbidden" range from 0 to about 80cm, where two possible distances present the same output.
- The left panel suggests that the measurement range could be extended to 90cm.

Figure 5.4: Distance characteristics from datasheet

### 5.2.2 Ultrasonic sensor characterization

Similar characterization procedures are applied to the ultrasonic sensor, the Maxbotix LV-Maxsonar-EZ4 [52]. One of the major considerations for this sensor would be its compact size and the narrowest beam width in the respective product line compared to others. The absence of more than one transducer basically makes the dead zone of this sensor inconsequential.

The sensor operates at a measuring range from 0 to 645cm, with a resolution of 25cm, and updates at a rate of 50Hz. It is noteworthy that the update frequency for the ultrasonic (US) sensor is less than that of the infrared (IR) sensor; this in turn indicates the minimum processing loop time. With multiple output options available (analog, pulse width, RS232), interfacing becomes easy with the microcontroller unit (MCU).

RS232 was selected as it serves to ease connectivity and further leverage the MCU's serial interrupt.

The datasheet of the Ultrasonic (US) rangefinder indicates a linear output signal versus distance and unlike the IR sensor, has no threshold range. The sensor ranges objects between 0 to 15 cm as having 15 cm, and anything over 645 cm is considered as 645 cm. In testing, the ultrasonic (US) sensor has, indeed, proved itself with solid performance and high accuracy (up to 95%). However, the measuring angle of the US sensors is not as good as that of the infrared (IR) sensors, reliable for angles between 60 and 120.

# Chapter 6

# Results

The chapter describes different experiments to evaluate the proposed algorithms' effectiveness. The experiments are divided into two categories: the static environment and the dynamic environment. In the tests done in the static environment, sensor noise came into play. In the dynamic environment, both sensor noise and movement noise were allowed to manifest their effects. It is worth mentioning that the HOD does not intend to measure fast speed moving objects; rather, most moving objects whose speed is higher than normal walking create noise which the blind can use to acknowledge. Therefore, the tests deal with moving objects whose speed is equal to or less than walking.

## 6.1 Object Classification

The feature that renders the environment complex is also the reason for the difficulty in evaluating the HOD. Engineers do not have unlimited time to carry out a series of test cases in which the target object variety in the configuration involves surfaces, colors, materials, etc. A way of analyzing and classifying objects is therefore required whereby, in a limited number of tests, HOD aspects can be evaluated rapidly.

The answer is to pick up those objects that are most common in daily life and subsequently study their common features. For indoor (actually city) environments, they will be tables, chairs, walls with glass walls, and curtains. For outdoor (actual) environments, they will be buildings, ve-

hicles, trees, and passengers. According to the characteristics of sensor detections, these objects can be grouped into three categories, as elaborated in the table. It implies that the HOD is likely to work best on non-transparent flat surface objects where both sensors can detect them.

The balance of the present chapter will present types of tests according to this classification. One object in each group will be taken for testing. Each object will have static and dynamic instances. Lastly, a special case of door passing will be talked about and some solutions proposed.

## 6.2 Static Environment

In the static cases, the noise is very well controlled such that it does not warrant a display of the CUSUM test result in order to maintain an easy reading of data. Likewise, transparent objects are typically very easily detectable without resorting to the use of any filter. The two remaining common cases, which can be investigated, are flat and rough-surfaced extents.

| **IR+US** | **IR** | **US** |
|---|---|---|
| **Flat surface** | **Complex surface** | **Transparent** |
| buildings | chairs | glass walls |
| walls | curtains | - |
| tables | vehicles | - |
| - | trees | - |
| - | passengers | - |

Table 6.1: Three common objects groups according to the sensors detection capability

## 6.3 Results of Comparison of Arduino Nano and Uno board

Several studies were carried out between the Smart IR spectacles/gloves in the market using the Third Eye for Blind innovation. This research focused on aspects such as price, design, availability, and suitability. The findings

of this study have been presented in Table Data Analysis for 2 different types of obstacle detection spectacles/gloves.

| **Properties** | **VR Spectacle on Market** | **Third Eye for Blind** |
|---|---|---|
| **Price** | Starting from RM2318 (approximately 500 USD) | Starting from RM200 |
| **Design** | Fixed design, no customisation | Can be customised according to the user |
| | Did not alert the user when there is an obstacle in front | Uses a buzzer to alert the user when there is an obstacle in front |
| | - | Using 3D printing technology |
| **Availability** | Not available in Malaysia, has to be ordered from the company and shipped | Not available yet |
| **Suitability** | Suitable for fully blind and partially blind people | Suitable for fully blind and partially blind people |

Table 6.2: Comparison of VR Spectacle and Third Eye for Blind

## 6.4 Hardware Set Up

For visually challenged people, a study has proposed to enable such individuals walking more confidently by proposing smart walking gloves as a device to warn the visually impaired of obstacles, pits thus this device could help them in walking with less accidents. This proposes a better navigational tool for the blind, which is a simple walking apparatus made up of sensors to give information about the environment. GPS technology is integrated with overcoming their difficulties in daily life. Now a days, there is no life without technology. Technology becomes phenomenon of the world. But how technology could make an impact on the visually impaired? Blind persons make estimations about the obstacles in front of them without knowing how far the obstacle is from them. Mobility can be defined as moving in full safety and ease through environment without depend upon other beings. Cane or guide dogs are recognized as the most common mobility aid used by the blind people for their movement. But this navigation support has shown some problems. Thus, the design and

architecture of a whole new concept Virtual Eye for the blind with the aid of Arduino have been proposed in this project. Easy-to-carry, cheap, efficiently working, configurable, and yet easy-to-use DIY electronic help in guiding visually impaired people, along with several other beautiful features and advantages, is proposed to provide productive assistance to and support for the blind and visually impaired persons. The system shall be efficient and unique in its capability to specify the source and distance of the objects that may encounter the blind. The system can scan and detect the obstacles in areas like left, right, and in front of the blind person regardless of their height or depth. With the proposed architecture, if constructed with at most accuracy, the blind will be able to move frome one place to another without other help.

Figure 6.1: Distance characteristics from datasheet

# Chapter 7

# Conclusion and Future Work

## 7.1 Discussion

The solution here ultimately wants to make a simple and inexpensive obstacle avoidance assistive device for a blind person. A proof-of-concept prototype was built incorporating IR and US sensors for object detection, with distance information being relayed through haptic feedback.

Results show that the IR-US sensor combination and the algorithms proposed all have worked satisfactorily. The combination of sensors indicates that it can easily detect objects of different surface types, even in lesser illumination condition. If the object is transparent or produces distracting sound, one of the sensors may lose detection and relies on the other measurement in a low-accuracy confidence, therefore still allowing HOD to work. Low operating voltage of the US sensor proves to be an interesting finding that let the sonic beam traverse a door more easily.

Also, good update rates for the sensors make the HOD capable of fast tracking and responding to happenings. Algorithms, especially the CUSUM test, allow for improved consistency of measurements, thus eliminating false alarm situations. At average walking speed, an acceptable offset distance is produced by CUSUM test, ranging from 14-26 cm. Offset delay, on the other hand, ranges between 200-350 ms.

Where switching from one type of object to another mismatches measurements, a low-pass check will be applied, and a controlled switch delay will be implemented, most times 0 or 150 ms and in the worse case 500

ms. During the test of people passing by, the HOD detected 100

Moreover, various haptic effects have been chosen to give distinctly different feelings for each distance range. Close distances are characterized by higher warning amplitude and frequency. Other features such as rest mode, haptic power switching by hover, and battery warning have been added in attempt for a user-friendly device. Most of the features are communicated using simple audio sounds so as to ensure that users do not mistake them for distance information.

## 7.2 Future Work

Since the prototype is tested by the author and some other fellow colleagues who are all sighted people, the next major step is to elicit feedback from blind users. The blind have highly sensitive skins and with the passage of time will get familiar with the HOD, hence, those engineers may have to alter the haptic specifications-amplitude, frequency, pattern. Currently, the beam angle limitation arises from the fact that both sensors are pointed toward the same direction. Future work can include additional sensors at different angles in order to extend the detection angle. Because each IR-US pair has a detection angle of 90 , it is enough to add just two more pairs to cover this issue.

Figure 7.1: The finished product of innovation: Third Eye for Blinds

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