Scooter Proximity Alert Final Report

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Final Proposal: Team #9 Fall 2023
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Introduction

Acknowledgement

Design Team 9 is grateful to the Resource Center for Persons with Disabilities (RCPD) and Tyler Smeltekop for their generous support, which has helped to make our project more inclusive. Dr. Radha's steady leadership as our facilitator and Dr. Biswas' incisive supervision as our lecturer have been important in developing our research. The joint efforts of RCPD, Tyler Smeltekop, Dr. Radha, and Dr. Biswas have been essential for Team 9's success, and we are grateful for their invaluable assistance.

Executive Summary

In the 1970s Michigan State University (MSU) created the Resource Center for Persons with Disabilities (RCPD) in response to equal access to a university education for all students. Since then, they have expanded their services to students with mobility and visual disabilities, as well as deaf or hard of hearing, any learning disabilities, brain injuries, psychiatric, and other chronic health conditions. RCPDs (Resource Center for Persons with Disabilities) mission is to lead Michigan State University in maximizing ability and opportunity for full participation by persons with disabilities.

One of the major challenges that visually challenged people face is the fact that these scooters are incredibly quiet and fast. This makes travelling around campus dangerous as they can neither hear the scooters nor have time to avoid these if they are aware of them. Michigan State University RCPD has a goal of allowing the visually impaired to travel safely around campus without fear and threat the scooters present. Currently there is no accommodation for this issue as the scooters are so recent to the East Lansing/MSU area.

To help with RCPDs mission, our project will focus on assisting the visually impaired with the increased usage of electric scooters on the university's campus. Our goal is to provide an alert system that will effectively notify the visually impaired of scooters in a way that is conventional for campus. We also want to have the environment accommodate the visually impaired, instead of the visually impaired conforming to the environment. If these scooters provide audible cues to alert them of any scooter present, the danger that the scooters present the visually impaired can be prevented. The biggest success will be for the visually impaired to have completely safe travels on campus in a way that does not burden them with making accommodations.

Background

The introduction and growing popularity of electric scooters has certainly revolutionized urban mobility, giving a handy option for many. However, for the visually impaired community, these fast-paced, quiet vehicles pose unexpected obstacles. The critical inclusion of technologies like auditory alarms, which might pave the way for safer interactions between scooters and visually impaired people, is sometimes disregarded. Furthermore, present regulatory solutions may not fully address the particular and real-time issues that electric scooters provide for persons with vision impairments. Incorporating contemporary Ultra-Wideband (UWB) technology can be a critical step toward closing this accessibility gap. When combined with a comprehensive approach to inclusion and accessibility, UWB may provide a creative and successful solution. The heart of our idea is based on using UWB technology to inform visually impaired users of incoming electric scooters, allowing them to traverse urban surroundings with increased safety and confidence. We want to empower those with visual impairments by keeping them up to date on the whereabouts of electric scooters. We foresee a happy coexistence in which all persons, regardless of visual ability, may confidently and securely navigate their surroundings by improving the accessibility and equality of the mobility environment.

Customer Requirements

Goal: Our customer's ideal solution to the current problem derives from a profound commitment to creating an environment that prioritizes the safety and convenience of the visually impaired. Our customer's main requirements are as follows:

Objectives:

1. Active Alert System
    a. Scooters in proximity will alert the pedestrians through sonic alerts
    b. Allow enough time for the pedestrian to react
    c. Supports interactions with multiple scooter and user tag units
2. Compact Form-Factor
    a. Small form-factor allows the tags to be hassle-free carriable item
3. Accommodating Environment
    a. The burden should be upon the environment rather than the people with impairments.
    b. Allow persons with impairments to roam safely, unhindered by the risks posed by the scooters.

Voice of customers:

We were able to do strong market research into different conditions and constraints visually impaired people face on the road when it comes to moving scooters. With the help of our customer, Tyler Smeltekop; who’s part of the RCPD and has experience working with visually impaired individuals, gave us some significant cues on things that must be focused on. For example, he helped us connect with a couple of visually impaired individuals whose conversations helped us in understanding the importance of the design aspects of the project. We were able to hear the struggle of students and faculty from their perspective and what we can do to help them.

Project Description

Our project concentrates on the creation of a UWB Tag and Scooter Communication System, which is especially meant to improve the safety and enjoyment of visually impaired persons who use electric scooters on campus. The development of a specific UWB tag for visually impaired users is a key component of our approach. This wearable tag is an important component, delivering audio notifications to the person to increase their awareness and safety when electric scooters are around. UWB technology establishes a continuous communication link between the wearable tag and the scooter, allowing for precise and real-time notifications. The addition of the scooter unit to the electric scooter serves as a central hub for signal transmission and enables tracking via Inertial Measurment Unit (IMU) integration.

Our research prioritizes developing an effective Sound Alert System within the wearable tag to provide audio alerts to visually impaired users. To make sure optimal signal reception and transmission between the worn tag and the scooter, we optimized the antennas. Furthermore, on the scooter, our system uses low power Radio Frequency (RF) technology to conserve energy by selective activation prompted by object or event detection. In conclusion, our UWB Tag and Scooter Communication System seeks to change the riding experience for visually impaired persons by taking a proactive and inclusive approach to campus safety.

Design Objectives

1. Active Warning System:
    - Implement a reliable alert system that warns visually challenged pedestrians of approaching scooters.
    - To provide timely and clear messages, use sound alarms produced by nearby scooters.
    - Ensure that the system gives pedestrians enough time to respond and make educated judgments.
2. Multiple Unit Support:
    - Create a system that allows you to interact with numerous scooters and tag units at the same time.
    - Allow for smooth communication between multiple scooter and tag units on campus to handle a variety of circumstances.
3. Compact Form-Factor:
    - Create tags with a small form factor so that visually impaired pedestrians may carry them simply and without difficulty.
    - To foster wider adoption, prioritize user comfort and ease in the design.
4. Accommodating Environment:

- Transfer the burden of accommodation from people with disabilities to the environment.
- Create a welcoming environment that anticipates and responds to the requirements of visually impaired pedestrians, by focusing on their safety and freedom of movement.

5. A Safety-First Approach:
   - Prioritize the safety of visually impaired people by creating a system that allows them to cross university places without difficulty.
   - Reduce the hazards posed by scooters with efficient alarm devices, allowing people with disabilities to travel securely and confidently.

By adhering to these design goals, our solution attempts to provide an effective alert system that not only solves urgent safety issues but also fosters a user-friendly and inclusive environment for visually impaired pedestrians on campus.

Design Approaches

UWB-based tracker + Device on the Scooter

Ultra-Wide Band based tracking system that uses radio waves to detect nearby UWB chips identifying people who hold on to these trackers, specifically visually impaired. Consists of 2 devices, a Tag that goes on the User (Visually Impaired Person) and a device on the scooter to identify the signal and use sound-based signals to acknowledge the user. The main advantage of this device is that it requires minimal effort from both the visually impaired and scooter users. They would have no responsibility for the alert system. The visually impaired would simply carry the tracking tag around so that incoming scooters may alert them. Although this would require the visually impaired to either purchase or be provided with a tracking tag, this is a cheaper and more available tracking option as UWB tracking is so widely available. Technically, this tracking device is ideal due to its precise tracking abilities and would allow for a consistently accurate alert system. However, because the Ultra-wide band chips have become so popular, being used in devices like smartphones, smartwatches, cars, etc., this can cause technical issues like signals being crossed.

RFID based tracker + Device on the Scooter

One approach is to use radio-frequency identification (RFID). Radio-frequency identification uses electromagnetic fields to automatically identify, and track tags attached to objects. This would require active tracking tags that contain an onboard power supply (from scooter solar battery) to always transmit data. This tracking and alert system would allow for minimal effort from scooter users and visually impaired. The visually impaired would carry around a tracking tag and the scooters would automatically set off an alarm within a certain range. This would require the visually impaired to either purchase or be provided with a tracking tag. Technically, this device is not ideal as the RFID’s have an extremely restricted range and its signal can be easily obstructed. This will lead to inaccurate tracking and alert abilities and can put the visually impaired at risk.

Proximity Warning System

Another approach is a Proximity Warning system that would detect any pedestrian within a certain radius. This would allow for the visually impaired to be completely unburdened by the scooters. They will not have to buy and/or carry a device. This alarm system is not practical as it will constantly be going off in high traffic areas. This makes this approach extremely unconventional. Technically, this system could not be completely dependable as these devices can have highly restricted ranges and scooters are able to move at high speeds. This could not allow the visually impaired to have enough warning time to avoid the scooters and put them at risk.

Adopted Design

Design Overview

This design is built based on Ultra-Wide Band technology. This system combines UWB technology with small carriable tags to provide visually impaired individuals with real-time alerts when an electric scooter is approaching them. The system will use sound-based alerts and proximity sensing to ensure the safety of all road users.

Hardware Setup

The Design consists of two units,

1. The transceiver, that goes on the scooter.
2. The user tag that goes with the visually impaired users

The transceiver would send a consistent radio wave-based signal and wait for the tag to pick them up and send them back. This will let the scooter unit, also known as the transceiver, calculate the distance where the tag is at, and let the tag and the transceiver units emit sound/haptic based signals, alerting the visually impaired users.

We are utilizing Ultrawide Band Transceivers like Decawave DW1000 or NXP SR100T which can be found in ESP32 system which can be purchased for cheaper cost. The tag uses a similar chipset, Decawave DWM1000C or Pozyx UWB Tags which uses way less power compared to the transceivers making them more portable and efficient.

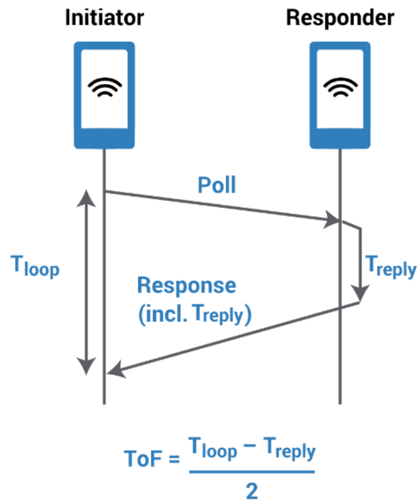


Figure 1: UWB Time Difference of Arrival (TDoA)

Our system comprises of 2 ESP32 UWB Pro (ESP32UWHP), the scooter unit with a display to visualize the calculated distance between the user tag and the scooter unit. On top of that each unit is equipped with a 9-DoF IMU unit generating accelerometer, gyroscope, and magnetometer data, which lets us calculate things like speed, velocity and direction between the systems, with additional radio frequency (RF) modules for longer detection, battery, and speaker system for alerting. In depth, the scooter system puts out an RF signal on a steady frequency, for the user tag unit to pick up and send it back. With this in place we can confirm there is a user tag unit in a 300 meters (about 984.25 ft) radius. When the scooter gets as close as 200 meters (about 656.17 ft) from the user tag unit, the UWB connection will be established, for more precise distance and direction tracking along with sending distance data to the user tag unit. Given that the scooter is traveling at a speed of 17 mph, top speed achieved by electric scooters on campus, a 200 meters (about 656.17 ft) distance will be closed in about 12 seconds. Hence, the alert system kicks in at about 200 meters (about 656.17 ft) when the UWB connection is established to give the visually impaired user about 6-7 seconds of reaction time. The alert system is of 2 parts, one on the scooter which goes off when the user tag is as close as 80 meters and the alert system on the user tag which starts beeping while the scooter is 200 meters (about 656.17 ft). The buzzer on the tag beeps at higher and higher frequency when the distance between the tag and the scooter closes in. This will effectively convey how close the scooter is and how fast it is approaching.

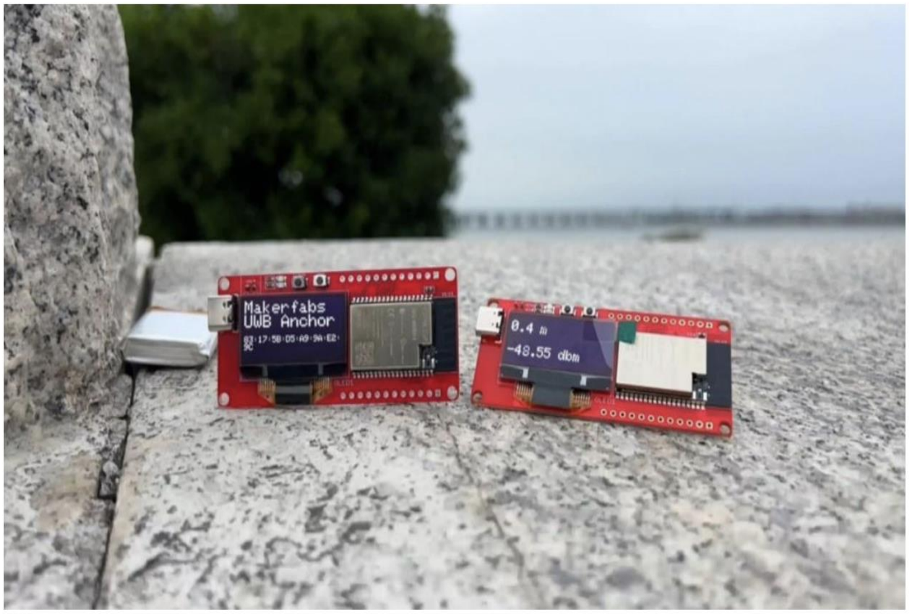
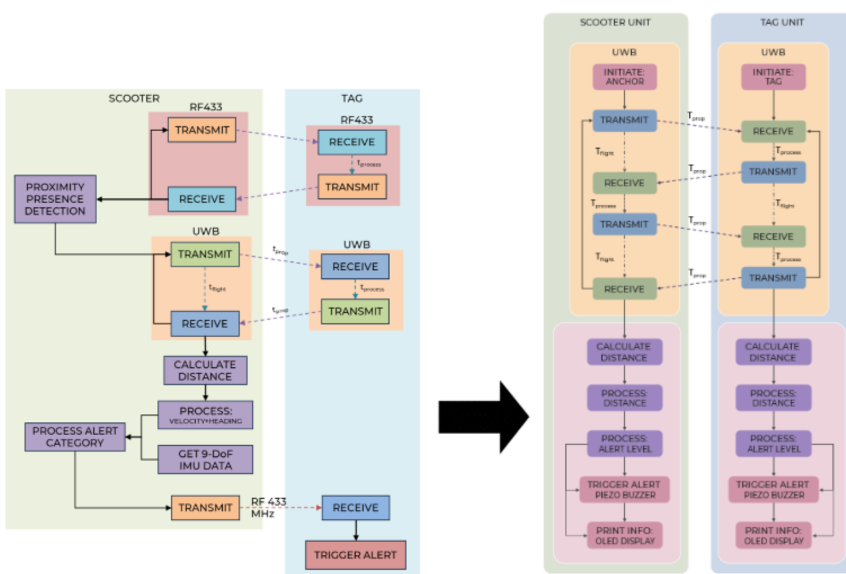


Figure 2: ESP32UWB Modules

Adopted Design Justification

The UWB + RF design was chosen purely for its range capabilities, distance and Direction calculation and effect data transmission. There is no other form of Technology that could effectively establish a successful Tag-Scooter System other than UWB. Especially when not using a GPS and still being able to locate the Tags with local references is efficient and mobile and makes it more practical.



Original Iteration Final Iteration

Figure 3: Overall Design Changes

Software Subsystems

The code development was performed in Arduino IDE. As both the tag, and scooter unit designs are symmetrical, there are only a few minor differences in the code. Such a system provides great flexibility in terms of additional upgrades to the software subsystem in the future.

Much of the software developed utilizes the “DW1000Ranging.h” library for Arduino/ESP Microcontrollers. This library enables core functionality of the DW1000 chipsets, specifically for distance measurement. The default parameters are specified in the setup function which initializes the system as either the anchor (Scooter Unit) or the Tag-unit. The unique device ID is also setup here which can be used to identify the tag/scooter units from each other. The distance measurement utilizes the Two-Way Ranging method that is provided by the library. Signal power is also measured for evaluating signal integrity during connection.

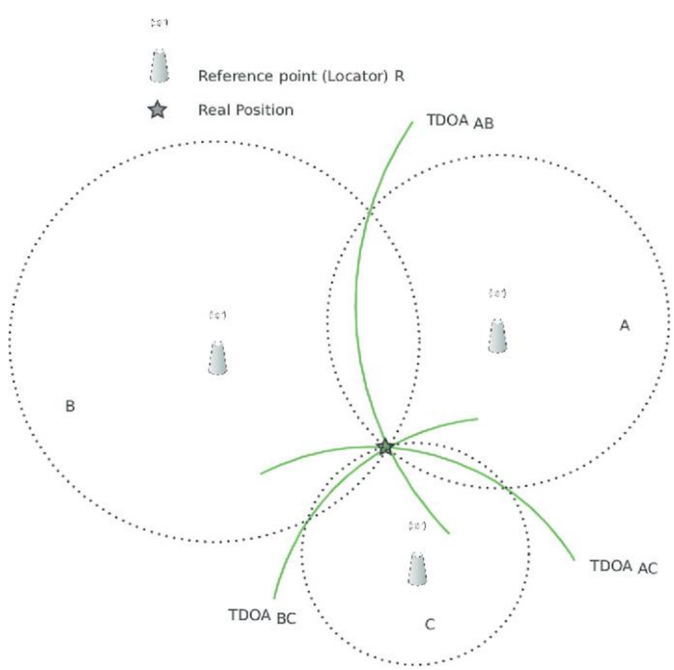


Figure 4: UWB distance measuring using circular radiuses from different anchoring point

User Interfaces

The core of our design is in its simplicity. Users must do nothing more than carry the UWB Tag. This passive engagement guarantees that the warning system operates autonomously and without the need for user participation. By reducing the requirement for contact, we improve the system's dependability and efficacy, guaranteeing that any diversions or operational faults are nearly removed. The UWB (Ultra-Wideband) Tag's current generation is powered by a battery that delivers steady performance for 12 to 18 months (about 1 and a half years). This implies that consumers will only need to change their batteries once every year and a half. However, we are not stopping there. Recognizing the significance of sustainability and user-friendliness, our team is continuously researching and developing a rechargeable battery solution. While the lifetime and efficiency of such a battery are still being researched, we expect that it will provide a more sustainable and user-friendly alternative to the existing single-use battery system. In the long term, this prospective enhancement might result in fewer replacements and a lower environmental effect.

Integration Issues and constraints

It is critical that we address integration issues as we create and integrate our Ultra-Wideband (UWB) alert system. The communication capability between tags and the transceiver module, as well as interference from other UWB devices, such as current cellphones, are two key areas of concern. Given our present system architecture, we acknowledge that the number of tags that can interact with the transceiver module at the same time may be limited. However, after examining the campus's visually challenged population, we are convinced that the density of simultaneous Tag users will not create a communication bottleneck. The system stays efficient in real-world circumstances due to the comparatively small number of users requiring simultaneous connectivity. Because of the fast-changing technological world, UWB modules are becoming more widespread, particularly in devices such as smartphones. This ubiquity raises the possibility of signal interference, which might jeopardize the accuracy and dependability of our alarm system. To overcome this, our team is actively looking for an untapped and more reliable frequency. By doing so, we intend to reduce interference and ensure the robustness and dependability of our UWB system. This part of the system is still under active study and development.

Scheduling and Project Planning

To deliver the best possible product to our customers we split the project up into three phases: preparation, design, final. In order to keep each other accountable, we implemented mandatory weekly meetings for the first two phases of the project. During phase 3 we met at a minimum of twice a week. The Gantt Chart allowed us to keep each other accountable and on task. The full schedule and individual phases are illustrated in the figures below.

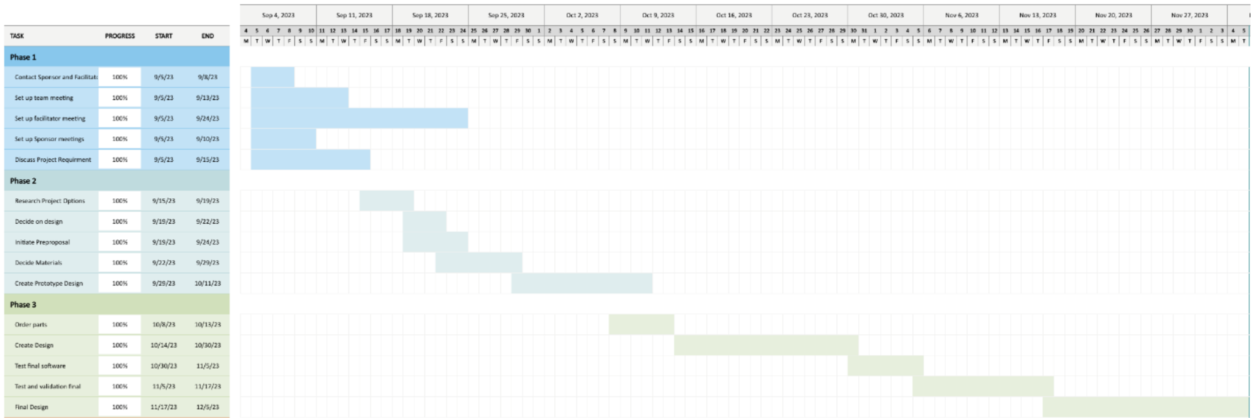


Figure 5 : Completed Timeline

Figure 5(a): Phase 1 Timeline

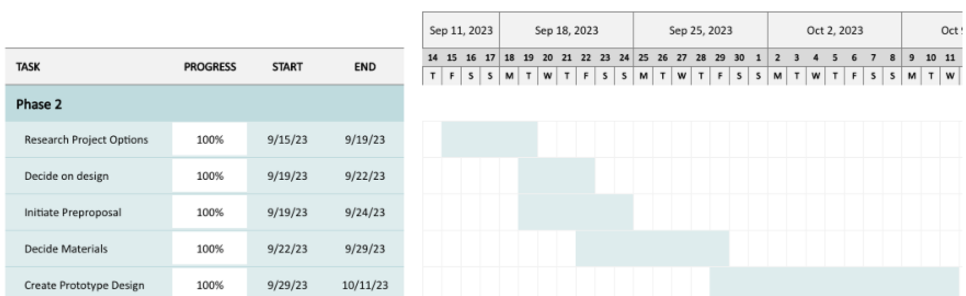


Figure 5 (b): Phase 2 Timeline

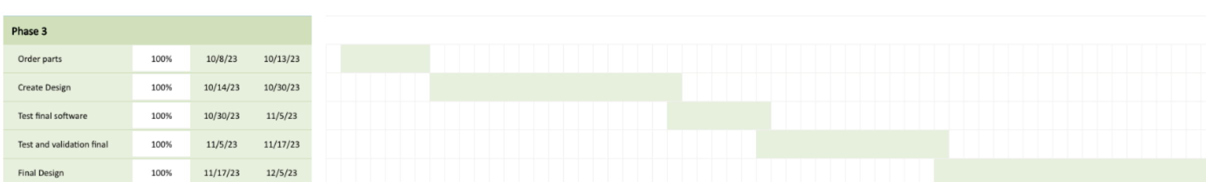


Figure 5 (c): Phase 3 Timeline

Budget

Within the $500 budget allotted for this project, we concentrated on acquiring the most crucial components that underlie the efficacy and quality of our product. Detailed budgeting has been critical for a variety of reasons, including:

1. Financial prudence: By methodically preparing and managing our budget, we've drawn out a clear roadmap of our spending, ensuring that every dollar is spent wisely.
2. Proactive Approach: The budgeting method allowed us to foresee and plan for contingencies. This proactive approach guarantees that we are ready to face unanticipated obstacles without sacrificing product quality or exceeding our budgetary limits.
3. Adaptability: While the latter aspects of our purchase list remain changeable, this adaptability is intended to allow us to make the best judgments based on real-time advancements, whether in technology or market prices. Regardless of these changes, one thing stays constant: our goal to keep under the $500 mark.

Table 1: Bill of materials

Part Description	Cost Each	Qty	Total
ESP32 UWB DW3000 (Ultra-Wideband)	$43.80	2	$87.60
ESP32 UWB PRO (Ultra-Wideband)	$51.84	2	$103.68
RFM69HCW 433 MHz Transceiver Radio Module	$9.95	2	$19.90
RFM69HCW 915 MHz Transceiver Radio Module	$9.95	2	$19.90
USB A/Micro Cable	$4.95	2	$9.90
MPU-6050 6-DoF Accel/Gyro Sensor	$8.99	1	$8.99
Piezo Buzzer	$6.99	1	$6.99
Variety Breadboard Set	$6.99	1	$6.99
Dupont Jumper Wires Set	$6.98	1	$6.98
Misc Electrical/Hardware Items	~$50.00	1	~$50.00
Shipping	~$50.00		~$50.00
	Total		$370.93

Final Product Development

The main components for our project are the ESP32 UWB Pro module for both the scooter and the user tag which processes communication between both. The OLED Displays prompts the distance in meters between the scooter and the visually impaired user tag.

The computational core is the ESP32 UWB Pro Module, which combines the power of an Ultra-Wideband radio with the microcontroller capabilities of the ESP32 to provide accurate scooter proximity detection. Efficient connection between the scooter units and UWB wearable tag is facilitated by this module.

With the ESP32 module installed, the wearable UWB tag has a Piezoelectric Buzzer that emits alerts at specified intervals, giving vital audio clues regarding electric scooters that are in the vicinity. The LED Indicator provides a visual proof of the system's activity by blinking simultaneously with UWB signal exchanges.

The alert system is dependent on the distance measurement from the UWB chip. This distance will determine the tone and the interval between the beeps from the piezo buzzer – the beeps are longer in duration and sharper in tone at shorter distances; and shorter in duration when the distance is above the specified threshold. Beyond 150 meters (about 492.13 ft), there are no beeps, to make the system less intrusive and bothersome for the user.

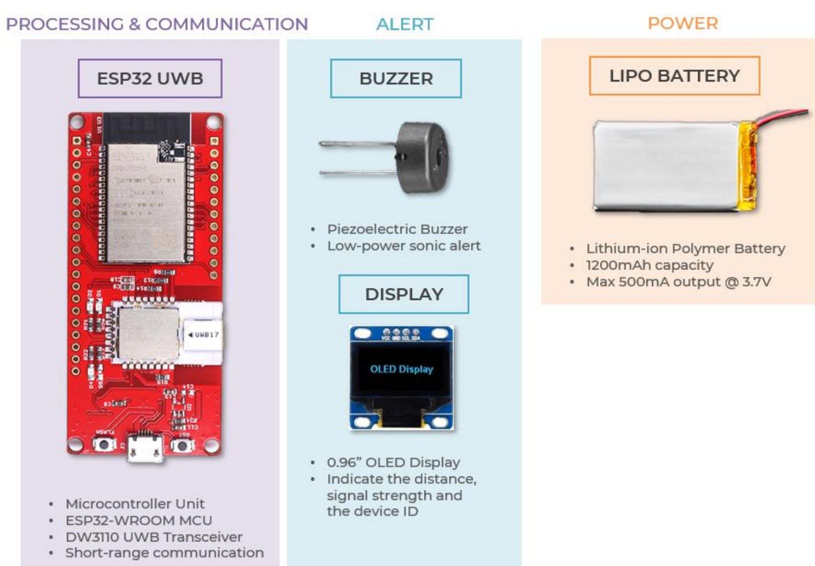


Figure 6: List and images of the components used

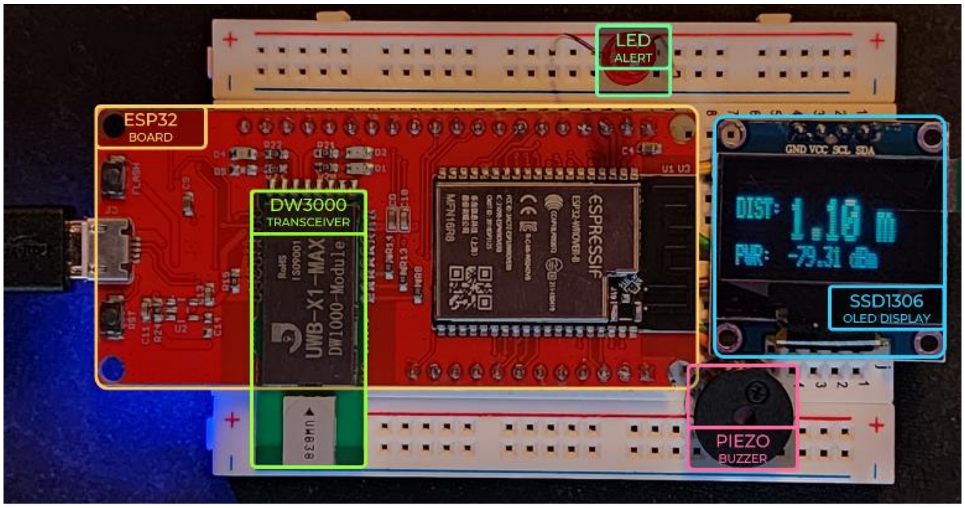


Figure 7: Birds eye view of the user tag unit prototype

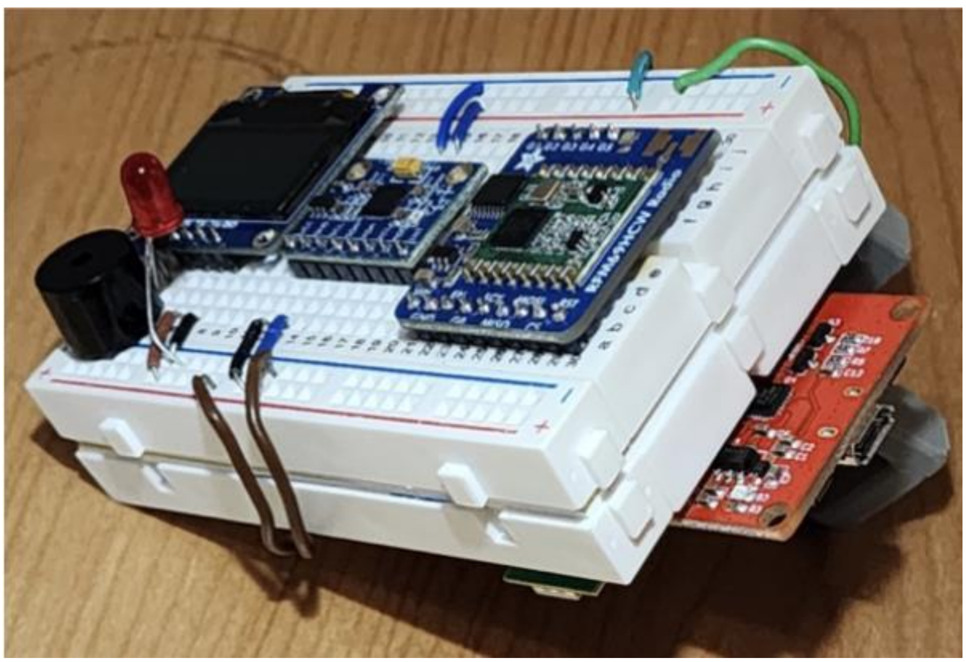


Figure 8: Final prototype of scooter unit

Enclosure

As shown in the figures below, you can see the evolution of our enclosure as we moved forward with our project design. Initially, we conceptualized an elongated enclosure as a starting point in our design process. However, through ongoing refinements on the breadboard and our final project overall, we notice an opportunity to enhance the products' practicality and portability.

Following the modifications it resulted in a more compact final design, reflecting our commitment to optimizing user experience. The figures illustrate some of the transitions from the initial elongated prototype to the bit more refined and portable iteration.

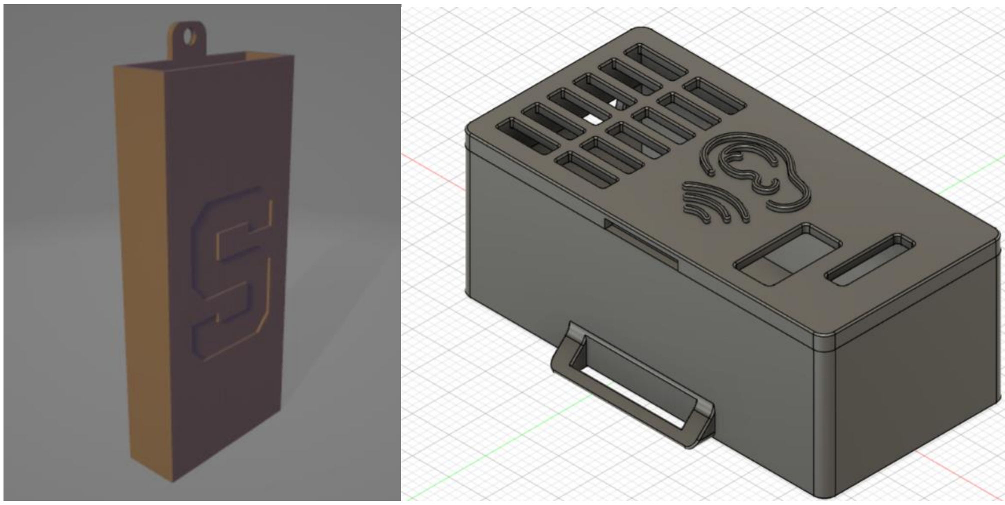


Figure 9: Enclosure on the left was the first prototype for the user tag. Enclosure on the right was the first prototype for the scooter unit

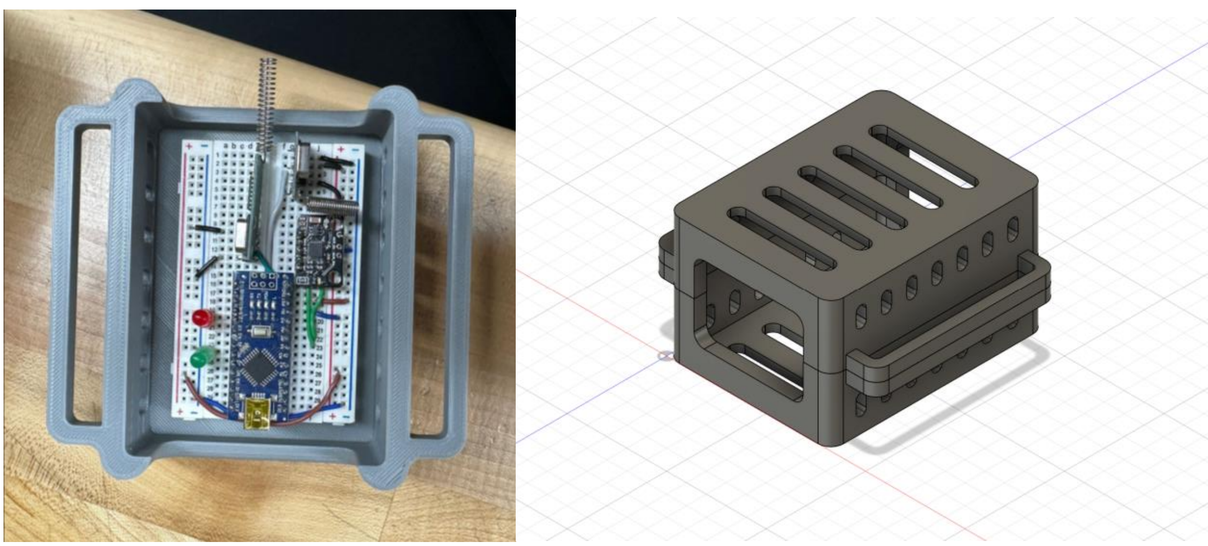


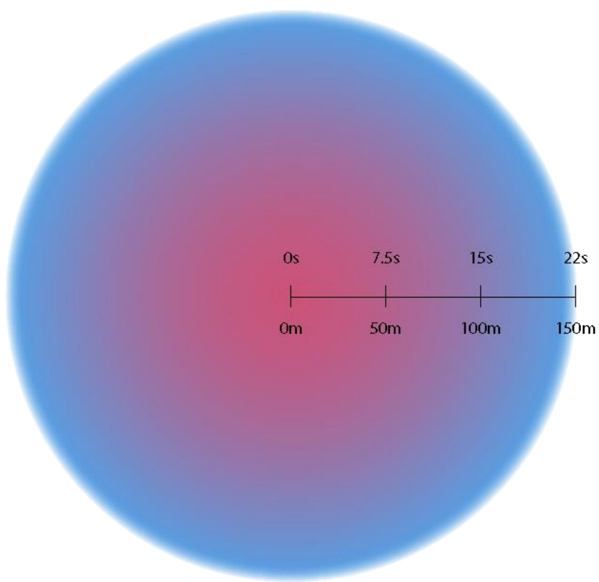
Figure 10: The final iteration of the scooter unit, which is compact and rugged

Alert System

Alert system is the main user interaction interface for the visually impaired effectively communicating the distance the scooters are approaching the user. Hence it holds a very significant role when it comes to the overall design. The alert system is comprised of 2 units, one in the user tag unit and another one in the scooter unit. The user tag unit holds a piezo buzzer based sonic alert unit, while the scooter unit uses a speaker based sonic alert system.

The alert system works on a sequence based on the distance between the user and the scooter. Using Ultra Wide Band technology, the distance between the user tag and the scooter is calculated precisely using the time of flight for the data transmission. This associates different distances for different alerts effectively communicating the distance to the visually impaired user. The alerting takes place using a frequency based beeping system that allows the user to understand how far the scooter is. The closer the scooter gets the higher frequency the beep alerts get. The table below can effectively indicate the alert system and the beeps based on distance and time

Alert Status	Distance/Time
First Single Alert Ping	150m / 22s
UWB Link	100m / 15s
First High Frequency Alerts	100m / 15s
Highest Frequency Alerts	50m / 7.5s
Reaction Time	75m / 12s



Test Data and Results

The system successfully established a connection and accurately measured distances between the scooter and user tag units through two-way ranging. Verification involved commencing tests from the same point in a hallway, moving away while accurately measuring the distance traveled, and closely monitoring signal integrity. Another test, starting with the units out of range and then moving closer, demonstrated swift initial pairing once within range. The measured distance accuracy reached up to 20 cm (about 7.87 in) at its best. Appropriate sonic alerts were triggered at the programmed distance intervals. The initial plan was to incorporate a 915MHz radio system for redundancy in scenarios where line-of-sight might be obstructed. However, this plan was abandoned, as in cases of line-of-sight blockades, the connection promptly restores upon receiving even a single ping.

Accessibility Features

- UWB Wearable Tag: Individuals who are visually challenged wear a lightweight Ultra-Wideband (UWB) tag that works as a real-time indication, providing important information about nearby electric scooters.
- Audible alarms: In addition to the UWB tag, different sound alarms assist in rapid identification, allowing users to make informed choices as they explore the MSU campus.
- Simplified Design: The UWB wearable tag worn by users and scooter units attached to electric scooters/bikes comprises the system's simple design. This simplicity assures use by eliminating the need for extra interfaces or programs.

By combining these elements, this project increases accessibility and simultaneously makes the Michigan State University community's experience more welcoming and safer for all participants.

Future Direction

RCPD aims to extend its support for the visually impaired by translating technological advancements into real-world benefits. In this project, RCPD is hoping to propose our concept to scooter companies, urging them to integrate our design for a safer environment catering to individuals of diverse backgrounds.

Despite the limited development time, the prototype serves as a functional proof of concept. Further development holds the potential for significant improvement. For example, many features of the ESP32, contributing to its footprint, are unnecessary for this project. Substituting it with a more compact microcontroller, like the Arduino Pro Micro, can yield a tag with similar functionality but notably smaller in size and power consumption.

Exploring renewable energy sources, such as small form factor solar panels for the tag unit, may significantly extend battery life, enhancing the product's eco-friendliness.

Team

The work was shared and distributed between all 5 members. The work was completed over weekly meetings and online teams meetings.

1. Lab Coordinator: **Vigneshwer Ramamoorthi**, Hardware
2. Documentation Prep: **Pradnya Ghorpade**, Software
3. Presentation Prep: **Shayna Wilson**, Software
4. Management: **Kattie Romero-Otero**, Hardware
5. Test Coordinator: **Ayush Chinmay**, Hardware

Left to right: Vigneshwer Ramamoorthi, Pradnya Ghorpade, Shayna Wilson, Kattie Romero-Otero, Ayush Chinmay

Appendices

Manual

It's a very simple system to use when it comes to user interface. We were very focused on making it usable to a visually impaired user. The devices automatically turn on when the battery ribbon is pulled off while unboxing. The charging port can be used to charge the TAG unit whenever necessary, which is like every 2-3 months.

As far as the alert system,

1. The first single beep represents a "Scooter found in a 150m radius"
2. The first high frequency beep / continuous beep represents "Scooter is 100m away"
3. The highest frequency beep / faster continuous beep represents "Scooter is 50m or less away"

For the scooter unit,

The device on board the scooter draws power from the scooter's battery system and stays on while the scooter is on. It has a set of speakers that can also beep while getting closer to the visually impaired users with our user tag. This can effectively let the scooter user and the visually impaired user know of each other's presence at different distances.

Product Code

The libraries required for this project are as shown in the figure [] below. *SPI.h* library is required for the communication between the DW1000 chipset and the ESP32 module. *Wire.h* libraries enable communication between I2C protocol-based peripherals (OLED Display) and the ESP32 board. The *Adafruit_SSD1306.h* enables core functionality for controlling the OLED display.

```
/** ==========[ LIBRARIES ]========== **/
#include <SPI.h>
#include <Wire.h>
#include <Adafruit_SSD1306.h>
#include "DW1000Ranging.h"
```

The Setup is executed first which handles initialization of the UWB chipset, OLED display, and GPIO setup for the Buzzer.

```
/** =========[ SETUP ]========= **
 *  Setup the UWB module as an anchor
 *  Setup the OLED display
 */
void setup() {
  Serial.begin(115200);
  Wire.begin();
  initOLED();
  initUWB();
  pinMode(BUZZ_PIN, OUTPUT);
  delay(800);
}
```

```
/** ==========[ LOOP ]========== **
 *  Main Loop
 */
void loop() {
  DW1000Ranging.loop();
}
```

The UWB initialization function starts up communication between the ESP32 and the UWB chipset on the SPI protocol. This initiates the UWB chipset in the ranging mode and sets up a unique device ID which may be used to differentiate between communication from multiple devices.

```
void initUWB()
{
  //init the configuration
  DW1000Ranging.initCommunication(PIN_RST, PIN_SS, PIN_IRQ);
//Reset, CS, IRQ pin
  //define the sketch as anchor. It will be great to dynamically
change the type of module
  DW1000Ranging.attachNewRange(newRange);
  DW1000Ranging.attachNewDevice(newDevice);
  DW1000Ranging.attachInactiveDevice(inactiveDevice);
  //Enable the filter to smooth the distance
  //DW1000Ranging.useRangeFilter(true);

  //we start the module as a tag
  DW1000Ranging.startAsTag("7D:00:22:EA:82:60:3B:9C",
DW1000.MODE_LONGDATA_RANGE_ACCURACY);
  display.println("TAG: INIT SUCCESS");
  display.println("\n7D:00:22:EA:82:60:3B:9C");
  display.display();
  delay(800);
}
```

The new range function will obtain the device ID, distance (in meters), and the signal power (in DeciBel meters) for the device that it is currently communicating with. This information is printed onto the display, and the variables for distance and power are updated for further processing.

```
/** ==========[ NEW RANGE ]========== **
 *  Callback function for new range data
 *  Prints the range data to the serial monitor
 */
void newRange() {
  uwbID = DW1000Ranging.getDistantDevice()->getShortAddress();
  distance = DW1000Ranging.getDistantDevice()->getRange();
  powerDBm = DW1000Ranging.getDistantDevice()->getRXPower();
  printOLED();
  alertBuzz();
  Serial.print("from: "); Serial.print(uwbID, HEX);
  Serial.print("\t Range: "); Serial.print(distance);
Serial.print(" m");
  Serial.print("\t RX power: "); Serial.print(powerDBm);
Serial.println(" dBm");
}
```

This adds the found tag into memory, and obtains its device ID.

```
/** ==========[ NEW DEVICE ]========== **
 *  Callback function for new device data
 *  Prints the blink data to the serial monitor
 */
void newDevice(DW1000Device* device) {
  Serial.print("ranging init; 1 device added ! -> ");
  Serial.print(" short:");
  Serial.println(device->getShortAddress(), HEX);
}
```

```
/** ==========[ INACTIVE DEVICE ]========== **
 *  Callback function for inactive device data
 *  Prints the inactive device data to the serial monitor
 */
void inactiveDevice(DW1000Device* device) {
  Serial.print("delete inactive device: ");
  Serial.println(device->getShortAddress(), HEX);
}
```

Initialization & Print functions to display information on the OLED display.

```
void initOLED()
{
  display.begin(SSD1306_SWITCHCAPVCC, SCREEN_ADDRESS);
  display.display();
  delay(500);
  display.clearDisplay();
  display.display();

  display.setTextSize(1);
  display.setTextColor(SSD1306_WHITE);
}
```

```
void printOLED() {
  display.clearDisplay();
  display.setCursor(16, 0);
  display.setTextSize(1);
//   display.print("TAG --> "); display.println(uwbID, HEX);
  display.print("\nDIST: ");
  display.setTextSize(2);

  if (distance >= 1) {
  display.print(distance); display.println(" m");
  // noTone(BUZZ_PIN);
  } else {
  display.print(int(distance*100)); display.println(" cm");
  // tone(BUZZ_PIN, middle_c, duration);
  }
//   display.println();
  display.setTextSize(1);
  display.print("PWR:  "); display.print(powerDBm);
display.println(" dBm");
  display.display();
}
```

Piezo Buzzer Alert functionality

```
void alertBuzz() {
  if (distance >= 5.0) {
  noTone(BUZZ_PIN);
  } else if (distance < 3.0 && distance > 2.0) {
    duration = 50;
  tone(BUZZ_PIN, alert_low, duration);
  } else if (distance <= 2.0 && distance > 1.0) {
    duration = 75;
  tone(BUZZ_PIN, alert_med, duration);
  } else if ( distance < 1.0) {
    duration = 100;
  tone(BUZZ_PIN, alert_high, duration);
  }
}
```

Design Day Poster

ECE 480 Scooter Proximity Alert System

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Abstract

Scooter Proximity Alert System (SPAS) tackles safety problems for visually impaired individuals on college campuses, concentrating on the challenges posed by fast and silent electric scooters. The initiative, developed by Michigan State University's Resource Center for Persons with Disabilities (RCPD), makes use of Ultra-Wideband (UWB) technology for scooter identification.

SPAS focuses on providing real-time distance computations and prioritizes safety through timely notifications by using wearable tags for visually impaired individuals and scooter-mounted transceivers. The project follows a tiered strategy spanning hardware setup, software development, integration, testing, and documentation, with an emphasis on minimal human contact, user-friendly interfaces, and seamless connection with current scooter systems. The planned output is a proactive alert system that will allow visually impaired persons to traverse campus areas securely.

SPAS, which is aligned with the RCPD's mission of establishing an inclusive campus, uses innovation and technology to improve the safety and mobility of the visually impaired.

Introduction

In the 1970s Michigan State University (MSU) created the Resource Center for Persons with Disabilities (RCPD) in response to equal access to a university education for all students. Since then, they have expanded their services to students with mobility and visual disabilities, as well as deaf or hard of hearing, any learning disabilities, brain injuries, psychiatric, and other chronic health conditions. RCPDs mission is to lead MSU in maximizing ability and opportunity for full participation by persons with disabilities.

One of the major challenges that visually challenged people face is the fact that these scooters are incredibly quiet and fast. This makes travelling around campus dangerous as they can neither hear the scooters nor have time to avoid these if they are aware of them. MSU RCPD has a goal of allowing the visually impaired to travel safely around campus without fear and threat the scooters present.

To help with RCPDs mission, our project will focus on assisting the visually impaired with the increased usage of electric scooters on the university's campus. Our goal is to provide an alert system that will effectively notify the visually impaired of scooters in a way that is conventional for campus. We also want to have the environment accommodate the visually impaired, instead of vice versa. The goal is that these scooters provide audible cues to alert them of any scooter present, the danger that the scooters present the visually impaired can be prevented.

Design Requirements

Goal: Develop an alert system that can effectively notify visually impaired pedestrians of scooters

Objectives:

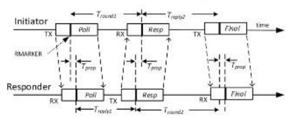
- Active Alert System
  - Scooters in proximity will alert the pedestrians through sonic alerts
  - Allow enough time for the pedestrian to react
  - Supports interactions with multiple scooter and tag units
- Compact Form-Factor
  - Small form-factor allows the tags to be hassle-free carriable item
- Accommodating Environment
  - The burden should be upon the environment rather than the persons with impairments
  - Allow persons with impairments to roam safely, unhindered by the risks posed by the scooters.

Components

Table 1: List of components

Component	Manufacturer	Functionality
ESP32 UWB Pro Module	Makerfabs	Processing & UWB communication
SSD1306 0.96" OLED Display	Adafruit	Display relevant information
Piezoelectric Buzzer	Adafruit	Create sonic alert at intervals
LED Indicator	-/-	Blink during signal reception

Technology



The *Final* message communicates the initiator's T_{round} and T_{reply} times to the responder, which calculates the range to the initiator as follows:

$$T_{prop} = \frac{T_{round1} \times T_{round2} - T_{reply1} \times T_{reply2}}{T_{round1} + T_{round2} + T_{reply1} + T_{reply2}}$$

FIG 1: Asymmetric Two Way Ranging ToF Formula

Ultra-Wideband, or UWB, is a short-range RF technology for wireless communication, employed for precise location tracking. It utilizes short nano-second pulses across an expansive frequency spectrum. This technology proves advantageous for portable ranging applications, facilitating high-data rate transmission over short distances while consuming minimal power, thereby enabling cost-effective and efficient hardware solutions. UWB operates by detecting ranges between two nodes through time-of-flight, calculating the duration for radio wave pulses to travel between devices.

For the purposes of this project, in the absence of fixed indoor positioning anchors, Two-Way Ranging (TWR) technology is employed to calculate distances between two devices. UWB can accurately determine the location of a device within a range of under 200 meters, with optimal performance observed within shorter ranges of 1-50 meters and under conditions of line of sight between devices or anchors. The time taken for a signal to traverse this distance is multiplied by the speed of light, forming the basis for determining their relative positions. The measured distance is then used to establish alert priorities conveyed to users.

The central communication and control unit for this project is the ESP32-UWB Pro board, manufactured by Maker-Fabs. This board integrates the ESP32-WROOM board with an on-board Decawave DW1000 UWB module. The ESP32 microcontroller manages data reading, initiation of communication events, calculation of alert priorities, and activation of the piezo-buzzer alerts. The dual-core architecture of the ESP32 facilitates concurrent execution of UWB communication and distance calculation, ensuring a reliable system without processing-related delays.

A compact piezoelectric buzzer is employed to generate sonic alerts due to its capacity to produce a sharp tone without requiring additional circuitry. While speakers offer enhanced fidelity, their use introduces increased power consumption, computational demands, and design complexity. The buzzer generates audible beeps at regular intervals, with the timing influenced by UWB distance measurements, resulting in shorter intervals between beeps at closer ranges. A 0.96" OLED display is incorporated to showcase tag-ID, distance data, and signal strength.

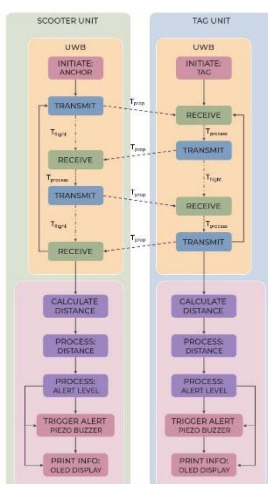


FIG 2: Proximity Alert system – Code Block Diagram

Budget

Within the $500 budget allotted for this attempt, we concentrated on acquiring the most crucial components that underlie the efficacy and quality of our product. Detailed budgeting has been critical for a variety of reasons, including:

1. Financial prudence: By methodically preparing and managing our budget, we've drawn out a clear roadmap of our spending, ensuring that every dollar is spent wisely.
2. Proactive Approach: The budgeting method allowed us to foresee and plan for contingencies. This proactive approach guarantees that we are ready to face unanticipated obstacles without sacrificing product quality or exceeding our budgetary limits.

Table 2: Bill of materials

Part Description	Cost Each	Qty	Total
ESP32 UWB DW3000 (Ultra-Wideband)	$43.80	2	$87.60
ESP32 UWB PRO (Ultra-Wideband)	$51.84	2	$103.68
RFM69HCW 433 MHz Transceiver Radio Module	$9.95	2	$19.90
RFM69HCW 915 MHz Transceiver Radio Module	$9.95	2	$19.90
USB A/Micro Cable	$4.95	2	$9.90
MPU-6050 6-DoF Accel/Gyro Sensor	$8.99	1	$8.99
Piezo Buzzer	$6.99	1	$6.99
Variety Breadboard Set	$6.99	1	$6.99
Dupont Jumper Wires Set	$6.98	1	$6.98
Misc Electrical/Hardware Items	~$50.00	1	~$50.00
Shipping	~$50.00		~$50.00
	Total		$370.93

Final Product and Results

The system successfully established a connection, measured distances between the scooter and tag units through two-way ranging. Verification involved commencing tests from the same point in a hallway, moving away while accurately measuring the distance traveled, and closely monitoring signal integrity. Another test, starting with the units out of range and then moving closer, demonstrated swift initial pairing once within range. The measured distance accuracy reached up to 20 cm at its best. Appropriate sonic-alerts were triggered at the programmed distance intervals.
The initial plan was to incorporate a 915MHz radio system for redundancy in scenarios where line-of-sight might be obstructed. However, this plan was abandoned, as in cases of line-of-sight blockades, the connection promptly restores upon receiving even a single ping.

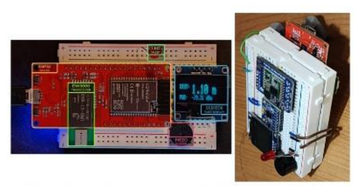


FIG 3: Final Proximity Alert system prototype Tag-Unit (left) & Scooter Unit (right)

Future Directions

RCPD aims to extend its support for the visually impaired by translating technological advancements into real-world benefits. In this project, RCPD is hoping to propose our concept to scooter companies, urging them to integrate our design for a safer environment catering to individuals of diverse backgrounds.

Despite the limited development time, the prototype serves as a functional proof of concept. Further development holds the potential for significant improvement. For example, many features of the ESP32, contributing to its footprint, are unnecessary for this project. Substituting it with a more compact microcontroller, like the Arduino Pro Micro, can yield a tag with similar functionality but notably smaller in size and power consumption.

Exploring renewable energy sources, such as small-form factor solar panels for the tag unit, may significantly extend battery life, enhancing the product's eco-friendliness.

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