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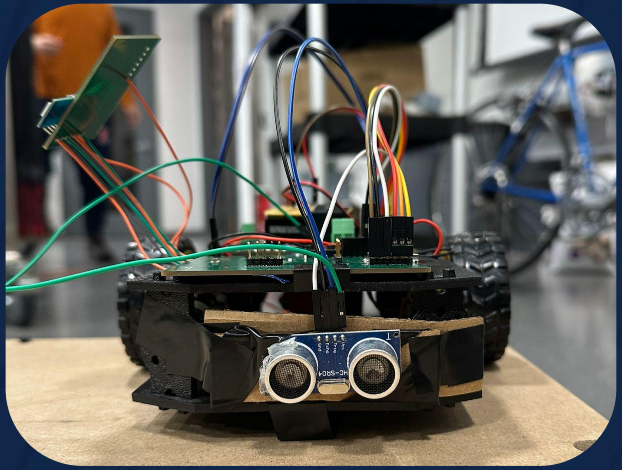

Person-Following Luggage System

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Teaching Assistant: Abhisheka Mathur Sekar

DECEMBER 5, 2023

Meet the team

Shubham Gupta
[System Integration]

Jai Anchalia
[Schematic & PCB design]

Varun Singhal
[Firmware]

Agenda

- ❑ Problem statement and solution
- ❑ Block diagram
- ❑ Overview of each sub-system
- ❑ Results and analysis
- ❑ High level requirements
- ❑ Future scope
- ❑ Questions

Problem Statement

Problem statement

Background and motivation

- ❑ As an international student, carrying 3 pieces of luggage along with a backpack in an airport is a tedious task.
- ❑ A hassle, especially in a crowded airport.
- ❑ With luggage wear and tear - the wheels often malfunction.

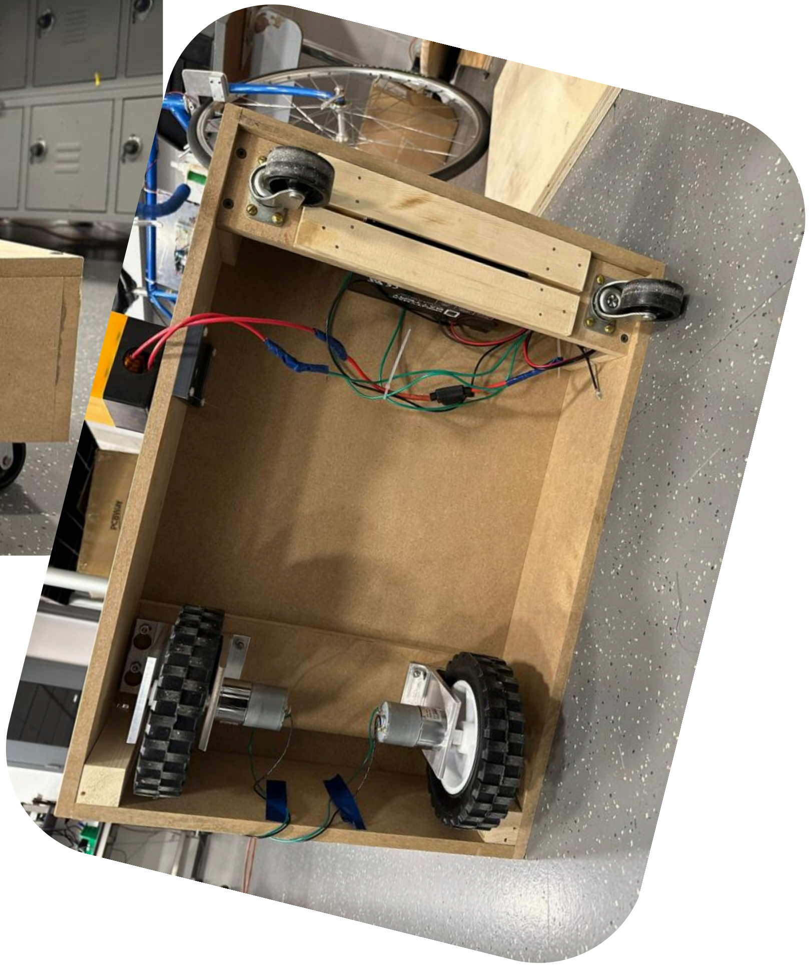
Solution

- ❑ Design a person-following luggage platform
- ❑ Stops upon detecting obstacles
- ❑ Changes direction and speed in accordance with the passenger's movement
- ❑ Alerts the passenger if distance between them becomes too large

Problem statement

What’s new?

- ❑ Did <u>not</u> want to use a camera
- ❑ <u>A platform</u> over luggage



Problem statement

How does it work?

Indoor triangulation!

Algorithm?

If x > y:

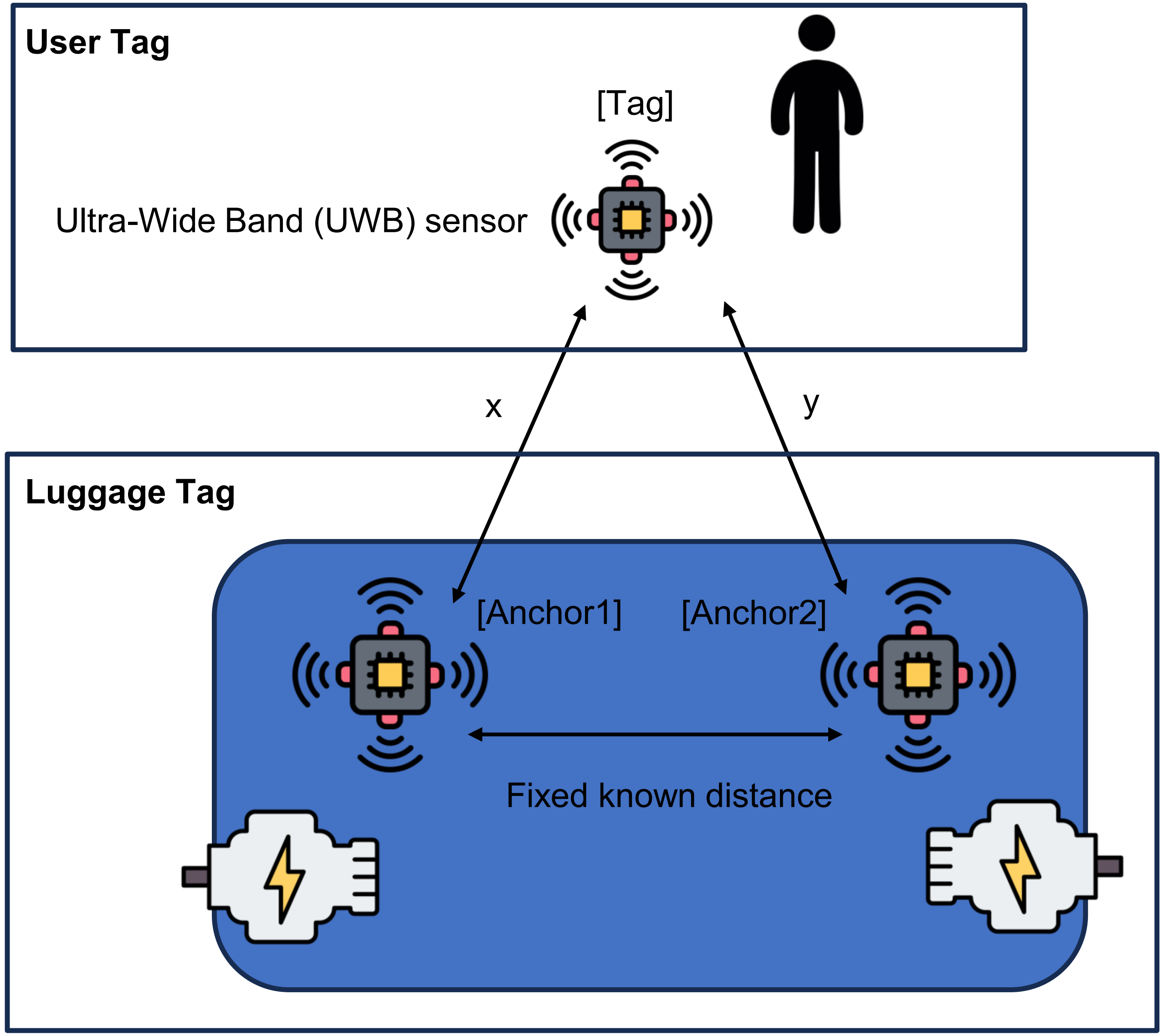
go right

If y < x:

go left

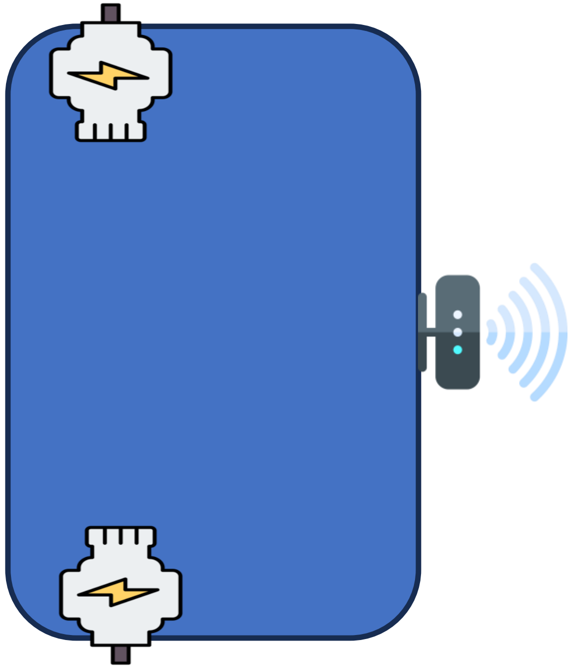
Else:

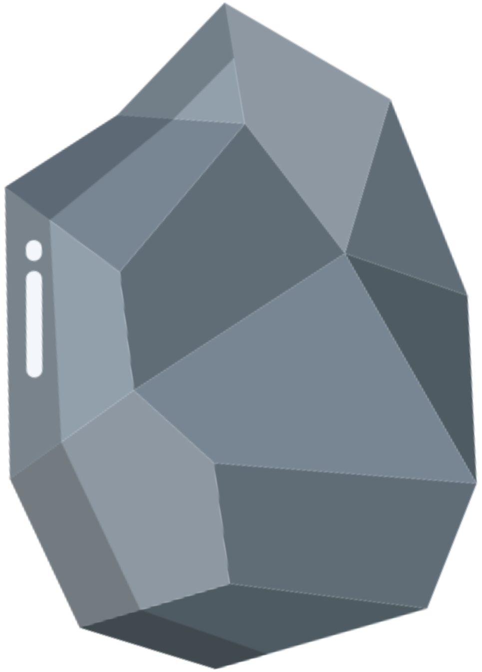
go straight



How does it detect obstacles?

Ultrasonic sensor!



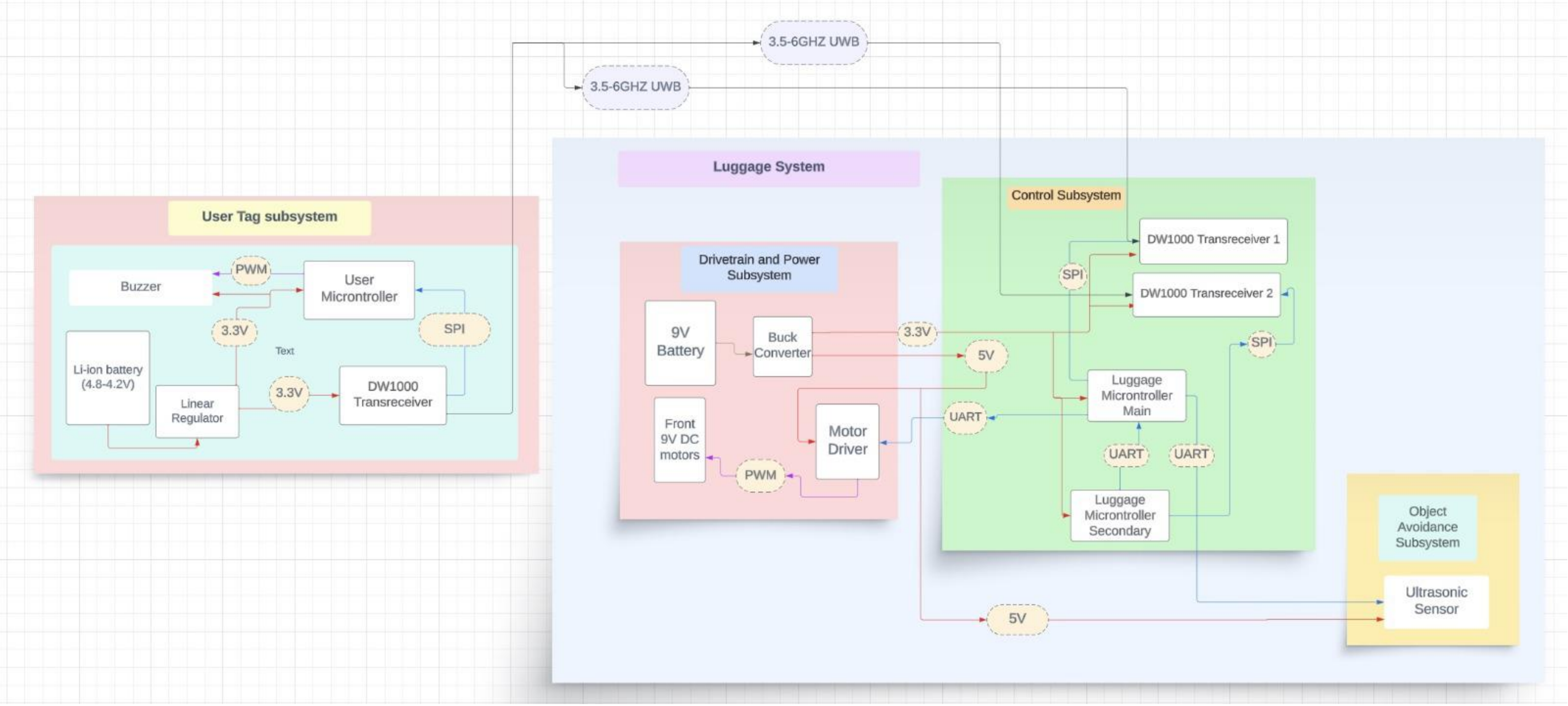


High-Level Requirements

- ❑ Achieve a user-following accuracy at a distance of 1-1.2 m with an error of ± 50 cm
- ❑ Platform follows the person with real time updates in the path with latency of no more than 1s, keeping pace with the user
- ❑ Avoid collisions with obstacles (upto 0.5 m). Alert the user if the luggage is left behind more than 10 m

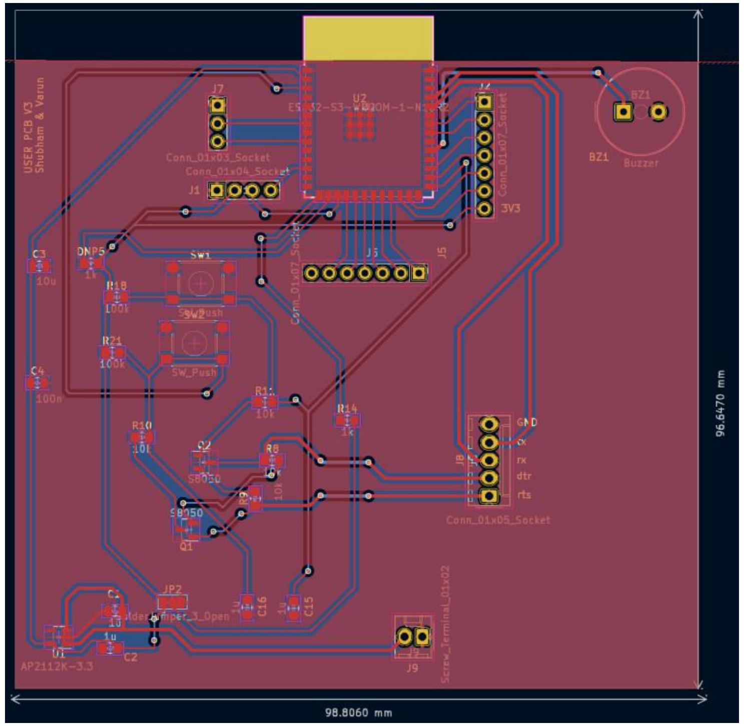
Block Diagram

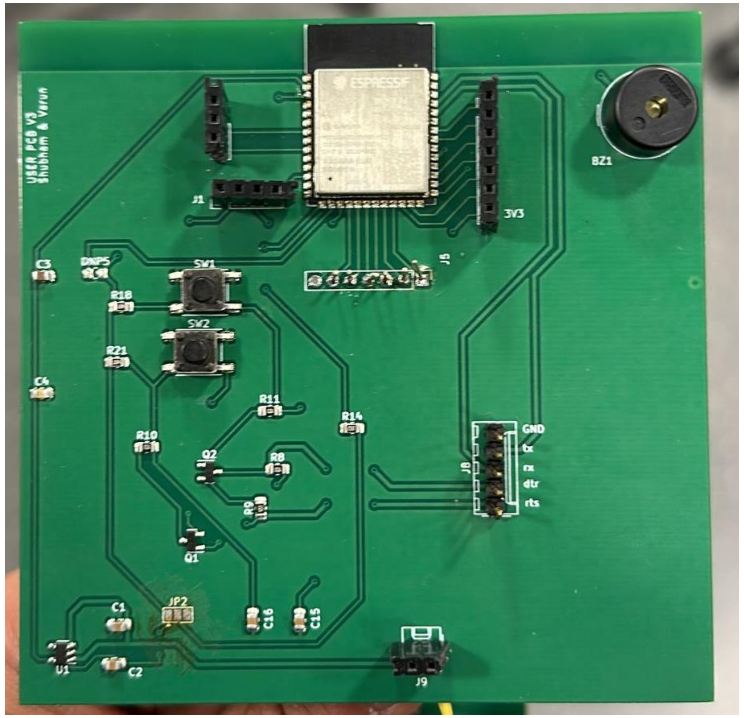
Block Diagram



User Tag Subsystem

User Tag


USER PCB V3
Shubham & Varun
Conn_01x03_Socket
Conn_01x04_Socket
BZ1
Buzzer
3V3
SW1
SW2
SW_Push
GND
tx
rx
dtr
rts
Conn_01x05_Socket
AP2112K-3.3
Screw_Terminal_01x02
J9
98.8060 mm
96.6470 mm

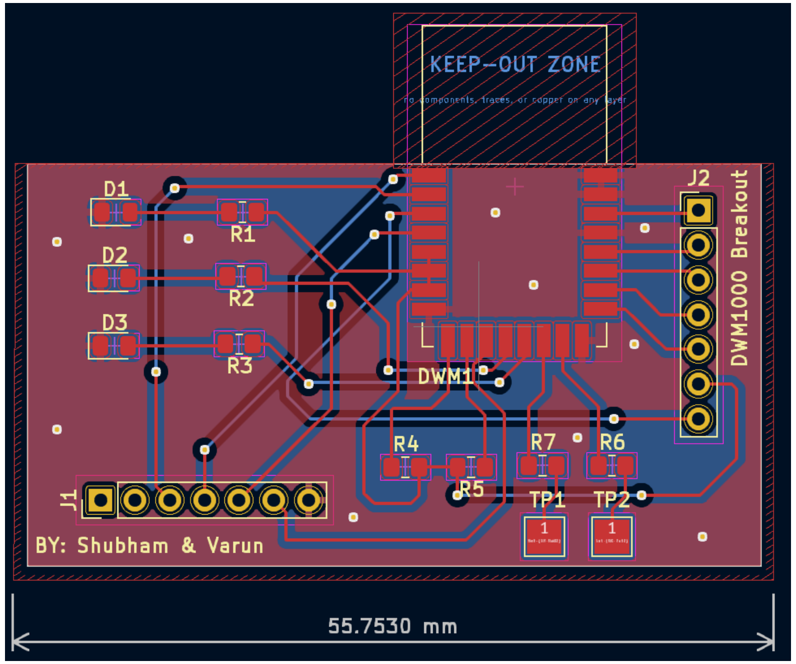

USER PCB V3
Shubham & Varun
ESPRESSIF
BZ1
3V3
GND
tx
rx
dtr
rts

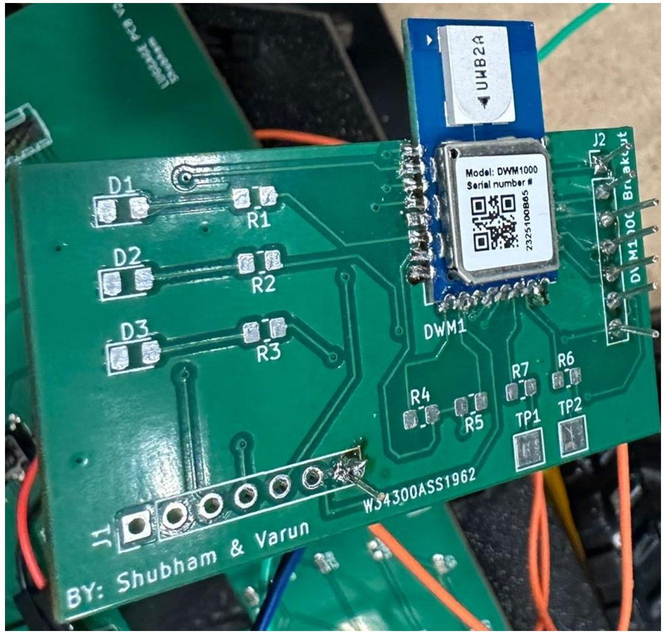
Objectives

- Reflects back UWB waves from the Anchors and Accurately measures distance from both Anchors
- Informs the User if Luggage is left behind through the buzzer
- Consists of a 4.8 V battery that is used to power the DW1000 sensor through a linear regulator

```
void loop()
{
    if(out_of_bounds){
      ledcWrite(0, 165);
    }
    else{
      ledcWrite(0, 0);
    }

    float sum = 0;
    int num = 0;
    for(int i=0;i<10;)
    {
      float dist = DW1000Ranging.loop();
      if(dist > 0 && dist < 20)
      {
        // Serial.println(dist);
        sum = sum + dist;
        num++;
        i++;
      }
    }
    if(num > 0)
    {
      Serial.print("Data: ");
      Serial.println((float)sum/num);
      //displayDistance(String((float)sum/num) + " m");
      if((float)sum/num > 6)
      {
        out_of_bounds = true;
      }
      else
        out_of_bounds = false;
    }
}
```

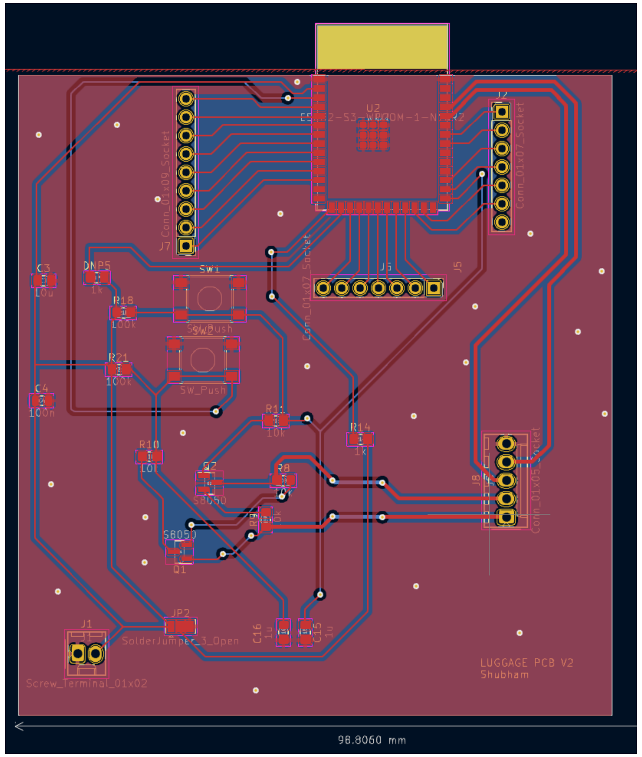
UWB Breakout board

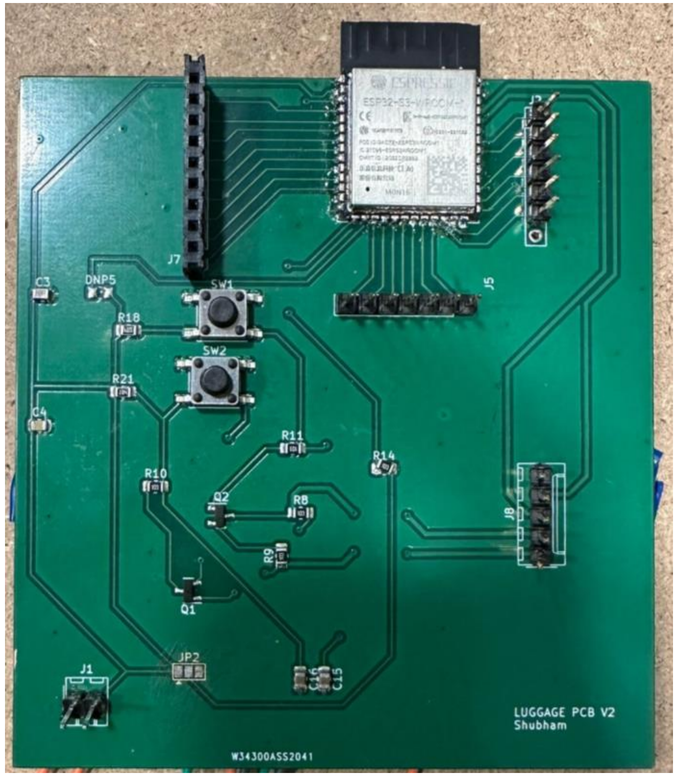




Luggage Tag System: Control Subsystem

Luggage Tag

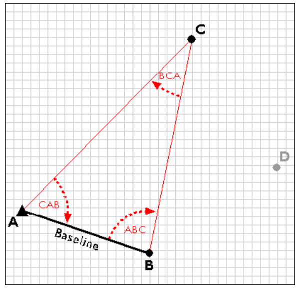

U2
J7
Conn_01x09_Socket
J2
Conn_01x07_Socket
J6
J5
C3
10u
DNP5
1k
SW1
SW_Push
SW2
SW_Push
R18
100k
R21
100k
C4
100n
R11
10k
R14
1k
R10
10k
Q2
S8050
R8
10k
R9
10k
S8050
Q1
J8
J1
Screw_Terminal_01x02
JP2
SolderJumper_3_Open
C16
1u
C15
1u
LUGGAGE PCB V2
Shubham
98.8060 mm


ESP32-S3-WROOM-1
J7
C3
DNP5
SW1
R18
SW2
R21
C4
R11
R14
R10
Q2
R8
R9
Q1
J8
J5
J1
JP2
C15
LUGGAGE PCB V2
Shubham
W34300ASS2041

Luggage Tag System: Control Subsystem

Objectives

- ❑ Obtain Distance values from both Anchors In their respective ESP32s.
- ❑ Pass information from One ESP to the other using a UART connection on the RX/TX pins
- ❑ Triangulate and correctly predict the person's position and use this information to drive the motors accurately



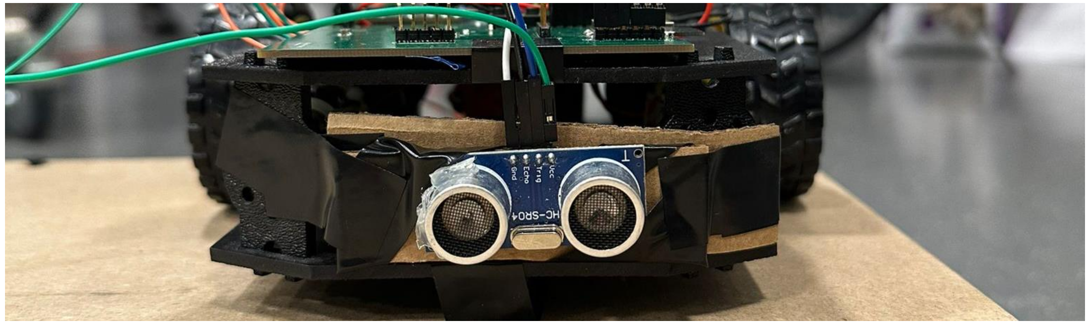

```
}
if (SerialPort.available())
{
  byte buf[4];
  byte* bp = buf;
  while(SerialPort.available()){
    *bp = SerialPort.read();
    if(bp - buf < 3)bp++;
  }
  float received = * (float*) buf;
  if(num > 0)
  {
    Serial.print("Data from main anchor: ");
    Serial.println((float)sum/num);
  }
  Serial.print("Data From Second Anchor ");
  Serial.println(received,2);
}
if (SerialPort.available())
{
  float number = SerialPort.read();
  Serial.print("Data from secondary anchor: ");
  Serial.println(number);
}
```

Luggage Tag System: Object Avoidance Subsystem

Luggage Tag System: Object Avoidance Subsystem

Objectives

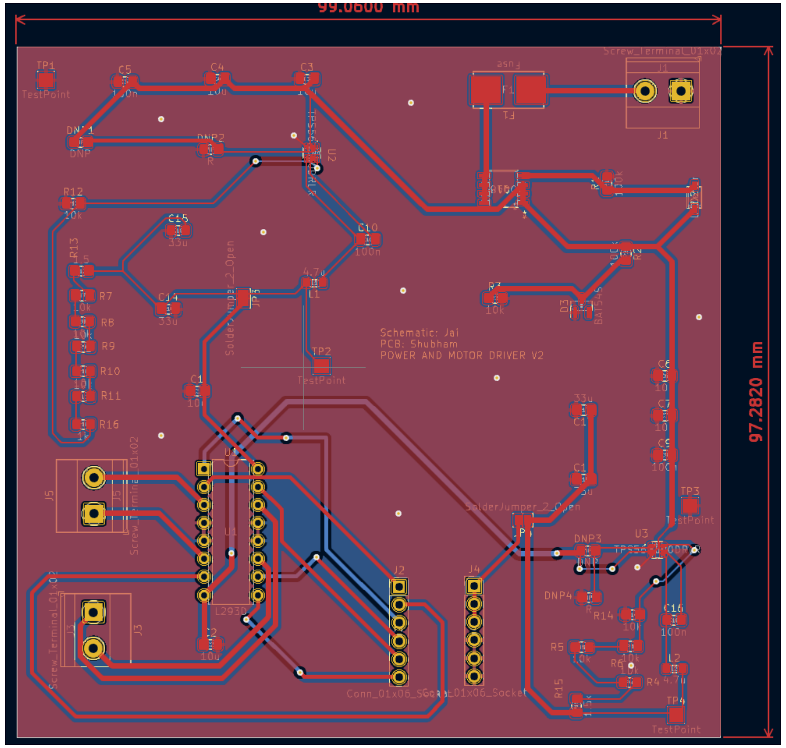
- ❑ Avoid Collisions by stopping the cart if anything comes within 50cm of the cart
- ❑ Stop the car if Tag is unreachable or out of bounds (6m)

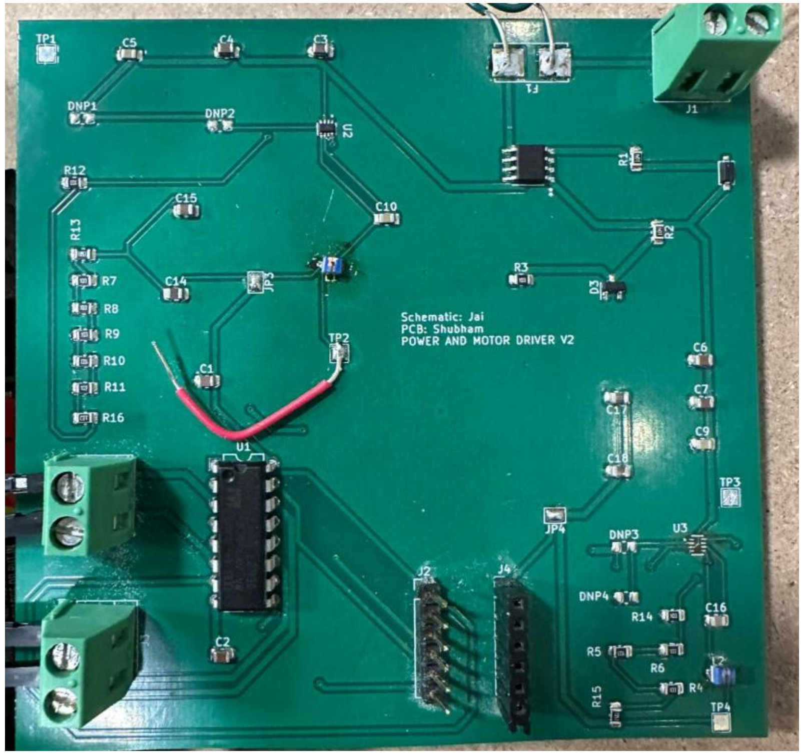



```
void ultrasonic(){
    digitalWrite(trigPin, LOW);
    delayMicroseconds(2);
  // Sets the trigPin on HIGH state for 10 micro seconds
    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);

  // Reads the echoPin, returns the sound wave travel time in microseconds
    duration = pulseIn(echoPin, HIGH);

  // Calculate the distance
   distanceCm = duration * SOUND_SPEED/2;

  // Convert to inches
    distanceInch = distanceCm * CM_TO_INCH;

  // Prints the distance in the Serial Monitor
    Serial.print("Distance (cm): ");
    Serial.println(distanceCm);
}
```

Block Diagram

Drivetrain and Power

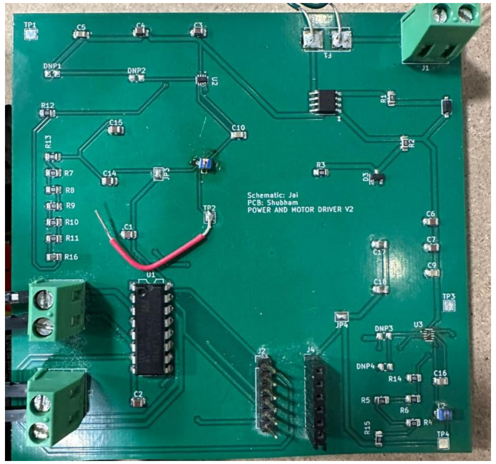




Luggage Tag System: Power and Drivetrain Subsystem

Objectives

- ❑ Powers the entire electronic system of the project by providing accurate operating voltages to the individual electronic components
- ❑ Enables the movement of the platform by implementing a bi-directional drive motor controller
- ❑ Consists of a 9 V battery, buck converters, linear regulator, motor driver and DC gear motors



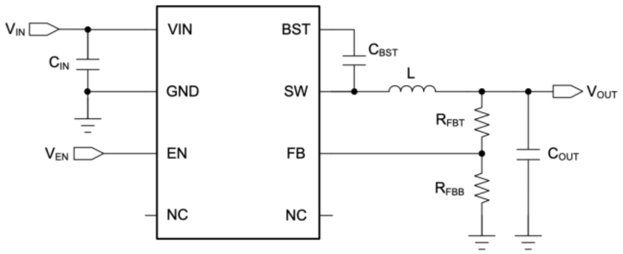
Luggage Tag System: Power and Drivetrain Subsystem

Design Choice

9V battery for the luggage subsystem and 4.8V for the user tag

Problem

- ❑ ESP32 requires 3.3 V
- ❑ Ultrasonic sensor and motor driver require 5V



Solution

- ❑ Use TPS563300 buck converters on the luggage subsystem
- ❑ Steps down voltages using a simple resistor divider equation

$$R_{FBT} = \frac{V_{OUT} - V_{REF}}{V_{REF}} \times R_{FBB}$$

where

- V_{REF} is 0.8 V.
- R_{FBB} is 10 kΩ (recommended).

- ❑ AP2112 linear regulator on the user tag to avoid complex circuitry

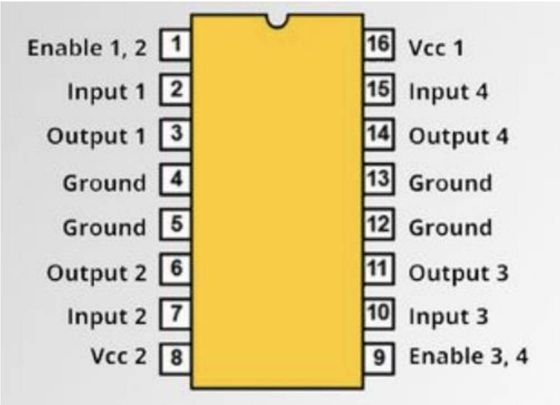
Design Choice

9V DC gear motors: 100 RPM, 80 Nm torque (per system requirements)

Problem

How to control operation and speed of two motors simultaneously?

Solution



- ❑ L293D motor driver with control pins for 2 motors
- ❑ Can change motor direction with complementary digital signals to the Input pins (Eg: HIGH on Input 1, LOW on Input 2)
- ❑ Vary speed by supplying digital PWM to the Enable pin

Quantitative Analysis

Buck Converter: Input 9V battery

- ❑ 3.3V output : R_{FBT} = 31.3 kOhm
- ❑ 5V output : R_{FBT} = 52.5 kOhm

$$R_{FBT} = \frac{V_{OUT} - V_{REF}}{V_{REF}} \times R_{FBB}$$

where

- V_{REF} is 0.8 V.
- R_{FBB} is 10 kΩ (recommended).

Linear Regulator: Input 4.8V battery

- ❑ Desired Output : 3.3V
- ❑ Battery Headroom : (4-8V - 3.3V) = 1.5V
- ❑ Max Dropout Voltage : 0.4V
- ❑ Power Disspation :

$$I_{out} * (V_{in} – V_{out})$$
$$= 0.6 * (4.8 - 3.3) = 0.9 \text{ W}$$

V_{DROP}	Dropout Voltage	I_{OUT} = 10mA	—	5	8	mV
		I_{OUT} = 300mA	—	125	200	
		I_{OUT} = 600mA	—	250	400	

Max Operation Temp: 110℃

$$T_{ja} = i_{out} * (V_{in}\text{-}V_{out})*(\Theta_{jc})$$
$$= 0.6 * 1.5 * 96 = 86.4 \text{ ℃}$$

(Allowable)

Results & Analysis

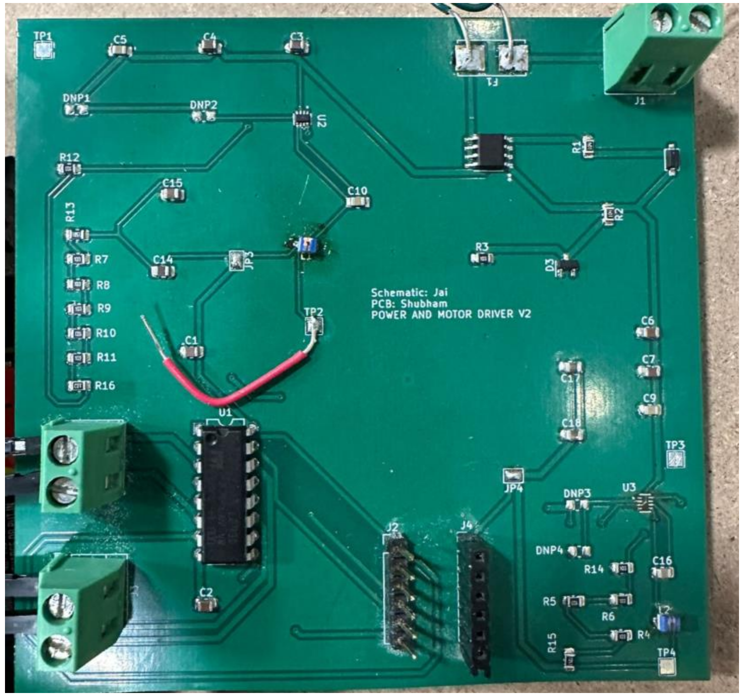
Results and Analysis

Drive-train and Power subsystem:

Requirements	Verification
The converter must be able to provide 5V and 3.3V from 12V to power the other subsystems. (+-0.2V)	• Using a power supply, we will provide a 12 V input to the buck converter. • We will then connect a voltmeter to the output of the converter at the designated test points of 5V and 3.3V and ensure voltage reading falls within the required threshold.

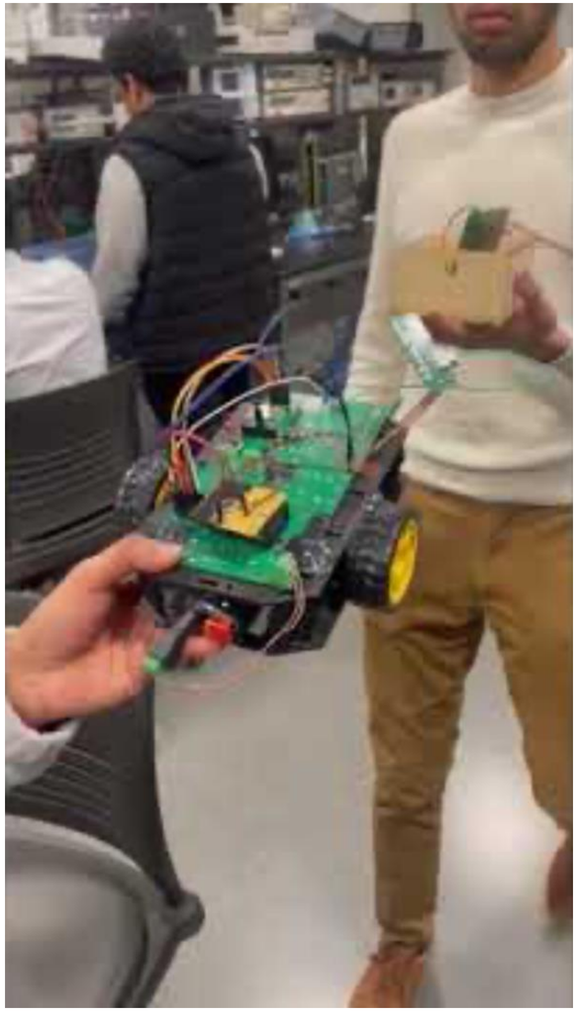
Drive-train and Power subsystem:

Since the subsystem also powers the entire system, when the battery is fully charged, the platform should be able to actively perform tasks (following the passenger + stopping in front of an obstacle + locating the passenger distance) for at least 30 min. (approximate time for one cycle of use)	• We will first fully charge the battery before the verification process. • Then, we will begin thefunctioning of the system while behind the passenger such that the machine will always be in the mode of following the passenger. • We also plan on introducing obstacles in the way of the platform. The requirement is met if the platform can remain active for more than 30 minutes.
Torque provided by each motor must be at least (with coefficient of friction of) 150 N*m to drive the entire system forward under full load of 20kg with a speed of 3 mph.	• We will hang weights using a string at the edge of the tire and then turn the motor on. • We will keep adding weights and examine whether the motor is capable of driving the system forward.. • If the motor fails to create motion, we can then calculate the torque as total_weights * wheel_diameter. • The requirement is met if the calculated torque exceeds 150 N*m.



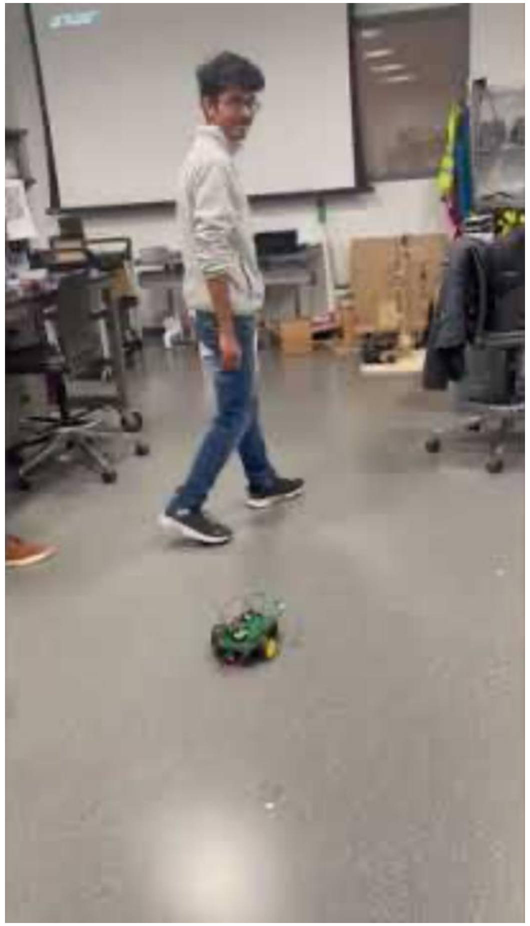
User tag subsystem:

Requirements	Verification
The tag should be able to communicate with the other transceivers.	• Power user tag • Power control subsystem • Calibrate the user tag with the anchors • Get reading from serial output of ESP32 • This reading should be +/- 20 cms of actual scale reading.
The tag should be able to alert the user upon going out of range (10m).	• Take the tag out of range of the luggage • Power user tag • Power control subsystem • The buzzer should beep
Tag's distance calibration with the luggage - user should be able to calibrate the tag before using the luggage system.	• Keep the tag on the designated mark on the cart. • Then start the calibration process. • The calibrated distance should be within the tolerance level of the true distance which is +/- 20 cms.



Obstacle detection subsystem:

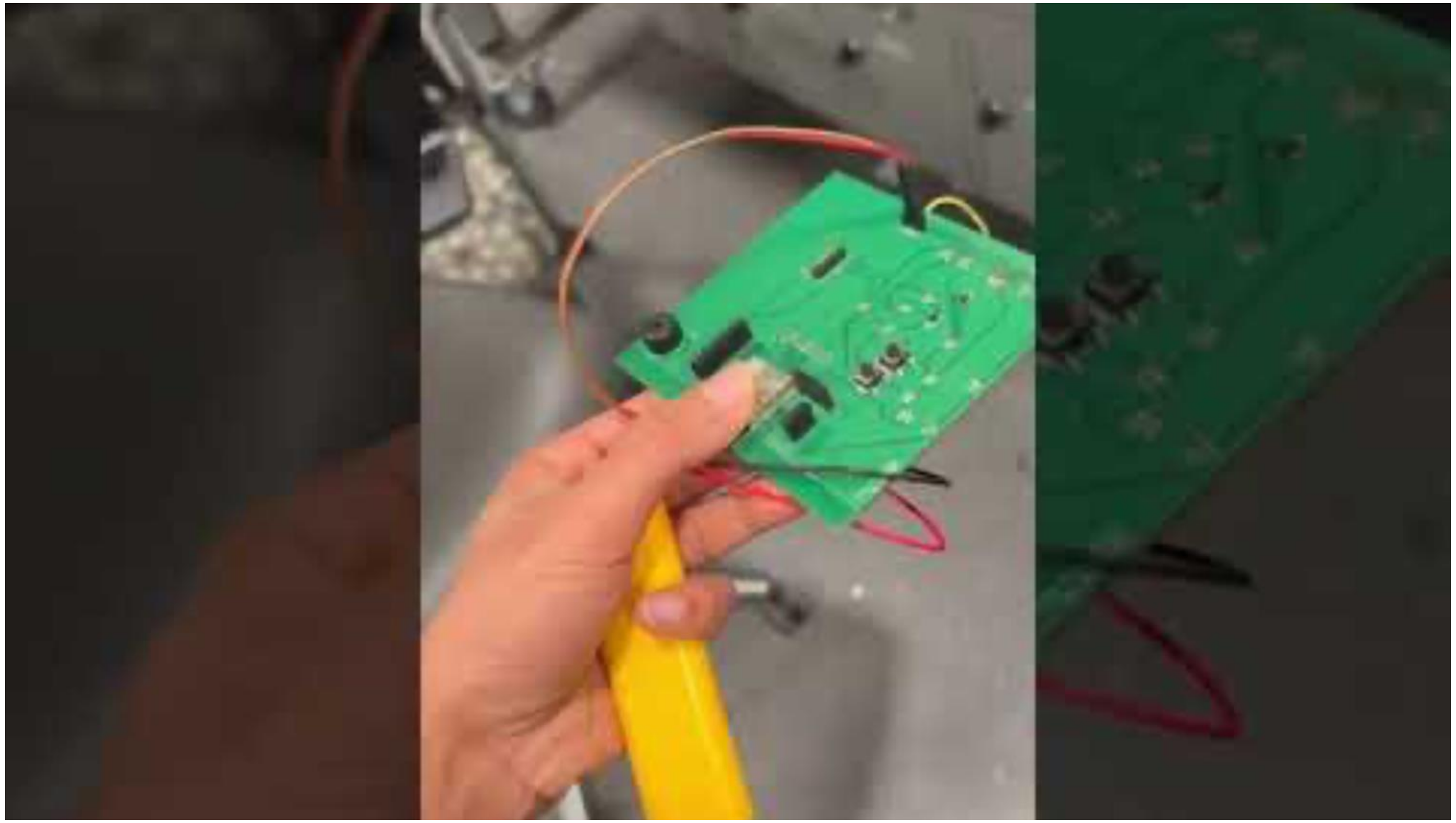
Requirements	Verification
When the obstacle avoidance subsystem detects that there is an object within the path of the luggage (0.5m), it should output to GPIO of ESP32.	• Power the sensor with 3.3V and GND. • Connect the correct GPIOs to ESP32. • Provide an obstacle in front of the senor. • Check the output voltage of the ESP32 designated GPIO to be 0V.
When the luggage is obstructed by an obstacle and the person goes out of range (10m), the subsystem should not still move the luggage but generate a signal to alert the user.	• Keep the tag at a distance > 10m. • Power the sensor with 3.3V and GND. • Connect the correct GPIOs to ESP32. • Provide no obstacle in front of the senor. • Check the output voltage of the ESP32 designated GPIO to be 0V.



Control/Luggage subsystem:

Requirements	Verification
The 5V-3.3V converter should be able to output 3.3 V (±0.3V).	• Using a power supply, provide a 5 V input to the 5 V- 3.3 V Converter. • Connect a Voltmeter to the output of the converter and ensure voltage reading falls within the required threshold. • Turn the power supply off and on. • Repeat experiment 10 times and ensure that voltage reading falls within the expected threshold at least 9 out of 10 time
All 3 DW1000 Sensors on the luggage subsystem should always be equidistant from each other and they should stay equidistant from each other throughout the working of the device.Sensor 1 is 25 cm away from Sensor 2 and 75 cm away from Sensor 3. Sensor 2 should be 75 cm away from Sensor 3 as well.	• We will move the Luggage system and check if all sensors still give the same constant distance values throughout the test. • We will measure the distance between each sensor and the distance should be the same as the given values.
The subsystem should be able to communicate with the User Tag Subsystem accurately with a max ±10cm error rate.	• We will keep a scale and check if the output from the User Tag Subsystem is accurate even when we move it around within the error rate. • With the scale we will be able to check the accuracy of the output.

Control/Luggage subsystem demo:



High Level Requirements

High Level Requirements

Initial Design	Final Design
Achieve a user following accuracy at a distance of 1-1.2m with an error of ± 50 cm.	The platform is unable to follow the user due to sensor noise and inaccuracy, therefore making the control algorithm ineffective.
Platform follows the person with real-time updates in the path with latency of no more than 1s, keeping pace with the user.	The sensors update the distance every 1s, enabling the platform to vary its speed proportionally with the distance of the user.
Avoid collisions with obstacles (up to 0.5 m). Alert the user if the luggage is left behind more than 10 m.	The platform comes to a stop on detecting obstacles in front of it (0.5 m). Buzzer beeps in case the platform goes out of bounds (10 m).

High Level Requirements

The <u>engineering</u> reason behind failure:

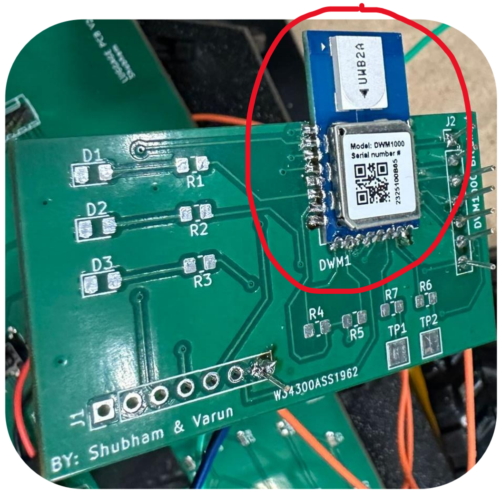
1. Damaged a DWM1000 UWB sensor:

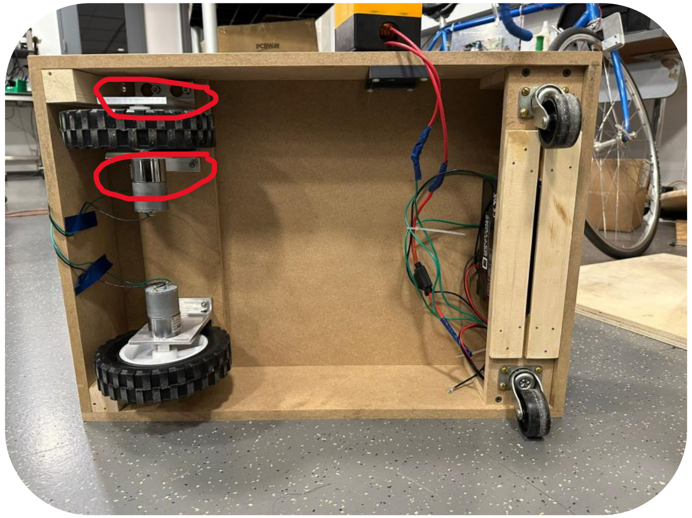
a. Expensive sensor ($25)
b. Resulting in very poor accuracy
c. A minimum of 3 sensors are required for triangulation

2. Misaligned motor in cart build:

a. Linear correction in firmware wasn't possible
b. Cart cannot go in a straight line

FIX: Down scaled to a small cart for proof of concept

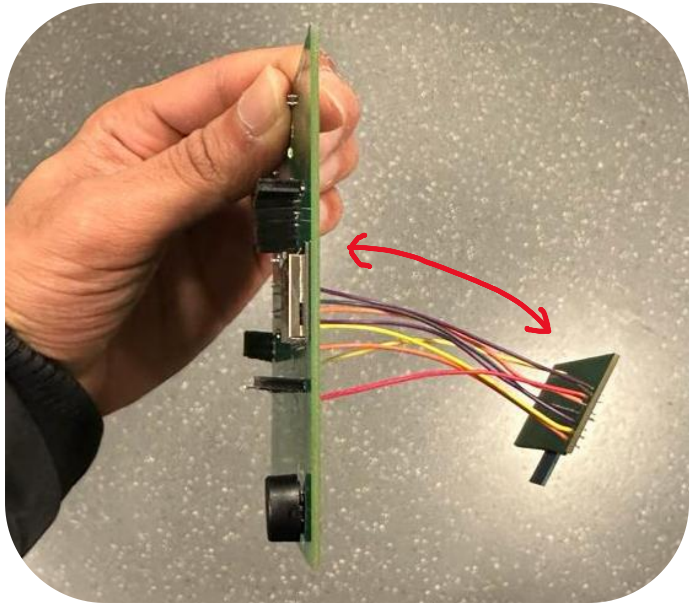


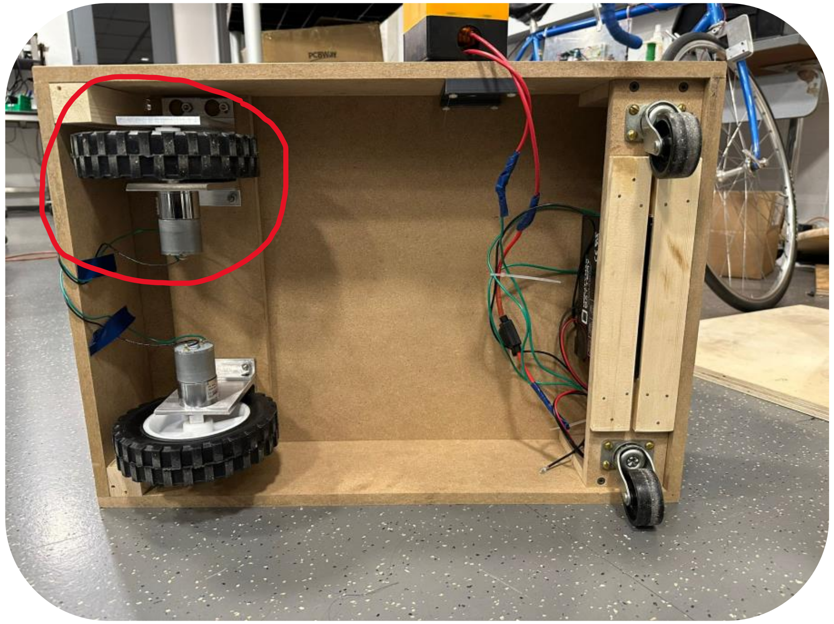


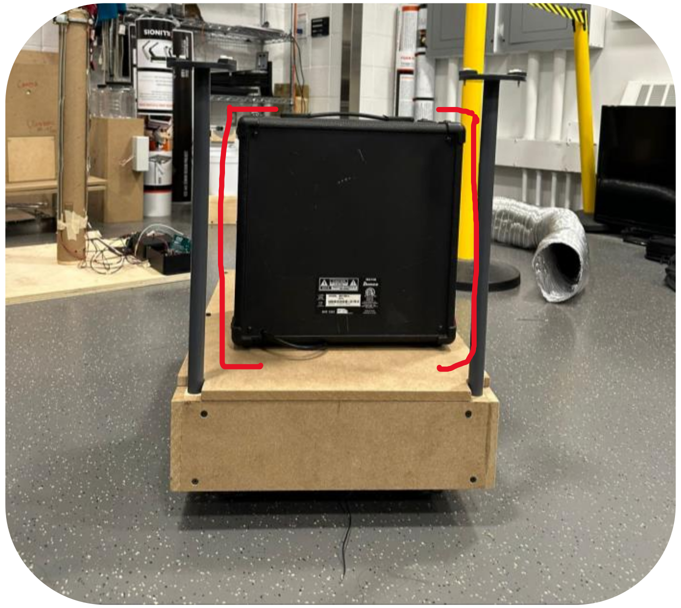
Future Scope

Fixes and recommendations:

- ❑ Fix motor alignment – enabling straight differential drive
- ❑ Ensure luggage safety – locking mechanism
- ❑ Enhance EM shielding – between ESP32 & UWB sensor







Conclusion

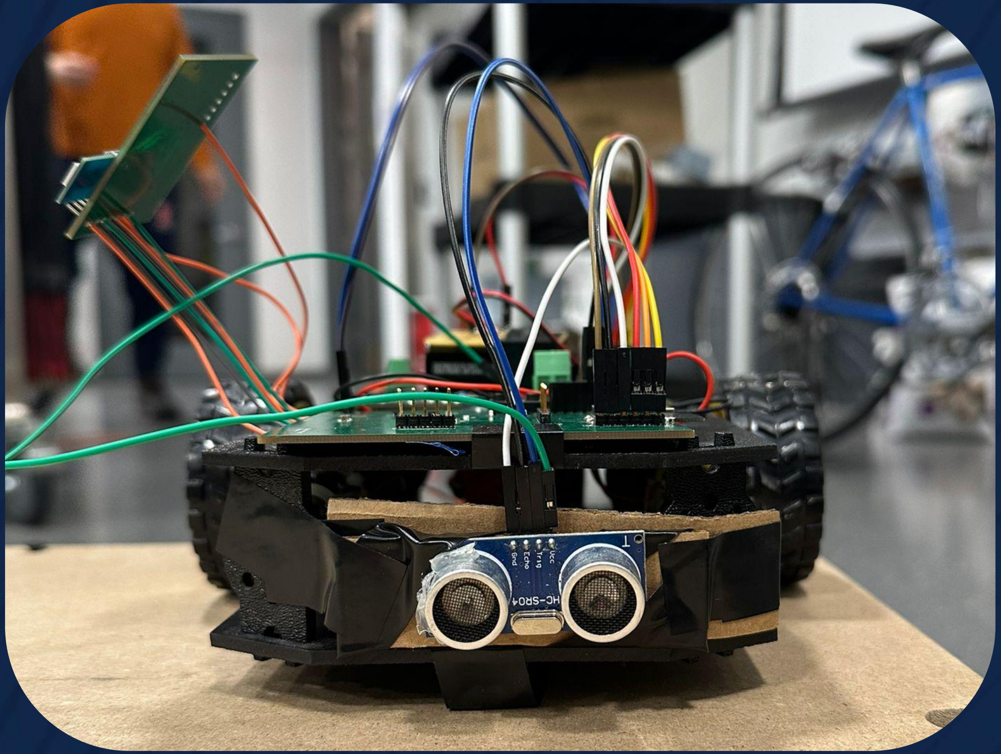
Learning and Challenges:

- ❑ Always use over current protection for delicate circuits
- ❑ Invisible bridging can occur
- ❑ UWB sensor integration was a challenge

Alternative Considerations:

- ❑ Use computer vision to track the user
- ❑ Use a mechanical system – a directed thread attached to the user

Thank you!



Questions?

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