ELEC 391 2024W2
Project Proposal

Group C5

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Introduction:

This document outlines the extra features our team will implement on our two-wheel balancing robot. It outlines the rationale, features, RCGs, functional diagrams/ CAD models, demonstration, technique, BoM and a conclusion.

Rationale:

Currently, there has been a boom in household robots that can help with daily tasks. One of the key aspects these robots have to implement is the ability to map their surroundings and use this knowledge to their advantage to navigate. With this rationale, we are aiming to implement a simple system that utilizes a Sonar Sensor rotating continuously to provide a 2D layout of a space and also detect objects by transmitting a set of data points measured and having it process on the laptop and display it on our GUI that incorporates the mandatory features.

Features:

Goals

1. Design and fabricate a self-balancing robot on two wheels that is able to maintain balance in a vertical position while being driven by an external operator on a course track that may present sloped portions.
2. Successfully map the surrounding environment using the SLAM algorithm and send it back to the user via BLE.
3. Avoid collision while being able to collect data points for mapping.
4. Process data points over BLE to create a 2D layout of the environment and display it using GUI.

Requirements

1. The robot must be able to scan 180 degrees in front of the robot.
2. The robot must be able to Detect an object within a radius of 10 cm and avoid collision.
3. The robot must balance simultaneously i.e. does not interfere with the original balancing algorithm.
4. The robot detects the distance it has moved in the x-axis and y-axis direction.
5. Communicate over BLE the x-coordinates and y-coordinates of the robot in reference to its starting position.

Constraints

1. Sonar does not detect objects at a distance beyond 100cm.
2. Distances detected have a larger error as the distance between the robot and the object detected increases.

Things to accomplish:

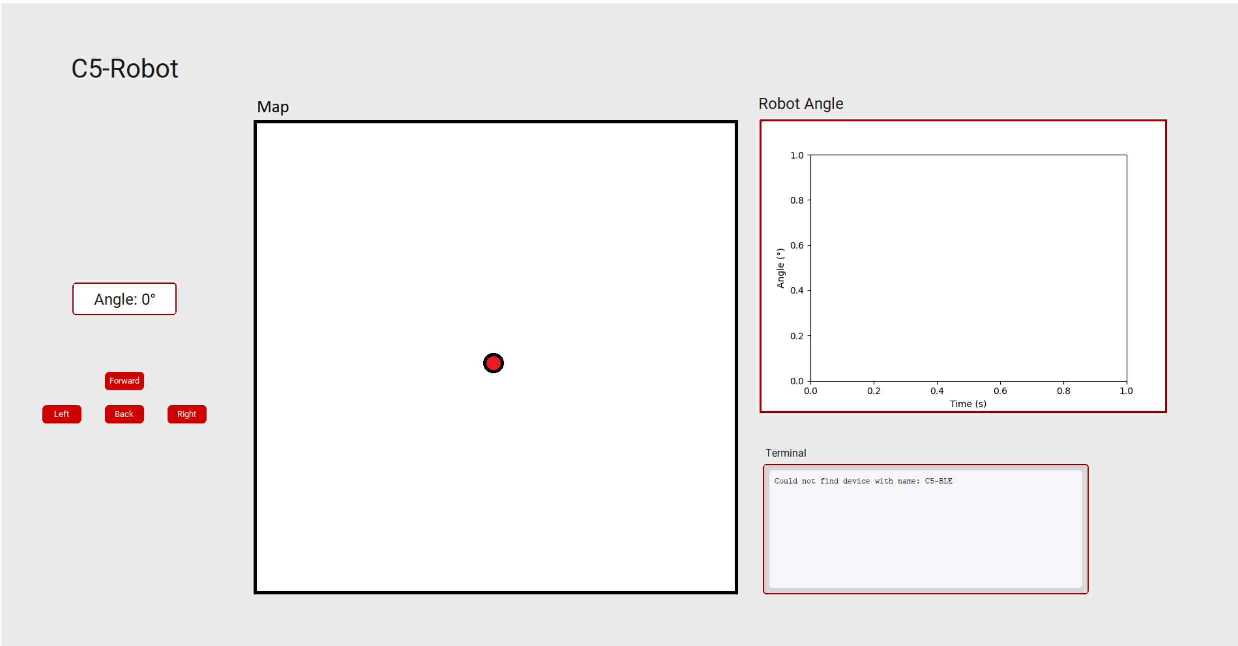

Figure 1 - Example GUI for the mapped data

Explanation of the SLAM Algorithm:

- SLAM (Simultaneous Localization and Mapping) is an algorithm that uses information from sensors such as an IMU and our Infrared Sensors to determine the amount of movement that is required for the robot, this is what we call localization of the robot. Then we use sensors like our ultrasonic sensor to simultaneously create a map of the surrounding area.
- As data points are collected, there is an accumulation of errors (bias) and the robot will not be able to accurately map the environment about its starting position. To fix this, we use Pose graphs and loop closures.
- Loop closure is the process of the robot taking several measurements and making a circle (or a closed shape) back to the starting point.
- Pose graphs are a graphical representation of the robot's movements on the map and place a node every time a measurement is made and use these nodes and distance measurements to optimize the map for corrections.

Hardware accompanying the SLAM algorithm

1. Distance Measuring Using IR

- One of the requirements of being able to measure the distance covered will be done by modifying the bottom layer and the wheels.
- The battery holder will be modified where 75% of it will be printed with the bottom later attached, and the 25% will be completed by a mount for the IR sensor for each wheel that is going to measure distance.
- The wheels will be printed with Matte black PLA and the end spokes with Matte while PLA used by IR to calculate the distance covered.
- The distance is measured by the ultrasonic sensor emitting a sound signal at a speed of approximately 343 m/s and starts a timer that counts how long it takes for the sound signal to come back. Then the distance is measured by (v_sound)*dt/2.

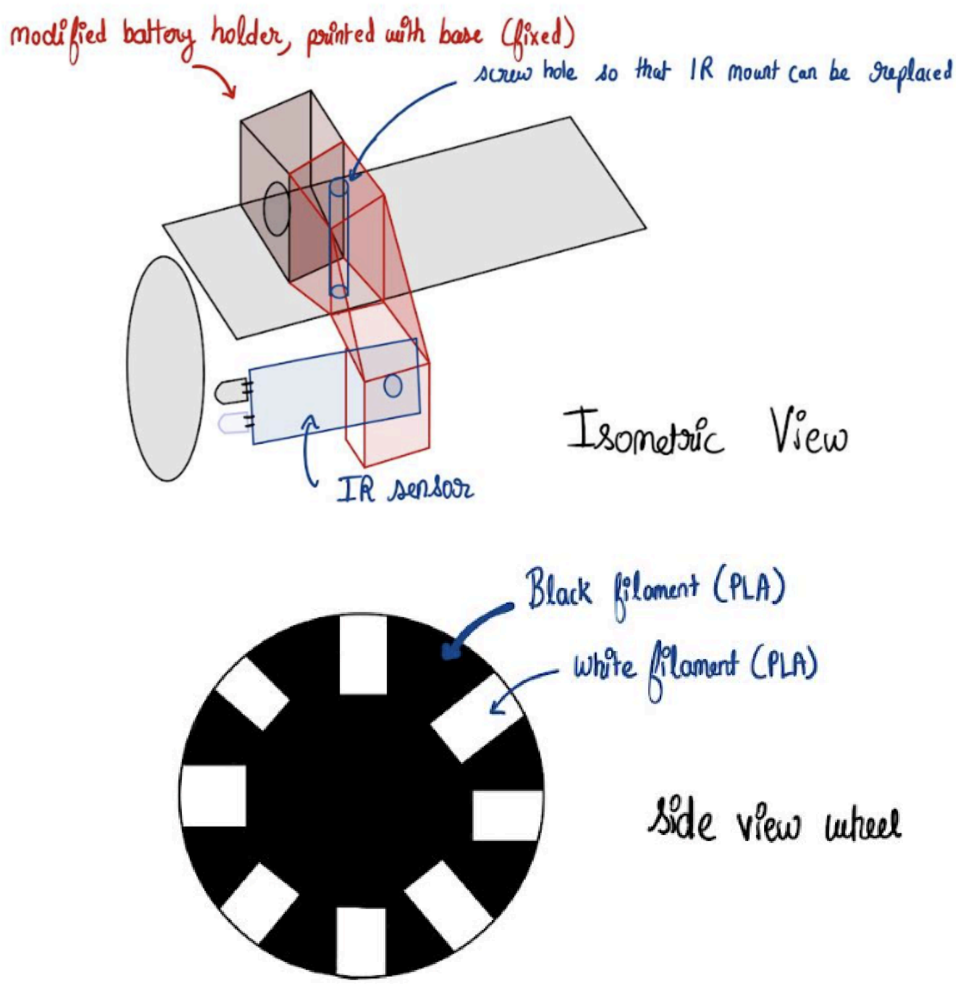

Figure 2 : Illustration of IR sensor Mounting and sensing the wheel

2. The third level integrating various components

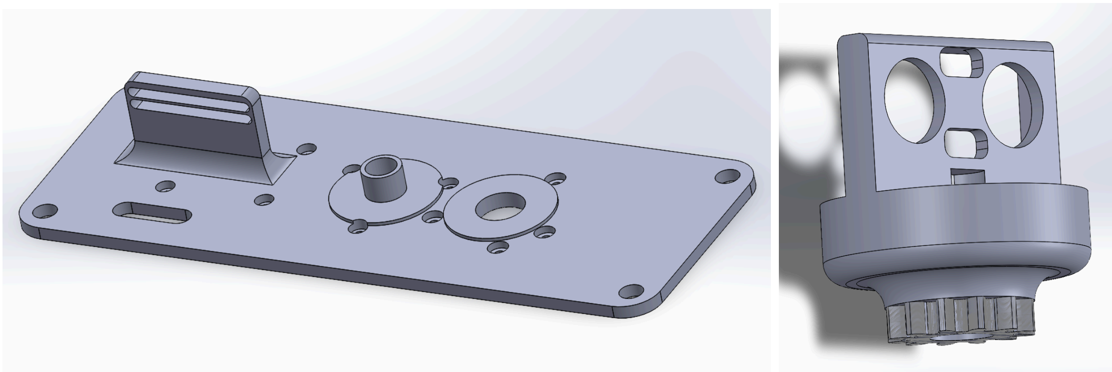

Figure 3 : CAD model of the Third layer

- These diagrams show the 3D model of the third floor of the robot.
- As shown above, the ultrasonic sensor encasing is connected to a stepper motor through a gear ratio used to turn the sensor.
- The stepper motor is connected to a stepper driver. The stepper driver takes inputs from the microcontroller using a logic level shifter which is used to step up 3.3V output to 5V needed for the stepper driver.
- A slip ring is utilized to allow for continuous rotation, surpassing the requirement of 180-degree rotation.
- Initially, to have a reference of 0 degrees, the IR sensor is being used to home the sensor using black electrical tape.
- The angle is computed by knowing the speed of rotation of the stepper and applying the gear ratio.
- Furthermore, to eliminate biasing, the angle is overwritten to 0 degrees when the electrical tape is sensed by the IR sensor.

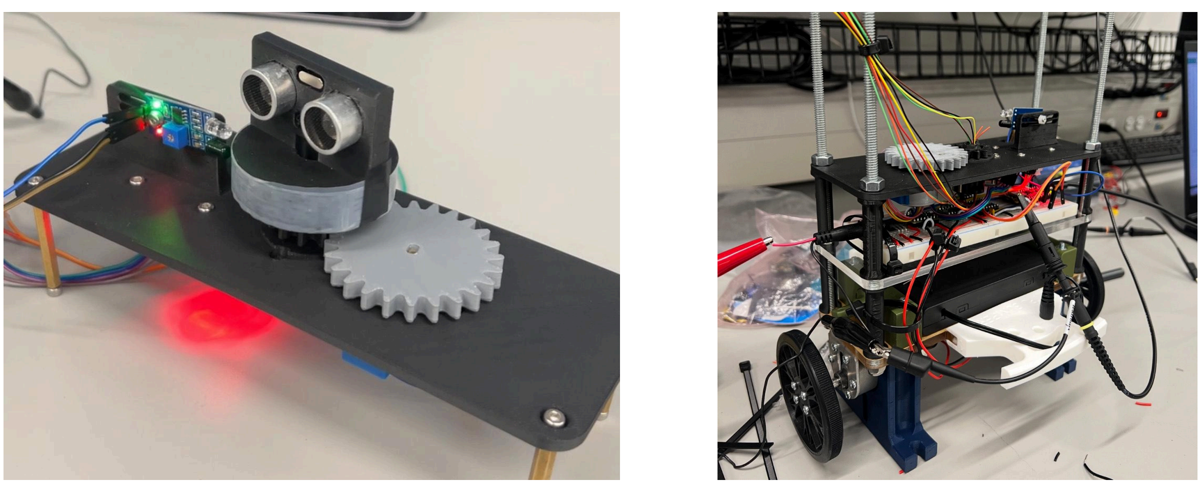

Figure 4: Physical prototype of the third floor

High-Level Functional Diagram:

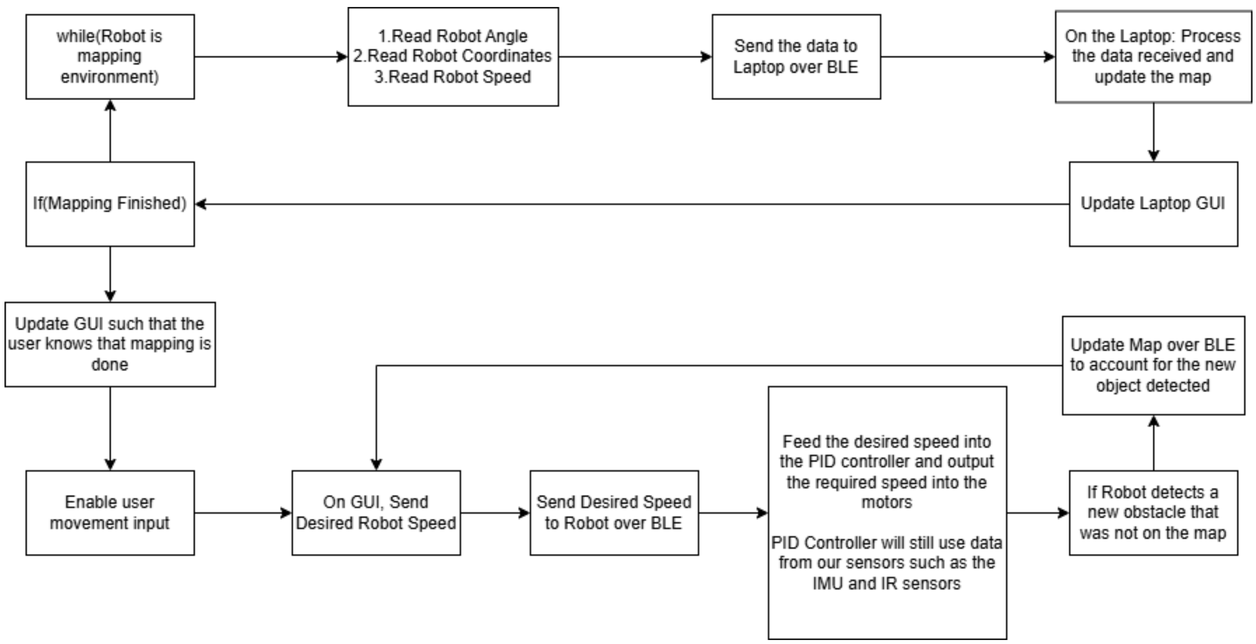

Figure 5 : High Level Functional Diagram of Extra Feature

- The high-level functional diagram above explains the process of how our extra functionality operates. We begin by first starting the mapping process of our robot and it will keep on looping in the diagram until a closed box has been mapped on our GUI. Afterwards, the robot will allow the user to input desired movement speeds to the motor and then will enable the ultrasonic sensor to still detect any objects in its vicinity to make sure the robot does not collide with any new objects that are placed in the environment.

Criteria for Success:

1. Test Case 1: Mapping a square-shaped environment (cardboard walls)
2. Test Case 2: Mapping a circular-shaped environment with no distinct corners in the walls
3. Test Case 3: Mapping an environment with a border wall as well as walls within the environment.
4. Accurately measure the coordinates of the robot with an error of ± 6.5 cm in all cases.

Demonstration to Teaching Staff:

- Show the full mapping of our surrounding environment while still avoiding objects.
- Show the map updating as it gathers new data points.
- Show the robot coordinates being transmitted to the GUI.
- After the mapping of the environment is completed, demonstrate the robot being able to move at different speeds controlled by the laptop.
- Avoiding new objects placed into the environment after the map has been created.
- Use a large cardboard box to showcase environment mapping.

Accompanying Documentation:

- Circuit diagram for the Stepper Motor + Driver, 3 Infrared Sensors, Slip Ring, Ultrasonic Sensor, Logic Level Shifter, and the LM7805 concerning the Arduino Nano 33 BLE Sense Rev2 microcontroller.
- Documentation of how to connect the robot to the Python laptop GUI using BLE.
- Documentation of how to operate the GUI with the robot.
- Documentation on the maximum operating conditions of the Ultrasonic Sensor, Stepper Motor Speed, etc.

Budget:

- Our team is provided with a budget of $65. For the extra features we will require the following:
- Ultrasonic Sensor (HC-SR04) - Measure the distance of the surrounding perimeter.
- Stepper Motor + Driver - To rotate the Ultrasonic sensor by 180 degrees.
- Infrared sensor - To measure the distance moved by the robot.
- Logic Level Shifter - Ensure the stepper motor receives the required inputs at the required voltage.
- LM7805 - Needed to step down voltage supplied by the batteries to 5 volts needed by the stepper motor.
- Slip Ring - Allow the ultrasonic sensor to continuously rotate 360 degrees while still maintaining proper electrical connections.

List of Components (BOM):

SI No	Component	Model	Link	QTY needed	QTY w Purchase	Cost (CAD)	Cost/piece (CAD)
1	Ultrasonic Sensor	HC-SR04	Digikey Link for Ultraviolet Sensor	1	1	9.62	9.62
2	Stepper Motor + Driver	28BYJ-48 and ULN2003	Amazon Link for Stepper Motor + Driver	1	2	12.99	6.495
3	Infrared sensor	EK1254	Amazon Link for Infrared Sensor	3	5	13.03	7.818
4	Logic Level Shifter	TXS0104E	Digikey Link for Logic Level Shifter	1	1	1.36	1.36
5	Linear Voltage Regulator	LM7805	Digikey LM7805 Link	1	1	2.81	2.81
6	Slip Ring	SRC-22-06A	Amazon Link for Slip Ring	1	1	12.81	12.81
Total (CAD)							40.91

Table 1: List of Components (BOM)

Conclusion

Having successfully tested our circuitry for the third level-displaying points over BLE-we are confident in our ability to integrate and implement our extra feature within the given deadline. Our current tests demonstrate feasibility, reinforcing our readiness to move forward with the final implementation.