ECE445

Spring 2023 Senior Design Laboratory
Project Proposal

Personal Carrier Robot

Team No. 36

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Abstract

This document is intended to provide a more detailed overview of the Personal Carrier Robot project compared to our RFA. Provided within this document are the relevant high-level implementation details, requirements and safety considerations.

Contents

1 Introduction

1.1 Problem

In our society, there are individuals who may lack the ability to carry objects by themselves. An example of this is elderly individuals who may be unable to carry heavy groceries.

1.2 Proposed Solution

Our solution is to create a path-finding robot that will follow the individual while avoiding obstacles. We plan to implement this using ultrasonic depth imaging to detect obstacles. A series of rotating ultrasonic sensors will be imaging out the surroundings of the robot. A static mounted camera will be used to estimate the distance and bearing of the person of interest by tracking an article of clothing printed with QR code via OpenCV. In the event that the QR code is not visible, the robot will plot a path using the person of interests' phone's accelerometer and gyroscope sent via bluetooth. Combining the obstacle and goal direction data, we will employ a path-finding/SLAM algorithm to direct and move the robot through terrain via a grid map as depicted in figure 1. The overall structure of the robot is depicted below in figures 2 and 3.

1.3 Visual Aid

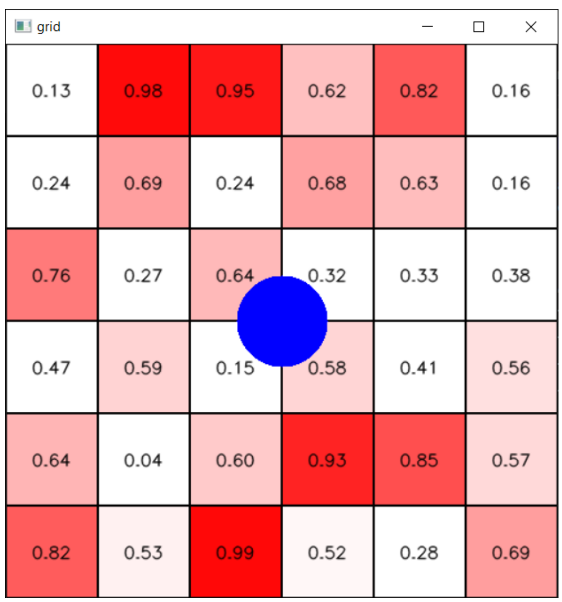


Figure 1: Sample OpenCV visualization of grid roadmap

Figure 2: Visual representation of the robot

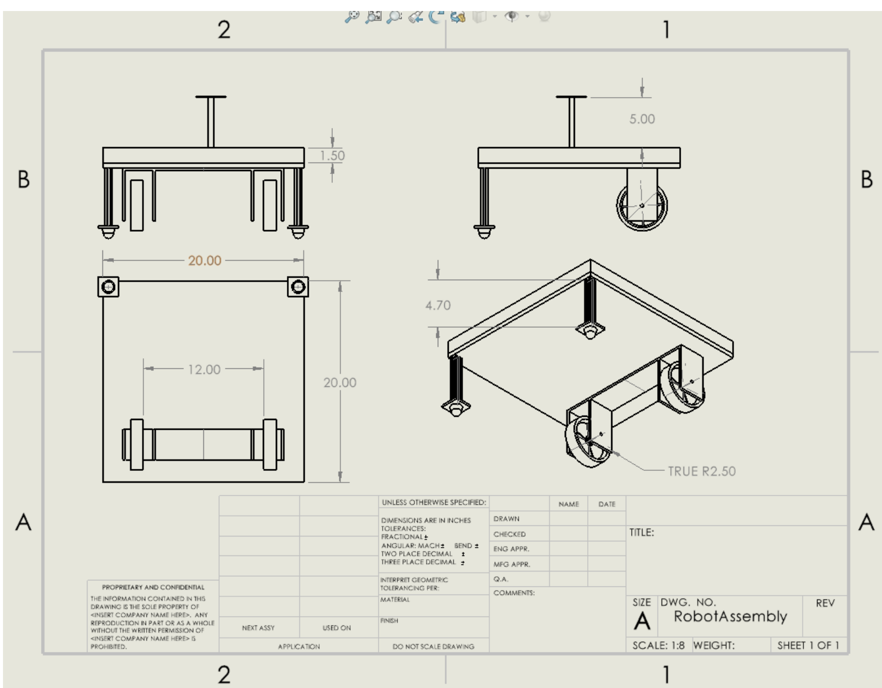


Figure 3: Robot frame dimensions

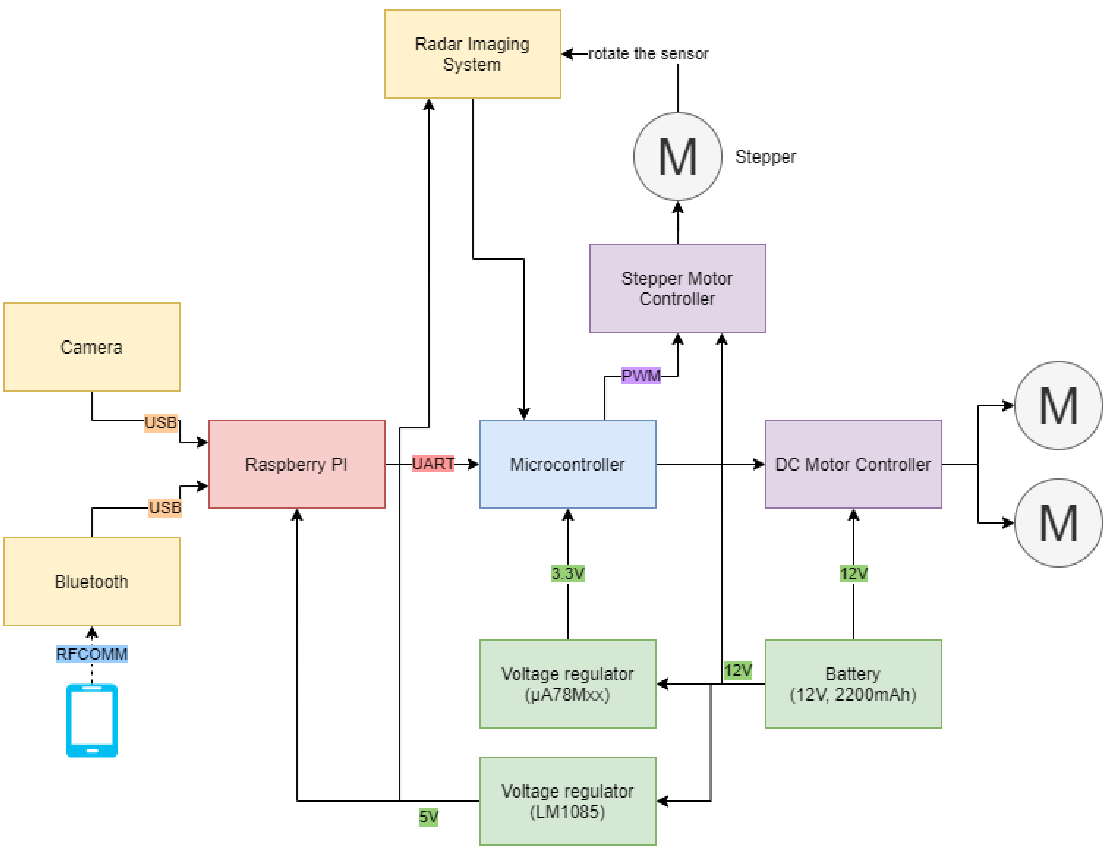
1.4 High-Level Requirements

To succeed, the robot must achieve the following criteria:

- The robot should be able to consistently follow the phone holder/color marker through flat terrain with static obstacles with a height of at least 30 cm
- The robot should also be able to carry a load of 3 kg over level ground
- The robot should be capable of moving at speeds of up to 0.5 miles per hour (0.8 km/h)
- The robot will maintain a distance of 1-5 meters away from the person of interest

2 Design

2.1 Block diagram



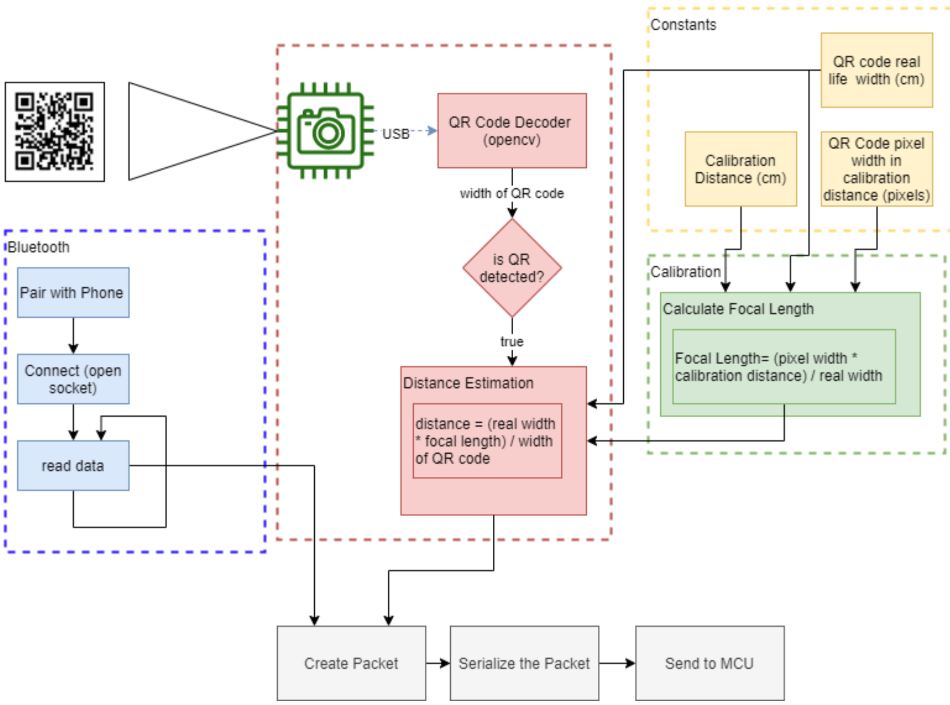
2.2 RPI Sensory Subsystem

2.2.1 Overview:

The Raspberry Pi subsystem's main goal is to provide information about the user, such as position, rotation, and heading. This subsystem has two main underlying components: a camera interface and a Bluetooth interface, as shown in Diagram #. The outputs of these two components are then stored in a packet and serialized, to be sent to the microcontroller over serial communication.

The Camera component uses QR code detection and decoding to determine the distance between the robot and the user. It first searches the camera input for a QR code using OpenCV. The QR code contains a unique sha256 hash for each user. Upon finding the correct QR code, the distance is calculated by using the focal length of the camera and the pixel width of the found QR code. This distance is sent to packet generation.

The Bluetooth component uses python to connect to the User's phone and receives sensory data in a fixed intervals. This data is processed to remove noise, then sent to packet generation.



2.2.2: Requirements:

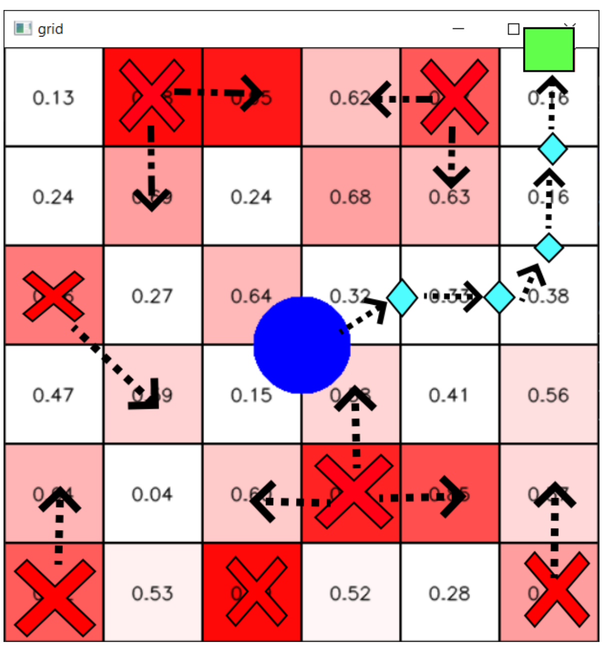
- Measure the distance to the user.
- Receive phone data
- Serialize measured and collected data, and transfer it to the microcontroller quickly.

2.3 Microcontroller Subsystem

2.3.1 Overview:

The Microcontroller Subsystem consists of three main parts, pathfinding system, driving subsystem, and radar imaging control. These three components work together to detect obstacles, find the path, and control the motor to follow that path.

The path decision system is the main computation in this project. This system uses data from radar imaging sensors to generate obstacle objects. These objects are then fed into a Kalman Filter (EKF). The Kalman Filter returns as with estimated trajectories of these obstacles. Next, the system generates a grid based on fixed cell size and max distance as bounds. Using the estimated trajectories the cells are assigned a collision probability. The grid is a two-dimensional array; the visualization of this grid can be seen in Figure #. After the grid is generated, the microcontroller uses the A* algorithm to find the shortest and safest path. For the A*, the heuristic will be based on the lowest collision probability and shortest Manhattan distance. The heuristic will be weighted in favor of minimum collision probability. Finally, after the path is determined it is sent through an encoder which turns these points into motor instructions.



Motor Instruction List

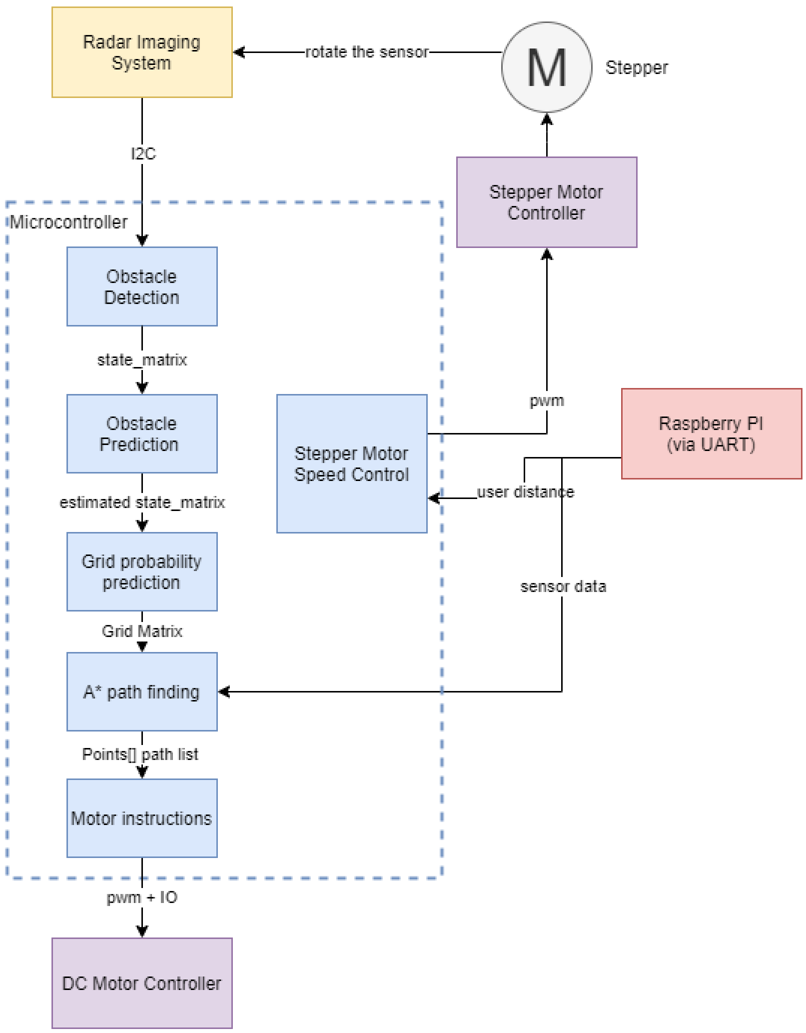
Index, Distance(m),Speed(RPM)
[
[0,1.11,100],
[1,1,100],
[2,0.7,50],
[3,1,50],
[4,1,50]
]

Legend:

- Green Square: User
- Cyan Diamonds: Waypoint generated
- Red Crosses: Obstacles
- Dashed Arrows: Possible Movement of the object

The Driving Subsystem receives a list of motor instructions which describes how long the motor should run in terms of distance and at what speed. The size of this list is determined by the number of decisions made per second by the path decision system(dps). It should be noted that dps relies on measurements per second of the radar imaging system(mps). In other words, mps and dps are directly proportional while the size of the motor instruction list is inversely proportional. For this system, we will be using a DC Motor Controller.

Radar imaging control uses a single Lidar sensor (###) and using a stepper motor (####) turns this sensor 360 to generate a 2d distance map. The stepper motor is controlled by a controller (####) which is controlled by a PWM from the microcontroller. The frequency of the PWM controls the speed of the microcontroller. This speed is adjusted by the distance to the user provided by the RPI to optimize imaging resolution.



2.3.2 Requirements:

- System is able to detect obstacles
- System is able to predict trajectories for those obstacles
- System is able to generate a probability grid based on obstacle data
- System can generate a path using the probability grid.
- System can generate motor instructions using a defined path.

2.4 Power Management

2.4.1 Overview:

For the power system we will be using a 12V, 2200mAh lithium polymer battery alongside a uA78Mxx and LM1085 voltage regulators. From the battery, the system will supply 12V, 2.2A to the drive motors. Via the uA78Mxx voltage regulator, the system will supply 5V, 2.5A to the RPI subsystem and via the LM1085 voltage regulator, the system will supply 3.3V, <0.5A to the microcontroller subsystem. Due to safety considerations, charging of the battery component of the subsystem will be accomplished by removing the battery from the subsystem and charging separately from the robot using a separate Xt60 connector compatible battery charger.

2.4.2 Requirements:

- System is able to provide sufficient voltage and current for all components
- System is able to step down voltage to safe levels for all components
- System is able to provide sufficient power for the required run-time
- Battery component of the subsystem is able to be removed and replaced in a safe and easy manner not requiring any specialized tools.

2.5 User

2.5.1 Overview:

For the user subsystem, we are using react native to create a mobile app that sends sensory packets via Bluetooth to RPI subsystem via a USB Bluetooth Adapter connected to the Raspberry Pi. The mobile app will transfer the user's gyroscope and accelerometer data to assist the robot in pathfinding, particularly when the user is not in line of sight.

2.5.2 Requirements:

- System is able to reliably deliver data from the user within the required 1-5 m distance from the person of interest

2.6 Tolerance Analysis

The subsystem is primarily limited by the operating requirements of the lithium polymer battery and the voltage regulator ICs.

The LM1085 voltage regulator ICs are rated for a maximum input-output voltage differential of 27V and temperature ranges of -40 to 150C. The uA78Mxx voltage regulator ICs are rated for a maximum input voltage of 35V and temperature ranges of -65 to 150C. From the output voltage of the battery, the maximum voltage differential is unlikely to be a concern given the 12V output of the battery. However, in continuous operation heating, particularly in hot settings with poor airflow, may be a concern. To mitigate this, the IC and battery components of the subsystem will be mounted in a porous enclosure to allow for cooling via airflow.

As a whole, the robot demands a maximum current load of 2.34A. Of this total, 0.15A is drawn from the LIDAR, 0.64A from the DC drive motors, 1.2A from the Raspberry Pi and 0.35A from the stepper motors with the required current for other ICs being negligible.

$$Time\ (hours) = (mAh\ rating)\ /\ (mA\ current)$$
$$1\ h = 2200\ mAh\ /\ 2200\ mA$$
$$0.94\ h = 2200\ mAh\ /\ 2340\ mA$$

The battery selected for this project is rated for a capacity of 2200 mAh with a discharge rate of 50C. This allows the battery to supply a 2.2A current for 1 hour or a maximum of 110A for 1.2 minutes. Thus, at peak current demand of 2.34A, the robot can be expected to remain operational for 56.4 minutes under ideal conditions as detailed in the above calculations. As a whole, the robot remains capable of performing under peak demands for an acceptable period of time. Detailed below are the peak current values of relevant components.

Battery Discharge: 50 C
Battery Capacity: 2200 mAh

LIDAR Current = 0.15A
DC Motor Current = 0.32x2 = 0.64A
RPI Current: 0.5 to 1.2A
Stepper Motor Current = 0.35A
Microcontroller Current = Negligible
Motor Controller Current = Negligible *
Voltage Controller Current = Negligible

* Outputted to controlled motors

3 Ethics & Safety

Regarding the ethical considerations of this project, our team intends to hold ourselves to the highest ethical standards through adherence to the IEEE Code of Ethics. Outlined below are the relevant safety, ethical and regulatory concerns we have identified as well as the means through which we intend to alleviate these issues.

1.) As the power management subsystem only makes use of a single battery while charging intended to not occur during use, the subsystem does not include a battery management system (BMS) circuit. Having discussed the matter with a teaching assistant, the absence of BMS in a single battery system should not pose any issues given the intended discharge-only use of the battery. Thus, to avoid the risk of battery failure or fires, we have designed the robot to require the battery to be charged separately from the rest of the system.

2.) Regarding the user subsystem, we will ensure that only necessary user data is obtained and transmitted. The data, transferred via Bluetooth, shall only be transferred between the user's phone and the robot, shall not be used for any purpose other than the pathfinding of the robot and shall not be retained by any system of the project when not in active use.

3.) We will ensure that our project follows any relevant licensing terms and conditions for all software and parts used in the project.

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