ECE 445

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Project Proposal

Automated Driveway Salt Dispenser

Team 31
Candy Gao
Mayura Kulkarni
Arya Tyagi

1. Introduction

1.1 Problem

Freezing rain and extremely low temperatures during the winter season cause slippery driveways and sidewalks which make it difficult for people to walk and drive. Current methods of dispensing salt in these areas are done manually and are not very efficient. This is because salt is thrown randomly across these areas which results in wastage of salt and sometimes less salt in very icy areas. Also, these methods have safety risks as ice covering these areas makes it harder for people to walk to dispense the salt. It also increases the burden on homeowners to manually salt their driveways.

1.2 Solution

To solve this issue, we want to create a fully autonomous salt dispenser. Our solution would be a self-driving car that would dispense salt evenly across driveways and sidewalks. This would solve the issue of having slippery ice on the sidewalk/driveway when trying to leave your house. Also, by allowing the car to only dispense salt on driveways and sidewalks will help to reduce the amount of salt that is wasted from randomly dispensing salt manually. The dispenser will consist of two main components. The first component is the autonomous steering of the car which will prevent the car from driving out of bounds, such as on the grass or outside of the driveway. Also, the second component is the dispensing of the salt using motors to allow the salt to be spread evenly across the surface.

1.3 Visual Aid

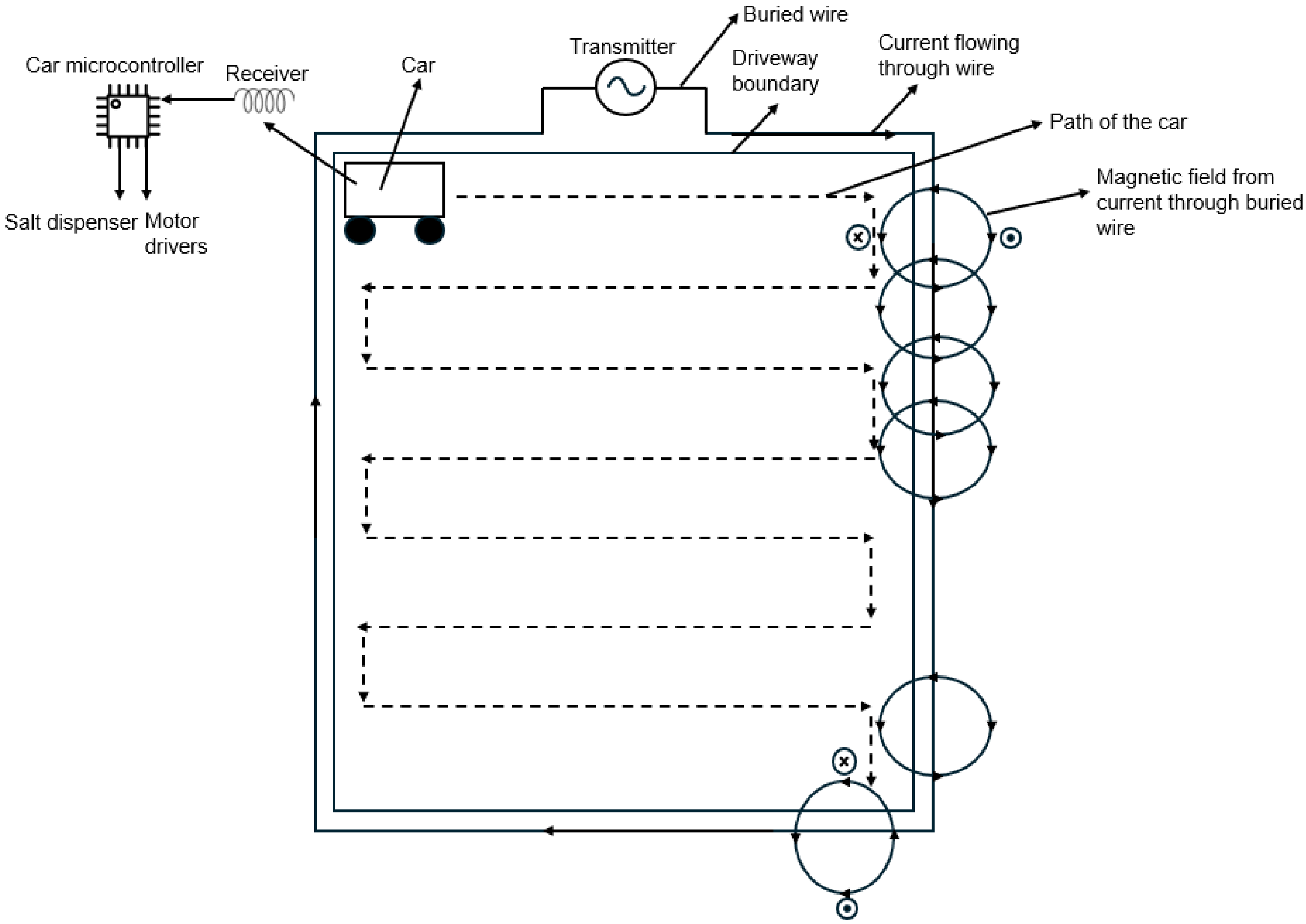


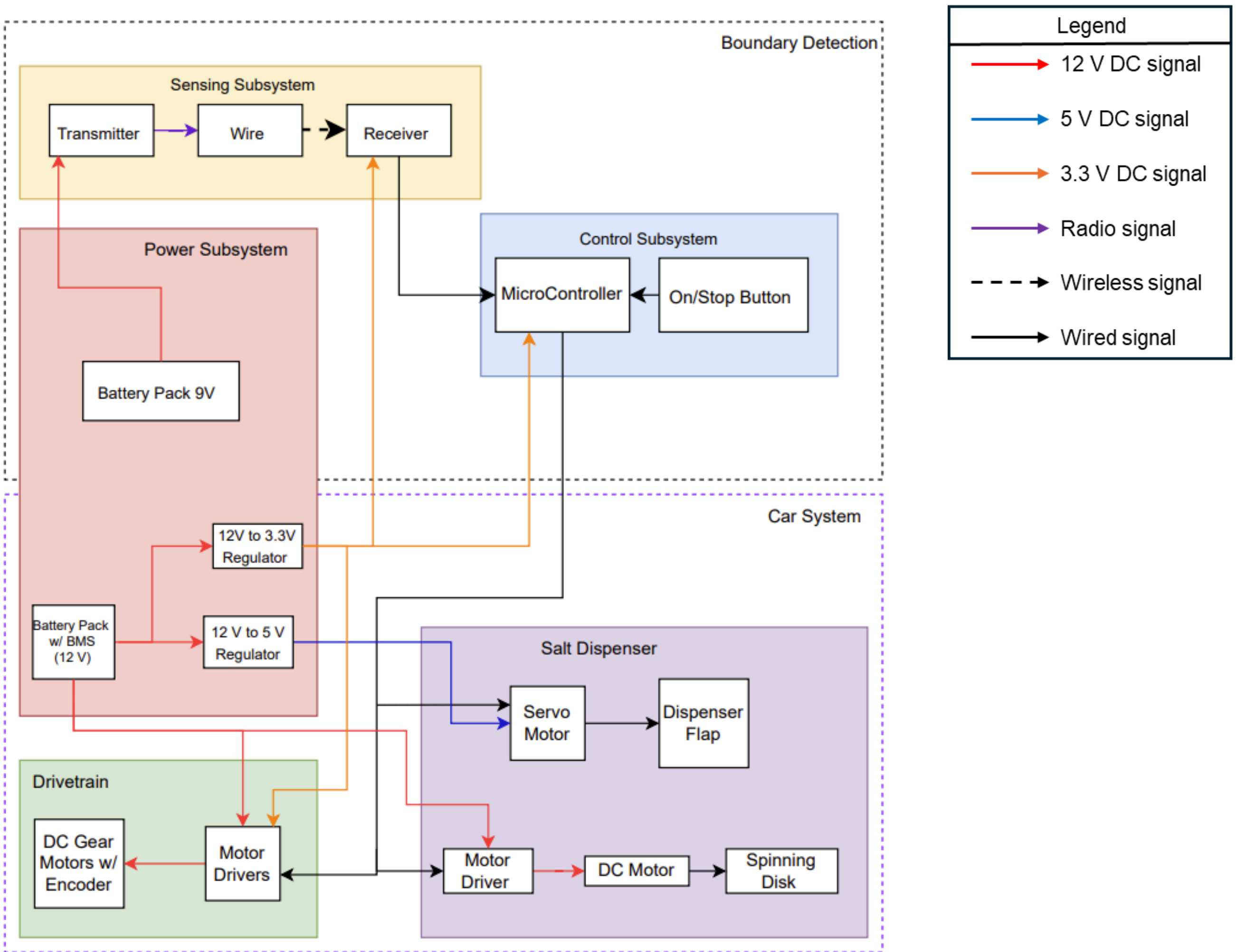
Figure 1: Movement of the car around the driveway and position of wire around the driveway

1.4 High-Level Requirements List

- The robot is able to distribute the salt onto a 2m x 2m driveway in under 10 minutes.
- The robot is able to detect the edge of the driveway within 10 inches of the edge.
- The robot is able to come to a complete stop once it has reached the end of the driveway in under 10 seconds.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview and Requirements

Sensing subsystem:

Overview:
The sensing subsystem will consist of the transmitter, wire, and receiver, which will be placed on the car. The transmitter will consist of an astable multivibrator comparator (TLC555) which will generate an AC signal that will travel through the buried wire. The AC current through the buried wire will create a changing magnetic field throughout the wire. The receiver circuit will have a coiled wire which will induce a voltage once it has come in proximity to the changing magnetic field (buried wire). This voltage signal will then be sent to the ADC input pin of the microcontroller. Upon receiving the signal, the microcontroller will tell the car to turn away from the boundary of the driveway. To ensure that the bipolar voltage signal will be in the range of the unipolar ADC input, a rail splitter circuit is used to create a virtual ground.

Requirements:

1. The transmitter must be able to output a voltage signal that alternates between 0V to 9V
2. The receiver must be able to output a voltage signal that alternates between 0V and 3.3V once it has come within 10 inches of the buried wire.

Power subsystem:

Overview:
The power subsystem will be used to power the sensing subsystem and the car system. The power supply for the sensing subsystem will be used to supply power to the transmitter using a 9V battery pack. The power subsystem will also provide power to the receiver within the sensing subsystem, the microcontroller within the control subsystem, and the motor drivers within the drivetrain subsystem and the salt dispenser subsystem. The system will include another 12 V battery pack and step-down voltage regulators to achieve the correct voltage levels that are required for each of the different subsystems.

Requirements:

1. Must provide a constant supply voltage of 12V ± 10% to the drivetrain, control, and salt dispenser subsystem
2. Must provide a constant supply voltage of 9V ± 10% to the sensing subsystem
3. Voltage regulators must provide a constant supply voltage of 3.3V ± 10% and 5V ± 10%
4. The power subsystem should also switch off once the emergency stop button has been pressed or when the car has finished salting the driveway.

Control subsystem:

Overview:
The control subsystem will consist of the board microcontroller and an on/stop button for the car. Once the button has been pressed, the microcontroller will send an ON signal to start up the salt dispenser and drivetrain subsystem. If the car has reached a boundary, the microcontroller will receive a signal from the car and will then communicate with the drivetrain motors to indicate which direction to turn. The microcontroller will ensure that the car has traveled throughout the entire area of the driveway by stopping only when it has reached two consecutive boundaries of the driveway. Once the car has completed dispensing the salt throughout the driveway or if the on/ off button has been pressed again (in case of an emergency stop), the microcontroller will send an OFF signal to the salt dispenser and drivetrain subsystem.

Requirements:

1. The initial press of the on/off button must start up the car and begin dispensing the salt.
2. The second press of the on/off button must stop the car moving, the spinning disk rotating, and close the dispenser flap on the car.
3. Once the car has completed dispensing the salt throughout the entire area of the driveway, the dispenser flap on the car should close, the car should stop moving, and the spinning disk should stop rotating.

Drivetrain Subsystem:

Overview:
The drivetrain subsystem will consist of the motor driver and two DC gear motors which will each have an encoder and will be attached to the front two wheels of the car. The motor drivers will receive a signal from the microcontroller to determine which way the car should turn. For the car to turn, only one motor will be on depending on the direction of the car turns. For example, if the car turns right, the left wheel will be on while the right wheel will be off. Likewise, if the car turns left, the right wheel will turn on while the left wheel will remain off. The encoders for the DC gear motors will be used for more precise control of the wheels' direction and speed.

Requirements:

1. The wheel motor must be within .01 mph of each other.
2. Once the car reaches the edge, it should turn 90 +/- 5 degrees.
3. Once the car turns 90 degrees, the car should move forward 6 +/- 2 inches before turning 90 degrees again.

Salt dispenser subsystem:

Overview:
The salt dispenser will consist of 2 motor drivers, a servo motor, and a dispenser flap that will be placed at the bottom of the salt dispenser. The motor driver within the salt dispenser subsystem will receive a signal from the microcontroller within the control subsystem when the on/ stop button has been pressed. If the on/ stop button has only been pressed once, the servo motor will open the dispenser flap. If the car has completed dispensing the salt throughout the driveway or if the on/ stop button has been pressed again, the motor drivers will receive a signal from the microcontroller and close the flap using the servo motor. The salt dispenser subsystems will also include the motor driver and DC motor for the spinning disk which will rotate once the car has been switched on.

Requirements:

1. The servo motor for the dispenser flap must rotate about 90 +/- 5 degrees to open or close the flap.
2. The spinning disk must rotate at a constant rate of about 100 RPM once the on/off button has been pressed once.
3. The spinning disk must stop rotating once the salt dispenser has completed dispensing the salt throughout the driveway or the on/off button has been pressed a second time while it is running.

Integration of subsystems:

The power subsystem has 2 main components, a 9V battery pack for the transmitter and a 12V battery pack for the car. The transmitter and the wire will be buried around the driveway. This is what will create a magnetic field that will allow the receiver to detect when it is near the wire. Once the receiver is within range, it will send a signal to the microcontroller through a physical connection on the PCB. The microcontroller has a button that is physically attached that tells the car what state we are in, On or Off. During the ON state, the microcontroller will send a signal to start the drivetrain and salt dispenser subsystem such that the dispenser flap will open and dispenser disk will start spinning and the car will proceed forward. Once the receiver has detected that the wire is within range, the microcontroller will send the proper signals to the drivetrain subsystem allowing the car to turn away from the boundary wire. If the car has reached the end of the driveway or the on/off button has been pressed, the car will switch to the off state. During the off state, the microcontroller will send a signal to the drivetrain subsystem to stop the DC gear motors and stop the car from moving. The microcontroller will also send a signal to the salt dispenser subsystem to stop the dispenser disk from spinning and close the dispenser flap.

2.3 Tolerance Analysis

One of the risks to the successful completion of this project is ensuring that each of the subsystems receives the required power supply voltage for the different components. Within the power subsystem, a 12V battery is used as the input voltage to different voltage regulators. We will use a 12V to 5V converter (BD50FC0FP-E2) to power the servo motor and a 12V to 3.3V converter (AZ1117CD-3.3TRG1) for supplying power to the different motor drivers and microcontroller. To ensure the correct operation, we must meet the dropout voltage given by the regulator. The dropout voltage is the minimum value of the voltage that is required between the voltage input and the voltage output of the voltage regulator (Vin - Vout > Vdropout). The BD50FC0FP-E2 ultra-low quiescent current voltage regulator has a dropout voltage of 200mV. As we are supplying 12V to the voltage regulator, the voltage across the input and the output of the voltage regulator will be 12V - 5V = 7V, which is greater than 200mV and thus satisfies the dropout voltage requirement.

The BD50FC0FP-E2 has an internally set thermal shutdown point of 150°C and operation near this point should be avoided as it will negatively affect the life of the device. To ensure we are well below this threshold, we can calculate the maximum output current we can draw using the power dissipation equation. The maximum power dissipation at any ambient temperature can be given as PMAX = (TJMAX − TA)/θJA where TJMAX is the junction temperature, TA is the surrounding ambient temperature, and θJA is the junction to ambient thermal resistance (given by θJC + θCA). From the datasheet, TJMAX is 150°C and θJA is approximately 20.8°C/W. We can set TA to be around 17 °C since we are assuming our testing will take place around March/April which would be a worst-case scenario since the actual practical use of our project would take place during the winter season. The calculated PMAX = (150 − 17)/20.8 = 6.3942 W. Since the power dissipation across a device is given by : P = IOUT (VIN - VOUT), we can find the maximum IOUT. Therefore, the maximum allowable current for the 12V to 5V regulator used to power the servo motor is about 913.46mA. Also, the AZ1117CD-3.3TRG1 12V to 3.3V regulator has a thermal shutdown point of about 160°C. The value of TJMAX for the AZ1117CD-3.3TRG1 was found to be about 160°C and the value of θJA was found to be about 70°C from the datasheet. Therefore for the 12V to 3.3V regulator used to power the motor drivers and the microcontroller, the maximum allowable current is 234.81mA.

Another risk to the successful completion of this project is ensuring that the required torque provided by the DC gear motors for the front two wheels of the car is enough to move the car including the salt dispenser at the required speed of 80 rpm. Assuming the weight of the salt and the car is distributed evenly across the the two wheels, the torque required for each wheel can be calculated by the equation T = F*r, where ‘T,’ is the torque, ‘F,’ is the force, and ‘r,’ is the radius of the wheel, which is 3 inches, or 0.0762 meters. The force of the car is found by the equation, F = m*a, where 'm,' is the mass of the car in lbs, and 'a,' is the acceleration of the car. The mass of the car was assumed to be 11 lbs in total, with 10 lbs composing the weight of the base of the car and the salt dispenser, and 1 pound composing the salt. Therefore, the amount of weight carried by each wheel if evenly distributed would be equal to 5.5 lbs. The acceleration of the car was found by the velocity divided by the amount of time it should take the car to stop. The velocity of the car is calculated by (80 rpm)(2*pi*r). The amount of time the car will take to stop was assumed to be ten seconds. Therefore, the acceleration of the car was calculated to be equal to (80 rpm)(2*pi*(3 in))/(10 seconds) = 0.063 m/s^2. The force was then calculated to be F = (5.5 lbs)(0.063 m/s^2), which when converted to kg*m/s^2, resulted in 0.15687 kg*m/s^2, or 0.15687 N. Thus, the torque was calculated to be T = F*r = (0.15687 N)(0.0762 m) = 0.012 N*m, or 0.122 kg*cm. The rated torque of the 80 RPM gearmotor is about 1.6 kg*cm. Therefore, the torque required to move the car is less than the rated torque of the gearmotor which ensures that the motor will be able to support the specifications of the car.

3. Ethics and Safety

Ethical Issues:

As outlined in the IEEE Code of Ethics II, we strive to create a fair and non-discriminatory working environment throughout the entirety of the project development. To achieve this, all work will be distributed evenly and fairly and all members will be expected to treat each other and any mentor TA and Professor with respect. In addition, according to IEEE Code of Ethics I.1 and I.5, we will take in any feedback and practice proper testing procedures to produce honest and accurate results to ensure the functionality of the device and address any safety concerns.

Safety Issues:

One possible safety concern that may arise is the exposure of electrical components. This device is intended to work during the winter season, we will need to ensure that all electrical components are properly secured on the car and protected from any possible water damage. One way to accomplish this is by creating a small 3D-printed enclosure to conceal everything. In addition, as we will be using batteries as power supply

Even though the car will be autonomous and should stop once it has covered the entire driveway, we also have to consider the case where the car fails to respond to the boundaries and goes out of control. We plan on adding a stop button on the car that will allow the user to manually stop the car.

Another safety concern for the demo and the practical use of the salt dispenser car is if there are obstructions within the driveway that may be in the path of the car which could result in damage to the car or to the obstacle. These obstructions include people, electrical wires, trash, or debris. To ensure that the car will not be impacted by the obstacles, the wire will be placed to surround an area that is clear of any obstructions. The emergency stop button can also be pressed manually if there is an obstacle in the path of the car.