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Remote Soil Monitoring Robot

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Abstract—**With the Remote Soil Monitoring Robot (RSMR), the future of farming will be effortlessly water efficient. We aim to create a robot to better determine hot spots for inefficient water usage on farmland and gather meaningful data for water conservation. The robot will do so by traversing the farmland and probing the soil for moisture content and communicating this data to a mobile application through Bluetooth. As of the 2019 Fall Quarter, we have assembled our robot to traverse with varying speeds to mimic actual use. We have completed integration of basic probing mechanisms with the actuator design. This quarter we have achieved basic hardware construction of our robot.**

Index Terms—**Remote Soil Monitoring Robot (RSMR), Soil Moisture Content, Pulse Width Modulation (PWM)**

I. INTRODUCTION

AGRICULTURE, according to the Food and Agriculture Organization of the United Nations (FAO) , accounts for 70 percent of the global freshwater withdrawals and most of it is wasteful use [2]. The increase in population and food production over the last few decades has caused detrimental water usage. Good soil management and structure leads to water conservation and soil efficiency. Our robot will traverse farmland based on user inputted dimensions on our Android mobile application. The robot will then probe and gather sensor data for moisture content of soil to provide a choropleth map and suggest where water can be conserved. We aim to promote sustainable environmental development by creating a faster way to collect and gather meaningful data for water conservation. By using data driven technology, tools like this will be able to assist farmers to optimize their yield, minimize input costs, and reduce environmental impact on crop growth [1].

Prior approaches to achieve a tool that can provide moisture data was to simply create a stationary probe that required manual relocation. This method proved to be time consuming and lacked efficiency and consistency because it required the farmer to traverse a farmland with sizes that can differ greatly. The current method we decided upon is to have a robot to do the traversing with accurate increments and storage of data. The probing mechanism required different approaches as well. We originally approached this mechanism with a drop-down arm mechanism to pierce the soil with the probe itself. This motion proved to be harmful to the probe because it was a rougher, inconsistent, and more sudden way to pierce soil that could be denser. The varying consistencies of soil can lead to hardware damage. To prevent breaking the probe, we decided to approach this issue by implementing a less invasive and more careful insertion method that did not rely on gravity as the driving force by placing it underneath the robot and using an actuator mechanism that rely on the torque of the wheels.

II. HIGH-LEVEL HARDWARE AND SOFTWARE

In the design of the RSMR our goal as a group was to integrate various hardware components in order to construct a robot that can effectively gather the soil data over our test area. In going through the engineering design process, we refined the initial details of our project to align with what could be economically and socially viable. This quarter our focus has been on learning how these hardware components work individually and mapping how they can be added to our robot.

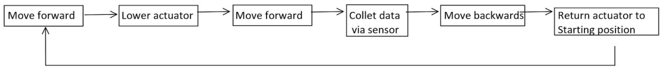

Fig. 1. Flowchart for robot in the field

The current code is for the motors, sensors, and Bluetooth module. The motors dictate the direction, while the sensors collect data about the soil; while the robot is in the field, these two will be used the most, as shown by the field flowchart. Once the robot is back at the home base, it will connect to the user's phone and send the data collected by the sensor.

A. RC Car Assembly

Through this quarter we have working on continuously refining the design of the robot based on the purpose that it served for the project. During our first phase of development we opted to make the robot itself rather than buying a prebuilt RC car that we could attach the various hardware components. Mainly for the interest of having free range in how our robot can be built with flexibility of the placement and wiring of the other parts. The CAD model below shows the design of the robot.

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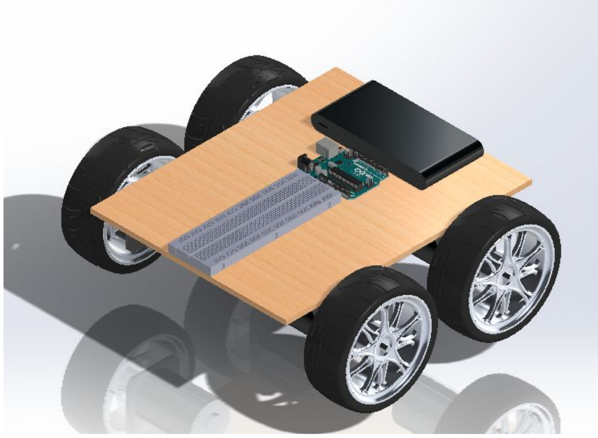

Fig. 2. Robot CAD

Materials included for assembling the robot and other parts of the robot for senor integration include: Arduino Uno, Duratrax Performance Racing Tires, 4 3000RPM DC Motors, Motor Driver Controller, Breadboard, Jumper Wires, Battery Holder Case and 12V Batteries, Wood Panels, Bracket Holder. We first started our assembly by using PWM (pulse width modulation) to lower/increase speed as desired for when we probe and traverse, described later in the report. From there we worked on attaching the wheels to the motor shaft, and the motor to the wood panels with additional drilling to the tires and bracket holders. As per our reasoning for creating our own RC car the wiring was much more simplistic more connecting the motors, through the breadboard/Arduino Uno to power. The diagram below shows a schematic of the wiring for the motors with the Arduino Uno, 4 3000RPM DC Motors, Motor Driver Controller, Moisture sensor, and HC-05 Bluetooth Module.

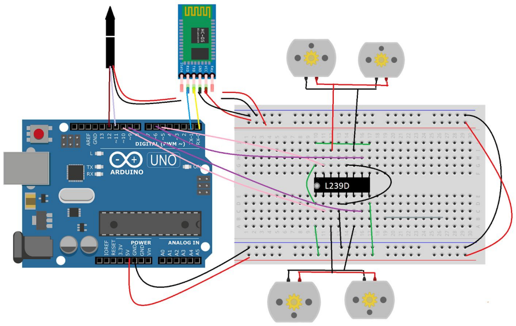

Fig. 3. Robot Schematic

B. *Soil Sensors*

Regarding the sensors themselves we had initial background research on what sensors would effectively provide information on water levels of a given soil sample, on the basis that its cost effective for probe construction. We refined from using a multi-sensor approach to strictly focusing on a moisture and temperature sensor. These sensors can provide the most translative data on water levels. Below show the main sensors for our robot including the moisture and temperature sensor with additional materials for implementation provided through the Arduino Rural Hack Kit.

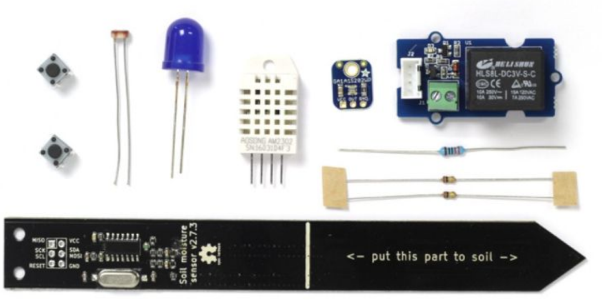

Fig. 4. Sensor Supplies

C. *Bluetooth Module*

The Bluetooth module was added as an addition to the RSMR as a way to facilitate communication between the data collected from the sensors and a mobile application. In adding the HC-05 Bluetooth module to the Arduino board, the wiring follows Figure 3.

III. METHODS

A. *Motors*

The motors are connected to a motor driver, which determines what direction the robot will move-- forward, backward, left, or right. As seen in Figure 5, the motors are connected in pairs to the driver; the positive terminals of two motors are connected to one motor driver output, while their negative terminals are connected to another motor driver output. The respective inputs are connected to the Arduino; when the input gets a high signal, then the output will turn “on”, and the motor will turn.

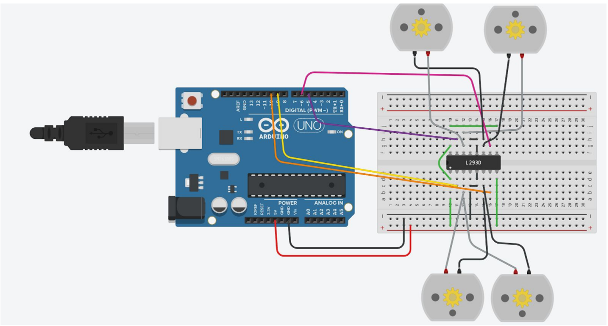

Fig. 5. Sensor Supplies

Our directional motion is implemented using pulse width modulation (PWM) via Arduino’s analogWrite function. PWM is a technique that changes the pulse width of a signal, resulting in a lower current; in our case, this results in a lower RPM. Using a lower speed will reduce the potential for damage while we move during probe insertion because there will be less force on the sensor as it enters the soil.

B. Bluetooth Module

We're using an HC-05 Bluetooth module to communicate our sensor data from our robot to our phones. Using a Bluetooth module uses less power and can send and retrieve information in a short range; since we only needed data to be transferred while the robot is back base, it made more sense to choose Bluetooth over WIFI.

In our code, we first open the serial port and set the data rate to 9600, in accordance with the HC-05 module. Our code loops with the following: if there are any bytes available for reading for the serial port, then proceed to read and print to the phone. One issue we ran into was that we were struggling to upload our code while our Bluetooth module was fully wired. We later learned that our TX/RX pins (the digital pins 1 and 0) needed to be disconnected during the uploading process, because it was also sending an additional voltage to the device. In our current stage, we can send data that can turn and LED on/off from an Android and print out a message on a Bluetooth terminal on our phone. Future modifications to the code will include receiving sensor readings in an easy to process format, such as a JSON string.

C. Sensors

The sensor used can measure soil moisture capacitance, temperature, and light levels. Our code is based on the I2C Soil Moisture Sensor library provided by Miceuz, the manufacturer of the sensor being used. Light readings can be interpreted in the range of 0 to 65565, where 0 is the lightest, and 65565 is the darkest; it is also worth noting that it takes more time to get a value in lower light environments. While we don't plan on using this reading in future stages of our project, the light readings were able to show us that our sensor was wired correctly and working. The temperature measurement reports data in Celsius; this number may be converted in future versions of our project to line up with the imperial system. The moisture capacitance measurements will give a higher reading in soil with a higher moisture content. Our base value is expected to be around 200-300 when the sensor is not in the soil [3].

Once we can get more accurate readings in various soils, the next step will be to send the data collected by the sensor to the Bluetooth module. One future challenge will be making sure we don't go over the Bluetooth buffer limit of 64 bytes; to circumvent this, we may store the data elsewhere, and then send the data in batches over Bluetooth.

D. Actuator

In designing the probing motion of the robot, there were various factors to consider such as how forceful the motion of the actuator probing should be based on the fragility of the sensors. In the beginning phases of our design process we relied on the sensors being probed into the soil based on a drop-down arm driven by the force of gravity. Through further testing, the sensors are at risk for possible long-term damages. Therefore, an actuator was a necessary hardware component to aid in a more calculated and less invasive insertion method. The actuator facilitates in creating "accurate, repeatable performance[s] of pushing/pulling" [4]. The prototype of our actuator is based on the motion of a dump truck. This quarter we have made a prototype of this model with the use of a mini Servo. We constructed an initial prototype to test the design that is placed underneath the robot. The mechanism will mimic that of the dump truck by replacing the dump body with the sensor and recreating the hoisting motion to lower it closer to the soil. This angle will allow us to be at an optimal position to insert without risk of damaging the sensor. The wheels will then move forward to allow steady force to pierce the soil.

E. Future Code Implementation

We plan on making an android compatible app that can communicate with our Arduino Uno. Using the app, the user can send field dimensions to the robot, receive sensor data, and see a mapping of moisture concentrations of the field.

IV. RESULTS AND PERFORMANCE

A. Motors

This quarter, we were able to get the motors to move our robot using PWM and analogWrite. Because we have the robot wired to send high power to both terminals, it's possible to move forward and backwards. To stop, we simply set analogWrite to 0, which results in a pulse width of 0; the short pulse width results in a low current being sent to the motor, resulting in no movement.

B. Sensor

In working with this kit, the wiring follows the Figure 3 schematic above. We worked this quarter on soldering the wiring for the moisture sensor and testing the sensors for accurate data collection. In purchasing these sensors, we had to take into account the testing conditions that the sensors had to work with, and these sensors seemed as the most viable option with the robot we are constructing.

C. Bluetooth Module

This quarter we've focused on having the Bluetooth module be able to communicate information between a smartphone mobile application and the Arduino board with simple LED tests to test its capabilities in our project. The coming quarter our focus will be on translating the sensor data collected on a mobile application that can remotely display this data with informative graphics and water saving strategies.

V. MATERIALS USED

In the beginning phase of our project, we allocated time to choosing materials that more effectively work to the purpose of our project. These materials abide by the constraints of the project itself and altered based on challenges that we faced throughout the quarter. Below show the materials used as far in the construction of the robot, Bluetooth module, soil sensors, and actuator.

TABLE I
MATERIALS USED

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

[a]Gaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

VI. CONCLUSION

The robot developed so far was tested to traverse firm, soft soil to be the basis for our soil texture to be tested. Given this parameter, wheel speed and torque were adjusted accordingly by using pulse width modulation to optimize traversal time and controlled force to assist the probing mechanism. Our robot can be separated into three different modules: wheels/motors, actuator, and Bluetooth. Each of these modules were tested for Arduino integration and successful results were obtained. Our motors were able to run at the speed and increment specified. Moving forward, these specifications will have to be read from our Android mobile application user input. Our actuator can move the probe and perform basic mechanisms. If time permits, we would like to recreate this mechanism but with better quality materials. The Bluetooth module provided satisfactory results as a separate implementation. We are still in the process to integrate it with the sensor data and the communication of it.

The system implemented uses an Arduino Uno with the 3000 RPM DC motors, HC-05 Bluetooth module, and I2C Soil Moisture Sensor. Hardware designs for traversal and sensor designs for moisture have been successfully implemented. Continued assembly and implementation of Bluetooth for mobile application communication and data storage is underway for 2020 Winter Quarter.

APPENDIX

A. Technical Standards

Our project is heavily based on the usage of the Arduino and its functionalities. The Arduino Developer standardization is very helpful to our project as the main components are to be modules that must be individually controllable through the Arduino itself. The motors, sensor probe, and the Bluetooth module all rely on the integration of the Arduino to create a cohesive product. Since we were able to connect all three individual modules together on one breadboard, it was integral that we had one source to easily keep track of and develop our software. We chose the Arduino Developer standardization because two of the three tools we are using were built to best integrate with the Arduino. The HC-05 Bluetooth module and the IC2 Soil Moisture Sensor were built to be used with single board computers like the Arduino. By using the Arduino Developer standardization, we were also able to keep our software consistent.

The hardware limitations of the Arduino require specific pins/ports to be declared in the same standard throughout the program despite using three different modules. Although we were physically limited to how many pins/ports we were able to use given the Arduino size we picked, using the Arduino Developer standardization allowed us to optimize and better plan out the layout of the robot and its hardware. Our design follows the Arduino Developer standardization because without doing so, the hardware of the Arduino itself would not be able to comply with what we are asking of the modules. The standardization requires explicit declaration of which physical port we are reserving to do a specific task. Due to these requirements, we must comply with the standardization in order to properly sync the modules to the Arduino.

B. Constraints

With the multitude of hardware and software aspects to our project, there was a large sum of time spent on refining our project details and capabilities based on various constraints we were met with during the design process. To start, in terms of cost constraints since our initial idea was based on gathering various soil measurements, there was a constraint on how much realistically we could spend with high cost sensors, and how valuable the information collected will be. We worked around this problem by taking a more holistic approach of what we want our robot to do, and especially with the current concerns of drought and water conservation in the agricultural sector it seemed much more feasible to shift the focus to be water conservation centered. As a result, we opted for using the moisture sensor as our main avenue of data collected. In reaching this decision we dedicated a great deal of time on researching this topic for more perspective on what type of data our software will handle.

Another major constraint that in terms of our robot construction, was based on the CAD model, understanding how our actuator should move while not interfering with the sensors or consuming too much power. This gave an understanding of other factors to consider such as: power capacity, weight of the materials, and range of movement. In understanding the time that we had to dedicate to the actuator itself, it became very apparent that building our own RC Car would give more room for construction and range of movement, especially for the purpose of our robot. In making this decision it was easier to envision how the actuator would be built. In creating the prototype of the actuator based on the dump truck actuator as well there was a much more realistic and safer approach to handling the probing mechanism. In solving this constraint, we were able to become aware of other concerns we may have in range of movement and how are robot can traverse the soil, considering the delicate nature of the sensors itself.

C. Security Issues

The main vulnerability stems from the Bluetooth module. This can be reduced by minimizing Bluetooth use-- limiting it to only the beginning and the end. When users connect to the robot via Bluetooth, they'll also have to input a password. Additionally, the HC-05 module we chose also follows the IEEE 802.15.1 standardized protocol, which has compliancy for MAC and physical layer. The MAC layer handle data packets moving from one Network Interface Card to another on a shared channel; the physical layer is for bit level transmission between different devices. Both these layers are vital for communications; following a protocol ensures security, which minimizes potential tampering.

Acknowledgment

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