The Plant Planting Planter

Group D

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Figure 1: The Plant Planting Planter robot.

Motivation

Pollinators like bees, hummingbirds, and butterflies are some of the many cornerstones that support Earth's diverse variety of ecosystems and agriculture [1]. As humanity's population has grown, so has its physical footprint, taking valuable space away from these critical fauna. This project aims to ameliorate some of the issues that these animals are facing by increasing the opportunities that they have for reproduction and migration through the creation of small to medium-sized floral gardens. Our small robot is capable of traversing different types of terrain to plant multiple kinds of wildflower seeds. Its semi-autonomous nature allow it to complete its tasks without without any user input. Our ideal goal for this project is to deploy multiple *PPP* robots in a community where they would be able to navigate locally and plant wildflowers throughout the community to attract pollinators.

The Product

With the goal of creating small to medium sized gardens set, the next step was to determine what type of system would be able to perform this task efficiently. We decided upon a four-wheeled robot, with two drive wheels at the front and two caster wheels at the rear. We chose this design for its ability to traverse dirt and mud, modularity with respect to the type and amount of seeds it can carry, and low cost due to the myriad of manufacturing methods available for producing this common type of robot.

Two high-torque DC motors position the robot by rotating in unison for linear movements, and rotating deferentially for turns. The planting mechanism then releases a predetermined amount of nutrient rich soil packed with a variety of local flora. The robot then moves into place for the soil to be probed with a moisture sensor. Once the moisture content of the soil is known, the robot aligns itself to dispense water on the soil in accordance with the moisture content measurement. An early concept of a system of this type that could perform these actions is shown in Figure 2.

Mechanical Design

Chassis and Drive System

For the chassis, laser-cut planar panels of 1/4in plywood were selected. 1/4in plywood has a great balance of low cost and, when oriented appropriately, high stiffness. The panels were designed with tabs and slots so that they could be locked together in the correct place while the joints are bonded with wood glue.

The front drive motors bolt to the chassis and the output shaft goes through a hole in the panel they mount to and attach to the wheels via a 12mm hex drive. The rear caster wheels were specified at such a height that no additional structure needed to be designed in order for them to mount to the chassis.

Soil and Seed Dispenser

An activated drawer mechanism was designed to dispense a mixture of seeds and soil. This dispenser consist of a cylindrical reservoir with the capacity to store the 0.6 m^3 of soil and seeds; this is sufficient to dispense 9 drops in the 3×3 grid. The volume of the drawer allows the robot to maintain the amount of soil dropped consistent throughout each cycle. This drawer is linearly activated with the use of a stepper motor which delivers enough torque to combat the frictional forces induced by the shearing of the soil. Once the drawer is moved to its activated position, a small lid opens up with the aid of gravitational forces to allow the contents of the drawer to fall to the desired location. The drawer returns to its initial configuration and its contents are replenished by the cylindrical reservoir. The inner workings of the soil dispenser are shown in Figure 5.

Probing Mechanism

We designed the probing mechanism around a rack and pinion, allowing us to insert the probe into the soil at an appropriate depth as well as retract the probe for storage. In order to precisely control the probe depth, we used a stepper motor for its position control. Our rack was made of very flexible acetal plastic, making it difficult to properly probe the soil. Thus, we reinforced the rack by surrounding it with a wooden sheath, increasing the stiffness and making it easier to probe. We designed a track for the rack in order to secure it and limit it to one degree of freedom.

Based on figures of soil strength and our probe's area, we calculated that we would need to deliver a 3 N force to the probe to break the soil. Given our gear's pitch diameter, we determined that our stepper motor would need to deliver 0.015 Nm of torque, which it meets.

Watering System

To water the plants, a gravity fed watering system was implemented using a 2L bottle mounted to the chassis using a laser cut structure. A PLA bottle cap and nozzle was 3D printed along with a TPU gasket to seal the cap. A combination of polyethylene and silicone tubing was used to route the water (Fig. 4a). The system had a 0-300Pa working pressure, well within the NC solenoid valve's specifications.

Electrical Design

A three-cell lithium-ion battery with a nominal voltage of 11.1V was used to power the robot. The DC drive motors, and probing and planting stepper motors use the battery directly as shown in Figure 7. In order to power the microcontroller and other logic circuits on the robot, the battery voltage is regulated to 5V. An STM NUCLEO F446RE was the microcontroller of choice for this project due to its low cost and abundance of GPIO pins.

A pair of 16 step-per-revolution encoders are mounted on the auxiliary shaft of the DC gear motors and produce a total resolution of about 14,000 steps-per-wheel-revolution. A Cytron 10A dual-channel motor driver receives PWM signals from a PID controller run on the microcontroller at 1000Hz.

The planting and probing stepper motors are run by the MP6500 stepper motor driver, which receives a PWM signal from the microcontroller, where each rise of the signal correspeonds to a step.

Software

The NUCLEO microcontroller was programmed using C++ with the MBED software development kit. Each action the robot is required to perform is encoded in a vector that is then iterated through during operation. These vectors contain the flags that set the state during each action. When one action is complete, the robot moves onto the next action and thus states, as seen in Figure 8.

Limit switches monitor the complete actuation of the soil dispenser and probing mechanism, and a timer monitors the completion of linear and rotational moves. If the limit switches are not met at the correct time, or the robot takes significantly longer than estimated to reach a given position, the robot will go to the error state and wait for the problem to be resolved.

Lessons Learned & Advice for Future Students

One issue that arose during testing was the lack of grip the drive wheels have on wet dirt, leaves, and rocky terrain. We purposefully selected inexpensive wheels knowing this may be an issue, but could have resolved it through the use of wheels with deeper tread and a larger outer diameter.

Bill of Materials

Description	Manufacturer	Qty.	Cost per part	Total
1432kc [fried]	Amazon	1	$18.95	$18.95
DC 12V Motors [design change]	Amazon	2	$14.02	$28.04
Power Wire	Amazon	1	$5.98	$5.98
JST-XH connectors and crimper	Amazon	1	$39.99	$39.99
Ribbon Wire	Amazon	1	$7.99	$7.99
xt60 Connectors	Amazon	1	$8.99	$8.99
Pin Headers	Amazon	1	$6.75	$6.75
Motor Driver	Amazon	1	$25.80	$25.80
Wire Clips	Amazon	1	$9.59	$9.59
Cable Glands	Amazon	1	$7.99	$7.99
Zip Ties	Amazon	1	$4.99	$4.99
Power Wire	Amazon	1	$8.38	$8.38
Wire Sleeve	Amazon	1	$9.99	$9.99
Green Led Button	Amazon	1	$9.45	$9.45
Enclosure	Amazon	1	$14.99	$14.99
DC Motors	Amazon	2	$13.76	$27.52
f446re	Amazon	1	$22.95	$22.95
Wheel Adapters	Amazon	1	$12.98	$12.98
Caster Wheels	Amazon	1	$17.62	$17.62
Front Wheels	Amazon	1	$13.99	$13.99
Proto Shield	Amazon	1	$7.39	$7.39
Standoffs	Amazon	1	$8.99	$8.99
Check Valve	Amazon	1	$10.91	$10.91
Fasteners	Ace Hardware	1	$2.00	$2.00
Hole Saw	Ace Hardware	1	$6.00	$6.00
Heat Shrink	Ace Hardware	1	$15.00	$15.00
Wood Glue	Ace Hardware	1	$6.00	$6.00
Zip Ties	Ace Hardware	1	$10.00	$10.00
Hardware and Velcro	Ace Hardware	1	$15.00	$15.00
Hardware	Ace Hardware	1	$20.00	$20.00
Limit Switches	Amazon	2	$1.58	$3.16
5mm Dowel Pins	Amazon	2	$0.11	$0.23
Stepper Motor Mounts	Amazon	2	$3.66	$7.33
Stainless Steel Screws and Nuts	Amazon	80	$0.07	$5.26
Timing Belt and Bearings	Amazon	1	$14.99	$14.99
Ball Bearings	Amazon	150	$0.02	$3.29
Stepper Motor	Amazon	1	$13.99	$13.99
Filament	Amazon	0.4	$16.99	$6.80
Pipe	Amazon	2	$1.85	$1.85
Acrylic	Jacobs Material Store	1	$3.00	$3.00
Plywood	Jacobs Material Store	1	$54.79	$54.79
DRV8834 Motor Driver	Pololu	1	$5.95	$5.95
Stepper Motor	Pololu	1	$17.95	$17.95
Gear Rack	McMaster-Carr	1	$3.69	$3.69
Gear	McMaster-Carr	1	$2.46	$2.46
Gravity Moisture Sensor	DFRobot	1	$5.85	$5.85
			TOTAL	**$528.61**

Table 1: This list includes all parts purchased in the process of designing, prototyping and manufacturing the final product. Components that were not included in the final product are shown in red.

Figures

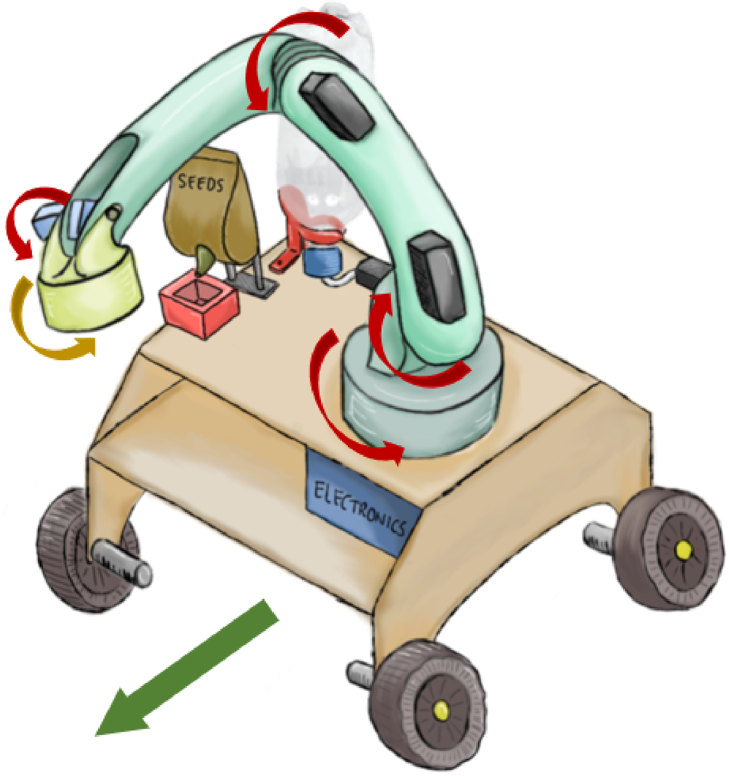
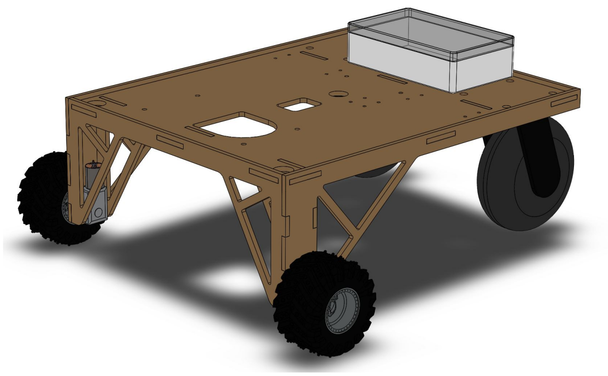


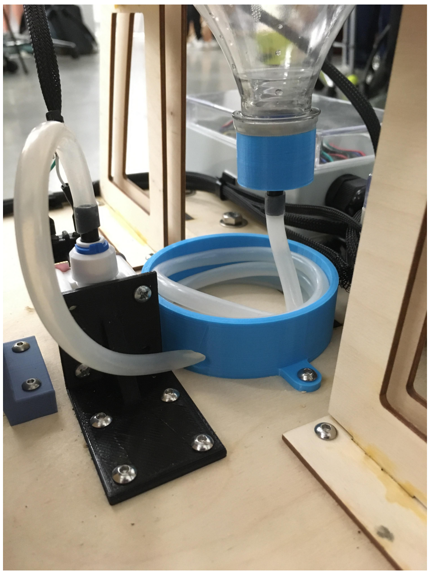
Figure 2: Early concept of the robot.

(a) Physical System

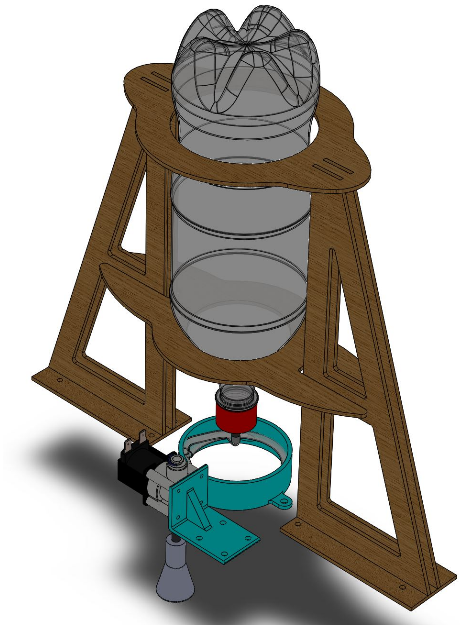


(b) CAD

Figure 3: Chassis and Drive Mechanism



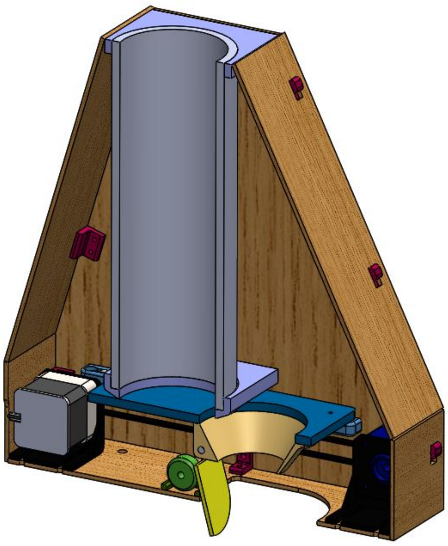
(a) Physical System



(b) CAD

Figure 4: Watering Mechanism

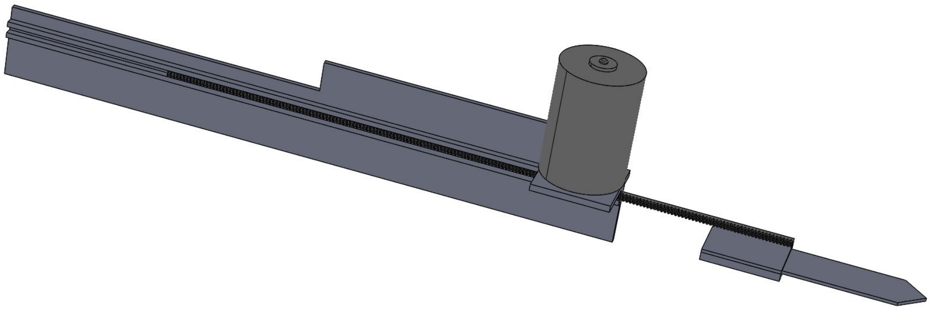
(a) Physical System



(b) CAD

Figure 5: Soil and Seed Dispensing Mechanism

(a) Physical System



(b) CAD

Figure 6: Probing Mechanism

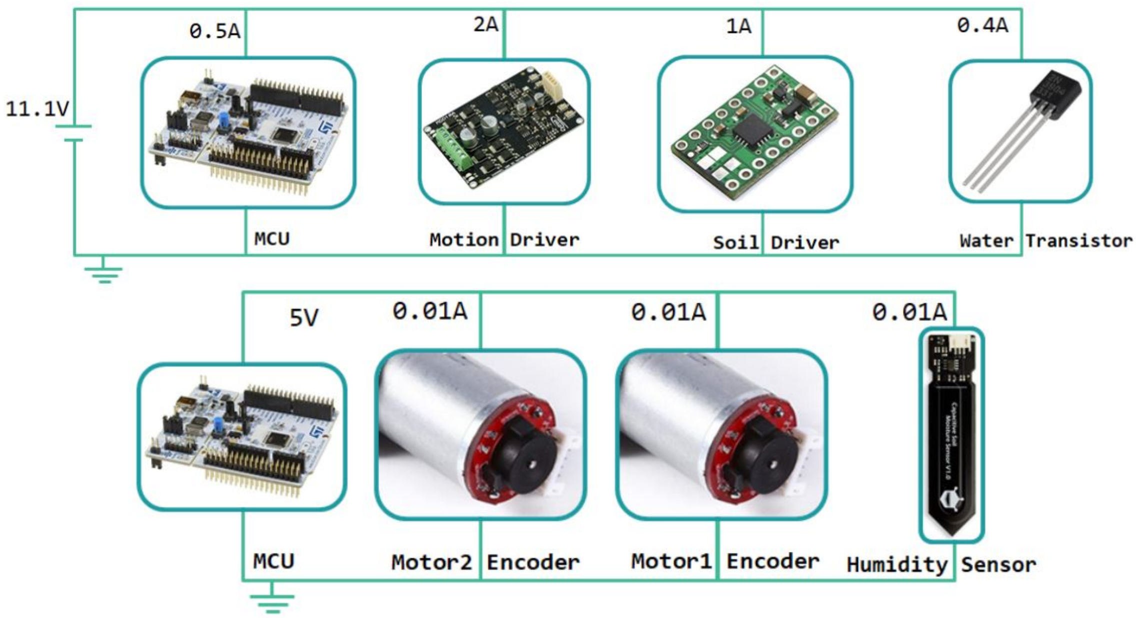


Figure 7: Electrical Diagram

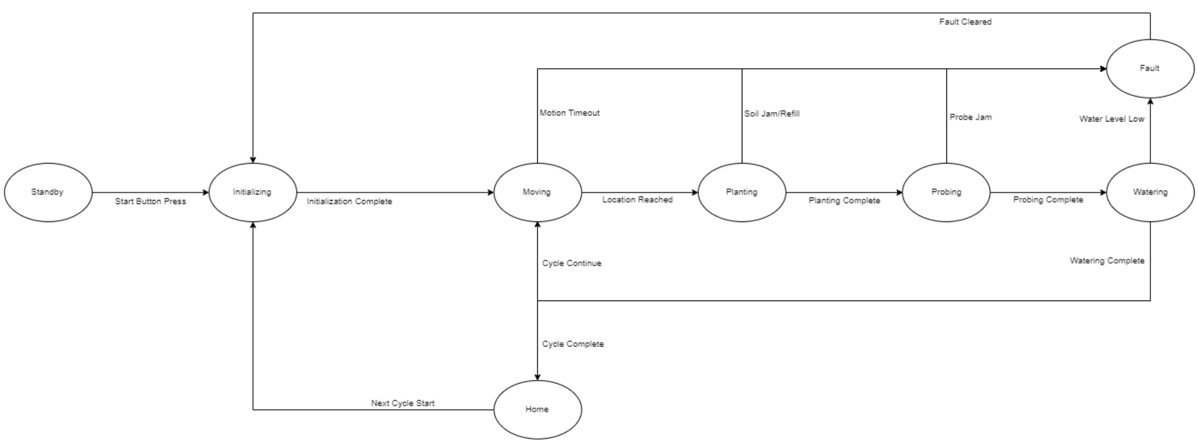


Figure 8: State Diagram

Bibliography

[1] What are pollinators and why do we need them? *Center for Pollinator Research (Penn State University).*