Smart Sprinkler Robot System

Project Proposal

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Introduction

1.1 Statement of Purpose

The project that we are doing is the Smart Sprinkler Robot System. We chose to do this project because we wanted a cost effective way for people to save money when they water their lawn. When someone uses a traditional sprinkler, it is difficult to monitor the amount of water being used which leads to a lot of waste. For installed sprinkler systems, they have the capability to efficiently water your lawn, but the installation is quite expensive. Our project combines the flexibility of a traditional sprinkler with the water savings of an installation sprinkler. We are excited about this project because this is an area of the market that is underdeveloped. It will also test our skills from many different areas of Electrical Engineering to put together this product.

1.2 Objectives

1.2.1 Goals

The overall goal of this project is to design a robot system that will determine when a lawn needs to be watered and how much it needs to be watered. Below are the sub-goals that will make this possible:

- A wireless communication system must first be built between the robot and base station
- A GPS unit will need to determine where the robot is and where it needs to go
- The different robot modules need to be powered by the correct voltage to prevent damage to components
- A communication network between the internet and base station needs to be made to predict if watering needs to occur based on weather forecasts
- A moisture probe needs to be able to measure the amount of water in the ground to determine if an area needs watering

1.2.2 Functions

All sub-goals will be done by combining data for rain forecasts with measurements of lawn soil moisture done by an autonomous robot. After it has been determined that an area of the lawn needs watering, the robot will water the area using a sprinkler that is attached to the top of it. The robot will continue to measure areas of the lawn and water as needed until the entire lawn is finished. The robot will then return back to the base station where it will wait until it is sent out again to measure and water.

1.2.3 Benefits

- Reduces the amount of water wasted from watering
- Can be easily moved and set up at a new location
- Does not require user command to water (automatic system)
- Saves on the time it takes for someone to water (all automatic)

1.2.4 Features

- Records and stores soil moisture data from different lawn areas
- Gathers weather forecasts to predict when watering will be needed
- Innovative wheel design to prevent damage to the lawn
- Determines when the optimal time of day for watering based on moisture in air
- Wireless communication between robot and base station
- 360° sprinkler watering pattern
- Two-point-probe soil moisture measurement device
- Retractable garden hose to prevent tangling

Design

2.1 Block Diagrams

Figure 1. Top Level System Layout

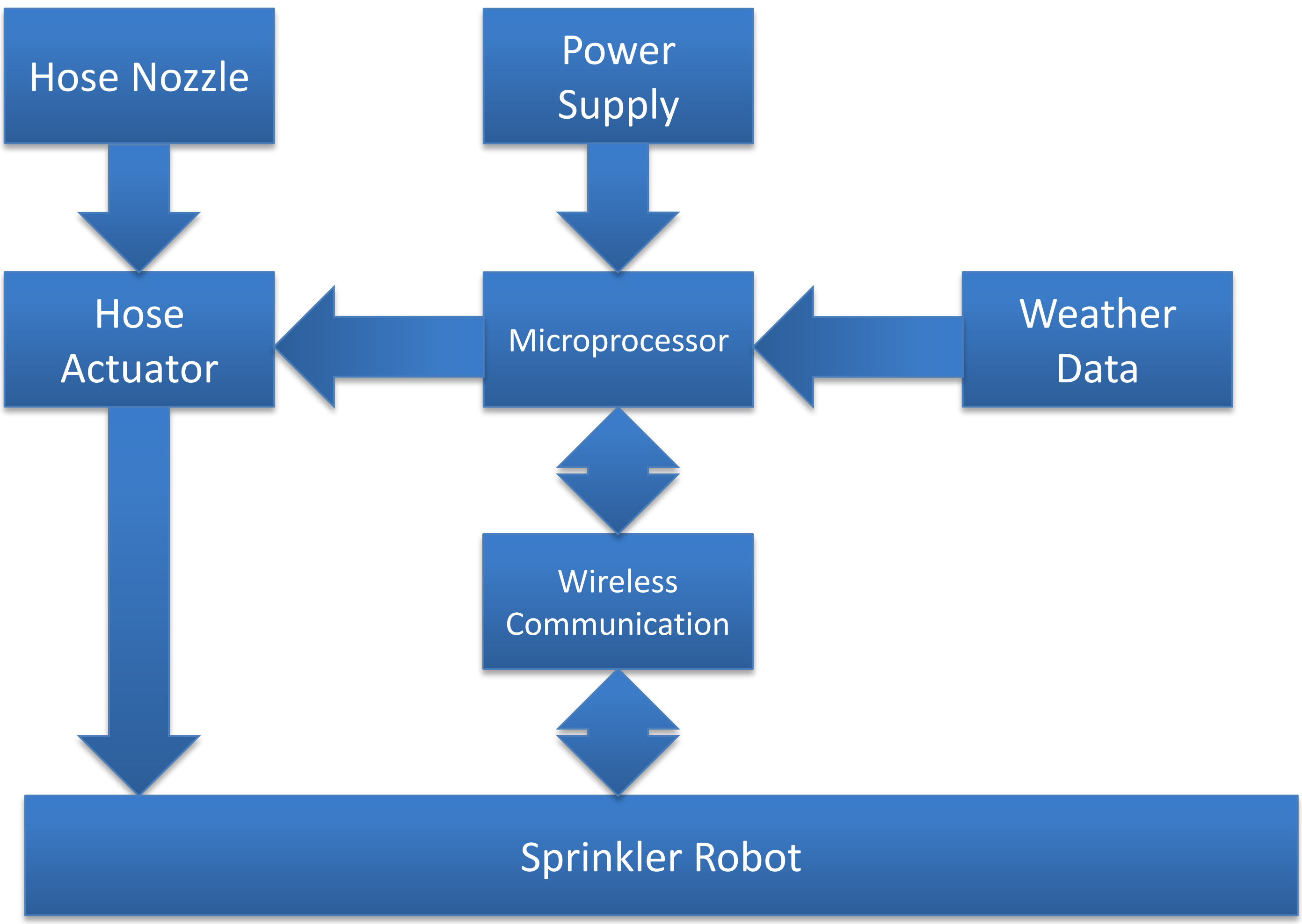

Figure 2. Base Station Module Block Diagram

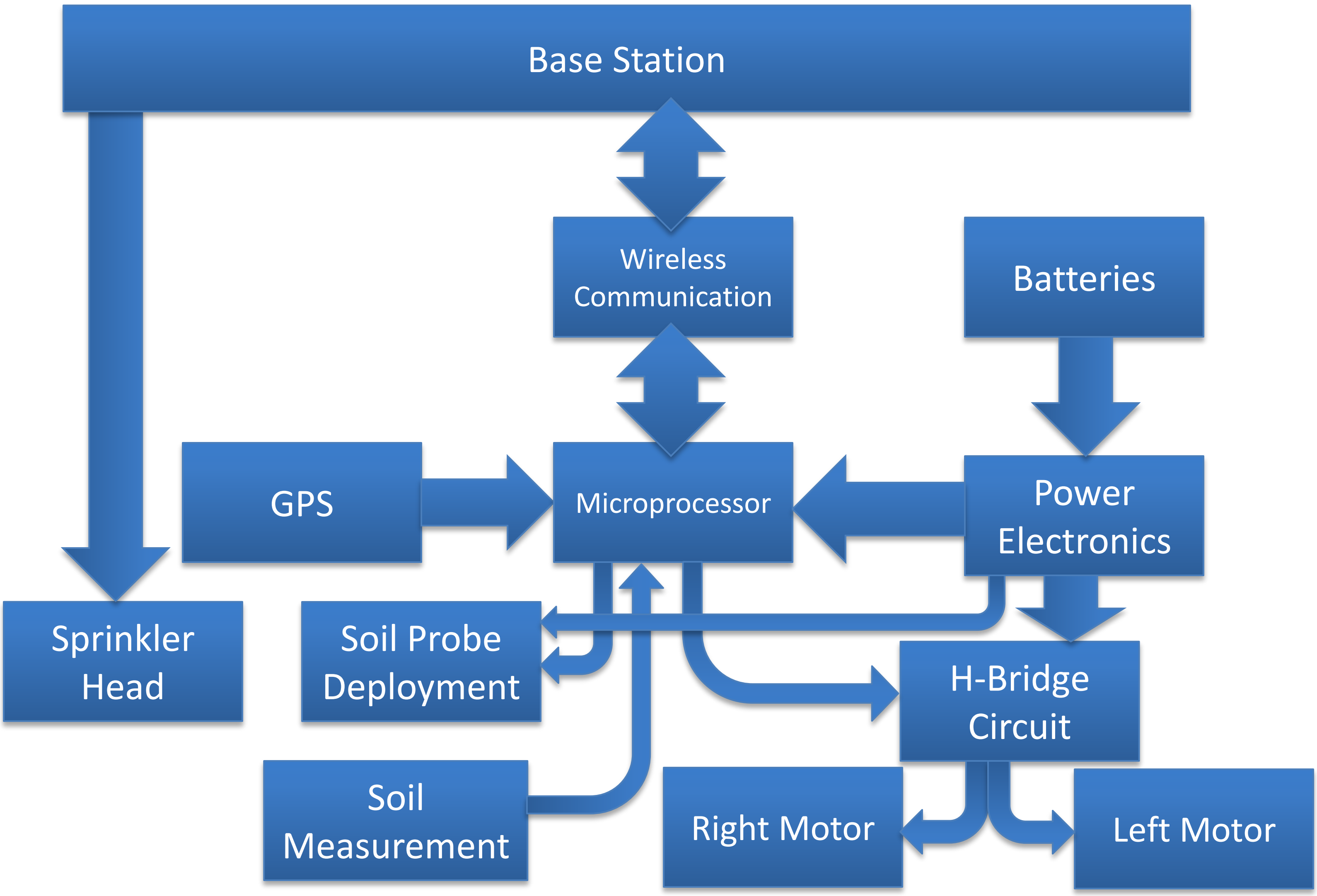

Figure 3. Sprinkler Robot Module Block Diagram

2.2 Block Descriptions and Requirements

2.2.1 Block Description – Base Station

Microcontroller
For the base station microcontroller, we will be using an Arduino. This device will be receiving data from the robot's microcontroller though the wireless communication network. The data that this microcontroller will be receiving will be GPS location and soil moisture resistance, The commands that this microcontroller will be sending are to turn the hose actuator on and off, to

deploy the soil probe, and when to drive the robot's two motors. The microcontroller will also be getting periodic information about the weather to predict when the lawn will need watering.

Hose Nozzle with Hose Actuator

The hose that is attached to the robot will contain an actuator that can be sent a signal to shut off the water. This will be in direct contact with the base station and will control the water flow that goes to the robot.

Power Supply

The base station will be inside and will have direct access to a power outlet. Therefore it does not need to be run on batteries and can be hooked up through the wall socket.

Weather Data

The base station will be in direct contact with a weather forecast system through the internet. Using an algorithm, it will be able to determine if the robot even needs to go water for the day based on current weather patterns and the past days rain.

Wireless Communication

A transmitter and receiver circuit will be built near the base station and will be responsible for sending and receiving information between the base station and Arduino on the robot using serial communication. Both chips will be required to have multiple channels since both the base station and robot will have one receiver and transmitter. This requires getting the Linx chips that operate at 902-928 MHz to allow multiple channels. FCC regulations allow free use of this band so this works perfectly for our setup.

GPS

The GPS will not be on the base station but rather the robot. However, it will be sending signals to a microcontroller on the base station from the robot. This data will be analyzed to send the robot its next command. This setup will allow the microcontroller to receive the relevant data to operate a real-time system that updates the robots position continuously so it can keep track of its position.

2.2.2 Block Description – Sprinkler Robot

Battery

The main power supply will come from multiple 12 V batteries. The majority of these will be used to power the sprinkler robot (including the on-board Arduino, Dayton Motors and Gear Motor). The battery supply will have a voltage regulator to ensure that once the battery is depleted, it will stop powering the components.

Power Electronics

The Linx transmitter and receiver chips on the module have a maximum power supply voltage of 5.2 V. This requires us to build a buck converter that will step down the 12 V power supply to somewhere in between 2.7 V to 5.2 V. Two common problems with DC-DC converters are connecting the input voltage in the reverse direction and a short circuiting the output. The circuitry that is designed will be able to handle both of these issues for safety reasons.

Motor (Left and Right) and H-Bridge Circuit

The two main motors that are controlling the robot's movement will each be connected using H-Bridge circuitry. This set up will allow the robot to travel in forward and reverse directions depending on the switch setup. Since some of the switch combinations can cause a short circuit, a current regulator will be attached to both H-Bridge circuits to ensure this shuts off the circuit.

Microcontroller

An ARUDINO board will exist on the robot and will be responsible for the majority of communications between the base station and different on-board components. It will be responsible for sending direct instructions to the circuitry that controls the motors for movement, as well as the motor that controls the moisture deployment probe. The probe will also send signals to the ARUDINO and the ARUDINO will send those signals to the base station for processing. In addition, it will send and receive signals wirelessly through the on-board Linx receiver and transmitter chips to the microcontroller to get updated information about the weather and pre-programmed movement plan. It will also be powered directly by the 12 V batteries.

Wireless Communication

A transmitter and receiver circuit will be built on the robot that will be responsible for sending and receiving information between the base station and robot using serial communication. Both chips will be required to have multiple channels since both the base station and robot will have one receiver and transmitter. This requires getting the Linx chips that operate at 902-928 MHz to allow multiple channels. FCC regulations allow free use of this band so this works perfectly for our system.

Soil Probe Deployment and Soil Measurement

A gear-motor will exist on the robot that will be used to deploy a two-point resistance probe into the ground to determine whether the soil in a certain area needs to be watered or not. The gear-motor will be powered directly by one of the 12 V batteries on the system. The two point probe will send a voltage value to the ARUDINO so it can handle the data properly.

Sprinkler Head

The robot will contain a sprinkler head that will spray water to a certain area. The robot itself does not need to worry about anything related to turning the water on or off as all of this is handled by an actuator at the base station.

GPS

A Garmin GPS unit will be responsible for keeping track of the position of the robot and the direction that it is facing. This will allow the microcontroller on the base station to send the correct signals to move the robot to the different locations. The GPS will be in direct contact with the microcontroller so it does need to send signals over the Linx chips. This component does not need to talk directly to the ARUDINO.

Verification

3.1 Testing Procedures

3.1.1 Testing Procedures for Base Station

Power Supply

Test the outlet at the base station to ensure that there are no spikes from the wall outlet measurements and check for proper grounding. This way we can power up the microprocessor and weather data source properly. A plot of the voltage will be generated on the oscilloscope.

Hose Nozzle

Make sure the hose nozzle does not leak water, and determine the water pressure coming out of the hose nozzle. We will take multiple water pressure measurements for different water valve positions and show the values of water pressure on a table. That way we could know how to properly adjust the water valve when it comes time to demonstrate the project.

Hose Actuator

Test to make sure that the hose actuator does not leak water, and make sure that it can handle the different water pressures coming out of the hose nozzle. We also will need to test that we can properly send a signal to the hose actuator because the hose actuator will control the water flow to the sprinkler robot. We will present graphs of the signal being on and off to indicate the different states.

Weather Data

Test that the weather data device is consistent with local weather forecasts. This will be done by comparing the data the microcontroller receives to that of the online source to make sure they are the same.

Wireless Communication

The input and output signals will be plotted to show serial communication through an eye diagram to see how noisy it is. This will be done by sending a 0 and 1 and looking at the difference.

Microprocessor

Make sure that the Arduino is reading the correct analog and digital signals from the GPS and the receiver. We can check this by having the Arduino print out its stored values.

3.1.2 Testing Procedures for Sprinkler Robot

Sprinkler

Test the sprinkler watering pattern by applying different water pressures to see how it performs optimally. We will also measure how much water is used over a time period.

Global Position System (GPS)

Test that the GPS device is consistent with the actual location. A lot of data will be taken and recorded, so that we can account for the deviation errors when updating the location of the sprinkler robot. In order to test, we will need to make sure that we can transmit the correct data from a position to the microcontroller.

Soil Deployment Probe

We will need to test the gear-motor that controls the probe deployment system. In order to do this, we will need to measure the amount of force necessary to both insert a two-point probe into the soil and remove it. We will also need to make sure that the soil deployment probe is not damaged when it encounters an obstruction in the ground. The system will need to be durable enough that it is not damaged after repeated usage.

Soil Measurement

Testing the soil measurements will be done by placing the two-point probe into the soil and recording the resistance values found for different soil moistures. This will allow us to find the range at which the ground needs to be watered.

Batteries

Test to ensure that the battery has a constant 12 V DC at its output.

Power Electronics

Ensure that the correct V_{IN}/V_{OUT} effect is taking place. In addition, a reasonable efficiency value will be necessary in order to avoid overheating components. The design will need to be tested and further modified if better or larger components are needed.

Motor Controller

The H-Bridge controller will contain four switches. Two of the switches will be controlled by one gate driver while the other two are controlled by another gate driver. The switches will need to be tested to ensure that short circuit can never occur and that the two switches turn on in parallel.

Right/Left Motor

Test to make sure that the motors are receiving 12 V DC at the correct 1 A current. The cutoff current value will be found that prohibits the motor from moving with no load.

Wireless Communication

The input and output signals will be plotted to show serial communication through an eye diagram to see how noisy it is. This will be done by sending a 0 and 1 and looking at the difference.

Microprocessor

Make sure that the Arduino is reading the correct analog and digital signals from the soil probe. We can check this by having the Arduino print out its stored values.

3.2 Tolerance Analysis

The most important part of the sprinkler robot will be ensuring the system is powered correctly. This means that we need to ensure that the batteries are always outputting 12 V DC at all times. In addition, we will need to test how long each battery lasts and the voltage/current drop over time that ensues. This will in effect help us determine the amount of voltage regulation that will be necessary for the system. Also, it will help us determine if we need to build closed-loop systems for the power converters and H-bridge circuit. We will need to push the batteries to their lowest voltage values and see what kinds of effects it has on the entire system. Furthermore, we will need to test each battery powered block component individually and see the amount of power consumption each takes over a specific time interval.

Cost and Schedule

4.1 Cost Analysis

4.1.1 Labor Cost

	Hourly	Hours	Total	x2.5
Denis	$37.50	200	$7,500	$18,750
Kevin	$37.50	200	$7,500	$18,750
Jose	$37.50	200	$7,500	$18,750
Total			$22,500	$56,250

4.1.2 Parts Cost

Name	Part Number	Quantity	Unit Price	Combined Price	Personal Cost
Arduino	Arduino Mega	1	$56.08	$56.08	$0.00
Arduino	Arduino Ethernet	1	$59.95	$59.95	$59.95
Circuit Board(s)		1	$10.00	$10.00	$10.00
Dayton DC Motors	1LPV6A	2	$230.00	$460.00	$0.00
Pittman Gear-Motor	GM9434G807	1	$100.00	$100.00	$0.00
Linx Transmitter Chip	RXM-900-HP3-SPO	2	$31.94	$63.88	$63.88
Linx Receiver Chip	TXM-900-HP3SPO-ND	2	$39.24	$78.48	$78.48
Retractable Garden Hose		1	$100.00	$100.00	$100.00
Stream Spray Sprinkler Nozzle		5	$1.00	$5.00	$5.00
Valve with Flow Control	Signature 9011 9000 Series 1 Inch FNPT Valve	1	$13.75	$13.75	$13.75
Sprinkler Connector		2	$2.00	$4.00	$4.00
Two 12" Wheels		2	$12.50	$25.00	$0.00
Garmin GPS	12 XL GPS Receiver	1	$300.00	$300.00	$0.00
On-Board 12 V Batteries		3	$30.00	$90.00	$0.00
Various Resistors not in Lab		1	$1.00	$1.00	$1.00
Various Capacitors not in Lab		1	$5.00	$5.00	$5.00
Various Inductors not in Lab		1	$1.00	$1.00	$1.00
Power Diodes not in Lab		1	$1.00	$1.00	$1.00
Power MOSFETs not in Lab		1	$1.00	$1.00	$1.00
TOTAL				$1,375.14	$344.06

4.1.2 Grand Total

Grand Total:

$56,250 + $1,375.14 = $57,625.14

4.2 Schedule

Week	Task	Responsibility
28-Jan	Talk with Machine Shop	All
	Research Moisture Probe	Kevin
	Research Motors and Power	Denis
	Research GPS and Software	Jose
	Work on Proposal	All
4-Feb	Design Moisture Probe	Kevin
	Design H-Bridge and Buck Converter	Denis
	Test/Design GPS and AURDINO Software	Jose and Denis
	Finish Proposal	All
	Mock DR Sign-up	Denis
	Call in with Lincoln Lab	All
11-Feb	Talk with Parts Store	Jose
	Mock Design Reviews	All
	Continue Design From 4-Feb	All
18-Feb	Sign up for Design Review	Denis
	Call in with Lincoln Lab	All
25-Feb	Order Parts	Kevin
	Assemble Base Robot Components	Jose
	ADUIINO Programming	Denis
	Design Review	All
4-Mar	Call in with Lincoln Lab	All
	Testing Moisture Probe	Kevin
	Work on Retractable Hose/Sprinkler	Denis
	Work on GPS System	Jose
11-Mar	Individual Progress Reports	All
	Communication Between Base Station and Robot	Kevin & Denis
	User Interface	Jose
18-Mar	Spring Break (Continue Individual Work)	All

25-Mar	Testing of Complete System	All
	Mock-Up Demos	All
	Mock Presentation Sign-up	Denis
	Call in with Lincoln Lab	All
1-Apr	Debugging and Error Testing	All
8-Apr	Debugging and Error Testing	All
	Call in with Lincoln Lab	All
15-Apr	Debugging and Error Testing	Kevin & Jose
	Demo and Presentation Sign-up	All
	Working on Final Paper	Denis
22-Apr	Final Touch-ups	All
	Demo	All
	Call in with Lincoln Lab	All
29-Apr	Presentation	All
	Final Paper Due	All
	Lab Notebooks Due	All
	Checkout	All