TBD Gardening Project Name - Group 9

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1 Executive Summary

New gardeners typically struggle getting their garden started due to a lack of tending to their plants. This project seeks to solve many of the problems that new gardeners have through sensing and control. The main issues with plant growth relate to soil composition, soil moisture, temperatue, and sun light. This project seeks to use optics to measure the soil moisture and composition; then an MCU will capture this data and control solar shades to control sunlight and solenoids to control watering. A web component will be included to check the weather as well as notify the user of impending weather events that could affect their plants adversively (frost or heat wave). The entire system will be powered with solar panels that are capable of tracking the sun through the sky and can act as blinds over the plants.

This project all starts with scoping out the project. The team has immediately compiling a list of must-have requirements and some things the team would like to accomplish as "nice to haves". The team started this process by looking at all the similar projects that have already been done and looked at all the ways the team can expand on the work they have already accomplished. For example, the team liked the weather aspects of a project for getting rain information; a problem the team were thinking about was how to get the system in as much of a "set it and forget it" state as possible as it pertained to frost. The solution is to integrate with a weather service online and send notifications when there is a frost or freeze advisory.

After assembling the list of requirements, the team set out to create a high-level functional block diagram for each of the subsystems. This helps the team see where the different systems integrate for the future as well as breaking out all the different components that may need to be purchased.

The ultimate novelty in this project is all of the sensing that will be done through spectroscopy. The team has found a plethora of research on the topic and has started familiarizing themselves with the limitations and capabilities of the available technology. Ideally, the team would like to find a scalable solution to the sensing in which the optical sensing could be attached to a drone or satellite to survey fields for farming.

2 Project Description

2.1 Project Background

Gardening is difficult. There are so many variables that a gardener must try to keep within their control. Soil moisture, temperature, soil composition just to name a few. The entire process of gardening is primarily uninvolved as a more involved process could be equated to the old adage "watching grass grow." Here lies the issue, since plants grow without hardly any involvement from the gardener despite controlling the watering and feeding, a large part of the process can be automated.

There have been numerous "Garduino" projects that anyone could find and quickly modify to their needs. These projects generally use the sensors in the Arduino starter kits as well as an LCD or dot matrix display to read out the sensor data. Such a project is not well scoped for a senior design project. The difference in what we propose and what has already been done are the control aspects, automating watering and feeding and even temperature and sunlight regulation.

The sensors in the Arduino starter kits are all electrical sensors which in the high moisture environment of a plant bed will decay quickly. There has been a lot of progress in optical sensing and in our original preliminary research we found promising devices to sense soil moisture and composition optically instead of electrically. The hope is that such an optical sensor may one day be mounted on a drone and flown over a field to get the same data we are using to control our plant bed.

From the sensors, the project will also implement a control scheme. The hope is to build a gantry that supports a swiveling solar panel array as well as solenoids to control water. There are also items beyond the control of the plant bed such as weather (namely frost) which will be resolved in software by notifying the user of such conditions.

2.1.1 Motivation

The idea came from seeing the "Garduino" style projects all over hobbyist forums and websites but the idea really took hold in that each member of the team saw an opportunity to explore a new facet of engineering they held an interest in. This project provided the team an opportunity to apply our knowledge on power systems and delivery, controls, digital signal processing, and optical sensing. These are all areas that the team wanted to demonstrate a high level of understanding in and grow at the synthesis level.

2.2 Objectives

2.2.1 Goals

There are four distinct subsystems each that have their own necessary and stretch goals.

The first of the subsystems is the controller subsystem comprised of the microcontroller and links to the sensing subsystem and the web subsystem. Through the use of digital signal processing the MCU will be able to read sensor data and adjust parameters of the controllable interfaces accordingly. The necessary goal for this interface is to be able to supply water to the plant bed. The stretch goal however is to use the solar panel array as blinds to reduce/increase sunlight and temperature. The MCU will also be able to send data to the web subsystem for alerting the user of different conditions present within the plant bed.

The power subsystem as a necessary goal should be able to supply power to all the necessary components via a solar panel array and batteries. The stretch goal is to incorporate this array into the control scheme by having the array act as blinds and allow more or less sunlight to the plant bed as necessitated by the plant health parameters and battery charge parameters.

The sensing subsystem will include infrared spectroscopy to detect soil moisture, soil temperature, and soil OH group content which will provide useful data about soil acidity. This will accomplished using infrared spectra signal processing. The stretch goals for this subsystem is to be able to check on various areas of the plant bed and take multiple samples as opposed to a single static sample on the same area of the plant bed. Soil nutrient estimation is also a stretch goal for this subsystem.

The web subsystem will be able to communicate with a weather service API to get rain, temperature, frost, and humidity data and be able to relay this information to the microcontroller. The web subsystem will also be able to alert the user to conditions outside of the control of the plant bed (i.e. soil composition and frost). From the web subsystem the user will be able to change different control parameters such as sun light or water. This will all be accomplished via a graphical user interface. The stretch goals for the web subsystem are to be able to take a plant type and find the ideal parameters for growth and all the communications would occur over a secure connection such as TLSv1.2 or later.

2.2.2 Requirements Specifications

* “The system” refers to the plant bed and is subsystems (control, sensing, power and web)

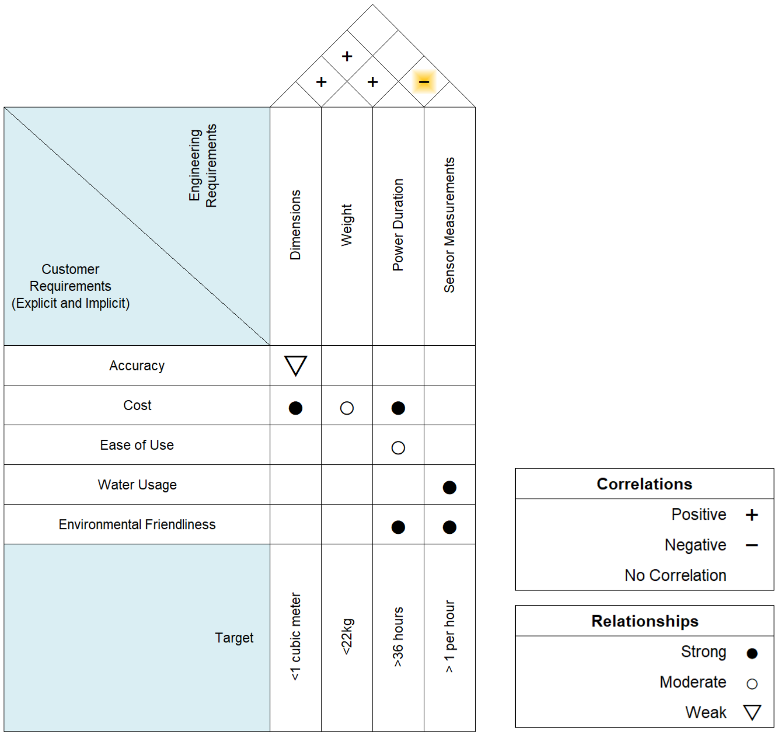
- The system shall take up no more than a meter cubed of volume
- The system shall use solar energy and battery power with an AC source backup
- The power system shall have an overcharge protection
- The power system shall have current leakage protection
- The system shall be able to control the water supply
- The microcontroller shall be capable of internet communication via HTTP requests

- The microcontroller shall be capable of digital signal processing
- The system shall be able to convert analog signals to digital signals for processing
- The system shall be weatherproof
- The system shall weigh no more than 40 pounds empty of soil
- The system shall be of physical construction pursuant to any governing construction standards

2.3 Marketing Requirements and Engineering Requirements

Find our House of Quality figure below:

Figure 1: House of Quality



3 Research

3.1 Previous and Related Works

3.2 Related Technologies

3.3 Part Selection

3.3.1 Controller Subsystem

At minimum, any chosen microcontrollers (MCUs) shall support natively, or by addition of a module, these features and traits:

- Analog-to-digital converter (ADC)
- cURL compatibility
- IEEE 802.11
- In stock and available to order
- JTAG module or equivalent
- Module communication bus (UART, I2C, SPI)
- Onboard CPU sufficient for our purposes
- Onboard memory sufficient for our purposes
- Onboard nonvolatile memory
- Pins dedicated to analog input
- Pins dedicated to digital I/O

These features would be ”nice to have” on any MCU selected, but are not required:

- Digital-to-analog converter (DAC)
- microSD card slot
- Onboard battery
- Pins dedicated to pulse-width modulation (PWM)
- Timer(s) and an RTC
- USB compatibility
- Additional wireless communication protocols (e.g. BT or BLE, Zigbee)

Table 1: MCU option breakdown

Model	**LAUNCH-XL-CC26X2-R1**	**LAUNCH-CC3220-MODASF**	**Pico W**	**Nano 33 BLE**	**B-L4S5I-IOT01A**
Manufacturer	Texas Instruments	Texas Instruments	Raspberry Pi	Arduino	STMicro-electronics
Micro-controller	CC2652R	CC3220-MODASF	RP2040	nRF52840	STM32-L4S5VIT6
Processor	1x ARM Cortex-M4F	1x ARM Cortex-M4	2x ARM Cortex-M0+	1x ARM Cortex-M4	1x ARM Cortex-M4
Maximum Speed (MHz)	48	80	133	64	120
Memory (KB)	256 ROM, 352 flash, 100 SRAM	1024 flash, 256 RAM	16 ROM, 264 SRAM	1024 flash, 256 SRAM	2048 flash, 640 RAM
Wireless capability	BLE5.2, Zigbee, Thread	802.11b/g/n	802.11n	BLE5.3, Zigbee, Thread, Matter	BT4.1, 802.11b/g/n, NFC
Serial capability	UART, I2C, I2S, SPI	UART, I2C, SPI	UART, I2C, SPI, USB1.1	UART, I2C, I2S, SPI, USB2.0	UART, I2C, SPI, USB2.0
Price ($)	40, maybe free	60, maybe free	6	28	53
ADC	8-channel, 12-bit	4-channel, 12-bit	4-channel, 12-bit	8-channel, 12-bit	16-channel, 12-bit
Clock capability	Timer, RTC	Timer, RTC, WDT	Timer, RTC, WDT	Timer, RTC, WDT	Timer, RTC, WDT
GPIO (pins)	31	29	30	13	16
PWM (channels)	Supported	Supported	16	4	6
Required voltage (V)	1.8 – 3.8	2.3 – 3.6	1.8 – 3.3	4.5 – 21	4.75 – 5.25

The following selections, not listed in any particular order, match the above criteria and are being considered for selection: Use of single-board computers (SBCs) was considered, but will not not need to be used; cURL used on an MCU in conjunction with Amazon EC2 services will allow us to offload computing to a cloud solution.

Use of an external Wifi module is discouraged due to the following:

- Added cost
- Added complexity
- Modules in common use by hobbyists often have poor or no proper documentation, to the extent of:
  - Quick start guide
  - User's guide
  - Datasheets
  - Theory of operation
  - Application uses
  - Troubleshooting guide
  - Schematics and mechanicals
  - Quality and reliability
  - Errata

Therefore, all of the MCUs listed above support either the 802.11 or Bluetooth standards.

3.3.2 Power Subsystem

At minimum, this power subsystem will operate with the following:

- Solar Panels
- Rechargeable Batteries
- Solar Charge Controllers
- AC/DC converterter

Solar Panels

The stretch goal for this project is to use solar panel arrays as blinds to increase/decrease sunlight as well as temperature. The solar panels are also use to-collect energy and power our model. We must be strategic when choosing our solar panels so that they are operational, provide the proper amount of power, and more.

There are many different types of solar panels. These include monocrystalline solar panels, polycrystalline solar panels, and thin-film solar panels. Each solarpanel has different compositions that make it as efficient as they are, how much power can be collected, etc.

For this project, we have selected multiple types of solar panels based on efficiency and cost.

Table 2: Solar panel types

Solar Panel Type	**Monocrystalline**	**Polycrystalline**	**Thin - Film**
Efficiency	>20%	15 - 17%	6 - 15%
Power Rating	≤300W	240 - 300W	Indefinite
Performance	Most efficient	Efficient	Least efficient
Temperature	High Tolerance	Low Tolerance	High Tolerance
Cost per Watt	$1 - $1.50	$.70 - $1	$.43 - $.70

From there we found these solar panels:

Table 3: Solar panel part breakdown

Manufacturer Part #	P108	P103C	P105	SP-80X60-4-DK	SP-68X37-4-DK
Manufacturer	Voltaic Systems	Voltaic Systems	Voltaic Systems	AMX Solar	AMX Solar
Dimensions	10.9 x 8.8 x .16	8.27 x 4.46 x .2	5.39 x 8.74 x 0.16	3.15 x 2.362 x .079	2.677 x 1.456 x 0.079
Voltage at Pmpp	17.34V	6.5V	6.12V	1.5V	5.28V
Current at Pmpp	570mA	550mA	940mA	440mA	69.3mA
Open Circuit Voltage	20.45V	7.7V	7.13V	1.8V	6.27V
Price ($)	49	39	35	36.65	28.94

From there we needed to choose what kind of rechargeable battery we wanted to use for. Out on the market there are many different types of batteries including Nickel-Cadmium(NiCd), Nickel-Metal Hydride(NiMH), Lithium Ion(Li-Ion), and so many more.

Of these batteries, we decided to go with the Lithium Ion battery because it was the most commonly used battery for electronic devices while allowing high output voltage.

Table 5: Battery investigation

Manufacturer	**Ampere Time**	**Expert-Power**	**Eco Worthy**	**Eco Worthy**
Voltage	12	12	12	12
mAh	6000	10000	5000	8000
Price ($)	29.99	59.99	35.99	43.99

For the solar panels, having a solar charge controller is important to the system. The purpose of the solar charge controller is to optimize the charging of the battierys by the solar panels. There are two major types of solar charge controllers: Maximum Power Point Tracking (MPPT) and Pulse Width Modulated (PWM).

With these two in mind we chose these charge conrollers:

Table 6: Charge Controller

Manufacturer	**Expert-Power**	**Expert-Power**	**Renogy**	**Renogy**
Nominal Voltage	12/24V	12/24V	12/24V	12/24V
Rated Charge Current	10A	20A	10A	30A
Max PV Input Voltage	50V	100V	50V	50V
Self Consumption	≤10mA	≤10mA	<10mA	≤13mA
Price ($)	23.99	69.99	34.99	69.99

While the model is charging during the day or as a back up, this will be plugged into a wall outlet for power. This means we have to be able to convert the AC voltage coming from the wall is converted to DC voltage for the model to use.

Table 7: AC/DC Converter breakdown

Manufacturer	**SmoTecQ**	**ANLINK**	**TMEZON**
Input Voltage	240V	100 - 240V	100 - 240V
Output Voltage	12V	12V	12V
Current Rating	2A	2A	2A
Connector	5.5 mm x 2.1 mm	5.5 mm x 2.1 mm	5.5 mm x 2.1 mm
Price ($)	12.99 for 2	11.59	8.99

3.3.3 Sensing Subsystem

The required sensing subsystem capabilities include:

- Diffraction Grating or Diffraction Wheel
- Motorized frequency selection mechanism
- SWIR regime Photodiode

Frequency separation mechanisms under consideration are:

Table 8: Infrared Sensors

Model	**0.07mm Dia., TO-46 Package, InGaAs Photodiode**	**0.12mm Dia., TO-46 Package, InGaAs Photodiode**	**FGA01 - InGaAs Photodiode**	**FGA015 - InGaAs Photodiode**
Manufacturer	Edmund Optics	Edmund Optics	ThorLabs	Thorlabs
Spectral Response (nm)	900 - 1700	900 - 1700	800 - 1700	800 - 1700
Active Area Diameter (mm):	0.07	0.12	0.01	0.018
Responsivity (A/W)	0.9	0.9	1.003	0.95
Price ($)	88	88	67.55	63

Diffraction gratings and LED Probes are still being evaluated for necessity:

4 Design Constraints

4.1 Related Standards

4.2 Economic Constraints

4.3 Time Constraints

4.4 Equipment Constraints

4.5 Safety Constraints

4.6 Environmental Constraints

4.7 Manufacturability Constraints

4.8 Ethical Constraints

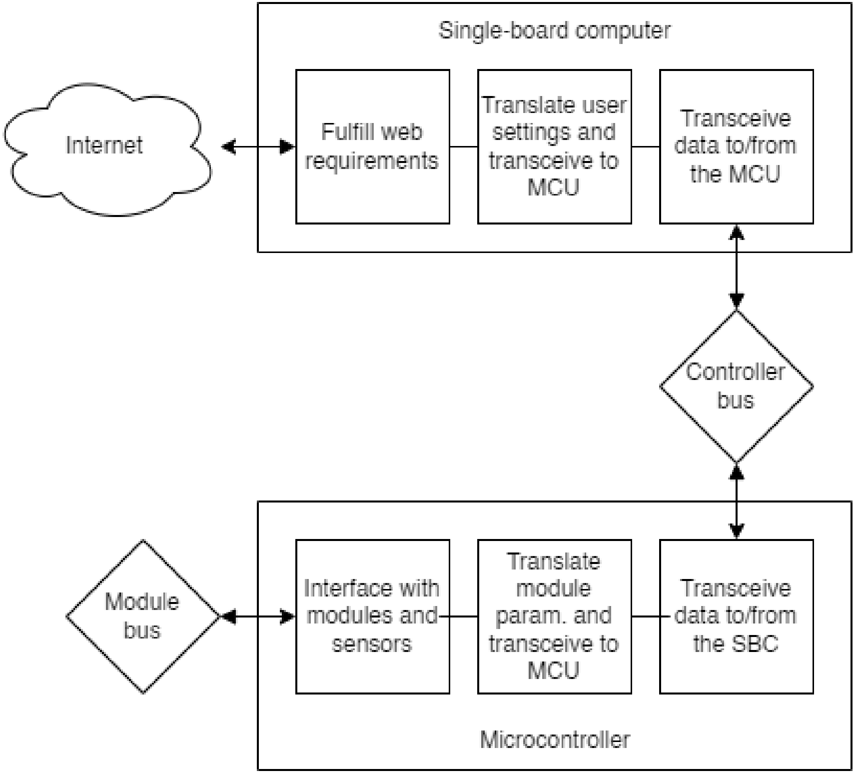
4.9 Sustainability Constraints

5 System Hardware and Software Design

High level overview of design

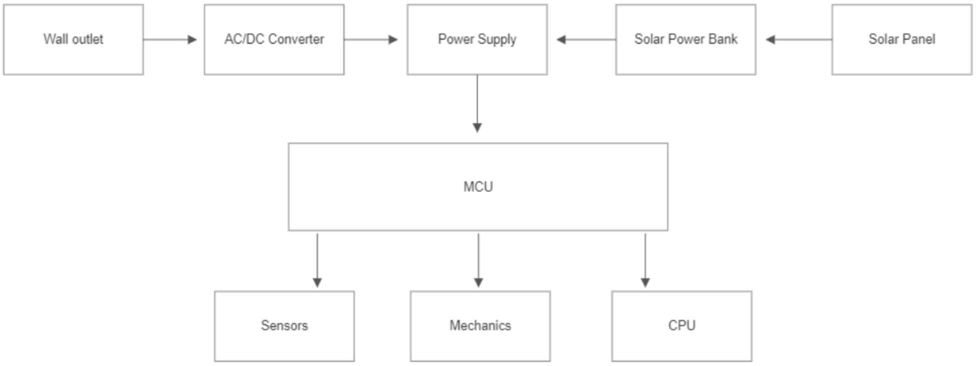
5.1 Controller Subsystem

Figure 2: MCU block diagram



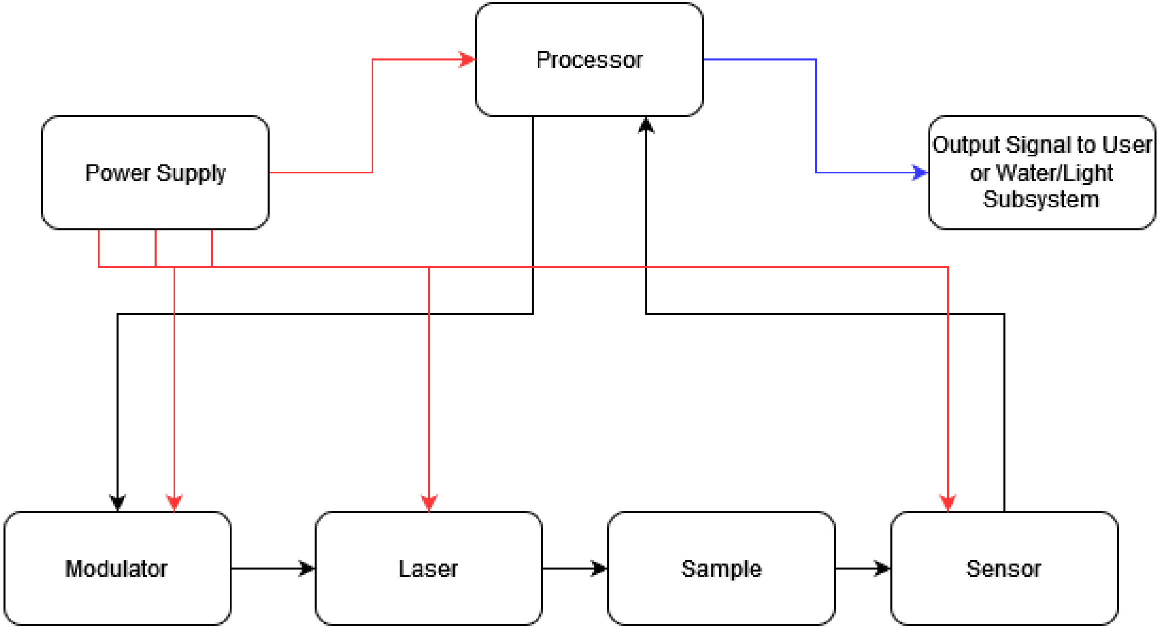
5.2 Power Subsystem

Figure 3: Power subsystem block diagram



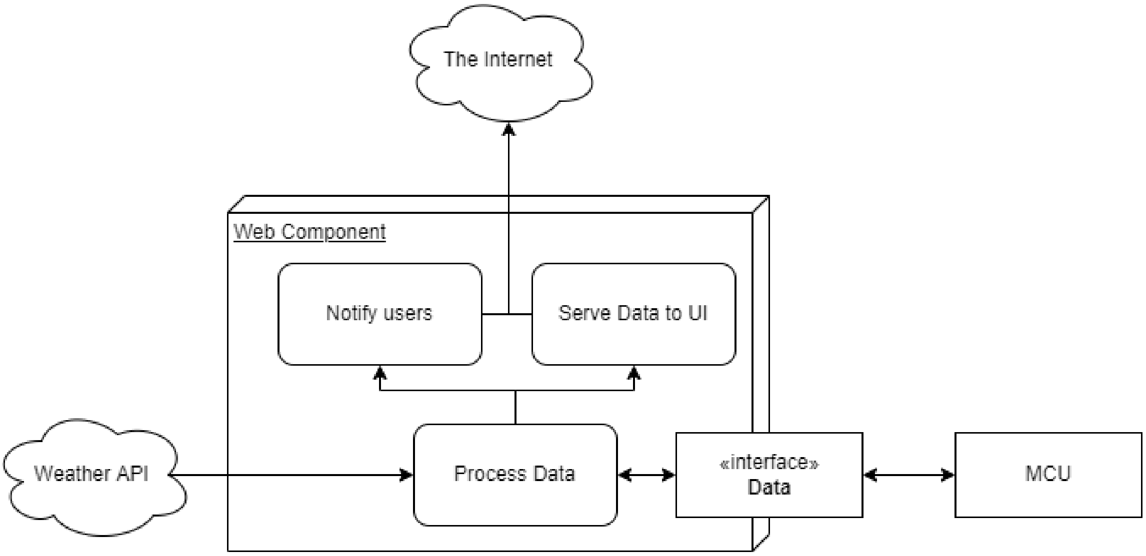
5.3 Sensing Subsystem

Figure 4: Sensing subsystem block diagram



5.4 Web Subsystem

Figure 5: Web component block diagram



6 Testing

7 Administrative Content

7.1 Milestones

From a project management perspective, the team will be utilizing Agile to get quick turn arounds on small deliverables. Choosing to use agile, the team will also be using Jira to track progress and add reports throughout the process. A high-level of the goals by semester can be found below.

7.1.1 Fall

- Select components for each subsystem
  - Document selection reasoning
  - Order to ensure on-time delivery
- Model physical bed
- Build physical bed
- Understand how subsystems will integrate:
  - Communication protocols (REST, I2C, SPI, DSP, etc)
  - Power requirements
- UI for Web subsystem

7.1.2 Spring

- Test subsystems in isolation
- Start integrating subsystems
- Control scheme for moving solar panels with sun and to provide shade
- Web API complete
- MCU coding complete
- Stretch goals

7.2 Budget

Table 9: Breakdown of budget by subsystem

Subsystem	Estimated Cost	Comment
MCU	$60	The MCU, wiring harness
Power	$200	Solar panels, batteries, control system
Sensing	$100	Components for sensing, optical sensors
Web	$30	Web service pricing
Non-Subsystem	$100	The plant bed, soil, water, fittings, etc
Total	$490	