

# AutoPot

Team 7

Anny Ni  
Edwin Cho  
Grace Lee  
Raymond Xu

May 5, 2016

## **Abstract**

Some plants require extensive care and knowledge to successfully grow due to the many environmental variables involved and this growing process can be quite tedious with current plant pots. The numerous variables one needs to keep track of to keep a plant healthy and alive is not only hard and time consuming but also dull and boring. Current planters do not solve this problem as they do nothing more than hold the plant. Our solution is to create an automated plant pot capable of helping users keep track of variables, such as temperature, moisture, and sunlight, in order to help make the plant growing experience less stressful and more exciting.

Using a wireless microcontroller, sensor data is accumulated and used to calculate the health of the plant, which was then displayed to the user. The plant then reacts in different manners based on its health, sometimes watering the plant and other times asking to be moved to a warmer location. While there are other smart planters, they have never been effective at keeping a plant alive and they are not very intimate. The main purpose of this project is to develop an automated planter which helps us keep track of the health of our plants. With the success of this project, we would be able to save the lives of more plants and collect more data to bring about more ecofriendly pet plants.

# Contents

<b>1</b>	<b>Project Description</b>	<b>1</b>
<b>2</b>	<b>Design Requirements</b>	<b>1</b>
2.1	Explicit Requirements . . . . .	1
2.2	Implicit Requirements . . . . .	2
<b>3</b>	<b>Functional Architecture</b>	<b>2</b>
3.1	Block Diagram . . . . .	2
3.2	Moisture and Dispensor . . . . .	3
3.3	Light Sensor and Rotating Base . . . . .	3
3.4	Web Application . . . . .	3
3.5	LED Display . . . . .	3
3.6	Bluetooth Audio . . . . .	3
<b>4</b>	<b>Design Trade Studies</b>	<b>3</b>
4.1	Microcontrollers . . . . .	3
4.2	Light Sensor . . . . .	4
4.3	Structure . . . . .	4
4.4	Plant Display . . . . .	4
<b>5</b>	<b>System Description/Depiction</b>	<b>5</b>
5.1	Block Diagram . . . . .	5
5.2	Sensors . . . . .	5
5.3	Audio . . . . .	5
5.4	Chassis . . . . .	5
5.5	Dispensing . . . . .	6
5.6	Power . . . . .	6
5.7	User Interface . . . . .	6
<b>6</b>	<b>Project Management</b>	<b>7</b>
6.1	Schedule . . . . .	7
6.2	Individual Responsibilities . . . . .	8
6.3	Budget . . . . .	9
6.4	Risk Management . . . . .	9
6.4.1	Design Risks . . . . .	9
6.4.2	Schedule Risks . . . . .	10
6.4.3	Resource Risks . . . . .	10
<b>7</b>	<b>Conclusions</b>	<b>11</b>
7.1	Lessons Learned . . . . .	11
7.1.1	Technical . . . . .	11
7.1.2	Management Related . . . . .	11
7.2	What would we do differently? . . . . .	11
7.3	Future Work . . . . .	12

<b>8 Related Work (Competition)</b>	<b>12</b>
8.1 Parrot Pot . . . . .	12
8.2 DIY Automatic Plant Waterers . . . . .	13
<b>References</b>	<b>13</b>

# 1 Project Description

Plants are difficult to grow and keep alive. There have been countless times when people forget to water their plants or end up watering them too much. AutoPot is a smart gardening system that will allow the users to easily raise and monitor their plants. After users place their pots with their plants in them onto the AutoPot base, AutoPot will track plant health and growth by keeping track of the soil moisture, soil temperature, and sunlight exposure. It will also enable easy refilling of these resources when they are lacking, and provide additional features, such as music playing, to improve the plant-growing experience.

In order to lessen the chance of user negligence, AutoPot will have an improved user interaction through a web app with information such as the plant status and possible concerns and tasks and a display on the pot where the plant will become more like a pet. There will also be customizable settings for the AutoPot for amateur and experienced plant owners and these settings will be populated with defaults for common plants. This allows for both an easy-growing, no-research experience for beginners and a more selective experience for experts who want to more intensely monitor certain temperature or moisture ranges.

## 2 Design Requirements

### 2.1 Explicit Requirements

- Track soil moisture, soil temperature, humidity, and sunlight exposure
  - Moisture, temperature, and humidity sensing
  - Light sensing and plant rotation to accommodate light source
- Automatically satisfy a lack of resource:
  - Moisture - waters the plant
  - Sunlight - rotates the plant
- Data collection from the sensors for plant monitoring
- Customizable settings for different plant needs, controlled via web app
- Display on plant to notify users of its status as well as a notification system that pings the users with possible concerns
  - UX component and web app
- Measure temperature and humidity, and alert users when there are unfavorable environments

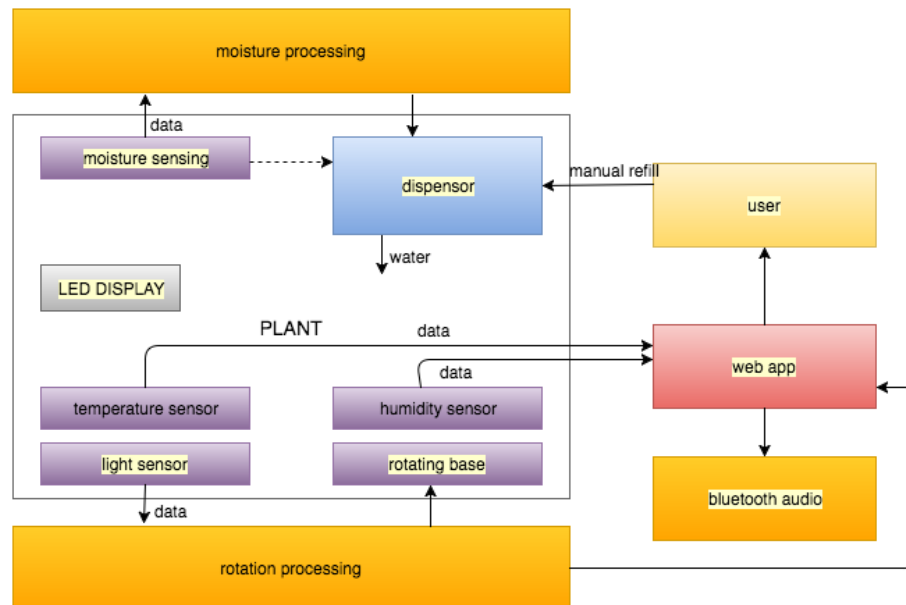
- Allows for music playing to enhance plant-growing environment, both for the user and the plant itself
  - Can be a speaker for users to broadcast their favorite songs
  - Vibration from the speakers, which will be mounted onto the pot, helps with plant growth

## 2.2 Implicit Requirements

- Safety
  - Should operate without any major safety concerns to the user or the plant
- Reliability
  - Should operate with minimal user input, other than tasks that require human interaction
  - Readings should be accurate, actions should occur in a timely manner
- Usability
  - Pot needs to be within certain dimensions

## 3 Functional Architecture

### 3.1 Block Diagram



## **3.2 Moisture and Dispenser**

Time event sensing of moisture within pot soil. When moisture levels are below the set threshold, dispense water from reservoirs. Water is dispensed directly into the soil. When the water reservoir is below threshold, users are prompted to refill.

## **3.3 Light Sensor and Rotating Base**

Time event sensing of sunlight. Reported data is used to compute rotation of the pot, so that the plant receives even amounts of sunlight from all directions.

## **3.4 Web Application**

All data gets compiled and visualized in the web application. The user interfaces with the project mainly through this application.

## **3.5 LED Display**

This allows the user to see the status of their plant. Any immediate worries will be displayed on the screen and the user should be alerted through the web application as well as the display.

## **3.6 Bluetooth Audio**

Music can be played through bluetooth for the plant. Speakers are connected to the pot itself so the vibrations will transfer through the soil to the plant.

# **4 Design Trade Studies**

## **4.1 Microcontrollers**

The choice of type of microcontroller to use was between distributed microcontrollers and centralized microcontrollers. Centralized microcontrollers are easier to use and access. There is no need to connect them to all of the other microcontrollers. However, they are bad for unit testing and if there is a failure then the whole system will fail. With distributed microcontrollers, there can be different units that adhere to the different timings of each sensor. Distributed microcontrollers can constantly read and store data on a schedule so that timing and hanging do not have to be worried about. Distributed also allows for more work on the project to be done in parallel. Distributed microcontrollers pose difficulties in implementation, where they are dependent on a successful connection between microcontrollers. We did not see a need to parallelize the workload, and thus used a single distributed node.

Another consideration is whether calculations and actions should be event-triggered or time-triggered. Although event-triggered would be better for only doing calculations when things actually change for the plant, errors are costly. There could be instances where an event trigger gets missed and that leads to no calculations ever being made which leads to a faulty system. On the other hand, time triggers would lead to a more constant tracking although there are some subtle events that may sneak by during the time between checks. However, since changes with the soil and plant are usually not sudden, time-triggered calculations would not miss many crucial events and would be a better choice for the project's goals.

## 4.2 Light Sensor

Initially the choices for a light sensor were between a sunlight sensor, an infrared sensor, and an ultraviolet sensor. However, after researching the subject, it was concluded that plants seem to use the full spectrum of visible light. Photosynthesis does not rely on infrared or ultraviolet light. There are also certain plant cycles where plants are more attuned to lights near the lower end of the visible light spectrum while they absorb more of the higher end during other cycles. Ideally, the light sensor should be able to sense the full visual spectrum in order to account for this.

## 4.3 Structure

The base structure of the project should ideally be able to be applied to different types and sizes of pots. All of the different structures considered for the project included a rotating base for the pot in order to satisfy the even sunlight requirements. However there were considerations for where all of the other subsystems resided. The designs being considered were: (A) a circle attached on top of the rim of the pot, (B) a contraption that hangs off of the pot, (C) all subsystems built inside of the pot, and (D) all subsystems attached to the base. Design A does not allow for different pots being used since there are different rim sizes for each pot. Design B also restricts the usage of pots since different pots also have different shapes and rim sizes. Design C is the most limited since it needs to be able to fit in current pots and there are complications when connecting all of the components together. Design D is the one that allows the most usability and would allow for the most different pots used.

## 4.4 Plant Display

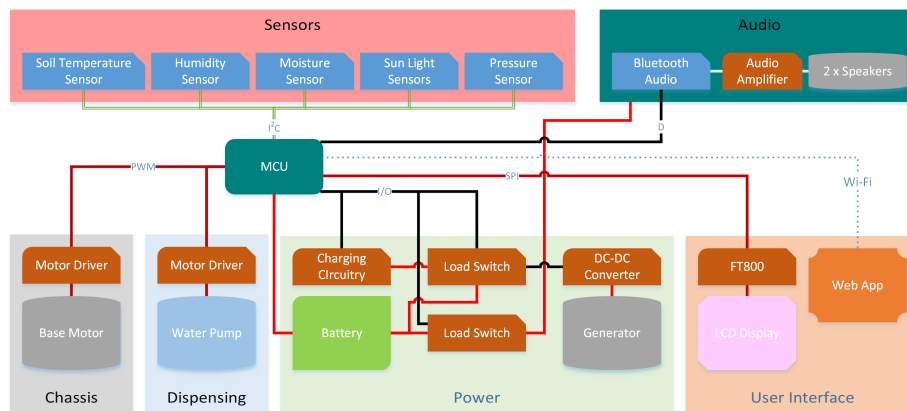
The plant display must be able to show possible emotions or other visual cues. Different considerations for this display included having a LCD or OLED display or an eInk display. eInk displays have no glare in the sunlight so the display can be easily seen and deciphered when in the sun and the eInk displays draw less power than LCD or OLED displays so they last longer. eInk displays also provide more detail in their displays. However, the eInk displays have a



slower refresh rate so that leads to a slower response time to possible triggers. eInk displays are also just black and white whereas LCD or OLED displays have a wider range of colors. Since eInk displays are more complex to control and harder to see in the dark as well as the slower refresh rate, LCD or OLED displays are more preferable. Between LCD displays and OLED displays, OLED displays are more efficient and have a higher contrast.

## 5 System Description/Depiction

### 5.1 Block Diagram



### 5.2 Sensors

Responsible for gathering information from the environment and passing it along to the microcontroller in order to interact with the dispensing systems and rotating base. Our product will include a soil temperature, humidity, pressure, moisture, and sun light sensor and utilize the information gathered from these sensors.

### 5.3 Audio

Audio speaker system that allows the user to deliver custom bluetooth audio to the plant. Two speakers have been attached to the interior rim of the pot to deliver equal amounts of audio vibration to the plant from either side.

### 5.4 Chassis

Base structure of the project should be able to rotate in order to allow for sunlight to reach all parts of the plant equally.

## 5.5 Dispensing

Subsystem responsible for dispensing the water to the plant through the use of servos and a water pump paired with a motor driver. The water tank will need to be refilled by the user whenever it runs low, and the command to water the plant can be send from the web app.

## 5.6 Power

System has the option to be powered by either battery or outlet. Power can be shut down so that the system runs only on battery, and the system can be put into a sleep mode while on battery power.

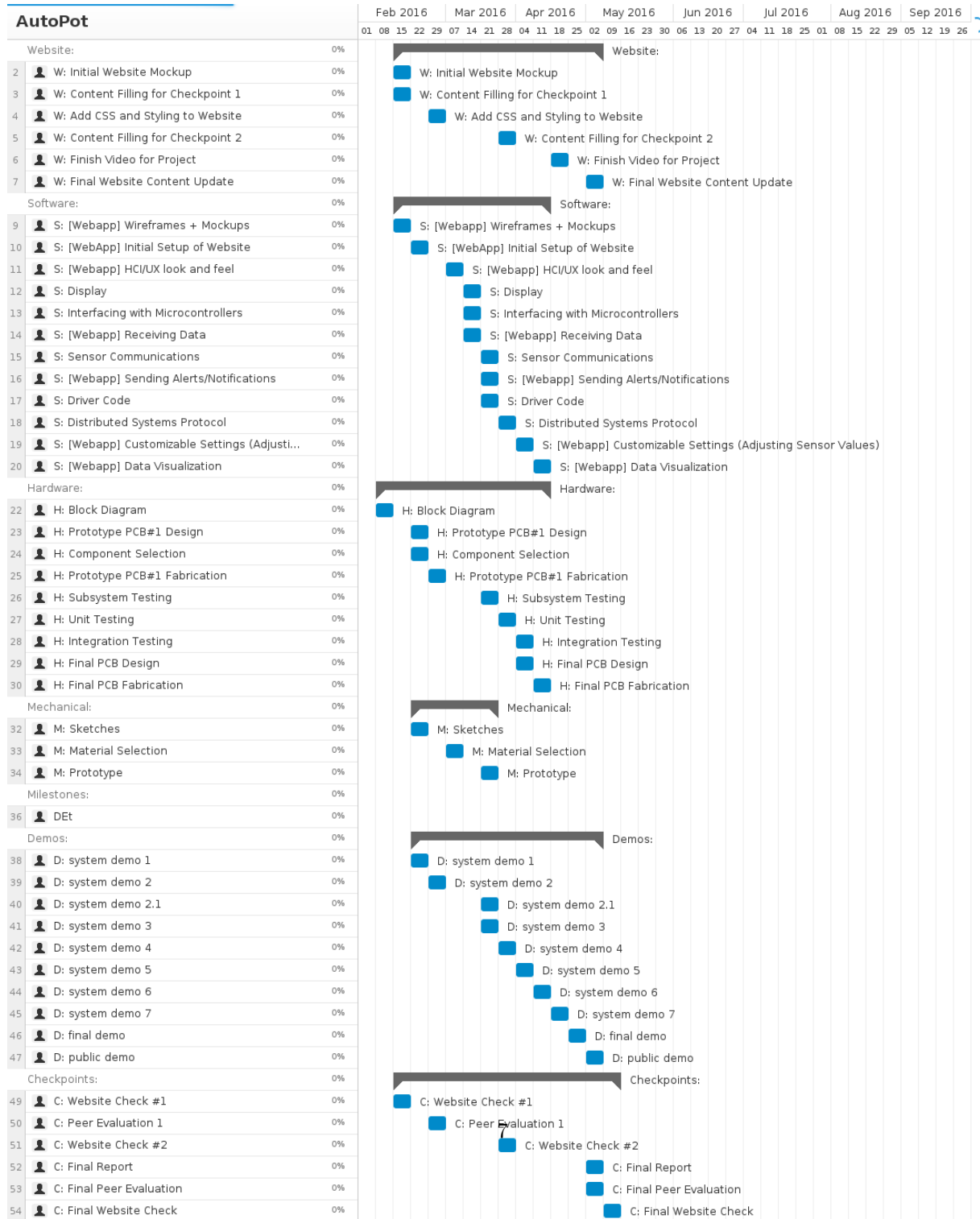
## 5.7 User Interface

Provides a way for the user to interact with their product through the use of a web app and an OLED Display on the pot itself. The LED display will show something like a smiley face to demonstrate that your plant is currently fine, or a frowny face in order to indicate that something is wrong if for example, the temperature conditions were not suitable for the plant. The background color of the OLED display also changes based on the plant's current status. Additionally, the display will show that something is wrong with the plant.

The web app also has a dashboard that contains current status information on the plant. The web app dashboard also suggests actions for the user to take to fix issues with the plant, and displays any important notices the user would be interested in, such as if the water tank needed a refill or the temperature of the room was unsuitable for the plant. Users will also be able to select different settings regarding the care of their plant, so if an experienced plant grower wanted to, they could have minimal assistance. The web app will also include a database for different plant profiles that would help users take care of different types of plants. These profiles would include information such as optimal room temperatures and moisture content. The web app collects data from the sensors to compute notifications, and also logs the data in graphs so users can track the long term progress of their plants.

# 6 Project Management

## 6.1 Schedule



## 6.2 Individual Responsibilities

- Anny Ni
  - Primary: Web app software
  - Secondary: Low level programming
- Edwin Cho
  - Primary: PCB design and assembly, mechanical design and manufacturing, system integration
  - Secondary: Driver code
- Grace Lee
  - Primary: Web app software
  - Secondary: Low level programming
- Raymond Xu
  - Primary: Embedded Programming
  - Secondary: communication between sensors and MCU

## 6.3 Budget

Model & Description	Unit Cost	Units	Total Cost
[NUCLEO-F091RC, M0] Microcontroller	\$10.99	1	\$10.99
[NUCLEO-F103RB, M3] Microcontroller	\$10.99	1	\$10.99
[NHD-1.69-160128ASC3-ND] OLED Display 1.69"	\$24.35	1	\$24.35
N,P,K,pH 20 Tests Each, Total 80	\$29.82	1	\$29.82
[TCS34725] RGB Color Sensor	\$7.95	1	\$7.95
[TSL2591] HDR Digital Light Sensor	\$6.95	1	\$6.95
Female/Female Jumper Wires	\$3.95	1	\$3.95
298:1 Micro Metal Gearmotor	\$15.95	1	\$15.95
Pololu Micro Metal Gearmotor Bracket Pair - Black	\$4.99	1	\$4.99
[DRV8838] Single Brushed DC Motor Driver Carrier	\$3.49	1	\$3.49
Stainless Steel Ball Bearing Flanged with Extended Inner Ring	\$6.93	1	\$6.93
Optically Clear Cast Acrylic Sheet 1/16" Thick, 12" x 24"	\$8.98	1	\$8.98
[BME280] I2C or SPI Temperature Humidity Pressure Sensor	\$19.95	1	\$19.95
chirp! the plant watering alarm	\$15.00	1	\$15.00
Pololu 3.3V Step-Up/Step-Down Voltage Regulator S7V8F3	\$5.95	1	\$5.95
Pololu 5V Step-Up/Step-Down Voltage Regulator S7V8F5	\$5.95	1	\$5.95
[262-BME280] Board Mount Humidity Sensor	\$5.66	3	\$16.98
[815-ABS25-32.768K6-T] Crystals 32.768KHz 6pF -40C +85C	\$0.50	10	\$5.00
Pololu 3.3V Step-Up/Step-Down Voltage Regulator S7V8F3	\$4.95	5	\$24.75
Pololu 5V Step-Up/Step-Down Voltage Regulator S7V8F5	\$5.95	1	\$5.95
PCB Components	\$190.75	1	\$190.75
Custom PCBs	\$93.16	1	\$101.49
Custom PCBs	\$63.98	1	\$63.98
Novelty 10082 Full Depth Round Cylinder Pot, White, 8-Inch	\$12.76	1	\$12.76
Light Duty Plastic Turntable Clear Ring-Style	\$6.84	1	\$6.84
3M Glue-on-a-Roll for Plastics, Gun-Dispensed, 1/4" Wide	\$12.27	1	12.27
ZJchao Peristaltic Liquid Pump	\$18.99	1	\$18.99
<b>Total</b>			<b>\$612.20</b>

## 6.4 Risk Management

### 6.4.1 Design Risks

- Sensors are not accurate enough
  - Carefully research different sensors and alternatives for them in case they don't operate according to expectations
  - If sensors do not end up working on PCB, use the standalone sensors instead.
- Too much power usage
  - Let sensors sleep longer/update less frequently

- Search for low power component alternatives
- Allow for charging for the battery source and a power down and power up sequence to conserve energy
- Weight and size of pot may affect performance
  - Make sure that pot does not exceed a certain size so that, with the soil in it, the base can still rotate
  - Make sure that shape of pot allows for easy rotation

#### 6.4.2 Schedule Risks

- Plants take a long time to grow so testing is difficult
  - Start testing on plants earlier in the development cycle or find plants that grow very quickly
- Underestimate time required to complete tasks
  - Utilize stretch goals to keep track of features that aren't necessary and better focus on the most fundamental and important ones
  - Reestimate the effort required to complete the project by meeting regularly. This will ensure each person stays on task until the deadline.
  - Produce a basic prototype as quickly as possible so that there is more time to test and add new features

#### 6.4.3 Resource Risks

- Sensors/fragile parts may break or malfunction
  - Order duplicates of parts in case of failure
  - Have backups in case of failure
- Plants might die as we begin testing with a prototype version
  - Perform initial system tests without a plant, and add plant life only to late stage tests
- People get sick, fall behind, lazy, etc.
  - Have overlapping responsibilities so team members can pick up the slack for other members
  - Constant communication among team members so that we know when somebody is falling behind

## 7 Conclusions

### 7.1 Lessons Learned

#### 7.1.1 Technical

- Start PCB design earlier, so that the PCB can be ordered in time for a possible second board iteration. That way more testing can be done, and additional boards can be ordered and improved upon.
- We ran into some issues with some of the sensors we ordered, and learned that it is best to order multiple copies of each sensor in case one of them is faulty or is lost or damaged. Not all sensors are guaranteed to work the way we expect.

#### 7.1.2 Management Related

- Order parts earlier so that testing can be accomplished sooner, and more time can be spent on putting the system together rather than waiting for a single part to arrive.
- In case parts are not what they were expected to be, ordering should happen earlier, especially so that new or substitute parts can be ordered and tested.
- Work ought to be divided more evenly, into smaller tasks so that each person always has something to work on concurrently.
- Project timeline and todos should be considered in terms of smaller, more accomplishable milestones so people know what they can work on and tasks can be completed in a timely manner.

### 7.2 What would we do differently?

- Include NPK testing in our design. An automated NPK testing process would be useful for a plant owner especially if it comes with automated fertilizing. Although not as popular for houseplants, fertilizing would be quite useful for farming purposes.
- Include a plant during more steps of testing so more data could have been collected for real plant growth and a database of settings could have been generated from the collected data.
- Possibly a different PCB design more similar to the stick-like shape of chirp that has all of the sensors on it so that it can be easily stuck into the soil and incorporated into the pot. This would benefit our light sensor placements and allow for an easier packaging of our components for the final product.

### 7.3 Future Work

- Deploy the web app, as it is currently hosted locally.
- Add more features to the web app, such as user authentication and email notification. That way the user can receive email updates on their plants status.
- Add more fields to the web app configuration page to make use of more sensor data. Additional sensor data should also be used to compute the current status, as displayed on the web app dashboard and on the OLED display. Charts should be added as well to track readings from additional sensors. Additional sensors include: sunlight, humidity, pressure, and moisture.
- Improve presentation and packaging so that the system can be easily attached or removed from a plant.
- Use multiple sunlight sensors and use the data from sunlight sensors to determine the degree of rotation of the base.
- Configure a working moisture sensor and use data from moisture sensor to determine when and how much to water the plant.
- Monitor the status of the water reservoir so that the user can be notified when it needs to be refilled.
- Manufacture and use a PCB with sensors rather than individual off the shelf sensors. A working PCB will allow for a distributed system of multiple boards, to acquire data from more sensors.

## 8 Related Work (Competition)

### 8.1 Parrot Pot

One similar product, called the Parrot Pot, is slated to be released in April 2016. It is being marketed as an automatic intelligent watering system because while it does have sensors, it does not actually interact with the plant outside of watering it. Parrot also has a plant database of over eight thousand different plant profiles to provide plant specific information. In addition, they plan to provide alerts and notices regarding their plant to users through a smartphone app. While it would be difficult to compete with Parrot's large database, our product offers a few advantages over the Parrot Pot. Specifically, the Parrot Pot can only water the plant, and does not automatically rotate the plant to evenly spread sunlight. Additionally, we plan to monitor more soil elements than the Parrot Pot.



## 8.2 DIY Automatic Plant Waterers

Several different types of DIY automatic plant waterers can be found. These designs are generally very basic and involve users buying various parts and constructing the plant waterers themselves. Creation of these products is done individually, and requires both a substantial amount of effort and technical knowledge that most users would not care to use. Additionally, most designs are quite basic and lack any sensory information or user interaction.

## References

- [1] Adafruit. Chirp! the plant watering alarm.
- [2] Kelly Hansen. Is full-spectrum light necessary for plant growth? *Horticultural LED lighting*, 2003.
- [3] Heliospectra. What light do plants need?
- [4] Chris Hoffman. E ink vs. lcd: Which screen is best for reading? *How-To-Geek*, 2014.
- [5] Jungseed.com. 3-way digital soil analyzer.