ECE 445

SENIOR DESIGN LABORATORY

PROPOSAL

Predictive Plant Care

Team No. 58

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1 Introduction

1.1 Problem

Having a plant in your house can be a great way to liven up the room. However, many plants require consistent, oftentimes everyday care, and forgetting to take care of a plant can be detrimental to the plant's health. Leaving a plant unattended for a long time (such as going on a vacation) can also result in the plant dying out unless it's a low-maintenance plant that can survive for that long.

1.2 Solution

In order to eliminate the dependence on human interaction, we will create a plant care system that will take care of the plant's various needs such as water, sunlight, soil pH and nutrients. Each of the respective resources will have a sensor that monitors how much of that resource the plant has (such as the moisture level of the soil, how much light the plant is receiving, and soil pH). The plant's needs will be taken care of automatically based on either time or sensor outputs. Light will be administered predictively using a PID controller.

Our overall goal is to keep a plant alive for a long period of time. Specifically, we will be testing using a sunflower and we want to keep it alive and thriving throughout our time in the class. This will involve taking care of it on our own until we get our system working, but once we do the system should be able to take care of the plant on its own completely unless someone wants to put in some sort of manual input.

1.3 Visual Aid

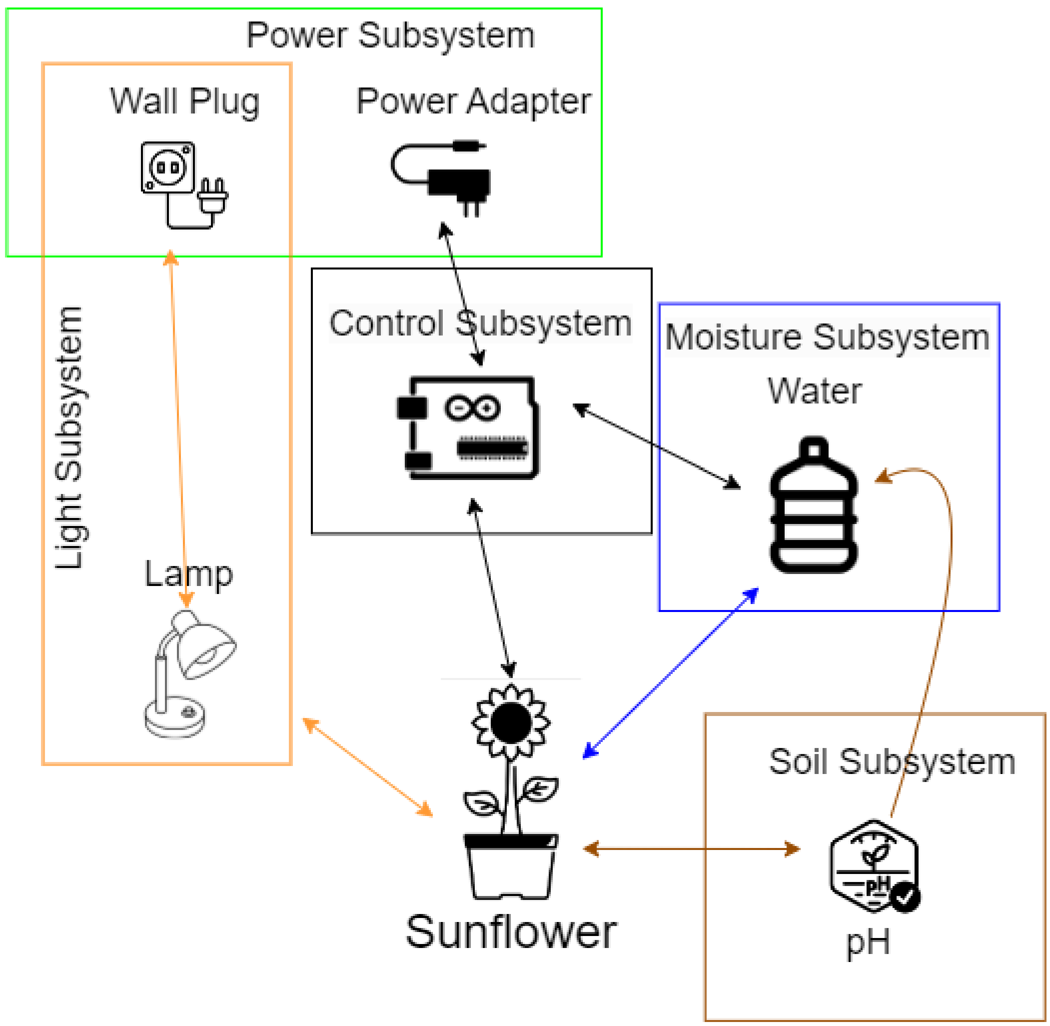

Figure 1: High level diagram of the Plant Care system

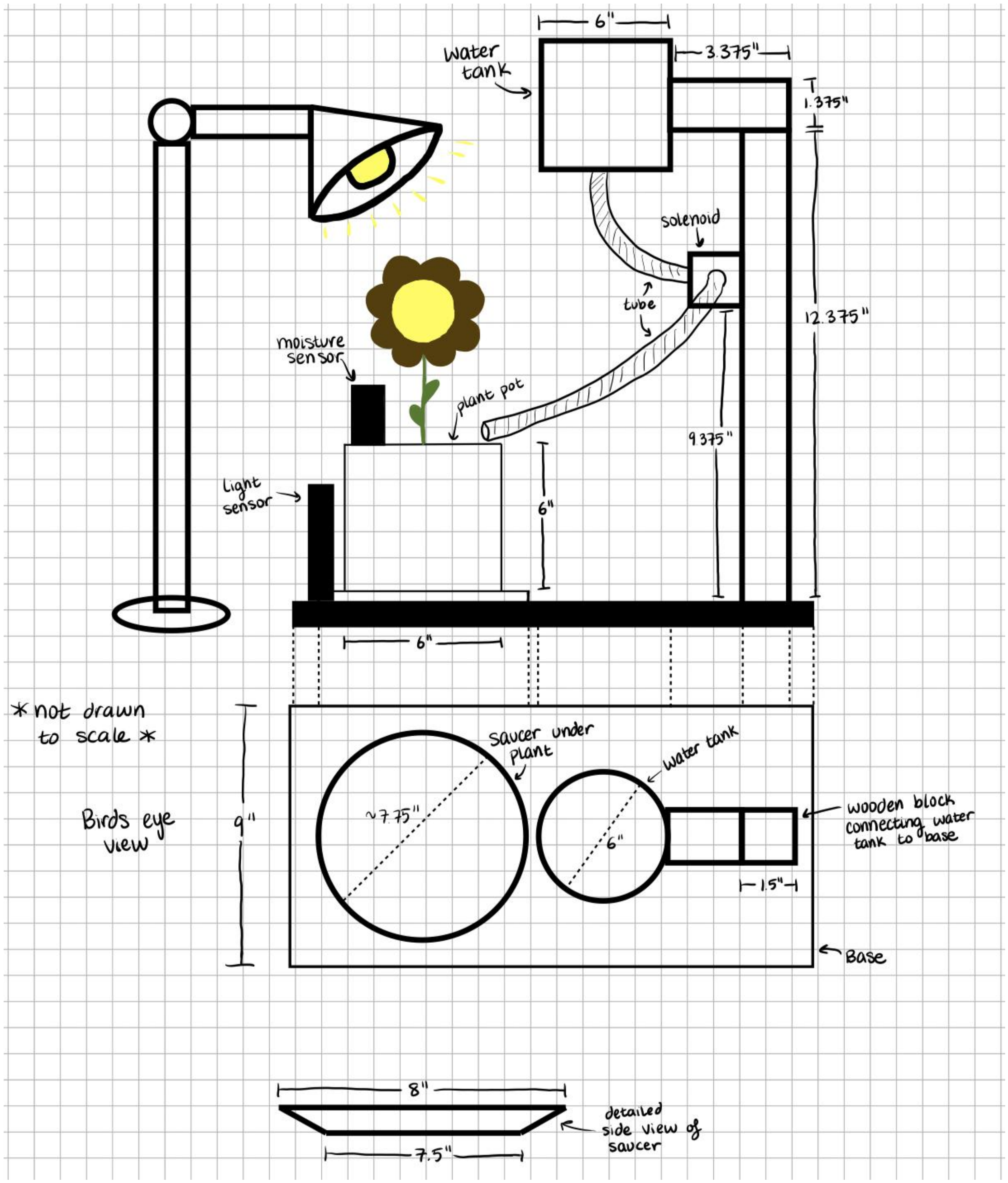

Figure 2: More detailed visual aid of the Plant Care system

1.4 High-Level Requirements

1. The plant (sunflower) is able to grow at least 6 inches and produce one flower.
2. Light levels are able to be maintained between 12 and 20 Daily Light Integral (DLI) for a sunflower.
3. Moisture levels are able to be maintained between 12.1%-13.1% water weight per total weight (water + soil) during flowering stages and 10.5%-11.5% water weight per total weight during other times for a sunflower.
4. pH levels are able to be maintained between 6.5 and 7.5.
5. The device is able to receive and provide care for different plant requirements.

2 Design

2.1 Block Diagram

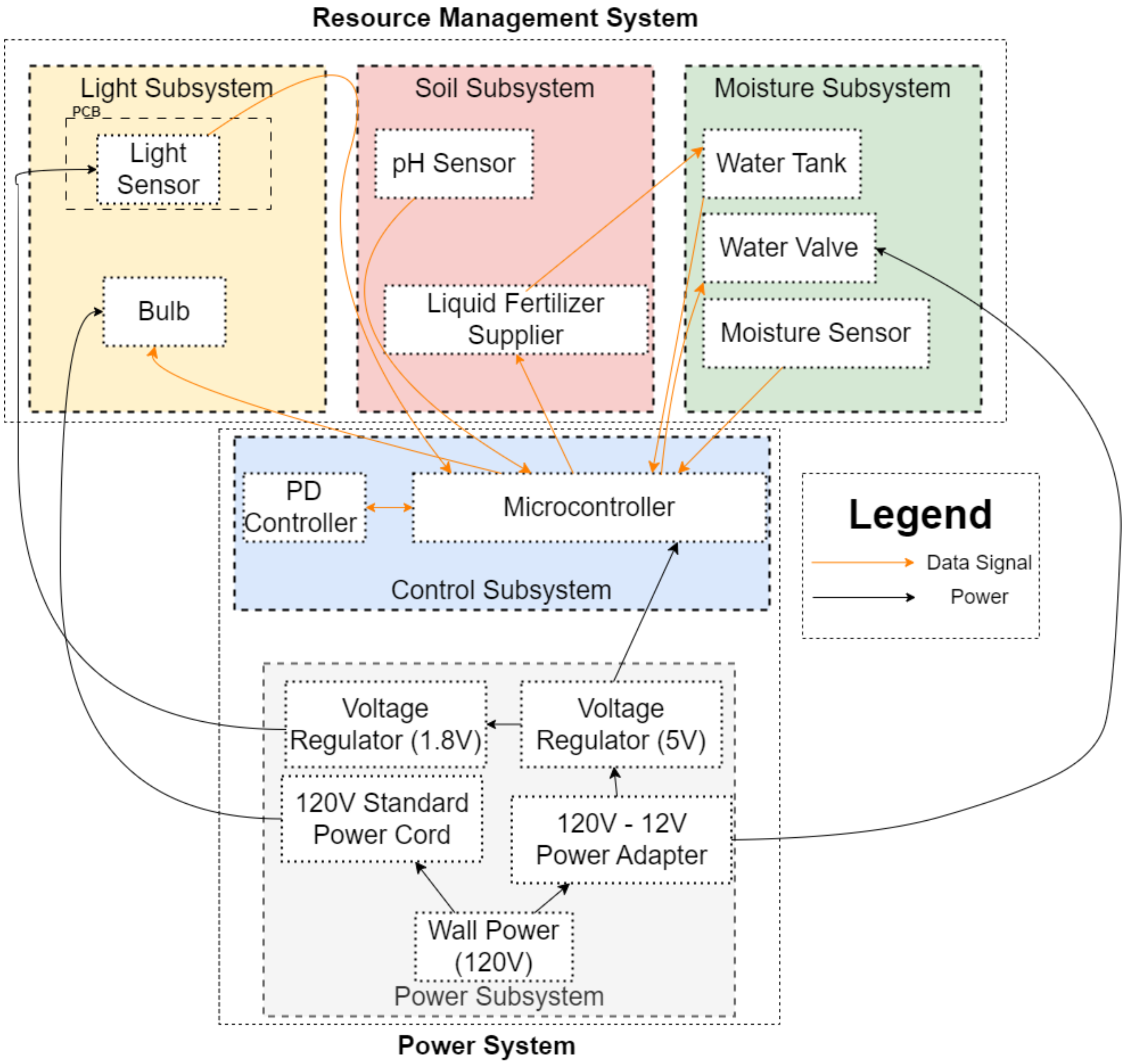

Figure 3: More detailed block diagram of the system

2.2 Moisture Subsystem

2.2.1 Overview

The moisture subsystem contains the water tank, water valve, and moisture sensor. This subsystem is one of the most important subsystems of the device. We will be using the FC-28 soil moisture sensor. This sensor works by measuring the resistance between its two probes. The higher the resistance, the lower the water content of the soil. The output value ranges between 0-70050, 0 being 0% water content and 70050 being 100% water content.

The soil moisture sensor will send a signal to the microcontroller, providing updates on the level of moisture in the soil. When the moisture level gets too low, the microcontroller will send out a timed signal to the solenoid, releasing water to the sunflower for a set period of time.

We can calculate the amount of water needed using the field capacity and wilting point of the soil used. Field capacity is the limit of water held in the soil without draining. Wilting point is the minimum amount of water in the soil that a plant can extract. Sunflowers thrive best in sandy loam soil. Sandy loam soil has a field capacity of 0.23 inches of water per inch of soil depth and a wilting point of 0.10 inches of water per inch of soil depth. This means that the available water capacity is 0.13 inches of water per inch of soil depth. Sunflowers grow best in moisture levels of 80% of field capacity during flowering periods and 70% at other times. This means that the optimal moisture levels using sandy loam soil for a sunflower would be 12.6% during flowering stages and 11% at other times (for calculations see tolerance analysis).

2.2.2 Requirements

The water subsystem needs to be able to do the following:

1. The moisture content of the soil must be consistently monitored (once every 5 seconds).
2. Water must be dispensed with a timed release when the moisture content is low.

2.3 Light Subsystem

2.3.1 Overview

The light subsystem contains the light sensor and the lightbulb. This subsystem is also one of the most important subsystems of the device. While the sunflower is still growing (pre-flowering), it is recommended to have a Daily Light Integral (DLI) of 12-16 mol·m-2·d-1. Once the sunflower bud emerges, it is recommended to have a Daily Light Integral of up to 20 mol·m-2·d-1. The DLI is the amount of Photosynthetic Active Radiation (PAR) per 24 hours. PAR is the type of light required for photosynthesis to occur. To encourage flowering, it is recommended to have a photoperiod of more than 12 hours but less than 20 hours a day. The photoperiod is the amount of time a plant receives light within 24 hours. With the PAR38 GE Grow Light for Plants, it supplies 50 micromoles per second of PPF. This means that to supply a minimum of 12 mol·m-2·d-1 of DLI, excluding natural light, this light would need to be on for a minimum of 14.5 hours a day. To supply a maximum of 20 mol·m-2·d-1 of DLI, excluding natural light, this light would need to be on for a maximum of 24 hours a day.

We will be designing our own PCB that will contain the light sensor system. We will be using the AS7341 – 11-Channel Spectral Color Sensor to measure and calculate the photosynthetic photon flux density (PPFD) for our system. We can then use the PPFD to calculate the DLI. The PPFD is the amount of PAR that reaches the plant.

We will also be creating a PID controller to control the duration of time that the light is on. The light sensor will be an input into the controller, which will take into account the natural light as well as the light from the light bulb. The PID controller will aim to achieve 14 mol·m-2·d-1 of DLI each day during the growing phase, and 18 mol·m-2·d-1 of DLI each day during the flowering phase.

2.3.2 Requirements

The light subsystem needs to be able to do the following:

1. The light sensor must be able to measure the PPFD for the system.
2. The PID controller must be able to monitor and control the light duration between 12 and 20 mol·m-2·d-1 of DLI.

2.4 Soil Subsystem

2.4.1 Overview

The soil system will be in charge of determining the state of the soil over time through monitoring different qualities of the soil. Specifically, the most important quality that we want to measure is the pH of the soil. We want to use our microcontroller and build a sensor utilizing its aspects in order to detect the value of pH. Typically, pH of soil wants to stay between 6.5-7.5, so that is our target range. If the pH is too low or too high, the plant's caretaker will be notified by a visual on the system that will let them know to add certain materials to bring the soil level back within range. If possible, our soil subsystem will also monitor the nitrogen levels in the soil and resupply nitrogen should it get too low.

2.4.2 Requirements

The soil subsystem needs to be able to do the following:

1. The pH and content of the soil must be monitored moderately often (at least once a minute, ideally constant).
2. Users must be notified of the need to fertilize the soil in some way once pH or levels are outside the specified range.
3. System must be able to resupply a small amount of fertilizer to restore nutrients or pH solution to lower pH.

2.5 Control Subsystem

2.5.1 Overview

The control system will connect the sensing system and power through to the microcontroller to allow every component to work together. It will be directly connected to the sensing systems so that if any of these systems have an overabundance or lack of resources, the microcontroller can send commands to give less or more resources respectively. The microcontroller used for this project will be the ATMega328P-AU.

2.5.2 Requirements

The control subsystem needs to be able to do the following:

1. The control system must be able to utilize the capabilities of the microcontroller to send out and read in signals that will affect the automation of the entire plant care system.
2. The microcontroller must be able to send signals (mostly 5 Volts) out to multiple different devices that are connected to it.

2.6 Power Subsystem

2.6.1 Overview

The power subsystem is what will provide power to the rest of the subsystems. This will be done through a 100-240V AC to 12V DC power adapter that will take power from the wall and send it to a voltage regulator, converting that down to 5 Volts. 12 Volts is also used to power the solenoid in the moisture subsystem. The 5 Volts will then be used to power the microcontroller. The microcontroller will then power most of the other sensors through several 5V pins. The lightbulb will be powered by a separate wall plug.

2.6.2 Requirements

The power subsystem needs to be able to do the following:

1. Power system must be able to provide the requisite amount of voltage to each subsystem that requires it.
2. Power system must be able to provide power to multiple devices without overloading.

2.7 Tolerance Analysis

In order to accurately create a model for the moisture level of the plant, we have to have some way for the system to calculate the water moisture range that would be suitable for the plant. This is a little risky since it involves calculations as it goes along and finding out a good value based upon the data in a certain amount of time. We don't want our moisture level to be too high or too low, so the system needs to find a good balance. However, we can compare our plant and the area of the soil that our plant is in to other similar cases in order to provide a rough estimate for how much moisture our plant may need each day. From there, it should only need to make rough changes in order to find a good, consistent moisture addition.

The optimal moisture content of the soil depends on which soil is used. We will use sandy loam soil. We can find the optimal moisture of the soil based on the soil's available water capacity and the sunflower's optimal water depletion. Available water capacity is the field capacity subtracted by the wilting point. The field capacity is the maximum water held in the soil without draining due to gravity and the wilting point is the minimum amount of water in the soil in which a plant could still extract water. Sandy loam soil has a field capacity of 0.23 inches of water per inch of soil depth and a wilting point of 0.10 inches of water per inch of soil depth, which means that sandy loam's available water capacity is 0.13 inches of water per inch of soil depth.

Sunflowers grow best in moisture levels of 80% of field capacity at flowering stages and 70% of field capacity at all other times. For a moisture level of 80% of field capacity, this means the optimal water content within sandy loam soil would be 0.184 inches of water per inch of soil depth, which would be 5.2 cubic inches of water per inch of soil depth. Assuming we use a 6" diameter pot with a 5" depth, this would amount to 25.99 cubic inches of water total in the pot, which is 425.9761 grams of water. The density of sandy loam soil is 1460 kg per cubic meter, which means the optimal moisture level for a flowering sunflower would be 12.6%.

For a moisture level of 70% of field capacity, this means the optimal water content within sandy loam soil would be 0.161 inches of water per inch of soil depth, which would be 4.55 cubic inches of water per inch of soil depth. Assuming the same pot size as before, this would amount to 22.75 cubic inches of water total in the pot, which is 372.8725 grams of water. Assuming the same density of sandy loam soil as previously, the optimal moisture level for a growing non-flowering sunflower would be 11%.

3 Ethics and Safety

One of the single biggest safety concerns in using our project is the lightbulb breaking and cutting the user. Also, the use of a 120V plug introduces the risk of a severe electric shock. Since both of these risks are present in our project, they pose a safety concern to any user and are of concern in regard to IEEE Code of Ethics Section I.1. To minimize the risk of shock, we can put a warning for a shock risk on the wall plug and pack the lightbulb separately with a warning of fragility and the risk of sharp glass.

The biggest way to misuse this product would be to grow illegal plants with this device. This would include mostly any plant that could be produced into illegal drugs such as opioid plants or marijuana, depending on the location. While there is not much that we can do on our end to prevent this, we can very clearly discourage the misuse of our product.

Since we will be utilizing high voltages for our lightbulb and other devices, our entire group will be taking an additional safety training as a requirement for this course. In addition, since we will be working with many electronic devices around water as well, we will try to keep our subsystems separate as long as possible, and make absolutely sure that our solenoid for our moisture system fits on well so we don’t leak any water.

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