Smart Health System for Plants

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Introduction

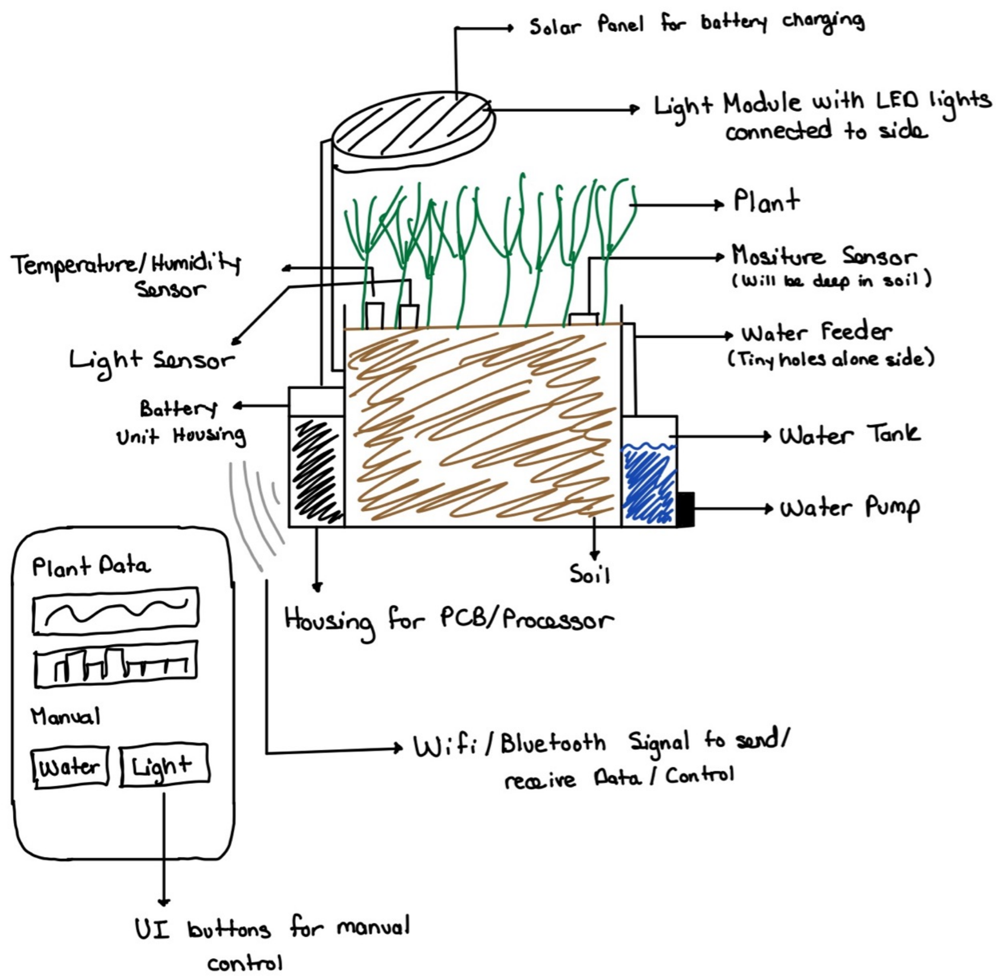
1.1 Problem

There are many families in this world that - for a variety of reasons - are away from home and have plants sitting at home waiting for them to come back and provide water and sunlight. Further, many families love to have plants but don't have time to watch over them due to jobs and busy schedules. In these times, many plants can die out causing the owners to either purchase a new plant or throw out the old one completely. This is not only a problem of neglect, but also sustainability on a broader scope.

1.2 Solution

To solve this problem, we would create a Smart Health System for Plants with a Phone UI for the owner. We would create a plant potter which is built in with our Smart Health System and provides connectivity to the owner through a UI. In our system, we would use different sensors to measure values like humidity, soil moisture and sunlight provided to determine exactly how much water/sunlight the plant will need. We then pump in water from our water reservoir straight to the roots and provide light when needed. Further, through the UI, the owner would also be able to provide manual water and artificial light when they want to and see critical values from the sensor module. Overall, this Smart Health System for Plants will provide plants with the most ideal conditions they need to grow and survive and owners will never have to worry about dead plants due to their busy schedules and family vacations. Further, this system will consist of a sensor module, microcontroller, watering system, artificial sunlight system and a phone UI.

1.3 Visual Aid

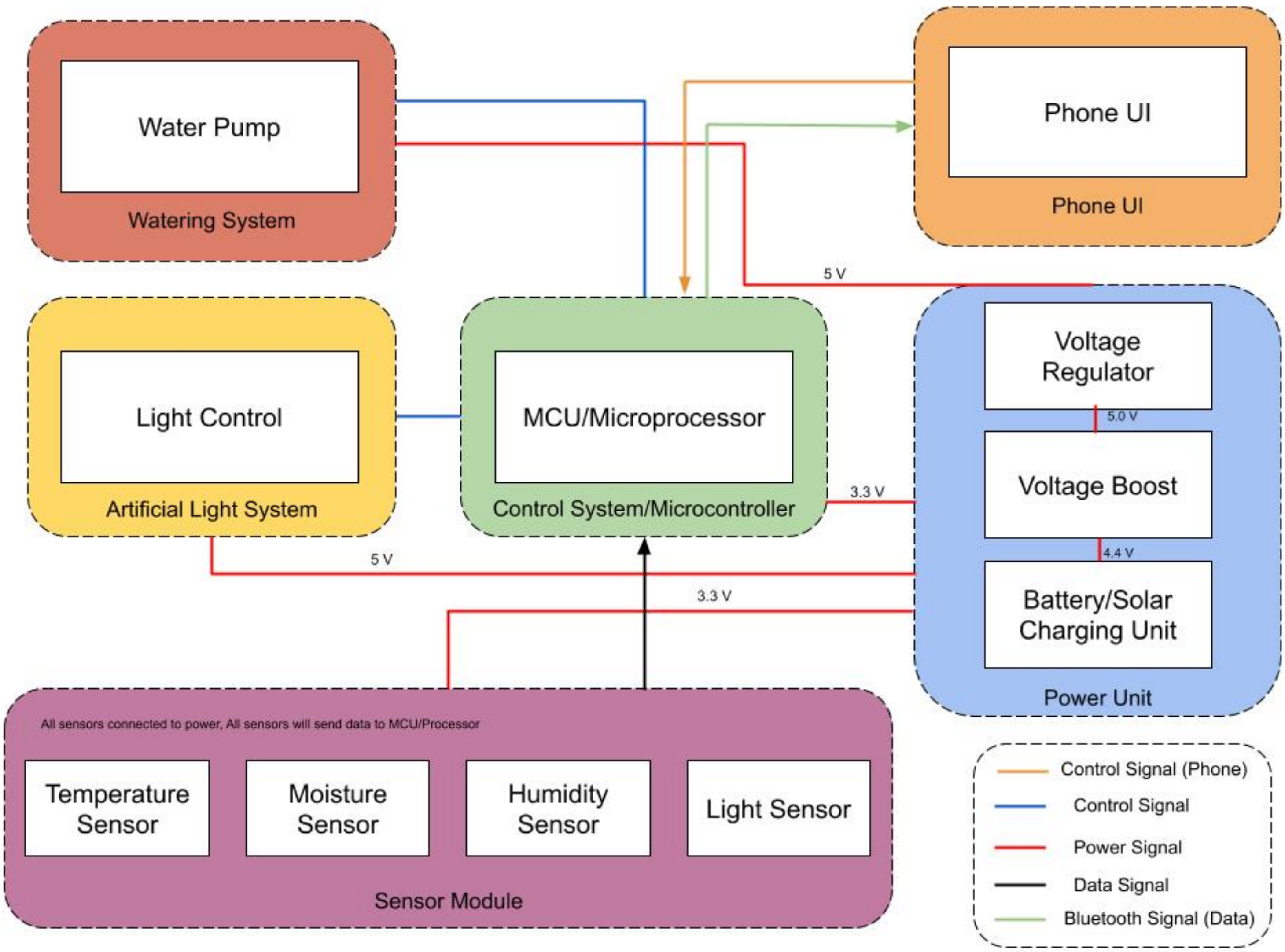


1.4 High Level Requirements

- The system should provide appropriate amount of water and light when required by the MCU/ Microprocessor to do so using our created algorithm
- The system should be able to run on battery power and recharge the battery using the solar charging unit
- MCU/Microprocessor is able to communicate with a central system that the Phone UI can poll from and aggregate plant information and metrics to display to the user

Design

2.1 Block Design



2.2 Subsystem Overview

2.2.1 Sensor Subsystem/Module

Temperature Sensor:

The temperature sensor will be used to measure the environmental temperature around the plant. It will send the data to the microprocessor to be used in our algorithm to figure out when to provide water or light

Requirement: Sensor can provide temperature with a tolerance of ±4 °F [4]
Part Name: DHT 11 Sensor
Operating Voltage: 3.0-5.0V [4]

Moisture Sensor:

The moisture sensor will be put about three inches into the soil and be used to measure the moisture of the soil. It will send the data to the microprocessor to be used in our algorithm to figure out when to provide water or light

Requirement: Sensor can provide soil moisture levels with a tolerance of ±1%
Part Name: Grove- Moisture Sensor
Operating Voltage: 3.3-5.0V [5]

Humidity Sensor:

The humidity sensor will be used to provide the environmental humidity around the plant. It will send the data to the microprocessor to be used in our algorithm to figure out when to provide water or light

Requirement: Sensor can provide humidity around the plant with a tolerance of ±5% RH [4]
Part Name: DHT 11 Sensor
Operating Voltage: 3.0-5.0V [4]

Light Sensor (Photoresistor):

The light sensor will be used to gather data on how much light is being provided to the plant. It will send the data to the microprocessor to be used in our algorithm to figure out when to provide water or light

Requirement: Sensor can provide ambient light intensity with a tolerance of ±100 lux
Part Name: Grove- Digital Light Sensor
Operating Voltage: 3.3-5.1V [3]

2.2.2 Watering Subsystem/Module

Water Reservoir:

The water reservoir will be our storage spot for water that will be fed into the plant using the water pump when needed. The reservoir will be a hard plastic container which will be used to store enough water to feed the three to four times before needing a refill. Further, to provide water to the plants, the water reservoir will have a pipe connected to the plant pot which will contain tiny holes to evenly distribute water to the plant when the pump is turned on.

Requirement: Water reservoir is able to hold water to feed the plant at least three to four times before needing a refill. Also, the reservoir is able to provide water when the water pump is turned on by the MCU/Microprocessor

Water Pump:

The water pump will be our mechanism to pump the water from the reservoir to our water pipe which has small holes feeding water into the plant. Further, the water pump will have a water outlet connector which will be connected to the water pipe feeding into the plant. Lastly, the water pump will be connected to our MCU/Microprocessor unit which will control when to turn the pump on/off based on our algorithm.

Requirement: Water pump is able to pump water to the water pipe and feed the plants. Also, the water pump is able to turn on/off from the MCU/Microprocessor when our algorithm determines the plant needs water
Part Name: Alamscn Mini Water Pump
Operating Voltage: 3.0-5.0V [1]

2.2.3 Artificial Light Subsystem/Module

LED Light (Yellow):

The artificial light system will consist of a LED ring light which will be attached above the plant to provide light like sunlight would. Further, this light will be connected to our MCU/Microprocessor which will control when to turn the light on/off based on the sensor values and our created algorithm. The main purpose of this system is to provide the plant light when there is not enough sunlight needed for the plant to grow properly.

Requirement: LED light is able to provide light to the plant from above and is able to be controlled by the MCU/Microprocessor
Part Name: WS2812 LED Ring Lamp
Operating Voltage: 4.0-7.0V (5.0V Ideal) [6]

2.2.4 MCU/Microprocessor Subsystem/Module

Microprocessor (ESP32):

The MCU/Microprocessor will be the hub of data for all the sensors used in our design. The processor will collect raw data from all of the sensors and convert it into data we can integrate into our algorithm to control our water pump and artificial light source and provide precise water and light to the plant when needed. Further, the processor will provide data to our UI through Wifi or Bluetooth connectivity which will be presented to the user in a meaningful way. Lastly, our processor will also read signals from the UI to start features like manual watering and lighting. Overall, the processor is the heart of our system and will be important in having the system work simultaneously.

Requirement: The processor can efficiently collect data from the sensors and control the water pump and light module based on the algorithm we create. Furthermore, the processor can communicate with the phone UI sending data and receiving manual control signals
Part Name: ESP32
Operating Voltage: 3.3V [2]

2.2.5 Power Subsystem/Module

Battery/Solar Charging Unit:

The battery will consist of three lithium ion batteries which will be given the option to be charged on a solar panel (outdoor use) or USB connector (indoor use). The batteries will be used to provide power to our whole system. Further, the battery unit will be connected to a voltage regulator and a voltage booster to get 3.3V for the MCU/microprocessor and sensors and around 5V for the water pump and light module.

Requirement: Batteries can provide enough voltage to the whole system and recharge when needed through the solar panel or USB connector based on location of plant
Part Name: Adafruit Universal Charger

Voltage Regulator:

The voltage regulator will take the 4.4V output [7] from the battery charger and convert this into a 3.3V output which can be passed to the sensor module and MCU/microprocessor.

Requirement: Regulator should be able to convert the 4.4V to 3.3V with a tolerance of ±0.1 V
Part Name: TLV62569 3.3V Buck Converter

Voltage Boost:

The voltage booster will take the 4.4V output [7] from the battery charger and convert this into a 5.0V output which will be passed into the water pump and light module.

Requirement: Regulator should be able to convert the 4.4V to 5.0V with a tolerance of ±0.1 V
Part Name: Comidox Voltage Boost Converter

2.2.6 Phone UI

UI:

The phone UI will be created by us using a mobile framework like React Native and a backend like AWS. We will connect our MCU/Microprocessor to a backend source like AWS where it will store and provide our phone UI data from the sensors polling at a rate of once every 2 mins. In the UI, we will provide the user useful information about their plant health and capability to manually control the light system and watering system. Overall, our phone UI will be connected to a backend source to get data from the MCU/

microprocessor and our phone UI will also connect to the MCU/microprocessor to provide manual control options to the user.

Requirement: Phone UI should be able to connect to the MCU/microprocessor to provide manual control to the user. Further, phone UI should be able to get data from the sensors through some backend source like AWS

2.3 Tolerance Analysis

When discussing a tolerance analysis of the system, we can consider points of failure within specific components, and how that might lead to overall system failure. Let's consider the soil moisture sensor. The specified sensor can detect soil moisture with a tolerance of $\pm 1\%$. Users will input metrics about specific plants in the bed - depending on these metrics, an ideal soil moisture level will be determined, alongside other conditions. A problem arises when determining when to add water to the plant environment - if the moisture is too low in regards to the ideal environment moisture, then this will trigger the watering feature. A point of failure here is if the system isn't calibrated correctly - say our ideal moisture is 30%, with a tolerance allowing values between 29% and 31%. In the case that the watering feature exceeds this threshold, we'd have to take measures of increasing sunlight in order to reduce moisture levels. This could easily get stuck in a cycle - where moisture dries up, and tolerance of the sensor is too small to accurately account for how much water to inject into the soil in order to keep moisture levels. This will not only affect plant health, but could also overload the system - if the watering system is constantly drawing power to account for lack of moisture, and the sunlight providing system has to account for overshoots in moisture injected, this could potentially overload the power supply.

Another factor to consider is the health of the sensors themselves. Over time the soil/moisture/sunlight sensors could lose efficacy, and contribute to the system functioning ineffectively. At first glance, there isn't much information on the "rate of decay" of these sensors available from manufacturers, so we plan to test this metric when starting to build our system. Through this, we will be able to mathematically simulate the health of sensors, and provide indicators as to when the sensors need to be replaced to the user. This is an important component in determining failures in the system, and will be tested further along in our project.

Ethics & Safety

When considering ethics and safety of the product, we must consider potential pitfalls and safety concerns in the products being placed in an individual's living space. We must consider the components that exist in the system - primarily the microcontroller, sensors, and watering/sunlight mechanisms. Although there isn’t a huge safety concern at first glance, potentially malfunctioning or overheating of the microcontroller or sunlight systems may impose a risk of fire depending on where the device is located. In order to “avoid harm”, we plan to ensure that elements are properly insulated, and don’t impose a risk of mal-action in the case of misuse or malfunction.

On the note of ethics, our system simply attempts to aid families and plant owners maintain plants in a more convenient manner - this doesn’t pose an ethical risk in regards to a broad objective. In accordance with the IEEE Code of Ethics Section 7.8.I.1, we will strive to implement an ethical design and follow all of the sustainable practices possible, while not endangering the public or the environment [8]. Additionally as stated in section 7.8.I.2, we plan to improve society’s understanding and educate them of our project’s capabilities, all while doing so in a safe and ethical manner [8]. As per section 7.8.I.5 , we plan to accept constructive criticism regarding our work, and will correct any and all errors regarding our project and its overall design and implementation [8]. This feedback and criticism will be provided to us by our professors, TAs, and even amongst ourselves. Furthermore, we plan to only perform tasks for which we are qualified for after the adequate technical training, as stated in section 7.8.I.6 [8]. To fulfill this, we are required to perform activities such as the ‘Lab Safety Training’, ‘CAD Assignment’, and ‘Soldering Assignment’ so that we are fully aware and prepared to use tools such as CAD to assist with building PCBs, and implement proper soldering practices to ensure no one is harmed. Finally, according to section 7.8.III.10, we will make sure that as a group, all three of us will check in on each other to make sure that we uphold the IEEE Code of Ethics at all times and encourage ethical and safe behavior and practices at all times [8].

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