ECE 445: Plant Health Monitor

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1. Introduction

1.1 Objective:

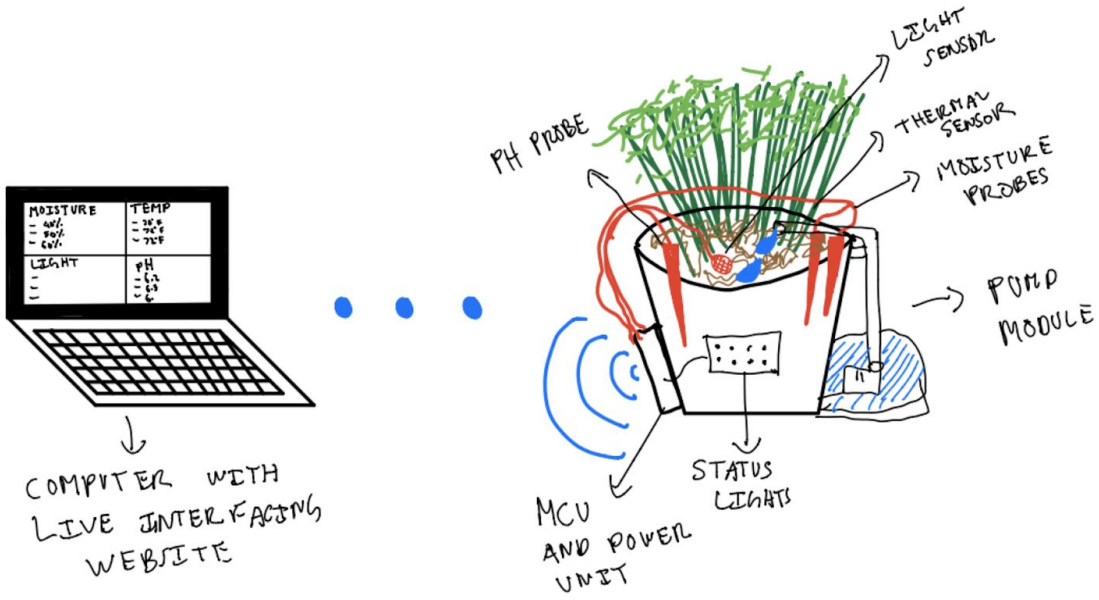
The main issue with growing plants at home is monitoring their health. Plants regularly dry out or even die if not given the proper attention. Many people do not know the proper way to care for a plant and this project attempts to remedy this problem by giving the grower precise measurements about the plant's health and automating repetitive tasks.

We are planning to make a multi sensor device that can accurately measure various soil health indicators in real time, so the user can get live feedback and can adjust the conditions accordingly. The device will also allow watering of the plant automatically when needed. This would provide the user with a way to conveniently check on and maintain their plants even when they are not around.

1.2 Background:

Growing plants at home is a hobby that many people enjoy but maintaining the health of the plants is not always easy. The main problem with plant health usually comes in the form of the soil. This includes bad pH levels, under/over watering the soil, temperature, and insufficient lighting. This way people do not have to do their own research into the more difficult aspect of plant growing, soil health. An additional concern for houseplants is travel. Being away from home for extended periods can leave plants dry and withered from the lack of watering and basic care. This project also attempts to remedy that by having an auto watering system.

1.3 Physical Design:



1.4 High-level Requirements:

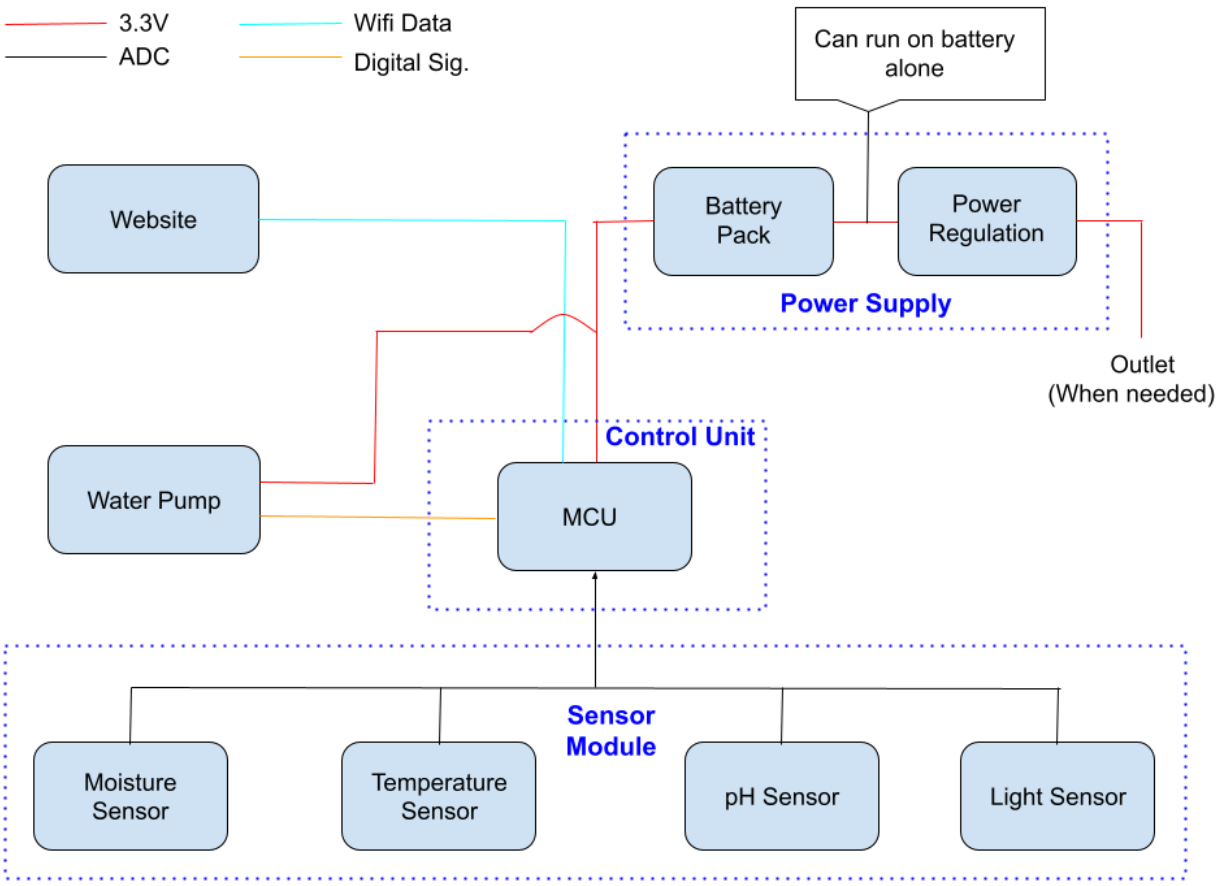
Should be able to get information from the various sensor modules and relay information to the user through Wifi and status lights at least every 5 minutes.

This project must be able to automatically adjust the moisture level of the soil to achieve a target level within ±10% of in 1 hour.

Must be able to work indefinitely while connected to an outlet and for at least 3-5 days on a full battery charge.

2. Design

2.1 Block Diagram:



2.2 Functional Overview:

- Control Unit
  - The ESP32 microcontroller will sample the sensors periodically and use calibrated algorithms to convert these measurements into meaningful data. [1] This data will then be sent over the integrated wifi antenna to be published on a website where the data can be reviewed. The data will also be used to control several warning lights indicating plant health and battery level. This is critical for the first two high-level requirements because it processes and publishes raw data from the sensors as well as controls the pump.
- Sensor Module
  - The moisture sensor will simply be a probe consisting of two electrodes as part of a voltage divider. An ADC reading of this sensor will indicate the resistance of the soil which can be used to track moisture levels. Testing will be needed to determine the optimal moisture level and the analog measurements taken at this level.

    - The temperature sensor will be composed of a thermistor connected to a voltage divider where the resistance of the thermistor can be measured using an ADC. Using this and the manufacturer provided data relating resistance to temperature, the ambient temperature can be recorded.
    - The pH sensor will be composed of a pH electrode connected to either an included module for processing the data, or it will be processed using op-amps and measured by the microcontroller's ADCs.
    - Similarly to the temperature sensor, a photoresistor will be used to track ambient light levels and the datasheet can be used to match the electrical measurements to real world data when an ADC reading is taken.
    - These sensors are important for the first two high level requirements because it theaters raw data to be shown to the user and is used when deciding when to turn on the pump.
- Power Supply
    - The power supply will consist of several components. The first would be an off the shelf USB power brick to convert from 120V AC to 5V DC. A micro USB cable will plug into the PCB, and the power from this cable will be used in conjunction with a battery charging IC to charge the small lithium ion battery. A linear regulator will also be used to regulate the voltage going to the rest of the system, and an ADC from the microcontroller will be used to measure battery voltage in order to report charge level. This is important for the third high-level requirement because it allows the system to function both plugged in and with a battery. It also provides power that is needed for the first two high-level requirements.
- Website
    - The website itself will at the very least display the sensor values for the user to see. This data will be sent over wifi from the microcontroller. This can be improved to contain expected values and thresholds for various kinds of plants, giving the user necessary feedback on values for their specific plant species. This relates to the first high level requirement because it allows the user to review the collected data and therefore monitor the plant's health remotely.
- Pump
    - This module will contain a basin with water and a pump with a tube. The input will be a digital signal from the MCU. This will be in the form of either supplying power to the pump or not through a driver. The output will be the mechanical function of actually feeding water into the plant.
    - The pump should be able to feed in incremental amounts of water and then wait for the next signal from the MCU. The moisture sensor will monitor soil moisture for changes after water has been pumped to determine if more water should be added. This allows the moisture level to be accurately changed to the desired level in order to fulfill the third high-level requirement.

2.3 Block Requirements:

- Control Unit
    - This unit has several ADC connections to each of the sensors and the battery. It will also connect to 2.4 GHz wifi using an internal component.
        - Must be able to take consistent and reliable ADC measurements and process these inputs at least every several seconds.
        - Must be able to send wireless signals on demand without interruption.
        - Status lights must be indicative of the most recent measurements taken.
- Power Supply
    - This module will take an input of 120V AC from a wall outlet, and output a constant uninterrupted 5V/3.3V regardless of whether it is plugged in.
        - Module must be able to supply 500 mA at +/- .1V from the target voltage.
        - Module must continue to output the target voltage regardless of the charge level of the battery or whether USB is plugged in.
- Sensor Module
    - This module will take in a 3.3V input and will consist of 4 different sensors, each measuring one specific plant health indicator. These indicators include soil moisture, soil temperature, light, and soil pH. The output will be each measurement value going to the MCU.
        - All the sensors must work simultaneously with each other to send real data to the MCU at least every second.
        - Sensors must provide consistent readings so that their values are within 1% of past measurements in the same conditions.

- Pump Module
    - This module will take an input of either turning on or off from the MCU. The output is the mechanical feeding of water into the plant pot from the basin.
        - Pump must be able to accurately
        - Pump must be able to pump a cumulative 500 mL of water per day from the basin to the pot.

- Website
    - The website will receive and display the information from the sensor module through wifi via the ESP32 MCU.
        - The website will receive the desired threshold levels for temperature, moisture level, light level and pH then send them to the MCU for appropriate response.
        - Website will display pH, moisture, temperature, light level and battery charge measurements.

- The website should always display data from the plant that is no older than 30 minutes. More recent data will be shown if a drastic change has occurred.

2.4 Risk Analysis:

The highest risk to the success of the project lies within the integration of the hardware components to the website. This requires knowledge of components that none of us have experience with, so getting the data from the MCU to the web based interface will be our biggest challenge.

We are also apprehensive about making our own pH sensor accurately, since it is a very complex component. Making an accurate one without spending too much and using low level electrical components will be a challenging task.

3. Ethics and Safety

Our main safety concern is the battery portion of the project. Improper use of rechargeable battery components can lead to them overheating or even exploding, so we plan to ensure that the electrical connections to the battery portion don't draw more power than the safe level. The project also involves water being pretty close to the electrical components because of the automatic watering mechanism.

This created the need for some way to ensure that these components, especially the batteries, don't come in contact with the water. For this, we plan to have some sort of 3D printed housing for the electrical components. This is also to ensure that they don't come in contact with the soil and just the sensor probes do.

There are some ethical considerations from the IEEE Code of Ethics that we are keeping in mind while working on this project. The main one is #1: 'to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment;'. [2]

We know that there are certain harmful metals like cadmium and arsenic that can enter the soil or deposit itself on the plant through various sources like cigarette smoke and water. This is a big issue for home plants since a majority of these tend to be herbs and small vegetables and fruits that people use in their food. Exposure to such harmful materials can cause health complications to the grower in the long run. Our product aims to safeguard their health and safety by using the pH sensing technology to ensure that the soil pH is maintained at a safe 6.5-7 range. [3] The use of a peristaltic pump will also allow the water to be pumped without risk of contamination.

References

[1] Espressif Systems, “ESP32 Series Datasheet,” 22-Jan-2021. [Online]. Available:https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf. [Accessed: 17-Feb-2021].

[2] Espressif Systems, “ESP32 Hardware Design Guidelines,” 25-Sep-2020. [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32_hardware_design_guidelines_en.pdf. [Accessed: 17-Feb-2021].

[3] *IEEE Code of Ethics*. www.ieee.org/about/corporate/governance/p7-8.html.

[4] Support, Extension Web. *Should I Worry about Heavy Metals in My Garden Soil?* 2 Aug. 2019, extension.oregonstate.edu/food/safety-storage/should-i-worry-about-heavy-metals-my-garden-soil.