Auto-Adjustable Micro-Terrarium

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1. Introduction

1.1 Objective and Background

The Covid-19 pandemic has sparked a nationwide interest in gardening as it is a great way for people to pass time during shelter-in-place while learning about a fascinating new hobby. In some areas in the nation, demand for seeds even increased by upwards of 300%[1]! However, with the increased interest comes the confusion from novice gardeners -- taking care of a plant is not easy work. In order for plants to have the optimal growth rate, many factors need to be considered: the most widely agreed upon factors include temperature, humidity, soil pH, and light[2]. For many of these gardeners, it may be a challenge to maintain optimal conditions for the plants they grow, as their backyards may be lacking the expensive equipment or complex setups that more experienced gardeners have. As a result, they may have trouble germinating and growing the plants they want.

For our project, we want to mitigate these gatekeeping factors as much as possible such that gardening will only require a low level of expertise. Our goal is to create a programmable micro-terrarium to assist the novice gardener in growing and maintaining their plants. With just some user research and input into the device, our project will create the best environment for plants which will keep the terrariums' humidity, temperature, and pH in the desired range. Thus, gardeners can enjoy growing their plants without worrying about micromanagement. There are already a few products similar to an adjustable terrarium online; however, none tackle the difficult problem of maintaining soil pH, they are too large and not rapidly scalable for a wide variety of plants, or they are designed for industrial purposes and experienced botanists. We will design and build an adjustable terrarium with these considerations in mind that can self adjust or use some manual inputs to regulate the environment.

We will use Basil as a test plant since it is a popular plant with a fairly small size. Its PH range is 6.2 to 6.8; the temperature is 70℉ to 85℉; the light should be full sun/ 14 to 18 hours; the humidity is between 40 to 60% .[3]

1.2 High-Level Requirements

- The terrarium has an easy-to-use user interface, understandable and operable by any inexperienced users.
- The terrarium size will fit dimensions of 6”x6”x12”, ideally under a $100 price point.
- The terrarium will maintain the environment the user inputs, and self-adjust should certain conditions fall outside of optimal ranges.

2. Design

In order for the terrarium to completely control the growing environment for the plant, we will need the device to react and adjust to changes in humidity, temperature, light and pH. To accomplish this task we will divide the logic for our terrarium into four components: the power supply, the control unit, the environment regulator, and the physical display. We will first use the corresponding sensors in the control unit to monitor the settings in the terrarium, which will feed data to a microcontroller chip. Depending on the user input, the microcontroller will then control the outputs to the heating/cooling system, the water and pH chemical valves, and the light source. The microcontroller will also interface with an embedded LED display/button interface that will let the user know/control the current settings within the environment.

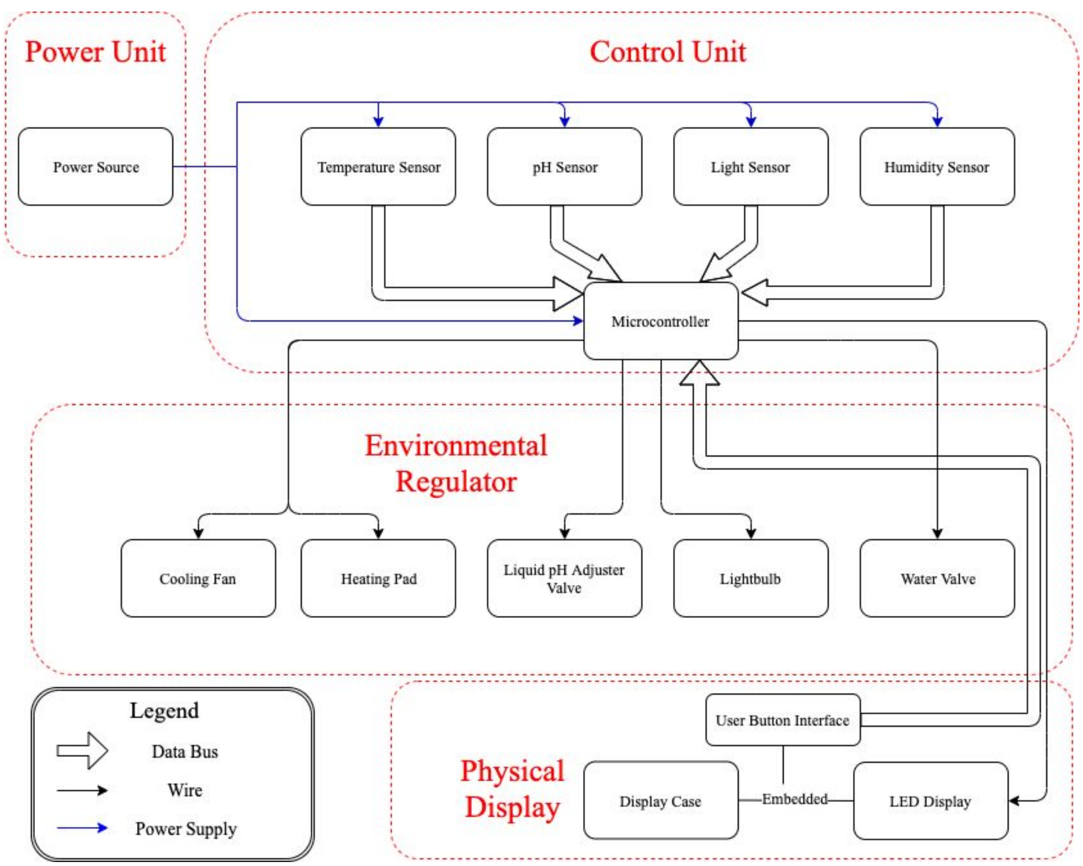

Figure 1: Terrarium Block Diagram

2.1 Power Unit

The power unit needs to provide energy to make sure that the sensors, microcontrollers, and environment regulators can continuously work. The wall plug to be our power source. The outlets usually supply a 120V AC. We will have an AC-DC converter to generate DC voltage to supply the elements of the project. Since different parts of the project require different DC voltage, we will also have a DC-DC converter to meet the requirements.
Requirement 1: The ADC has to supply 5V +/- 0.5% for temperature , soil moisture, ATmega32 Microcontroller from the wall plag.
Requirement 2: The DC to DC bulk converter has to supply modules below 5V, DC to DC boost converter has to supply modules above 5V.

2.2 Control Unit

The control unit must analyze the humidity, temperature, lighting, and PH level of the terrarium and communicate with the environment regulators to adjust those factors to the desired level.

Sensor Requirements:
Requirement 1 : All the sensors need to be waterproof .
Requirement 2: All sensors need to pass the data simultaneously and has quick response which needs to be quicker than 16 MHz, the clock cycle of the ATmega

2.2.1 Temperature Sensor

Option 1: LM35 temperature sensor can measure temperature from -55℃ to 150 ℃. The supply voltage is from 4V to 30V The output is an analog voltage that we can use an ADC to convert to digital so a microcontroller can process it. (ATmega16/32 Microcontroller has embedded ADC with it)
Option 2: HDC1010 humidity and temperature sensor[4] can measure temperature between 0℃ and 60℃. It has a supply voltage of 2.7 V to 5.5 V and the output is digital using I^2C so we wouldn't need to use an ADC to convert to digital.

2.2.2 Light Sensor

OPT3001 ambient light sensor[5] can measure ambient light from 0.01 lux to 83k lux while rejecting infrared light at an efficiency rate of 99%. It has a supply voltage of 1.6 V to 3.6 V and outputs the measurements using the I^2C interface.

2.2.3 Humidity Sensor

HDC1010 humidity and temperature sensor[6] can measure humidity at with an accuracy of +/-2% and utilizes very low power. It uses an I^2C interface to output the digital data and remains in sleep mode until it is triggered to begin measuring.

2.2.4 pH Sensor

Most pH sensors are far too expensive to incorporate into the project. However, we found a cheap pH meter on Amazon that can measure pH from 3.5 to 8[7]. It may be possible to utilize the digital readings of the meter. Otherwise, we may have to scrap the pH portion of the project.

2.2.5 Soil Moisture Sensor

Soil Moisture Sensor[8]: 5V supply, the output will change range in 0-5V which is proportional to the change in the content of water in the soil.

2.2.6 Microcontroller

Microcontroller: ATmega 32bit microcontroller chip. This microcontroller chip will read the sensors' data, communicate with the user, and give commands to the environmental regulators. The operation voltage is from 4.5V to 5.5V[9]
Requirement 1 : The microcontroller has to communicate with the sensor simultaneously.
Requirement 2 : The microcontroller has to pass the condition to the display unit to let the user understand the situation.

2.3 Environment Regulation

The environment regulators will adjust the environment based on the signal from the microcontroller. For example, if the soil moisture sensor passes a low data to the microcontroller, the water valves will open to water the plant until the sensor gives proper data to the microcontroller.

2.3.1 LightBulb

Fluorescent grows light, provides the wavelength that plants need for growth, and produces much less heat than incandescent bulbs[10]. The input voltage is 120V.
Requirement : The lightbulb needs to be set up directly above the plant to satisfy the lighting needs for it.

2.3.2 Water/pH Chemical Tubing

A 12V solenoid valve can control the flow of water or pH chemical. In normal conditions, the solenoid blocks the liquid. When a 12V applies to it, the liquid will be able to flow through the solenoid[11].
Requirement 1: The solenoid needs to have a quick response after it reads the command from the microcontroller inorder to provide the correct amount of solution.
Requirement 2 : The material of tube needs to to prevent the corruption from the chemical solution

2.3.3 Temperature regulator

An electrical heat pad will start heating when the microcontroller gives a high signal to raise the temperature. A general one needs a 5V supply.
A cooling fan will be on when the microcontroller gives a high signal to lower the temperature.
Requirement : The temperature regulator needs to maintain the terrarium at a constant range of temperature, the control switch needs to be sensitive.

2.4 Display unit

The display unit allows the user to set input for the device. The user can choose the manual to adjust the environment or the terrarium automatically does it. There is an LED to display the existing conditions to the users. If the user chose to manually adjust the environment, the LED will notify the user and guide them to do the corresponding adjustment. The display case is under the considerations for conductivity to keep conditions as constant as possible. The display unit meets our high level requirements to set up a easy-to-use user interface.

2.4.1 Button Interface

In order to create a button interface for the user to interact with the display and environment, we've decided it would make the most sense to use several push buttons with corresponding labels. PB-1B-DC-2-B push button switches[12] are easy to implement and require little power.

2.4.2 LCD Display

NHD-C12832A1Z-FSW-FBW-3V3 LCD COG display[13] is 128 x 32 pixels, offering enough room to display all current conditions, then updating the user on the dynamics of the environmental regulation. Its supply voltage is 2.7 V to 3.3 V.
Requirement: The LED should update in one clock cycle.

3. Risk Analysis

The component most likely to fail would be the pH regulating component, namely the pH chemical delivery system. Commercial chemicals take around a month to fully incorporate into the soil, as they are often dry materials -- lime and wood ash to increase pH, and Aluminum Sulfate to lower pH -- that take longer to chemically react with the soil[14]. Liquid alternatives where minerals are dissolved are available; however, they are often more concentrated and dispersing them haphazardly can rapidly damage the plant. As a result, we will have to consider the tradeoffs between the dissipation time and potency of liquid regulators we use.

For the scope of this project, in order to realistically adjust soil pH as quickly as possible, we will have to use liquid chemicals. To account for the aforementioned consideration, we will directly feed tubes into the soil and closely monitor how the soil pH reacts to the chemical balancers. We will fine-tune the spacing of the drip system as well as the concentration of pH fed into the soil when pH falls outside the range setting of the device.

Should we not be able to get the pH sensors to work for the project, either due to the sensors not working well with the device or being well outside our price range, we will incorporate an additional feature in our button interface that will read in pH and time values from the user and have the valve drip for that amount of time. We understand that this will increase the difficulty of operating the device, but decided that a pH augmenting feature is more useful than completely omitting it.

4. Safety and Ethics

There are several safety and ethical considerations we will have to make while we develop our project.

4.1 Safety

The biggest safety consideration we must take into account is that we are using electronics in a humid environment with plants that must be regularly watered. Thus, we need to ensure we are always practicing safe techniques when introducing water and humidity to the environment, especially during testing and in the early phases. We must limit our exposed electronics and make use of any waterproof casings.

In addition, we must remember that plants can catch fire, especially if the environment is hot and dry with a lot of direct light. Thus, we must practice lab safety and be ready to extinguish any sight of smoke or flames from its onslaught. We must only leave the power source on when we have the ability to supervise, especially during testing and in the early phases of the project when we are still getting comfortable with the environmental regulation. We must also wait to introduce the plant to the environment when we are fully comfortable with the progress of the project and know that it is a safe time to do so.

4.2 Ethics

One of our biggest goals for this project is to bring the joy and excitement of gardening to prospective gardeners by demonstrating how new technologies can aid them through the difficulty of maintaining plants. Thus, following the IEEE Code of Ethics #2, we hope to "improve the understanding by individuals and society of the capabilities...of conventional and emerging technologies"[15].

Due to the nature of our project, we are aware that users may use the terrarium to grow dangerous plants. This will contradict #4 and #9 of the IEEE Code of Ethics, which state respectively "to avoid unlawful conduct in professional activities" and " to avoid injuring others, their property, reputation, or employment by false or malicious actions....or physical abuses"[15]. Unfortunately, there will be no way to control what plants the user decides to grow in the terrarium, we believe that the benefit of the terrarium will outweigh the potential downsides of having a small malicious user base. We believe by disclosing these caveats that we comply with the IEEE Code of Ethics #6, "to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations"[15].

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