SDP 2021: Team 28 Project: Herb Chamber

First C. SanBento, EE, Second D. Tran, CSE, Third S. Mekonen, EE, and Fourth N. Nguyen, CSE

Abstract:

Going back to our roots, we are agrarian that have perfected the art throughout the years through trial and error. As we are in an era that values productivity and time, tending to our plants every need is too much of a waste of time for whatever can be accomplished. This is especially true during quarantine and we have so much of that to our disposal.

We have designed and built Herb Chamber to be a solution to having a garden of your own that one does not need to take care of, allowing you to better spend your time. This system is built with an automating watering system with various sensors monitoring that plants environments to best fit optimal plant growth. The system also has a companion app that allows you to monitor the system enclosure, with various features, such as a total remote shutdown in case of failure.

I. INTRODUCTION

A. *Significance*

Most consumers do not have much knowledge about plants and their various needs, creating a host of problems when the plants are grown poorly. Some simple knowledge that most consumers don't know is that plants do not need daily watering and because of this they tend to allow the plant to have too much water or too little, not knowing how much to give. There is also the problem of how much sun is needed and during which stage the plant is in. With the system, it will have a basic guide for what is needed for the plants allowing the system to maintain the environment, while allowing you to watch it grow.

B. *Context and Competing Solutions*

An automatic watering system is a problem that we have faced since the beginning of when we started farming for ourselves. We like to grow our own food to allow for better sustainability for the increasing population. Thus we have devised various different means to alleviate this problem in different automatic watering systems.

The first method we devised in ancient times would be an irrigation system. This method is traditionally used for industrial farming. Irrigation, the use of various tunnel or tunnel like structures to distribute water in a fast and efficient way to all of the plants, effective in farming many acres of fields at once. The issue with this system is that it loses effectiveness when downscaled to something the size of a small home project. Traditionally irrigation methods include canals, drip release, and timers. Most canals systems just flood the plants in a controlled manner that prevents overwatering, but this method is inefficient in water management, wasting tons of water in the process. Irrigation systems simply do not meet the needs of individual plants, and can not be scaled for consumers to use easily.

The second method is less sophisticated that involves a probe with an attachable water bulb. Typically these designs are very ornamental and don't have any management needs except for the refill. But this also makes it so the consumer doesn't have any control over the water the plant needs as it is constantly feeding the water in the bulb until it is empty. This creates the problem of the plant having too much water and not being able to stop it as there is not a failsafe system in place for that as this system is not sophisticated enough.Though it's convenient and scaled to a consumer's needs, it is too unsophisticated and not optimal for plant growth, and needs more robust mechanical components to allow it to do so.

Another similar method to the previous one is a "self watering" solution, where the plant is placed suspended above a water reservoir with a "wick" that goes into the soil, allowing the plant to slowly absorb the water from the reservoir. But like the previous one, this lacks sophistication allowing for water wasted and poor optimal plant environment for best plant growth.

The last two products are similar, where they are more sophisticated than the previous, but only allow growth of a single plant or setting. The first would be a drip irrigation system run by a machine that runs on a timer, not allowing you any other settings and lack of sensor monitoring the plant environment. The second would be an arduino kit that can be assembled. But this system is still primitive and simple, only meeting the needs of a singular plant. Our devices will meet sophisticated needs of multiple plants. These kit systems are just the sensor, and some pump controls making the consumer have to buy the other mechanical components themselves and assemble. This greatly limits their accessibility to consumers that will buy this to hobbyists that know the in and outs of how the system is made, making them unfeasible as a solution. The major difference and selling point of our system is that it is a fully integrated system with enough sophistication that allows for different options, but not enough that it overwhelms most consumers.

C. *Societal Impacts*

Our Herb Chamber is a fully integrated system that is consumer ready. All that is needed is simply assembly of the enclosure and pumps that anyone with simple instructions can follow. Our product taps into a largely available market with little to no competition, resulting in little to no impact on other competitors in the market in a negative way as most automated systems are enthusiast made with specialized knowledge.

This integrated system enhances the water usage as everything is carefully managed and calculated so no wastage is created in the environment. Our product is environmentally benign with low to zero impact on the environment, except for the creation of the various components. We predict that with our product, it will allow more to begin becoming self-sufficient with their herbs and create more time for the consumer to spend on more productive ventures, with no associated drawbacks that can be seen.

D. *System Requirements and Specifications*

- Compact indoor form that fits on most tables
  - 4 Soil containers
  - Compact tent enclosure 23” x 23” x 42”
- Power supply
  - Low cost, low power system that delivers 50W
- IP65 water and dust resistance rating
- Water system
  - 1x 12V DC pump with ½ inch tubing
  - 4x 12V DC solenoid controlled watering channel with ½ inch tubing
- Light System
  - Indoor grow light
- Sensor System
  - humidity/temperature module
  - moisture sensor
- Product app interface
  - Connected with a wifi module allowing remote access
  - Alarm notification when set harvest time is approaching
  - Displays various measured parameters
  - Default plant directory for optimal growth

Above are the general system parameters that the full integrate system works with. The System works with a PCB that works with multiple switches that control the various lights and pumps that are programmed into the systems Atmega328P along with the esp wroom 02 that sends the sensor data collected to the cloud servers that are received and transmitted to the companion app. With the companion app various systems can be configured to the users preferences.

II. Design

A. *Overview*

The Herb Chamber is a small-scale enclosed herb garden that is able to automatically monitor and control the environment inside so that the plants can grow in ideal conditions. We designed it as a tent enclosure with various sensors and actuators connected to a microcontroller which controls variables such soil moisture, temperature and lighting. It also includes the ability to view real-time readings on a phone application. We considered two other design alternatives, one using hydroponics and the other was an outdoor system with a moving watering machine. Refer to Appendix A for further details.

We will now discuss the specific technologies we used. The main controller in our project is the ATmega328P, which we programmed using the ANSI C standard. We included a secondary controller, the ESP8266, which we use for sending data to the cloud through WiFi. The cloud service we used is Google Firebase, which we then interact with using an Android application programmed in Java. The specific sensors we used are capacitive soil moisture sensors and an integrated air temperature and humidity sensor. In terms of physical actuators, we used solenoid valves, PC case fans, a heating pad, a plant growing light, and a submersible pump, all controlled through relays and powered by a 60W power supply.

The block diagram in Figure 1 shows the high level description of our system. The control unit directly controls the relays and light power switch as shown. The relays then control all the individual actuators listed in the output modules block, which they can turn on by connecting to our power source. The blue lines indicate the flow of water, which go into the four growing pods or soil beds containing the plants. The sensors in the input module block take readings from the pods and feedback to the controller for it to process. The controller also sends these readings through serial communication to the ESP8266, whose main purpose is to then update the Firebase cloud with the incoming data. Finally, the Android application reads from the cloud to display to the user.

B. Control Unit and Relays

The control unit performs all the processing and decision making in the system. It uses input from sensors and internal memory to select an action, such as which pod to water, and it translates that into which relays to turn on or off. The microcontroller we used is the ATmega328P [1]. We programmed it using the Arduino library at first, then we moved to using C. There were many skills and concepts from our embedded systems course that we used for this part, such as proper C programming using datasheets, the idea of polling and interrupts and startup testing to name a few. We did testing of digital outputs using the scope and logic analyzer on the ADALM2000 scope which connects to a computer.

C. Power Unit

The main power supply we used is a 12V, 60W external supply which uses 220V AC input. We also used a DCDC converter to get 5V which we use to power the sensors and relays. For this module, we learned how to calculate the total power consumption of our system by referring to datasheets and finally testing the calculation by measuring the current from the power supply when all components are turned on.

D. Input Module

This module includes the two different types of sensors we used in our system. The first are regular capacitive soil moisture sensors. The second is a combined temperature and humidity sensor which sends digital data. We needed to do some initial calibration work with the sensors to make sure they were consistent. See Appendix C for detailed test procedures.

E. ESP8266, Cloud, and Application

The ESP8266 is responsible for receiving sensor data from the ATmega328P at regular intervals and then uploading it to the Firebase cloud as shown in the system block diagram. The Android application then reads from the cloud and displays the data to the user.

III. The Refined Prototype

A. Prototype Overview

In our prototype, we started out with a *12-volt* power source that will connect to voltage regulators, which will produce 5 volt and *3.3-volt* sources, sensors, and at one port of each of the most vital aspects of our project, the relays. As shown in our block diagram, the relays act as a switch to power on and off *multiple* components of our system, which will create an environment suitable for the herbs to live and grow. For example, the relays will allow the pump and a solenoid to turn on, to allow the flow of water to reach one of the pots where the herbs are being grown. Then, when the moisture sensor reads that the soil is wet, the relay will turn off the pump and close the solenoid.

Also in our prototype, readings from our sensors will be displayed to the User via a user interface (a phone app), through a google firebase cloud. That way the user will be able to *monitor* the soil, temperature, and humidity of the system. Better yet, be able to *monitor* the environment within the tent that the herbs are thriving in.

B. List of Hardware and Software

Hardware Components:

- Esp-wroom-02 - Transistor chip - Relays

- 5 volt and 3.3-volt voltage regulators

- Sensors (moisture, temperature, humidity)

- Pump - Solenoids - fans - Light source
- heating pads

- Resistors (10k, 1k, 100) - Capacitors (0.1u, 22p)

- Buttons - LEDs - Crystal (16M)

Software Components:

- Altium Designer - Arduino IDE - Android studio

C. Custom Hardware

In the design of our PCB, we had to think about what components can go on the PCB, and which components will have to be connected via external pins. For example, the sensors, pump, fans, light source, and solenoids are all parts that are required within the tent and cannot be attached to the PCB. For these components, we had to put external pins onto the printed circuit board to connect to them later. On the PCB, we can find the Esp-wroom-02, transistor chip, and the relays, as well as some of the other components listed in part B. We connected the ESP to the transistor chip to act as an input, which then will provide instructions for the relays.

For the fabrication, or board layout, I had to place the components so that none would be touching each other and would cause any fatal errors. I placed the transistor chip in the center of the board, the relays to the left, and everything else falls to the right or near the top part of the PCB. Due to not placing the ESP correctly, and the ground copper layer was messing with its antenna, we had to place the ESP on its own board in order to use its wifi function.

As of right now, for the population and testing of the board, we have it finished, tested, and connected to two separate boards, one containing the ESP and the other for power. We can provide instructions for the relays to power on and off the external components of our system.

D. Prototype Functionality

In our prototype, we were able to get the relays to function as they should, and act as a switch to give or take away power from the external sources. The pump was able to turn on and provide water, and when the moisture sensors declared that the soil was dry, the relays had the solenoids for that pot to open, to allow water to flow through and reach the soil. when the moisture sensors declared the soil is wet, the solenoid closed, and the pump turned off. In our testing, the light source will turn on and off given a time interval and the fans will be activated depending on the reading from the temperature and humidity sensors, which is what we wanted. Since the relays work, that means that the wiring from the Esp-wroom-02 to the relays are correct. Which also means that the PCB is receiving power, to give to all the components that require it. Since we were unable to purchase a new board, we placed the Esp-wroom-02 on its own board, and were able to wire it to power, a transistor chip, and the external components. After a few tries we were able to get the ESP to function as the input for everything and was able to see data within the user interface.

E. Prototype Performance

For the most part, our system is able to meet the requirements and specifications that were stated in both Table 1 and in our presentations. We are able to provide 4 soil containers within a compact tent enclosure with the dimensions of 23"x23"x42". The power supply is of low cost and can provide the 50 watts that we stated in the specifications. All the components within the tent will be wrapped or waterproofed, to avoid any mishaps and problems.

We use a pump and solenoids that require 12 volts to function, that are connected by 1/2-inch tubing. The water will be able to flow from the pump, through the tubes, and out of the solenoid with minimal to no problems. The light source contains all the different lighting necessary for the herbs to grow as if they were outside underneath the sun, and for each stage of their growth. The moisture sensors tell the pump to turn on or off. The humidity and temperature sensors tell the fans to turn on or off, to allow the air to flow within the tent. The app interface is able to provide the percentages for moisture within the soil, the humidity and temperature within the tent, as well as contact information

IV. Conclusion

In conclusion, at the state of the draft report, we are currently having a working prototype. Our system now is able to control 4 solenoids, as well as enabling growing light, fans, and heating pads based on the data reading from various sensors. Our system is also capable of transferring the readings onto a Google Firebase real-time data for monitoring.

Acknowledgment

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We would like to acknowledge Keith. Thank you so much for all your help with getting the parts ordered, making sure all the information in the cart is correct, and keeping us in the loop on their progress.

References

[1] https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf

Appendix

A. *Design Alternatives*

There were a few design alternatives that our team considered during the first few weeks of PDR period. The most common ones that we found were outdoor automatic growing systems and indoor hydroponic growing systems. However, due to the fact that SDP started from Fall transitioning to Winter, we discarded the outdoor growing system into an indoor option. As for hydroponic, due to the limited access to constant water source and the lack of hygiene because of the possible algae growth in the reused water, we decided not to go with that.

Therefore, we settled with Herb Chamber, an indoor growing system with soil in a small tent enclosure. The choice that we made eliminates the environmental factors as we can calibrate our system to deliver the optimal growing condition to the plants within a closed growing space. Moreover, it is a more robust project compared to hydroponic ones because of the wider range of features that can be implemented such as a wifi controlled phone app that can turn on and off devices such as growing light, fans, heating, and water valves at will.

B. *Technical Standards*

Team 28 aims to design a fully integrated wireless system with a controllable mobile application for easy access to real-time data compliment features. In order to achieve the desired goals, here are the list of design standards that we follow:

- Low power consumption
- Fully integrated working product on a custom PCB
- Fully wireless with IoT implementation
- Access to real-time database via Google Firebase cloud service
- A fail safe system
- A robust and automatic system that requires little to no maintenance

C. *Testing Methods*

As for the testing methods, the key procedure that we did to ensure a successful working prototype was gathering essential data.

Here are several important data that we obtained from various sources and testing methods:

- The optimal level of water for most types of herb is an inch deep within a growing container
- Most herbs require a growing temperature of 65 - 70 fahrenheit
- Herbs need to be watered at a certain degree of dryness

In order to find the exact amount of water for our plants, we first needed to find the volume of a cylinder shaped growing pod with an inch depth. Then we moved on to finding the rate of flow provided by the water pump we had. Based on the two information, we were able to calculate the duration of the water pump that needed to be on to provide an inch depth of water, which was 28 seconds to be specific.

For the desired temperature, we implemented a heating system to keep the temperature lower or equal to 70 fahrenheit at all times, and enabled the growing fan when the temperature reaches above 80 fahrenheit. Temperature data is captured by our DHT11 humidity and temperature sensor, which then can be viewed in real time via Firebase cloud.

Lastly, all of our capacitive soil moisture sensors that we bought gave out hard to understand values. We tested the data by dipping the sensor into water to obtain its maximum water content, which was stated as approximately 300, and 700 for absolutely dry. We then calibrated these values to an easier to read format under percentage of water content ranging from 0% to 100%. After obtaining the data, our team determined the threshold to water the herbs at 30% water content. This was done by dipping a finger into the dry soil, there is no soil sticking when remove indicates the soil needs to be watered, hence the 30% water content.

D. *Project Expenditures*

For project expenditures during covid time, we spent more that we could have for our hardwares to ensure the possible parallel workload for individual team members. Still, at the point of the report, we are staying within the given budget of $500.

E. Project Management

Each member of team 28 has a role in the project according to their interests and expertise.

Nam Nguyen, a CSE major, is the team coordinator, and is responsible for the well being and communication within the team, setting up meetings with the project advisor and course coordinators. Nam is also responsible for the power unit of the project as well as establishing a communication with Google Firebase Cloud.

Simon Mekonen, an EE major and is our budget manager. Simon has focused mostly on hardware and software integration, as well as debugging our circuit to ensure everything works as intended.

Duoc Tran, a CSE major, has devoted most of his time into mobile application development and cloud integration.

Christian Sanbento, an EE major, is our Altium lead. Christian mostly responsible for PCB schematic and layout design, as well as PCB population and debugging process.

F. Beyond the Classroom

Duoc: "*This project has given me a great opportunity to develop various skills that I have always been interested in and meaning to improve on when I was working on creating the person app for the project and HTML when I worked on the website. This was also a great opportunity to apply my knowledge that I have acc umulated into practical use and what I might want to focus on in the future*"

Nam: *"Herb Chamber has given me a chance to develop my communication skills as well as team leadership skills. Moreover, this is the first time I get to apply the knowledge that I have accumulated throughout my career as an CSE undergrad and be able to interact with both hardware and software at the same time. As a maker, IoT has always been my interest, and I am glad that I have learned more about it in designing Herb Chamber."*

Christian: "*During the duration of this project, I was able to develop skills in using the online interfaces altium, with creating our printed circuit board, and learning the necessities of an at home garden. I am glad i was able to take part in this project that we called Herb Chamber, and If given the chance, hopefully i'll be able to create another PCB in the near future.*

Simon: *"I have learned a lot about the development cycle of a project from start to finish from SDP. There were many valuable lessons on making a design with specifications and taking a prototype to a more finished product. I also learned about working together with a team and managing time and responsibilities."*

G. Gantt Chart