Plant Nanny: The Automated Plant Growth System

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***Abstract* — The Plant Nanny is a self-contained, self-sustaining plant system that receives power from any household outlet to keep your in-door garden plants healthy. The device converts the A/C from the outlet to DC and then powers a custom Printed Circuit Board (PCB) which lowers the voltage to 5 Volts and then to 3.3 Volts. The 5 Volts powers our lighting system, water pump system, and a series of sensors, including: Moisture, Temperature/Humidity, Light, & Water Level. The 3.3 Volts powers a microcontroller that controls the sensors and connects wirelessly via Wi-Fi to our mobile application which has a readout of all sensor data AND allows some override controls to the Plant Nanny. The mobile application will allow a user to set custom timers for our light system.**

I. INTRODUCTION

Everyone wants fresh vegetables when they enter a grocery store, and no one wants a decaying plant to go in their latest food creation. The ingredients that go into your dish should always be fully green and full to the brim with nutritious content. Whether it's some basil you're carefully tearing apart and putting into a vibrant risotto or tomatoes that you're mashing up and using for a tomato sauce, these ingredients deserve to be in full bloom for someone that comes home from work. This leads to the problem of when there are so many things to take care of in your daily life, how are you supposed to remember to water a plant outside. It's out of the way probably in a place that it is untouched and could be easily forgotten, and you must constantly water it every day.

This was where a busy engineering student decided enough was enough, and they wanted to take matters into their own hands. They had left their herb plants unattended for a week or so after a plethora of late-night assignments, and once they had finally checked up on their plant only to find it withered and without life. Due to constraints and lifestyle, it can be hard to remember and find the time to water and nurture a plant. This is where they decided to solve the problem through a design project. They had always wanted to make something practical for not just themselves, but also society. The need for a system that was smart enough to take care of itself as well as the plants became a necessity. This was the project that would decide exactly what a plant wanted, and how to satisfy all the environment variables.

It's difficult to remember a plant outside when you come home and all you want to do is relax on the couch. That's why an indoor plant system became important for the final revision of this project. The ability to see the plant and remember to take care of it, by refilling the water reservoir or whatever duty the plant may require, was an important aspect of choosing this constraint. Another important aspect was for the system to be a complete encompassing of all the environment variables that could affect a plant. This required to look out for more than just the water content in the soil. The system must look out for all these variables in an indoor environment, and this is the last constraint towards creating a project to fulfill anyone's desires for fresh produce.

II. GOALS & OBJECTIVES

The main goal of the Plant Nanny system is to create an indoor ecosystem for people who can't take responsibility every day for some type of produce requiring daily care. The plan is to create a self-sufficient gardening system that's capable of taking care of multiple plants. This will be done through a UV lamp placed over the top of three potted plants and have an automated watering system. There would be a water reservoir that would constantly water the plants when their soil runs too dry. The temperature would be measured to help the user find an optimal place to place the system to keep the plants at an acceptable temperature.

All these features will come together into a single device that keeps a plant alive and thriving. Although this system might seem sophisticated at first, a main objective is to keep this system simple for the user and the plant. Although it's a complex system, the design and simple objective remain. This is an all-encompassing self-sufficient plant system that will take care of a plant when there might be multiple days of neglect before any care is given.

It's meant to give produce that is not only alive, but hopefully thriving and full of life to add to a person's diet. The end goal of this isn't just to create a system that keeps a plant alive, it's to help a person with their daily life chores and hopefully reduce their load of daily work.

III. REQ. & SPECIFICATIONS

The Plant Nanny's requirements coincide with our goals in order to approach the design in a reasonable manner. Table 1, listed below, will show each specification listed along with a description, comments, and priority level. The table will also specify each priority as a ‘essential’ or a ‘desirable’ in order to place an importance level on the feature to ease the decision-making process in our design.

Description	Comments	Priority
Utilize soil moisture sensor to activate pumps to water plants	Maintain healthy level of water	Essential
System should readout to mobile app via Wi-Fi	Keep track of plants anywhere	Essential
Weight less than 10 lbs	Maintain portability	Desirable
Detect water levels of reservoir at different levels	User will know how long until needs refilling	Essential
All system components operating at less than 12V	Low power & heat consumption	Desirable
Dimensions no larger than 10x36x36 inches	Countertop center piece/portability	Desirable
System will shut light off automatically based on user timer	User defined timers for light exposure	Essential
Cost production under $400	Cheap to produce/manufacture and lower cost to consumer	Desirable
Sensor measurements will be within 10% accuracy	Important that mobile app data readouts are accurate	Desirable

IV. HARDWARE DESIGN

The hardware design of the WaterWise system will consist of five main components including the physical structure, hydroponics system, power system, sensor interface, and the system-controlling PCB. This section will look to give a detailed overview of each component and its design.

A. Structural Design

After gathering ideas of a few different designs for the Plant Nanny, we all decided and agreed upon a design that would be practical, functional, and aesthetically pleasing as a house decoration. Something sleek, modern, and eye catching so that one can proudly display it in a home. The design will be that of a rectangle box made entirely of wood panels. Inside the box is the housing for the PCB, water pump systems, water reservoir, as well as the plants.

The size for the housing is going to be depict by the size of the reservoir. We are looking for the right size reservoir that can go inside the housing but also large enough to hold at least 1 gallon of water. The water reservoir will have an easy access to refill the tank. The wall of the reservoir needs to be thick for durability. Also, the height of the reservoir will have to be as small as possible. In order to fit an 8 to 10-inch pot. Where the pot will sit right on top of the reservoir. It’s highly important to us to make this physical design easy to build and mobile.

The lighting fixture is going to be held by a metal flat rod. The metal flat rod needs to be strong enough to hold at least two pounds. The light fixture is going to be either held by magnets or just screwed to the metal flat rod. However, we are leaning more towards the magnets, which will give the user the ability to change the light fixture if necessary. The display screen will be mounted on the front panel of the rectangle housing, right at the center of the panel. See Figure 1, pictured below, for the rough draft of our physical device.

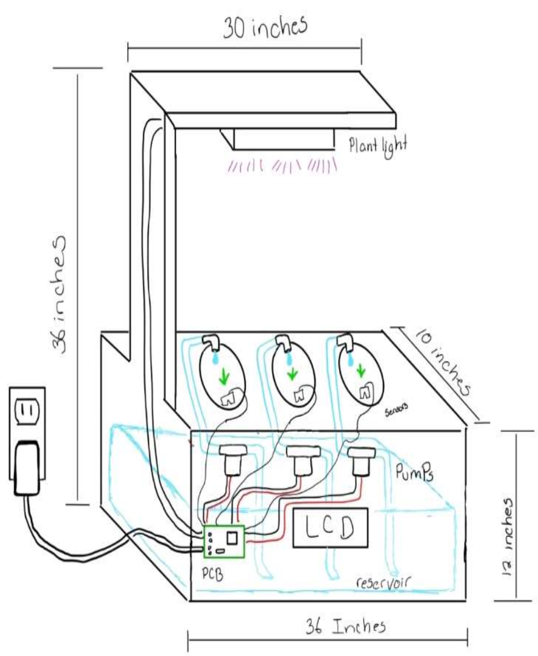


Figure 1 - Rough Draft of Design

B. Power Supply

A few different ideas were discussed in terms of powering the Plant Nanny device. We, of course, had the options of using a battery pack and a multitude of types of batteries. However, due to our design principle of a center piece we felt a power adapter from a wall outlet would fit the design much better. This is accomplished by rectifying the alternating current from a typical wall outlet in order to provide a steady voltage. From there voltage regulators were used in order to step down to the proper voltage. At first linear voltage regulators were discussed, but with some feedback from Dr. Richie, we opted for ‘switching’ voltage regulators instead. Two different versions of the LM2575 switching voltage regulator were utilized. One that initially steps down our transformed 12V voltage to 5V. This 5-volt regulator provides the proper voltage to nearly every component except for our microcontroller. Components powered by the 5-volt regulator include: water pumps, moisture sensor, grow light, temperature/humidity sensor, and water level sensor. The second LM2575 switching regulator provided a steady 3.3V output to power our microcontroller.

C. Microcontroller

The ESP8266 is a System on Chip (SoC) manufactured by Espressif, a Chinese company based in Shanghai, China. It consists of a Tensilica L106 32-bit micro controller unit (MCU) and a Wi-Fi transceiver. It has 11 GPIO pins (General Purpose Input/output pins), and an analog input as well. This means that you can program it like any normal Arduino or other microcontroller. It has a clock with a frequency of 80 MHz that can be increased. For communicating with peripheral, the ESP8266 supports I2C, UART, I2S, and SPI communication standards. With 11 GPIO pins available for use, there is enough pins for all the input and output for our project. It has a user memory space of 40 KB of RAM, it uses an external flash memory that usually range from 512 KB to 1 MB depending on the board. This means there is more than enough to save necessary functions. We have decided to use the ESP8266 microcontroller. This is because it satisfies the needs of our project with adequate memory space, clock speed and GPIO pins, allowing for our project to function without issue. It was also readily available to us for use due to the donation of one of our group members, this saved our group some money for other parts that we needed.

D. Sensors

Moisture Sensor - As a group, we decided that the best type of moisture sensor that can be used for the project is a capacitive soil moisture sensor. This is because other regular moisture sensors take advantage of the conductive nature of water and immerse them with copperplates. by running a current through one of the plates, it will measure the voltage between the plates. after a prolonged period of this, the copper could peel off and poison the soil. Capacitive soil moisture sensors do not possess such a weakness because they do not operate by being in contact with the soil. Figure 2, pictured to the right, shows the schematic of SKU: SEN0193 capacitive soil moisture sensor that we will be using.

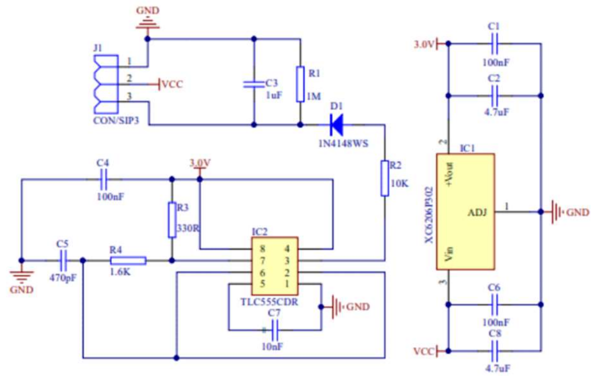


Figure 2 - SEN0913 Schematic

Temperature/Humidity Sensor - here are many different temperature sensors that we could use for our project but we have decided to go with a digital temperature sensor. digital temperature sensors are analog devices that can detect the current temperature of the environment and send the data as a digital signal to the microcontroller. These sensors use I2C and SPI communication protocols to send the information which is good for our project because our microcontroller will be able to support those communication standards. The specific digital temperature sensor that we have decided to use for our project is called the DHT11. Adafruit.com describes these sensors as “very basic and slow, but are great for hobbyists who want to do some basic data logging. The DHT sensors are made of two parts, a capacitive humidity sensor and a thermistor. There is also a very basic chip inside that does some analog to digital conversion and spits out a digital signal with the temperature and humidity”. The DHT11 is very low cost and has a price of range between $1 to $2 depending on the seller, some e-stores even sell it for less than $1. This temperature sensing device uses an operating voltage of 3V to 5V for the power and I/O. this is a very small sensor with the dimensions of 15.5 mm x 12 mm x 5.5 mm and can be easily fit into our system. It has 4 pins and but only 3 of them are used for project as you can see in Figure 3, this is because the 3Pin is the NULL pin and is usually not used.

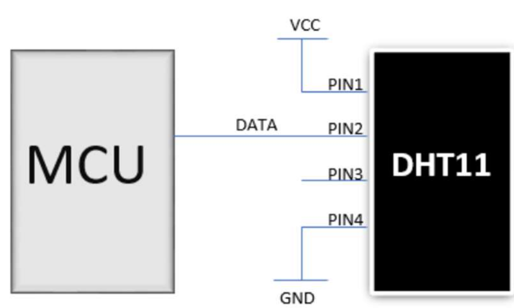


Figure 3 - DHT Pin Layout

The DHT11 is able to sense temperature accurately within the range of 0 –50 °C (32 –122°F). The DHT11 temperature sensor readings have a 5% accuracy, but for the purposes of our project this range in error is acceptable. The DHT11 temperature sensor also has a sampling rate of 1 Hz (once every second) which is usually a bit too slow but since our plant growth system that will be placed indoors, we can assume that temperatures will not change drastically. Therefore, this sampling rate is more than acceptable for the project.

Light Sensor – Photosynthesis is the process by which plant and other organisms convert light energy into chemical energy. It is through photosynthesis that plants can synthesize their food using light, carbon dioxide and water. The amount of light needed for the process of photosynthesis to occurs is within the light waveband of 400 to 700 nm. Too much light can burn the plant causing it to lose water quickly and too little will make the plant malnourished therefore it is necessary to maintain a proper amount of light for the plant to grow well. For our plant growth system to provide the light needed, we will integrate a light intensity sensor into the system. The optimal intensity varies along with the growth stages of a plant and it will be up to the users of the Plant Nanny to determine when there is too little or too much light. They will then be able to turn the light fixture on/off or adjust its light cycle so that the plant can grow well. It is advised that users of the Plant Nanny system do not place it at locations with high ambient light so that the ambient light does not affect the data measured by the light sensor.

Water Level Sensor – Our Plant Nanny system will be using the HC-SR04 ultrasonic water level sensor to determine the amount of water in the reservoir. Ultrasonic water level sensors emit an ultrasonic wave of high frequencies that then get reflected by the target. By recording the time taken for the sound wave to travel to the target and bounce back we can use the equation below to determine the distance it traveled.

$$Distance = \frac{Speed\ of\ Sound\ *\ Time\ Traveled}{2}$$

In this equation, we can let speed of sound to be the speed at which sound travels through air which is 343 m/s. An issue that we found with these types of sensors is that they have a limited sensing range, usually between 2 cm to half a meter. However, they are very simple and easy to implement compared to using multiple metal probes. Ultrasonic sensors are very cheap and can be commonly found on the market. Since the sensor will never come into contact, it has the added advantage of being corrosion proof unlike typical water level sensors. With the speed at which sound travels in air, ultrasonic sensor can gather data very quickly, but it is still slower than some of the other sensors.

E. Pump System

In order to select the most suitable pump for our design we first had to set some standards the pumps need to have. First, the water pumps dimensions cannot be
62too large because it requires to be inside of the housing of the Plant Nanny. Second, it must be able to pump and discharge enough water in a short period of time for our design to be efficient. Third, the water pumps need to have a low power consumption for the design to not dissipate large amounts of heat. Lastly, since three water pumps are needed for this design, the cost for the pumps should be inexpensive. Most of the mini water pumps operate 3 to 12 input volts. However due to using a power outlet for the power supply, the amount of voltage needed is not an important factor. The most important factor will have to be the size of the pump. This is crucial for the spacing of the Plant Nanny because the PCB with all the other components and the wiring must fit inside of the enclosure. The Brushless Submersible water pump from amazon has the best size for this project design. The pump dimensions are 2X2X2.4 inches and it is small enough not to affect the spacing of the enclosure. Also, it pumps a large amount of water for its size. The brushless submersible water pump can discharge water at a rate of 7.5 liters per minute, while the other water pumps like the Sukragraha water pump only discharge 1.6 liters per minute. However, the Sukragraha water pump does have a lower power consumption than the Brushless Submersible water pump.

F. Light System

The plant lighting involved multiple options at different price points, but it came down to two different light fixtures based on the circumstances presented. Both would supply the ability to have a variable amount of light over the plants, and the proper colors of the light spectrum to provide the correct nutrients for whatever plant is chosen. The two models being heavily compared are the AquaIllumination SOL LED Lighting and the AOVOK Grow Lamp Plant Light Panel. Although the SOL is meant to be an aquarium light it still covers the full color spectrum required for a plant to grow, and it supplies a variety of lighting options that would lead to more customizability for a client. This lighting fixture is high quality and offers many options for anything a plant can require when it comes to light. The price point is a lot higher when it comes to lighting and nears close to two hundred dollars. This was considered an option because of a free offer from a secondary source on top of its large amount of customizable options. The AOVOK offers a plant light fixture with the full light color spectrum and can be essentially used for any size plant. The AOVOK uses little power in comparison and costs only a fraction of the cost of the SOL. The AOVOK provides an all-around good lighting fixture for the plants that provides flexibility and versatility of how it can be placed and what types of plants it can cater to.

69Both offer everything a plant could need, and that other details to decide the light fixture to be used. The SOL uses almost twice the power of the AOVOK at seventy-five watts, but there are other factors that help the SOL compete. When it comes down to the wire the newer technology will prevail for its versatility with the everchanging devices of the modern world. Therefore, the AOVOK will be the lighting fixture used for the project.

G. Printed Circuit Board

The design of our Printed Circuit Board (PCB) was done in the EAGLE Cad software available for use by students of the University of Central Florida. This process was a challenging hurdle as not much experience was had among the group doing this. Many of our chosen components were not directly available in the libraries provided by the default library of the EAGLE software. It took research and time in order to properly import all of the components. Snapshots of different schematic captures can be seen below.

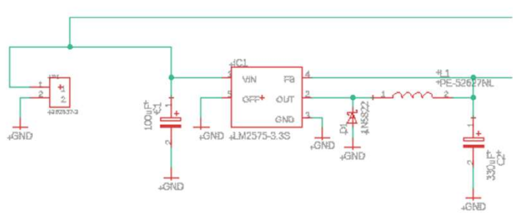


Figure 4 – 5V Schematic

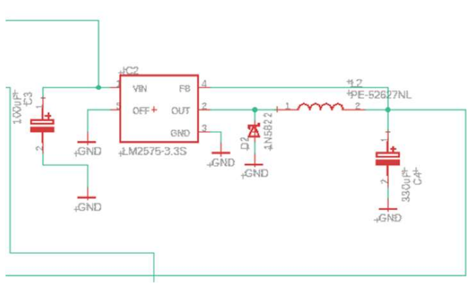


Figure 5 - 3V Schematic

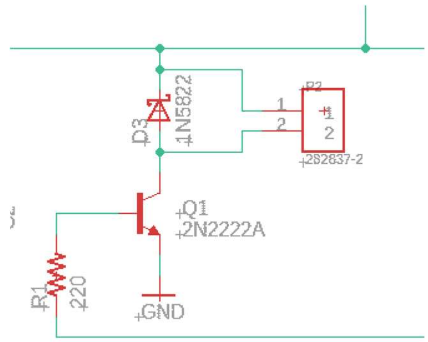


Figure 6 – Pump Design Schematic

A diode was used as a switch in order to signal the pumps to turn on, pictured in the schematic below.

The final PCB design that was used for this design can be seen in the figure below.

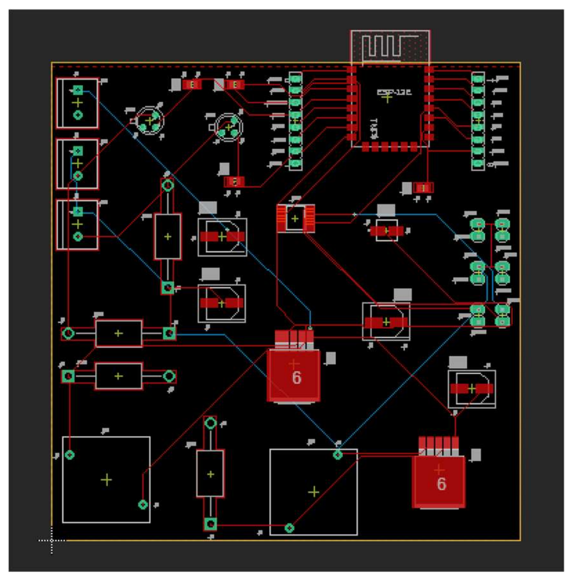


Figure 7 - Final PCB Design

IV. Software Design

A. Microcontroller Software

The microcontroller software was developed using the program for the Arduino IDE. The microcontroller software needs to be designed in such a way that all sensors and pumps will operate according to specifications. The basis of development began with developing a connection between the microcontroller and a WIFI enabled device through a local web server that the microcontroller would emulate. Once this was established commands could then be passed through to using any web browser. The command was simply the static IP address entered into the browser search bar with the requested action appended to the end. This would then be picked up by the microcontroller which would have the command connected to a function. The function would return based upon the requested command. The sensor data would activate a GPIO line for the specific command, and it would take the data to transmit back to the device. The water pump and lighting functions would simply enable the GPIO line and no further data would be transmitted.

Certain functionality is built into the software which is displayed with the soil moisture sensor built with the water pump. The water pump will run when a certain low value is returned from the soil moisture sensor. This built in functionality has no direct connection with the phone application. It takes the soil moisture value, which is displayed in the phone application, and it decides if the value is low or high. If the value is too low the water pump will automatically turn on if the water reservoir has an ample amount of liquid in the container. The water reservoir provides another automatic function that involves taking the reading and comparing it in other functions to deem if certain parts can run such as the water pump. The sensor data and other functions are pulled on a constant timer that will cycle every ten seconds and pull data. This will then be transmitted to the app and updated at about the same time interval. Manual commands such as the lights and water pump also have direct correlation with certain functions. All functionality has its own separate command that is picked up and interpreted by the microcontroller.

B. Mobile Application Software

The current software production will be based around the Android environment. This will be done due to the wide variety of android phones and software versions available. Having this variety will allow for a more universal standardization of this phone application. This was chosen over IOS due to issues with time, cost, and versatility. To accompany this choice of software will be the program itself that will help to build the application. The program that will be utilized is the MIT App Inventor 2. It will be chosen for its free domain use for any who wish to develop a phone application. Using App Inventor over other options would also lead to the versatility in the selected Android device to be used. Although XCode would be a good choice for IOS, it's not practical for its application here because of some limitations.

To program with XCode would require access to a MacBook as well as knowledge of their specific programming syntax. Although this could be learned, it would prove to be a simpler task to use existing Java programming knowledge to learn how to control the functionality of the phone application. Both would work for the purpose of this project, but one will provide more ease and functionality for the scope of this creation.

The home screen of the phone application would show basic statistics of what is going on in the plant's environment at any given moment as well as if the setup for the Plant Nanny needs any attention towards its water supply or lighting. Although light intensity might not seem like an important addition to the application it would be useful towards detecting if the lighting fixture is working at full capacity or if it's functional at all. Another additional feature would be a remote off switch.

User interface is one of the most important parts to an application. This is where the user and the programmer need to understand each other. That's why the user interface that will be used needs to be intuitive and easily understandable. To get straight to the point and get the message as well as the information across to the user immediately while keeping it versatile enough to be used to its fullest extent.

The Android application will have a couple of layouts such as a constraint layout to properly place objects and texts where they can be visibly seen and keep them in an easily readable format. The usability of this application is of great importance towards the overall success of this project. The application will have multiple functionality of what it will be used for. The different views of what will be the application involve a main tab that will display a lot of information and a view for controls for some of the main electronic components.

The main view will display basic plant data such as temperature and humidity. The other views will include button views that distinguish possibilities of what you're capable of doing with the internet connection of the phone application. This will revolve around the water reservoir such as manual watering from far away and turning the light fixture on and off. Another possibility is putting the lights on a timer. The plants would have plant ID's that would give a general idea of where the plants are and what water feeders are above them. This would give more exact feeding and light level placements.

Another part built into the statistics tab is options such as when you're warned that the water level is low, or if your plants need water. The lights should also have a setting that includes turning them on or off at certain times on a separate view. The application will provide a general idea of what is needed as well as characteristics involved with them. For instance, the plants will have moisture sensors that will tell through microcontroller functions that the plants need more water added to them. That is how the functions will work with the application to successfully create a working environment that allows for plant care from a mobile perspective.

There are parts that are more important than other functionality of the application such as the basic information of what the plant is experiencing in its environment. This was dealt with first to ensure that connectivity between the phone application and the microcontroller was achieved and maintained.

The other use this view has is that it has if the soil is too dry and needs to be watered. This will leave a basis if the option to manually water them is chosen instead of through the microcontroller functionality. The last is an option of how long and when the light fixture should be on. This will be done because the light a plant requires can vary, and some will need more or less than an average day of a certain location. The customizability becomes important towards plant maintenance.

Figure 4 - 5V Schematic

The last view is paired with the lighting timer which would involve buttons for various tasks that might need to be accomplished if automatic functionality fails. This includes a button to manually water the plants. It will activate the water pumps from the reservoir for a standard amount of time to ensure the plants are properly watered if the timer is not functioning properly, or if the plants need to have more water. This would also mean the timer needs to be adjusted to allow for more water in any given time period.

The other button would be for a light on and off type of manual functionality. That would be used in the case of a light fixture being left on for a long weekend when the user is away for a long period of time. They would be able to turn the light fixture on or off to prevent fire hazards. The other side of the spectrum would be if the light needs to be manually turned off due to a plant's long exposure to sunlight.

The button view is meant to be more of a safety feature for accidents that might occur due to negligence or misuse. Forgetting is a common problem with certain tasks, but the purpose of this view would to give complete control to the user to ensure that if automatic functionality is a problem then they have the power to turn off the system or turn it on.

The application will be both functional, stylish, and straight forward for the purpose of the user. The user should enjoy opening the app and looking at the most important data displayed right in front of them in a neat and concise format. It will be able to do any task the user might have such as setting timers for on and off functionality as well as allowing for manual use of the water and lighting. The application should be an all-encompassing main point of origin towards all information and functionality of the Plant Nanny.

C. Wireless Communication

Wi-Fi is the popular name of the technology that uses radio frequency (RF) technology to provide high speed wireless internet and network connections. It is thought that Wi-Fi is an abbreviation for "wireless fidelity", however it is simply the phrase used to refer to the wireless networking technology that is based of IEEE 802.11.

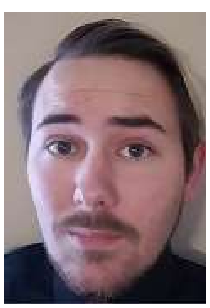
the Wi-Fi networking standards will transmit messages from one device to another by broadcasting electromagnetic radio waves and alternating the radio signals. The frequency at which the electromagnetic radio waves oscillate (the RF) varies between 3 kHz and 300 GHz. In this range, the various wi-fi standards operate within the frequencies of 2.4 GHz and 5 GHz. When the frequency of the wi-fi signals are increased, the rate at which data is sent can be increased but the range will drastically decrease. Wi-fi can directly send this data to the user's device when it is in the range of roughly the size of a small building. Our system uses wi-fi in order to communicate between the Plant Nanny and its accompanying Android mobile app. We have chosen to use the ESP8266 Wi-Fi module for our system to communicate wirelessly with the user. The ESP8266 is a System on Chip (SoC) that has become one of the most popular options for IoT (Internet of Things) devices. The biggest advantage for using the ESP8266 as the wi-fi communication module is that the ESP8266 can also function as a microcontroller.

V. Conclusion

Our end goal was to design an operational friendly self-care system that did not require the user to oversee it. A set it and forget it device that watered your plants and gave the user important information regarding their health. Home automation is the way of the future and we believe that plants should wholeheartedly be included in that aspect. The Plant Nanny has proven to be a great combination of agriculture, electrical engineering, and computer science.

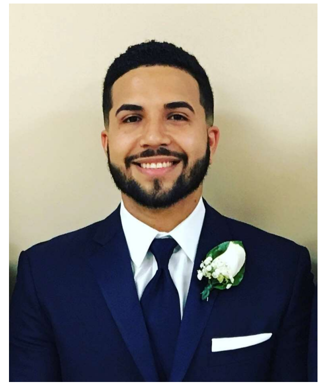
The Team

Ajay Emmanuel is a senior at University of Central Florida who is graduating with a Bachelors in the field Computer Engineering. Through his personal projects he has acquired a much experience in software development for a range of popular programming languages. Ajay hopes to further increase his knowledge on the field through working part-time and full-time jobs relating to his field.



Clayton Szoke is a senior at the University of Central Florida who is graduating with a Bachelor of Science in Computer Engineering. He hopes to join a company exploring new technology and excelling in his field through experience and hard work.

Christopher Jordan is a senior at the University of Central Florida graduating with his B.S. in Electrical Engineering. He has accepted a position in the power industry and hopes to continue the pursuit of clean and renewable energy



Gabriel Rodriguez is a senior at the University of Central Florida who is graduating with a Bachelor of Science in Electrical Engineering. He is currently working as an Electrical Design engineer for an engineering firm. He hopes to find a job as an Digital Design engineer.

Acknowledgements

The authors wish to acknowledge the assistance and support of Dr. Samuel Richie, the University of Central Florida.