University of Central Florida
Department of Electrical & Computer Engineering
Senior Design 1 – Summer 2019

Initial Project Documentation – Divide and Conquer

Smart Tabletop Greenhouse

Group 12
Jonathan Gilbert – CpE
Alex Lam – EE/CpE
Dany Mazboudi – EE
Megan Morris - EE

Motivation

Most people can appreciate the aesthetic and air-purifying qualities that house plants have to offer – not to mention the potential savings and health benefits of growing fruits and vegetables – but lack the 'green thumb' needed to keep them alive and happy. With greater monitoring and control of the plant's environment, indoor gardening could become more feasible for the typical household.

The appeal of indoor gardening extends past the convenience of producing vegetation for food, though that ability should not be taken lightly. 'Food deserts' – urban areas where it is difficult to obtain affordable or good-quality fresh food – are a rising issue in the United States. These regions tend to coincide with higher rates of poverty, and also bring in a slew of health issues such as obesity and heart disease. People living in these conditions often have to choose between buying expensive produce in inconvenient quantities to then go home and prepare meals for their household, or buying cheap, highly caloric fast food that is filling, albeit non-nutritious. If an indoor garden system could be made available to these homes at a reduced rate, it could at least save them time and money in procuring fresh vegetation and give more meal options.

In addition to providing greater access to fresh produce, indoor plants have been known increase the air-quality within a confined space and, quite simply put, can make people happier. Through photosynthesis, plants convert the carbon dioxide humans exhale into fresh oxygen. During this process, as found in a 1989 experiment conducted by NASA, plants have the ability to filter the air of volatile-organic compounds such as formaldehyde and benzene [1]. Within a space with regularly circulating air, such as a typical home, this effect is reduced. However, with a greater volume of plants in a controlled environment, it is possible reduce the level of pollutants that would be present in an urban environment. Another health-based benefit of houseplants are its effects on mood. A 2015 study conducted by the National Center for Biotechnology Information demonstrated how interaction with indoor plants can reduce psychological and physiological stress by calming the autonomic nervous system activity in young adults [2].

Even with all the benefits associated with indoor gardening, there are likely many people who wouldn't consider incorporating it into their daily lives due to the difficulty of providing and maintaining a nurturing environment for plant growth. Some main issues that can impact a plants ability to thrive indoors are over/under watering, lack of drainage, too much or too little sunlight, dry air, and depleted nutrients in the soil. The good news is that most of these factors can be monitored and controlled in a smart greenhouse setting – soil moisture sensors can be used to indicate when to water, sunlight sensors can determine if the garden is receiving adequate light, hygrometers can be incorporated to monitor ambient humidity, and soil pH sensors are able to serve as an indication for nutrient deficiencies. Having access to these factors alone could be sufficient to caring for this vegetation, but these sensors could also be used communicate with other devices to automatically maintain a nurturing environment; i.e., humidifiers, a watering mechanism, grow lights for supplemented sunlight, and even a separate watering mechanism for fertilization.

Project Description

The goal for this project is to create an indoor gardening system that will monitor and control the humidity, soil moisture, hours of sunlight, and soil quality to provide an ample environment for plant growth. This will allow for a fool-proof experience with a combination of automated controls and user input from a local touch enabled LED screen and remotely from a web app. Given that this system is to be indoors, space is to be conserved whenever possible. To accomplish this project, four distinct areas of focus have been assigned: power supplies, sensors and PCB, embedded controls, and software. The general plans and descriptions for each group will be noted below.

An arrangement of power supplies will be needed for the microcontroller, various sensors, drivers, control mechanisms, and an LED display. The sensors, in general, should require the least amount of power, especially configured to operate in a low power mode. However, to save space and GPIO pins, it is possible that some of the sensors chosen will have WiFi capabilities; in the case of these sensors, more power may be required. In any case, the general idea is to provide a small local battery pack to the sensors to simplify the load constraints. This plan is to extend to other low-voltage devices if applicable. For the devices that require greater power, the design gets more complex. The ideal power supply in this scenario would be a hybrid system that has the capability of switching between battery charged via solar and a typical household receptacle. The solar system would be comprised as follows: a solar panel, a battery charger, and a battery. Ideally, when the battery has low charge due to weather conditions, a switch will change the supply from solar to the mains. The system should include maximum power point tracking to ensure efficiency. With the general supplies defined, various regulators, amplifiers, and creative circuitry will be necessary to implement a safe and reliable end product.

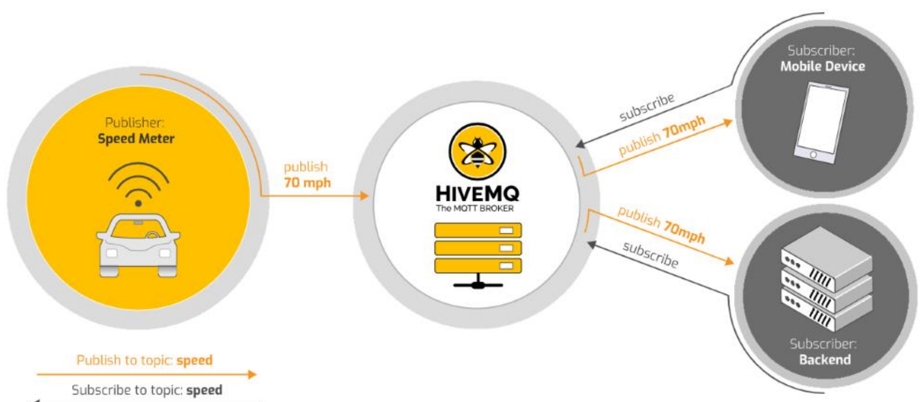
In our project we will be using a variety of sensors that will be monitoring various things within our indoor gardening system. We will be using sensors to monitor humidity, soil moisture, soil PH, sunlight and water level. We need these sensors to keep a careful watch over what’s going on within our indoor gardening system. We’ll be using more than one of each type of a certain sensor, but the exact amount is currently undecided.

We’ll be using a humidity sensor to monitor the level of moisture in the air at certain temperatures. Of course, the humidity sensor will also be monitoring temperatures as well. A soil moisture sensor that we’ll be using will also be of importance for keeping a watchful eye over the plants that will be growing within the gardening system. We want to make sure that there is just the right amount of soil in the plants and that there isn’t too much or too little. Next, we will have a soil pH sensor which will also be necessary for making sure that the plants we’re growing are not going to be growing at a pH level that would not be sustainable for them. We’re also going to be incorporating a sunlight sensor which will keep an eye on the amount of sunlight exposure that our miniature garden is going to get. The garden may be placed by a window being exposed to sunlight so that will also need to be monitored. Lastly, we’ll be adding a water level sensor to our miniature garden which will keep track of the amount of remaining water that will be in a separate hidden container to our miniature garden. These sensors are all required for this home gardening product to be successful.

To have a local interface with the controller and all its peripheral devices we will plan to have a GUI in the front of the Smart Tabletop Greenhouse. This will serve as a local interface for a user to be able to access and control all the environment changes in our greenhouse, look at data provided from sensors, and provide a troubleshooting system that will notify the owner if anything is out of the ordinary for the greenhouse.

To do this we plan on using an application on Code Composer Studio, as we plan to have our controller be from Texas Instruments. In addition to the GUI Composer application being the main complier for TI components, there are also features in this application to be able to easily access and show data through the chip via graphs along with numbers and words. There are even objects within the application that simulate thermometers to make ease of custom event handling as our data is pre-processed. For our error messages, the composer application has features where pop-up windows can be created just as if on a regular PC to notify it's users.

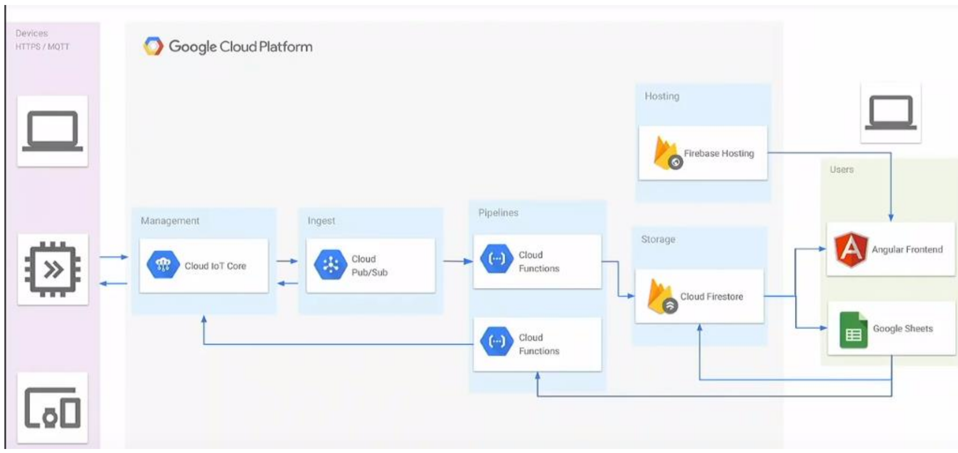
With the growing demand for “smart” devices, we want our tabletop garden to connect to resources and tools online in the cloud. Our smart garden will be fitted with a Wifi module that can communicate through HTTP or MQTT. This will allow us to work with the newest cloud functionalities available since they’re highly efficient protocols for IoT communication. Our first goal will be getting our microcontroller to host a server, preferably through MQTT, in order to send data to and from the microcontroller. MQTT is most desirable since it operates on a publish/subscription framework. Unlike a client-server architecture, in which the devices communicate directly, the publish/subscription method allows sensors to publish messages for an MQTT broker to send to devices subscribed to the incoming messages. This will make it easy to publish sensor data from our garden to the cloud, where a web server subscribed to our sensors can pick up on the data. Likewise, we can control our device from a web server by publishing tasks that our device will be subscribed to, such as turning on a water pump to water the plants even when on a computer away from home.



Example figure of how the pub/sub MQTT mechanism works

Embedded applications are often constrained by memory space and processing power. By connecting our device online, we can offload all the data we gather into the cloud so we don’t have to waste power or constrain our memory storing it on the device. We also get access to external APIs to help run analytics on our data if we wish, resources otherwise not supported by our microcontroller alone. The “cloud” is an umbrella term that refers to the vast amount of online resources we can use for the project. There are many providers we can use to give our project the online resources to be “smart”, but as of now we have focused on two in particular: TI cloud tools and Google’s IoT core.

Though there are many microcontrollers to choose from, TI offers hardware we are familiar with that can get the job done. Since we want to use a TI embedded processor in our device, TI cloud tools would be a great choice to go along with it. While building our software, we can use CCS cloud to compile and flash code from any device if the hardware has a wifi connection. The code gets stored in the cloud as well, so we won't have to worry about keeping our offline copies consistent with each other. It also comes with user friendly tools to get a simple web-based GUI set up, and combined with Temboo, can open a gateway to other external APIs we can use for data analytics and storage. However, for a more expandable and scalable software, we want to use Google's IoT core as well.



Example Google IoT device framework

Using Google IoT core, we can securely send our data into the cloud and pass it on to other applications for further processing. Once in IoT core, our data is stored online, no worrying about losing data while it transfers to our database. Google Cloud pub/sub implements the MQTT protocol that will control and listen for information from our device. Pipelines like Cloud Functions are a quick way of passing our information on to other applications we need. For our database, we can use Cloud Firestore, which will handle syncing our data across multiple devices that may connect to our device and allow for flexible scalability. Finally, Firebase will allow us to securely host our web app. Without using Google's framework, much of the heavy lifting on the backend would be on us to implement, which may be out of scope for this project. Google gets us on our feet quickly, securely, and efficiently enough to keep up with the newest trends in IoT devices.

Specification and Constraints

For this design, we will have a closed loop ecosystem setup with multiple sensors with specific functions. Sensors will be monitoring both temperature and humidity. Though the number of sensors may change in the future. To protect the circuitry in our design, we will be placing the PCB, batteries and all electrical components in a closed attachment on one of the sides of the miniature ecosystem. For monitoring purposes, we will have a GUI attached to the other side of the ecosystem to give us a visual display of the information that the sensors will be outputting with constant updates, ideally every 1-2 seconds.

Obvious constraints that need to be considered are cost, technology and time. Firstly, we should expand on the cost. Being university level students, we need to be cautious with the amount of money we can spend on a project like this. We need to be realistic with our ambitions when building something like this as to not reach an absurd price tag. When considering our future add-ons to this project, we should also consider how much this expansion is going to cost us as well. If the cost is way too high, we will most likely scrap it and come up with something different altogether that's more cost-effective.

When it comes to the technology we need to also need to consider if what we're designing is innovative and that we aren't using technology that could be considered old and obsolete. We will need to research the latest technology that is available for purchase and discuss if it's something that is within our budget for purchase.

Time is a major factor with a design like this because we will be on a tight schedule with a shorter time span due to the summer semester. As a group we need to set aside time dedicated to simply working on this project to reach a complete product in a timely manner. We do not want to be in a situation where we're simply rushing to reach the deadline. If we did that, we will be making mistakes and end up with an unsatisfying result. Discussion among all group members is imperative for us to be as efficient as possible with our limited time.

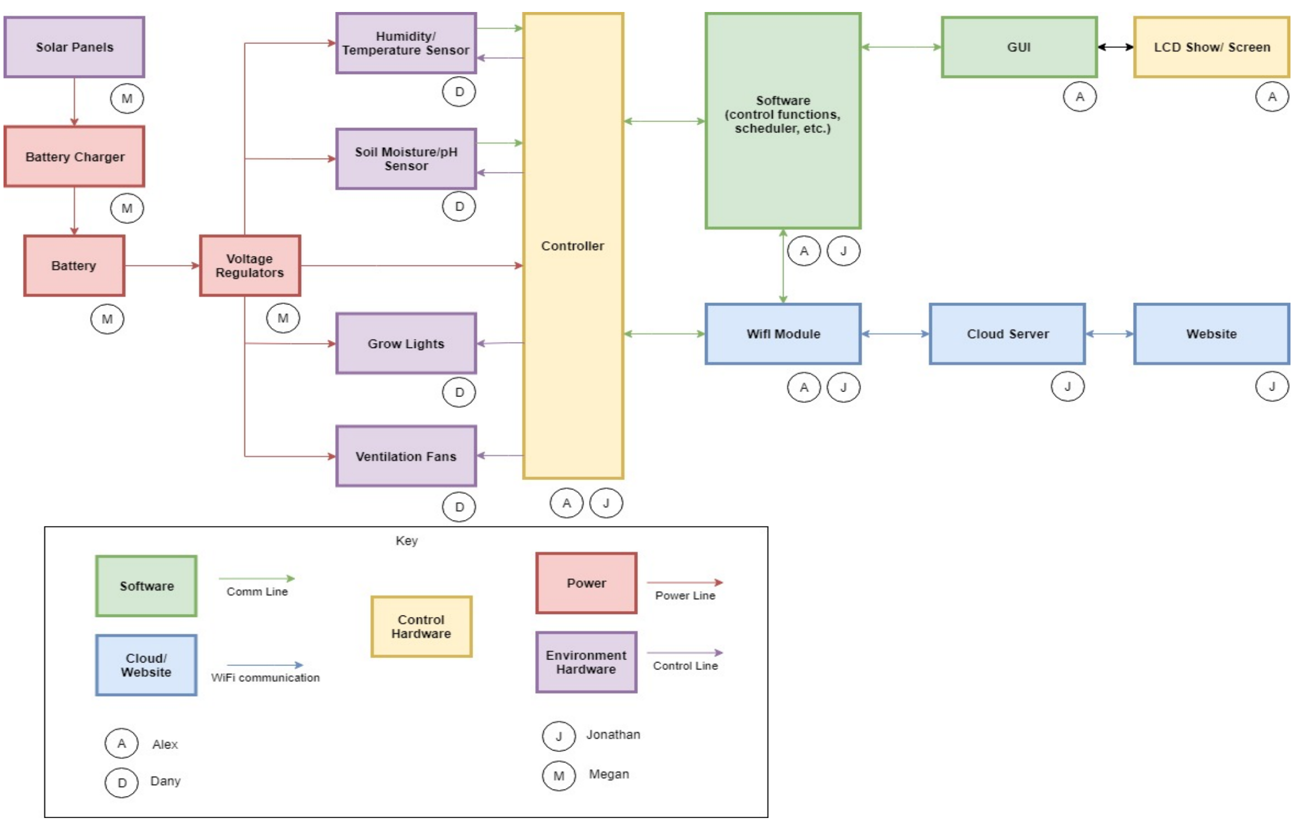
Engineering Requirements	Justification
Should have a web app that supports WiFi or Bluetooth 4.0 connectivity to a microcontroller	'smart' devices typically allow for mobile control and monitoring of a system over Bluetooth 4.0 or an internet connection
The wireless capabilities of the device must support MQTT version 3.1.1, or HTML	To connect to the cloud, must have up to date protocols
The device must communicate with the cloud to store data	We won't have much space on the microcontroller, so storing the data online is the best solution.
The device must have enough memory to host a webserver	So that we can communicate with the device over the internet
Should have an internal battery that can be charged	We want a battery powered device so that it can be moved around easily and not constrained by a power cord
Should have a solar panel that can charge the internal battery	A cordless solution to recharging the battery
Should have a safe mechanism for switching over to AC power	If batteries are an issue, we want the device to run off a wall outlet.
AC power should safely charge internal batteries, if there are any	If it's not sunny out and you need to charge the batteries
Solar panel shall not obscure the plants from receiving sunlight or detract from the overall appearance of the system.	Nothing added to the system is to negatively impact the quality of the plants.
Should have various sensors to measure the environmental factors that the plant life is experiencing.	In order to provide a nurturing environment for plant growth, factors such as humidity and hours of sunlight are to be monitored and used for controls
Should include a watering mechanism for all plant life within the system.	Having a self-watering greenhouse will give the system a user-friendly and foolproof nature

Should collect and display environmental data (from the sensors)	Users will want to be informed of the greenhouse conditions
Should be within 4 cubic feet with a vertical orientation.	Due to this being an indoor device, it should take up as little space as possible
Should have a user-friendly GUI	Have an easy-to-access interface is imperative for data collecting on this scale
Should be able to control environment changers in the system	We need to be able to change the environment to optimize the growth of the different plants

Market requirements:

1. The greenhouse must have a modern appeal and design
2. The power supplies cannot detract from the aesthetic appeal of the system
3. The greenhouse must be easy and safe to operate
4. The greenhouse should have a sustainable lifespan
5. The greenhouse system should be affordable
6. Controls through user interface should be easy to use

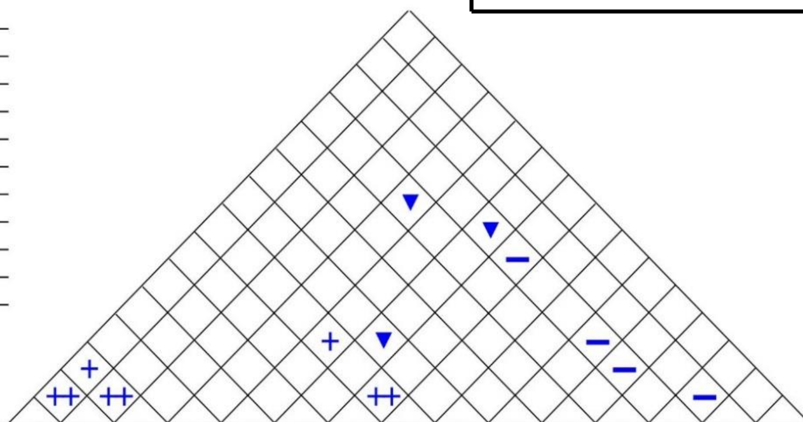
Block Diagram



Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	

House of Quality

Title: House of Quality - Smart Tabletop Greenhouse
Author:
Date:
Notes:



Column #	Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")
1	▲	Should have a web app that supports WiFi connectivity to microcontroller
2	x	Device must communicate with the cloud to store data
3	x	The wireless capabilities of the device must support MQTT version 3.1.1, or HTML
4	▲	The device must have enough memory to host a webserver
5	x	Should have an internal battery that can be charged
6	▲	Should have a solar panel that can charge the internal battery
7	x	Should have a safe mechanism for switching over to AC power
8	x	AC power should safely charge internal batteries
9	▼	Solar panel shall not obscure the plants from receiving sunlight or detract from the overall appearance of the system.
10	▲	Should have various sensors to measure the environmental factors that the plant life is experiencing.
11	▲	Should include a watering mechanism for all plant life within the system.
12	▲	Should collect and display environmental data (from the sensors)
13	▼	Should be within 4 cubic feet with a vertical orientation.
14	x	Should have a hidden clean water tank
15		

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	9	17.9	5.0	Greenhouse must have a modern appeal and design									O			O	O	Θ	
2	9	14.3	4.0	Power supplies cannot detract from the aesthetic appeal of the system									Θ						
3	9	21.4	6.0	Greenhouse must be safe and easy to operate							Θ	Θ		O	Θ				
4	3	10.7	3.0	Greenhouse should have a sustainable lifespan										O		O		O	
5	9	3.6	1.0	End product should be affordable				O	O	Θ	O	▲		Θ	▲	O	O		
6	9	25.0	7.0	Users can control and observe environmental data remotely	Θ	Θ	Θ	Θ						Θ	Θ	Θ			
7	9	7.1	2.0	Greenhouse should be environmentally friendly						Θ			O						
8																			
9																			
10																			
				Target or Limit Value															
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	7	4	2	4	4	5	7	2	2	4	4	6	4	2	
				Max Relationship Value in Column	9	9	9	9	3	9	9	9	9	9	9	9	3	9	
				Weight / Importance	225.0	225.0	225.0	235.7	10.7	96.4	203.6	196.4	203.6	353.6	421.4	321.4	64.3	192.9	
				Relative Weight	7.6	7.6	7.6	7.9	0.4	3.2	6.8	6.6	6.8	11.9	14.2	10.8	2.2	6.5	

Budget and Financing

As of right now, we do not have a sponsor and will organize our estimated costs under that assumption. Each component listed below will have the quantity as well as the estimated and total costs. These values are just an estimate and is expected to change in the future.

Item	Quantity	Link	Price	Total Price
Acrylic panels	4	X	$7	$28
Water tank	1	-	$5	$5
Tubing	1	X	$13	$13
Water Pump	1	X	$8	$8
Plants & Soil	-	-	$20	$20
LED Strip grow-lights	1	X	$14	$14
Solar panel &charge set	1	X	$89	$89
Miscellaneous power supply materials	-	-	$40	$40
Microcontroller	1	X	$13	$13
Humidity/temperature sensor	1	X	$9	$9
Soil moisture sensor	2	X	$13	$26
Soil pH sensor	2	X	$30	$60
Sunlight sensor	1	X	$10	$10
Water level sensor	1	X	$4	$4
Humidifier	2	X	$7	$14
LED display for GUI	1	X	$30	$30
Ventilation fan	1	X	$4	$4
			Total:	$387

Milestones

Senior Design 1 Milestones

Week #	Date	Activity
3	May 28	Divide and Conquer 1
4	Jun 4	Research
5	Jun 13	Begin writing document
8	Jul 4	At least half of writing is complete
11	Jul 23	Individual writing is complete
12	Jul 30	Format and print final paper
13	Aug 1	Turn in completed document

Senior Design 2 Milestones

Week #	Date	Activity
1	Aug 26	Order parts
4	Sep 17	Assemble PCB
6	Oct 2	Have completed code
7	Oct 9	Build project
13	Nov 20	Test/finish project
15	Dec 4	Prepare presentation
16	Dec 11	Final presentation