Project YingXao Final Report

ECE 4872 Senior Design Project, Section L-01

Date Submitted: 2021/5/4

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1. Team Information

Advisor: Dr. Linda Milor

Members:

- Yihan Jiang (yjiang400@gatech.edu)
- Yida Wang (yida@gatech.edu)
- Yilun Chen (allenchen@gatech.edu)
- Xi Li (xli832@gatech.edu)

2. Background

In modern cities, people in fast-paced life don’t have enough time to take care of their indoor plants or don’t have the necessary skills to take care of their plants. However, it’s still important to have indoor plants for human beings because indoor plants can improve the air quality by exchanging oxygen with other gases humans produce with breathing, like carbon dioxide. Also, researches have shown that indoor green plants can reduce the chance of getting mental illness and that looking at green plants can help humans maintain healthy eyesight. With all consideration above, team Shouku attempts to provide people with a new option, YingXao the Automatic EcoGardener, that automatically takes care of the user's plants. The only thing users need to do is to enjoy their easy green life.

3. Motivation

There are existing products on the market that automates the gardening workflow, but they share a lot of common problems. To name a few:

- Too expensive: Typically >$2,000 / device.
- Not portable: Typically too big in size.
- Not upgradable: After setting up, gardening plan can no longer be, or has to be manually updated.
- No GUI: Hard to interact with the system.

We aim to develop a device that solves all of the problems mentioned above, making household gardening an affordable, portable, upgradable and accessible thing to do.

4. Objective

Aimed users of YingXao are people who are buried with their work and have no extra free time to take care of their plants. To make it work, YingXao should be placed under sunshine and near a wall plug. YingXao can control light exposure and water supply. YingXao has motors and a glass shield attached for sunlight input control. The motor will adjust the angle of a sunlight blocker (called SolarShield) to block sunlight, reducing the amount of sunshine that the plant is exposed to. For water control, a humidity sensor, a water pump, and a water tank will be embedded in the pot. The water tank is at the bottom of YingXao so that after the humidity sensor sends signals to the water pump and pumps water, excessive water will be recycled. YingXao communicates with users and remote databases via Wi-Fi.

The remaining of this document will further specify the following aspects of this project: description and goals of the YingXao project, relative technical specification, design approach and details, tasks and schedule, cost analysis, demonstration of the project, current status, and leadership roles.

5. Project Description & Goals

5.1 SW/HW Architecture

The overall project is orchestrated by a microprocessor, which is responsible for parsing sensor data, sending control signals, and communicating with the cloud database.

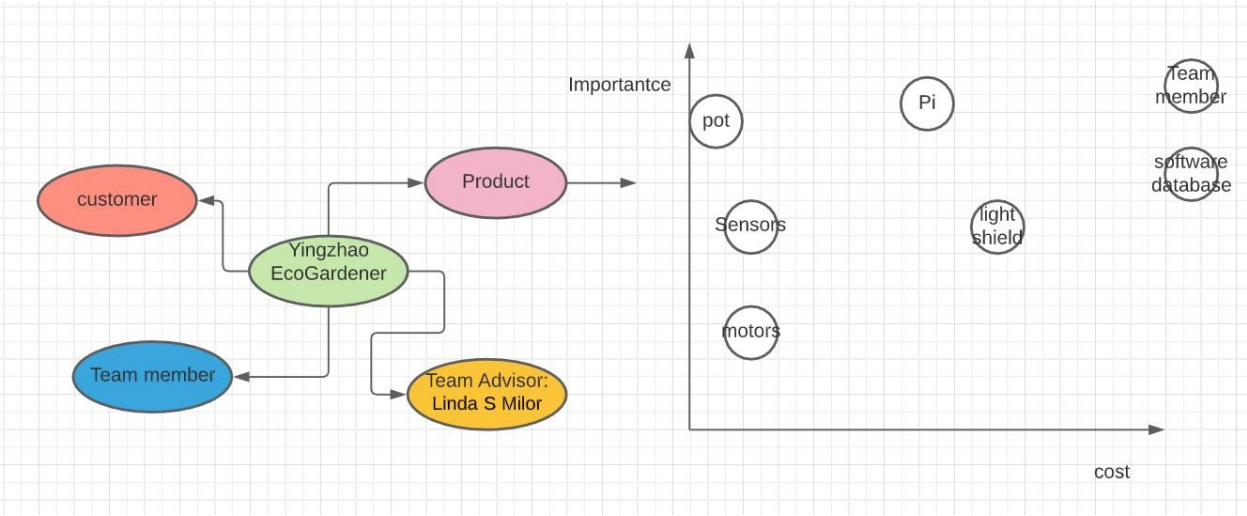

Figure 1. Stakeholder graph and Stakeholder 2×2 chart.

5.2 Customer requirements:

1. Lower electricity consumption
2. High autonomy
3. High portability
4. Cheap

5.3 Goals:

1. The final product should completely free customers from taking care of plants. Customers only need to instruct YingXao what plants they want to grow. The final product should be able to consume less energy and provide users with as much autonomy as possible. Customers can completely leave the plants to the YingXao. YingXao would have high portability so that an adult can carry it by one hand.
2. Target users are someone who has no time to take care of indoor plants, but they are still willing to decorate their living environment with plants.
3. The Target price is $200.

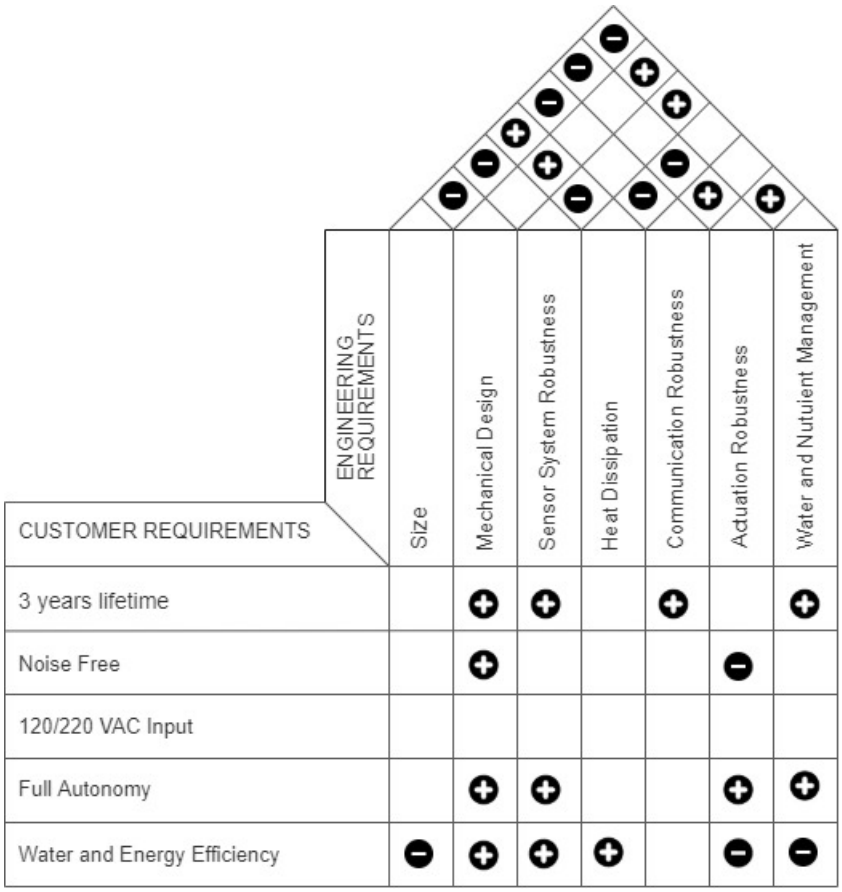

Figure 2. Quality Function Deployment (QFD) of YingXao EcoGardener.

From QFD table above, the design of Yingzhao has conflicts between water and energy efficiency and adoration robustness, heat dissipation and communication robustness. Better mechanical design can contribute to heat dissipation and noise reduction.

6. Table of Quantitative System Specifications Updated from Proposal

6.1 Microcontroller

Table 1 contains the performance specification for the Raspberry Pi Zero W.

Table 1. Raspberry Pi Zero W[1] Specifications

Feature	Specification
CPU	1GHz single-core ARMv6
RAM	512MB
Communication	802.11n wireless LAN + Bluetooth 4.0
I/O Pins	HAT-compatible 40-pin header
Power	Micro USB

6.2 Humidity Sensor

Table 2 contains the specification for the humidity sensor.

Table 2. DHT22 temperature-humidity sensor [2]

Feature	Specification
Power	3 to 5V
Data Output	I/O
Max Current (while requesting data)	2.5mA
Humidity Reading	0 to 100% with 2-5% accuracy
Temperature Reading	-40 to 80°C with ±0.5°C accuracy
Sampling Rate	0.5 Hz sampling rate (once every 2 second)
Body Size	15.5mm x 12mm x 5.5mm

6.3 Sunlight Sensor

Table 3 contains the specification for the sunlight sensor.

Table 3. Grove - Sunlight Sensor[3]

Feature	Specification
Operating Voltage	3.0-5.5V
Working current	3.5mA
Wave length	280-950nm
Default I2C Address	0x60
Operating Temperature	-45-85℃

6.4 Moisture Sensor

Table 4 contains the specification for the moisture sensor.

Table 4. Grove - Capacitive Moisture Sensor (Corrosion-Resistant)[4]

Feature	Specification
Operating Voltage	3.3V / 5V
Output Interface	Analog
Length	92.1mm
Width	23.5mm
Height	6.5mm
Weight	10.6g

6.5 Analog-to-Digital Converter (ADC)

Table 5 contains the specification for the ADC.

Table 5. ADS1115 16-Bit ADC - 4 Channel with Programmable Gain Amplifier[5]

Feature	Specification
Operating Voltage	2.0V to 5.5V
Current Consumption	150µA Single-Shot Mode
Programmable Data Rate	8SPS to 860SPS
Interface	I2C

6.6 Voltage Regulator

Table 6 contains the specification for the voltage regulator.

Table 6. Pololu 12V Step-Up/Step-Down Voltage Regulator S18V20F12[6]

Feature	Specification
Input Voltage	2.9V to 32V
Output Voltage	Fixed 5 V, 6 V, 9 V, 12 V, or 24 V
Accuracy	4%
Maximum Output Current	2A
Compact Size	1.7″ × 0.825″ × 0.38″

6.7 Stepper Motor

Table 7 contains the specification for the stepper motor.

Table 7. 28BYJ-48 - 5V Stepper Motor[7]

Feature	Specification
Rated Voltage	5V DC
Number of Phases	4
Stride Angle	5.625°/64
Pull in torque	300 gf.cm
Insulated Power	600VAC/1mA/1s
Coil	Unipolar 5 lead coil

6.8 Liquid Pump

Table 8 contains the specification for the liquid pump.

Table 8. Peristaltic Liquid Pump with Silicone Tubing - 12V DC Power[8]

Feature	Specification
Motor Voltage	12VDC
Motor Current	200-300mA
Flow Rate	up to 100 mL/min
Weight	200 grams
Dimensions	27mm diameter motor, 72mm total length
Silicone Tubing	4mm outer diameter, 2mm inner

The overall system performance specification is mainly determined by the microcontroller because it represents the brain of the system. The microcontroller is connected to all the sensors to receive necessary data from the plant. It is also sending the data to the database to notify the user when needed. The user can view different sensor data information through our mobile app based on the type of the plant. Some examples of sensor data are humidity, temperature, ultraviolet index, soil moisture level, etc. All of these features will be determined by how fast the microcontroller is processing the data and communicating with the sensors and database.

7. Table Expanded to include Recorded Measurements from Demonstration

Test	Measurement
Water Pump Test	Moisuture reading increases from 67% to 98%
User Log in and Sign Up	The log in process and sign up can be done under Android OS mobile phone
Solar Shield Test	The Solar Shield can move to designed location to perform sunshine control

8. Design Approach

There are three main components of EcoGardener: Sensing that acquires environment data and sent to the microcontroller, Controls that reacts to the environment, dynamically adjusting the systems' gardening strategy, and Communication that takes care of the system's interaction with our cloud infrastructure.

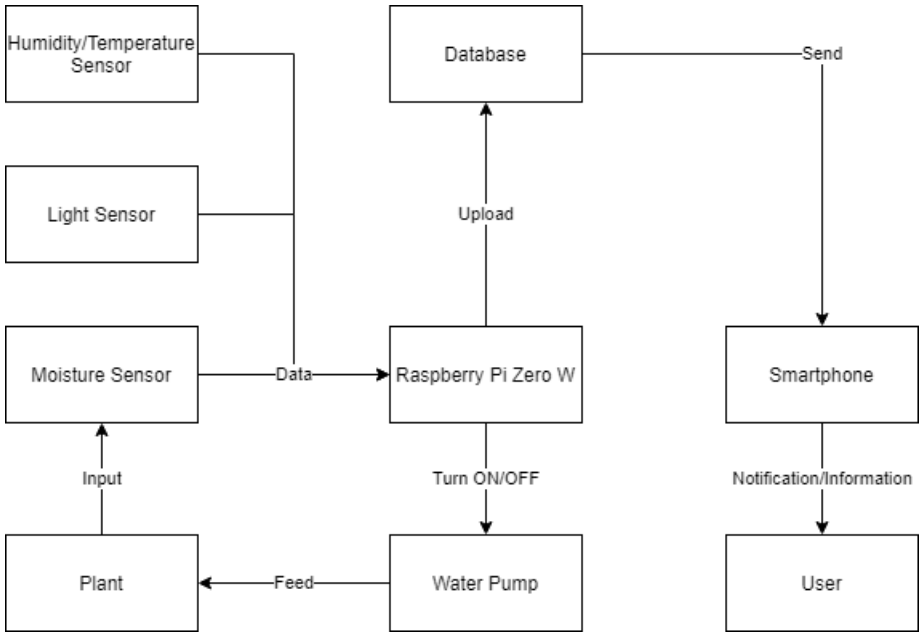

Figure 3. System overview block diagram of YingXao EcoGardener.

8.1 Sensing

Light sensor, humidity/temperature sensor, and moisture sensor will be installed onto the board to acquire environment data.

8.2 Control

Control actuators include 1 stepper motor and 1 liquid pump.

The stepper motor is responsible for controlling the movement of the solar shield, and the liquid pump will be responsible for controlling water ingestion into the pot.

8.3 Communication

YingXao communicates with remote databases to get the optimal strategy for growing the plant specified by the user by making RESTful API calls to the server, while also submitting its sensor data to the cloud infrastructure to process.

Figure 4. Final model of YingXao EcoGardener.

9. Codes and Standards

- Institute of Electrical and Electronics Engineers (IEEE)
- Coordinated with ANSI, ETSI, and other standards organizations (e.g. IEEE/ANSI N42)
- IEEE 802.xx standards are most cited and concentrate on telecommunications
- IEEE 1666 standards concentration on software
- Environmental Protection Agency (EPA)
- Occupational Safety and Health Administration (OSHA)
- Consumer Product Safety Commission (CPSC)

10. Constraints

The YingXao must be placed on a window with sunshine and the side with sunlight sensor is placed toward to the direction of sunshine.

The plant care plan must be updated when device is under WiFi network

The YingXao need users to add soil and water when there is not enough soil and water

The device uses power cable to power the whole device so it needs to be placed near wall plug

11. Tradeoffs

The implementation of DHT22 decreases the cost but the signal to noise ratio decreases.

The Android Studio decreases the app developing difficulties, but lost the all platform compatibility

The 3D printing simplifies the prototype building process but increases the cost.

Sunlight sensor position, which is outside of the universal mount, provides better sunlight control sensor input but decreases the aesthetics.

The implementation of Pi zero decreases the cost significantly but the computation power also decreased.

12. Actual Schedule, Tasks, Milestones (Graphically/Tabular)

Aa Name	Assign	Date
Mechanical Design	Allen Chen	@Jan 10, 2021 → Mar 13, 2021

Name	Assign	Date
Embedded Framework Integration	Yida Wang	@Apr 28, 2021 → May 1, 2021
Embedded Framework parts	Yida Wang	@Jan 10, 2021 → Feb 2, 2021
Database setup	Yihan Jiang	@Jan 10, 2021 → Feb 10, 2021
App Development	Yihan Jiang	@Mar 10, 2021 → Apr 10, 2021
Bluetooth Connection	xi li	@Mar 6, 2021 → Mar 27, 2021
Bluetooth and WiFi Connection	Yihan Jiang xi li	@Mar 27, 2021 → Apr 3, 2021
Test and Debug	Yida Wang Allen Chen xi li Yihan Jiang	@Mar 28, 2021 → Apr 10, 2021
Website Hosting	Allen Chen	@Mar 25, 2021 → Apr 22, 2021

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13. Details of Actual Documentation, Results & Acceptance Testing

Test	Result
WiFi Connection	The connection be built within 10s
Solar Shield	The solar shield can control sunshine at designed time
Water Transmissions	The humidity reading is under design specification
App login and signup	New users and return users can login with 5s

14. Marketing and Cost Analysis

14.1 Market Analysis

Plants are an essential element in a room for their decorative and practical usage. Their enjoyable appearance and the fresh air it brings increase the demand for in-door pot. The busy working or schooling schedules, however, prevent people from taking good care of the plants. By analyzing the customer reviews[9][10] under some EcoGardeners, we summarize several expectations and feedbacks of an automatic in-door gardener.

1. Customers want to see the real-time update of the environmental data on the app.
2. Large gardeners are too expensive.
3. Instructions are too complicated.
4. The light on the gardener is too bright and too hot.

YingXao meets all the expectations and improves the problems mentioned in the feedback. We create an app that can track the real-time data of the gardener environment. The price is much cheaper

compared to the existing gardeners of similar sizes. The instruction has only one step, which is choosing the plant seed and all other steps will be automatic. YingXao does not contain a bright and hot light since it uses the sunlight and a shield to adjust the lightning.

The application of using microcontrollers in IoT smart vase is not common. Instead of taking care of the plants, most of the “smart vases” are only functioned to play music or change the vase body color. A few commercial smart vases are designed to take care of the plants, but the price is too high to be a household appliance for a normal family. Brand Gardyn[11] has a series of competitive smart gardener products such as the “GARDYN EXPLORER”, “GARDYN HERO”, and “GARDYN HERO PLUS”. Their prices are as high as one thousand dollars each after the discount applied. Gardyn smart gardener allows customers to choose the type of plant in their Gardener app and provides the corresponding growing solution and seeds for users. The app will notify the users when more water or nutrients are needed by monitoring the growth of the plants with sensors.[12] All growth data are recorded on the Gardyn app.

Our automatic EcoGardener YingXao will offer similar functionality as Gardyn in terms of allowing automatic adjustment to the environment and updates this information on an app. The pricing of YingXao will be far lower compared to Gardyn at around one hundred dollars, which is 1/10 of the Gardyn’s or similar products in the market. The smaller size also increases its portability and makes it far more energy-efficient.

14.2 Cost Analysis

The following table is an analysis of the cost and profit before finalizing the design. As we illustrated in the technical specification section, the microcontroller is the Raspberry Pi Zero W, which is the cheapest one that meets the minimum requirement of building YingXao. The battery and sensors are a little bit expensive but they are durable and work well with the Raspberry Pi Zero W. The unit price of YingXao is $100 as we proposed before the design, which is only one-eighth of the price of existing in-door gardeners with similar sizes. The deficit will only occur in the first year since the overhead is expensive and the developing process is long. Profits will be made in future years.

Table 9. Proposed Revenue and Cost Sheet.

Non-Reoccuring Cost									
Total Non-Recost			$100.00						
Overhead %	30		$30.00						
Adjusted Non-R									
Total Units Sold									
Reoccuring Costs									
			Year 1		Year 2		Year 3		Year 4
Sales Volume (units)		2500		5000		6000		4000	
Unit Price		$100.00		$100.00		$90.00		$90.00	
Sales Revenue			$0.00		$0.00		$0.00		$0.00
Non-Re Cost			$0.00	$18.94	$94,700.00	$18.94	$113,640.00	$18.94	$75,760.00
1. Research and Development									
Redesign			$0.00		$0.00		$0.00		$0.00
Engr Change Order			$0.00		$0.00		$0.00		$0.00
2. Production									$0.00
Parts:									
Plastic Pot		$0.71	$1,775.00	$1.00	$5,000.00	$1.00	$6,000.00	$1.00	$4,000.00
Micro-controller (Raspberry Pi Zero W)		$15.00	$37,500.00	$15.00	$75,000.00	$15.00	$90,000.00	$15.00	$60,000.00
Sensors		$8.00	$20,000.00	$5.00	$25,000.00	$5.00	$30,000.00	$5.00	$20,000.00
Battery		$5.00	$12,500.00	$5.00	$25,000.00	$5.00	$30,000.00	$5.00	$20,000.00
Tupperware		$5.35	$13,375.00		$0.00		$0.00		$0.00
Light Shield		$1.14	$2,850.00	$2.00	$10,000.00	$2.00	$12,000.00	$2.00	$8,000.00
Assembly		$1.00	$2,500.00	$1.00	$5,000.00	$1.00	$6,000.00	$1.00	$4,000.00
Packaging		$0.50	$1,250.00	$1.00	$5,000.00	$1.00	$6,000.00	$1.00	$4,000.00
Testing		$0.50	$1,250.00	$1.00	$5,000.00	$1.00	$6,000.00	$1.00	$4,000.00
3. Package		$0.50	$1,250.00	$0.50	$2,500.00	$0.50	$3,000.00	$0.50	$2,000.00
4. Marketing	Non Engr		$30,000.00		$0.00		$0.00		$0.00
5. Sales	Non Engr		$30,000.00		$0.00		$0.00		$0.00
6. Distribution	Shipping	$1.00	$2,500.00	$1.00	$5,000.00	$1.00	$6,000.00	$1.00	$4,000.00
7. Support	Non Engr		$30,000.00		$0.00		$0.00		$0.00
Total Cost/Year			$186,750.00		$257,200.00		$308,640.00		$205,760.00
Overhead	20		$37,350.00		$51,440.00		$61,728.00		$41,152.00
Adjusted Cost =			$224,100.00		$308,640.00		$370,368.00		$246,912.00
Cost/Unit			$89.64		$61.73		$61.73		$61.73
Total Profit/Year			$25,900.00		$191,360.00		$169,632.00		$113,088.00
Total Profit			**$25,900.00**		**$217,260.00**		**$386,892.00**		**$499,980.00**
Profit/Unit			$10.36		$38.27		$28.27		$28.27

During the design process, we realized that more sensors are needed than before, so the adjusted price is $200 per unit instead of $100 per unit.

The actual cost shows in the following table.

Table 10. Actual Revenue and Cost Sheet.

	A	B	C	D	E	F	G	H	I	J
1	**Non-Reoccuring Cost**									
2	Total Non-Recost			$100.00						
3	Overhead %	30		$30.00						
4	Adjusted Non-R									
5	Total Units Sold									
6										
7	**Reoccuring Costs**									
8				Year 1		Year 2		Year 3		Year 4
9	Sales Volume (units)		2500		5000		6000		4000	
10	Unit Price		$200.00		$200.00		$200.00		$200.00	
11	Sales Revenue			$0.00		$0.00		$0.00		$0.00
12										
13	Non-Re Cost			$0.00	$18.94	$94,700.00	$18.94	$113,640.00	$18.94	$75,760.00
14										
15	**1. Research and Development**									
16	Redesign			$0.00		$0.00		$0.00		$0.00
17	Engr Change Order			$0.00		$0.00		$0.00		$0.00
18	**2. Production**									$0.00
19	**Parts:**									
20	Plastic Pot		$11.50	$28,750.00	$11.50	$57,500.00	$11.50	$69,000.00	$11.50	$46,000.00
21	Micro-controller (Raspberry Pi Zero W)		$10.00	$25,000.00	$10.00	$50,000.00	$10.00	$60,000.00	$10.00	$40,000.00
22	Moisture Sensor		$5.95	$14,875.00	$5.95	$29,750.00	$5.95	$35,700.00	$5.95	$23,800.00
23	Sunlight Sensor		$13.66	$34,150.00	$13.66	$68,300.00	$13.66	$81,960.00	$13.66	$54,640.00
24	Pump		$10.99	$27,475.00	$10.99	$54,950.00	$10.99	$65,940.00	$10.99	$43,960.00
25	Motor		$3.00	$7,500.00	$3.00	$15,000.00	$3.00	$18,000.00	$3.00	$12,000.00
26	DHT22		$9.55	$23,875.00	$9.55	$47,750.00	$9.55	$57,300.00	$9.55	$38,200.00
27	Light Shield		$0.94	$2,350.00	$0.94	$4,700.00	$0.94	$5,640.00	$0.94	$3,760.00
28	**3. Package**		$0.50	$1,250.00	$0.50	$2,500.00	$0.50	$3,000.00	$0.50	$2,000.00
29	**4. Marketing**	Non Engr		$30,000.00		$0.00		$0.00		$0.00
30	**5. Sales**	Non Engr		$30,000.00		$0.00		$0.00		$0.00
31	**6. Distribution**	Shipping		$0.00	$1.00	$5,000.00	$1.00	$6,000.00	$1.00	$4,000.00
32	**7. Support**	Non Engr		$30,000.00		$0.00		$0.00		$0.00
33										
34	**Total Cost/Year**			$255,225.00		$430,150.00		$516,180.00		$344,120.00
35	**Overhead**	20		$51,045.00		$86,030.00		$103,236.00		$68,824.00
36	**Adjusted Cost =**			$306,270.00		$516,180.00		$619,416.00		$412,944.00
37	**Cost/Unit**			$122.51		$103.24		$103.24		$103.24
38										
39	**Total Profit/Year**			$193,730.00		$483,820.00		$580,584.00		$387,056.00
40										
41	**Total Profit**			**$193,730.00**		**$677,550.00**		**$1,258,134.00**		**$1,645,190.00**

We assume the starting salaries for an engineer is 80,000 dollars per year. The development cycle of YingXao will take three months for our four engineers to finish. Thus, the total salary that needs to be paid is 80,000 dollars.

Table 11. Non-Reoccuring Cost.

Non-Reoccuring Cost					
		Number	Salary/Yr	Months	Cost
1. Research and Development					
Employees					
	Engineers	4	$80,000.00	3	$80,000.00
Computer Systems					$0.00
Other Cap Equip					$0.00
Documentation					
	Non Engr	0	$80,000.00	0	$0.00
Design for Testability					
	Non Engr	0	$80,000.00	0	$0.00
2. Production					
Setup Charges					
	Engineers	1	$80,000.00	0.5	$3,333.33
	Non Engr	0	$30,000.00	0	$0.00
Testing Design					
	Engineers	0	$80,000.00	0	$0.00
	Non Engr	0	$30,000.00	0	$0.00
3. Packaging					
Package Design					
	Non Engr	0	$30,000.00	0	$0.00
4. Marketing					
	Non Engr	0	$30,000.00	0	$0.00
5. Sales					
	Non Engr	0	$30,000.00	0	$0.00
6. Distribution					
	Non Engr	0	$30,000.00	0	$0.00
7. Support					
	Engineers	0	$50,000.00	0	$0.00
Total Non-Reoccuring Cost					$83,333.00

15. Conclusion

15.1 Current Status

YingXao automated gardener consists of two main parts, which are the physical device and the mobile app. It is fully automated so that the it will take care the plant by adding water and limit the sunshine,

and display the real-time sensor data on the app.

Users are able to choose the plant type and find out four sensor readings with both the real-time sensor reading and the desired data on the app: the humidity, the sunlight, the moisture, and the temperature. Figure 5 is the data displaying page on the app.

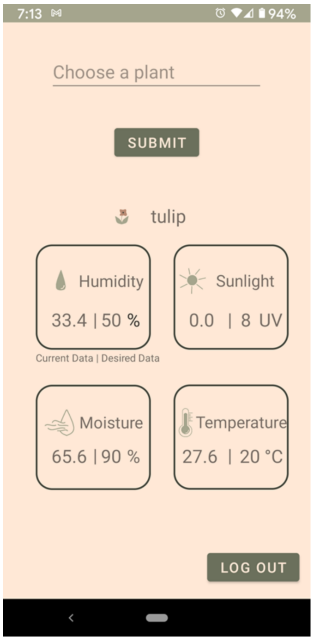

Figure 5. Data displaying page of app YingXao.

With the chosen plant type, the water pump will add water when the real-time sensor value is smaller than the desired value, and the solar shield rotates to block the sunshine for a certain amount of time.

15.2 What Happened

Our team spent the previous semester on deciding the product to build and the general idea of the design process. The idea got completed after writing the project draft summary, the technical review paper, the cost analysis, and the final proposal.

We started the actual building process at the beginning of this semester. Details were finalized, and some idealized design in our proposal became more practical as we develop. Some essential steps, such as the WiFi connection of the Raspberry Pi and the the UI design, that were not considered in the proposal resulted in some push backs of the schedule.

15.3 Discussion of Sustainability & Contemporary Issue

Compare to similar products on the market, YingXao is a eco-friendly and energy-saving gardener that meets all requirements from customers. As mentioned above, many in-door gardener uses LED light for adjusting sunshine to meet the plant sunlight requirement[11]. It is a waste of the natural sunshine. Our product YingXao takes advantage of the clean and sustainable resource, solar energy, that provides enough sunshine to the plant, adjusting it with a rotating solar shield. The water was also recyclable. Extra water will be filtered at the bottom of the pot and stored in the lower water tank for future use.

15.4 Lessons Learned

- Specify the deadline for each task
- Provide as many details as possible after finishing a certain part
- Always provide requirement files for programming script
- Communicate more with teammates
- Be concise when report during weekly meeting
- Do not spend too much time on trivial issues
- Be specific about each design step in the proposal in order to avoid some unexpected problem

15.5 Future Works

- Expand the user management system for larger capacity.
- Develop app for IOS.
- Improve the device registering process.
- Integrate possible plant info database.
- Apply information security rules in sign in & log in process.
- Include liquid fertilizer.
- Enable notification to users when the gardener needs more water.

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