Senior Design: Smart Irrigation

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1 Design Impact Statement

1.1 Public Health, Safety, and Welfare Impacts.

As mentioned in the environmental impacts the system is designed with a plastic enclosure which has long term health impacts that are a result of the environmental impacts. For safety the device has high power electronics that if used incorrectly could be detrimental to the user.[1] The highest power is the mains which can be dangerous but this risk is negated as the users interaction with power electronics is limited with the individual plug into mains and the electronics being internal once the design is fully implemented. Due to the modular nature of the irrigation controller the user has to have some contact to the screws that hold the 24VAC but with general electrical safety device should be safe to operate.

On the other hand more and more data shows that a good garden is good for health, According to the report of Masashi Soga, Kevin J. Gaston, Yuichi Yamaura (2016), 'Gardening is beneficial for health: A meta-analysis', 'With an increasing demand for reduction of health care costs worldwide, our findings have important policy implications. The results presented here suggest that gardening can improve physical, psychological, and social health, which can, from a long-term perspective, alleviate and prevent various health issues facing today's society.' It can be seen that a good garden will have a great impact on public health, and our project Vertical Garden and Irrigation Controller helps residents to create a perfect garden with less effort. Residents do not have to worry about irrigation and other issues every day, and in reference materials 'Gardening is beneficial for health: A meta-analysis' also pointed out that the garden may reduce the chance of residents getting sick. For public health, our project can play a positive role.

1.2 Cultural and Social Impacts

The main market for this device is for home lawns and home gardens. While gardens are a great and common way to grow personal food and improve general wellness.[2] the other side use of this product, home lawns are a wasteful practice that in the US alone uses half of it's outdoor water use around 9 billion gallons a day.[3]. The same reference also mentions that up to half of the water used outside is wasted to wasteful water usage. While our system addresses the waste created from leaving a system on it doesn't do anything to stop poor sprinkler planning or bad optimization of watering schedules so our system could encourage or improve water waste depending on the users use.

Community gardening has become an international sport, especially popular in the United States. Community gardens can improve the interaction process of community residents and increase the chances of residents participating and sharing knowledge. According to the report of Nicole Rogge, Insa Theesfeld, Carola Strassner (2020), 'The potential of social learning in community gardens and the impact of community heterogeneity', 'Community gardening has become an international movement with a simultaneously growing scientific interest. This is due to the community gardens' multiple contribution to sustainable development, among other characteristics, through their educational role and potential for social learning.' Through our project, a beautiful community garden can be created more easily, and most of the garden maintenance costs can be saved. This makes it easier to form a garden community culture and can have a positive impact on the community. But on the other hand, due to the epidemic, too many community gatherings may have an unimaginable impact on the community. For residents who use our project and those who intend to build community gardens, please carefully consider the use of gardens in a specific period.

1.3 Environmental Impacts

Plastics in general have caused major environmental disasters such as increased ocean acidity. Being the most common form of 3D printing plastic PLA will be focused on. Unlike oil based plastics PLA has some renewable factors as it is made from starch (glucose) meaning that it comes from corn instead of fossil fuels (It should be noted that ABS is still made from oil based processes and is the second most common plastic). There are arguments to make that the amount of resources that it takes to create a kg of PLA disrupts the normal food supply environmental damage from the need it creates in the supply chain. Additionally, while a bio product the ability for PLA to fully decompose is only achievable under very specific conditions. It requires an industrial composting facility to fully break down the plastic quickly.[4] Without the specific infrastructure the decomposition age is expected to be 80 years. During this time similar concerns exist to regular plastics including micro plastic contamination.
Because of these concerns there was still outcry to using plastic even after moving normal plastic grocery bags to PLA plastic.[5] This in Oregon resulted into a full plastic bag ban for grocery stores including PLA. Needless to say that while the world has relied on plastics for a long time they will be replaced as the world becomes more sustainable. Regardless, plastic is still the standard for electronic enclosures and is the easiest to access for a DIY consumer. So despite the environmental costs that are associated with plastic I believe that it is the best option for the project. In the end as this is designed for individuals to use in home systems, if they consider this to be unethical or the methods mentioned in the document become outdated, the rest of the project can still be used with adaptions to the enclosure.

1.4 Economic Factors

The design isn't created with economics as its highest priority so as technology changes or if the user doesn't have access to a 3D printer the design might not be economically viable for them to purchase. On the other hand, if a user has access to a 3D printer and a raspberry pi, there's only the PCB's that wouldn't be readily available to them. When comparing to other irrigation controllers such as the popular Rain Bird can range from $150 to $300 depending on the model.[6] Compared to that price point we have a good economic value as someone with no prior tools would be able to make our device at the same price point, reducing the cost if they again had access to a 3D printer or a spare raspberry pi.

On the other hand, if a company adopts an automatic irrigation system, it will lead to the cause of a large number of people, as the Guardian 'Automated farming: good news for food security, bad news for job security?' (2016),'For countries in the industrial world, this growing automation probably means the continued decline of rural life. The issue of labour is even more important for the economies of the global south, where there are fewer urban job opportunities. In those countries, technologies that take labour out of the fields may undermine efforts to reduce poverty and enhance development.' However, automatic irrigation technology will definitely be popularized, and the problem of population unemployment will undoubtedly be a new challenge.

2 Project Timeline

2.1 Group Timeline

Week 3	Team formed, meet with project sponsor, engineering requirements draft
Week 4	Communication evaluation meeting, risk register (individually), research individually
Week 5	Writing workshop
Week 6	(draft, sub-teams) block diagram, bi-weekly progress video,
Week 7	Update sponsor, instructor system architecture meeting, project charter
Week 8	Teamwork reflection video, bi-weekly progress video
Week 9	(sub-teams) engineering requirements, (sub-teams) block diagram
Week 10	Research implication report, project partner update, bi-weekly progress video, block validation(s)
Fall Finals	Prototype demonstrations
Week 13	Majority of blocks of system is done
Week 15	All blocks of system design done
Week 17	PCB sent out for fabrication
Week 23	Integrate hardware and software
Week 24	Build PCB
Week 25	Film the project summary video

Table 1: Groups Timeline

2.2 Individual Timelines

Caleb:

Week 1	Research
Week 3	Similar systems
Week 4	System Requirement
Week 7	Enclosure expectations
Week 8	Design schematic for power supply
Week 11	Enclosure drafting
Week 13	Verify requirements
Week 14	Design aesthetics
Week 17	Build enclosures
Week 22	Build PCB
Week 24	Mount enclosure and PCB
Week 26	Film Verification's

Table 2: Caleb's Timeline

Boyuan:

Week 3	Reasearch
Week 4	Humidity, temperature, light
Week 5	Water required by plants
Week 6	Design a PCB
Week 8	Order PCB
Week 13	Design a code for Sprinkle
Week 14	Try to connect the sprinkler and Controller
Week 16	Run Sprinkler code
Week 17	Assemble the PCB
Week 18	Put the PCB in the enclosure
Week 20	Begin testing the Sprinkler
Week 21	Try to connect the controller and Sensor controller
Week 23	Film the sprinkler and controller in action

Table 3: Boyuan's Timeline

3 Scope and engineering requirements summary

3.1 Nutrient Data

Customer Requirement: The system must suggest actions based on nutrient levels in the soil.

Engineering Requirement: The system must be able to determine nutrient levels of each nutrient within a 5% margin of error.

Verification Method: Test

Test Process:
1. Pour soil into a container of 1m*1m*1m
2. Use professional equipment to detect the content of nitrogen, phosphorus, and potassium in the soil
3. Record professional instrument data
4. Use soil sensors to detect the content of nitrogen, phosphorus, and potassium in the soil
5. Record the NPK content recorded by the system

Test Pass Condition: Comparing the data of the professional instrument and soil sensor, the measurement error is less than 5% for each nutrient.

Evidence Link: REQUIREMENT REMOVED.

3.2 Scheduling

Customer Requirement: The system must be able to water the garden at scheduled intervals.

Engineering Requirement: The system must turn the irrigation solenoids on within one minute of the scheduled time.

Verification Method: Demonstration

Test Process:
1. Schedule a time to open the solenoid pump program.
2. Observe the program one minute before the scheduled time while paying attention to the current time.
3. When the water pump is turned on, record the time.

Test Pass Condition: The pump turn on within one minute of the scheduled time.

Evidence Link: Link

3.3 System Power

Customer Requirement: The soil sensor must be remote and the irrigation controller must be power from a wall outlet.

Engineering Requirement: The soil sensor subsystem battery should last at least 3 hours and the irrigation controller should be powered by 110VAC

Verification Method: Test

Test Process:
Verify the raspberry pi will turn on when plugged into 110VAC wall outlet.

Test Pass Condition: The Irrigation controller's raspberry pi will turn on when plugged into a standard US wall outlet.

Evidence Link: Link

3.4 Solenoid Power Control

Customer Requirement: Each sprinkler in the garden can be controlled individually.

Engineering Requirement: The system will be able to output 5 differnet 24VAC at 60Hz and 0.14A channels, independently controlled by the Irrigation Controller.

Verification Method: Test

Test Process:
1. Plug the system in and manually turn on all of the solenoids
2. Using an oscilloscope probe each of the 5 solenoid channels to confirm the output is 24VAC at 60hz.

Test Pass Condition: Each connector displays 24VAC at 60Hz

Evidence Link: Link

3.5 Water proof

Customer Requirement: The system will be waterproof.

Engineering Requirement: The system will be able to be submerged completely under 3 inches of water for one minute and still function.

Verification Method: Test

Test Process:
1. Fill a container with water.
2. Submerge the system 3 inches under the water.
3. Wait 1 minute.
4. Remove from the container.
5. Test if the system continues to function.

Test Pass Condition: The unit still functions after being submerged completely under 3 inches of water for one minute.

Evidence Link: Link

3.6 Adjusts to weather

Customer Requirement: The system must adjust how much it waters the garden based on the weather.

Engineering Requirement: The system will reference the ideal water intake table and adjust schedule acordingly. In total the water the plant recieves should be within 5

Verification Method: Test

PART A:
1. Change the pump output (the first line), rainfall (the second line), and the water demand of the first plant (the third line) in the txt file.
a. txt file's first line is 20
b. txt file's second line is 100
c. txt file's third line is 200
2. Start the water pump program, observe whether the water pump is turned on, and record the time it has been turned on.

PART B:
1. Change the pump output (the first line), rainfall (the second line), and the water demand of the first plant (the third line) in the txt file.
a. txt file's first line is 20
b. txt file's second line is 200
c. txt file's third line is 200
2. Start the water pump program, observe whether the water pump is turned on.

Test Pass Condition: In PART A, the opening time of the pump should be 5 seconds, and the measurement error should not exceed 1 second. In PART B, the pump cannot be turned on.

Evidence Link: Link

3.7 Mobile soil tester

Customer Requirement: The soil sensor can be easily carried and handled.

Engineering Requirement: The soil sensor subsystem will weigh less than 10 pounds and 90

Verification Method: Test

PART A:
1. Weigh the soil sensor.
2. Give the soil sensor to a user.
3. Ask the user to take a sample with simple instructions.
4. Allow the user to take the sample.
5. Ask the user about their experience and whether or not the process was simple.
6. Repeat steps 2-5 for at least 10 users.

Test Pass Condition: The soil sensor subsystem weighs less than 10 lbs and 90

Evidence Link: REQUIREMENT REMOVED

3.8 Various Plants

Customer Requirement: The system must adjust how much it waters based on what plant is being watered.

Engineering Requirement: The system will have watering data for at least 5 different plants, Users can call data to five different sprinkler.

Verification Method: Test

PART A:
1. Change the pump output (the first line), rainfall (the second line), and the water demand of the first plant (the third line) in the txt file.
a. txt file's first line is 20
b. txt file's second line is 0
c. txt file's third line is 100
2. Start the water pump program, observe whether the water pump is turned on, and record the time it has been turned on.

PART B:
1. Change the pump output (the first line), rainfall (the second line), and the water demand of the first plant (the third line) in the txt file.
a. txt file's first line is 20
b. txt file's second line is 0
c. txt file's third line is 200
2. Start the water pump program, observe whether the water pump is turned on, and record the time it has been turned on.

Test Pass Condition: In PART A, the opening time of the pump should be 5 seconds, and the measurement error should not exceed 1 second. In PART B, the opening time of the pump should be 10 seconds, and the measurement error should not exceed 1 second.

Evidence Link: Link

4 Risk Register

4.1 Expected Risks

As is, our highest risks are the product being too expensive, the app not working on all devices, and the GPS not having the accuracy that we need.

For the cost of our project we are making sure to consider multiple methods for each solution possible. The main risk that comes from going over budget is that we will not have a competitive product for the market not running over the budget given by our class and sponsor. As treasurer Caleb has taken over seeing that this risk is avoided.

For the app integration on all devices, we need to make sure that we are designing and coding our web interface with all devices in mind. It's important that we will be able to connect and retrieve sensor data into the raspberry pi and display on web applications. Furthermore, the web application will connect to a backend database that retrieves data from API to make schedules.

To do this we will need to research how to create a product that is flexible to be viewed on all the appropriate platforms (web, mobile).

Hardware integration lies in the Raspberry Pi, which is the bridge that connects between the CS database, web interface to ECE hardware. Each of the sensors will be tested separately first then connect together to make sure that the connection won't be interrupted. Furthermore, the value also needs to be correct with appropriate matching value (ph, %, celsius, fahrenheit), the backend code for raspberry Pi will be optimized so that the value being updated in real time. To mitigate this risk CS team will need to connect closely and establish a close line of communication to the ECE team so that any change won't conflict with both the hardware and software. Man Ha takes responsibility in testing and controlling this risk.

Lastly, the risk of the GPS not being accurate for our project will change the scope that we can achieve with the soil sensor section of the project. To mitigate this risk we have dedicated research time into different GPS modules with various ways to handle this facet of our project. If this fails to work the section of the project can be adapted as this isn't a vital component of our design but will lose functionality unique to our product. Trenton has decided to manage this risk as he has experience with Raspberry Pi interfacing with various types of sensors.

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance indicator	Responsible party	Action Plan
R1	Product too expensive	Cost	30%	M	Price	Caleb	Retain
R2	GPS not precise enough	Technical	20%	H	Accurate down to 2.5m	Trenton	Retain
R3	Soil probe does not interface with the app	Technical	15%	H	The app receives data from probe	Trenton/Man	Reduce
R4	App doesn't work on all devices	Technical	35%	M	If it works on iOS and Android and PC	Max/Josh	Retain
R5	Database will not support multiple users	Technical	20%	M	The database has more than one user	Josh	Reduce

Table 4: Risk Register

5 Future Recommendations

5.1 Add sensors to the irrigation system

As the team responsible for the sensor withdrew from the project, the smart garden irrigation system canceled the sensor part. As a result, the sprinkler system cannot detect the nutrient status and humidity of the soil, and users cannot know this information.
Recommendation: Please choose a sensor that supports Raspberry Pi. You can find cheap sensors on AliExpress, which include sensors for measuring nitrogen, phosphorus and potassium and sensors for soil moisture.

5.2 Regular sprinkler system update

The current system only supports the built-in timed sprinkling program, and users cannot update the sprinkling time on the web page. Since the cs team does not have time to add this function, we put aside the function of updating the sprinkling time.
Recommendation: If you need to add this function, you need to negotiate with the cs team to add the watering time data to the input file. And let the built-in timing program of Raspberry Pi can read the data of sprinkling time.

5.3 Add a sensor to detect the water output of the pump

At present, the water output of the water pump needs to be measured by the user and entered on the web page. If sensors can be added to the water pump to detect the water output of the pump,

the system will be more intelligent.
Recommendation: When choosing a sensor, it is not easy to find a sensor that accurately measures the water flow, and the price factor must also be considered. In addition, the data measured by the sensor needs to be synchronized to the local data of the Raspberry Pi and also needs to be entered into the database of the webpage.

5.4 Added power failure reminder

Currently, the Raspberry Pi has a 1000 mAh battery power supply solution, but we cannot detect when the system will be powered off. If possible, please add a power failure alarm function. When the system is powered off and the backup battery is activated, the program can notify the user of the alarm through the website.
Recommendation: The built-in battery of the system needs to send alarms to the database of the website during work, and the website sends the alarms to the user's e-mail address. This requires the two teams of ECE and CS to work together.

5.5 Research optimal layouts for home sprinkler system

This project intentionally avoided the idea of interacting with the plumbing of the project opting instead to only focus on the solenoids that that plumbing would use. While effective in isolating a major difficulty in creating a DIY home sprinkler system it is the first step in creating a fully functional system. This part is highly dependent on the home owners layout and what they wish to separate in terms of watering.
Recommendation: There are many guides online on how to big the trenches, measure the pipes, and calculate the radius that the sprinklers will cover. This information would be useful for the user and such should be combined in an easy way to read giving the user an installation guide.

5.6 Integration of the ECE and CS groups work

With the removal of a member from our group the goal of combining the work of both the scheduling of the CS team and irrigation controller from the ECE team got pushed back in order to hit the deadlines that the hardware required. This meant that while the ECE and CS teams both had work ready to interact with the other team the two teams didn't have the chance to combine the efforts into a single system.
Recommendation: The final steps should be easy as both where designed to make sure that they would interact properly. The ECE team focused on making an interface that will update the flow rate of the pump and the time that it needs to be on to determine that amount while the CS team focused on a user interface that allows the user to schedule schedule times and interface with multiple plant types.

5.7 Additional terminals for more solenoids

The current number of solenoids that can be driven by the controller is 5, this could easily be scaled up with additional hardware. Choosing the number that would be useful to the user could be created for each individual project possibly making a modular method that would allow for more terminals to be attached in groups of 5. This would depend on the desires of the user.
Recommendation: Redesigning the PCB to allow connection to multiple PCB's all with the ability to output the required voltage for the solenoids should be an easy design but power requirements

and GPIO pins from the Raspberry Pi might be limiting factors. Once the limits of those two elements are hit then major redesigns will need to supply additional power and allow for additional logic channels.

5.8 Alternative designs for different solenoid types

One of the limitations of this design is that it only has the ability to power a 24VAC solenoid. While less common solenoids can run on different voltages such as the 12V DC. Designing a version of the PCB that also would be able to control the power output of the multiple different solenoids and be able to choose which solenoid would be on which output terminal. In general this might not be a incredibly prominent need for most users but would allow a more generalized design if it where to be created and shipped to others.
Recommendation: This would require an additional power line that would choose between the AC and DC voltages. In this project I started the design hoping to use a triac with an optocoupler to give the AC line out and decided in the end to settle with relays instead. While a simpler design to create and potentially cheaper a more robust design might want to return to the original design as it would have a smaller footprint and allow the DC control to also have space on the PCB. The inclusion of a DC line should also be kept separate from the common of the AC line changing the design on the PCB to no longer connect all of the common ends of the solenoids.

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