DESIGN AND SYSTEM THINKING B

Professor Nguyen Hop Minh

AUTOMATIC IRRIGATION SYSTEM FOR SMALL GARDEN

GROUP 3

Nguyen Duong Thao Vy (220067)   Luong Ngoc Chung (210195)

Nguyen Hoang Ngoc Ha (210206)   Nguyen Chinh Quan (220066)

PROJECT SPECIFICATION

DESCRIPTION OF THE USE CONTEXT

Used:

This product sample is designed for 3 medium plant pots with a height and diameter of around 10 - 20 cm which is not dispersedly distributed in a 4m2 balcony. It is subject to the battery for the system to sustain, which is estimated to be active for up to one week.

The system, with the control of the Arduino, will open the valve for the release of water to pots in 30 seconds per day in the early morning, at 5 - 6 am, because this is the best time to water (Staff, 2022). The product includes:

- 1 container
- 1 main and 3 sub-water pipes
- 1 control valve
- 2 pairs of batteries

The user manual is handed to the customers with the following basic steps:

- Connect the main pipe to the water tap on the balcony, fasten the connection with the hose clamp, and then attach the sub pipes to the pots with the double clip available in the kit.
- Turn on the switch at the control valve and open your water tap.
- Close the tap, turn off the switch and fold the kit into the box when not needed.
- Replace the batteries if needed.

Misused:

We do not recommend users leave the system for more than one week, because the batteries would run out while the valve is open. Also, users need to replace the batteries if needed and ensure to fasten joints so that water cannot be released outside.

Besides, avoid critical physical damage to the Arduino and the pipes, while users also should not leave Arduino in direct sun and rain. In conclusion, we recommend that users should read the manual carefully before using it.

Other systems that interface with the project:

We designed the system to reach the water tap around the balcony with a maximum distance of 3m, and the sub pipes could reach the pots with the same maximum distance. The plants could be distributed horizontally or vertically.

Limitations of space for use and storage:

There are some physical limitations such as the length of the pipes (maximum of 3m), and the space that the box kit could hold (w x d x h = 30cm x 40cm x 20cm). Also, the batteries have their own limited energy to supply the system for up to one week.

Vision on maintaining the project:

We, the core team, will collaborate with the manufacturer in developing the design variations to give customers more choices and customization options. We will choose the main suppliers for each part of the kit based on quality standards and reasonable prices.

With distributors, we will establish retail strategies and main marketing concepts which convey the key features of the product. Meanwhile, the distributors will take the responsibility to spread the products, run marketing activities and give guidance to the users. We will create the standard user instructions including booklets and videos, and a training program for salespeople and customer care staff.

For the sake of our end users, we also work to provide do-it-yourself replacement and maintenance solutions by selling detachable pipes, and double clips, and support users to replace the kit at home.

Environmental conditions:

Thanks to the waterproof feature, the product is suitable for outdoor weather conditions on the balcony. The project is only exposed to the family, so we do not have to worry about the public or neighbors' children's affection for the product.

We may raise the concern over the security regarding thieves, because the system could, to some extent, signal human absence for bad purposes. As the project is exposed to weather conditions, the battery and the main circuit must be protected carefully as these are the most concerns. For the pipes, it is preferable to put the pipes away from the sunlight and heat, but we are able to replace them with new pipes.

Social/Societal factors that may affect the project:

There are several social/societal factors to be highlighted, such as the social demands of the public towards the product, which social interactions would affect. For example, house designs may prevent neighbors from helping to water the plants of other people.

Also, it is subject to the income of the people, although we do aim for this product to be affordable for most people because we estimate that the price would be around $10, roughly equivalent to the salary of a person per day based on the current GDP per capita of Vietnam (World Bank, 2021).

Technological limitations of the project:

Users need a decent understanding of coding if they want to adjust the timing system. Although it is a short project, we may acknowledge that we would probably have the best research about technological advancements to apply for this product so that it could be as easy to use, compact, electrically efficient and environmentally sustainable as much as it could be.

BENCHMARKING

Potential solutions and products to compare:

In the current market, there are many solutions for automatic irrigation systems. Each of them has strengths and shortcomings and we consider them as references to improve our product. With different designs, we intend to compare the effectiveness with different solutions as follows:

1. Wi-Fi and App-Controlled Watering System for Indoor Plants with Pump
2. Tưới Nước Tự Động Cho Trong Vườn Cây Tự Tưới Nhỏ Giọt Trong Nhà
3. Bộ 4 dụng cụ tưới nhỏ giọt tự động cho cây cảnh

We consider the (1) to be by far the most competitive solution to our project. As this solution has Wi-Fi and app-controlled features in the product, this is more convenient in the long-term run, and we do not need to worry about having to know coding to use the product. However, this product has not been popular in Vietnam's market and currently, it is unable to deliver this project to Vietnam. So, it is still inaccessible to Vietnamese people.

The second and third solutions, which are (2) and (3) are considered much simpler solutions compared to our project. In addition, the price of these two products is much cheaper and more affordable than our project. Also, these products are manufactured and sold in Viet Nam, which is easier to reach and buy. However, theoretically, our product seems more efficient.

To conclude, while there are many competing solutions to our project, we are still confident in our project because it is more efficient and accessible to Vietnamese people in comparison with (1) (2), and (3).

Potential barriers from intellectual property:

Our solution is not unique, so there might be barriers to registration for intellectual property. If the original idea of an irrigation system has been registered, we need to pay for the intellectual property right to start mass-producing this product. In addition, we can sign up for the box kit design, which is authentically fabricated by our team.

SPECIFICATION LIST

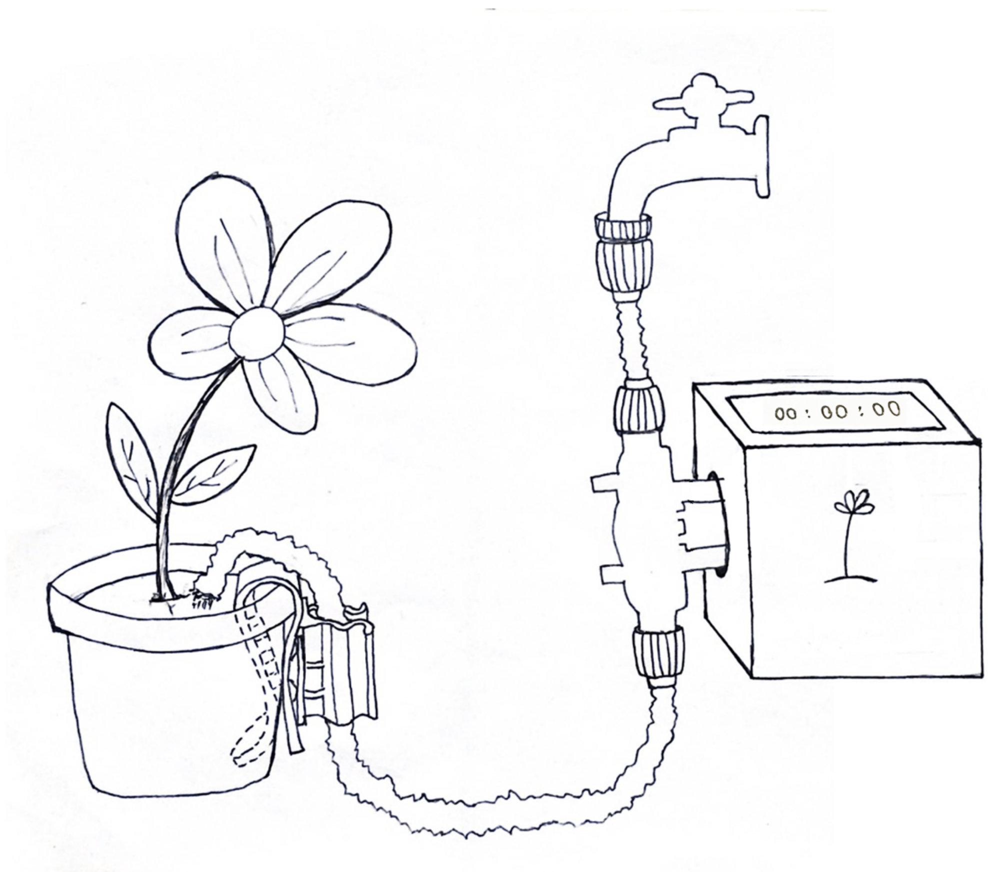
Need#	User need	Spec #	Specification
1	Colleague	Must be electricity safe	Use 3 battery AAA
2	Colleague	Affordable	The listed selling price must be under 300,000 VNĐ/per kit
3	Professor	Easy to use and install	Following the instructions, users can install the automatic irrigation system in less than 5 minutes
4	Professor	A simple system that solves the basic needs	A fixed setup watering frequency: 30s opening valve once in 24 hours that solves the contemporary demand.
5	Parent	Must have multiple ports	Our prototype system includes 3 ports for 3 plants
6	Teaching assistant	Compact product kit	A contain box with the dimensions: w x d x h = 30cm x 40cm x 20cm
7	Janitor	Able to replace water pipes	Water pipes must be easy to find and are common in the current market. We also provide replacement solutions.

References

GDP per capita (current US$) - vietnam. Data. (n.d.). Retrieved October 29, 2022, from https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations =VN

Staff, S. L. P. (2022, June 23). *When to water*. Southern Living Plants. Retrieved October 29, 2022, from https://southernlivingplants.com/planting-care/when-to-water/#:~:text=Morning%20watering%20is%20actually%20preferable,%2C%20fungal%20growth%2C%20and%20insects

CONCEPTUAL DESIGN



CONCEPT GENERATION

What method was used to generate ideas?

Generally, we followed steps and methods introduced in the EPICS Design Process. We first tried to generate and appreciate any ideas or insights from teammates and partners to open sufficient room for creativity, which would be refined later.

After gathering all the possible ideas, we applied the SCAMPER method in discussions (Substitute, Combine, Adapt, Mobility, Put to other uses, Eliminate, Reverse, Rearrange) to sift repeated or less efficient ideas, condense and consider new suggestions within our financial and academic ability. For example, we initially searched for rechargeable batteries for long-term usage and fewer chemical impacts on the environment. However, our limited budget could not be that affordable, so we use AA Energizer batteries instead. However, we still consist of changing to rechargeable batteries if our product is in mass production or finding other more sustainable ways.

Figure 1. Rechargeable batteries from Panasonic that we intended to purchase (Left) and AA Energizer batteries we eventually bought due to the financial limits (Right)

Then through several steps to compare, via a decision matrix, and further filter and evaluate options, with insights from our partners, to have the (tentative) best option building on the guidelines of EPICS Design Process.

Were a sufficient number of concepts generated?

We initially went back to our product identification and specification, and especially partners' feedback to have an overall review about the product, such as functions or elements which could be elaborated more, or eliminated, which could be modified to reduce the cost and the size of the product, or to balance the cost with environmental repercussions it would bring.

We have sketched several drafts to visualize all the ideas we have had and agreed upon. First, we thought about the main parts of the product by listing and sketching all of them on paper. This step was to consider what we really need to have and purchase or prepare for our automatic irrigation system and roughly about how to put it in a smart design.

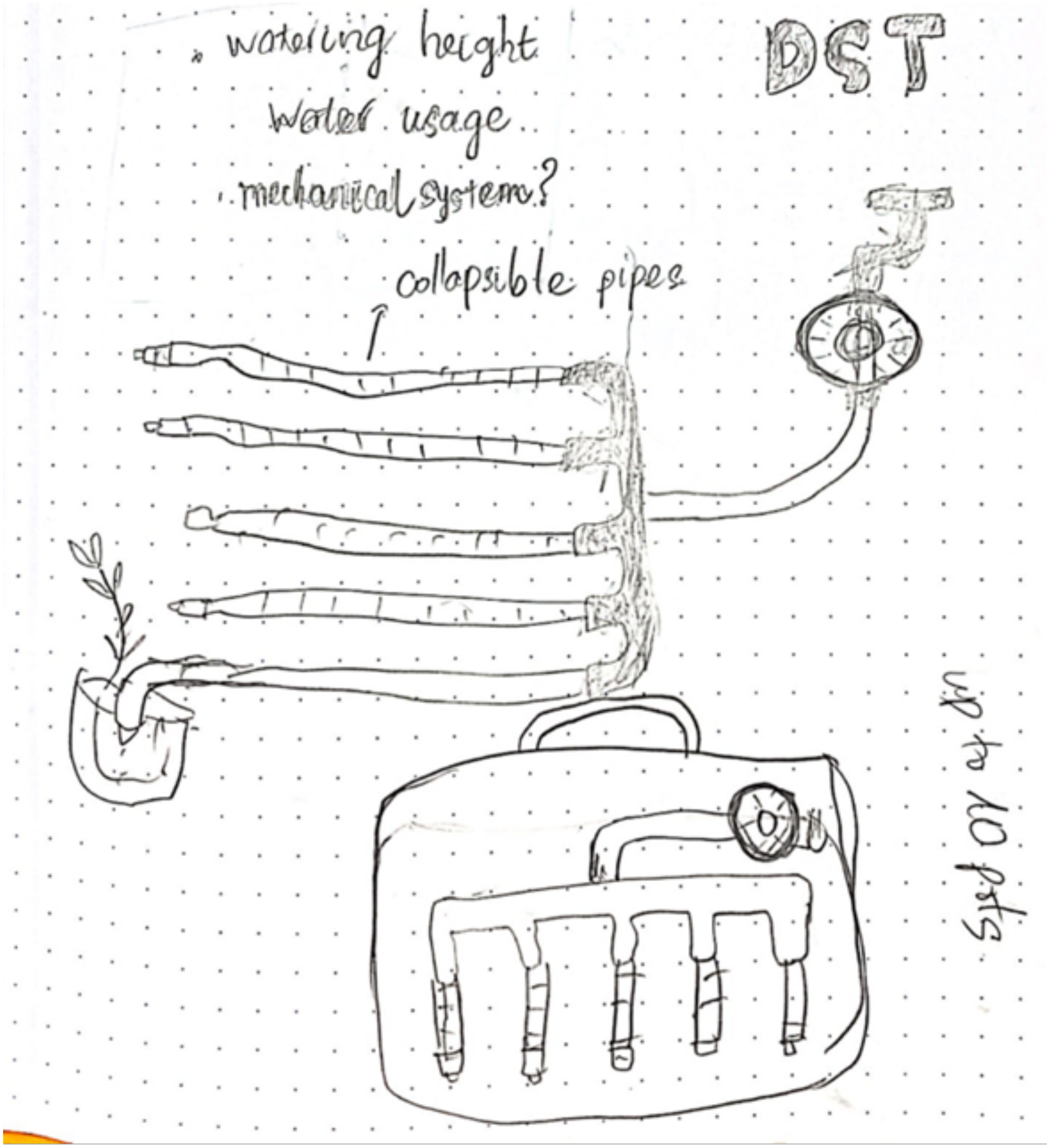


Figure 2. The first sketch by pencil for the product

The second step was to sketch to see how all the elements would be connected as a product, which required group discussions and consultations from the school advisor to modify and rearrange to have a smart and compact design. During the second draft, we began to purchase necessary things (collapsible water pipes, Arduino, solenoid valves, and an automatic irrigation system, timer). In the second step, we generated two designs to compare and then continued to modify the better version because we gradually had better imagination about the product through physical elements we bought earlier.

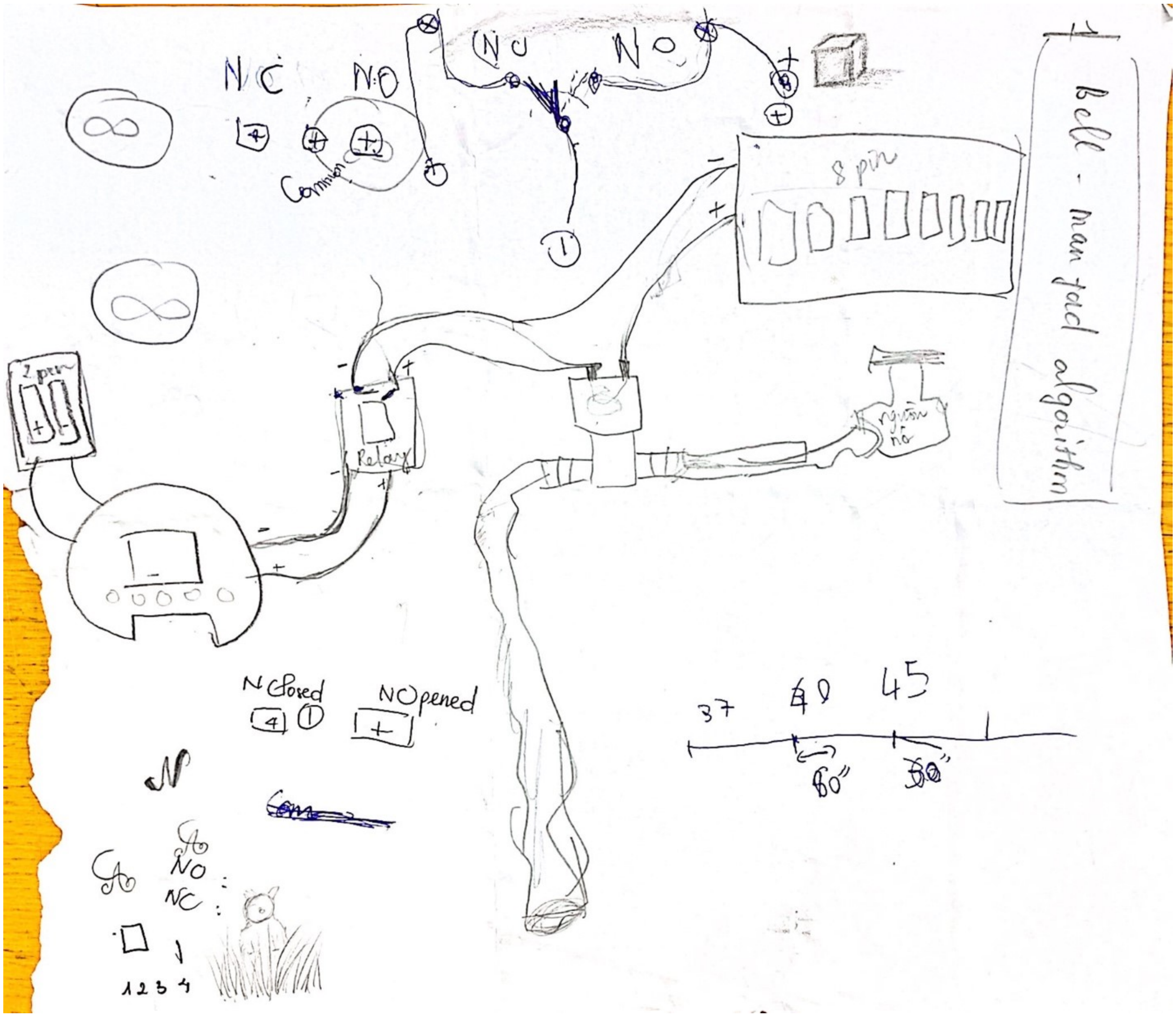


Figure 3. Second sketch revised by pencil over time

After that, we prioritize our time this week to schedule two meetings with the partners (team 4) in the same week to present our conceptual design to receive insights and feedback to better refine the design. Then we finalized the conceptual design with a clear sketch for the assignment, which is tentative and subject to changes in implementations in the future.

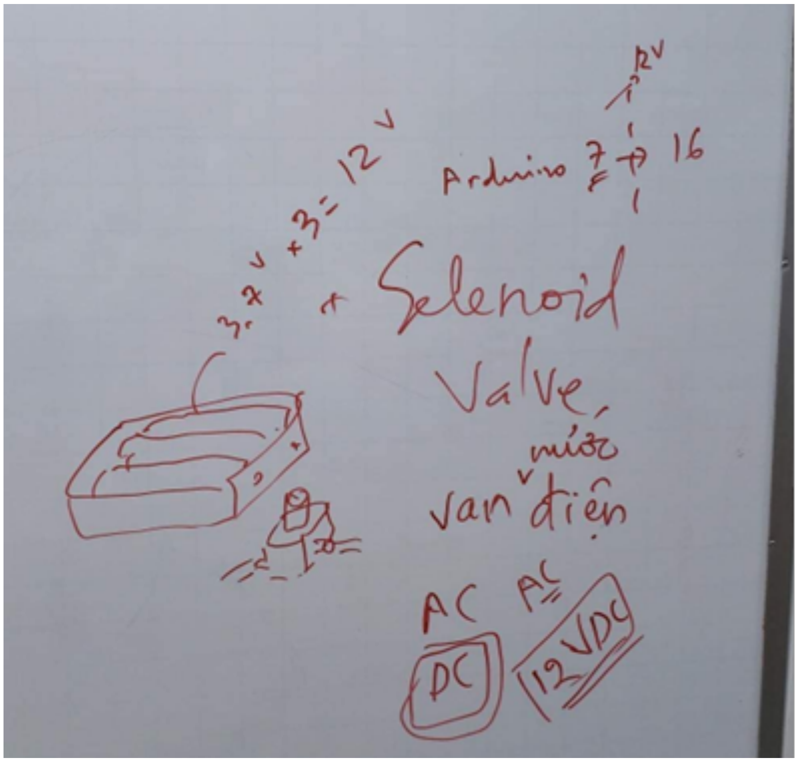


Figure 4. Working about the electrical operation of the irrigation system

What are the viable concepts that the team ideated?

At the very first sight, we thought about an automatic watering device using a mini pump (Solution 1). We need a CPU box that includes some electrical/mechanical components to control the bump with our set time. Our idea is that when we start the device, in the setting time, the pump will be activated and start to pump the water into our pipeline to water our plants. This idea is suitable for the low place where the water sources don't have the potential energy to flow from the low to high position.

Our second idea (Solution 2) is about an automatic watering device which is directly connected to the house's water source. In this case, we assume that the force of the water supply from the house is strong enough for the watering. That means we will try to control the waterpipe line through a special valve. If this valve is opened, the waterflow will go through the pipeline. We are currently titled to this solution.

We also thought about different materials for the pipeline based on our research. They are the common plastic pipeline (U-PVC tube agriculture irrigation system PVC tube water pipe, Figure 1a), the magic hose which is flexible in length and shape (1b), and the PE pipe which is commonly used for car wash (1c).

Figure 5.

Moreover, we also questioned how to keep the pipe in the right position while the owner isn't at home and the system is automatically working. That concern leads us to imagine an accessory like a clamp to help fix the waterpipe to the pot.

PROTOTYPING

What was the purpose of the prototype?

Prototyping offers us several benefits for the success of our project, as listed below:

We could realize the project by considering its achievability. Feasibility is one of the most important priorities in our project. Within one and a half in the coming month, with our limited knowledge and experience and the available budget, we always think about the achievability of the project. For example, related to financial feasibility, to reduce the cost, while keeping the same functions of the system, we decided the final product will have only one pipe out to a pot. If it comes to fruition, it is not difficult to attach more pipes for more pots by first replacing the valve with an alternative with more holes out, and then modifying the codes to let the water be released longer, because the approximately same amount of water from the fixed supply now has been divided into different outputs.

Sketching also helps us to better imagine how the different gadgets would be organized in the system in its final version. For instance, when visualizing, we tried to put the element that controls the system into a CPU box, which could ensure electrical safety while enhancing its compact design. We also could imagine better the actual size of components in our product, which in turn helps to have the overall look of the product, and to build true size for the CPU box.

Was the concept intended for internal team use or for external partners?

Our concept aims to provide an intuitive, portable, and effective automated watering system for medium plant pots, specifically for going-out periods of up to one week. People who live in apartments with tightly packed gardens on their balconies are highly supported with this device.

By doing this, we hope to assist users who routinely work hard and plant trees to worry less about their trees while they travel on extended trips. As an answer to the question above, our concept can be used by both internal team and external partners.

Evaluate feasibility of the different concepts

	Weights	Potential Solutions

Criteria for comparisons	1=low 5=high	Solution 1	Solution 2
Functionality	5	4	4
Safety	3	2	3
Cost efficiency	2	1	2
The ease of implementation	4	2	4
Flexibility	3	1	4

In the two main solutions, we evaluated and see that solution 2 seems to be more efficient. First, while a qualified bump is much expensive than a special valve (we explored it through the help of Mr. Thai, a water system expert), solution 2 seems to be more affordable. Moreover, while reading about the electrical bump and valve, we feel more familiar with designing a system with special valve. Our first users will be the students who live in Docklands dorms of Fulbright, where the water pipeline on the balcony has the potential power. That's why we intend to move with solution 2.

While thinking about different materials for the system, we come up with the plan to use magic hose which can expand up to 3 times its size and easy to be kept in cramp place. Moreover, in order to keep the hose's position stably with the plant, we use a type of hanger to keep the hose. These materials will be described clearly in the below parts.

What simplifications were made?

At first, when knowing nothing about solenoid valves which help allow or not allow the water to flow according to the electric power provided or not provided, we were confused and thought of a more complex and expensive solution with a water pump motor or users need to prepare a certain amount of water before going out.

In addition, the central processing unit including Arduino, relay, real-time clock module, pin case, also a part of the solenoid valve will be placed in a plastic box, which not only saves space but also protects the electrical circuit from water and hung on the wall or put in a higher position. The magic hose that we use can be stretched out by the water force and is very flexible compared to the standard solid plastic water pipe. Finally, with the easy-to-adjust hose hanger, users will not be concerned about how to set up the system according to their specific garden system and think of risks such as the pipe is blasted.

How was the prototype fabricated?

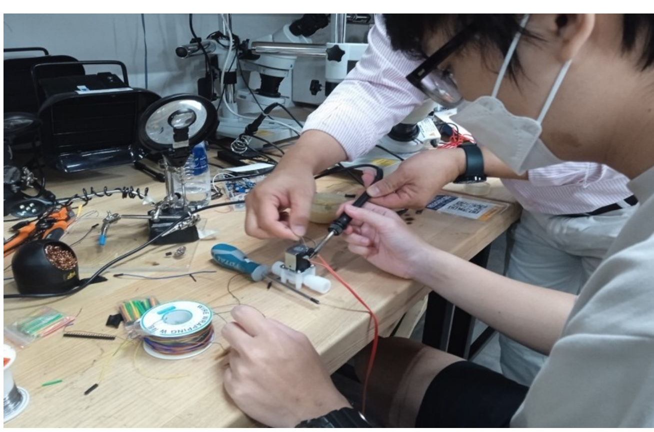


Figure 6. The actualization of the sketch

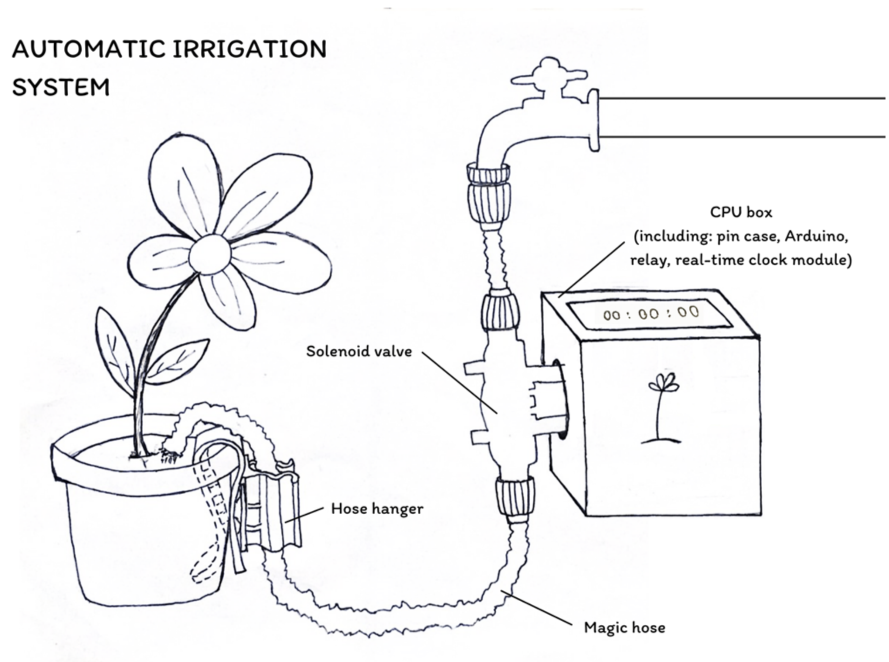


Figure 7. The final sketch design of automatic irrigation systems with description

The picture above is our sketch for the prototype of the final product. As you can see it looks quite compact and easy to set up for the users. Looking outside, the whole system includes a solenoid valve, a magic hose, a hose hanger, and a CPU box with the timer displayed on the top surface. This sketch is fabricated based on our observations of each realistic component. Please refer to the following illustrations and images to figure out what is inside the CPU box and the real pictures of each part. Our main concern right now is to make the CPU operate within the system we create, and after discussions with the teachers and teaching assistants, we have come up with two main considerations: (2) if the system doesn’t work, we will go with our second plan: control the switch for the solenoid valve by an available time controlling circuit set which was set up before (with PCB inside). However, this circuit set is more expensive and less flexible.

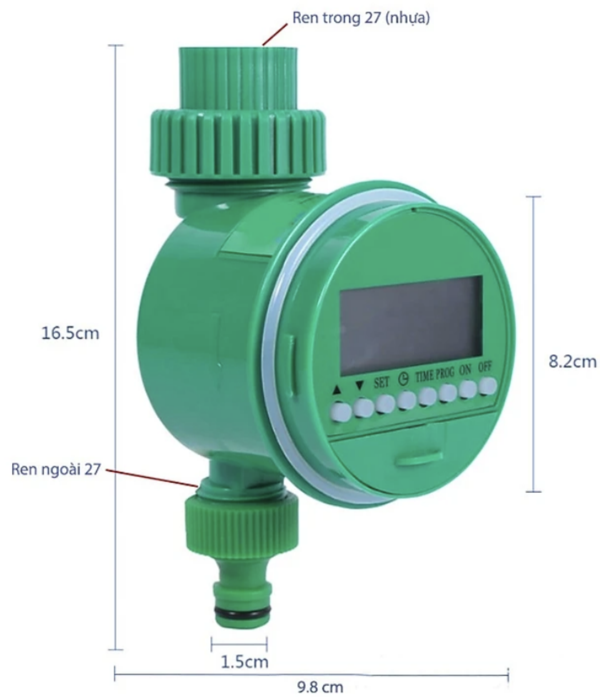


Figure 8. The time controlling circuit for watering which was programmed before (with PCB inside)

Because we want to push the flexibility of the product to match our goal, we will first come up with the first option. Then, we completed the first design of the CPU box (Figure 10). This CPU box can use the Arduino to control the solenoid valve with a fixed opening and closing time after conducting the electricity via our 12V pin case (with 8 AA pins). We are working to improve the system with a manual time set-up from real-time o'clock which looks like the prototype below.

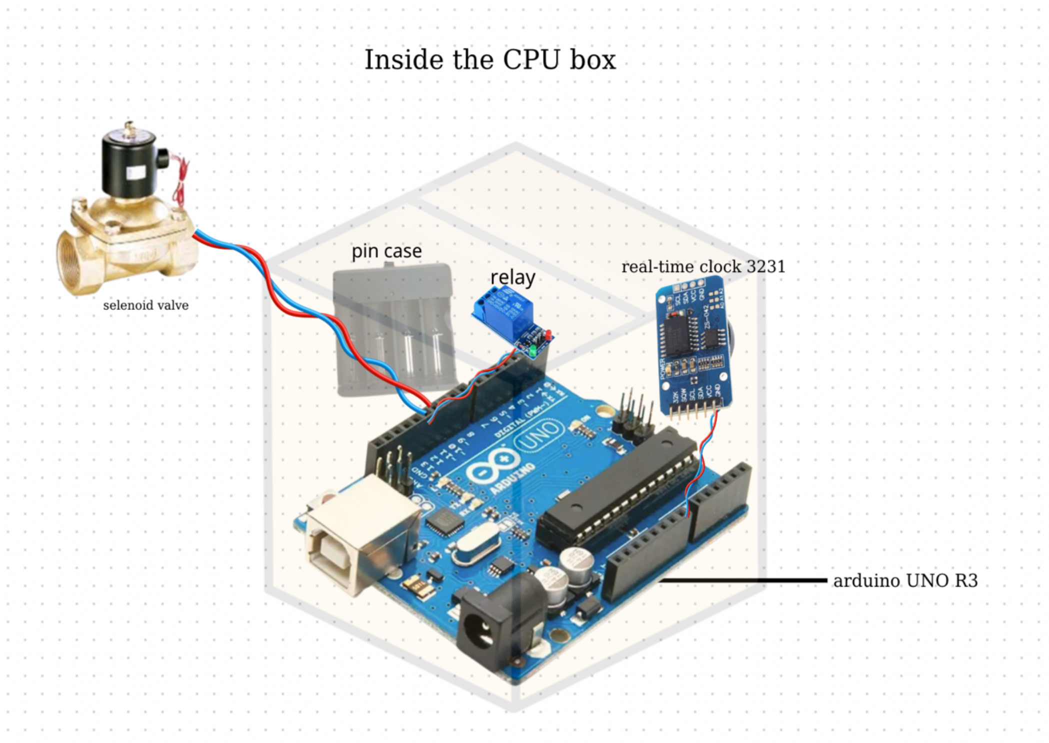


Figure 9. Inside our CPU box

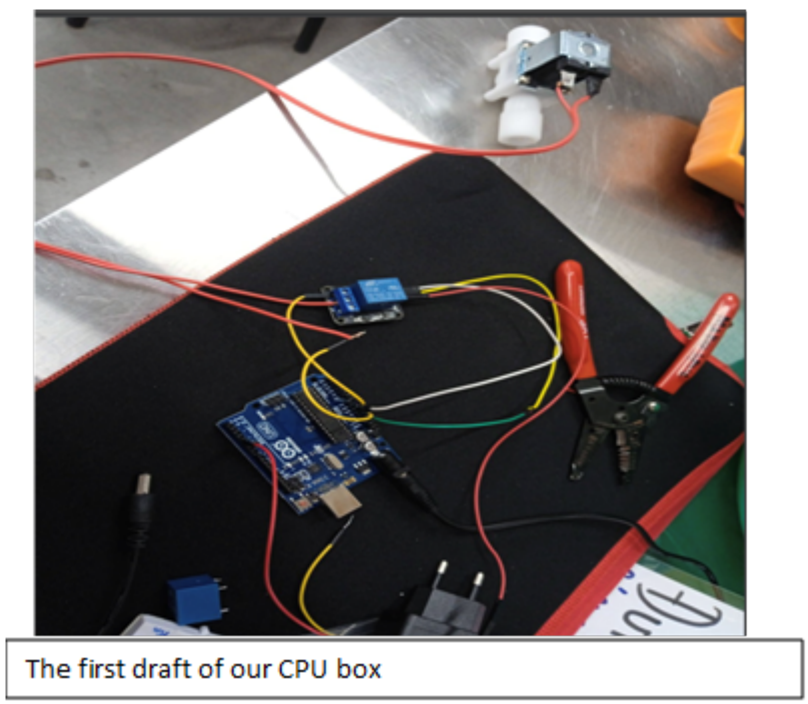
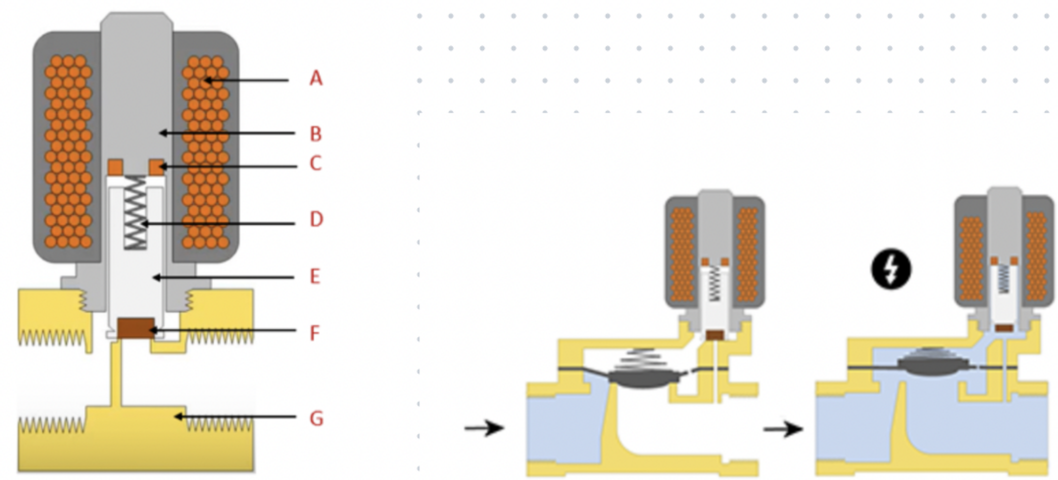


Figure 10. The first real design of our CPU box

The box includes the main electrical system of the product which has components as listed below: a pin case (including 8 AA pins) to provide power for the system, an Arduino board to control the system, real-time clock to set the watering time for users, a relay as a switch for the system. This electrical system will be connected to the solenoid valve. After the user set the time in the system, through the real-time clock, at the programmed time, the relay will be activated. Then, the CPU box (via the relay) will open the solenoid valve via its electrical power, which allows water to flow, and vice versa.



Components of a solenoid valve: coil (A); armature (B); shading ring (C); spring (D); plunger (E); seal (F); valve body (G)

Operating principle of normally closed solenoid valve: de-energized (left) & energized (right)

Figure 11. Components and operating system of the solenoid valve

As stated below, the solenoid valve is an electro-mechanical controller for the water in a pipeline. This valve consists of two main components: a solenoid and a valve body (Figure 3: coil (A); armature (B); shading ring (C); spring (D); plunger (E); seal (F); valve body (G)).

We will use the normally closed type of valve. That means the valve is closed when de-energized and the water cannot flow through it. When electricity is sent to the coil of the valve, it creates an electromagnetic field that forces the plunger upwards overcoming the spring force. This process will open the orifice, allowing the water to flow through and reach the plant.

Figure 12 (Left). Hose hanger (from vn.biggo.com)

The hose hanger is adjustable and helps fix the hose to the plant pot and reduce the risk of the hose blasting out and accidentally filling the balcony with water.

Figure 13 (Right). Magic Hose (from Amazon.com)

As its name suggests, the hose "magically" collapses and expands. In particular, the normal length is 5m and it can be expanded up to 15m. Also, it is very flexible for the users to lead the hose through their garden.

Index	Name	Numerical information
1	Solenoid valve	12V DC, Ø 21mm (¼ inch)
2	Arduino UNO R3	68.6mm x 53.4 mm
3	Relay	15mm x 15mm x 15mm
4	DS3231 Real time clock	30mm*20mm*1mm
5	Hose hanger	Can clip pipes with diameters from 8-16mm, 9.7cm x 5.3cm
6	Magic hose	5m, expanding up to 15m
7	Pin voltage converting box	1.5V (8 pins) to 12V, 5.5mm jack
8	CPU Box	Mica box, 100mm*80mm*60mm

What did the team learn about that concept?

After discussing with our partners, they learned about the optimality of our product as we try to make our prototype as neat as possible for easy transportation and electricity safety. They also learned about the use of each electric component (Arduino, Relay, Timer) in our concept and can imagine the way all of them are connected to contribute to the concept operating principle. Finally, they acknowledged the source of materials as the materials we use are easy to access in case of replacement or enhancement.

They advised us to wisely arrange all the electrical parts of the system to control the water into a small CPU, which should be attached firmly near the water supply and also make it waterproof and electrically safe. This did help us to have the final sketch. Second, they wanted to have experiments with the hose hanger, because when the water runs through the magic pipe, it will pull certain forces onto the hose hanger, so we need to be thoughtful about that force that let it not pull the hose hanger and the pipe out of the pots. They finally recommended us to use the batteries instead of direct outlet for electrical safety and in case there are no outlets in the reach adjacent to the water supply. We agreed upon, and it was also sketched.

What excited your user? What frustrated them?

When our partners had their first look, they were first amazed by the timer in our prototype sketch. They liked the concept that instead of calculating the amount of water to water the plants, we input the amount of time for the water to flow through. They also like the feature that allows the user to easily adjust the number of water pipes when it comes to adding more plant pots to their balcony and easy to replace the pipes.

Yet at the same time, they had a hard time imagining how our prototype would be organized just by looking at the sketch. Specifically, they could not imagine how the water pipes would be organized in narrow places such as the balcony in Docklands. They also commented about the place to put the electronic box for example putting it on a chair will cause issues when the users have work to do outside the balcony like drying clothes as they will accidentally kick the chair and break the box or putting it on the floor may cause the box to get wet when the water pipes are broken. Finally, another features our partners had concerns about is the clips. As our partners have experience in interacting with the clip in their product, they said that both teams need to consider the material for the clip carefully as it plays an important role in supporting our product's structure. They stated, strong clips will cause the plant pots to chip, and in contrast, weak ones will not be able to stabilize the water pipes to the pots.

At the moment, we are still on our way to completing our prototype for testing. We have kept in mind that the clip material and the arrangements for the pipes and the electronic box need to be considered. Therefore, further adjustments will be made based on our first testing results.

DETAILED DESIGN

BILL OF MATERIAL (B.O.M)

Sub - Assembly	Item	Catalog / Part No.	Manufactured / Purchased	Vendor / Method	Quantity	Unit / Cost
Water conveyance	*Magic hose*	*n/a*	*Purchased*	*giamuatot*	*1*	*76,188 VND*
Electrical Circuit	*Solenoid valve*	*VAKS V12-21 N/C*	*Purchased*	*Truong Thanh*	*2*	*185,000 VND*
Pipe holder	*Hose clamp*	*n/a*	*Purchased*	*Thuy sinh Sai Gon*	*2*	*46,500 VND*
Electrical circuit + Time display	*Automatic watering timer using battery*	*n/a*	*Purchased*	*LEX VN*	*1*	*107,000 VND*
Solenoid valve power supply	*AA Battery*	*n/a*	*Purchased*	*7 - Eleven*	*12*	*139,000 VND*
Electrical circuit	*Real time clock*	*n/a*	*Purchased*	*itechcool*	*1*	*59,000 VND*

Electrical circuit	*Arduino Uno*	*R3 Dip*	*Purchased*	*itechcool*	*1*	*219,000 VND*
Electrical circuit	*Relay*	*n/a*	*Purchased*	*do sang tao*	*1*	*25,800 VND*
Automatic watering timer power supply	*AAA Battery*	*n/a*	*Purchased*	*7 - Eleven*	*2*	*21,000 VND*
Electrical circuit cover	*Circuit box*	*n/a*	*Manufactured*	*School 3D printer*	*2*	*n/a*

PRINTS/SCHEMATICS/CODE

Important components of our product include the Arduino UNO R3, solenoid valve, pin case with 8x1.5AA pin, and a relay.

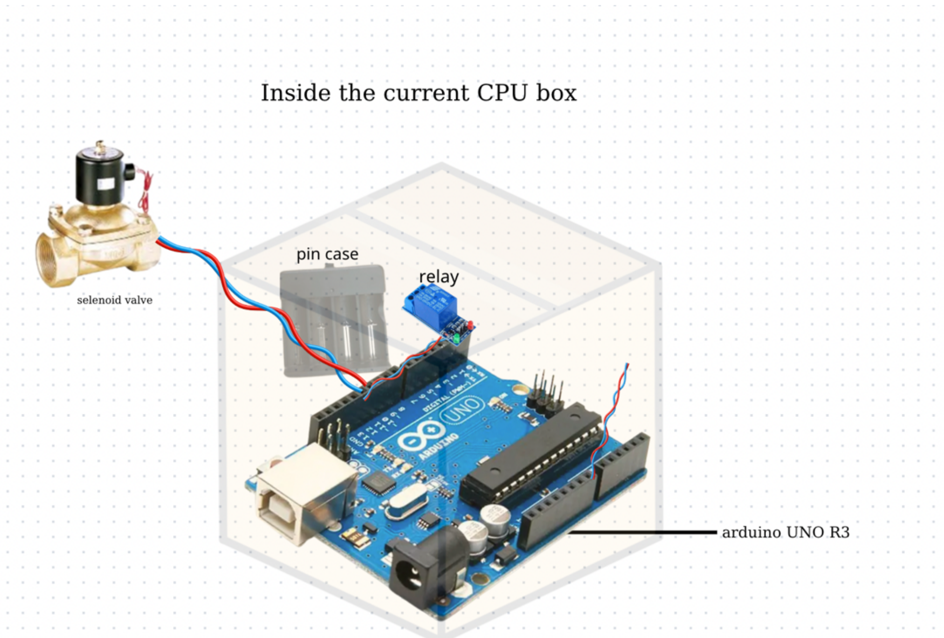


Figure 1. The sketch of the elements inside and connect directly to the CPU box

Outside the CPU box

Outside the CPU box is the 12AA pin case including 8 AA pins and the solenoid valve which connects to the water source and the plan-watering hole through two heads. This solenoid valve also links directly to a wire connecting to the inside part of the box. These elements were purchased easily from the outside shops and attached closely to the box such that the pin can provide the electrical power for the system and the valve can be controlled by the inside CPU box.

Figure 2. Outside the CPU box

Inside the CPU box

Inside the CPU box, the product uses the Arduino board to control the solenoid valve using electricity power. The fundamental technique of the box is that via the power provided, the relay in the CPU box can work as a switch, helping to control the system via the Arduino while this “switch” is on. The elements in the CPU box are also purchased from outside sources. The only thing that we have to notice is some of the elements make us feel confused due to their similarity in parameters. With some constraint ability in electrical engineering, our team develops this system for about 3 weeks.

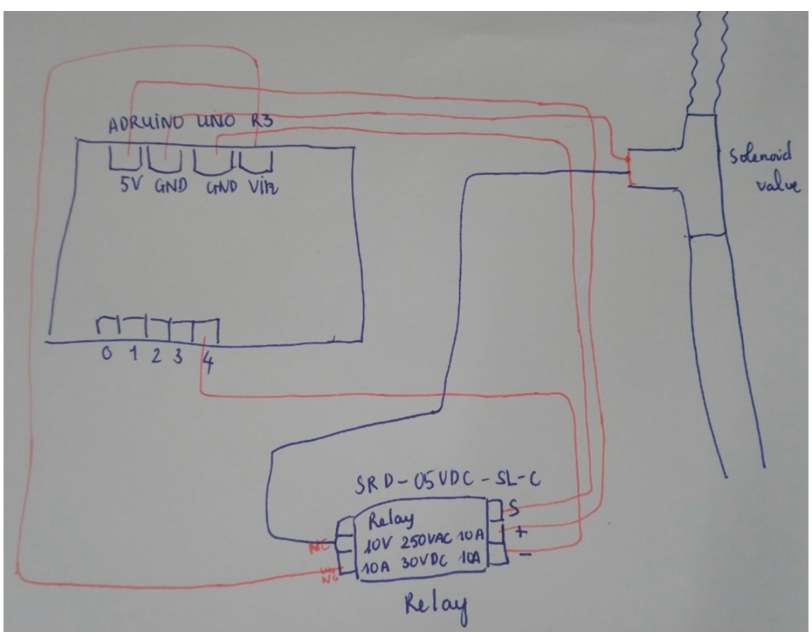


Figure 3.1. Circuit design

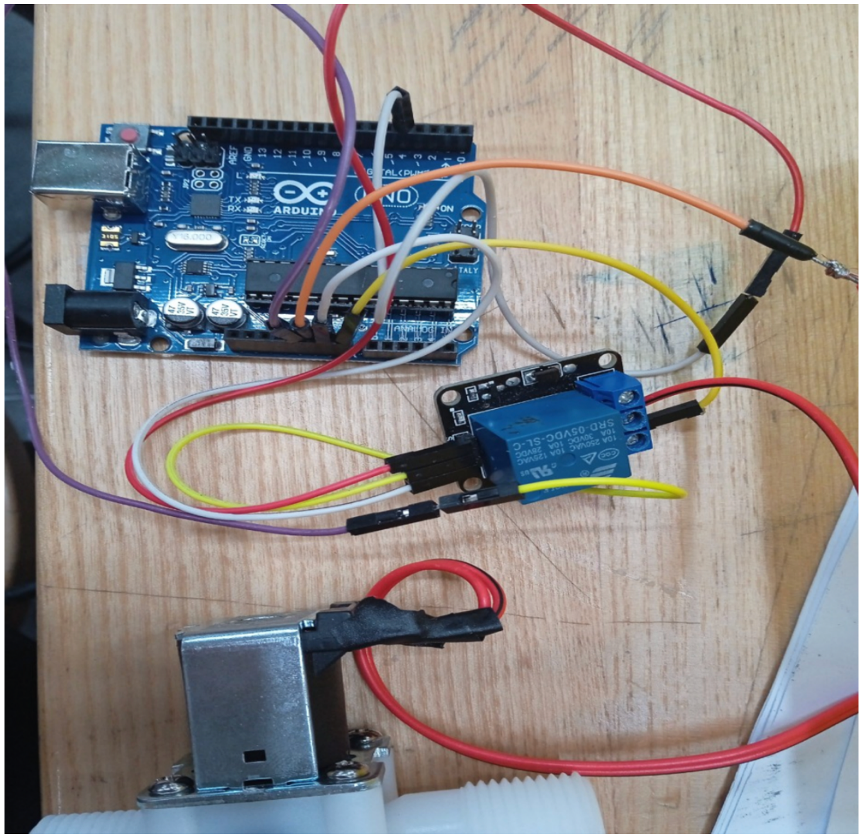


Figure 3.2. Circuit design

The code

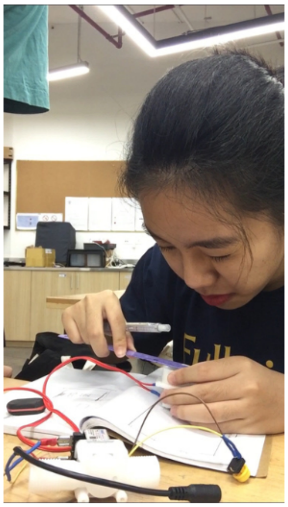
In the code uploaded to the board Arduino, we set a fixed “m" second opening and “n” seconds of closing time. That means with the electricity power, after putting the button “On" on the pin case, we can control how long the solenoid opens and closes.

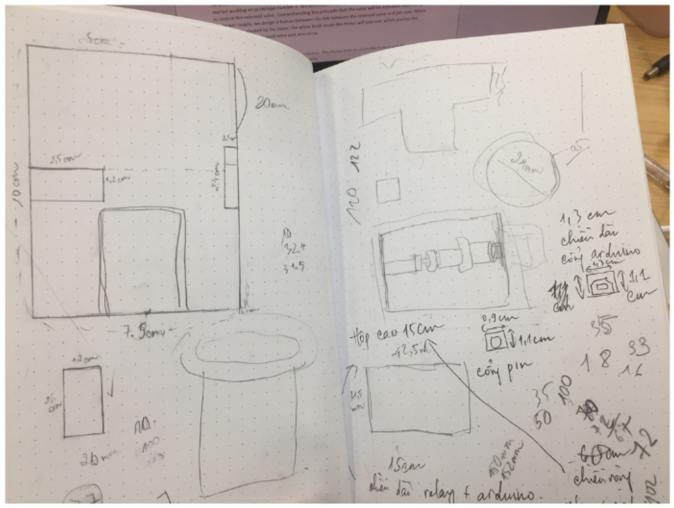
```
int solenoidPin = 4; //This is the output pin on the Arduino we are using

void setup() {
// put your setup code here, to run once:
pinMode(solenoidPin, OUTPUT); //Sets the pin as an output
}

void loop() {
// put your main code here, to run repeatedly:
digitalWrite(solenoidPin, HIGH); //Switch Solenoid ON
delay(60000); //Wait 60s
digitalWrite(solenoidPin, LOW); //Switch Solenoid OFF
delay(60000);
}
```

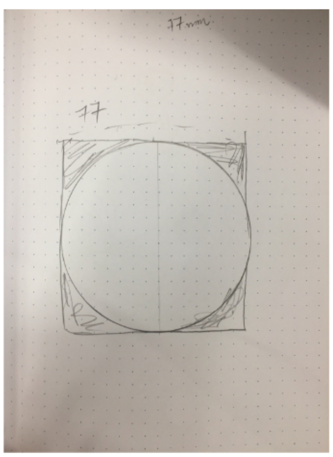
Figure 4. Arduino code with n=60, m=60

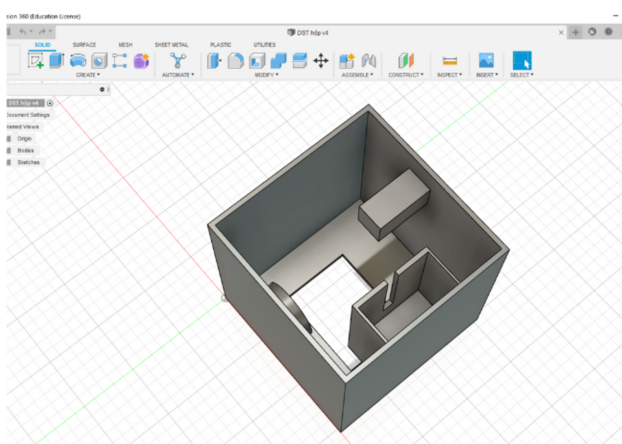
3D printing

We measure every element in the product and sketch the shape with detailed dimensions. Then we use Fusion 3D to draw the 3D design and start printing with the Prusa 3D machine in Makerspace. The composition is solid plastic which ensures the sustainability of the box kit. It takes us about 3 days to finish the process because our designs are printed in more than 6 hours on average.









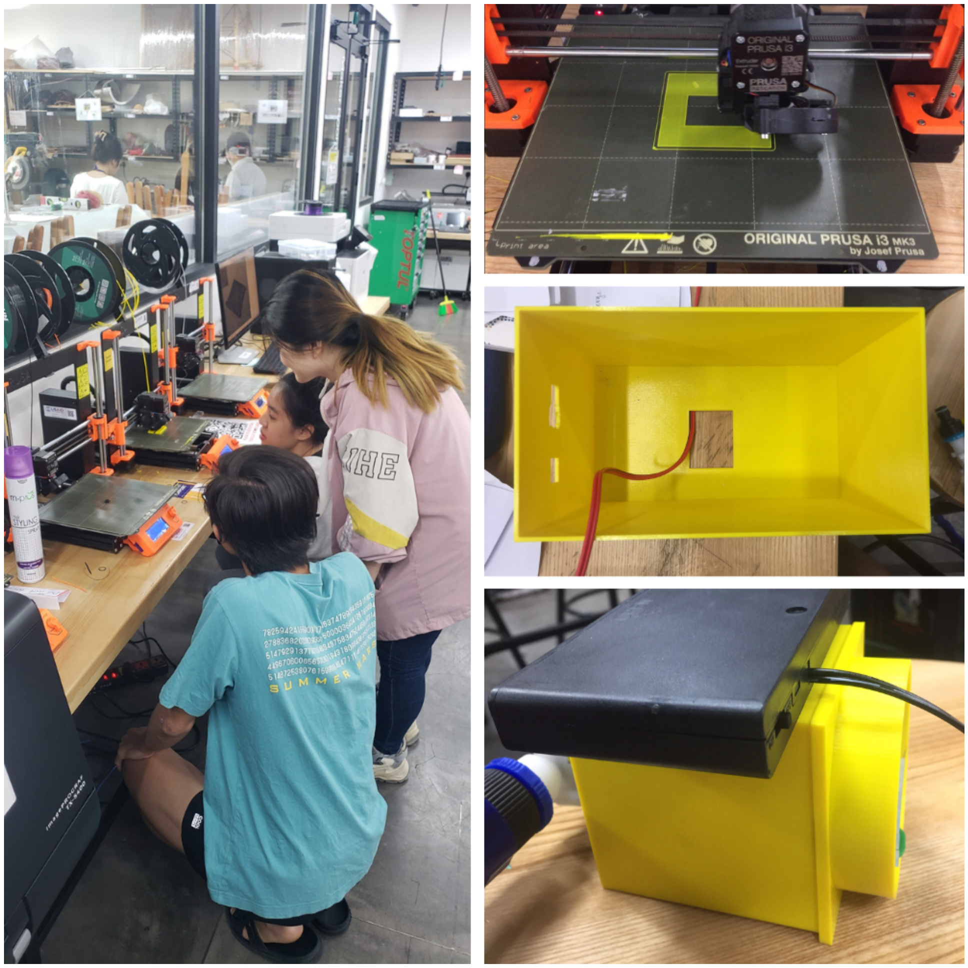
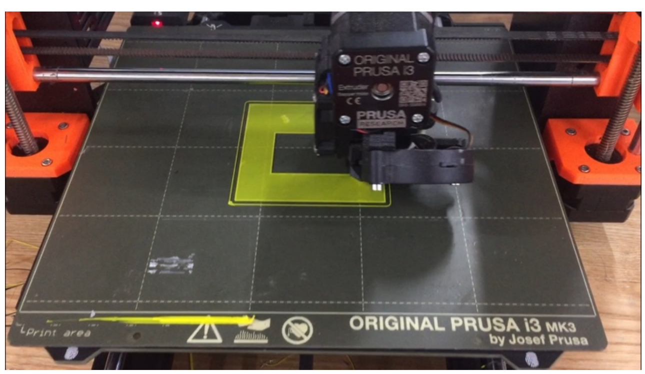


Figure 5. Our 3D Printing process to design box to contain the CPU



Another effort to understand more about the product

To understand more about the system, especially the solenoid, and carry out the second solution, we started working on prototype number 2. We developed a system using a programmed timer and motor to control the solenoid valve. Comprehending the principle that the valve will be activated depending on the power supply, we design a button between the link between the solenoid valve and pin case. When the motor is activated by the timer, the white knob inside the motor will pop out, which pushes the button to open the solenoid valve and vice versa as the gif in the following link: https://imgur.com/a/p1KcoAv

The design of the box is important in this solution. The design tries to place the button and the motor in particular positions, that is enough for the knob to push the button without always pushing it in the inactivated state.

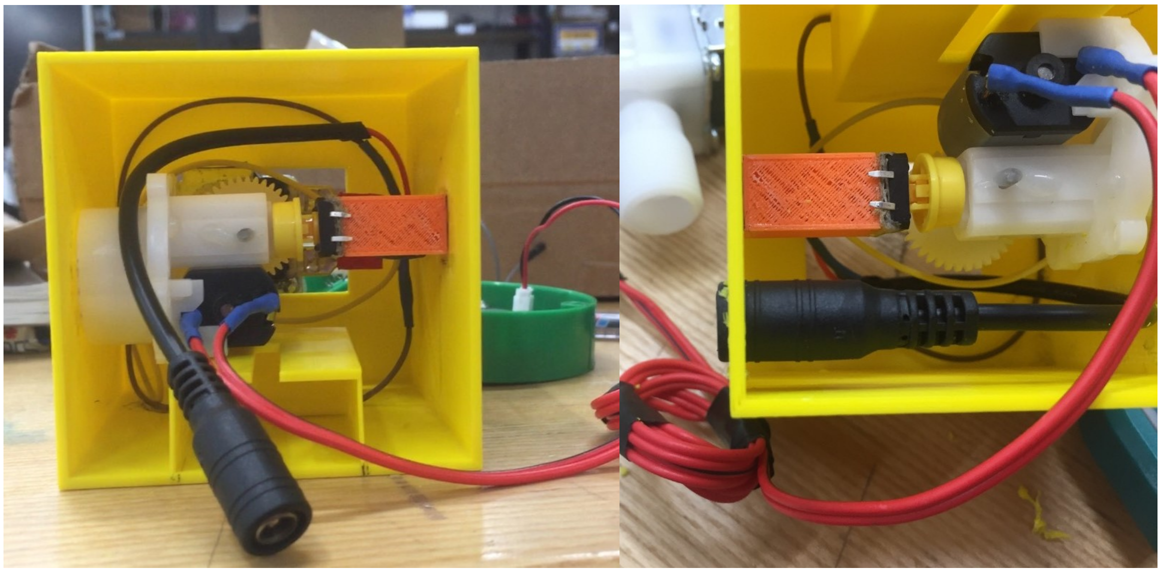


Figure 6. Please watch this video to visualize how this model works: video 1.mov

Figure 7. The complete system design of the second model

MANUFACTURING AND ASSEMBLY PROCESSES

1. **Make a components checklist:** The first step in the manufacturing and assembly process was to gather the requirements needed for the project. This includes making a checklist of all the necessary resources, such as raw materials, tools, and equipment that need to be prepared to make the product.
2. **Prepare the components:** Once the checklist was completed, the next step was to assign each team member to purchase different project components. This step was done individually by doing market research, specifically searching for component keywords on different vendor's pages and comparing the prices between them to get the most affordable price on the market. When it comes to buying the materials for the project, we tried to carefully calculate the price for each component to be under 200,000 VND so that we did not need to collect VAT invoices.
3. **Components observation:** Scrutinized all the project components to decode the working mechanisms, specifically the electrical components because it potentially created different approaches to the final product. Moreover, we did some research about the functionalities besides our observations to see if we could collect anything new and to have a further understanding of how these components should be connected to one another. While doing online research, we found and kept the material safety data sheets for our team and read through all the instructions as

well as the information about the potential hazards to avoid unfortunate situations from happening.

4. **Product consultation/review:** Before making the prototype, it was important for us to refer to existing products and objects that had likely features as ours via websites as well as consulting with the Teaching team to have a better design and to maximize the productivity when prototyping.
5. **Prototype:** After consulting with the Teaching team, the next step was to make the product in different parts. We assigned different tasks to each team member to do and had discussions later to finalize our prototype, particularly, we assigned based on the previous individual research/preferences about the specific project components. Unfortunately, our prototype met several errors (and after a few adjustments, we were able to create a solenoid valve circuit and control the valve to our desired expectations).
6. **Finalize the product:** Having our electrical circuit worked, we started to finalize our product by assembling the rest of the materials we had as a system. As this step, we still missed water pipes. We wanted to ensure that water pipes could fit with our valves, so instead of ordering the pipes online, two members of the team purchased them at an electrical water store near our university.
7. **Testing + Footage collecting:** By finishing up the product, we conducted several tests to check again whether the product had been running smoothly or not, especially since we were checking for any code errors and water leakages to fix before recording the team's final product.
8. **Partner's review:** Finally, we held a product evaluation session with our team's partner to showcase our final product and clarify any related questions they had in order to have further improvements for the product in the future.
9. **Improvements:** After meeting our partner and re-evaluating our final product, we want to improve our set time mode as currently, the final product uses only the Arduino code to control the solenoid valve based on the given input. A downside is that the Arduino itself has a limit when it comes to counting time and when it reaches its limit, the timer will be reset, which causes the wrong watering time. In addition, we also want to add a feature that allows controlling the pressure of the water flow for a more consistent conveyance through pipes. Finally, we want to re-design the 3D protective case for our electrical components in the product so that when assembling and replacing the components inside, we will have an easier time and at the same time avoid letting the water in, which will damage our components inside.

RISK ANALYSIS

Design	Process Function	Potential Failure Mode	Potential Effect(s) of failure	Potential Cause(s)/Mechanism(s) of failure	Actions taken
Exterior	**3D printing of CPU box**	The box is too big	It is not compact enough to hang on/near the water supply. Also, it fails to meet design expectations	Improper 3D design on Fusion 360 due to wrong calculations of sizes and dimensions	Double check sizes and dimensions of all components before printing
		The box is too small	It is too small to contain all the components		

		Box is flawed because 3D printing machines get errors when printing	Could not use the box because it does not meet design expectations	Out of control	Reprint and recycle the flawed box.
		The box does not have the battery case holder	It fails to meet design expectations if the battery case holder is detached from the CPU box	Not yet thoughtful in 3D design	Use hot stick glue to firmly attach it to the CPU box
		The box does not have enough holes for valve and/or electric supply from outside	The battery case holder could not supply electricity/makes the system bulky, and so the water supply		Drill holes where necessary
		The lid and the box do not fit to each other/not easily fit	It makes the system not compact, and probably lets water in		Use super glue
		The valve is not fixed to the box			
		The box is not waterproof, or waterproof but still lets the water in	It poses electrical safety concerns		Use hot stick glue
	Connect water pipes to water supply and electric valves	Water pipes are too small to fit with water supply	Cause leakages and cannot convey full water flow from the water supply	Wrong calculations before buying material + not doing enough research about the material data	Use the scorch technique to expand the head of the water pipes to fit the water supply (use little heat to avoid burning or damaging the pipes)
		Water pipes are too big to fit with water supply	It is too loose, so it is hard for stabilization		Use stainless-steel band to tighten the gap between the pipe with the water supply
		Water pipes are too small to fit with valves	Cannot fully convey the water through the valve and eventually cannot connect to		Use the scorch technique to expand the head of the water pipes to fit the valves (use little

			the valves, which breaks the whole system		heat to avoid burning or damaging the pipes), use a valve converter to connect to the water pipe instead of directly connect
		Water pipes are too big to fit with valves	Cause leakages between the connection points due to the gap of difference in size		Use stainless-steel band to tighten the gap between the pipe with the valve
		Water supply requires a bigger pipe to fit than valves (The sizes of water supply and vavles are different)	Water could be leaked	Use only one type of water pipe	Connect two different types of water pipe, or shrink an either side of the water pipe by heating
		The pipes are pulled out of water supply and valves because of the residential water pressure	Need re-installation and cause a massive “flood”, which wastes water if the user is not there at the right time to cut the water supply	Wrong pipes’ size used, no stabilized components and having no component to help restrict the water pressure.	Add a restrict flow valve to control the pressure of the water flow and use the stainless-steel band to stable the connection points
		Valves have two sides for water in and out. The pipe from water supply connects to the wrong side of water pipe	Water cannot flow through the valve due to the wrong connection and eventually can cause leakages	Not knowing the functionality of the valve, so that wrong installation happened	Double check the input and the output sides of the valve before installing the pipes
Interior	**Put all the product components into the box**	They are not fixed inside the box.	They could be damaged when shipped or used, especially the control system	Not yet thoughtful in 3D design.	Use the super glue/hot stick glue to attach them firmly inside the box
		Connections between electric wires are not closed.	Electricity could be leaked	Solder electrical wires not yet carefully	Re-solder

		Electric wires are too long and messy in the box.	It makes the box messy	Not yet cut unnecessary wires/not yet tied up wires	Cut unnecessary wires/tie up wires
	Control system	Input wrong code	Set wrong time for automatic watering time and affect the program	Lack of understanding of the working mechanism of Arduino	Do research and learn fundamentals of Arduino codes, especially refer to existing projects
		Connect wires to each other inappropriately	The solenoid valve does not work because of no electricity flow, the wrong wire connection cannot help uploading the code properly and eventually the whole electrical circuit could not be used.	Lack of understanding of how the electrical circuit works	Do research and read through the electrical components data sheet to know how to install the wires and to avoid risks
		Code is uploaded completely	Cannot make code changes to the Arduino circuit in case for replacement and cannot upload the code to new Arduino circuits.	Lack of code libraries, suitable packages, port's devices are out of service, or bad wire connection	Try to re-install the Arduino program or try to use different devices to upload the code

VERIFICATION

1	*Must use pins whose total supply is under 12V*	The power supply is 12V\ combined by 8 pins of 1.5V
2	*The price for each system must be under 300.000 VNĐ*	It costs 200.000 VNĐ for each irrigation kit (not included pins) and has full ability to change the code and timer settings
3	*The dimensions of the box kit must be no more than 30cm x 40cm x 20cm*	Model 1:18x10x12cm Model 2: 8x8x8 cm
4	*Automatic irrigation function from 30 seconds to 1 minutes*	Model 1: 1 minute per watering (the volume of water depends on the degree of opening the faucet Model 2: Run time setting is variable between 1 minute to 9 hours
5	*Fewer than 3 steps to set up the system*	1 step of settings to activate the system after connecting to the already opened water source
6	*Using the waterpipes That fits the size of 21mm of the solenoid valve*	Using 21 mm adaptors and hose clamps for waterpipes size that fits the input and the output of the solenoid valve

VALIDATION

Need #	User need	Validation
1	*Easy to use and set up*	Only three steps included: 1. Hang the CPU box on/near the water supply; 2. Connect water pipes to water supply and valves; 3. Turn the battery case on. (See our testing video here)
2	*Compact*	An 8cmx8cmx8cm cube of around 300gr. Our product photo is featured on the first page of this document.
3	*Aesthetic*	The CPU box is well-polished by 3D printing machine.