Integrated Program Final Report

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Abstract- This article describes the complete process of group 1 about the integrated program, lake sweeping robot. Focusing on the relevant tasks completed by Tianshuo. Guo, the article records the completion process of the integrated project in general. The whole project is a comprehensive engineering project guided by design thinking. The purpose is to guide students to find and solve problems.

I. Preliminary Research

A. Garbage distribution observe

The lake on campus is usually cleaned by the workers, but some floating garbage can still be saw. We observed the distribution of floating garbage on our campus lake. After many observations on our campus lake, the common garbage was mainly distributed along the lakeside and in the middle of the lake.

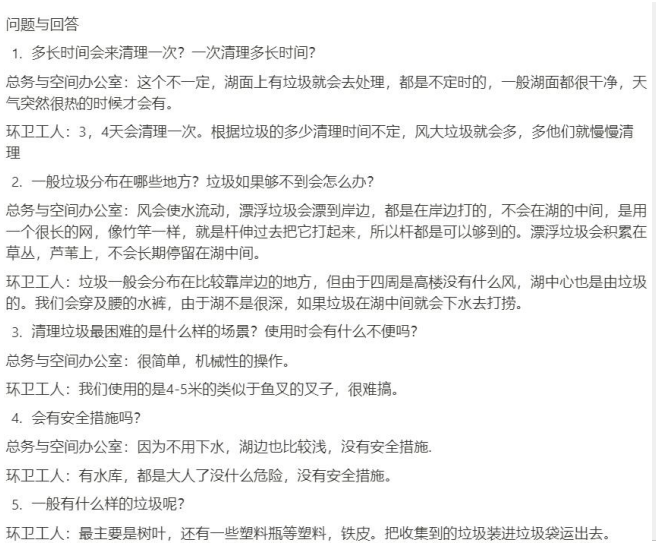
Fig. 1. Garbage along the lakeside

Fig. 2. Garbage in the middle of the lake

According to our observations, we defined our scenario as floating garbage cleaning scene on the calm lake in SUSTech.

B. Cleaning worker interview

Our purpose is to get first-hand information and find out the pain points of manual salvage by interviewing cleaning workers. We designed five questions and interviewed them twice in total. The first time we interviewed on phone with the staff of the Office of General Services and Space, and the second time we interviewed cleaning workers face to face. We got different answers in these two interviews. The staff thinks that this work is very simple, without danger and difficulty. However, the cleaning workers pointed out some difficulties and problems in the cleaning process. According to our analysis, the staff we interviewed is not a garbage salvage worker and is not very familiar with the process of garbage salvage. Secondly, the staff will be alert to our interview, so there may be unreal content when answering.



问题与回答

1. 多长时间会来清理一次？一次清理多长时间?

总务与空间办公室：这个不一定，湖面上有垃圾就会去处理，都是不定时的，一般湖面都很干净，天气突然很热的时候才会有。

环卫工人：3，4天会清理一次。根据垃圾的多少清理时间不定，风大垃圾就会多，多他们就慢慢清理

2. 一般垃圾分布在哪些地方？垃圾如果够不到会怎么办?

总务与空间办公室：风会使水流动，漂浮垃圾会漂到岸边，都是在岸边打的，不会在湖的中间，是用一个很长的网，像竹竿一样，就是杆伸过去把它打起来，所以杆都是可以够到的。漂浮垃圾会积累在草丛，芦苇上，不会长期停留在湖中间。

环卫工人：垃圾一般会分布在比较靠岸边的地方，但由于四周是高楼没有什么风，湖中心也是由垃圾的。我们会穿及腰的水裤，由于湖不是很深，如果垃圾在湖中间就会下水去打捞。

3. 清理垃圾最困难的是什么样的场景？使用时会有什么不便吗?

总务与空间办公室：很简单，机械性的操作。

环卫工人：我们使用的是4-5米的类似于鱼叉的叉子，很难搞。

4. 会有安全措施吗?

总务与空间办公室：因为不用下水，湖边也比较浅，没有安全措施.

环卫工人：有水库，都是大人了没什么危险，没有安全措施。

5. 一般有什么样的垃圾呢?

环卫工人：最主要是树叶，还有一些塑料瓶等塑料，铁皮。把收集到的垃圾装进垃圾袋运出去。

Fig. 3. Interview questions and answers

	时间	形式	对象	目的
1				
2	9月30日	电话	总务与空间办公室	打捞垃圾流程
3	10月6日	现场	环卫工人	打捞垃圾方法
4	10月9日	电话	环卫工人负责人	打捞垃圾安排
5	11月17日	电话	总务与空间办公室	了解客户需求
	11月18日	电话	总务与空间办公室	了解市场价值

Fig. 4. Interview notes

Considering all the available information, we obtained that leaves are the most common floating garbage, which is also the most troubling for cleaning workers. Then is the plastic. Floating garbage may distributed in the center of the lake and other areas sometimes which means that cleaning workers cannot collect on the shore all the time. This situation requires workers to collect garbage in the water. At the same time, they think the forks used to collect garbage are difficult to operate.

However, since the interview is not very intuitive, the information we get through the interview is relatively vague, so we need to observe their working process personally.

C. Collecting Process Observe

We got in touch with the cleaning workers in charge of the lake cleanup and asked them to arrange an on-site cleanup for us.

Firstly, we found that the garbage distributed around the lake do not need to go into the water but only need to be salvaged on the shore. Then, we found that the garbage in the center of the lake needed to be salvaged in water, and cleaning workers need to wear water pants when collecting.

Through observation, we further found that if it is an on-shore working situation, cleaning workers' work is not difficult. However, if it is an in-water working situation, it needs to be divided into two detailed situations to discuss. Firstly, We observed that if it is an obstacle-free situation, it is not difficult for the cleaning workers to enter the water, and the subsequent salvage is also not difficult. Then, if it is an obstacle situation, it is very difficult for the cleaning workers to enter the water.

Among them, obstacles refer to the depth of the water, the far location of the garbage, the lakeside plants that are difficult to cross, the large slope of the shore, and the complex underwater terrain. In contrast, obstacle-free situation refers to the shallow water, the close-shore location of the garbage, fewer lakeside plants, the small slope of the terrain, and the underwater terrain is not complex.

Fig. 5. Collecting garbage on shore

Fig. 6. Collecting in the water

Fig. 7. Obstacle-free situation

Fig. 8. Have obstacle situation

II. Problem and Pain-point Define

A. Pain-point Define

After our analysis, we defined the difficulties for cleaning workers to clean the garbage are as follows.

(1) Workers need to cross shoreside plants, which may also cause damage to vegetation;

(2) The complex terrain underfoot;

(3) The water resistance is large which causes difficulties for moving;

(4) The wearing and taking off of water pants is troublesome;

(5) Workers can not find hand-lending points when walking in water.

Thus, we define that the pain point is: Solving the difficulties of collecting floating garbage that in an inconvenient location on the lake.

B. Point of View (POV)

We used the POV method in design thinking to summarize the results of the research.

User	Pain point	Insight
The cleaner	Difficulty in getting into the water when clearing the obstructed lake rubbish	When picking up trash in the middle of the lake, cleaning workers have to wear protective clothing, push through tall plants and step over flowers to get into the lake. The difficulty of this process is: 1. The plant cannot be crossed without destroying the landscape; 2. Complex terrain under foot; 3. Need to wear water pants; 4. Walk in the water with no help from the hand.

Fig. 9. POV chart

C. Stakeholders

Through our investigation and analysis, stakeholders include Water Conservancy Bureau, Environment Bureau, Property management company, and Residents near the lake.

The situation and quality of water may have influences on living water, such that, the stakeholders will include Water Conservancy Bureau and Environment Bureau. The responsibility of the Water Conservancy Bureau is to ensure the supplement of living water, while the Environment Bureau is mainly for maintaining a good ecological environment. The garbage on the lake may not only affect the living water but also may damage the ecological balance of the water body, which will cause irreversible environmental damage.

It is obvious that the Property management company and Residents near the lake are the stakeholders of lake cleaning. Property management company needs to find methods to clean the garbage on lakes, such that the cost, effect, safety, and so on will be considered. Then, the environment of lakes will have a lot of influences on Residents' life. The quality of living water and the environment of the living place will be considered as basic living issues.

III. Solution Diverge and Concept Validation

A. Concept Development

(a) How Might We

After defining the pain points, in order to find the solution to the problem, we used the HMW method in design thinking to diverge the possible solutions. We put forward four directional questions from negation, affirmation, transfer, and imagination. We give possible methods in four directions then.

Negative: Can we let the sanitation workers without entering the water can salvage the garbage in the lake?↵

Positive: How can we make it easier for sanitation workers to get into the water?↵

Transfer: Can we put something else in the water without putting the sanitation workers in the water?↵

Imagination: Can we let the garbage move itself to a place where sanitation workers can easily pick it up?

Fig. 10. HMW questions from 4 directions

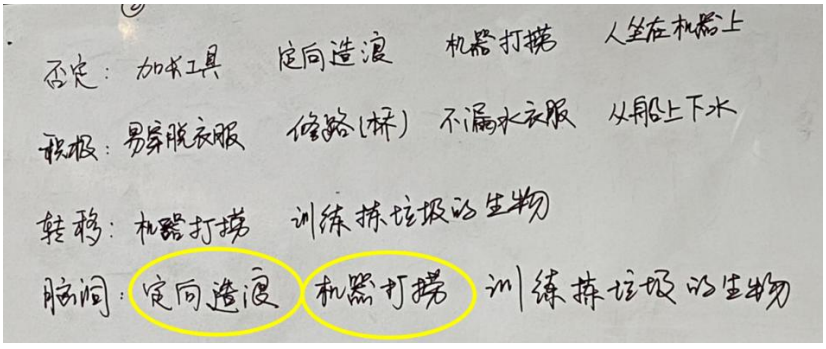


Fig. 11. Discussion answers for HMW questions

We considered the feasibility of each method, and combined with the requirements of the course, we chose two methods: "directional wave building" and "machine collecting".

(b) Functional Morphology Matrix

After we use the HMW method to determine the solution directions, we use the functional morphology matrix to analyze the whole machine. We also named the machine as the “Lake Sweeping Robot”.

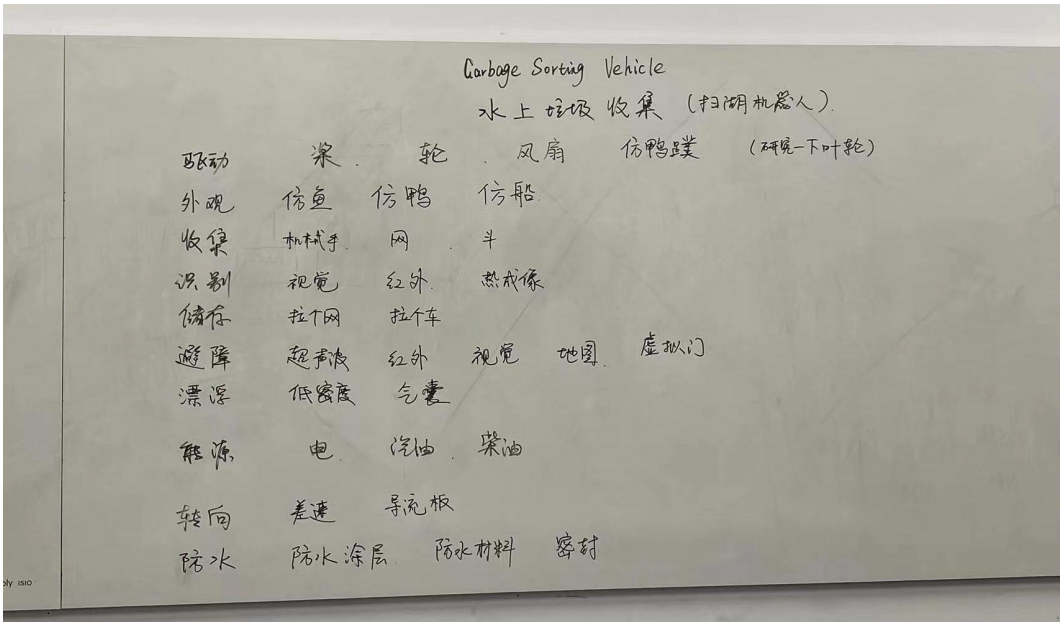


Fig. 12. Functional morphology matrix

(c) Competitive Analysis

We analyzed the products in the market from collection methods, using scenarios and size, as well as the advantages and disadvantages of the application in using scenarios we set. Most garbage collectors in the market use water pumps to suck garbage. Their prices vary from 1000 RMB to 10000 RMB according to different brands.

Although they can clean leaves and garbage on the water, they cannot clean large garbage such as plastic bottles and plastic bags. At the same time, it cannot move and can only float in a fixed position. The collection area and efficiency are very low. The first four garbage cleaning tools rely too much on manpower, and they cannot solve the pain points we defined. When the cleaning area becomes larger, the labor cost and pain points cannot be solved. Crawler-type garbage collector is not suitable for collecting a large number of fallen leaves. The cost of the remaining machines is too high and they cannot move, which cannot meet our requirements to solve the pain points.

product	picture	method of application	size	usage scenario	advantages	disadvantages	reference
1		Grab the handle of the pole with one hand and reach for the water to grab the trash.	40cm-120cm	Pick up rubbish from books, the ground and the river.	1. Easy to operate 2. Portable	1.Weak bearing capacity 2.Unable to collect garbage in the middle of the lake 3.Laborious. 4.It is difficult to grasp small volume garbage	https://detail.tmall.com/item.htm?abbucket=3&id=616852003945&ns=1&spm=a230r.1.14.273.518b3937egFeVN&skuId=4518978899120
2		Grab the handle of the pole with one hand and reach for the water to grab the trash.	85cm-117cm	Pick up rubbish from books, the ground and the river.	1.Easy to operate 2.Portable 3.Easy to grab small volumes of garbage	1.Weak bearing capacity 2.Unable to collect garbage in the middle of the lake 3.Laborious. 4.It is difficult to grasp small volume garbage	https://item.taobao.com/item.htm?spm=a230r.1.14.165.518b3937egFeVN&id=638881779769&ns=1&abbucket=3#detail
3		Hand the net down to the surface of the water to pick up the rubbish	length:1m-4.5m Net mouth : 44cmx26cmx37cm	Swimming pool, fish pond	1.Easy to operate. 2.Portable 3.Able to pick up dust.	1.Laborious. 2.Easily clog up. 3.Unable to pick up garbage accurately.	https://detail.tmall.com/item.htm?abbucket=3&id=653429199722&ns=1&skuId=4712140773690&spm=a230r.1.14.228.3432e5d0xCL6a4
4		Hand the net down to the surface of the water to pick up the rubbish	length:1m-9m Net mouth : about 20cmx50cm	Swimming pool, fish pond, river, lake.	1.Light. 2.Portable 3.Able to pick up dust.	1.Laborious. 2.Easily clog up. 3.Unable to pick up garbage accurately. 4.Sometimes hard to operate.	https://detail.tmall.com/item.htm?abbucket=3&id=396636842058&ns=1&spm=a230r.1.14.116.51a8e5d0U8GRV4&skuId=4629377360920
5		Use the water pump to suck the rubbish on the water into the storage box	600×300×460mm	Swimming pool, fish pond	1. durable 2.Not easy to block 3.Able to pick up dust.	1.Non movable 2.Small cleaning area 3.low efficiency	https://m.tb.cn/h.U2C5Jfi?tk=E6V82BYuthS
6		Use the water pump to suck the rubbish on the water into the storage box	170×260mm	Swimming pool, fish pond	1.Avoid troubles caused by water level rise and fall 2.easy to install 3.light	1.Non movable 2.Small cleaning area 3.low efficiency	https://m.tb.cn/h.UWpggb4?tk=envu2BYsoDL
7		Collect floating garbage on the water by moving quickly.	1000×800×500 mm	Coast, In the port	1.Self navigation 2.It can load 360 kg of garbage 3.Water quality can be monitored	1.high cost 2.When the machine is backed up or stopped, the garbage stored in the savings box may float out.	https://www.bilibili.com/video/BV1ds411g7JU/?spm_id_from=333.788.recommend_more_video.1
8		The garbage on the water is transported to the savings box through the conveyor belt.	1000×500×500 mm	river, lake	1.Automatic garbage collection 2.Can classify garbage	1.Slow moving speed 2.Small rubbish such as fallen leaves may stick to the conveyor belt and be difficult to clean.	https://www.bilibili.com/video/BV1EE411o75y/?spm_id_from=333.788.recommend_more_video.2

Fig. 13. Competitive analysis notes chart

(d) Idea Visualization Pretotype and Concept Verification Prototype

After our analysis and discussion, we sketched to visualize our idea. After iterative optimization, we made a concept verification prototype. In the process of iterative optimization, the difficulty of the project and the feasibility of the workflow are mainly considered.

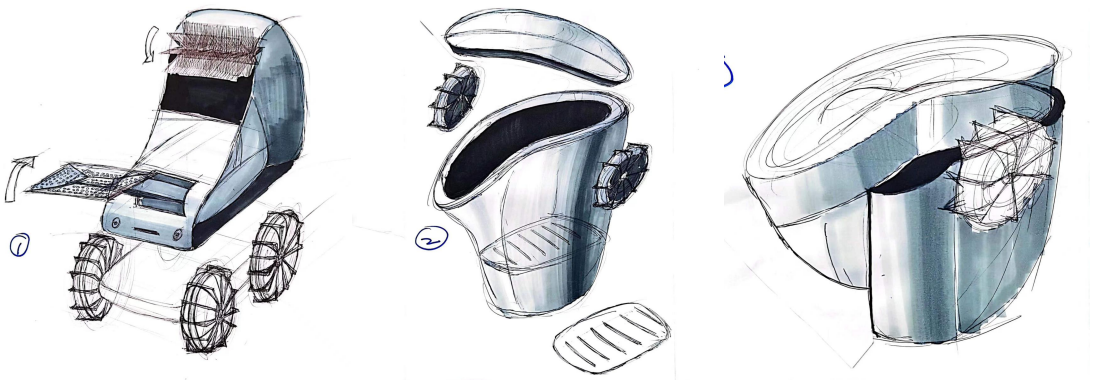


Fig. 14. Idea visualization pretotype

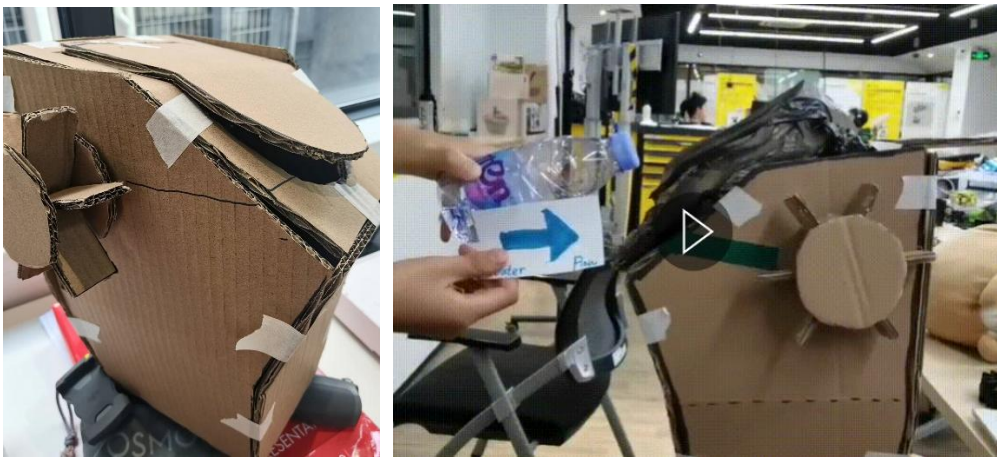


Fig. 15. Concept verification prototype

Through our design, we hope that the water and garbage will be sucked into the machine together, and the water will flow out from the bottom of the machine, and the garbage will be filtered by the filter plate and left inside the machine.

B. Concept Validation

(a) Value Proposition Canvas

In order to further understand our customer, we also searched the official website and found the telephone number of the General Affairs and space office, and interviewed the staff of campus cleaning, hoping to know whether the design of a product to salvage the garbage on the lake could bring benefits to the customer.

After the interview, we learned that the campus cleaning is outsourced to the cleaning company, and the machine for salvaging garbage on the lake can reduce the expenses of the school to a certain extent and reduce the cooperation content with the outsourcing company. Nowadays, although there are such cleaning machines on the market, the cleaning intensity and application degree are not very popular. Compared with the direct labor union, the burden is greater, so the machine is not used. If we design a machine that can clean up floating garbage and it can be tested effectively, the school will consider putting it into use. Generally speaking, the staff has a positive attitude towards our product design.

总务室

1. 市面上有这样的湖面垃圾收集机器，请问为什么不投入使用（有没有考虑过使用机器）
2. 你们负责这些垃圾的管理吗?
3. 清洁工人是属于外包公司的
4. 决定使用人工的人是谁?
5. 你们在这个湖面垃圾收集的过程中扮演什么样的角色？员工的工资开支是谁负的。
6. 雇佣的是哪个物业公司 联系方式是什么?

Fig. 16. Questionnaire for interview with the head of the Office of General Services and Space

Customer	Job-to-be-done	Gains	Pains
Head of the Office of General Services and Space	Considering the way to clean up the garbage on the campus lake, we choose to outsource it to a cleaning company.	Reduce costs and effectively clean the lake.	Outsourcing to the company does not belong to direct management, there are certain security risks. Costs can be high.

Fig. 17. VPC of the head of the Office of General Services and Space

(b) 2nd Prototype Making

We found three problems with the Concept Verification Prototype.

(1) The buoyancy may not be enough if the buoyancy is only provided by paddle wheels.

(2) The forward power is provided by the paddle wheel, so the working efficiency is very low.

(3) The position of the gravity center is low, which will lead to instability such as shaking when moving.

After our analysis and design, we designed our second prototype to verify our garbage collection function.

We think for a long time to choose materials. Firstly, to ensure waterproofing, we decide to use Glass-fiber Board to make the whole body. It will be manufactured for one time in this method, which can ensure the waterproof. Therefore, firstly we need a model. We use Wire and PVC-board to make the model. I take easy working and stability into consideration at the same time. We use the Acrylic plate to make our loading board because of its Stiffness. I choose the Screw to fix the bottom to have the ability to support loads. We choose Glass Glue as our machine's waterproof material.

At the same time, we designed and modeled the steering mechanism, and used a 35kg servo to drive it. We used 3D printing technology to manufacture the steering mechanism, and selected PLA material as the material for 3D printing.

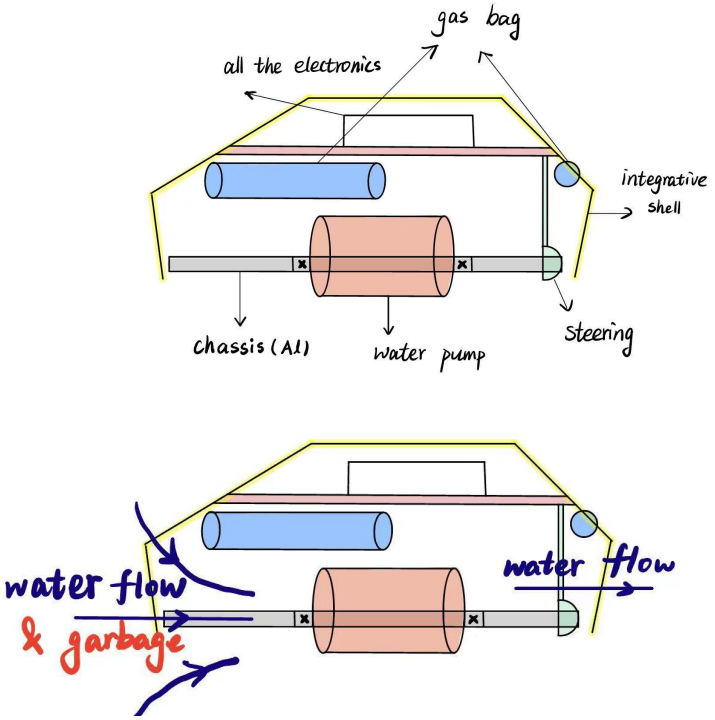
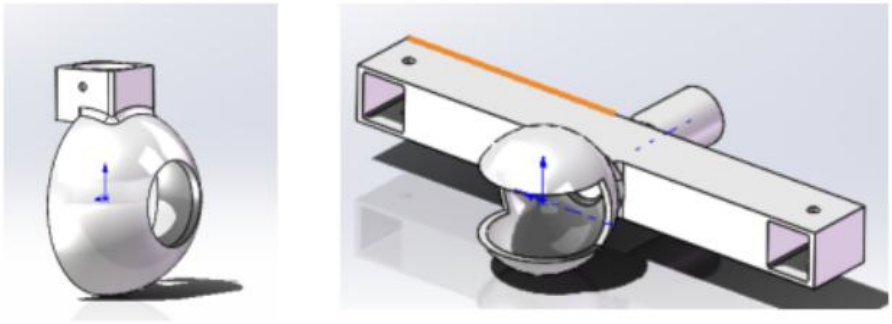
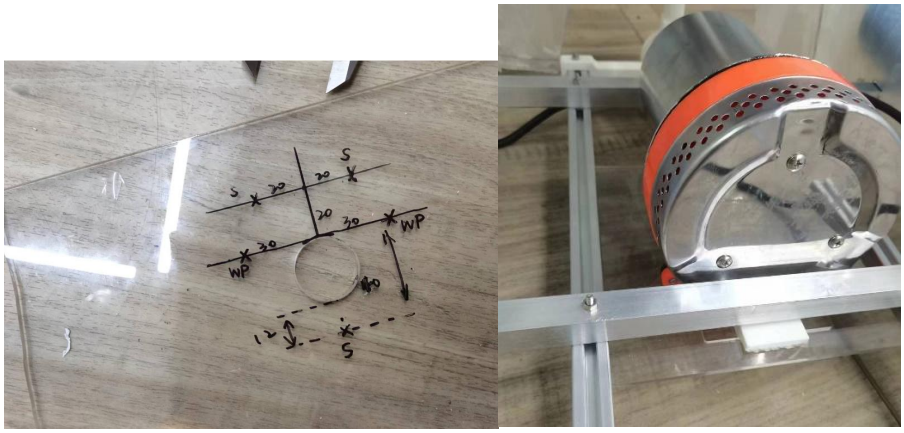


Fig. 18. Structure and working principles we designed for 2nd prototype





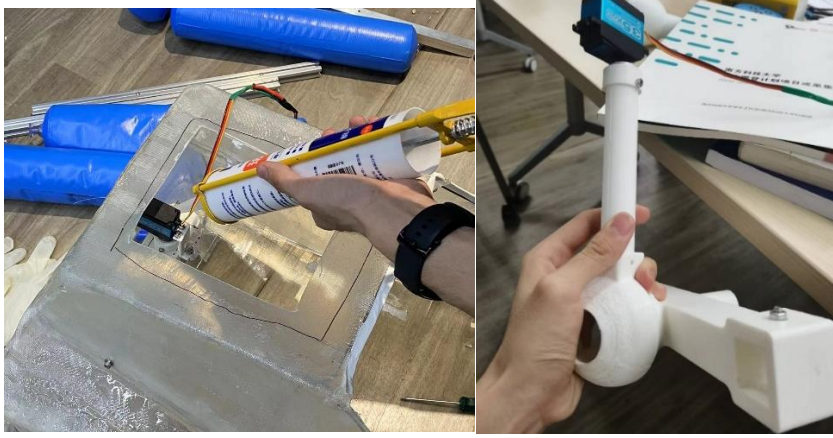


Fig. 19. Some making details for 2nd prototype

Fig. 20. 2nd prototype

(c) 2nd Prototype Testing

At the beginning, we found that the position of the center of gravity was too backward, and the position of the airbags were too downward, which led to the inability of the water pump to be immersed in water, which will cause the failure of the working principles of our design.

Then, we adjusted the positions and distribution of airbags. We put them in the leftward, rightward, and backward. We also adjusted the position when putting our machine on the water. This time, our machine can float vertically, and the pump can be almost immersed in water. We test the moving and turning performance of it, which can perfectly meet our expective.

After we tested the moving performance of our machine. We realized the importance of Debugging. When we find the situation, we think we will fail and back. Before we leave, I have an idea to have a try. We analyzed the center of mass and try to untie the zip tie by separating the snap and teeth line, which enable the reusing of these zip ties. We try to adjust the position of these airbags and succeed when trying to put it as shows in picture. It is very important for us to know how to solve the problem that unexpected, which will be a rewarding experience for us in the future.

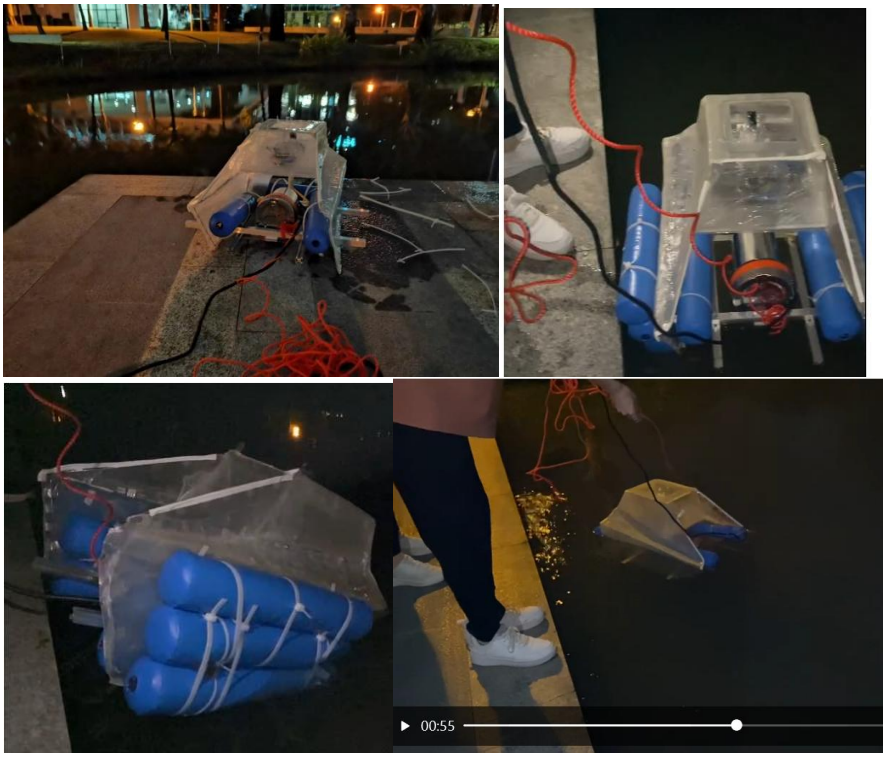


Fig. 21. Testing process of 2nd prototype

C. Problems and Testing Results

After our testing, our design can well meet the requirements of garbage collection. At the same time, we also found some problems that need to be solved. It need a back off function because sometimes may get stuck. Then, it is useful to add a light belt as Warning Light. At the same time, the stressed structure needs further optimization.

IV. Solution Converge and Final Product

A. Product Definition

We redesigned our product's Function, Feature, and Form as shown in Fig. 22.

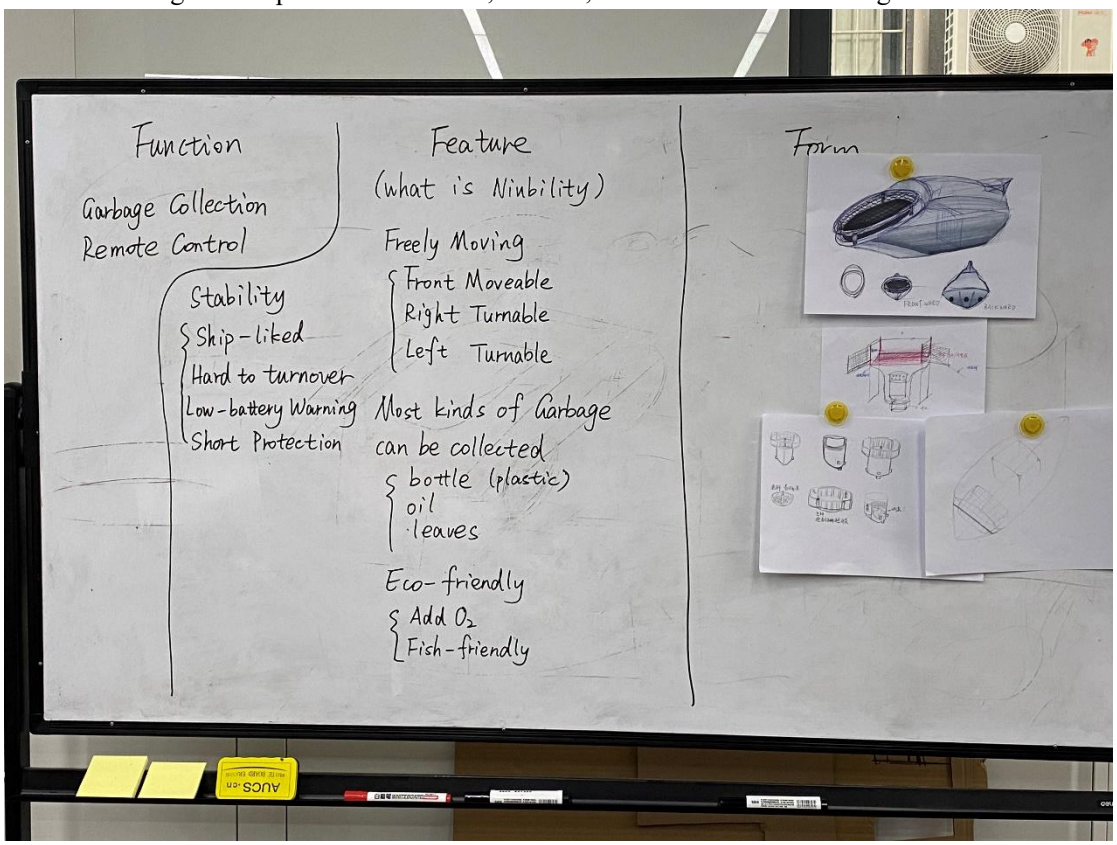


Fig. 22. Our product's Function, Feature, and Form

B. Mechanical Design and Calculation

We redesigned the mechanical structure of the machine and changed the load-bearing structure from the original integrated structure to the current load-bearing structure. At the same time, we have added a backward mechanism to enable the machine to switch between forward and backward states.

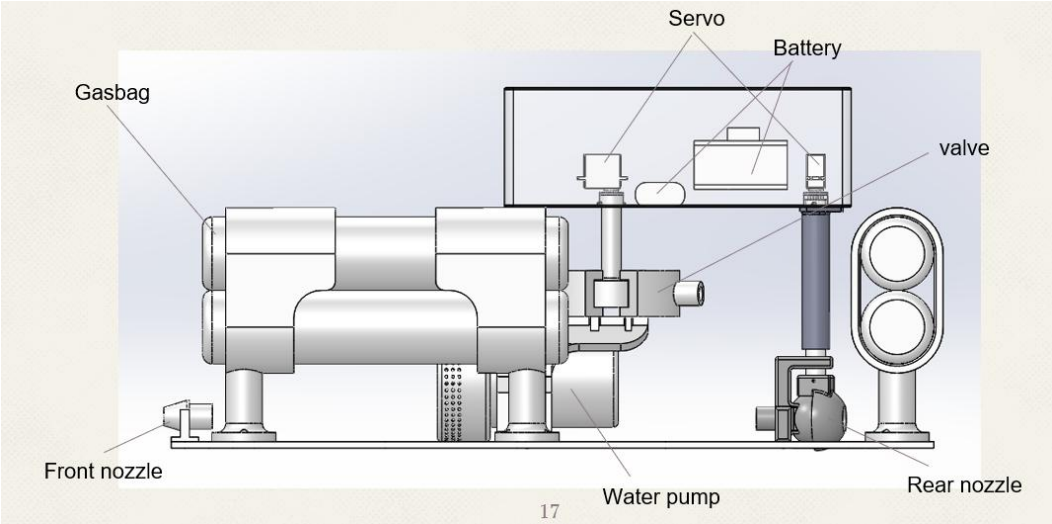


Fig. 23. Mechanical structure of final product

We did not use the motor in the term project, but we used two servos. As we all know, the servo is a servo device that is decelerated after the motor through the reduction gear set. We carried out experiments and calculations on the selection of servos.

We measured the required torque by experiment. We use a 30cm long bar and fix it on the shaft. Then, we use a spring scale to pull on the edge of the bar to make the shaft rotate. Due to the defects in our design, the internal and external coordination of the device is not very good. We observed that the maximum force is about 7N. At this time, the required torque is 2.1N · m.

After calculation, the maximum torque provided by 20kgf.cm servo is 1.96N·m, so we choose 35KG servo which can provide 3.43N·m torque maximumly.

We also calculated the buoyancy accurately.

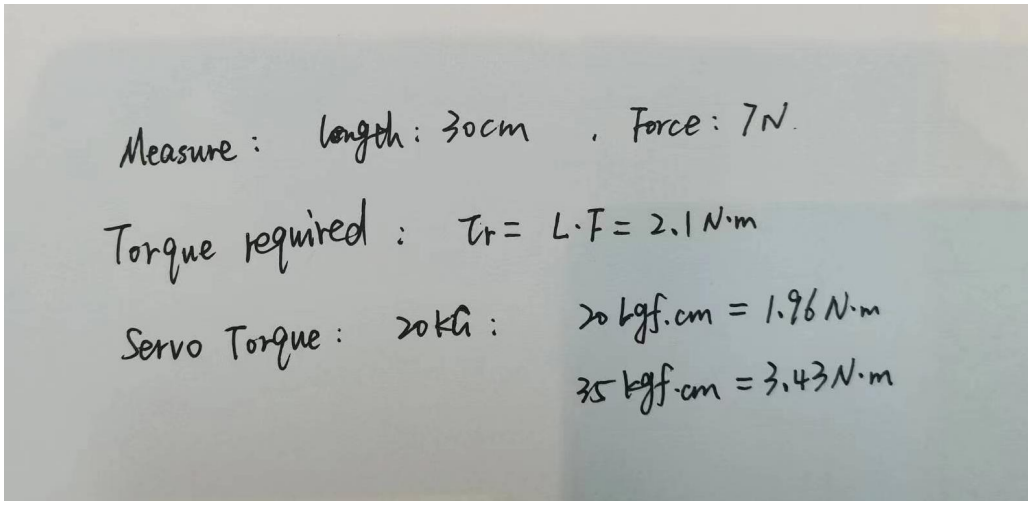


Fig. 24. Servo selection caculate

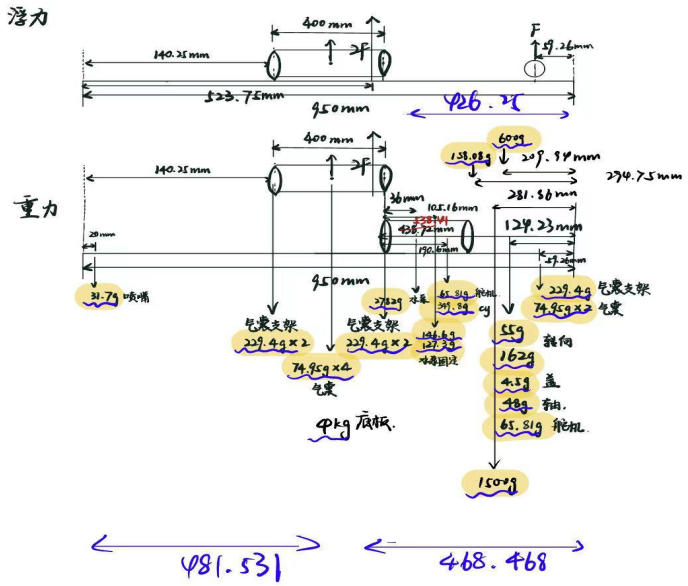


Fig. 25. Buoyancy calculation

C. Electronic and Interaction Design

According to our design, the whole electric control is divided into four parts, remote control send transceiver, signal transmission, remote control receive transceiver, and battery management system (BMS). My task is to finish the send transceiver of the remote controller.

(a) Control Logic Design

At the beginning, we did not design the remote control logic, and we began to complete our own part after directly allocating tasks. However, we found that in the process of editing codes or making devices, there are always problems with cooperation and communication. Every time we communicate, we will misunderstanding other people's ideas, which leads to some code that cannot be connected and needs to be rewritten. This cause a great reduction in work efficiency. After our analysis, we think that we should first define the logic of remote control, and then every cooperations should be based on this logic.

In the remote-controlling logic, as we can see, “push 1” is the key for the power supply. After pressing the “push 1” key, the power supply will open, and then other keys will enable to use. Then, the “push 2” key is the switch of the water pump. You can open the pump by pressing the key “push 2” while closing the pump by pressing the key “push 2” again. After power on, we can control the two servos for turning and changing moving directions. The switch “change” is designed to have two situations, moving forward and moving backward. Therefore, we can change the moving direction by toggling the switch “change”. At the same time, we can control the turning of the robot by toggling the rocker “turn”. Last but not least, the key “push 1” is designed to trigger at any time, that is when the second time pressing that key, the power will shut down until you press it again.

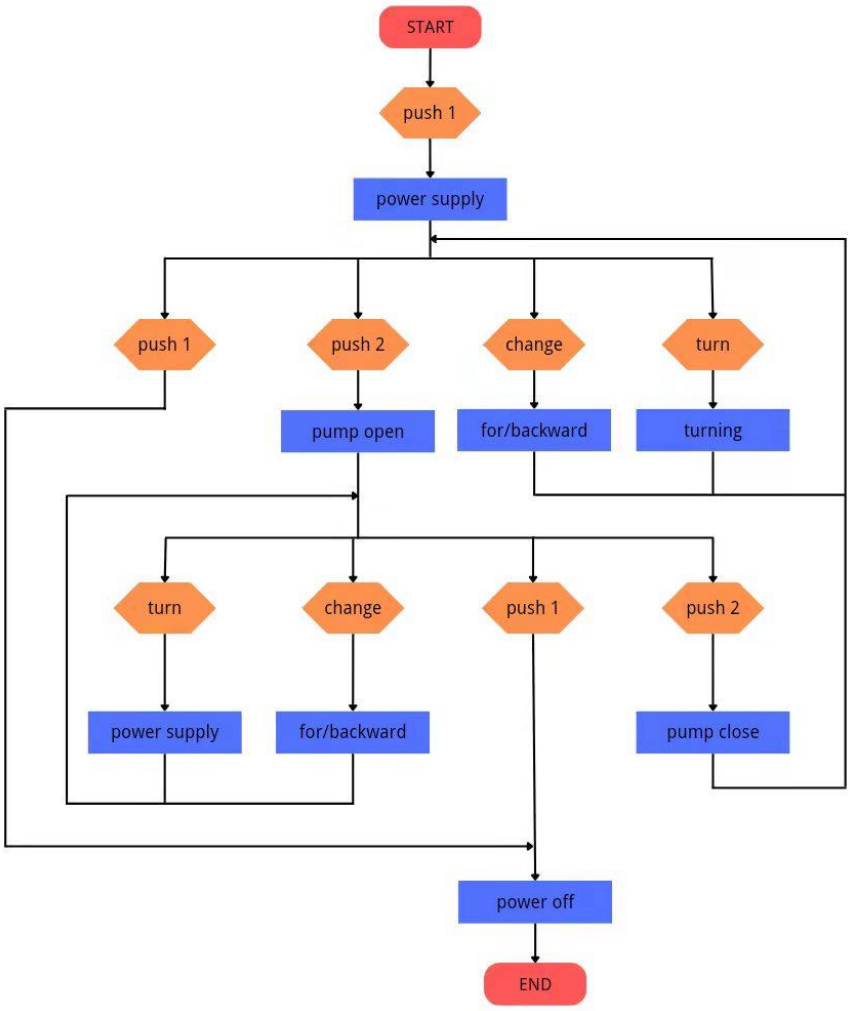


Fig. 26. Remote control logic I designed

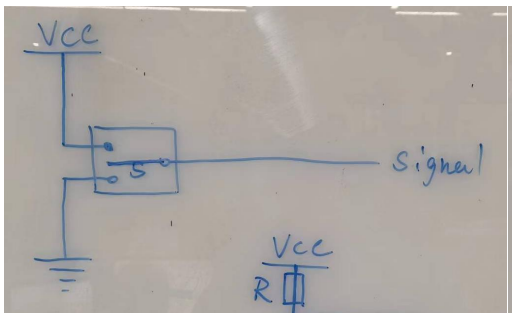
(b) Filter Design and Manufacturing

In the beginning, I designed the circuit as Fig. 27 shows. When changing the switch, the signal pin will connect to VCC or GND, which can output two different values: 1 and 0. However, I found it is not stable for the signal when switching the key. Sometimes I switch the key to another case, but the output signal will change twice. Sometimes the signal jitters between 0 and 1 when I toggle the switch.

After encountering this problem, I asked the engineer Jin Wei for help. According to the analysis, the switch will not be firmly connected at the moment of disconnection and connection, and the resistance will jump sharply at this moment, which will cause the circuit to change back and forth between connection and disconnection.

Then, I redesigned the switch circuit by referring to the pull-up resistor circuit I learned in the SDM242 Lecture. I make the signal pin connects to the VCC and always output 1 when the Switch is not connected. I remember that Prof. Hong said a capacitor may solve the problem that the signal is unstable as a filter. Along with this idea, I designed this module as Fig. 28. The capacitor there is used to eliminate the unstable of the signal as a filter when switching the key,

and the resistor there is a pull-up resistor to prevent excessive current when the switch is connected.



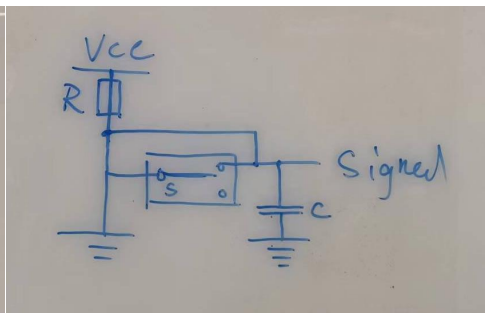


Fig. 27. Preliminary design of switch circuit **Fig. 28.** Redesign of switch circuit

After designing this circuit, I decide to make a PCB board to realize this model. I tried to use Li Chuang EDA to finish the Schematic drawing and PCB drawing. I choose the 0805 Electronic package model under the guidance of Engineer Jin Wei.

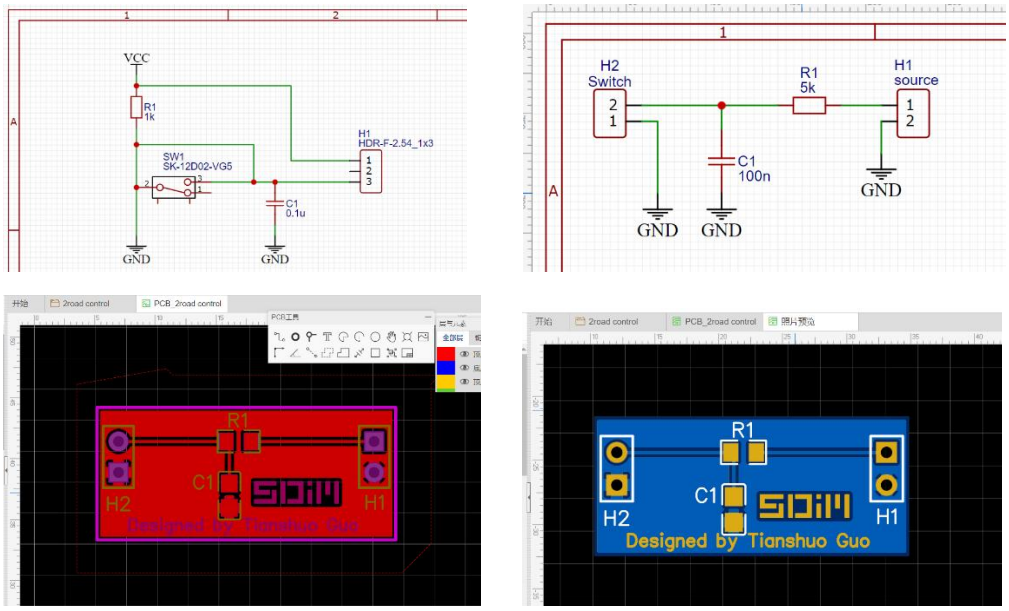


Fig. 29. PCB design process

(c) Human-Computer Interaction Design

Considering the different habits of left-handed and right-handed people, I hope this remote controller can be used by more people. I put the main two keys and a rocker at the center of the remote controller in a row. The button in the middle is the power key “push 1”, and the button next to it is the key “push 2” to control the water pump. This design is for the convenience of opening and closing the water pump, and the also is to prevent misoperation to turn off the power. We only use the key “push 1” when starting and shutting down, and the water pump button will be used often.

The rocker is placed on one side to adapt to the different habits of left-handed and right-handed people. People with different habits can use the remote controller comfortably just by turning it over.

Also, we just use the “moving backward” function when special situations occur, such as hitting the shore. Therefore, the switch “change” is designed to be put aside. Because most people have the right-handed habit, I designed it upward when right-handed people use it. It is not

necessary to worry about the convenience of using this switch for people with different habits, because we rarely use it except in emergencies.

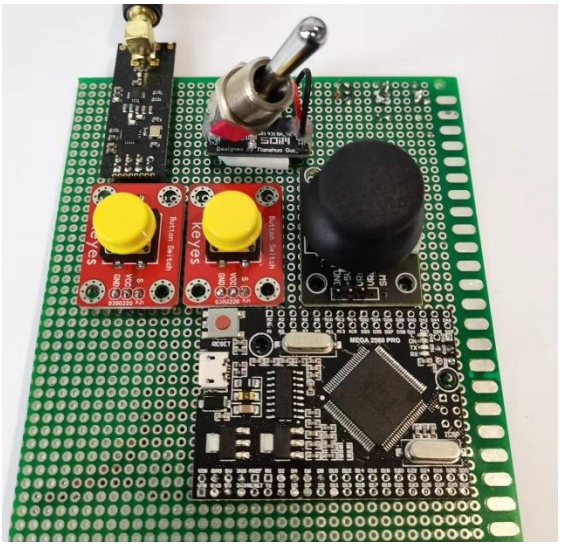


Fig. 30. Remote controller

D. Appearance Design and Manufacturing

After we designed the appearance, we optimized the composite materials used in the second prototype. Firstly, we use acrylic plates to make the shell. The confinement and assembly method between acrylic plates adopts the method of sheet metal parts and rivets. Then, we use car putty to treat the surface and also paint the appearance.

The reason why acrylic plates are used instead of composite materials is that this method is more suitable for making sharp edges and corners, and the transition of composite materials is more rounded.

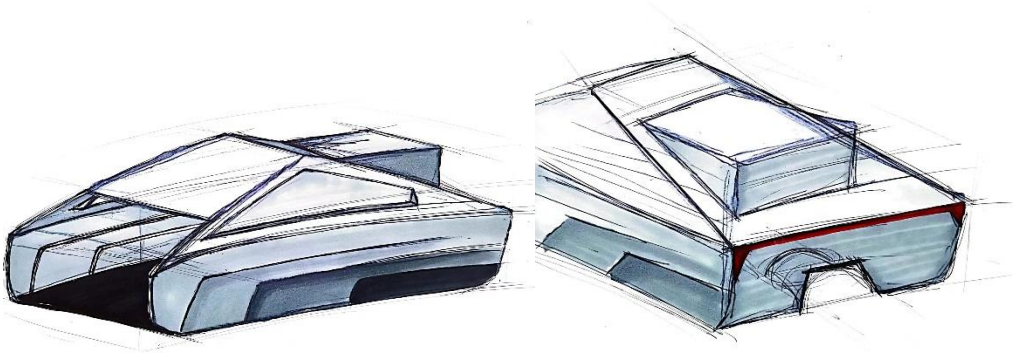


Fig. 31. Appearance design sketch

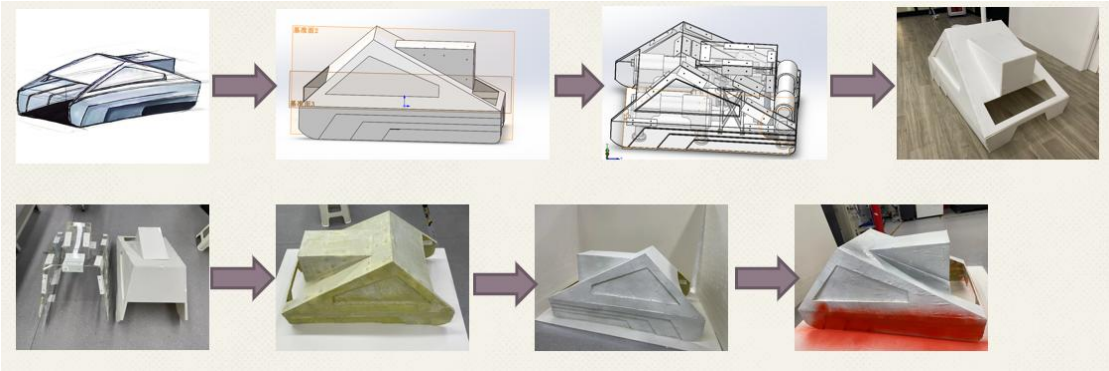


Fig. 32. Machine appearance manufacturing process

Fig. 33. Final appearance of our final product

V. Conclusion

Through this integrated program and the whole semester's study, I have exercised a lot of ability in design research and design thinking. I increased the ability in project management and project implementation. The ability of self-study and the ability to define and solve problems have been increased. Group 1 completed the expected goal of the integrated program, and completed the whole process of design thinking from research to final product testing. It further improved our teamwork and problem analysis ability.