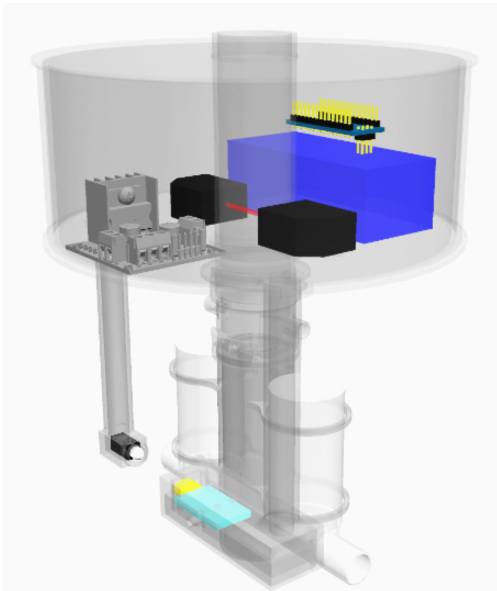
Automatic Brush Washing Machine



TEAM C-4

FAN ZEKAI,	517021911109
HUANG PENGYUAN,	517370910025
LIANG XINYI,	517370910130
ZHAO SHAOCHONG,	517370910125
ZHU WENXUAN,	517370910263

August 8, 2018

Contents

1 Executive Summary

Our automatic brush washing machine can wash away all the pigments attached to paint brushes. Targeted at painters, this device is intended to relive the their burden of washing brushes by hands since this process is time-consuming, tiring, distractive and dirty. This problem has existed for a long time, but few similar solutions have come out, so we come up with such a product. We aims to develop a controlling system with reminder of changing water, an effective and efficient washing system, a portable design with suitable size and weight and waterproofness throughout washing process. We conducted a market survey and many experiments of washing brushes. Then we designed and 3D printed the mechanical structure with mountable parts, bought other parts and assembled our device. Tests involving different pumps, sinks etc. are conducted then. Arduino is used to control our mechatronic system. Other tests with real customers are also in process. Modifications are done according to the tests and now we're using the third version model and realizing all of our expected functions. By now, our product has fulfilled the requirement that it can run automatically whenever a brush is inserted. The brush can be cleaned in 20 seconds. It reminds the user to change the dirty water when the turbidity is high by lighting a LED light. It is adaptive to different pigments and different size and shape of brushes, and is also portable. Our solution is low-cost as part of a painting studio, relieving painters of the trouble of brush washing, which is also unique and effective. So our project is generally successful.

2 Introduction

2.1 Introduction of the team

The automatic brush washing machine is a device designed and built by team C-4, whose team members are Fan Zekai, Huang Pengyuan, Liang Xinyi, Zhao Shaochong and Zhu Wenxuan. All of them are freshmen majoring in engineering from the University of Michigan - Joint Institute of Shanghai Jiaotong University.

2.2 Functions of the device

This device can wash away all the pigments including both watercolor and acrylic paint that are attached to different sizes of brushes within 20 seconds. Considering user-friendliness, the washing process starts and ends automatically after detecting the inserted brush. It reminds the user to change the dirty water when the turbidity is high by lighting a LED light. Moreover, the device has good adaptation, since it is portable enough to be used in outdoor painting.

2.3 Reason of our competent accomplishment of the device

Our team is competent to take on the assignment for the following reasons:

1. A survey is conducted to provide important information for design. This survey has interviewed more than 100 professional painters and amateurs including both males and females who range in age from 18 to 45 years old. This survey is conducted online, we invite familiar art students and their friends to do it. So it is a reliable and meaningful survey. Because of the survey of painters habit of washing brushes, the device can successfully meet the users need.

2. We choose to build a mechatronic system, which builds a solid foundation of the functions of the device. We use Arduino Nano board to control the whole system and various sensors to gather timely data. For example, the photo gate sensor can detect whether a brush is inserted or not, and then Arduino board will start the washing process depending on the received signal. This system makes sure that the device can finish tasks with high accuracy.

3. We choose the components carefully. We have tested various kinds of pumps and sensors, so that this device can be portable enough to be used outdoors and work with great efficiency. For instance, after testing, we finally decided to use submersible pumps, since they are high-power and have good waterproofness.

4. Different tasks are assigned to different person according to everyones strengths. So everyone is in charge of what he or she is good at, and many tasks have been accomplished closely followed the schedule.

3 Problem

This device is intended to relieve the painters' burden of washing brushes by hands since this process is time-consuming, tiring, distractive and dirty. Based on the conducted survey, it takes about 45 seconds to wash a brush thoroughly. Painters usually need to wash brushes many times while painting, so it will occupy a lot of time. Also, painters have to exert force to wash away all the attached pigments, which is tiring. Washing brushes by hands is also distractive, especially when a painter has to wash brushes while painting. He or she has no choice but to stop painting, but after washing, he or she may feel lost about what to draw next. When someone is washing brushes, there are chances that dirty water will splash out the bucket. So the clothes will become dirty. We identify these problems due to our own experience and the conducted survey.

Length of time that problems have existed

This problem has existed for a long time, which is hard to estimate. But we believe that this problem came into existence since there were brushes and different color of pigments. Since then, painters have been washing brushes by hands. Because of rapid development of technology in recent 15 years, people have been more and more concerned about this problem.

Former solution of similar problem

After investigation, there was a device that could wash the uniform size of brushes that were only used for Chinese Calligraphy. And that device hasnt been applied into mass product.

Impact of problem on target population

This device's target population is the professional painters and amateurs. Because of washing brushes while painting, they are usually distracted from painting and feel at lost what to paint next after washing . Also this takes a lot of time, so they feel it is time-consuming and meaningless. Some water usually splashes out while washing brushes, so their clothes usually get dirty. We know the impact of washing brushes by hands through a survey conducted by us.

Impact of problem on surrounding populations

Dirty water always splashes out, which makes the floor dirty. So surrounding people will feel bothered about the dirty environment.

In summary, washing brushes by hands can cause problems including:

- **Distracting painters from painting,**
- **Consuming painters energy meaninglessly,**
- **Making surroundings and clothes dirty,**
- **Becoming more inconvenient while painting outdoor,**
- **Failing to remove all pigments on brushes.**

4 Needs

To solve the problems of washing brushes by hands, new tools are required, including:

- **Automatic electronic controlling system with reminder of changing water,**
- **Automatic washing process,**
- **Waterproof design without splashing water,**
- **Portability, with suitable weight and size,**
- **Ability of cleaning brushes quickly and thoroughly.**

5 Solution: Automatic Brush Washing Machine

As a solution, an automatic brush washing machine is proposed, along with a mechatronic system, which provide:

1. **Accurate automatic electronic controlling system with reminder of changing water,**
2. **Effective and efficient washing system,**
3. **Portable design with suitable size and weight,**
4. **Waterproofness throughout washing process.**

5.1 Working Principle

The interconnection of every part is shown in fig. 2 on the following page.

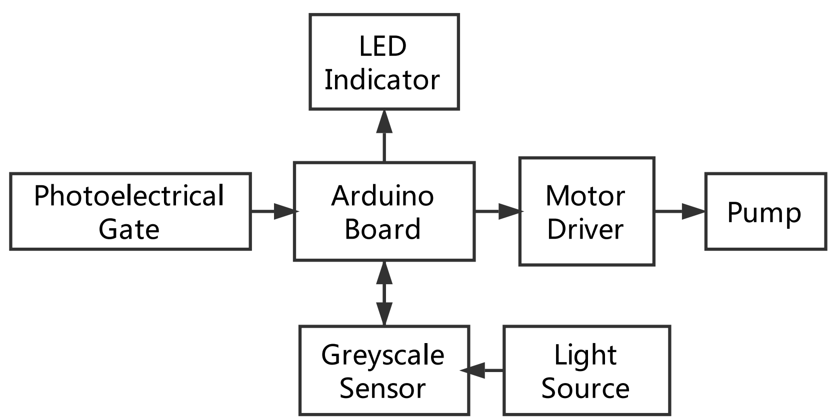


Figure 1: Flow chart of the working principle of the electric system

This figure shows both the working principle of the system and interconnection of every part. Generally, our device is a half-submerged platform standing on a common bucket. Most of he electronic components, such as the arduino board and the motor driver, are installed on the platform and carefully separated from water; the pump and the sensor which can detect turbidity of the water are submerged in the water. At the top of the device there is a photoelectrical switch, which can detect whether a brush is inserted or not. When a brush is inserted into our device, a signal will be sent to the Arduino Nano board. After processing the data, the Arduino board will turn on the XY-160D DC motor driver, which controls the water pump. Then the water pump will start to pump water from the bucket to the 3cm diameter water sink. Two currents in opposite direction will create a vortex that can wash away the attached pigments. After 20 seconds, the red LED light installed on the surface of our device will start flashing, indicating that the cleaning has been completed, and the user can pull out the brush, so that the red light will be turned off. Meanwhile, the greyscale sensor will test the turbidity of the water. If the turbidity is high, then a signal will be sent to the Arduino board and the blue LED light, which is installed right next to the red one, will start shining continuously until the water is changed.

All parts are labeled in fig. 2.

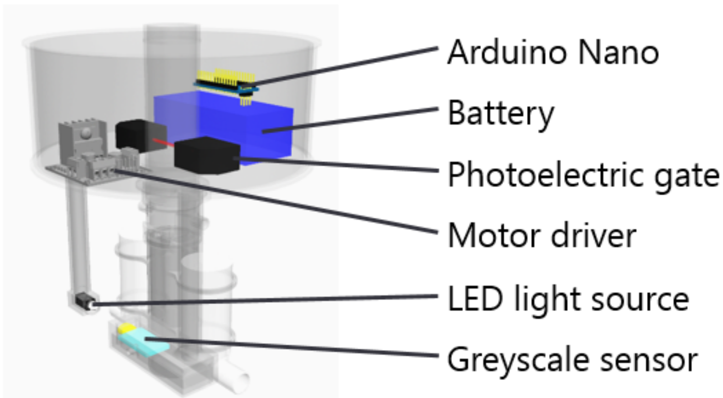


Figure 2: Design of electric component usage

5.2 Functional Components

5.2.1 Photoelectric sensor

As shown in fig. 3, a photoelectric sensor emits a light beam from its light-emitting element, and there is a light-receiving element. If the light-receiving element doesn't receive the light, it will return a signal.

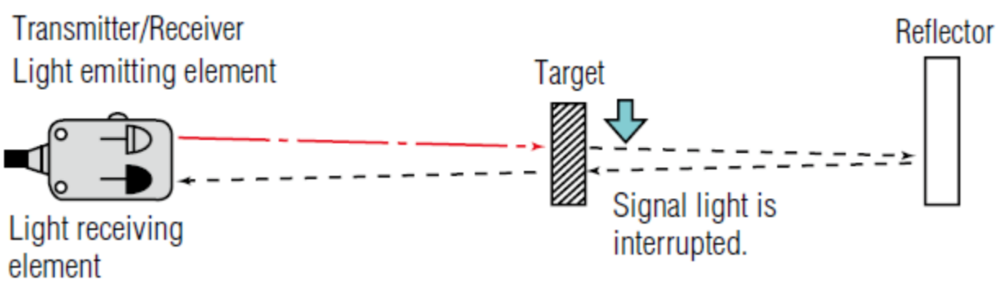


Figure 3: Working principle of photoelectric sensor

In our product, the photoelectric sensor is at the top of the device where a brush is inserted in. When the brush blocks the emitted light, a signal will be sent to the Arduino board. We choose to use the photoelectric sensor, because it can accurately and immediately detect the inserted brush. Also, the light can pass through the transparent tube containing the brush, so that it can finish its task while completed separated from water. It helps to build an automatic electronic controlling system.

5.2.2 Arduino Nano board

By using arduino nano, we can integrate all our functions within a chip. The space in the container of all the electronic components is limited, so arduino nano is a better choice for us since the pins are just enough to connect all the components. It is essential for our automatic electronic controlling system.

5.2.3 Greyscale sensor

The greyscale sensor and a LED light source are separately put below water level, and both of them are protected by a sealed container to ensure the waterproofness. If the turbidity increases, there will be less light reaching the detector. When the turbidity reaches a certain level, the arduino will send a signal to turn on the blue LED light, indicating that the water needs to be changed.

5.2.4 Pump

In this project, the brushes are washed by vortex that is created by two currents in opposite directions. A pump can create strong water current and by using pipes currents in opposite directions are created. This pump should be chosen carefully because it should be high-power enough to create strong current, small enough to be portable and have good waterproofness. After taking these into consideration, we have tested several kinds of pumps. And we finally decide to use 24V 3A submersible pumps, which satisfy all the requirements.

5.2.5 Motor driver

The high power pump can not be controlled by a normal motor driver, so we use a XY-160D DC motor driver to control the pump. Also, since this motor driver is one of the smallest motor driver we can find that can finish our task, much space is saved.

6 Objectives

Objective 1: Specifying the needs

To determine the device's parameters and functions, we should know some details about how they wash brushes. So we can design a project that is suitable for them to use.

Objective 2: Finding ways of washing brushes

According to our survey and problems listed above, painter usually can not wash away all the pigment on the brushes and it is tiring to wash them. It usually takes about 40 seconds to thoroughly clean a brush. To solve these problems, this device should wash the brushes completely within 20 seconds.

Objective 3: Producing a prototype

To do more actual test to solve existing practical problems and get parameter constraints of our device, we needed a prototype as early as possible to test with. Further modification can be also base on this prototype.

Objective 4: Electronically controlling the machine

Most painters who don't want to wash brushes by hands complain about how distracting it can be and they hope there is a machine in which they just insert a dirty brush and get a clean one. So we should design an automatic electronic controlling system to make sure the washing process wont interrupt painters work.

We want to add a a detect and remind system to control water quality in our device. If water in the bucket is no longer effective to wash brushes, the machine should remind users of changing water.

Objective 5: Controlling over water

There are both electronic elements and water in our device, so it must have good waterproofness. Otherwise, there will be dangerous to use it. Also, with good waterproofness, dirty water won't splash out, which can make surrounding dirty.

Objective 6: Ensuring that needs are met

We have to make sure our design take the best choice to meet the needs of our target audience precisely, for example, the washing time, the operating process, the appearance, etc., so that we can modify our products more purposefully.

Objective 7: Optimizing size, weight and appearance

We want to minimize the size and weight of the device. As what stated in the Need part, users need a device with good portability. Many painters go outside and sketch from life regularly, and at that time it is inconvenient to bring a big and heavy device with them. So the machine should be designed in a proper size and weight, even demountable.

7 Tasks

Both conceptually and practically we encountered these tasks to complete, as shown in fig. 4. This section will introduce these tasks in detail.

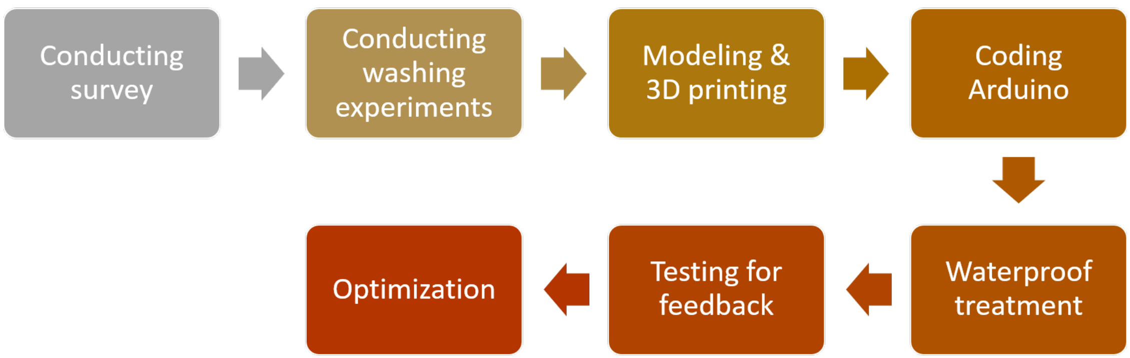


Figure 4: Task Flow Diagram of the Project

Task 1: Conducting Survey

We first conducted a survey interviewed 105 professional painters and amateurs including both males and females who ranged in age from 18 to 45 years old. From this survey, we got some detailed information about their habits of washing brushes, such as how often they changed the water in buckets. The survey data are included in appendix section A on page 20.

Next, based on gathered information, we decided to build a mechatronic system. We also decided the function of the device, washing colored brushes quickly, thoroughly and automatically. So this survey successfully specify the users needs.

Task 2: Conducting washing experiments

To determine the design of the washing machine, we need to conduct washing experiments first. Since our machine should be efficient and energy-saving, we purchase a 40W pump and a 75W pump; since our machine should be adaptable for different kinds of pigments and different size of brushes, we purchased acrylic pigments and gouache pigments.

There are two kinds of water flow we may adopt in our machine, one is jet flow, the other is vortex. In the first experiment, we examine the two methods. Firstly, we connect a pipe on the 40W pump and pump the water jetting directly at a dirty brush with gouache pigment. The effect is not satisfied. Next, we replace the 40W pump with the 75W pump, though the effect is better than 40W pump, pigment on the side of the brush is not washed. Then we make a simple sink by cutting and folding a paper cup, and pump water in to the sink to create a vortex. Though it takes a little more time to wash the dirty brush, the brush can be washed thoroughly, and the efficiency is acceptable. Therefore we choose vortex as our washing method. Finally we use the acrylic pigment to do the same experiment and find that washing acrylic pigment needs a little more time, but still acceptable (within 20 seconds). Shown in fig. 5 is a photo of the experiment process.

Figure 5: Photo of the washing experiment

Task 3: Modeling & 3D printing

Since our parts have to follow their expected shape closely to be both mountable and waterproof, we chose 3D printing to fabricate our mechanical components. The engineering draftings of these parts are included in appendix section B on page 21, combining to get fig. 6 on the next page.

Here are some of our considerations: The upper part will be connected to the top container of our device. To save the wires from being exposed to water, we design the hollow cylinder in which we can put the wires; the lower part can be fixed with the upper part by some joints; the height of the "cap" is enlarged so that it can be fixed on the container part without slipping; the two pipes on

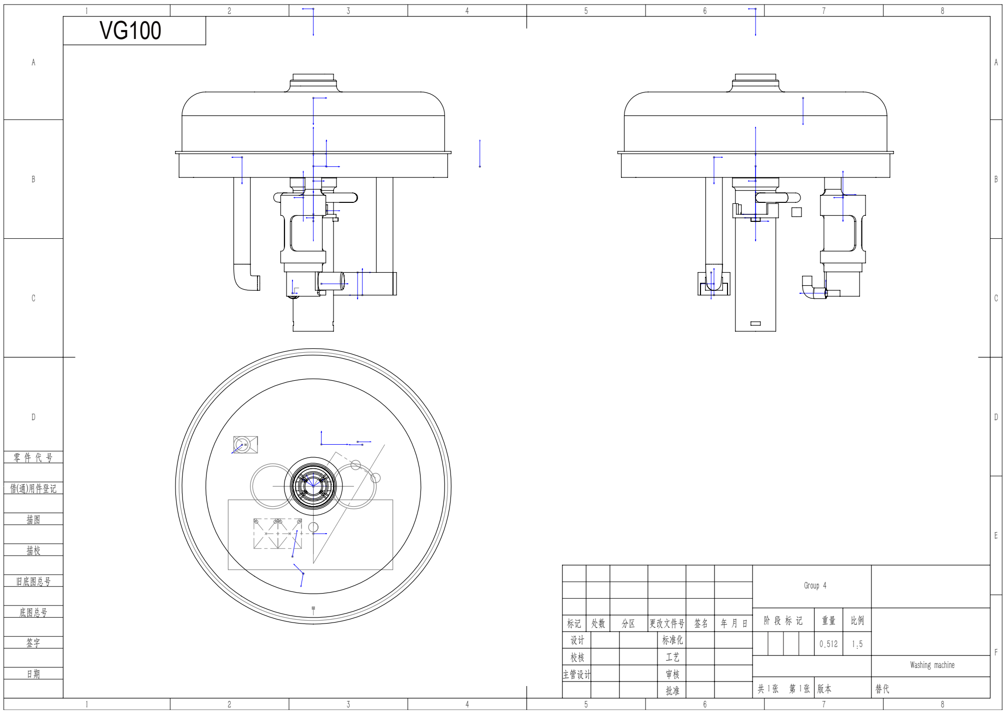


Figure 6: Engineering drafting of the whole system

the sink will be connected with pumps indirectly to avoid the plastic hoses getting winded in the bucket which will make the water currents not strong enough.

Task 4: Coding Arduino

In terms of the arduino coding, we mainly divide the process of washing into three parts, namely, before washing (when no brush is inserted), under washing and after washing (when the washing has finished and the brush hasn't been pulled out yet). Since there're several light sources installed in our device, we make a special function to control the state of each light, to wit, whether to flash, to shine or to turn off. To save energy, we only turn on the laser light source of the photoelectric when the brush is under washing and the led light source for the sensor when the washing is finished.

For more details, please refer to the code listed in appendix section C on page 25.

Task 5: Waterproof treatment

As is shown in fig. 7 on the next page, the contact surfaces are marked in blue. Instead of simply joining two tubes together, a small tube is inserted tightly into a larger tube, so that the contact surface becomes a cylinder instead of a loop. The large contact area blocks water from traveling through the seam and climb up the cylinder.

At the same time, we keep the water level in the sink in a safe range. Since it is difficult to estimate how large the outlet should be to drain the water at a certain speed, so that the water level of the vortex can be controlled at an expected height, we decided to make a ring baffle. The baffle

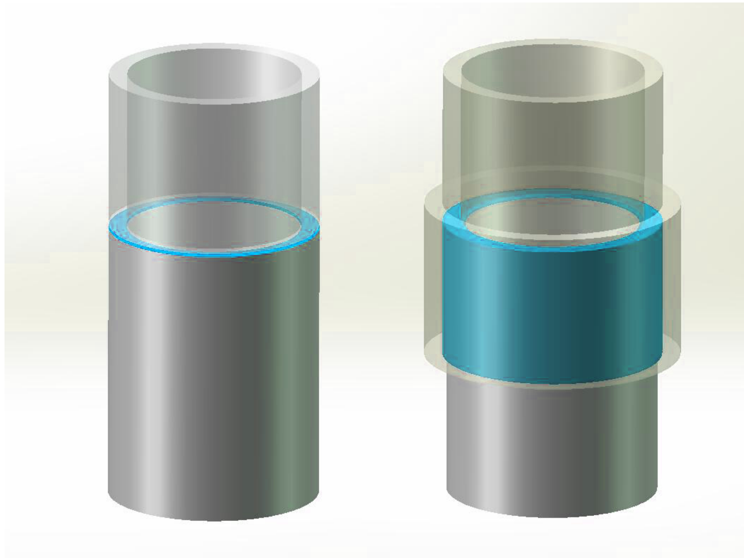


Figure 7: Photo of the washing experiment

can be adjusted to dynamically adjust the amount of the water kept in the sink.

Task 6: Testing for feedback

After finishing the prototype of our device, we need to test whether it can exactly meet the identified need. We invited several familiar art students to use it and give some feedback. After using this device during a complete painting, they found that water was too dirty when the LED light reminded them to change water. They also gave some other advices such as the watering process should be more faster.

Next, we made some changes to the device. For example, after more testing, a colored brush can be washed within 20 seconds. We revised the Arduino code to shorten the washing process to meet the need of users. We also revised the Arduino code to remind the user to change water earlier than the original one. After testing for feedback, we actually satisfy the users need.

Task 7: Optimization

We totally made three versions of our device, their conceptual figure are compared in fig. 8 on the following page. The first prototype just looks like the skeleton of our final device, with most of the core components designed, such as the pump holder and the sink containing the vortex. However, we underestimated the space that the electronic components may take, so the container is too small to contain all of them. The sink is also too small, resulting in severe splashing. So we made a second version with a large electronics container, which is a platform to be put on the bucket. A transparent cylinder is inserted in the center of the container, both to contain the vortex and to separate all the electronic components from water.

But there are two holes drilled at the bottom of the container, which is made to connect the wires of the pumps to the motor driver, which cause waterproof problem when we were doing experiment with the acrylic pigment. We found that during the process of washing, lots of bubbles

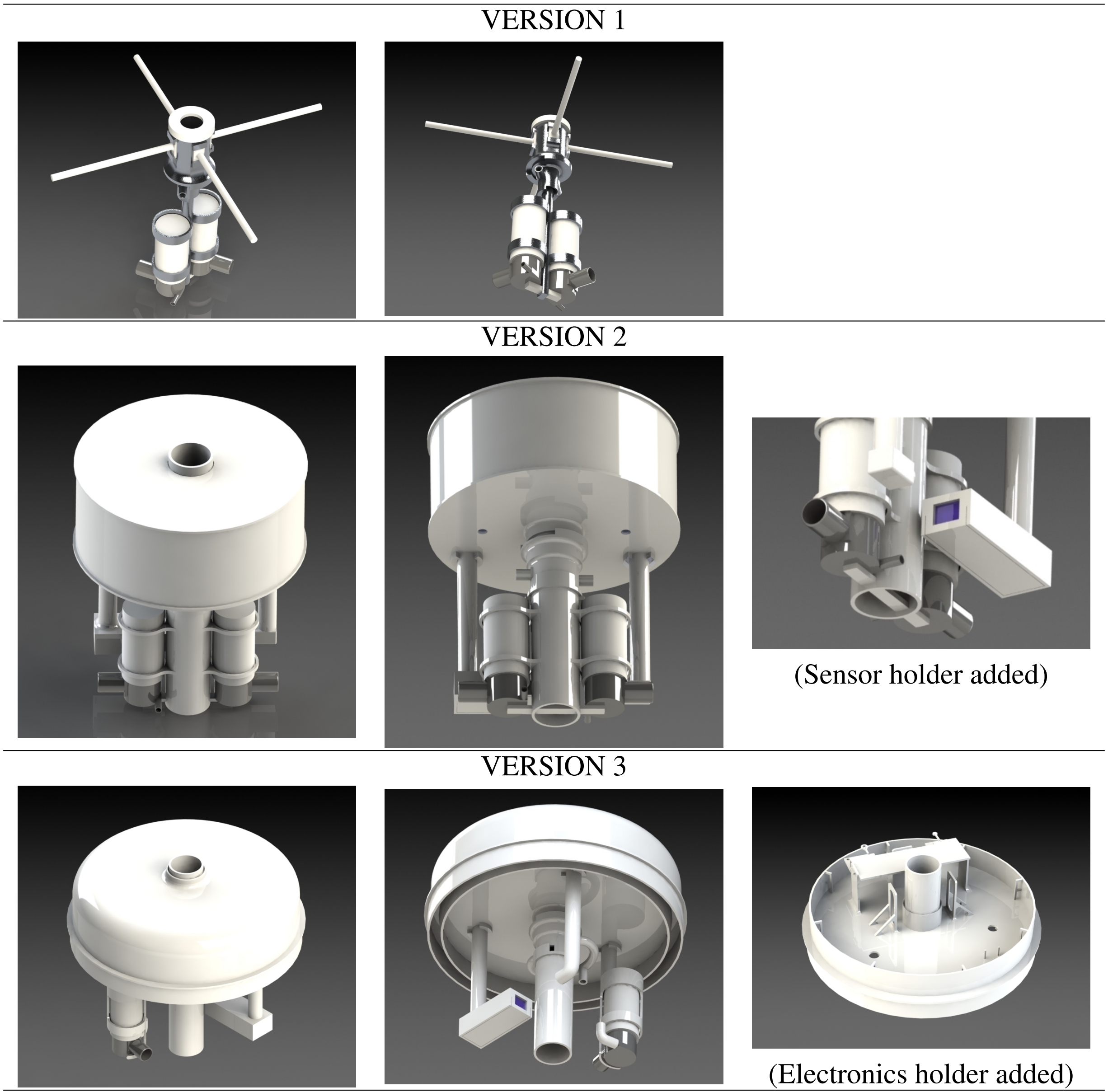


Figure 8: Comparison between different versions

appeared due to the strong water current. The amount of bubbles increased so rapidly that they may get into the container through the holes we made for the wires, and they may even get out the bucket since the device is simply put on the bucket. Other problem include the container's incompatible size with the photoelectric gate, and the handle of the bucket. These problems are done by redesigning the container. We can see that the led light source, the photoelectric gate and the battery are all carefully fixed into holders, and the transparent cylinder is additionally protected by a larger cylinder to prevent the water from leaking out. Moreover, we can see that there are 8 small cells around the platform. They are set to arrange the wires uniformly. From the bottom view we can see that the sensor and the light source resemble the previous version, and since we find that one pump is enough to create a strong vortex, we use a structure similar to the container of the sensor to fix it. The whole structure is also fixed to the bucket below, so bubbles mentioned above will not escape.

8 Budget

The overall budget use is shown here in table 1. We purchased or ordered all our parts online. Their part number and manufacturer information can be found in e-shops listed in section D on page 27 as an appendix.

Items	Number	Cost [RMB]
24V battery	2	175
3D printing part	2	832
Acrylic board	2	15
Dupont line	100	7.7
Photoelectrical switch	1	48
Greyscale sensor	2	5.5
Arduino nano board	1	39
LED indicator	3	36
XY-160D Dual DC motor driver	1	58.8
Pump	2	80.6
Total	–	1297.6

Table 1: Budget of the project

Then we assembled the device by ourself. Due to the mountable design, our device will also be easy for anyone to assemble or disassemble in 10 minutes, without any extra cost.

9 Key Personnel

FAN ZEKAI is mainly responsible for testing and revising designs, managing the 3D printing process, Arduino programing, and demonstration video editing. In this report he contributed the solution section.

HUANG PENGYUAN is mainly responsible for 3D modeling and their revising, especially about waterproof design, and realizing extra functions provided by the sensors. In this report he rendered all the conceptual figures.

LIANG XINYI is mainly responsible for technical communication with instructors, conducting survey, coordinating jobs inside the team, writing drafts and organizing practice for presentations. In this report she wrote from the introduction section to the needs section.

ZHAO SHAOCHONG is mainly responsible for purchasing of testing of materials, waterproof processing, making 3D demonstration animation, and purchasing other electrical parts. In this report he contributed the tasks section.

ZHU WENXUAN is mainly responsible for designing the appearance of our product, investigating users' feedback, and designing and formatting in communication tasks, including slides design and report composing. In this report he wrote sections from schedule to the end, and composed the LaTeXcode.

10 Conclusion

When we found that some of the painters spend much time washing their brushes, we thought it will be a good idea if we could design a machine which can automatically finish this disturbing process. After conducting a thorough survey among the art students, we knew the specific demands of our target population, such as the expected price and the time it takes to make a brush clean.

Moreover, according to our initial expectation, our machine should be composed of a flow system and an electronic system. Water should go through the entire flow system without intervening the electronic system, so these two system should be carefully separated, which requires a comprehensive water repellency. The process of washing should be finished within a fairly short time. When washing the brush, there shouldn't be any splashing water. Our device should be able to remind the user to take the clean brush away and change water when necessary.

With all these requirements born in mind, we make the following design. All the electronic components are contained in a platform standing on the bucket; the pump and the sensor detecting the turbidity is submerged in the water. The pump will create two strong water flows in the chamber where the brush is inserted, and the flows will merge with each other to form a vortex, which can thoroughly clean the brush.

During the process of making our device, we modified our design; some of our initial objectives are realized, while others are not.

10.1 Realized Objectives

1. Wash the brushes thoroughly
   After testing different methods to wash a brush, we find out that creating a vortex with strong water current is the most effective and efficient way. We bought various pumps and found out that pumps with rated voltage 24V and rated power 75W are very suitable for our goal.

2. Wash the brushes within a short time period
   We expect that our machine can finish the washing process within 20 seconds. It means that our vortex and current need to be very strong. After we did the experiment, the result shows that pumps with rated voltage 24V and rated power 75W can meet our needs.

3. Automatic electronic controlling system
   In our definition, "automatic" means users just need to insert a dirty brush into the machine and the machine will detect the brush, wash it and stop automatically. We use a photogate to detect whether or not the brush is inserted. And we decided to build an electronic system based on arduino board.

4. Waterproof
   Waterproof is the most important part but very difficult. At first, we decided to use the screw thread to connect each components. However, it's very imprecise in 3D printing. And other processing technologies, like CNC, cost very much. We can't afford it. So, we decided to created some special designs to prevent water from splashing.

5. Be portable
   To achieve this goal, we remove all the unnecessary parts and design it to be demountable,

so that after disassembling our device, it can be contained in a relatively small space.

6. Reminding users of changing water
   To achieve this, we put a light source and a greyscale sensor at the bottom of our device. After the washing process is over, the light source emits a light signal through the dirty water. If water is too dirty, the greyscale receives low intensity of light. If the intensity is less than a certain number, the LED indicator will be lightened and remind the user of changing water.

10.2 Abandoned Objectives

1. A catcher to hold the brush
   During our first discussion, we agreed that we needed a catcher to hold the brush and realized that it was easier said than done. When we got the first version of our device, we found out that if the brush could be inserted deeply, we didn't need a catcher. So in our further design, we decided to make the brushed inserted more deeply rather than use a catcher to hold it.

2. Make the clean brush drier
   During our first discussion, we agreed that our machine should do more than just washing. It was also able to dry the brush. But after we conducted our survey and talked with some painters, we realized that different painter prefer the brushes to be different levels of wet. It means it's useless to dry the brush.

10.3 Future development

If our product is put into mass production, the price can be reduced to around 300 yuan so that almost any painter can afford this machine.

Moreover, we find that some pigment will attach to our device after washing, and it is not easy to clean it up (though the efficiency will not be affected at all). We may use a special coating to prevent this from happening.

Additionally, by now our device is simply put on the bucket with a groove. That's to say, our device cannot be apply to a bucket with different size. In the future, we may design a spring structure so that the device can fit tightly into any bucket easily.

References

[1] Bowden, T., "Vg100 Final Report Template", from `https://www.umjicanvas.com/files/88452/download?download_frd=1`

[2] Carter, A., "Arduino_Nano Board — 3D Model Library — GrabCAD", from `https://grabcad.com/library/arduino_nano-board-1`

[3] photogate?

Appendices

A Part of the survey result

Answer for the question, “What is your level of painting?”

Choice	Number of people	Percentage
Beginner	20	19.05%
Amateur	18	17.14%
Semi-profession	22	26.67%
Professional	39	37.14%
Total	105	100%

Table 2: Survey result 1

Answer for question,“ What is the main reason that you don’t like washing brushes by hands?”

Choice	Number of people	Percentage
Make surrounding dirty	40	38.10%
Be tiring	35	33.33%
Distract from painting	29	27.62%
Other problems	1	0.95%
Total	105	100%

Table 3: Survey result 2

Answer for the question, “How long do you change the water in the bucket”

Choice	Number of people	Percentage
Less than 30 minutes	10	9.52%
31 to 60 minutes	32	30.48%
61 to 90 minutes	22	20.95%
More than 90 minutes	41	39.05%
Total	105	100%

Table 4: Survey result 3

Answer for the question, “After washing how many brushes, you will change the water in the bucket?”

Choice	Number of people	Percentage
1 to 3	23	21.90%
4 to 6	39	37.14%
7 to 9	14	13.33%
More than 10	29	27.62%
Total	105	100%

Table 5: Survey result 4

B Engineering draftings

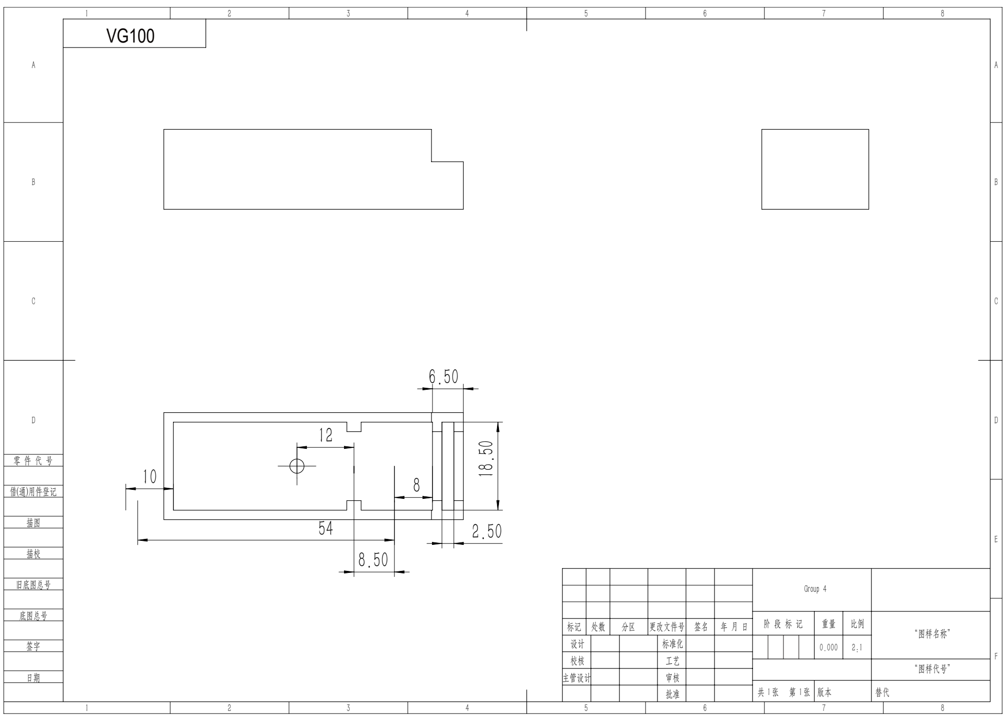


Figure 9: Engineering drafting of the bottom of the sensor holder

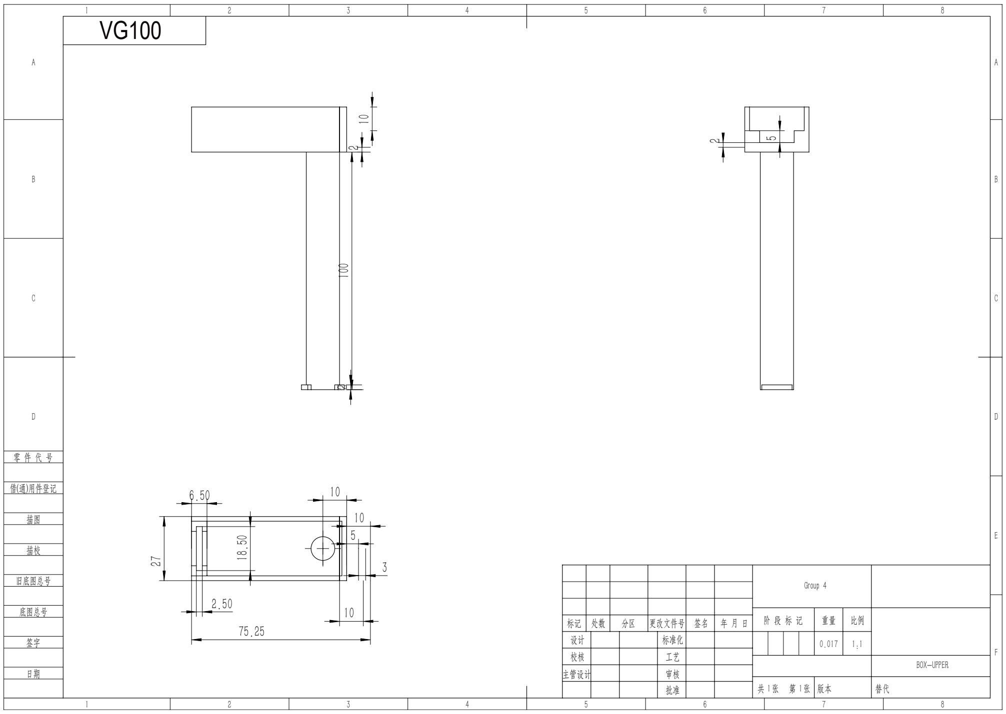


Figure 10: Engineering drafting of upper part of the sensor holder

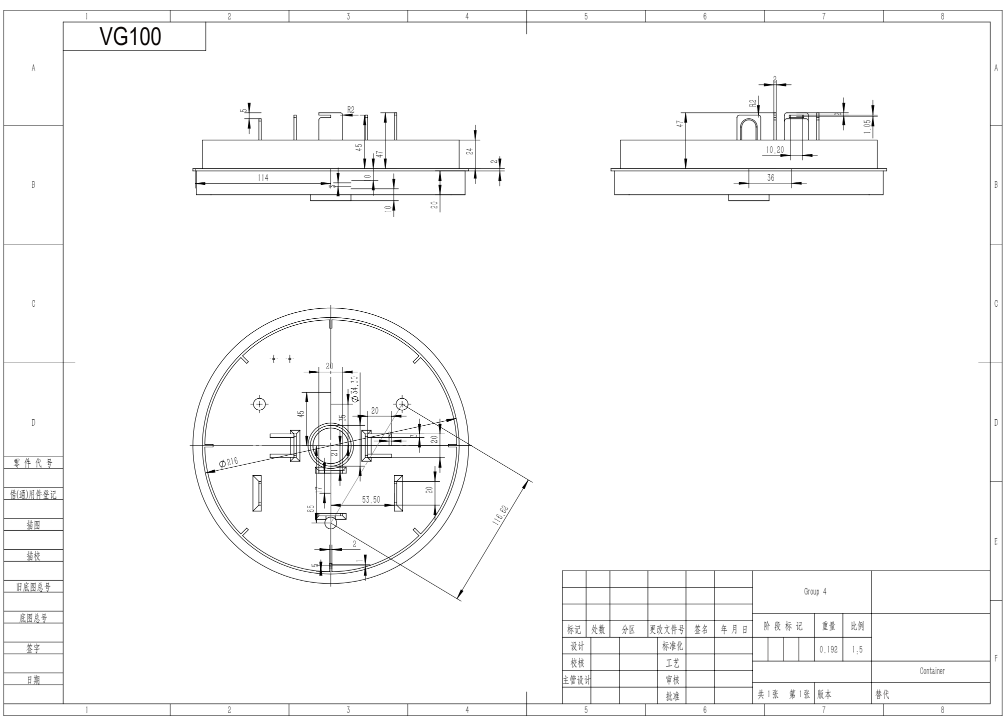


Figure 11: Engineering drafting of the electronics container

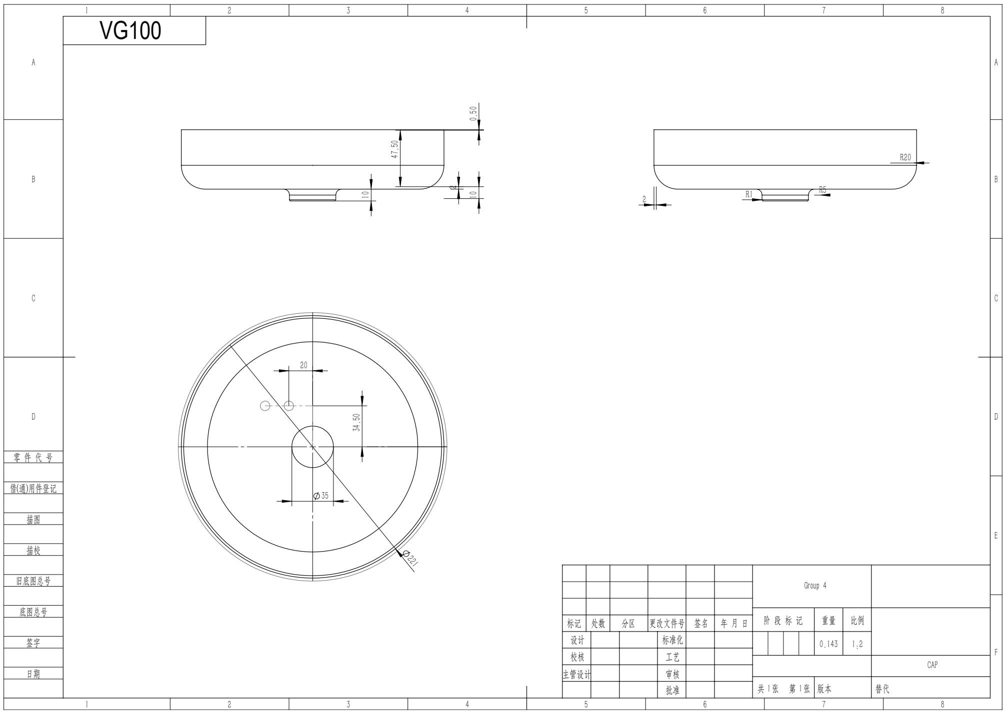


Figure 12: Engineering drafting of the cap of the container

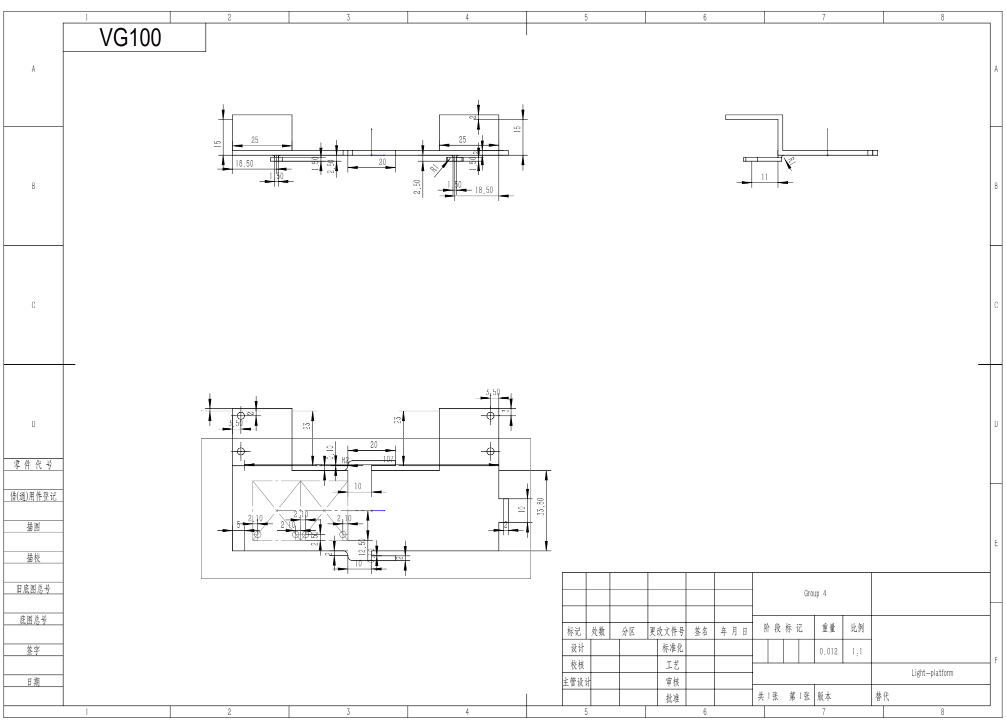


Figure 13: Engineering drafting of the light source holder

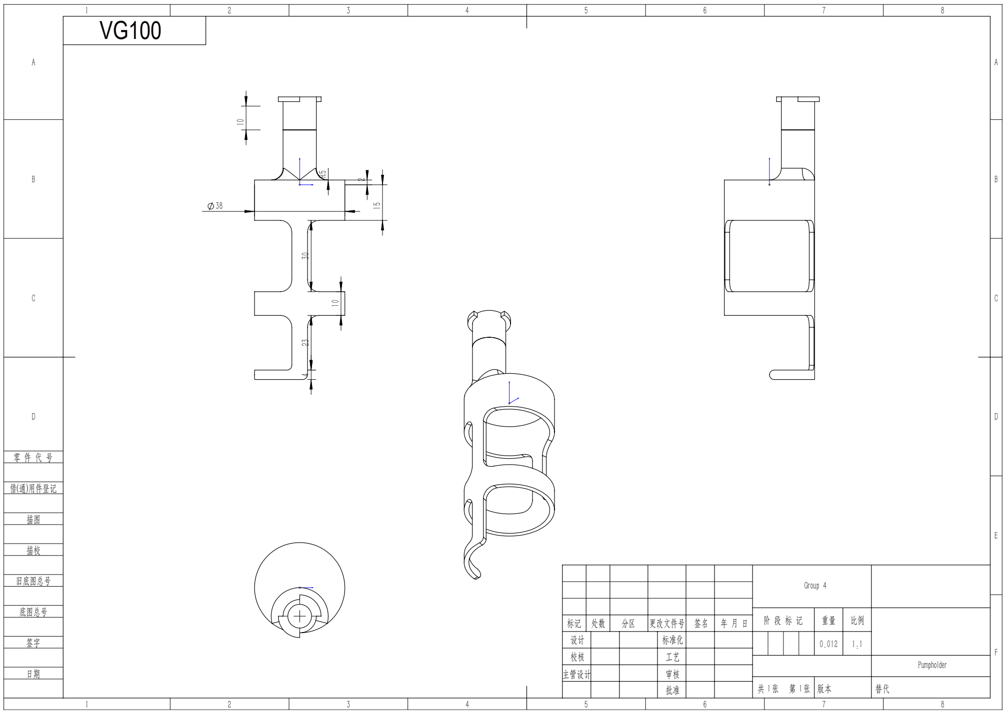


Figure 14: Engineering drafting of the pump holder

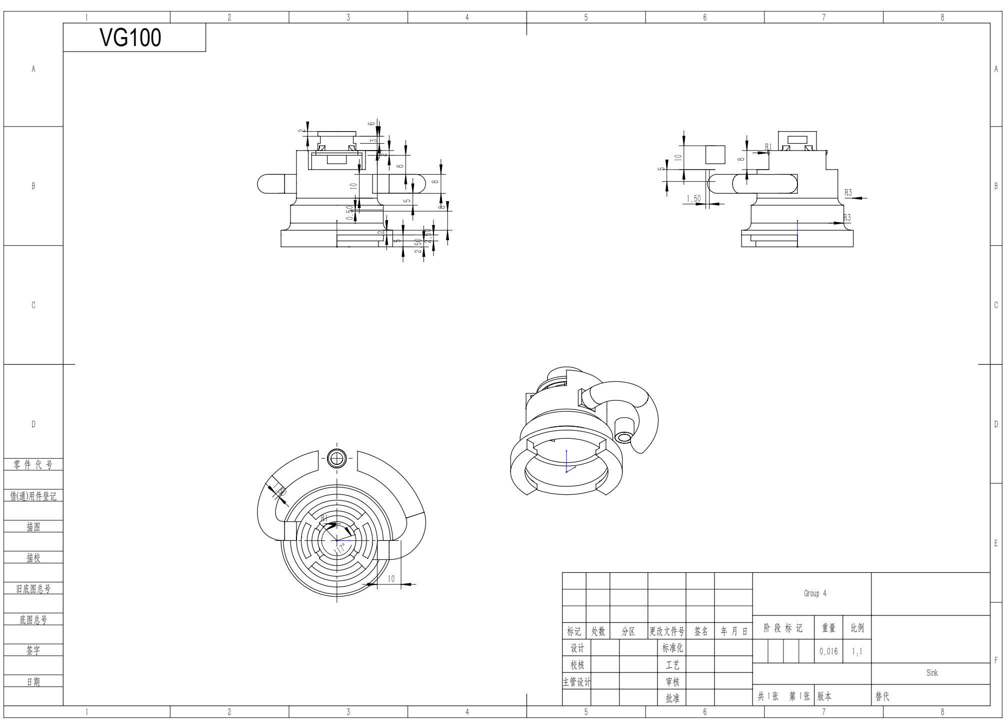


Figure 15: Engineering drafting of the sink

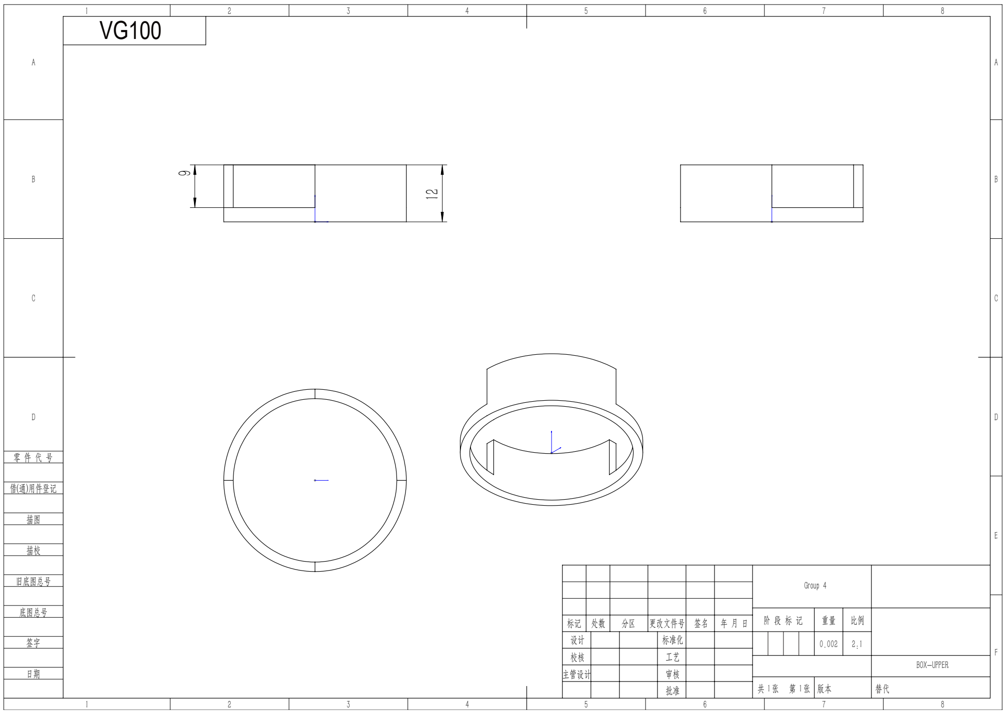


Figure 16: Engineering drafting of the ring baffle on the sink

C Arduino Code

```
#define pumpPinL 9
#define pumpPinR 10
#define redLED 5
#define blueLED 6
#define sensorLED 7
#define greyscale A0
#define pegsensor 11
#define T 100
#define THRESHOLDL 100
#define THRESHOLDR 200
#define WPERIOD 100
#define maxN 5
int t = 0;
bool redflash = false;
bool redshine = false;
bool sshine = false;
int state = 0;
//0 indicating before washing
//1 indicating under washing
//2 indicating after washing with brush still inserted
//when brush is removed, state 2->0
bool blueshine = false;
```

```
int pro = 0;
int washingnum = 0;
//the time of washing

void setup() {
// put your setup code here, to run once:
pinMode(pumpPinL, OUTPUT);
pinMode(pumpPinR, OUTPUT);
pinMode(redLED, OUTPUT);
pinMode(blueLED, OUTPUT);
pinMode(sensorLED, OUTPUT);
pinMode(greyscale, INPUT);
pinMode(pegsensor, INPUT);
t = 0;
redflash = false;
blueshine = false;
redshine = false;
state = 0;
Serial.begin(9600);
}

void Lightstate(int state, int t){
if (sshine)
   digitalWrite(sensorLED, HIGH);
else
   digitalWrite(sensorLED, LOW);
if (blueshine)
   digitalWrite(blueLED, HIGH);
else
   digitalWrite(blueLED, LOW);
if (redflash)
   if (t < T/2)
   digitalWrite(redLED, HIGH);
   else
   digitalWrite(redLED, LOW);
else
if (redshine)
   digitalWrite(redLED, HIGH);
else
   digitalWrite(redLED, LOW);
}

void loop() {
// put your main code here, to run repeatedly:
Serial.print("State = ");
Serial.print(state);
Serial.print(" greyscale = ");
```

```
Serial.println(analogRead(greyscale));
if (analogRead(greyscale) < THRESHOLDL) {blueshine =
   false;sshine = false;}
if (++t > T) t = 0;
Lightstate(state, t);
if (state == 0) {
   if (digitalRead(pegsensor) == LOW && pro == 0) {
   delay(1000);
   if (digitalRead(pegsensor) == LOW && pro == 0) {
      state = 1;
      pro = 0;
      redflash = true;
      blueshine = false;
   }
   }
} else
if (state == 1) {
   analogWrite(pumpPinL, 0);
   if (pro < 255) analogWrite(pumpPinR, pro);
   else analogWrite(pumpPinR, 255);
   if (++pro > WPERIOD) {
   state = 2;
   pro = 0;
   blueshine = false;
   sshine = true;
   }
} else
if (state == 2) {
   redflash = false;
   redshine = true;
   digitalWrite(pumpPinL, LOW);
   digitalWrite(pumpPinR, LOW);
   if (analogRead(greyscale) > THRESHOLDR) blueshine = true;
   if (digitalRead(pegsensor) == HIGH) {
   delay(1000);
   if (digitalRead(pegsensor) == HIGH) {
      state = 0;
      redshine = false;
   }
   }
}
}
```

D Hyperlink of materials

1. Arduino board: Nano

"https:&&detail.tmall.com&item.htm?id=38816262040&spm=a1z09.2.0.0.501c2e8dW15yf2&_u=i2tn01g3d3e4"

2. Dupont line
"https://detail.tmall.com/item.htm?spm=a230r.1.14.27.52956a522Yacdu&id=41254478179&ns=1&abbucket=12&sku_properties=122216547:20213"

3. LED indicator
"https://item.taobao.com/item.htm?spm=a230r.1.14.1.432865cfrAq5Kf&id=556973438835&ns=1&abbucket=15#detail"

4. Greyscale sensor
"https://detail.tmall.com/item.htm?spm=a230r.1.14.16.649a6434mXrl2O&id=41236263649&ns=1&abbucket=12"

5. 24V battery
"https://item.taobao.com/item.htm?spm=a230r.1.14.16.62603cb426SsW5&id=42164560730&ns=1&abbucket=12#detail"

6. Pump
"https://item.taobao.com/item.htm?ut_sk=1.WppqZOtnu9YDAMKg4NtgVB1e_21380790_1530541682641.PanelQRCode.1&id=567907823496&sourceType=item&price=7-92&origin_price=10-95&suid=C5683A4C-77F1-4FB7-B287-D3B27E6
un=c44d4519298b552d88bd3787856a60a9&share_crt_v=1&sp_tk=4oKsRkoxYjB6b2R
&cpp=1&shareurl=true&spm=a313p.22.19r.956133252750&short_name=h.31UmPF3&app=chrome"

7. Motor driver
"https://detail.tmall.com/item.htm?id=544493551668&spm=a1z09.2.0.0.37952e8dibdFz3&_u=j35slmu26c23"

8. 3D printing service
"https://detail.tmall.com/item.htm?spm=a230r.1.14.6.3bb0714bIrP6D6&id=43901666034&cm_id=140105335569ed55e27b&abbucket=12"

9. Acrylic board
"https://item.taobao.com/item.htm?spm=a230r.1.14.20.4b472af80rYdXC&id=40672059104&ns=1&abbucket=12#detail"