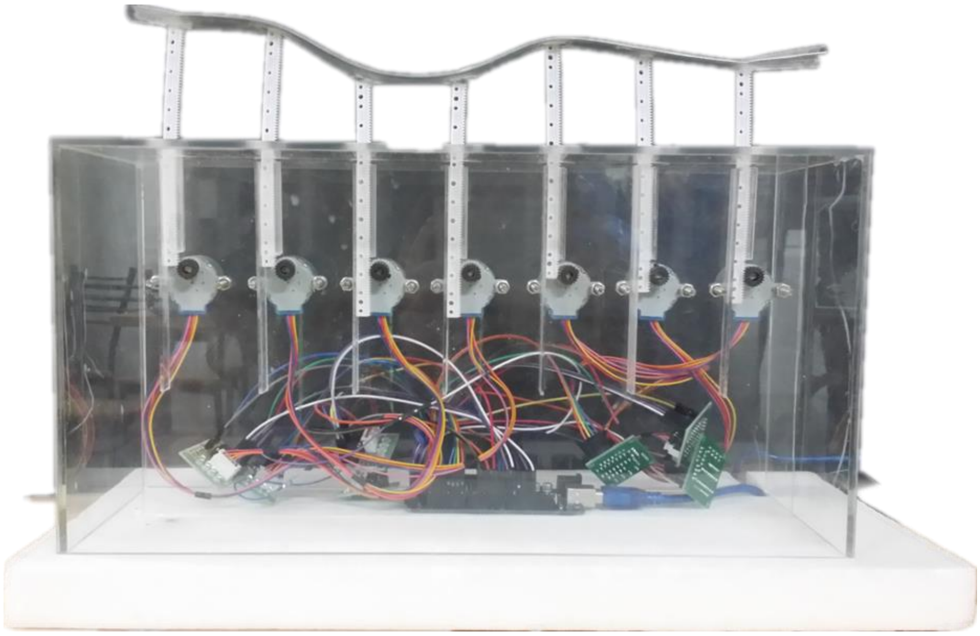
December 16, 2014

Polynomial Actualization



The Fantastic

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I. Executive Summary

As modern industry develops rapidly, companies are paying more attention to the capability of the mold to raise the production efficiency. Although there are many solutions to raise the capability such as RP&M (Rapid Prototyping and Manufacturing) technology, fast-molding soft mold and 3D printing technology, there still exists many problems such as extremely high prices and low portability. To solve these problems, our group, the Fantastic, designed a device, polynomial actualization, which has shorter production period and low cost. It can also change its inner structure freely, and it has high portability. In order to make the device function as designed, we divided our tasks into 7 parts. Two major tasks are designing the structure of the device and testing both the stepper motor and the operation of the rack when it goes up and down. In all the steps, assembling step is a very important step to ensure the working of our project. Since 90 percent of our project is connection, every step during assembling should be careful and precise. Therefore, we tested the working of each rack after we inserted it into the track on the device. The result went well when we input a function to form a corresponding curve. However, we need more time to improve the performance of the stepper motor and the rack. In conclusion, our project, can realize the designed functions and work smoothly. With sufficient investment, the device can be extended from 2D to 3D by using the same method. In a long term, if the polynomial actualization can be put into production and used by companies, the cost for manufacturing molds can be lowered, and the production period will also be shortened.

II. Acknowledgements

Thank Dr. Shane Johnson, the instructor of Vg100, for his interesting lectures and help on technical instructions.

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Thank Steven Song, Yao Yichao, and Pan Yijun, TAs of Vg100, for their help and instructions during the whole process of our project.

Thank all the teammates, every single person in Group 4, The Fantastic, for their effort and dedication on project.

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III. Problem

In the modern industrial manufacturing, there are several problems with the current molds which play an important role. The first problem is that the period of manufacturing enough molds is always “several months” [1] and it always costs manufacturers “more than ten thousand” [2], especially those with complex structures. Second is that the process of injecting raw materials into the mold sometimes “fail to achieve perfection” [2], which will lead to flaws on the product and it will consequently reduce the quality of the product. Third is that there is “no flexibility” on traditional molds [1] [2], which means that one must recreate new molds when producing different products. Forth is that it is impossible for people to move a mold with a huge volume from one place to another place due to the low probability.

Figure 1: The current chair mold with unchangeable inner structure and low probability

Industrial manufacturers are the direct victims of this problem because the problem slows down their production speed and reduces their efficiency, which results in higher prices and lower product quality. The higher the price of their products is, the less customers buying the products will be, which finally leads to the fact that the manufacturers will benefit less.

Nowadays, there are three methods attempting to solve the problem. The first method is to improve the current "RP&M (Rapid Prototyping and Manufacturing) technology" based on the traditional molds [3]. But the disadvantage of this method is that although RP&M technology is greatly improved, it is still far from perfection. To be specific, the accuracy of the RP&M technology is about "several centimeters" [3], which is far from the industrial standard. The second method is the use of fast-molding soft mold. This method is based on "the use of agar" and it can be used to produce products "with complex structures" because of the flexibility [4]. However, because the normal boiling point of agar is "95 degree centigrade" [4], it is "not resistant to extreme heat" [4], which will limit its range of application. The third method is producing without any mold, in other words, 3D printing technology. This method uses computer applications to design products and produces products based on one kind of equipment. Although 3D printing technology is advanced, it still has several shortcomings, such as extremely high prices and pretty low portability. The prize of the most fundamental 3D printer is about "50,000 to 60,000 RMB" [5], which are not acceptable for many people. Besides, the volume of the current smallest 3D printer is "470*250*430 mm" [5], which are impossible for people to carry.

In summary, molds are basic and key to industrial manufacturing, but there are:

- **Long production periods and high costs to manufacture**
- **Almost no perfection when injecting raw materials**
- **No flexibility to change the structure of the mold**
- **Lack of materials resistant to extreme heat and pressure**
- **No portability in all current methods.**

IV. Needs

To solve this problem in mold manufacturing, such things are required:

- **A device giving manufacturers an alternative way to produce products**
- **Shorter production periods and lower costs to manufacture**
- **Injecting raw materials completely accurately**
- **Changing the inner structure to create different shapes freely**
- **Qualified surface materials resistant to extreme heat and pressure**
- **Small volume to carry conveniently**

V. Solution

A new kind of device which can achieve the purpose of polynomial actualization can:

1. **Give manufacturers an alternative way to produce products**
2. **Shorten production periods and lower costs to manufacture**
3. **Make the process of injecting raw materials completely accurately**
4. **Change the inner structure according to the specific polynomial**
5. **Be equipped with flexible and strong surface materials**
6. **Be small enough to move from one place to another place**

The proposed device which can achieve the purpose of polynomial actualization is shown schematically in Figure 2. The new device is totally different from the traditional mold. The new device is composed of seven stepper motors. If the Arduino board gives a specific signal, the signal will be first sent to the stepper motor controller and an electrical pulse signal will be sent to the stepper motor actuator. Then the stepper motor actuator will convert the electrical pulse signal into current signal. And the stepper motor will form a certain angle according to the electrical pulse signal it receives. Then the stepper motor will put the gear attached into motion and makes it rotate to a certain angle. Consequently, the rotated gear will drive the rack to go up and down into a certain height, with the height easy to control by computer applications. After that, the raised or concave rack will put the flexible surface up and down to form various shapes in one dimension. Finally the various shapes made by the flexible surface will be fixed to make the injecting raw materials form a certain shape until it cools down.

For example, if a manufacturer plans to make a toy rubber duck, what they need to do is to input the polynomial function of the outline of the rubber duck. Then each rack will rise to a certain height according to the polynomial function, and the several racks will form a curve together, which leads to the surface on top of the racks form a certain shape as well.

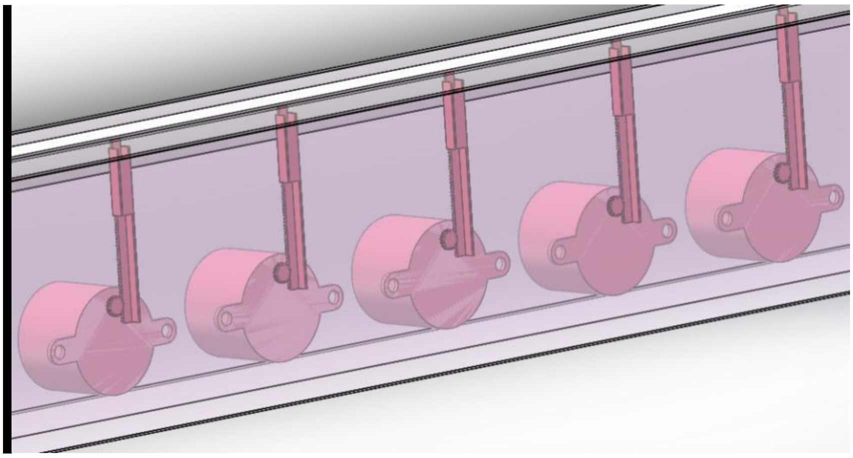

Figure 2: Polynomial actualization's device that can actualize polynomial

If the Arduino board gives a specific signal, the signal will be first sent to the stepper motor controller and an electrical pulse signal will be sent to the stepper motor actuator. Then the stepper motor actuator will convert the electrical pulse signal into current signal.

In terms of the stepper motors, they are powered differently as they are driven with pulses instead of an AC or a DC voltage. And each pulse is translated into a degree of rotation. When the stepper motor receives an electrical pulse signal, the top electromagnet on the motor will be turned on, attracting the nearest teeth of the gear-shaped iron motor. With the teeth aligned the top electromagnet, they will be slightly offset from right electromagnet. Then the top electromagnet is turned off, and the right electromagnet is energized, pulling the teeth into alignment with it and a rotation occurs. After that, the bottom electromagnet is energized and another rotation occurs. Finally, the left electromagnet is energized forming a rotation again. When the top electromagnet is again enabled, the rotor will have rotated by one tooth position. And with this process repeating again and again, a large angle will be formed by many slight angles.

With the stepper motor rotating a certain angle, the stepper motor will put the gear attached into motion and the gear will rotate a certain angle as well. Then the gear will drive the rack which is perfectly linked with the gear to go up and down. And the height can be easily changed by changing the angle the gear rotates. Then the raised and concave rack will put the surface up and down to form a certain type of shape and then the stepper motor will stop rotating and the rack and the surface will be fixed. After that, the raw materials, such as melting plastic or metal will be poured into the fixed shape and a product will be made when the heated materials cool down.

The use of stepper motors assisted by gears and racks makes it possible to form the shape whatever people want so that it can replace molds to produce industrial accessories. Besides, when people need to manufacture a new product, what they only need to do is to change the parameters which define the rotation of stepper motors and the shape formed by the surface will be changed instead of producing new molds, which can greatly shorten the period of production and lower the costs. In addition, when stepper motors stop rotating, gears and racks will be fixed and the surface will remain its shape, which makes the raw materials fit in the surface perfectly. What's more, the operation of stepper motors with gears and racks makes it possible to control the concavity of the surface by changing the angle freely. And this advantage realizes the need of a changing the inner structure of mold without making a new one. Plus, the selected surface is strong enough to resist extreme heat and pressure, which will realize the need of maintaining fixed shapes of surface when injecting. Finally the length of one side of stepper motor is about 5 centimeters and there are about ten stepper motors in the device, so the volume will be acceptable to carry conveniently.

To prevent the rack from rotating vertically, a track made by acrylic board is fixed on the middle board. With the help of the track, the rack will not rotate when it goes up and down. To make a surface that is both flexible and strong, a unique structure is created. The special structure is made up of two parts: a soft steel ruler and a piece of soft PE board. The steel ruler is wrapped in the soft PE board. The structure is like the composition of human fingers—the steel ruler is the bone and the PE board is the skin. With the help of the bone and the skin, human finger can move freely. Similarly, the surface will not blend between two adjacent points. With the surface, the device can actualize the polynomial perfectly.

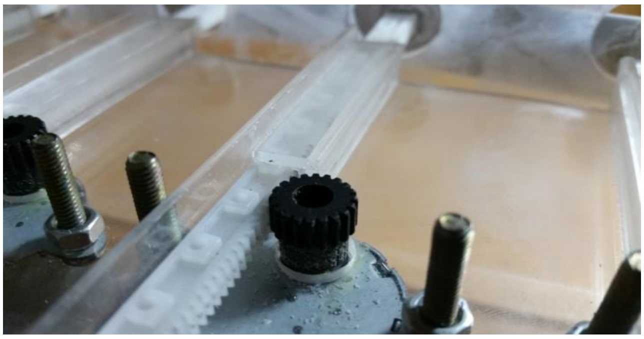

Figure 3: The track which fixes the rack

Figure 4: The surface with steel ruler and PE board

VI. Objectives

- Objective 1: design our device

  All parts is considered and designed carefully to make the design usable and portable.

- Objective 2: get the materials and tools

  Find the proper and cheap materials. The cost of the device is lower than 3D printing, which costs more than a thousand RMB.

- Objective 3: be familiar with the parts of our device

  The parts we bought can be used in a proper way.

- Objective 4: Satisfy the function by programming

  Make sure that the device can show the shape of the inputted polynomial.

- Objective 5: build the structure

  Make the flexible changing mold with smooth surface.

- Objective 6: improve our device

  Make sure the device can produce various shapes. Make the device work stably.

- Objective 7: report and demonstrate our device

  Write the final report. Get ready for the symposium and expo. Show our project to other professional or nonprofessional people for advices or sponsorship.

VII. Tasks

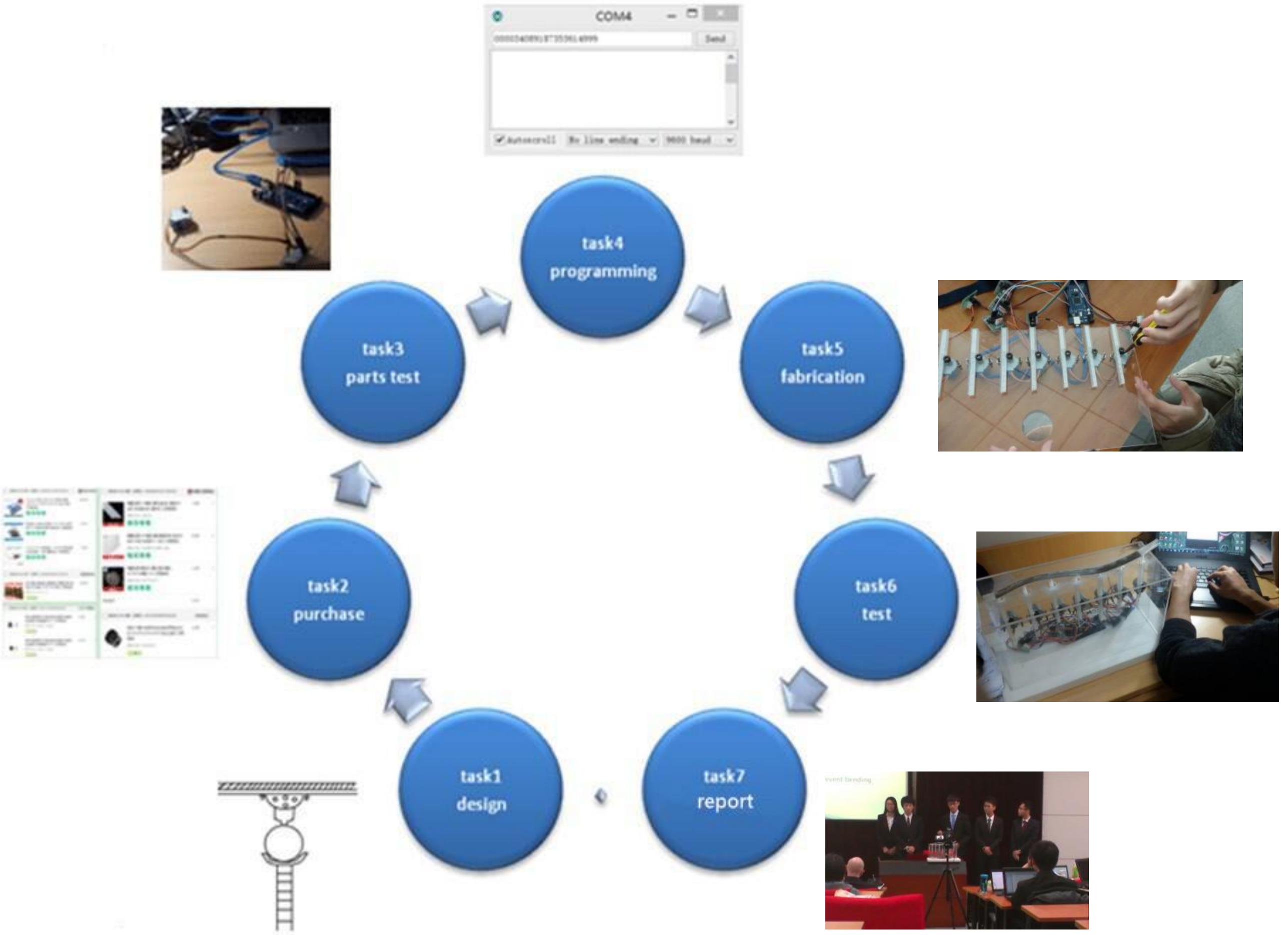

Figure 5: The task flow diagram

• Task 1: Design the structure of our project

First, we draw the diagram of our rough design, which is just using the stepper motor to change the height of the rack so that the surface can be changed into different shapes.

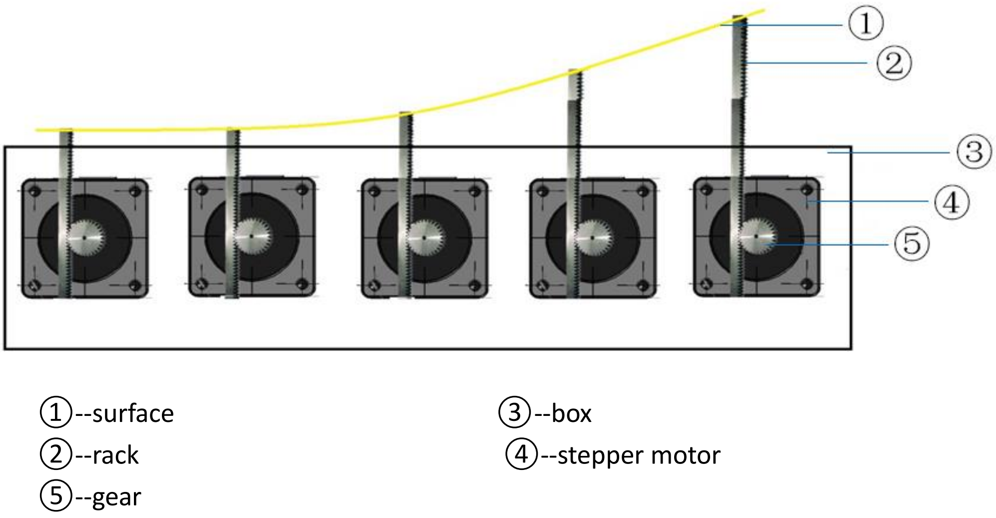

Figure 6: Concept diagram of polynomial actualization

After team members’ discussion with Shane Johnson, we find a problem that the rack will slope when it goes up and down, which will further prevent the rotating of the stepper motors from forming a smooth surface.

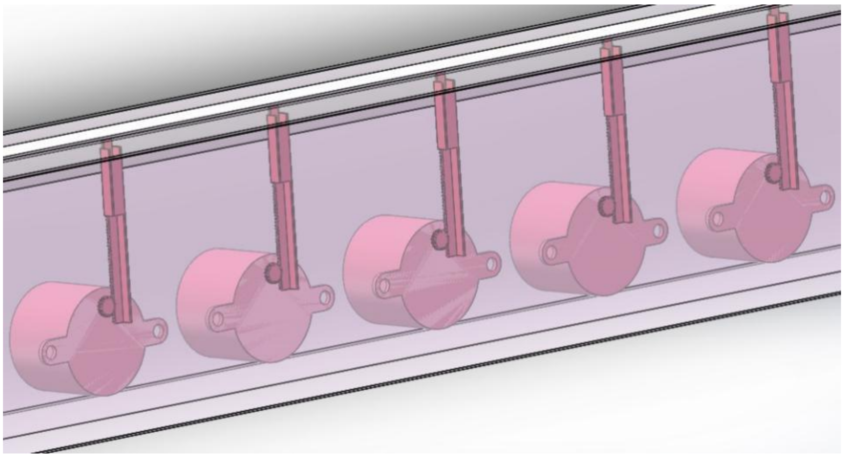

Figure 7: Final concept diagram of polynomial actualization

Therefore, we use the acrylic board to make a track, which is fixed on the middle board in the device, so that the rack can go up and down vertically in the track.

After the completion of Task 1:

• The final diagram was confirmed.

• What we need to make the device was listed.

• Task 2: purchase the materials and tools from Taobao

After designing the structure of our device, we made a list of what parts (including spare parts) the device needs, and what tools we need. They were stepper motors with drivers, Arduino Mega, racks, gears, rubber as surface materials and paperboard. Then, we found the parts we needed on Taobao and compared the parameters (i.e. mass, price, proper size) of the choice to select the best ones, and place the orders (figure 8). We got all the packages we bought from the package collecting centre of SJTU and we unpacked the packages to make sure all the packages we received are correct.

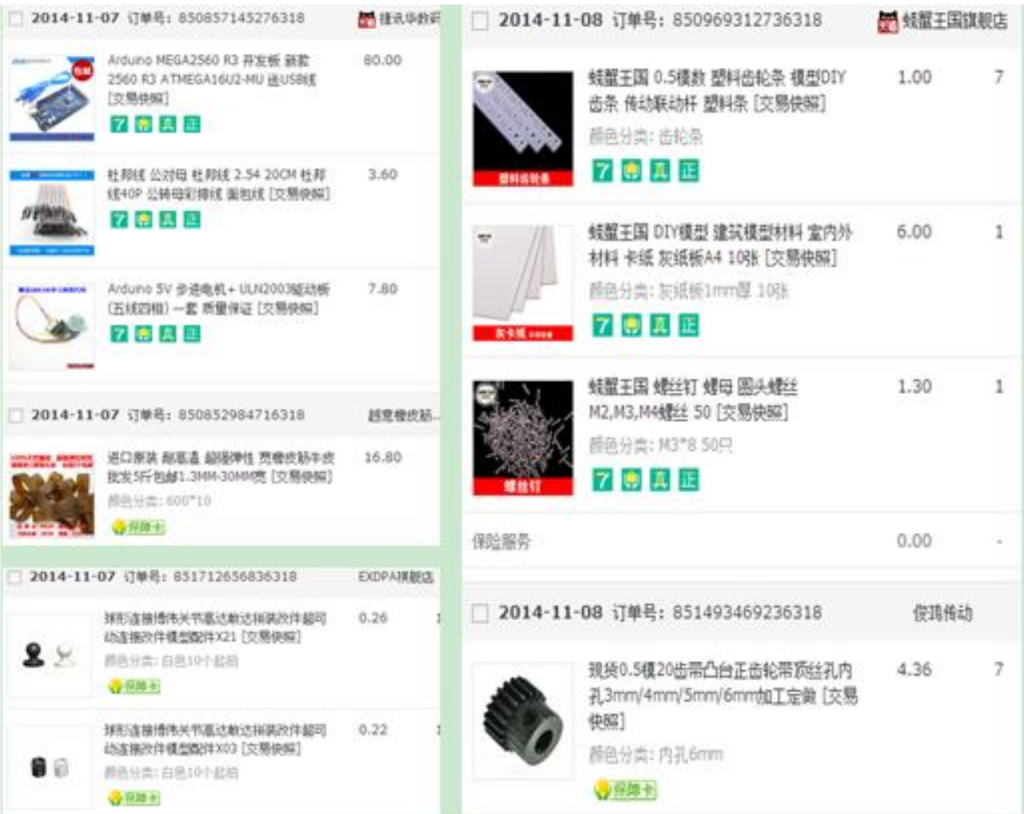

Figure 8: Order 1 for the materials

The surface materials were found improper or could be improved in task3, task4 and task 6, so we asked the customer service of the Taobao Vendors about the properties of the surface materials. The size of the gears also adjusted. We purchased the materials the second time(figure 9).

Figure 9: order 2 for the materials

We wanted the structure of our device to be more stable and well-formed, so we sent the design paper of the Aramaic boards to the Taobao Vendor to cut the Aramaic boards for us. (figure 10)

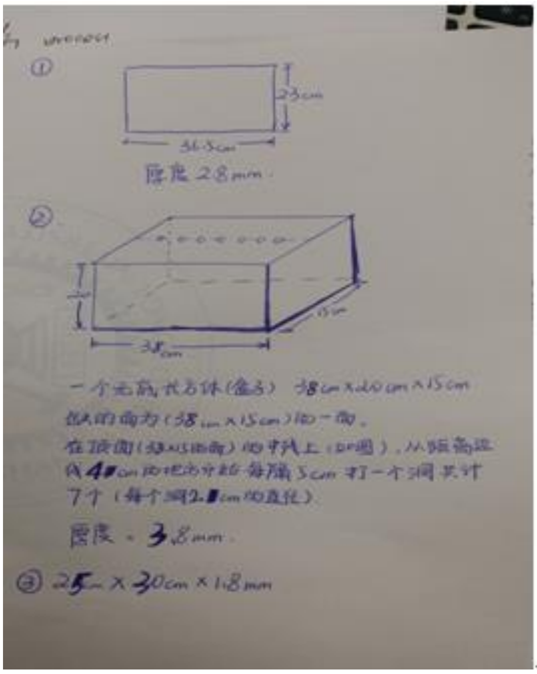

Figure 10: the Aramaic boards special order

After the completion of Task 2

• The proper materials were chosen to satisfy the functions of our device.

• The materials were ready for the fabrication.

• Task 3: Test all the parts in the device

First, we use the rubber as the material of the surface. But when we use two adjacent racks to push the surface, the surface bends to form a gap.

After our discussion with Shane Johnson, we use a special material as the surface, which is made of a steel ruler covered with PE. Similar to the structure of people's fingers, the PE is the skin, and the steel ruler is the bone.

Figure 11: The surface of polynomial actualization

Then we connect the surface with the rack by the glue we have bought before. Twenty minutes later, we try our best to pull the rack. The surface and the track are not separated no matter how large the force we use. Therefore, the connection is good.

After that, we use the program to drive the stepper motor. We find that the rotation of the gear can drive the rack, and then the height of the rack can be adjusted.

After the completion of Task 3:

• The surface could meet our requirements.

• The glue we used to connect the surface and the rack was good.

• The rotation of the gear could drive the rack.

- **Task 4: Write the computer and arduino program.**

The computer program is aimed to change the polynomial into the rotation parameter.

We use Matlab to complete the program. When we input the coefficient of polynomial from the highest to the lowest, it will give out the rotation parameter of every stepper motor. Because the changeable range of rack is limited, the computer program will enlarge or narrow the polynomial to fit the range of the rack. The program is in Appendix A. The following figure 12 is show the user interface.

```
>> polynomial
from high times to low times [ 1 -9 20.25 0]

a =

    1.0000   -9.0000   20.2500         0


ans =

     0   318   324   175    26    32   350
```

Figure 12: the user interface of computer program

The Arduino program is aimed to control the stepper motor. When the rotation parameter is inputted, the stepper motor can rotate according to the rotation parameter. At first, our arduino program make the stepper motor rotate one by one. In other word, the second stepper motor will begin to rotate when the first one complete rotating. However, there comes out a problem. After the first steeper motor, there will be a large altitude difference between the first rack and the second one, which will cause a large force on the rack. Hence we alter our program. The modified program let all seven stepper motor work at the same time. The program is in Appendix B.

After the completion of Task 4

- **Any polynomial can be changed into the rotation parameter we want**
- **The stepper motor can rotate according to the rotation parameter.**

- **Task 5: Assemble the device**

After the programming is finished, it is the time to assemble the device. Perforate on the scheduled position of the acrylic board, and then use screws to fix stepper motor and acrylic together. The following figure 13 shows the position of stepper motors on the acrylic board.

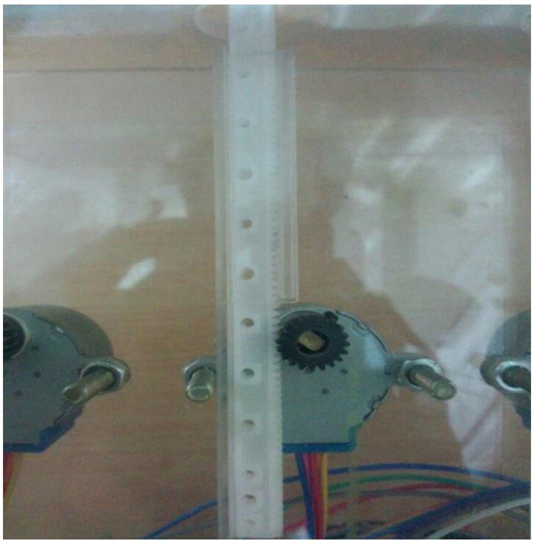

Figure 13: The track and its position

Use laser cutting machine to make some fixed size of acrylic board, and then put them together with glue to make track for rack. Stick tracks to the acrylic board. The following figure 14 shows the structure of the track and their position on the acrylic board.

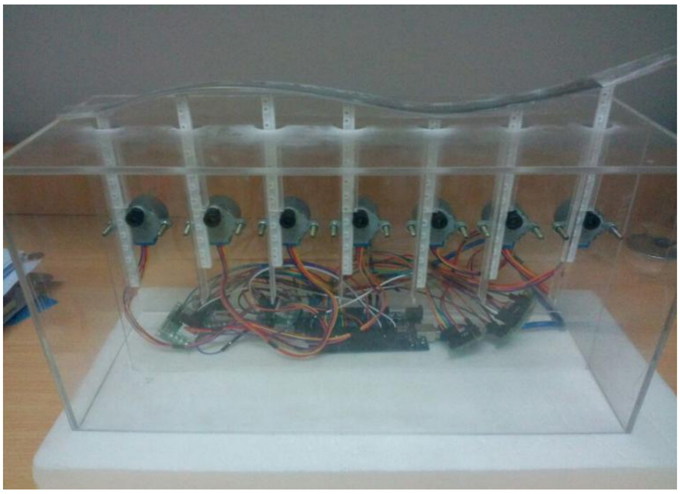

Figure 14: The whole device

Connect stepper motor and control circuit board. Use a piece of foam board as a base, and then plug the acrylic board equipped with stepper motor on it. Make a transparent acrylic plate shell to cover the entire device, and perforate several holes on the top to ensure the rack can get through. Wrap up a piece of tin with PVC sheet to make the surface. At last, stick the surface with the racks. The following picture XX shows the device.

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After the completion of Task 5

- **The whole device has comleted.**
- **The racks can move in certain direction.**
- **The surface can change into the specific shape.**

- **Task 6: Test and improve**

After assembling is completed, we test our device. We found two rack can not move smoothly. The cause of first one is that the track is not fit the rack well. We use some abrasive paper to reprocess the track. The other one can not move smoothly because some glue are dropped into the track. We use a blower to dry the glue. At last, all rack can move smoothly.

We write two extra program to increase the practicability. After writing the first program, if we input the order “over”, the surface will come back to its original position. After writing the second program, we can change the position of surface by input rotation parameter by hand. By this program, we can adjust the original position and the final position of surface.

After the completion of Task 6

- **Polynomial actualization can actualize any polynomial**
- **All stepper motors and racks work as expected**

Task 7: Reporting

After completing the device, we are required to give a presentation in front of the whole class and all the professors and teaching assistants. On Dec.6th 2014, we have the symposium in Room 117, Cheng Ruiqiu Building. The presentation of our group is given by all of the team members. Cheng Tao is responsible for the opening part, end part and introducing the bill of the materials. He Chun takes the responsibility for introducing the problem statement and the result of literature review. Lian Qi is responsible for the need section, and he introduces the solution statement of the device. Shao Shengting takes the duty for stating the objectives and the tasks part. Li

Chunchao is responsible for physically demonstrating the device and instructing the audience how to use the device to actualize polynomials.

Apart from the symposium, we are also required to display our project at the expo. The expo is held in the library on Dec. 16th 2014. At the expo, all of the team members introduce our project to everyone who is interested in our project. To make people clear about the device, we first let them give a polynomial. Then we input the polynomial into the program and actualize the device to form a certain shape. When the device is working, we first introduce the practical meaning of the project. After that, we introduce the function of every part of the device. Finally, we tell the difference between our device and the current molds.

After the completion of Task 7:

- **The whole class know every detail of our project**
- **People interested in our project know more details of our project at the expo**

VIII. Discussion

After completing all the tasks, our device, the polynomial actualization can actualize any polynomial. Here we will discuss the outcome in three aspects:

- Advantages

The greatest advantage of our project is its high applicability and its reusability. As long as we have an polynomial or some data of a curve, the polynomial actualization can show the graph of the polynomial or the curve in reality. After using the surface as a mold, we only need input the order “over” to arduino. Then the surface will return to its original shape. After that, the polynomial actualization can actualize another function.

- Drawback

The biggest Drawback of our project is the small changeable range of the surface. Because we use stepper motors with low torque and plastic racks, they can not provide a force strong enough to change the surface a lot.

- Further Improvement

If the polynomial actualization is put into manufacturing. We can use stepper motors with high torque and steel racks to replace the present ones. Then the changeable range will be large enough for surface to act as most molds. In the meantime, if time and fund allowed, we can find a more elastic material to take the place of PVC board, which will also increase the changeable range of the surface.

IX. Conclusion

Our group, the Fantastic, successfully built a changeable mold, called "Polynomial Actualization". The main objective of the "Polynomial Actualization" is to improve the capability of the mold. To achieve the objective, we designed a device which has shorter production period and low cost. It can also change its inner structure freely, and it has high portability.

The most important achievement we have made is that we finally find a method to prevent the rack from sloping when it goes up. Using the acrylic board to make a track and fixing the track on the middle board in the device, we can let the rack go up and down vertically. In addition, the whole connection is beautiful.

The most important lesson we have learned from the project is that it is a waste of time if we only revise our diagram without practically manufacturing it. There are even more problems when we practically assemble our project 2. Therefore, what we should do is to revise the design on the basis of what we have done, not just to revise it in our mind.

As modern industry develops rapidly, companies are paying more attention to the capability of the mold. Our project 2 provides a method to manufacture a changeable mold to raise the production efficiency. With sufficient investment, the device can be extended from 2D to 3D by using the same method. In a long term, if the polynomial actualization can be put into production and used by companies, the cost for manufacturing molds can be lowered, and the production period will also be shortened. .

X. Schedule

The following Figure 16 shows the major tasks of our project.

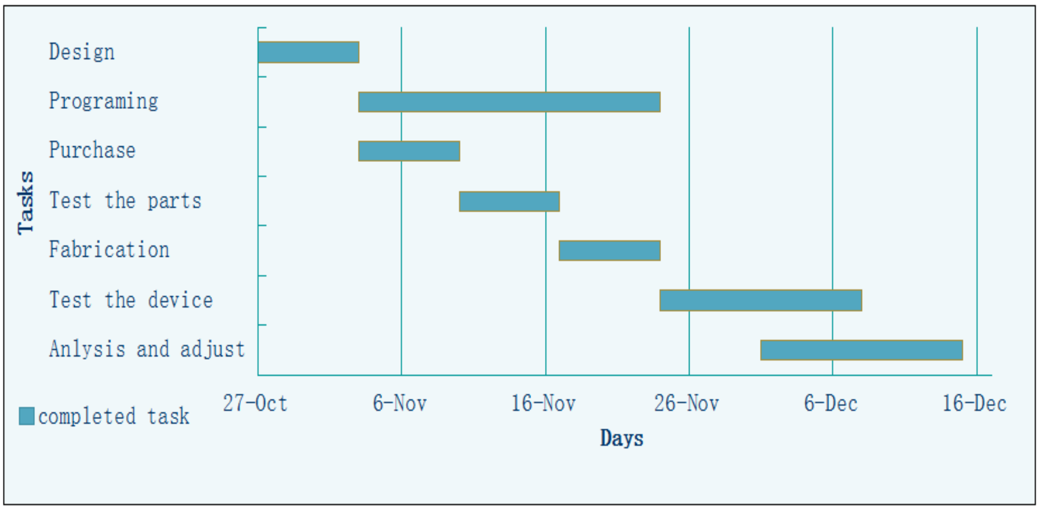

Figure 15: The condensed Gantt Chart

XI. Bill of Materials

Table 1: The Material List

Quantity	Part Description	Purchased From	Part Number	Price (each)
7	Gear 5mm inner diameter	Taobao Vendor1		￥4. 36
7	Rack 125mm*4mm*7mm	Taobao Vendor2		￥1
7	stepper motor with driver	Taobao Vendor3	ULN2003	￥7. 8
1	Arduino Mega	Taobao Vendor4	2560 R3 ATMEGA16U2-MU	￥80
1	PVC soft board	Taobao Vendor5	ZY135	￥1.8
1	iron ruler	Taobao Vendor6	vogel001	￥55
1	Aramaic board	Taobao Vendor7		￥95
1	Aramaic glue with injector	Taobao Vendor7		￥9

Total=￥331.12

[1]http://item.taobao.com/item.htm?spm=a1z09.2.9.270.mwCjRa&id=41301832371&_u=p210gj17adef

[2]http://detail.tmall.com/item.htm?id=20574392778&spm=a1z09.2.9.232.mwCjRa&_u=p210gj1773e4

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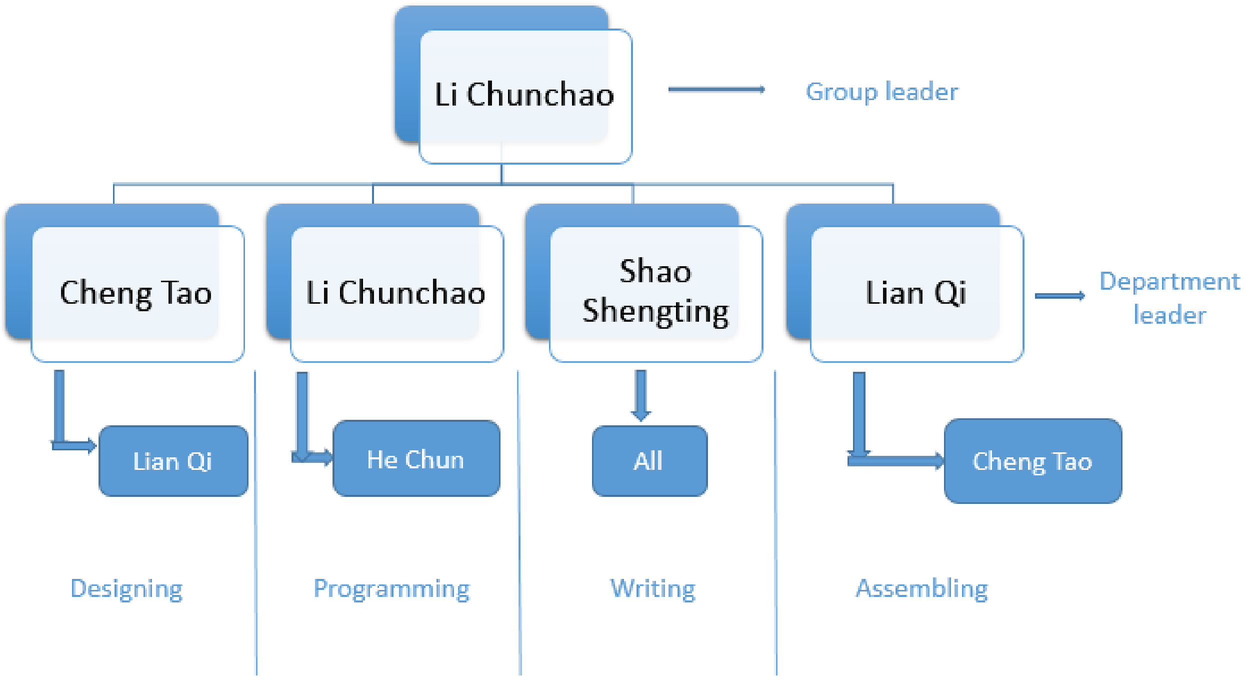
[6]http://detail.tmall.com/item.htm?id=21787047242&spm=a1z09.2.9.111.hRlvje&_u=g210gj177f21

[7]http://item.taobao.com/item.htm?spm=a1z09.2.9.261.hRlvje&id=13603291616&_u=

g210gj17394f

XII. Key Personnel



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XIV. Appendix A

```
a=input('from high times to low times')
p(1,1)=polyval(a,0);
p(1,2)=polyval(a,1);
p(1,3)=polyval(a,2);
p(1,4)=polyval(a,3);
p(1,5)=polyval(a,4);
p(1,6)=polyval(a,5);
p(1,7)=polyval(a,6);
ma=max(p);
mi=min(p);
a(1,1)=((p(1,1)-mi)/(ma-mi))*999;
a(1,2)=((p(1,2)-mi)/(ma-mi))*999;
a(1,3)=((p(1,3)-mi)/(ma-mi))*999;
a(1,4)=((p(1,4)-mi)/(ma-mi))*999;
a(1,5)=((p(1,5)-mi)/(ma-mi))*999;
a(1,6)=((p(1,6)-mi)/(ma-mi))*999;
a(1,7)=((p(1,7)-mi)/(ma-mi))*999;
round(a)
```

XV. Appendix B

```
String comdata = "";

#include <Stepper.h>
#define STEPS 100
Stepper stepper1(STEPS, 2,3,4,5 );
Stepper stepper2(STEPS, 6,7,8,9 );
Stepper stepper3(STEPS, 10,11,12,13 );
Stepper stepper4(STEPS, 14,15,16,17 );
Stepper stepper5(STEPS, 18,19,20,21 );
Stepper stepper6(STEPS, 22,23,24,25 );
Stepper stepper7(STEPS, 26,27,28,29 );
Stepper stepper10(STEPS, 3,4,5,2 );
Stepper stepper20(STEPS, 9,6,7,8 );
Stepper stepper30(STEPS, 13,10,11,12 );
Stepper stepper40(STEPS, 17,14,15,16 );
Stepper stepper50(STEPS, 21,18,19,20 );
Stepper stepper60(STEPS, 25,22,23,24 );
Stepper stepper70(STEPS, 29,26,27,28 );
int x1 = 0;
int x2 = 0;
```

```
int x3 = 0;
int x4 = 0;
int x5 = 0;
int x6 = 0;
int x7 = 0;
int x10 = 0;
int x20 = 0;
int x30 = 0;
int x40 = 0;
int x50 = 0;
int x60 = 0;
int x70 = 0;
void setup()
{Serial.begin(9600);
stepper1.setSpeed(90);
stepper2.setSpeed(90);
stepper3.setSpeed(90);
stepper4.setSpeed(90);
stepper5.setSpeed(90);
stepper6.setSpeed(90);
stepper7.setSpeed(90);
stepper10.setSpeed(90);
```

```
stepper20.setSpeed(90);
stepper30.setSpeed(90);
stepper40.setSpeed(90);
stepper50.setSpeed(90);
stepper60.setSpeed(90);
stepper70.setSpeed(90);}

void loop()
{
  while (Serial.available() > 0)
    {
      comdata += char(Serial.read());
      delay(2);
    }
    if (comdata =="over")
    {
for (int i=0; i <= 3500; i=i+10)
{
  if(i<x1){
  stepper10.step(10);
  digitalWrite(2,LOW);
digitalWrite(3,LOW);
```

```
digitalWrite(4,LOW);
digitalWrite(5,LOW);
}   if(i<x2){
stepper20.step(10);
digitalWrite(6,LOW);
digitalWrite(7,LOW);
digitalWrite(8,LOW);
digitalWrite(9,LOW);
}   if(i<x3){
stepper30.step(10);
digitalWrite(10,LOW);
digitalWrite(11,LOW);
digitalWrite(12,LOW);
digitalWrite(13,LOW);
}   if(i<x4){
stepper40.step(10);
digitalWrite(14,LOW);
digitalWrite(15,LOW);
digitalWrite(16,LOW);
digitalWrite(17,LOW);
}   if(i<x5){
stepper50.step(10);
```

```
digitalWrite(18,LOW);
digitalWrite(19,LOW);
digitalWrite(20,LOW);
digitalWrite(21,LOW);
}   if(i<x6){
stepper60.step(10);
digitalWrite(22,LOW);
digitalWrite(23,LOW);
digitalWrite(24,LOW);
digitalWrite(25,LOW);
}   if(i<x7){
stepper70.step(10);
digitalWrite(26,LOW);
digitalWrite(27,LOW);
digitalWrite(28,LOW);
digitalWrite(29,LOW);
}
}

     x1=0;
     x2=0;
     x3=0;
```

```
    x4=0;
    x5=0;
    x6=0;
    x7=0;
    x10=0;
    x20=0;
    x30=0;
    x40=0;
    x50=0;
    x60=0;
    x70=0;
        Serial.println(comdata);
      comdata = ""; }
  if (comdata.length() > 21)

{ x1=(comdata[0]-48)*1000+(comdata[1]-48)*100+(comdata[2]-48)*10;

x2=(comdata[3]-48)*1000+(comdata[4]-48)*100+(comdata[5]-48)*10;
```

```
x3=(comdata[6]-48)*1000+(comdata[7]-48)*100+(comdata[8]-48)*10;

x4=(comdata[9]-48)*1000+(comdata[10]-48)*100+(comdata[11]-48)*10;

x5=(comdata[12]-48)*1000+(comdata[13]-48)*100+(comdata[14]-48)*1
0;

x6=(comdata[15]-48)*1000+(comdata[16]-48)*100+(comdata[17]-48)*1
0;

x7=(comdata[18]-48)*1000+(comdata[19]-48)*100+(comdata[20]-48)*1
0;
for (int i=0; i <= 3500; i=i+10)
{
  if(i<x1){
  stepper10.step(10);
  digitalWrite(2,LOW);
```

```
digitalWrite(3,LOW);
digitalWrite(4,LOW);
digitalWrite(5,LOW);
}   if(i<x2){
stepper20.step(10);
digitalWrite(6,LOW);
digitalWrite(7,LOW);
digitalWrite(8,LOW);
digitalWrite(9,LOW);
}   if(i<x3){
stepper30.step(10);
digitalWrite(10,LOW);
digitalWrite(11,LOW);
digitalWrite(12,LOW);
digitalWrite(13,LOW);
}   if(i<x4){
stepper40.step(10);
digitalWrite(14,LOW);
digitalWrite(15,LOW);
digitalWrite(16,LOW);
digitalWrite(17,LOW);
}   if(i<x5){
```

```
stepper50.step(10);
digitalWrite(18,LOW);
digitalWrite(19,LOW);
digitalWrite(20,LOW);
digitalWrite(21,LOW);
}   if(i<x6){
stepper60.step(10);
digitalWrite(22,LOW);
digitalWrite(23,LOW);
digitalWrite(24,LOW);
digitalWrite(25,LOW);
}   if(i<x7){
stepper70.step(10);
digitalWrite(26,LOW);
digitalWrite(27,LOW);
digitalWrite(28,LOW);
digitalWrite(29,LOW);
}
}

    x1=0;
    x2=0;
```

```
x3=0;
x4=0;
x5=0;
x6=0;
x7=0;
x10=0;
x20=0;
x30=0;
x40=0;
x50=0;
x60=0;
x70=0;


   comdata = ""; }
   if (comdata =="clear")
{
x1=0;
x2=0;
x3=0;
x4=0;
x5=0;
```

```
x6=0;
x7=0;
x10=0;
x20=0;
x30=0;
x40=0;
x50=0;
x60=0;
x70=0;
      Serial.println(comdata);
   comdata = ""; }
if (comdata.length() > 0)
{
x1=x1+(comdata[0]-48)*1000+(comdata[1]-48)*100+(comdata[2]-48)*1
0;
      Serial.println(x1);
      }
if (comdata.length() > 3)
{
x2=x2+(comdata[3]-48)*1000+(comdata[4]-48)*100+(comdata[5]-48)*1
```

```
0;
            Serial.println(x2);
            }
      if (comdata.length() > 6)
      {

x3=x3+(comdata[6]-48)*1000+(comdata[7]-48)*100+(comdata[8]-48)*1
0;
            Serial.println(x3);
            }
                if (comdata.length() > 9)
      {

x4=x4+(comdata[9]-48)*1000+(comdata[10]-48)*100+(comdata[11]-48)
*10;
            Serial.println(x4);
            }
                if (comdata.length() > 12)
      {

x5=x5+(comdata[12]-48)*1000+(comdata[13]-48)*100+(comdata[14]-48
)*10;
```

```
Serial.println(x5);
}
if (comdata.length() > 15)
{
x6=x6+(comdata[15]-48)*1000+(comdata[16]-48)*100+(comdata[17]-48
)*10;
Serial.println(x6);
}
if (comdata.length() > 18)
{
x7=x7+(comdata[18]-48)*1000+(comdata[19]-48)*100+(comdata[20]-48
)*10;
Serial.println(x7);
}
comdata = "";
if (x1+x2+x3+x4+x5+x6+x7-x10-x20-x30-x40-x50-x60-x70>0)
{
for (int i=0; i <= 3500; i=i+10)
{
if(i<x1){
```

```
  stepper1.step(10);
  digitalWrite(2,LOW);
digitalWrite(3,LOW);
digitalWrite(4,LOW);
digitalWrite(5,LOW);
}  if(i<x2){
stepper2.step(10);
digitalWrite(6,LOW);
digitalWrite(7,LOW);
digitalWrite(8,LOW);
digitalWrite(9,LOW);
}  if(i<x3){
stepper3.step(10);
digitalWrite(10,LOW);
digitalWrite(11,LOW);
digitalWrite(12,LOW);
digitalWrite(13,LOW);
}  if(i<x4){
stepper4.step(10);
digitalWrite(14,LOW);
digitalWrite(15,LOW);
digitalWrite(16,LOW);
```

```
digitalWrite(17,LOW);
}   if(i<x5){
stepper5.step(10);
digitalWrite(18,LOW);
digitalWrite(19,LOW);
digitalWrite(20,LOW);
digitalWrite(21,LOW);
}   if(i<x6){
stepper6.step(10);
digitalWrite(22,LOW);
digitalWrite(23,LOW);
digitalWrite(24,LOW);
digitalWrite(25,LOW);
}   if(i<x7){
stepper7.step(10);
digitalWrite(26,LOW);
digitalWrite(27,LOW);
digitalWrite(28,LOW);
digitalWrite(29,LOW);
}
}
}
```

```
x10=x1;

x20=x2;

x30=x3;

x40=x4;

x50=x5;

x60=x6;

x70=x7;

}
```