Simple and Reliable and Easy-to-control Robot Driven by Linear Actuator and Gear Motor with Soft Pneumatic Gripper

VM250 Group 2

I. Abstract

With the development of industry, robots are becoming more and more common. However, traditional robots are made of rigid materials which have poor ability for elastic deformation and adapt their shape to the external constrains and obstacles. As a result, soft robots, which are made of easily deformable materials to adjust the environmental conditions have become an emerging field. In this project, we studied one of the most popular soft robotic grippers, which is made of silica gel. We designed a robotic arm and a soft gripper in order to produce an easily controlled and reliable robot to grab various things through our control. We used SolidWorks and 3D printing to make the model of the gripper. Then, we injected silica gel to the model to obtain finally gripper. Through experiments and examinations, we have tried many different designs of the gripper and eventually found a practical one. We have successfully invented a device which can grab thing like tennis balls, pens and bottles with very easy commands.

II. Introduction

The problems we are facing can be divided into two parts. The first problem is how to design the robotic arm and the overall structure to achieve goals with light weight and minimum cost. We need to make sure that our device can remain steady when grabbing things. And as we need to grab things in different places and put them in the required position, our structure should allow gripper to go up, down and rotate at least 90 degrees to both sides. The other problem is based on the soft gripper. We have to find a useful design to make sure that our gripper can grab all these required things without being short-circuited. To be more precise, we have to figure out the size of the wall, size and shape of the cavity, etc.

We have done some research and found some relevant literatures to help us design our soft robotic gripper better. The literatures are listed as follows:

No.	Method	Major findings	Unresolved issues	Refs.
L1	A qualitative overview of the suitability of the three different gripper	The best choice for us is gripper controlled by a	We have to find some way to grab the flat things. Also, we have	[1]

	technologies (Actuation, Stiffness and Adhesion) for different object shapes	actuation.	to find the actuation and the way to control.	
L2	The impact that different dimensions have on the bending of gripper actuated by a pneu-net	How the rate of inflation, geometry of the internal channels and exterior walls affect the bending.	The actual dimensions should be found by our practical attempts.	[2]
L3	Comparison to a rigid gripper	Soft gripper can interface smoothly with the environment and grasp delicate object	The soft gripper is easier to be broken	[3]
L4	Working modes for the robotic gripper	Two different modes, contact mode and force application mode to make the gripper work better.	Hard to design and achieve the goal.	[4]

Based on these literatures, we divided our work into two parts. Two of us designed and manufactured the whole structure of our device, especially for the robotic arm. The other two designed the soft robotic gripper and tested its performance with the control of actuator. Finally, we achieved our goal: control the whole system with ease to grab various kinds of things.

III. Design

A. Creative parts

There are three creative parts of our device. Each of them represents a solution to implement one degree of freedom. The main purpose of these innovation is to make the mechanical design simple and easy to control.

We design a spur gear and a stepped gear wheel, together with a plate-shaped bearing, to implement the rotation of the main platform with a gear motor. The stepped gear wheel is attached to the motor which is fixed to the platform while the gear is attached to the supporting legs which are standing on the ground. When the motor starts rotating, the stepped gear wheel transmits rotational torque to the gear. However, since the gear fixing with the supporting legs remains stationary due to the friction of legs with the ground, the anti-rotational torque will be applied to the stepped gear wheel and, accordingly, to the motor itself to rotate the platform. (Figure 1)

The advantages of such design are obvious: simple, reliable and easy to control. Gear transmission is one of the most commonly used solution to rotary motion, and we can control the direction and the speed of rotary motion easily by applying certain voltage level to the gear motor. The control of DC motor is much easier than the control of step motor which requires special square-wave signal and specified driving board to actuate. The platform can also carry heavier load and rotates faster using a gear motor compared with using a servo.

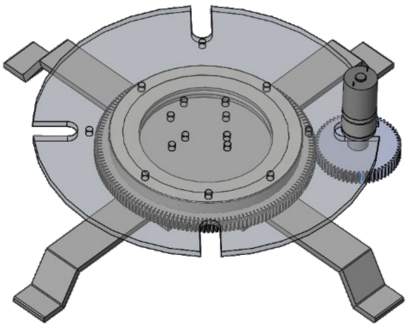


Figure 1

The plate-like bearing is sandwiched by the platform and the gear, with the inner ring fixed with the gear and outer ring fixed with the platform. It has two functions: to implement the rotary motion and to reduce the friction of rotating so that the platform can carry heavy load with small rotational torque.

The linkage structure of the gripper (Figure 2) is the biggest highlight of our design. Typically, a servo should be attached to the gripper to rotate it, but we consider it not suitable for our structure because the vertical linear actuator itself has an original length L_0 so that the servo attached to the end of the horizontal linear actuator cannot touch the ground. Therefore, we design a set of linkage connecting the gripper and the servo to transmit the rotary motion so that the gripper can rotate left and right as well as touch the ground. When the servo rotates, one rod of the linkage moves upwards while the other moves downwards, causing the gripper underneath to rotate in the same direction as the servo. Theoretically, the linkage always forms the shape of parallelogram.

There are several advantages of this idea. First, since the linkage is assembled by links and joints, it is very flexible to adjust to meet different demands. For example, we can either adjust the length of the rods to change the position of the gripper, or adjust the width of the servo horn to refine the performance of the rotary motion. Second, since the linkage structure is very light, the reduced weight provides the gripper the capacity to carry more loads compared with other designs that attached the powerful but heavy servo directly to the gripper.

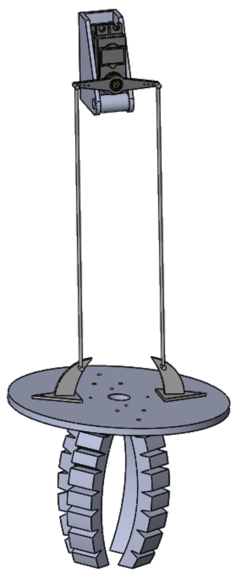


Figure 2

For the robotic arm, we use two linear actuators which are orthogonal to each other to meet the demands of both vertical and horizontal motions (Figure 3). The linear actuator is a kind of linear motor whose rod can either extend or shorten in both directions. Apparently, with two linear actuators we can have two more degrees of freedom other than the rotary motion.

The advantages of linear actuator also coincide with our principle of designing: simple, reliable and easy to control. Similar to the gear motor, by applying different voltage level to the linear actuator, we can control its motion easily. Also, since the materials of the linear actuators and the joint between them are aluminum and iron, this structure is strong enough to act as the skeleton of our device and support other components as well as the heavy load. Unlike other products made up of plastic or polymer, there is no need worrying about the maximum load that the skeleton of our device can afford.

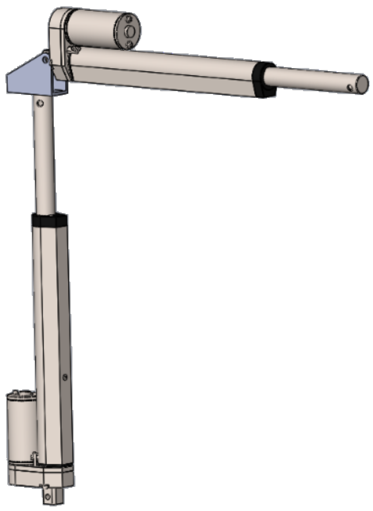
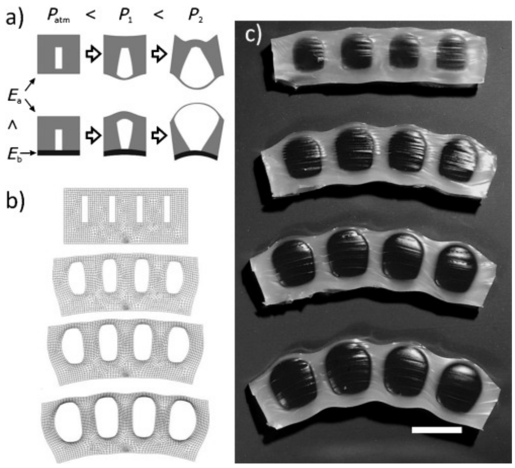


Figure 3



B. Soft robotic gripper

In the final game, we are expected to catch some small things on the ground and pour grains in the bottle out. Besides aiming the objects by rotary and linear movement, an important part of the project is the soft robotic gripper.

Soft and under-actuated robotic hands have a number of advantages over traditional hard hands. They can catch things with appropriate strength; they can deform with the objects they catch; they can defense against the collider, etc. According to some literatures, soft robot is now applied in lots of fields, medicine, agriculture, food industry and so on.

Basically, the most commonly used way of energy supply to soft robot gripper is a pneumatic system, which use air pressure to operate. Air, with low viscosity, fast actuation allowed the gripper to move. When air is pumped into the channels inside the gripper, the regions with lowest stiffness, which are often the regions with the thinnest walls will expand, therefore the gripper will stretch and bend.

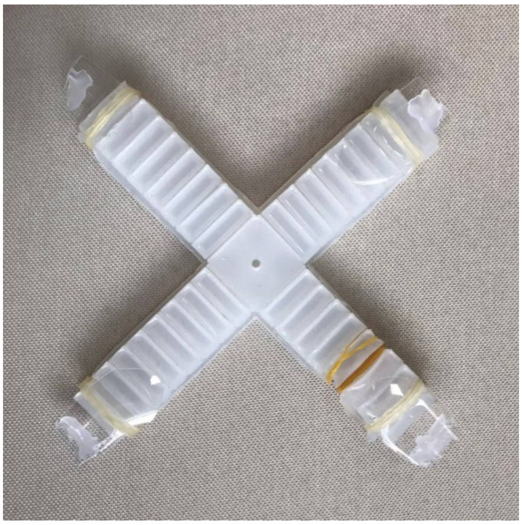


Figure 4

With this theory, we designed our gripper. We choose a basic gripper model: four-claw model (Figure 4).

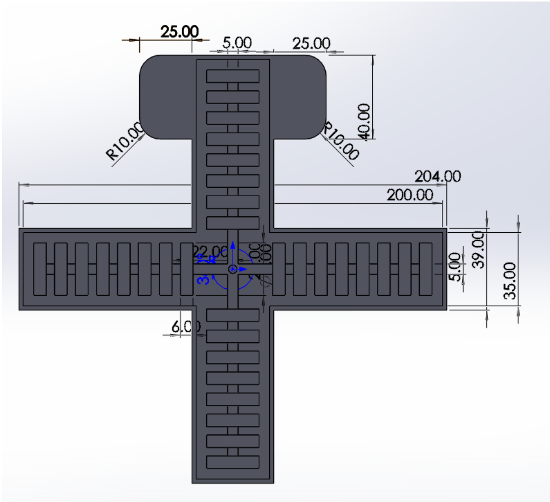
A four-claw gripper can handle different shapes of objects and hold them with uniform strength. What we should consider is following variables:

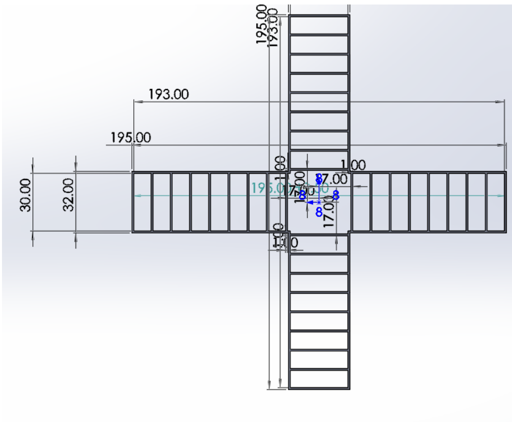
1. The thickness of the wall.
   Too thick wall will lead to harder deformation, while too thin wall may cause a leakage.

2. The width of the claw.
   Too wide claw will make a big blank at bottom, which in turn makes it easy for small objects to fall out. Too narrow claw will form big gaps between claws when catching, which will also lead to small objects falling out.

3. The number of the rectangle space and the height.
   The number of the rectangle spaces and their height for the air determines the curvature the gripper will form after fully pumped up. The more spaces the more the gripper will be bent.

After many trials, we finally get our final version:





Plus, we also add four plastic "nails" at the front. (Figure 4) The plastic chip is thin enough to dig into the bottom of the objects and lift it up to the center of the gripper. This make us much easier to catch non-sphere objects. Finally, some hot melt adhesive is attached on the plastic chip to add the friction on the smooth chip so that objects will not easily fall.

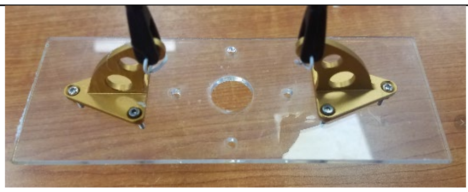
The advantage of the gripper:

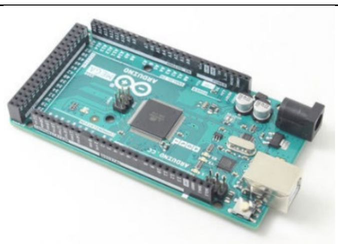
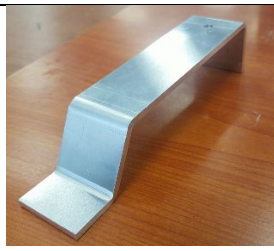
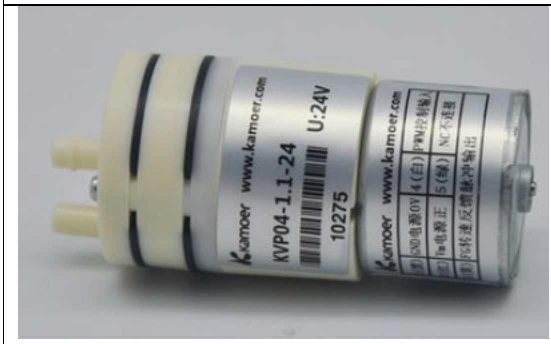
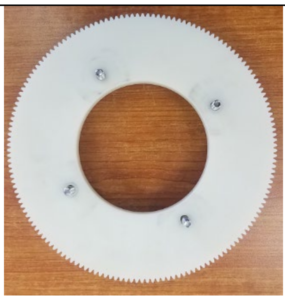
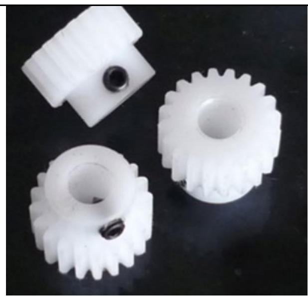
1. It is easier to design, fabricate and control
2. It is lightweight and has a relative

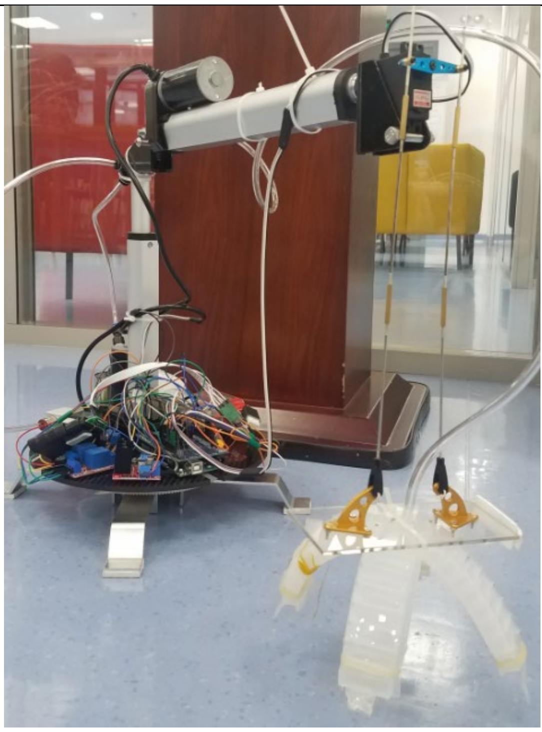
high load capability.

3. It is inexpensive.

C. Pictures of prototype and components

	
Linear Actuator	L-shaped Support
	
4s 1300mAh Battery	Big Carbon-fiber Platform
	
Solenoid Valve	L298N Driver
	
MG-995 Servo	12V DC Gear Motor
	
Small Acrylic Platform	Wireless Receiver

	
Arduino Mega	Supporting Leg
	
Air Pump	Plate-shaped Bearing
	
Spur Gear	Stepped Gear Wheel
	
Servo Horn	Steel Rod



Prototype

IV. Manufacturing

A. Selection of materials

Object	Material	Reason
Gripper	Silica gel	Weight--; Stiffness--; Flexibility++
L-shaped Support	Iron	Strength++
Plate-shaped Bearing	Aluminum	Weight--; Strength++
Supporting Leg	Aluminum	Weight--; Strength++ Easy for metalworking; Easy for machining
Big Platform	Carbon fiber	Strength++; Easy for machining
Small Platform	Acrylic	Weight--; Easy for machining
Gear	Polyformaldehyde (POM)	Weight--; Easy for machining
Servo Horn	Aluminum	Weight--; Strength++
Rod	Steel	Stiffness++; Strength++

The detailed calculation and analysis will be presented in Chapter VI.

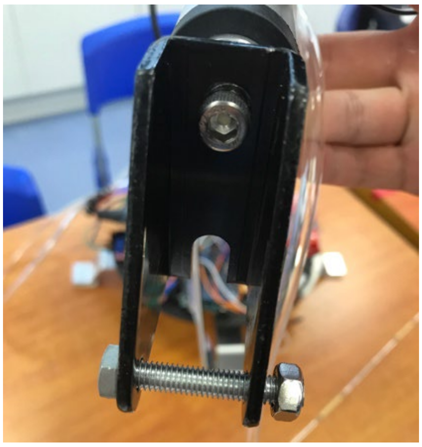
B. Manufacturing procedure of soft robotics gripper

1. Design the 3D model in SolidWorks.
2. Use 3D printer to print model.
3. Mix the A-silicon adhesive and B-silicon adhesive together.
4. Use the mixed adhesive to cast it.
5. Place it for 6-7 hours and get it out.
6. Use the same method to back it over.

C. Procedure of assembly

1. The assembly of servo

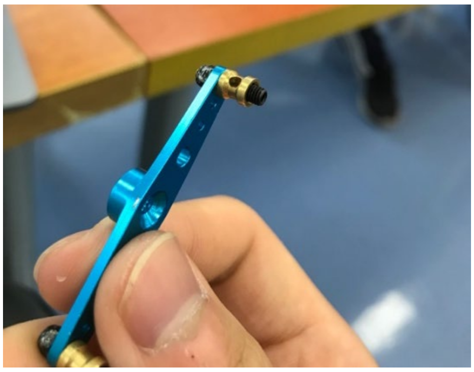
Due to the special structure of our L-shape support, we can simply fix our servo into the gap of the support. The gap of the support is shown below:



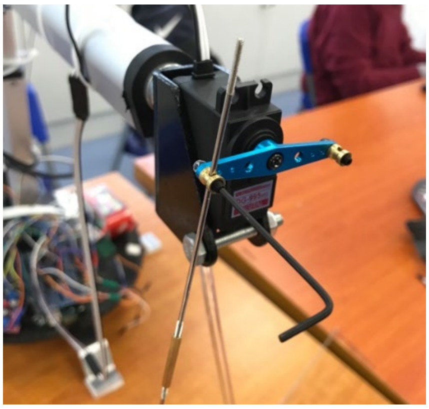
The servo is fixed into the support mainly by the friction force exerted by the screw below. The screw let the walls of the support grip the servo tightly. Also, the screw is located below the servo, which prevents the servo from dropping. The final scenario gives:

The servo arm is connected to the servo with a screw. The picture is shown below:

The fast regulator is used to fix and adjust the length of our steering rod. The detailed picture of the fast regulator is shown below. It is actually a joint and fixed with the Servo arm with a nut. Screw is used to fix the rod with the regulator.

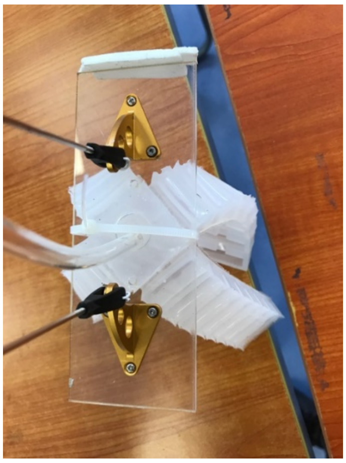


The figure below shows how the steering rod is fixed onto the fast regulator.



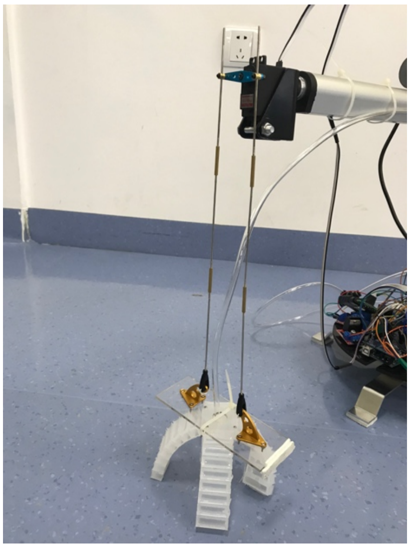
Since our device is relatively tall, we have to use two steering rods each side to achieve desirable length. Two rods are connected with a copper pillar. The figure shows:

Another end of the rod is attached with a clamping head which connects to the steering support fixed on the plate. The figure shows the detail:



We drill a few holes on the acrylic plate to fix the steering supports and our gripper. The figure shows:

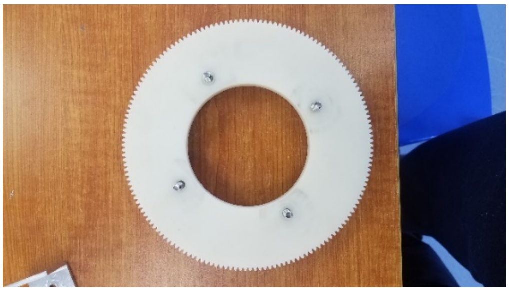
The final case shows:



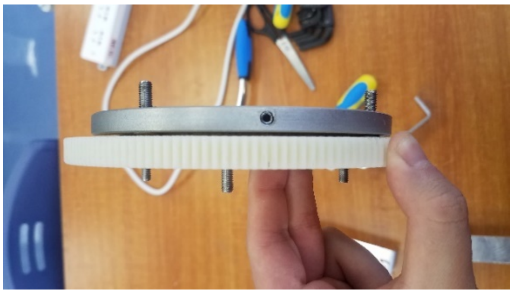
We notice that the double-sided tape on the side of our plate is used to pick up the CD disk.

2. The assembly of platform

Drill four holes on the surface of the spur gear for assembly.

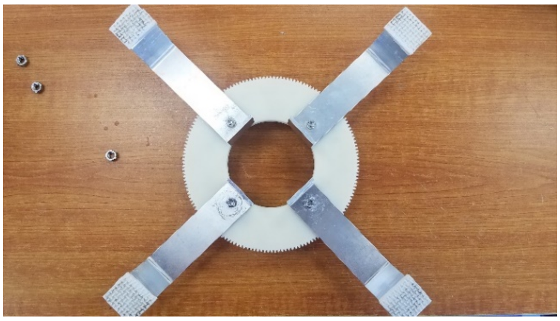


Fix the gear to the inner ring of the plate-shaped bearing using bolts.

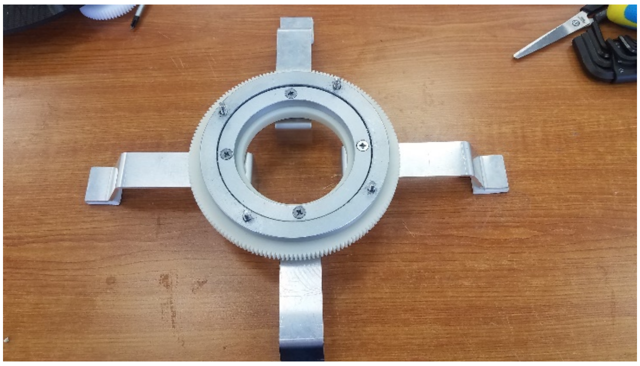


Attach the four supporting legs to the bolts and screw the nuts.

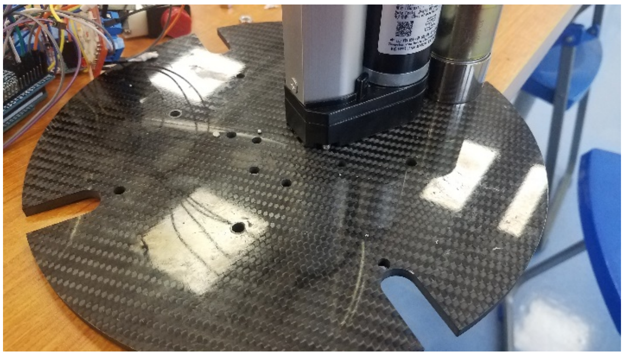
Adjust the direction of the supporting legs and tighten the nuts.



Prepare four bolts to fix the outer ring of the plate-shaped bearing and the carbon-fiber platform.

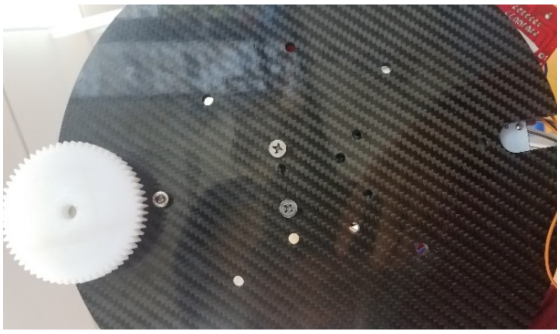


Drill holes on the carbon-fiber plate to assemble the gear motor, linear actuator and the plate-shaped bearing.



Screw the stepped gear wheel to the gear motor and fix the motor to the carbon-fiber plate.

Screw the linear actuator to the plate.



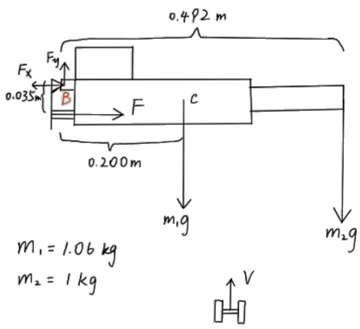
Tighten the nuts to fix the plate-shaped bearing and the carbon-fiber plate.

V. Analysis and tests

A. Static analysis of components with a free-body diagram

1. Shear Stress for the L-shape support:

The horizontal actuator is fixed to the vertical actuator with a L-shape support. The actuator is pined at the top of the support with a screw. We need to estimate the shear force at the screw so as to select the appreciate material. The free-body diagram gives



The length of the horizontal actuator is 0.492m. The mass center lies at the 0.200m from the bottom of the actuator.

The moment gives:

$$M_C = 0.2 * 1.06 * 9.8 = 2.078\ [N * m]$$

If the maximum load at the right side is 0.5kg, the total load to the rod at the end is estimated to be 1kg. The moment gives:

$$M_e = 0.492 * 1 * 9.8 = 4.822\ [N * m]$$

We take the pin as pivot. The support at the lower end gives:

$$M_e + M_C - M_p = 0$$

$$M_p = 0.035 * F = 2.078 + 4.822$$

$$F = 197.14\ [N]$$

So, the load at the pivot gives:

$$V = 0.5 * \sqrt{F^2 + N^2}$$

$$= 0.5 * \sqrt{197.14^2 + (2.06 * 9.8)^2}$$

$$= 99.1\ [N]$$

The stress gives when the cross-sectional area is constrained:

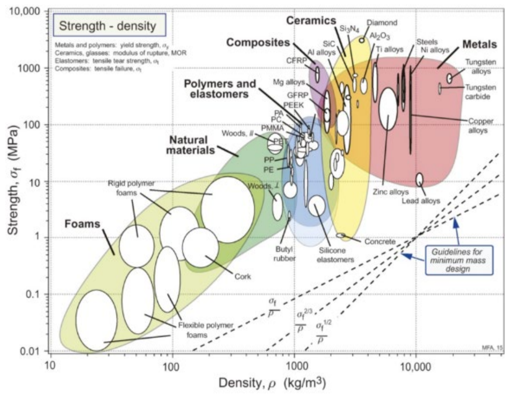
$$\tau_s = \frac{V}{A} = \frac{99.1}{\pi * 0.004 * 0.004} = 1971531\ [Pa]$$

Since this is the shear stress, we

need to translate it to tensile stress to use the Ashby charts. The formula gives:

$$\tau_{max} \geq \frac{\sigma_{max}}{2}$$

We then find the material. The maximum tensile stress is given by $2 \times \tau_s = 4[MPa]$. The chart gives:



Our candidates are Al alloy and Steel. The strength for Al alloy ranges from 20MPa to 400MPa. The strength for steel ranges from 200MPa to 1000MPa. The minimum safety factor gives:

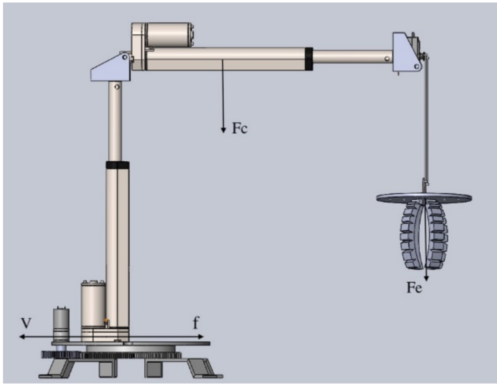
$$\frac{\sigma_{f,Al}}{\sigma_s} = \frac{20M}{4M} = 5$$

$$\frac{\sigma_{f,steel}}{\sigma_s} = \frac{200M}{4M} = 50$$

The screw is relatively small, we do not care about the weight of the screw. So, we choose steel for higher safety.

2. The shear stress for the screw at the bottom of the actuator

The screw at the bottom of the vertical actuator is under great stress when the system is lifting objects. Similarly, we calculate the average shear stress. The free-body diagram gives:



The total external moment gives:

$$M = M_c + M_e = 6.900\ [N * m]$$

We take the plate as reference. The support at the three screws give the same force. The force is balanced by the friction force between the actuator and the plate:

$$V = \frac{M}{3 * 0.012} = 191.67\ [N]$$

The stress gives:

$$\tau_s = \frac{V}{A} = \frac{191.67}{\pi * 0.0025^2} = 9761672[Pa]$$

Since this is the shear stress, we need to translate it to tensile stress to use the Ashby charts. The formula gives:

$$\tau_{max} \geq \frac{\sigma_{max}}{2}$$

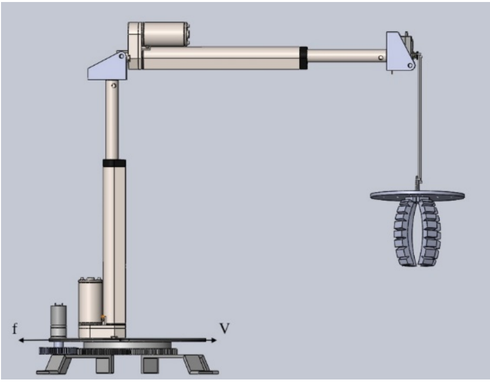
We then find the material. The maximum tensile stress is given by $2 \times \tau_s = 20[MPa]$. The material is steel. The minimum strength of steel is 200MPa, so the Factor of safety gives:

$$\frac{\sigma_f}{\sigma_s} = \frac{200M}{20M} = 10$$

It is very safe.

3. Shear stress for the plate

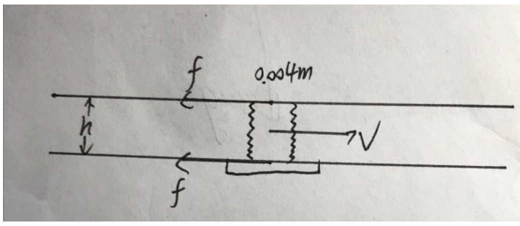
The plate for our design needs to be strong enough to hold our system. We need to calculate the shear stress and select the approximate material. The free-body diagram gives:



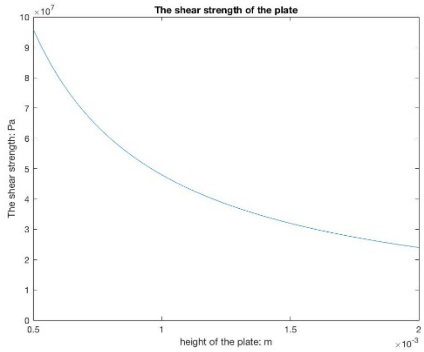
We consider the horizontal force exerted at the plate by a single screw. The stress is given by:

$$\tau_s = \frac{V}{A} = \frac{191.67[N]}{h * 0.004\ [m]}$$

Where h is the height of the plate and the height of the contact area. The cross-sectional width of the contact area is given by 0.004m since the screw we use is M4. Due to the size of our gears, the height of our plate cannot exceed 0.002m. a more detailed diagram is below:



We plot the shear-height graph in below:



Our candidate material for our design is Acrylic Board and Carbon Filter Board. Their minimum tensile strength is 50MPa and 1000MPa. Since this is the shear stress, we need to translate it to tensile stress to use the Ashby charts. The formula gives:

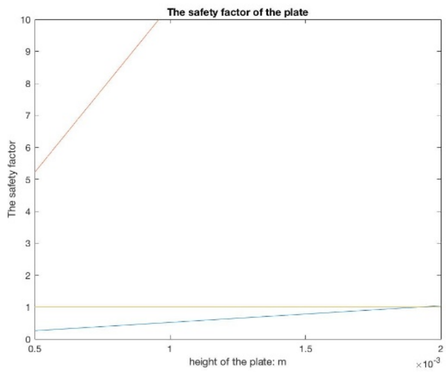
$$\tau_{max} \geq \frac{\sigma_{max}}{2}$$

We plot the safety factor by:

$$\frac{\sigma_{f,a}}{\sigma_s} = \frac{50M}{2\sigma_s} = \frac{25M}{\sigma_s}$$

$$\frac{\sigma_{f,c}}{\sigma_s} = \frac{100M}{2\sigma_s} = \frac{500M}{\sigma_s}$$

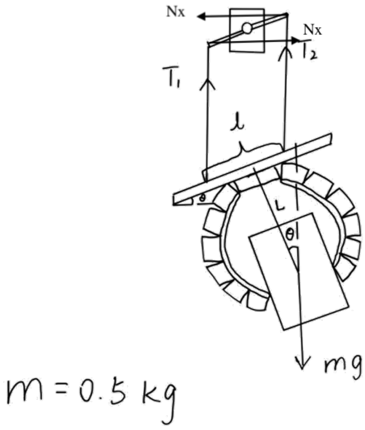
The plot gives:



We can see that the safety factor for acrylic board is below 1 until the height reaches 1.932mm. The choice of acrylic board is very dangerous. The carbon filter board has a much higher safety factor. So, we decide to use carbon filter board.

4. Plot—tensile stress & shear stress at the tiller

The plate of the gripper needs to be rotated. It is important to ensure that the strength of the tiller is large enough during the whole process. We need to calculate the tensile stress and shear stress. The free-body diagram gives:



The maximum total load under and with the plate is approximately 1kg. We suppose the load of the object is half of the total load. We suppose the plate rotates θ degree. We find the tensile for each tiller. The formula gives:

$$T1 + T2 = mg$$

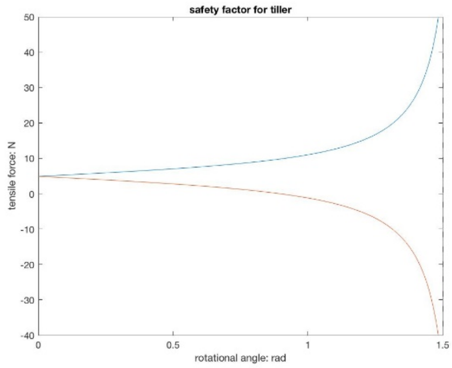
$$T1 l \cos\theta + 0.5mgL\sin\theta = T2 l \cos\theta$$

L is 8cm and l is 2.5cm. We get that:

$$T2 = 0.5mg + \frac{4mg\sin\theta}{5\cos\theta}$$

$$T1 = 0.5mg - \frac{4mg\sin\theta}{5\cos\theta}$$

The plot gives:



The sectional area is $A = \pi r^2 = 7.85 \times 10^{-7}\ [m^2]$

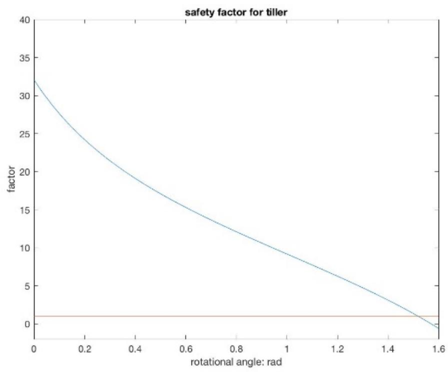
The pressure gives:

$$P = \frac{T}{A}$$

The material is steel. We find the minimum strength of steel is 200MPa, so the Factor of safety gives:

$$\frac{\sigma_f}{\sigma_s} = \frac{200M * A}{T}$$

We plot the factor of safety for the larger one:



So, the rotation can only be 1.527. About 87.5 degrees. If larger than this angle, the tiller will break.

We take the point at the left as the pivot to analyze the shear stress. We suppose the length of our Servo arm is 2x. The moment gives:

$$My = Mx$$

$$(T2 - T1) * x \cos\theta = 2 * Nx * x \sin\theta$$

We get $Nx = 0.8mg$. The shear stress gives:

$$\tau_s = \frac{V}{A} = \frac{0.8mg}{3.14/4 \times 10^{-6}} = 9.99\ [MPa]$$

Since this is the shear stress, we need to translate it to tensile stress to use the Ashby charts. The formula gives:

$$\tau_{max} \geq \frac{\sigma_{max}}{2}$$

We then find the material. The maximum tensile stress is given by $2 \times \tau_s = 20[MPa]$.

Again, we get the factor of safety:

$$\frac{\tau_f}{\tau_s} = \frac{200M}{\tau_s}$$

$$= \frac{200M}{20M}$$

$$= 10$$

For this factor, this is safe.

However, in reality, the tiller bends a little. This is because the tiller is composed of two steel tillers with a copper screw. The bending effect may be caused by this part.

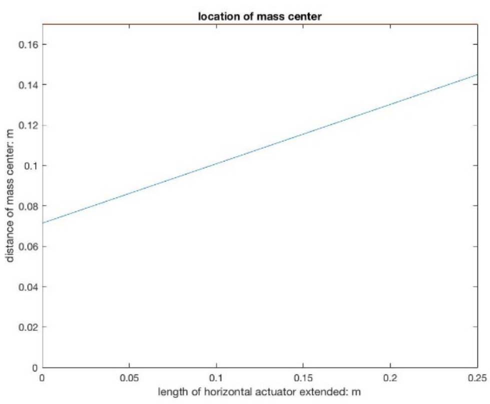
5. Plot—Movement of Mass Center

The movement of the mass center cannot go out of the four sticks, otherwise the system will collapse. We will first find the mass center with the length of the horizontal actuator. We suppose the end load is 1kg and the vertical load shift is 4cm. The motor is placed at the end of the plate opposite to the direction of the object. The remaining loads are uniformly distributed around the plate. We set the center of the plate as origin. We find the center:

$$l = \frac{-0.04 * 1 * 9.8 + 0.16 * 1.06 * 9.8 + (0.16 + x) * 9.8 - 0.125 * 0.375 * 9.8}{3.4 * 9.8}$$

$$= \frac{0.811 + (0.16 + x) * 9.8}{33.32}$$

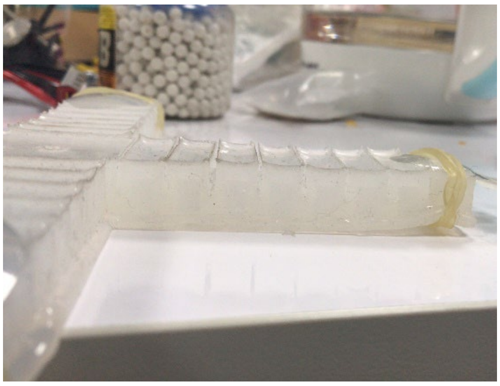
The plot gives:

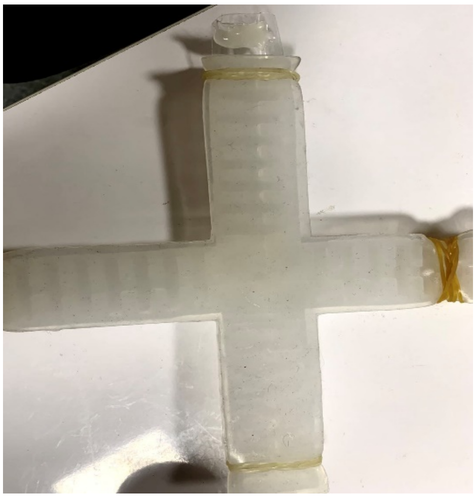


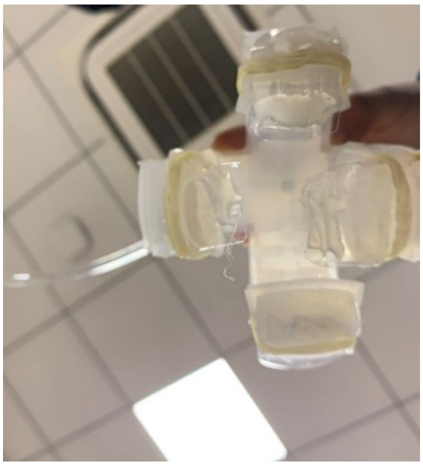
Since the diameter of our system is 0.170m, so the mass center can always locate in the sticks, so the system is safe from collapse.

B. Static analysis and test for gripper

1. Internal channel geometry





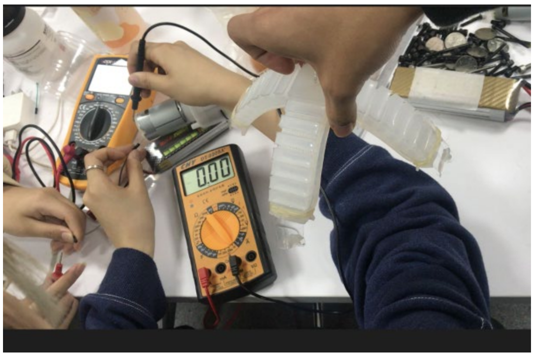


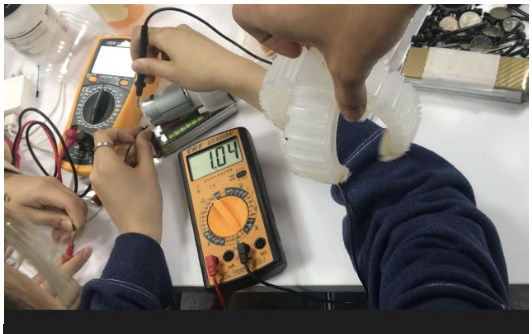
These are the photos about the channel before and after the gripper deflecting.

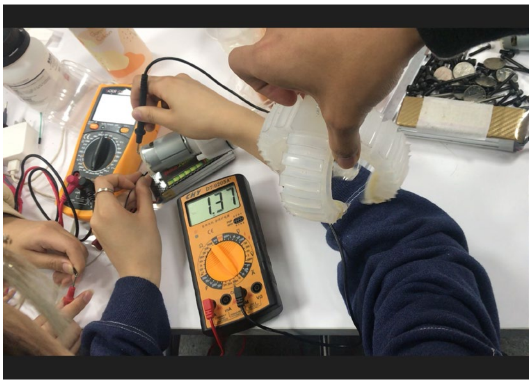
As you can see, the bottom channel of the gripper didn’t change much. While the top one deflected well. This matches well with the theoretical one.

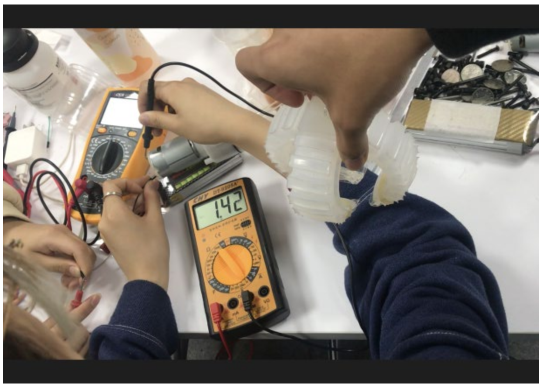
2. Pumping pressure

In this part, we have tested the relationship between the deflection of our gripper and the current of the pump. The results are as follows.







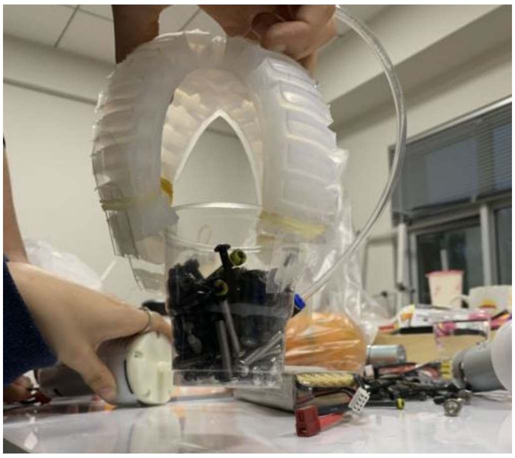


We have found that the reading of ampere meter changed very fast, which means due to the reaction time of the meter, the current we have measured was not very accurate. However, we can know the general trend. As you can see from the figure, as the current increases, our gripper deflects more. Finally, as the current reached 1.42A, the gripper reached the maximum deflection.

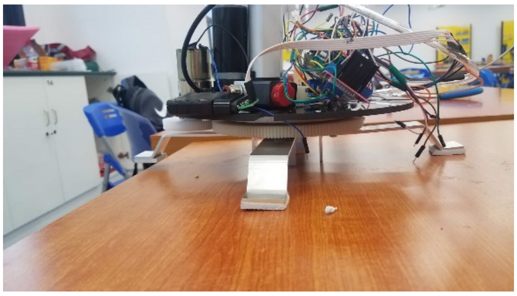
VI. Demonstration of the device

A. Gripping capability

After testing, the maximum weight our gripper can carry is around 417g when it is fully gas-filled. However, different shape may influence the result because the fiction between the surfaces are different. Thus, we find an appropriate shape for the gripper to get the largest weight. The largest weight we tested is much bigger than the weight of what we'll catch in the game day, so our gripper can accomplish the task.



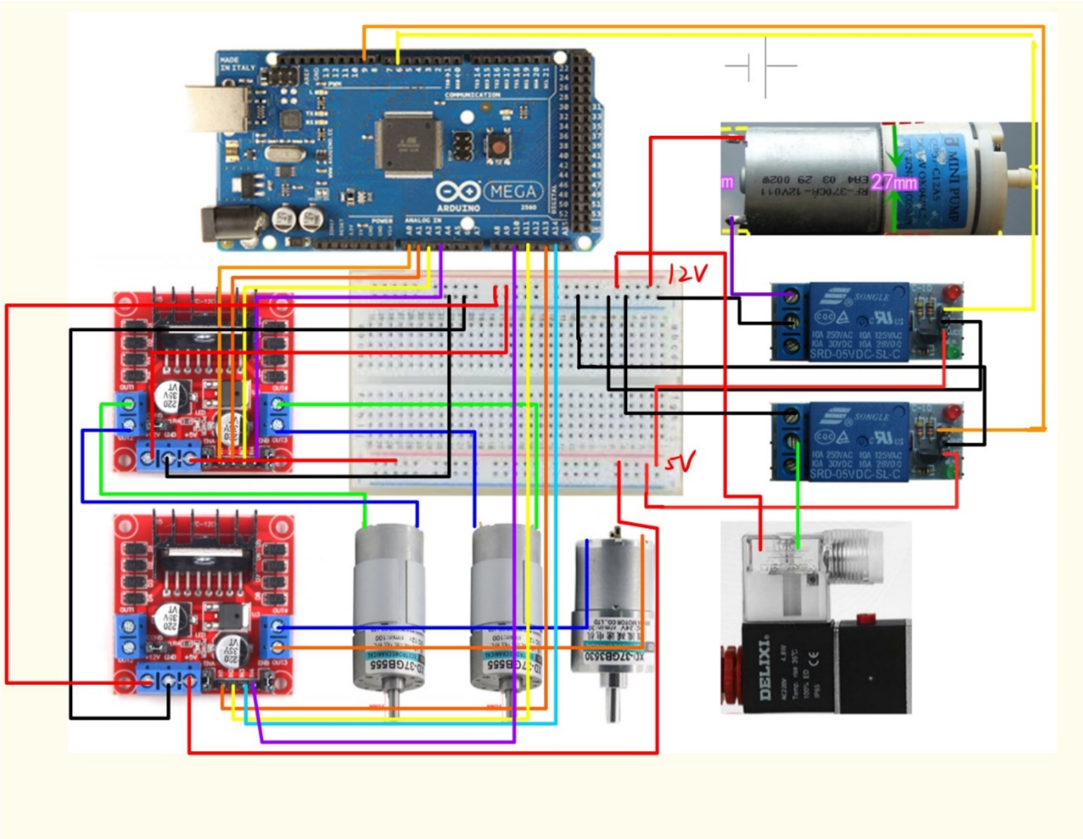
B. Load carrying capacity

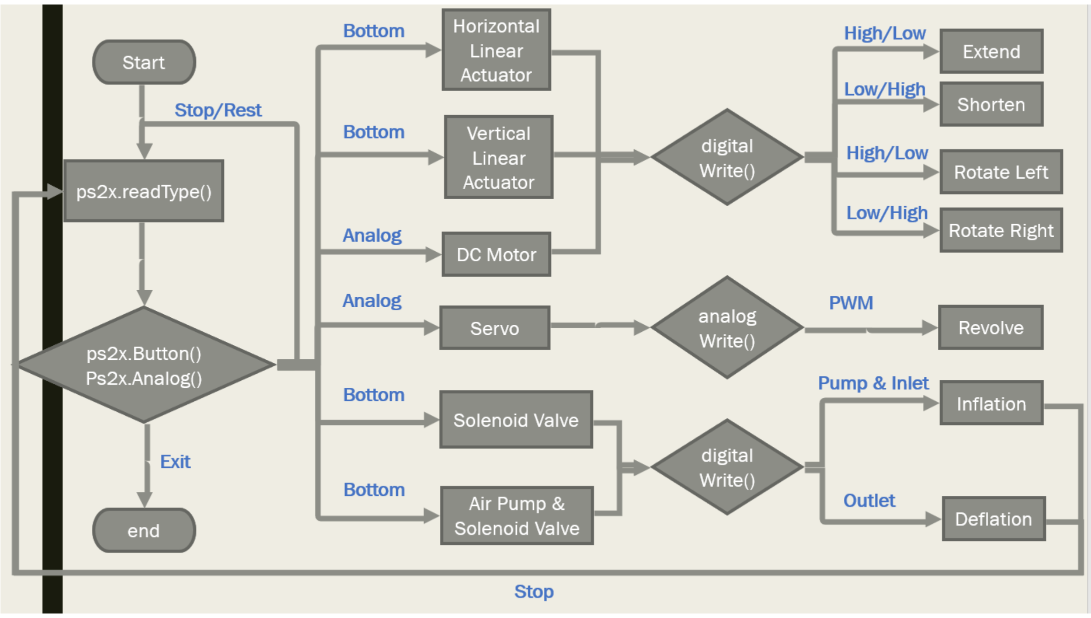


We have tested the maximum load that our structure can carry. The results are as follows.

The maximum load is 1.625 kg which is large enough for our device.

VI. Control and circuit





VII. Discussion

The maximum carrying load of our system is very large. What's more, our system can remain steady when we operate it. However, there are two shortages. The first one is that our gripper vibrated greatly when the system stop from rotation. The second one is that we find it's not enough for having only 90 rotational angle of our gripper. We cannot pour the things in the bottle out easily.

For our soft gripper part, as we have tested before, for the internal channel geometry, the deformed shape of channel agrees with the theoretical one. And we found that this deformed shape is enough for us to grab almost every required thing. And for the pumping pressure. We can only figure out the trend of the deflection of gripper with the change of current. We cannot obtain the exact current and can't match the figure that TA has given. However, according to the maximum load our gripper can carry, we know that the pressure is enough for our device.

We use two linear actuators as the robotic arm. The advantage is that it's very easy to design the whole structure. And finally, our device is easy to control. Another thing is that we add sharp "nails" on the ending part of our gripper, which makes it easier to grab flat things and small things.

In the theoretical part, our study has made a progress on the design and structure of the soft robotic gripper. We have tested the performance of soft gripper, which is good for future study of the soft robots. In the practical part, our device provides a possible way to help people grab things easily. And this device can also be modified and used in the production network to increase the efficiency.

VIII.Conclusion

The objective of our device is to catch various of things in certain distance (0.5m) using a soft gripper and robotic arms. We use linear actuators, gears, linkages, air pumps and many other components to achieve our goal to control the whole device easily and efficiently. We manufacture all kinds of parts like the mold of the gripper and the gripper itself. Then we assemble the parts together and programming them. We also use free body diagram and Matlab plotting to analyze the feasibility and safety of the device. We do tests on the performance of the gripper and air pump to refine the design and maximum the efficiency. We add loads to the gripper to test its gripping and load capacity. We have learnt many things from our experiences:

- Keep the design simple can help you a lot with the reliability of the device.
- Gear transmission is a very powerful method for rotary motion.
- Always pay enough attention to the selection of material, or you may get into the trouble.
- Air pump is not a very reliable machine because its power is always changing even if a stable voltage is applied.
- You should always leave yourself enough time for debugging the system, be it a mechanical or electronical one.

IX. Reference

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[2] B. Mosadegh, P. Polygerinos, C. Keplinger, S. Wennstedt, R. F. Shepherd, U. Gupta, J. Shim, K. Bertoldi, C. J. Walsh, and G. M. Whitesides, "Pneumatic Networks for Soft Robotics that Actuate Rapidly," Advanced Functional Materials, 10-Jan-2014. [Online].Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/adfm.201303288.[Accessed: 28-Apr-2019].

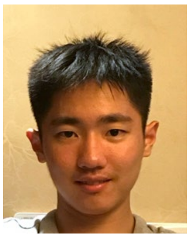
[3] "Haptic Identification of Objects Using a Modular Soft ..." [Online]. Available: http://groups.csail.mit.edu/drl/wiki/images/2/27/Homberg_et_al._-_2015_-_Haptic_Identification_of_Objects_using_a_Modular_Soft_Robotic_Gripper.pdf. [Accessed: 28-Apr-2019].

[4] A Novel, Variable Stiffness Robotic Gripper Based on Integrated Soft Actuating and Particle Jamming, Ying Wei, Yonghua Chen, Tao Ren, Qiao Chen, Changxin Yan, Yang Yang, and Yingtian Li, Soft Robotics 2016 3:3, 134-143

X. Appendix

A. Contribution of each team member

Jiajin Wu, design and manufacture of the mechanical structure and circuits.

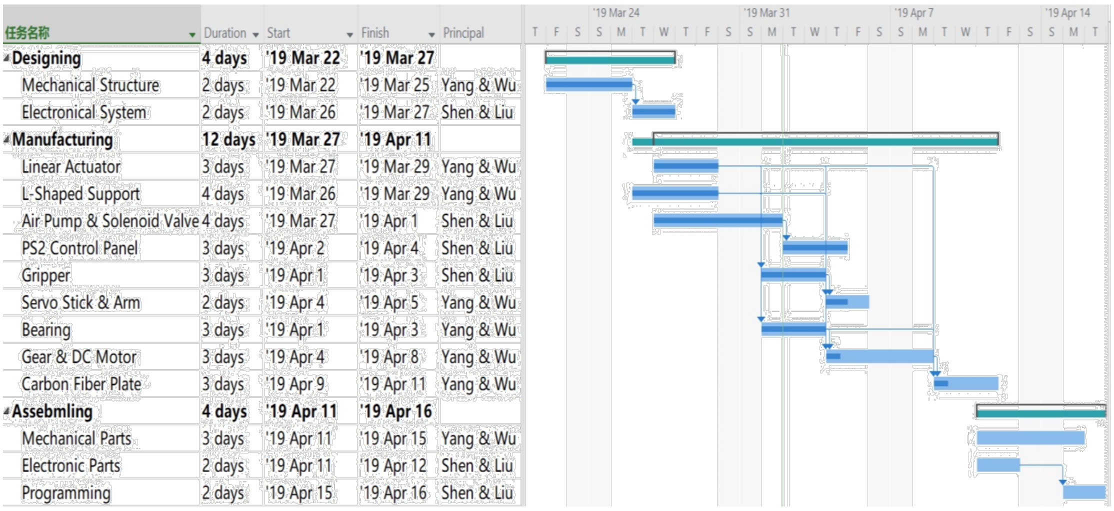


Yiwei Yang, design and manufacture of the mechanical structure and programming of the software.

Shiyi Liu, design and manufacture of the gripper, the operation of the air pump and the solenoid valve.

Mengyuan Shen, design and manufacture of the gripper, the operation of the air pump and the solenoid valve.

B. Gantt chart



任务名称	Duration	Start	Finish	Principal
Designing	**4 days**	**'19 Mar 22**	**'19 Mar 27**	
Mechanical Structure	2 days	'19 Mar 22	'19 Mar 25	Yang & Wu
Electronical System	2 days	'19 Mar 26	'19 Mar 27	Shen & Liu
Manufacturing	**12 days**	**'19 Mar 27**	**'19 Apr 11**	
Linear Actuator	3 days	'19 Mar 27	'19 Mar 29	Yang & Wu
L-Shaped Support	4 days	'19 Mar 26	'19 Mar 29	Yang & Wu
Air Pump & Solenoid Valve	4 days	'19 Mar 27	'19 Apr 1	Shen & Liu
PS2 Control Panel	3 days	'19 Apr 2	'19 Apr 4	Shen & Liu
Gripper	3 days	'19 Apr 1	'19 Apr 3	Shen & Liu
Servo Stick & Arm	2 days	'19 Apr 4	'19 Apr 5	Yang & Wu
Bearing	3 days	'19 Apr 1	'19 Apr 3	Yang & Wu
Gear & DC Motor	3 days	'19 Apr 4	'19 Apr 8	Yang & Wu
Carbon Fiber Plate	3 days	'19 Apr 9	'19 Apr 11	Yang & Wu
Assebmling	**4 days**	**'19 Apr 11**	**'19 Apr 16**	
Mechanical Parts	3 days	'19 Apr 11	'19 Apr 15	Yang & Wu
Electronic Parts	2 days	'19 Apr 11	'19 Apr 12	Shen & Liu
Programming	2 days	'19 Apr 15	'19 Apr 16	Shen & Liu

C. Arduino programming code

```
#include <PS2X_lib.h>  //for v1.6

#include <Servo.h>

/******************************************************************

 * set pins connected to PS2 controller:

 *   - 1e column: original
```

```
 *   - 2e colmun: Stef?
 * replace pin numbers by the ones you use
 ******************************************************************/
#define PS2_DAT        13  //14
#define PS2_CMD        11  //15
#define PS2_SEL        10  //16
#define PS2_CLK        12  //17

/******************************************************************
 * select modes of PS2 controller:
 *   - pressures = analog reading of push-butttons
 *   - rumble    = motor rumbling
 * uncomment 1 of the lines for each mode selection
 ******************************************************************/
//#define pressures   true
#define pressures   false
//#define rumble      true
#define rumble      false

PS2X ps2x; // create PS2 Controller Class
Servo myservo;
//right now, the library does NOT support hot pluggable controllers, meaning
//you must always either restart your Arduino after you connect the controller,
//or call config_gamepad(pins) again after connecting the controller.

int error = 0;
byte type = 0;
byte vibrate = 0;
```

```
int PinPump=3;  //for the air pump

int PinTrigger=6;  //for the solenoid valve

//signals for up actuator

int in1=26;

int in2=28;

//signals for horizontal actuator

int in3=30;

int in4=32;

//signals for motor

int in5=22;

int in6=24;

//signals for Servo

int servo=5;

//position angle for the Servo

int pos=0;


// Reset func

void (* resetFunc) (void) = 0;


void setup(){

  //The initial setup for the signals of our componants

pinMode(PinPump,OUTPUT);

pinMode(PinTrigger,OUTPUT);

pinMode(in1,OUTPUT);

pinMode(in2,OUTPUT);

pinMode(in3,OUTPUT);

pinMode(in4,OUTPUT);

pinMode(in5,OUTPUT);
```

```
pinMode(in6,OUTPUT);

myservo.attach(servo);

  Serial.begin(115200);

analogWrite(PinTrigger, 0);

  delay(500);  //added delay to give wireless ps2 module some time to startup, before configuring it


  //CHANGES for v1.6 HERE!!! **************PAY ATTENTION*************


  //setup pins and settings: GamePad(clock, command, attention, data, Pressures?, Rumble?) check for error

  error = ps2x.config_gamepad(PS2_CLK, PS2_CMD, PS2_SEL, PS2_DAT, pressures, rumble);


  if(error == 0){

    Serial.print("Found Controller, configured successful ");

    Serial.print("pressures = ");

    if (pressures)

      Serial.println("true ");

    else

      Serial.println("false");

    Serial.print("rumble = ");

    if (rumble)

      Serial.println("true)");

    else

      Serial.println("false");

    Serial.println("Try out all the buttons, X will vibrate the controller, faster as you press harder;");

    Serial.println("holding L1 or R1 will print out the analog stick values.");

    Serial.println("Note: Go to www.billporter.info for updates and to report bugs.");

  }
```

```
  else if(error == 1)
    Serial.println("No controller found, check wiring, see readme.txt to enable debug. visit www.billporter.info for troubleshooting tips");

  else if(error == 2)
    Serial.println("Controller found but not accepting commands. see readme.txt to enable debug. Visit www.billporter.info for troubleshooting tips");

  else if(error == 3)
    Serial.println("Controller refusing to enter Pressures mode, may not support it. ");

  type = ps2x.readType();
  switch(type) {
    case 0:
      Serial.println("Unknown Controller type found ");
      break;
    case 1:
      Serial.println("DualShock Controller found ");
      break;
    case 2:
      Serial.println("GuitarHero Controller found ");
      break;
    case 3:
      Serial.println("Wireless Sony DualShock Controller found ");
      break;
   }
}

void loop() {
```

```
/* You must Read Gamepad to get new values and set vibration values
   ps2x.read_gamepad(small motor on/off, larger motor strenght from 0-255)
   if you don't enable the rumble, use ps2x.read_gamepad(); with no values
   You should call this at least once a second
 */
 //For the main part of the loop, we set all the componants off. This can avoid unnecessary movement of any of our devices
 digitalWrite(in1, LOW);
 digitalWrite(in2, LOW);
 digitalWrite(in3, LOW);
 digitalWrite(in4, LOW);
 digitalWrite(in5, LOW);
 digitalWrite(in6, LOW);
 analogWrite(PinPump,0);
if(error == 1){ //skip loop if no controller found
  resetFunc();
}

if(type == 2){ //Guitar Hero Controller
  ps2x.read_gamepad();          //read controller

  if(ps2x.ButtonPressed(GREEN_FRET))
    Serial.println("Green Fret Pressed");
  if(ps2x.ButtonPressed(RED_FRET))
    Serial.println("Red Fret Pressed");
  if(ps2x.ButtonPressed(YELLOW_FRET))
    Serial.println("Yellow Fret Pressed");
  if(ps2x.ButtonPressed(BLUE_FRET))
```

```
    Serial.println("Blue Fret Pressed");
  if(ps2x.ButtonPressed(ORANGE_FRET))
    Serial.println("Orange Fret Pressed");

  if(ps2x.ButtonPressed(STAR_POWER))
    Serial.println("Star Power Command");

  if(ps2x.Button(UP_STRUM))          //will be TRUE as long as button is pressed
    Serial.println("Up Strum");
  if(ps2x.Button(DOWN_STRUM))
    Serial.println("DOWN Strum");

  if(ps2x.Button(PSB_START))         //will be TRUE as long as button is pressed
    Serial.println("Start is being held");
  if(ps2x.Button(PSB_SELECT))
    Serial.println("Select is being held");

  if(ps2x.Button(ORANGE_FRET)) {     // print stick value IF TRUE
    Serial.print("Wammy Bar Position:");
    Serial.println(ps2x.Analog(WHAMMY_BAR), DEC);
  }
}
else { //DualShock Controller, the PS2 we use
  ps2x.read_gamepad(false, vibrate); //read controller and set large motor to spin at 'vibrate' speed

  if(ps2x.Button(PSB_START)) {       //will be TRUE as long as button is pressed
    Serial.println("Start is being held");
    //The servo turns right
```

```
  myservo.write(pos);
  if(pos >=180){
    pos=pos;
  }else{
    pos=pos+3;
  }
  delay(50);
}
if(ps2x.Button(PSB_SELECT)){
  Serial.println("Select is being held");
  //The servo turns left
  myservo.write(pos);
  if(pos <=1){
    pos=pos;
  }else{
    pos=pos-3;
  }
  delay(50);
}
if(ps2x.Button(PSB_PAD_UP)) {      //will be TRUE as long as button is pressed
  Serial.print("Up held this hard: ");
  Serial.println(ps2x.Analog(PSAB_PAD_UP), DEC);
  //actuator turns up
  digitalWrite(in1, LOW);
  digitalWrite(in2, HIGH);
  delay(50);
}
if(ps2x.Button(PSB_PAD_RIGHT)){
```

```
    Serial.print("Right held this hard: ");

    Serial.println(ps2x.Analog(PSAB_PAD_RIGHT), DEC);

    //motor turns right

    digitalWrite(in5, HIGH);

    digitalWrite(in6, LOW);

    delay(10);  //we carefully choose this delay to make the motor rotate not too fast. Same for the next statement

  }

  if(ps2x.Button(PSB_PAD_LEFT)){

    Serial.print("LEFT held this hard: ");

    Serial.println(ps2x.Analog(PSAB_PAD_LEFT), DEC);

    //motor turns left

    digitalWrite(in5, LOW);

    digitalWrite(in6, HIGH);

    delay(10);

  }

  if(ps2x.Button(PSB_PAD_DOWN)){

    Serial.print("DOWN held this hard: ");

    Serial.println(ps2x.Analog(PSAB_PAD_DOWN), DEC);

    //actuator turns down

    digitalWrite(in1, HIGH);

    digitalWrite(in2, LOW);

    delay(50);

  }


  vibrate = ps2x.Analog(PSAB_CROSS);  //this will set the large motor vibrate speed based on how hard you press the blue (X) button

  if (ps2x.NewButtonState()) {        //will be TRUE if any button changes state (on to off, or off to on)
```

```
    if(ps2x.Button(PSB_L3))
      Serial.println("L3 pressed");
    if(ps2x.Button(PSB_R3))
      Serial.println("R3 pressed");
    if(ps2x.Button(PSB_L2))
      Serial.println("L2 pressed");
    if(ps2x.Button(PSB_R2))
      Serial.println("R2 pressed");
    if(ps2x.Button(PSB_TRIANGLE)){
      Serial.println("Triangle pressed");
    }

  if(ps2x.ButtonPressed(PSB_CIRCLE)) {             //will be TRUE if button was JUST pressed
    Serial.println("Circle just pressed");
      analogWrite(PinTrigger, 0);
        analogWrite(PinPump, 255);
        delay(150);
  }
  }
  if(ps2x.NewButtonState(PSB_CROSS)) {               //will be TRUE if button was JUST pressed
OR released
    Serial.println("X just changed");
    analogWrite(PinTrigger, 255);
    delay(1000);
  }



  if(ps2x.Button(PSB_L1)) { //print stick values if either is TRUE
```

```
      Serial.println("Left Stick!");
      //actuator turns in
      digitalWrite(in3, LOW);
      digitalWrite(in4, HIGH);
      delay(50);
    }
    if(ps2x.Button(PSB_R1)) { //print stick values if either is TRUE
      Serial.println("Right Stick!");
      //actuator turns out
      digitalWrite(in3, HIGH);
      digitalWrite(in4, LOW);
      delay(50);
    }
  }
}
```

D. Video

See attachment.