ISSN 2706-655X Vol.5, Issue 10: 97-103, DOI: 10.25236/IJFET.2023.051015

A Flexible Mechanical Claw Design Based on Fin Ray Effect

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Abstract: *In order to cope with the shortcomings of the most rigid mechanical claw on the market, that is, the lack of consideration for object protection and the inability to grasp objects with large size differences, this project designed a flexible mechanical claw based on Fin Ray Effect. This mechanical claw contains four modules, which are the fingertip, drive module, rotating joint, and base. It can realize the gripping of objects with large differences in shape. It can completely fit the contour of the object, providing a more flexible gripping method and avoiding damage to fragile objects. This mechanical claw is modeled by SolidWorks software, and 3D printing technology is used to print and process the critical non-standard parts in it. This project designed a variety of comparative experiments to explore the performance of the mechanical claw. After the experiment can be obtained, the mechanical claw can grasp objects below 700g and can grasp most of the smaller but more different shapes of objects.*

Keywords: *Flexible, Claw, Fin Ray Effect, 3D printing*

1. Introduction

A mechanical claw is a mechanical device that can imitate certain action functions of human hands and grasp objects according to a fixed procedure. Its structure and performance have the advantages of both manual and mechanical claws and can be divided into hydraulic, pneumatic, electric, and mechanical according to the driving method. According to the scope of application, it can be divided into two kinds of special mechanical claw and mechanical claw. According to the shape, size, weight, material, and operation requirements of the gripped object, it has various structural forms, such as clamping type, holding type, and adsorption type. The progress of modern technology makes robotics more and more developed, and mechanical claw is becoming more and more popular.

The three-finger mechanical claw is more common among the clamping mechanical claw, especially in industrial production. Although the traditional rigid mechanical claw has a large force but lacks flexibility and adaptability, these deficiencies are more obvious when grasping fragile objects such as fruits and vegetables, glasses, etc. Such as glass is a rigid mechanical claw that is difficult to grasp the object. First of all, the glass is fragile. The only use of fixed strength of the rigid claw grasp is very easy to break. This time should be used a flexible mechanical claw. The flexible mechanical claw can automatically deform according to the surface curve of the object during the gripping process so as to grip something that cannot be gripped by the rigid mechanical claw or something that can be easily damaged by the rigid mechanical claw. Moreover, a flexible mechanical claw can grip different objects of different shapes and sizes[1].

2. Theoretical design

For the fingertip design, this project uses a fin-type structure. This structure allows for a perfect fit between the curves of the object's surface to achieve a better grip. The "fin," or fingertip, consists of an isosceles triangle with a crossbeam parallel to the bottom surface in the middle. When a force is applied on one side, it causes the whole structure to bend inward to achieve a snug fit to the object. See Figure 2.1(b). The fin consists of two "V" shaped bones and the connective tissue between them. Pulling on one side of the "V" shaped bone causes the fin to deform, bending the root and tip in the direction of the applied load. The fin structure deforms to fit the surface of the object as it approaches the object.

The Fin Ray Effect was discovered by a biologist, Leif Kniese while catching fish. This structure can fit well to the curve of the surface of an object to achieve the effect of grasping what a rigid mechanical

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claw cannot grasp. Compared with the traditional rigid mechanical claw, it has a wide range of applications, high adaptability, more safety, wide operating space, etc., to achieve the grasp of irregular and a variety of shapes of objects, changing the mechanical claw in the rigid case of one claw one use mode.

As a flexible mechanical claw can better fit the surface of the object, it has high adaptability. It can be applied in many different fields, changing the nature of a rigid mechanical claw one claw at a time. The key to robot claw research is safety and reliability, self-adaptability, and higher intelligence. A flexible mechanical claw satisfies all three at the same time. First, the flexible mechanical claw deforms to the shape of the object, allowing for greater self-adjustment. Secondly, by using the pressure sensor on the fingertip, it can stop when the set pressure is reached so that the object will not be damaged by excessive force, and higher reliability and intelligence can be obtained. This makes it easy to handle objects of widely varying shapes and sizes and allows for "multi-purpose use of a claw."

3. Function introduction

The entire mechanical claw consists of three parts, respectively the claw structure, rotating joints, and the base. In the mechanical claw, the structure of the claw part is imitated by the human finger, and there are three types of joints: no joint, fixed joint, and free joint. The number of fingers can be divided into two fingers, three fingers, four fingers, etc., of which the two fingers are used most often. According to the shape and size of the gripping object, a variety of shapes and sizes of collets can be equipped to meet the needs of the operation. The role of the swivel joint is to guide the fingers to accurately grasp the workpiece and transport it to the desired position. The base is the support for mounting the arm, power source, and various actuators[2-3].

This exploration is expected to be able to grasp objects of various sizes and shapes. Since the main object of study is the flexibility of the mechanical claw, the base is simply to achieve the function of up and down. As is shown in Fig.1 and Fig.2.

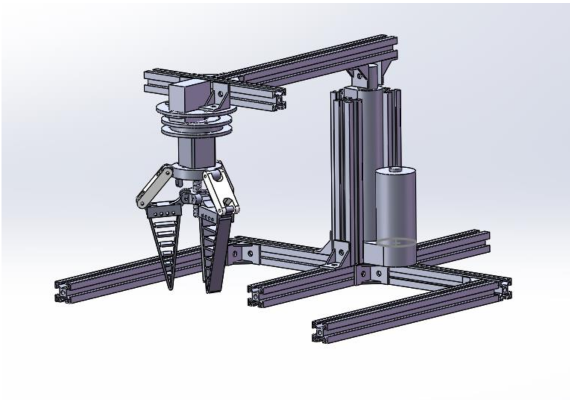
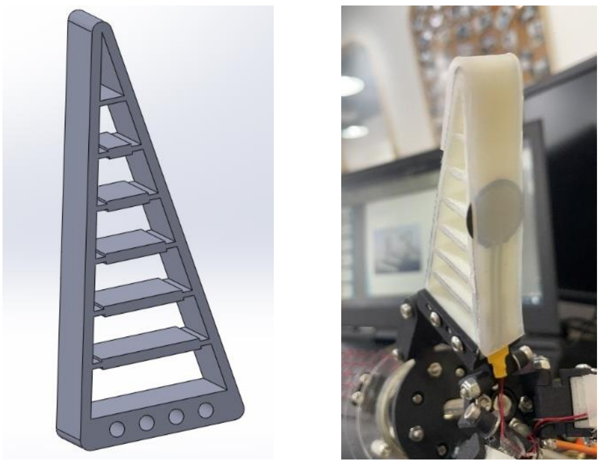


Figure 1: General model



(a) General model *(b) Fingertip object*

Figure 2: Fingertip model and object

The core component of the claw structure consists of the fingertips. There are three fingertips, and the choice of using three fingertips was chosen because three is the option to accommodate the largest variety of objects with the smallest number. The length of the claw is imitated to imitate the length of the human finger, close to the length of the human finger so that people can grasp the object, and the mechanical claw can also grasp. If the length is too short, the grip interval will be reduced a lot. If the length is too long, it will cause a waste of power.

The structure that controls the opening and closing of the claws is a linkage slider structure. A central member is driven by a stepper motor, and the rotary motion of the motor is converted into a linear motion by a screw. Utilizing the linkage slider structure drives the fingertip to open and close. The stepper motor is driven by the A4988 stepper motor driver chip. The stepper motor is chosen because it is more accurate and can control the stroke of the linkage slider structure more precisely, thus controlling the control claw opening and closing, making it easier to grasp fragile products. Moreover, the pressure sensor is used to control the pressure. The driver chip is installed because the stepper motor rotates by current pulses, and a driver chip is needed to convert high and low levels into pulses[4-6].

In order to increase the friction force, the fingertip gripping surface is wrapped with silicone, and silicone from the root of the fingertip gripping surface is wrapped to the opposite side in order to fix the silicone and gripping objects better. However, this type of wrapping will leave a triangular gap between the claws so that it cannot grasp objects that are too small. This problem can be solved by changing the shape of the silicone and filling the entire gap. As is shown in Fig.3 and Fig.4.

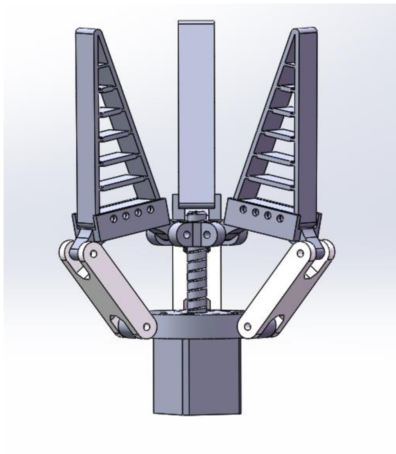


Figure 3: Claw model figure

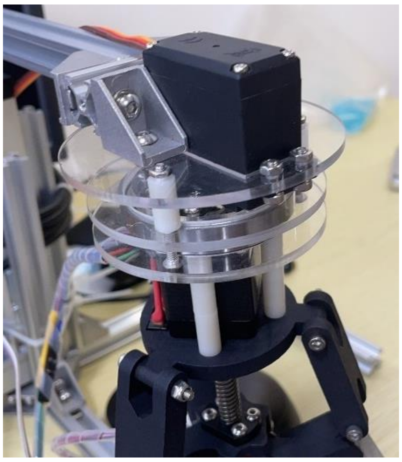


Figure 4: Swivel joint

The rotary joint is divided into three layers, consisting of acrylic plates. Two layers of joint plates are divided into internal and external clamping a 40 * 52 * 7 bearing. The rudder is fixed on the third layer of joint plates. The third layer of joint plates linked to the external two layers of joint plates is the rudder drive inner plate. A servo with a rotation range of 180 degrees is used, as shown in Figure 3.4. The servo is chosen because it can directly control the angle, which is more convenient than a DC motor. And because there are 3 claws, the 120 °servo can grip from any direction of the force point. Therefore, the use

ISSN 2706-655X Vol.5, Issue 10: 97-103, DOI: 10.25236/IJFET.2023.051015

of a 180 °servo meets the demand.

The base uses a linear actuator with a working stroke of 100mm, a working speed of 80mm/s, and a working thrust of 100N. The 1515 European standard aluminum profile is chosen due to its strength, suitability, and lightweight. As is shown in Fig.5

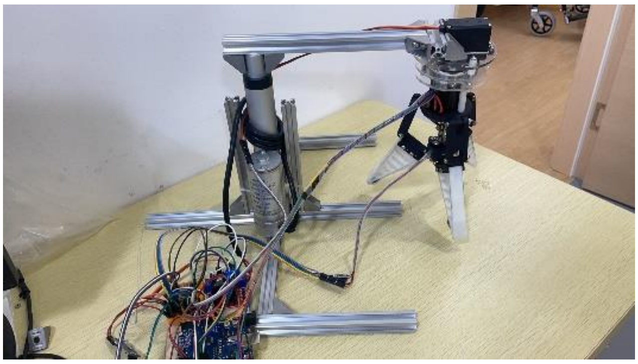


Figure 5: Base

4. Control

A changing electric field drives stepper motors, so a special driver chip is required. Here the A4988 stepper motor driver module is used. It includes three interfaces, switch, step, and direction. The corresponding step is energized, and the motor will take the corresponding step. The choice is to use Bluetooth to control stepper motors, linear actuators, and servos. A touch sensor was used to determine the zero position and to prevent the center link from dropping too low. The actuator section uses an L298N driver module. It uses control high and low levels to drive and control the linear actuator, which is a DC motor and therefore requires a chip to switch the current direction. The program is divided into two parts, the startup program, and the theme program, using C. Within the startup program, the servo will check itself, the linear actuator, and the stepper motor will be homed. The main program uses a while true loop to get the Bluetooth commands. When the off claw button is pressed, the stepper motor will use the while cycle to press down on the central connector to determine if it reaches a force or touches the touch sensor. If not, press down until the pressure reaches a certain value, or the central connector touches the touch sensor to break the cycle.

5. Test

5.1 Deformation test

In order to verify the deformation ability of fingertips, an experiment was conducted. In order to verify the deformation ability of fingertips with different hardnesses under the same force, fingertips with hardnesses of 30 and 90 were used in the experiment. The 90 durometer fingertips showed almost no deformation at 5N, while the 30 durometer fingertips deformed very quickly. In order to achieve the deformation of the 90 durometer fingertip at 5N, a force of 19N was used.

5.2 Crawl test

In order to verify the ability of mechanical claw to grasp objects of different sizes and shapes, a series of grasping experiments were conducted, in which spheres with diameters ranging from 2.4 cm to 6.3 cm, rectangular and square objects with lengths ranging from 1.3 cm to 6.4 cm in length, width and height were grasped successfully. However, some grasping is more difficult, such as the tennis ball with a diameter of 6.3cm. Because of the larger diameter, so the grasping strength is smaller and can not be well grasped. Fingertip hardness is too hard, basically invisible change. As is shown in Fig.6. The result is shown in Table 1.

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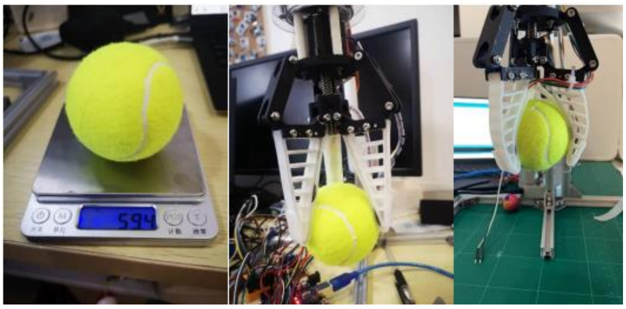


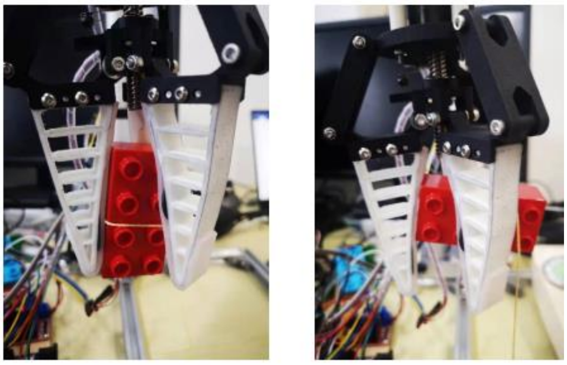
Figure 6: Gripping test tennis ball, weight 59.4g, diameter 6.3cm, 90 hardness gripping success, 30 hardness gripping success.

Table 1: The result of grasping experiments

Weight	Shape	Length	Width	Height	Number of successful hardness 90 grabs/total number of grabs	Number of successful hardness 30 grabs/total number of grabs
3.4g	Ball	2.4cm	2.4cm	2.4cm	1/6	5/6
5.3g	Square	3.2cm	3.2cm	2.3cm	3/6	6/6
60g	Ball	6.3cm	6.3cm	6.3cm	1/6	4/6
12g	Square	6.4cm	2.3cm	3.2cm	5/6	5/6
7.4g	Square	3.2cm	6.4cm	1.3cm	6/6	6/6
3.7g	Square	3.2cm	3.2cm	1.3cm	6/6	6/6
3.2g	Square	3.2cm	1.7cm	2.3cm	6/6	6/6

5.3 90 hardness grip direction test

In order to verify the necessity of the flexible mechanical claw swivel joint, a standard experiment was designed: A force gauge was used to drag a square of weight 12g, size 6.4*3.2*2.3c, gripped by the mechanical claw in the vertical direction by means of a short non-stretchable rope until the square was detached from the claw. The maximum pulling force during the process is recorded as the ultimate pulling force value of the mechanical claw. The following information was obtained through five repetitions of the experiment. The mechanical claw can provide an average ultimate pulling force value of 2N with the square in the horizontal position. In the vertical case, the mechanical claw can provide an ultimate pulling force value of 3N. The influence of the gripping direction on the gripping strength can be seen. We think it is because the tighter the claw is closed, the tighter the grip is because the vertical gripping claw is much more closed. As is shown in Fig.7. The result is shown in Table 2.



(a) Vertical grab *(b) Horizontal grab*

Figure 7: Gripping strength test chart

Table 2: The experiment result of mechanical claw swivel joint

Times	1	2	3	4	5	6	Mean value
Horizontal	2N	2N	2.5N	1N	3N	2N	2N
Vertical	2.5N	5N	4N	2.5N	2N	2.5N	3N

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5.4 90 hardness ultimate pull test

In order to test the ultimate pulling force of the flexible mechanical claw, a standard experiment was designed: a force gauge was used to drag the ball held by the mechanical claw through a short unstretchable rope in the vertical direction until the ball was detached from the claw, and the maximum pulling force during the process was recorded as the ultimate pulling force value of the mechanical claw. In comparison to the average tension value of 3N for the square in the previous set of experiments, it can be seen that the small ball performs much better. This is mainly because the small ball is smaller, which allows the claw to close more tightly and allows the claw to grasp more tightly. As is shown in Fig.8. The result is shown in Table 3.

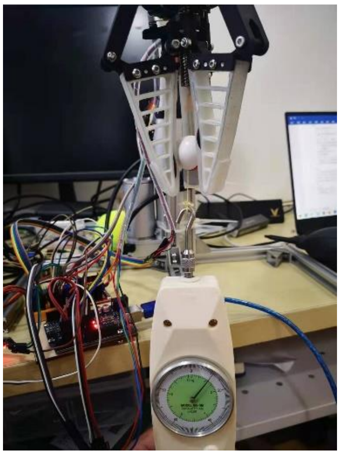

Figure 8: Small ball gripping strength test

Table 3: The experiment result of mechanical claw

Time	1	2	3	4	5	6	Mean value
Ball	7N	10N	12N	12N	11N	10N	10N
Square(vertical)	2.5N	5N	4N	2.5N	2N	2.5N	3N

5.5 30 hardness limit pull test

In order to test the ultimate pull of the flexible mechanical claw, a standard experiment was designed: using a force gauge in the vertical direction through the non-stretchable short rope dragged by the mechanical claw grip of the square until the square was detached from the claw leisure, recorded the process of the maximum pull, then the ultimate pull value of mechanical claw. By repeating the experiment five times, the following information was obtained, the mechanical claw can provide an average of 3N ultimate pulling force value. It can be seen that the gripping strength of 30 hardness is the same as that of 90 hardness. Compare the value of the average pulling force of 3N for the square in the last set of experiments.

6. Conclusions

In this paper, we propose a new self-adjusting mechanical claw flexible fin structure to achieve the goal of three degrees of freedom for each finger and a better fit on the object surface. But up to this point, the study only detailed the design of the mechanical structure. For the control, industrial design only preliminary planning, which is still in the process of further improvement.

Because 90 hardness fingertip hardness is too hard, deformation is limited, while 30 hardness fingertip is too soft, deformation is larger, resulting in the object will fall directly when grasping, but solving the problem of insufficient stepper motor torque. This is because the insufficient torque is compensated by the fingertip deformation. Therefore, the next study is expected to focus on adjusting the fingertip hardness. At present, we are considering trying 60 hardness and 45 hardness fingertips and selecting the material that is moderately hard and soft. It can grasp more powerfully and steadily and, at the same time, can also fit the surface of the object well so as to achieve the original purpose of grasping fragile and shaped objects without causing damage.

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