Mini-Project 02 Report

Design, analysis, and prototyping of a robot arm

Group Name: Group 14

Members

Name: Chen Rui ID: 515370910261

Name: Lu Changqing ID: 515370910192

Name: Ren Xuesong ID: 515370910154

Name: Teng Muwei ID: 515370910161

1. Design of a robot arm with syringe-based hydraulic actuation

We use UG software to draw a sketch on our robot arm. The sketch and the detailed information are shown in Fig.1, Fig.2, and Fig.3. The full dimensions used to draw the sketch is shown in Fig.4, some of the dimensions are not that important and they will not affect the whole system performance.

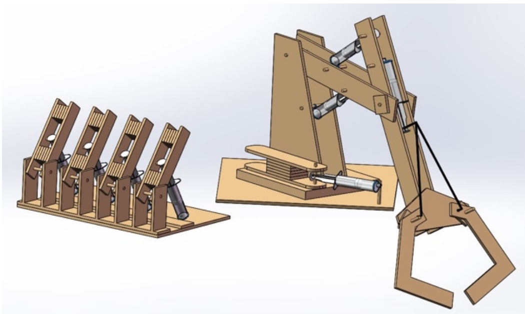

Figure 1. Overview of the prototype.

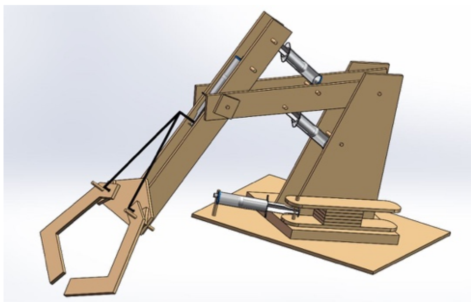

Figure 2. Our robot arm.

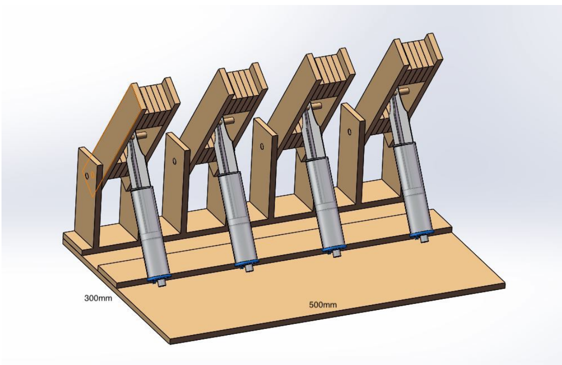

Figure 3. 300mm*500mm Controller platform.

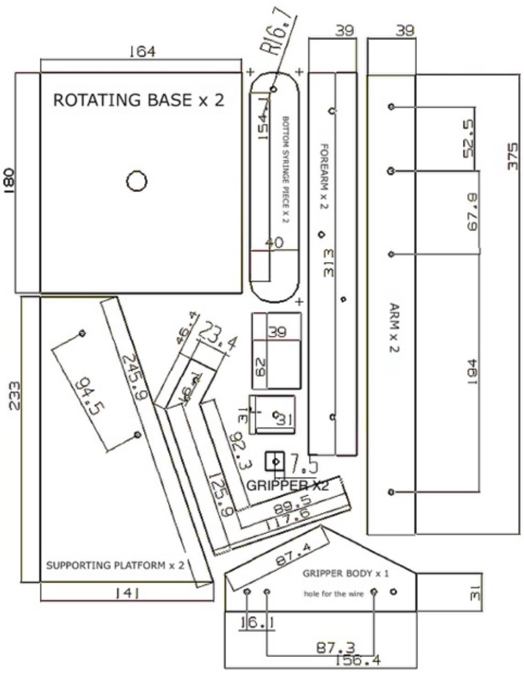

Figure 4. Full dimensions for sketch(mm).

2. Analysis of its motion

2.1 Gripper part

The gripper part consists of four links as shown in Fig.5, where L2 is the syringe, L3 is 2mm wire steel, L4 is the wood block, and L1 is the triangle wood block that acts as the ground of the claw part. There are also four joints. Joint A is grounded translating joint. Joint B and Joint C are moving rotating joint. Joint O is grounded rotating joint. Its mobility is calculated to be 1. This part is utilized to stretch or to close the gripper.

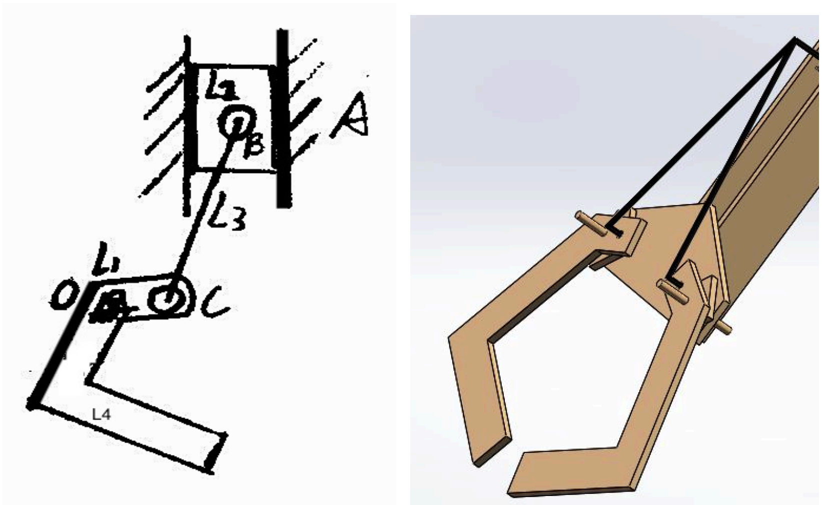

Figure 5. Kinematic diagram of gripper part.

2.2 Two arm rotating parts

This part consists of four links as shown in Fig.6, where L1 is the ground, L2 is the cylinder tube of the syringe, L3 is the piston of the syringe, and L4 is a wood block. The linkage has four joints. Joints O1 and O2 are grounded rotating joint, joint A is a moving translating joint, and joint B is a moving rotating joint. The mobility of the linkage is 1. This part is used to rotate an arm for a certain amount. There are two such linkages in our device, and each linkage controls one arm in the device independently.

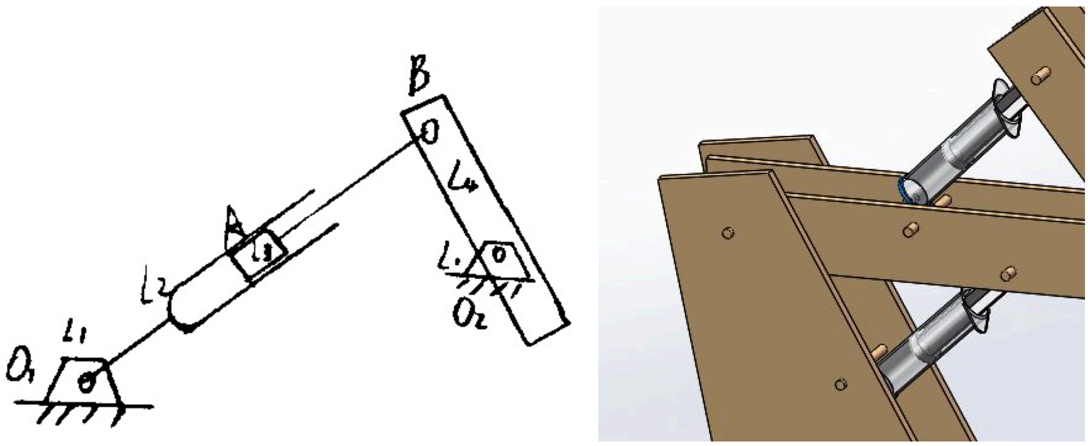

Figure 6. Kinematic diagram of Arm rotating part.

2.3 Base rotating part

This rotator part has four links and four joints as shown in Fig.7, where L1 is the ground, L2 is the cylinder tube of the syringe, L3 is the piston of the syringe, and L4 is a wood base of the device. Joints O_1 and O_2 are grounded rotating joint, joint A is a moving translating joint, and joint B is a moving rotating joint. The mobility of the linkage is 1.

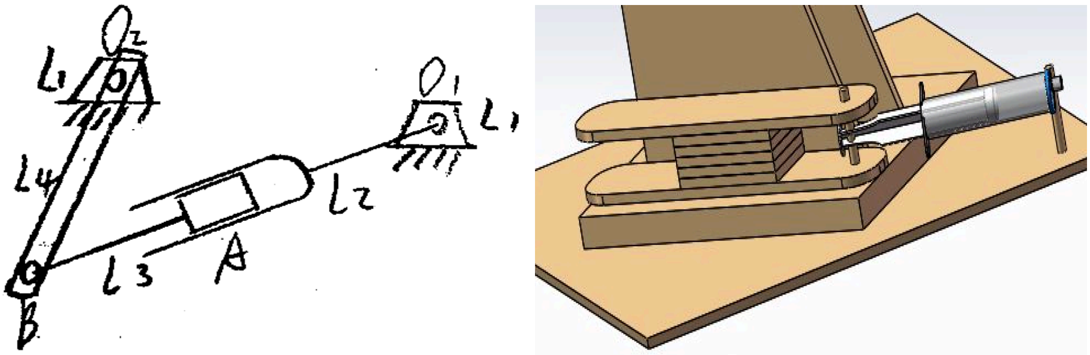

Figure 7. Kinematic diagram of base rotating part.

3. Discussion

3.1 Technical Problems

The first problem is that the motion of the gripper is asymmetric. One side of the gripper requires more torque to rotate by the same angle. As we can see from Fig.8 for the mechanism of the gripper. Theoretically, the mechanism is symmetric about the centerline. The input is a single force F along the centerline. The force is then transmitted by the thin steel wires. The force component F'_{normal} is responsible for providing the torque to rotate the gripper arm. There are two types of reasons that might cause two arms to move asymmetrically.

The total force F is not along the centerline. This will result in F' on both sides have different magnitude, which will result in different F'_{normal} magnitude on two sides. Since the torques provided for two sides are different, the arms will have different motion.

The torques required to rotate the arms by the same angle are not the same due to manufacturing. Therefore, even if the force F is aligned with the centerline and the forces are transmitted symmetrically, since the torques required are not the same, the arms will have different motion.

Essentially, the asymmetric motion of two gripper arms is caused by two types of reasons, asymmetry in forces provided and asymmetry in linkages and joints. These reasons are coupled with each other. To eliminate the problem, we need to make sure both types of asymmetry are eliminated.

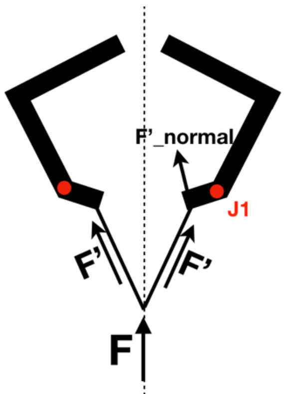

Figure 8. Gripper Mechanism

The second problem is that the ends of the gripper fail to adapt to objects with different shapes. On the prototype we manufactured, the ends of the gripper arms are single layer of corrugated paper. Due to the accuracy of manufacturing, the ends of the arms may not in the same height. Therefore, they will introduce a moment on the object being gripped, causing unintended rotation of the object as shown in Fig.9.

Figure 9. Object Unintended Rotation

The third one is that same input distance of the syringes results in different rotation angle of the degree of freedom under control. Four hydraulic actuators of this systems are constructed using pairs of syringes of the same size. As Fig.10 shows, the displacement of the output will be the same as the displacement. However, after prototyping the robot arm, we've found that the range that each linkage needs to cover is not the same. With the same input displacement of the syringe, the rotation angle of each linkage is different. This adds difficulty to controlling the system since the operator needs to take the different ratios between the input displacement and the output rotation angle into consideration.

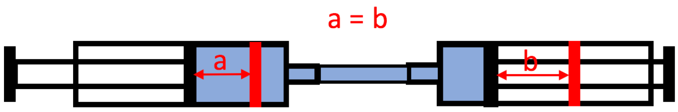

Figure 10. Hydraulic Actuator

3.2 Purposed Correction

To eliminate the asymmetry of the system, symmetry of each part should be guaranteed during manufacture. For example, the lengths of the steel wires on two sides should be the same. The position of the gripper system should be placed along the centerline of the entire robotic arm system. The bushing pieces placed at the joints needs to be adjusted so that they provide the approximately the same amount of friction while the linkages are rotating.

To help stabilize the objects being grabbed, another two pieces can be added as shown in Fig.11. These parts can increase the contact area between the grabber and the object and therefore providing more friction. Also, it can eliminate the effect of moment generated due to the different height of two arms because the increased contacting areas can generate a counter-moment itself now.

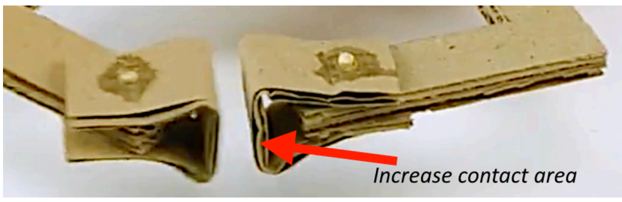

Figure 11. Increase Contact Area of the Grabbing Arms

To help the operator gain a better idea on the extent of rotation for different linkages, we can calculate the ratio between the input and the output that is “user-friendly” and change the hydraulic actuator into syringes that have different cross-section as shown in Fig.12. As we can see from the figure, when the left syringe input displacement of c, the output syringe has a displacement of d, which allows us to change the input and output ratio.

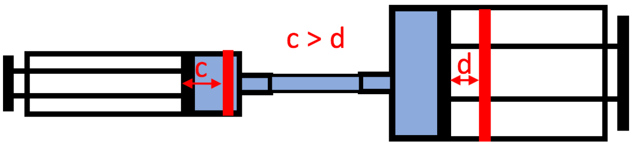

Figure 12. Improved Hydraulic Actuator

3.3 Design Iteration

To eliminate the asymmetry of the prototype, we adjusted the length of the steel wires and improved the motion of the arms to a certain extent.

Due to limited time and resource, the purposed correction on the syringes cannot be achieved but the idea is promising to increase the user-friendliness of the robotic arm.

4. Contribution

Chen Rui-prepare the dimensions and making arms and controller, and improving the performance, Lu Changqin-making the gripper and base part, Ren Xuesong-design and making the arms and controller, Teng Muwei- design and making the the gripper and base part.