北京航空航天大學
BEIHANG UNIVERSITY

Design and experimental verification of underactuated prosthetic hand

School of Biological Science and Medical Engineering,
Beihang University

Reporter：Jianan Zhang | corresponding author：Yu Wang

1 ABSTRACT

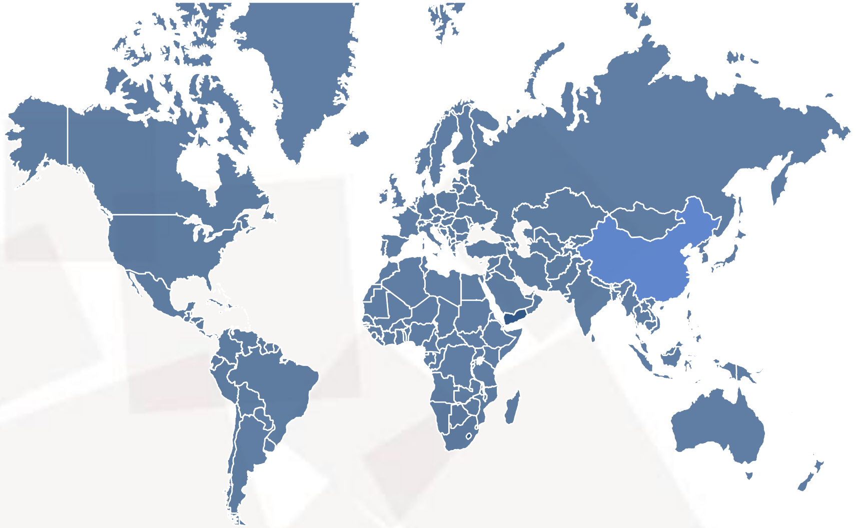
北京航空航天大學 BEIHANG UNIVERSITY

Underactuated prosthetic hand

Underactuated prosthetic hand has attracted growing attention due to its light weight and easy control. In this paper a single linear motor is used to drive the prosthetic hand, and the palm of the hand has three arches similar to that of human hands. Besides a series of experiments were carried out to test the power grasp and the precision grasp function of the prosthetic hand. The factors influencing the success rate of power grasp and the stability of precise grasp are analyzed, and the direction to improve its performance and usability is given.

INTRODUCTION

Reasons for prosthetic abandonment:



- The difference between the perceived needs of ULAs and the functionality of prosthetics.
- Consumers' double high standards for the **form** and **function** of prosthetic hands.

How to achieve dexterous grip control through simple operation form?

- A new underactuated prosthetic hand based on the continuum structure.
- Grip performance test of the prosthetic hand.
- Indicate directions for further optimization of prosthetic hands.

Keywords

The underactuated prosthetic hand has humanlike size with the weight of **273.2g** (excluding power supply and microcontroller development board) and is driven by **a single linear motor.**

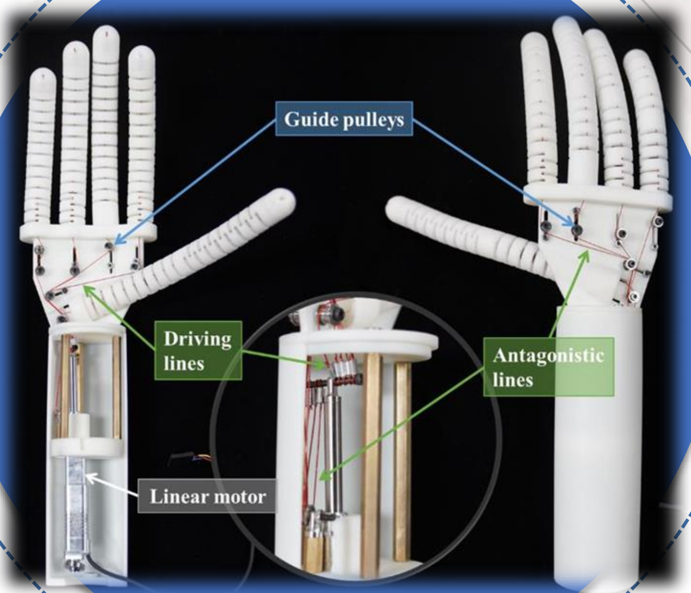


Fig. 2. The underactuated prosthetic hand.

Bionic Palm

Light

Adjustable Stiffness

北京航空航天大學 BEIHANG UNIVERSITY

A. Bionic Palm Design

The palmar concavity results from the formation of three arches that run in different directions as shown in Fig. 1.

Oblique arch
Distal arch
Longitudinal arch

→ Pre-shaping

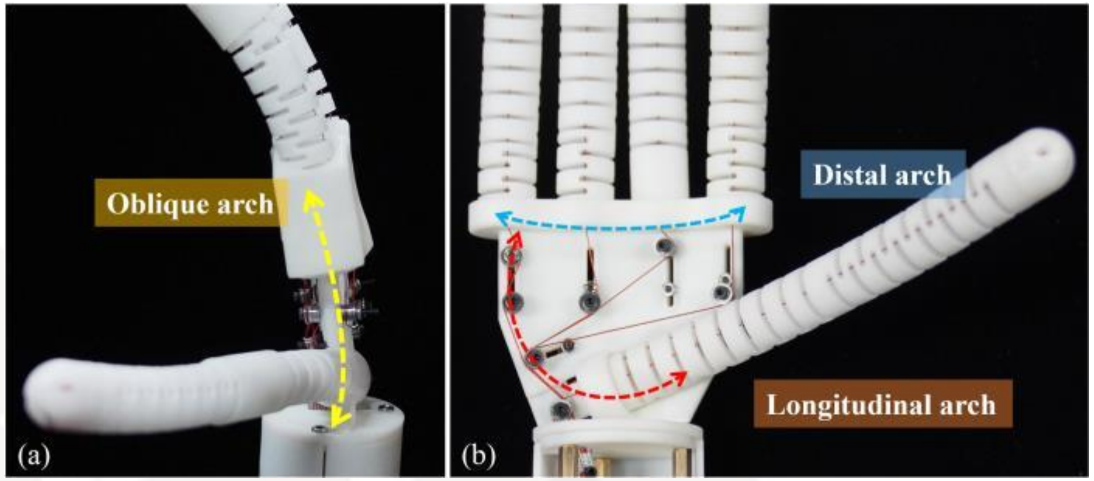


Fig. 1. (a) The yellow line represents the oblique arch of the prosthetic hand. (c) The blue line represents the distal arch and the red line represents the longitudinal arch of the prosthetic hand.

- **The angle of distal arch is set as a fixed value of 140°.**
- **Modulations in longitudinal arch angle is directly related to the outreach movement of the thumb.**
- **The deformation of oblique arch can be observed when applying a load to the prosthetic hand, which is related to the flexibility of the palm material.**

B. Underactuated Structure

The prosthetic hand is driven by a single linear motor, when the finger flexes or extends, the length of the **drive lines and reset lines vary by the same amount**.

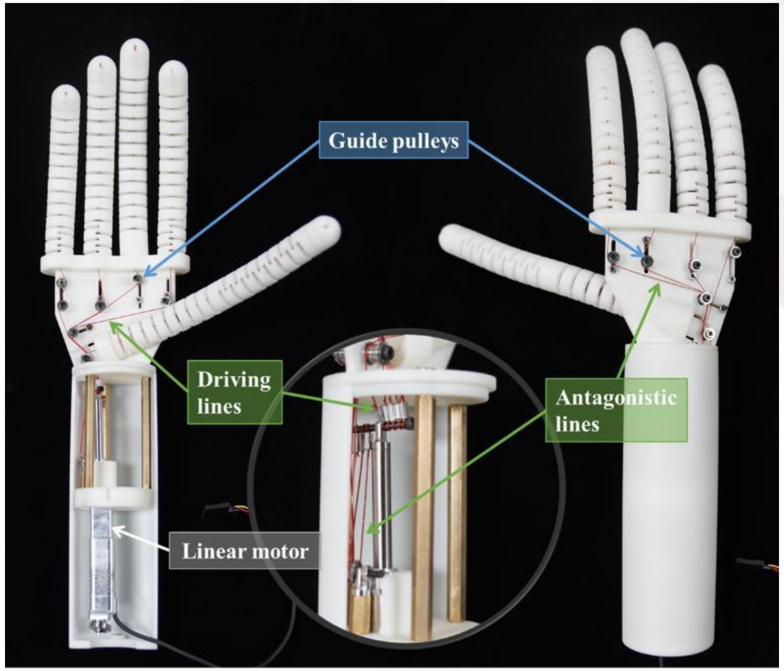


Fig. 2. The underactuated prosthetic hand.

Reset lines’ function:

- Allow the finger to reduce its reset time during extension.
- Ensure that the finger can still maintain its original posture after multiple flexions.
- Provide antagonistic effect—— change the stiffness of the finger.

Functional tests

Power Grasp, Precision Grasp, Fingertip Trajectory

This section will introduce the methods of experiments were conducted to test functions and motion characteristics of the prosthetic hand.

Power Grasp Test

In the experiment healthy subject was asked to use the prosthetic hand to grasp, transfer and place the six objects.

Stability Test of Precision Grasp

Pull the tension sensor horizontally to record the external force when grasping instability and repeat for ten times to take the average value.

Fingertip Trajectory Test

change the displacement of the linear motor, and record the movement track of the fingertips in the opening and closing action.

A. Power Grasp Test

In the experiment healthy subject was asked to use the prosthetic hand to grasp, transfer and place the six objects in Fig. 3. with one hand.

If the object falls during grasping or transfer, it is a failure. It should be noted that only the prosthetic hand is allowed to contact the object during the above operation.

The electromyographic (EMG) sensor is attached to the brachioradialis muscle of the right arm of the subject.

Before the experiment, the subject needs to control the contraction and relaxation of brachioradialis muscle according to the instructions, and a reasonable threshold is set according to the changes of the EMG signal.

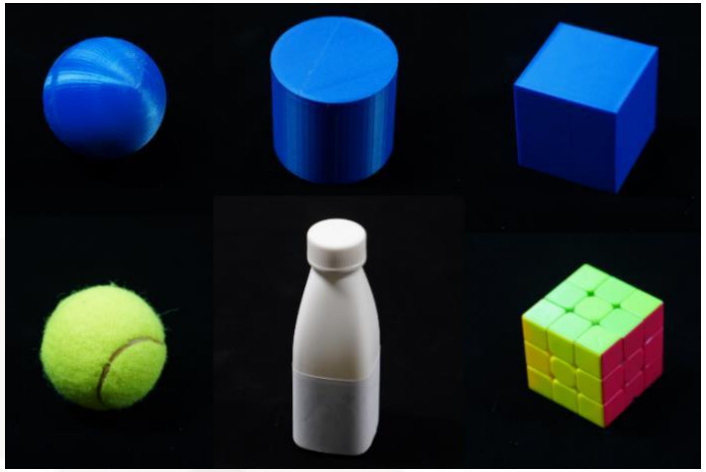


Fig. 3. Six objects selected for grasping test.

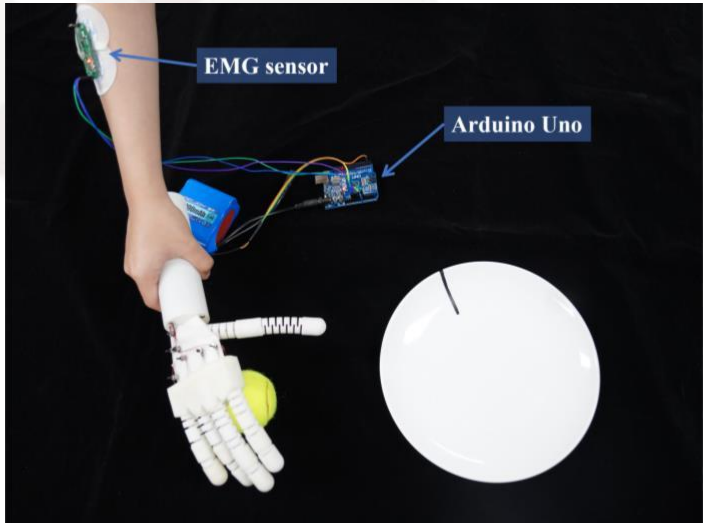


Fig. 4. Subject was using the prosthetic hand to grasp a tennis ball.

B. Stability Test of Precision Grasp

The prosthetic hand is fixed on the experimental platform to accurately grasp a light object (regardless of its gravity). Pull out the object horizontally and record the external force when grasping instability and repeat for ten times to take the average value. Change the displacement of the linear motor and repeat the above experiment.

C. Stability Test of Precision Grasp

As shown in Fig. 5 markers were fixed on the fingertips of the prosthetic hand, and the Polaris Vega® was used to track the position of the markers. Keeping the initial posture of the prosthetic hand unchanged, change the displacement of the linear motor, and record the movement track of the fingertips in the opening and closing action.

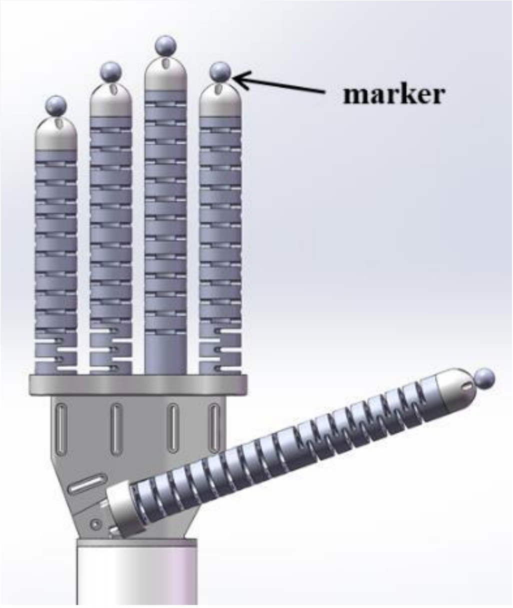
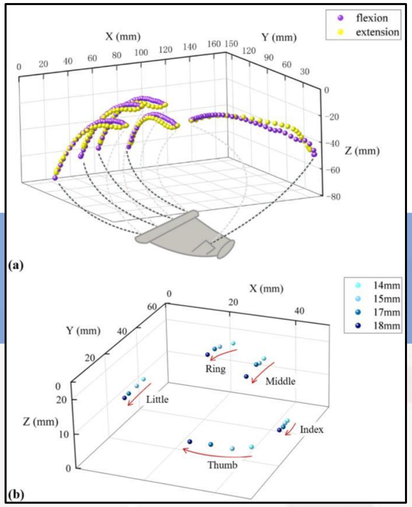
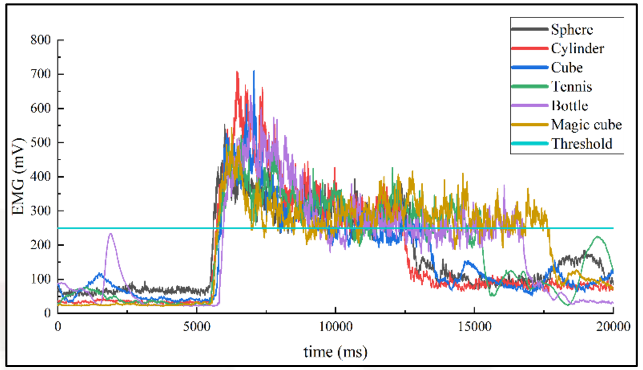


Fig. 5. Placement of markers on each finger of the prosthetic hand.

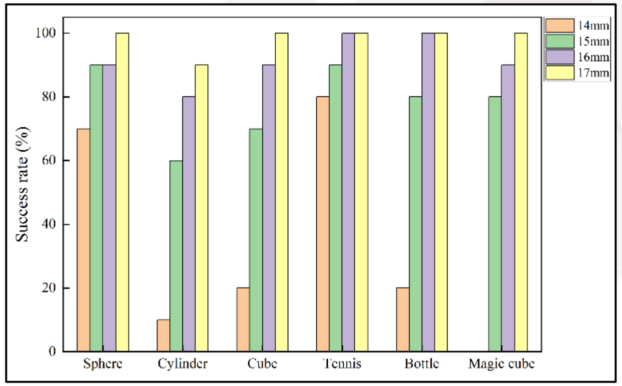
5 RESULT AND DISCUSSION

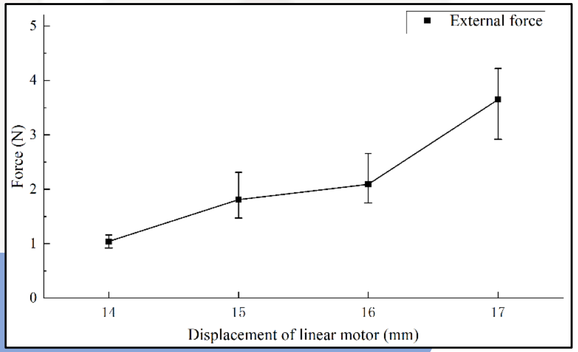
北京航空航天大学
BEIHANG UNIVERSITY





Results &
Discussion





After the experiment, the experimental results were summarized and discussed to analyze the future direction of prosthetic hand optimization.

A. Kinematic Characteristics of Prosthetic Hand

- In actual movement, the friction force on the driving lines will lead to the low coincidence of the motion trajectory of the thumb fingertip in the reciprocating movement.
- The initial and final fingertip positions of the prosthetic hand remain basically unchanged after several open and close movements.
- The fingers are more gathered while the bending degree increases, which is consistent with the motion characteristics of the human hand.

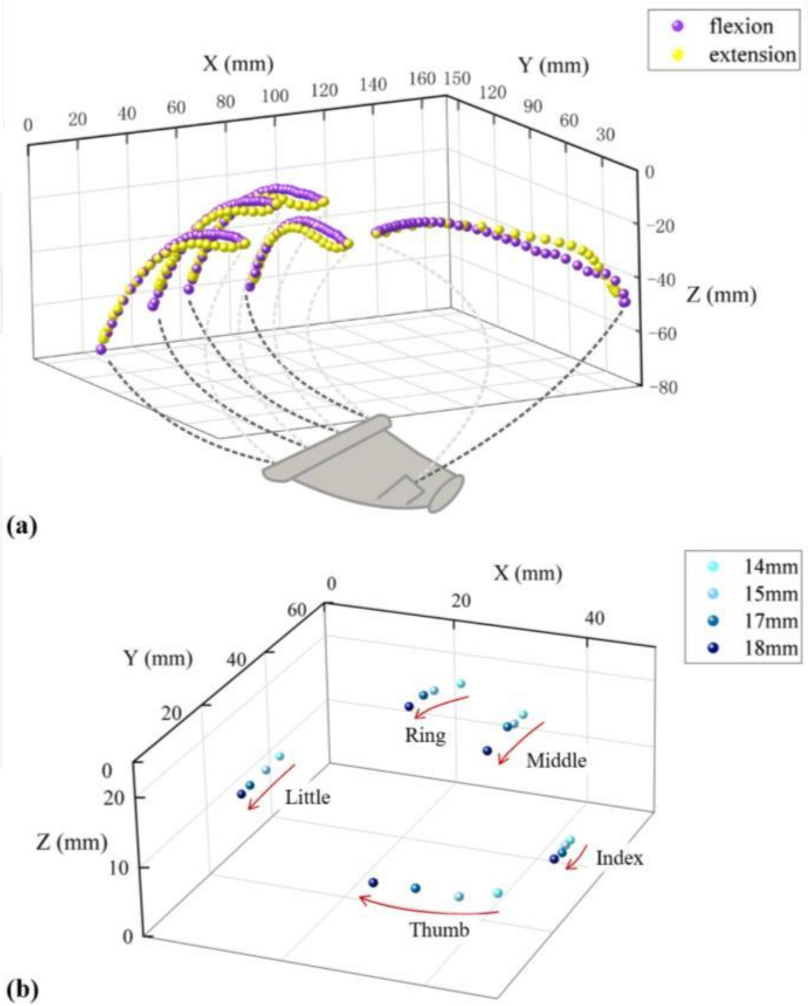


Fig. 6. (a) The opening and closing trajectory of the fingertip. (b) Convergence of fingertip position during sustained flexion.

B. Success Rate of Power Grasp

- The grasping success rate increases with the increase of linear motor displacement.
- Increasing the convergence of the finger of the prosthetic hand can improve the success rate of power grasping.
- With the traction of the driving line, both fingers and palms will produce elastic deformation.
- Improving the compliance of EMG control and reducing the operation burden of users are the key to improve the availability of prosthetic hand in the future.

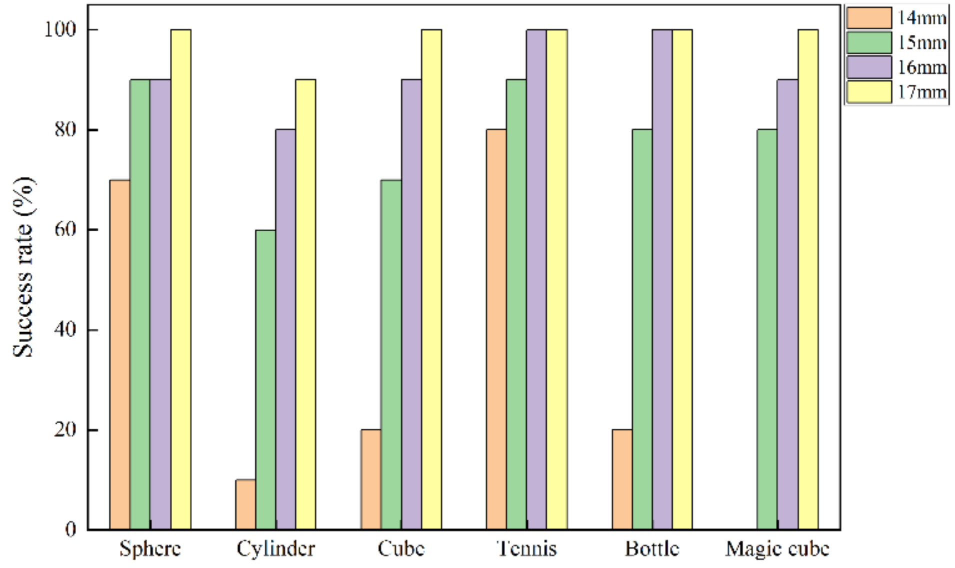


Fig. 7. The grasping success rates of six experimental objects corresponding to different displacements of linear motor.

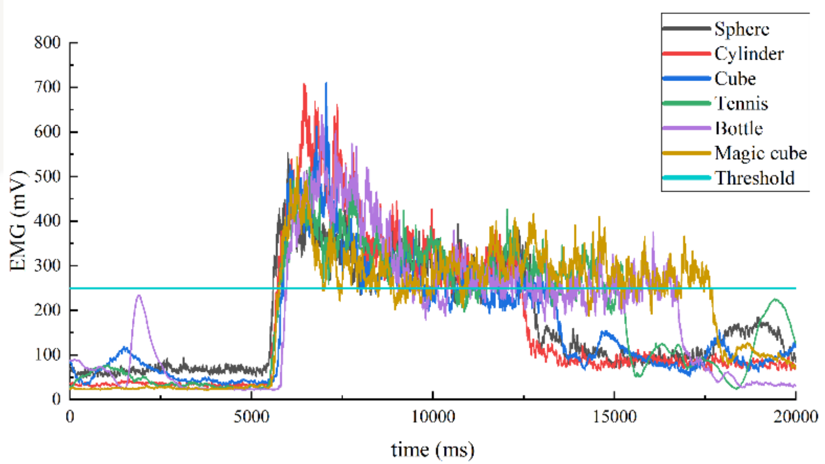


Fig. 8. Electromyography in six object grasping tests.

C. Stability of Precise Grasp

- The precision grip stability of the prosthetic hand increases significantly, which is related to the stiffness change of the finger during flexion.
- The deformation of the finger from the non-grasping state to the grasping state is the source of the positive pressure exerted by the fingertip on the object.
- Improving the stiffness of the prosthetic hand is conducive to improving the stability of accurate grasping.

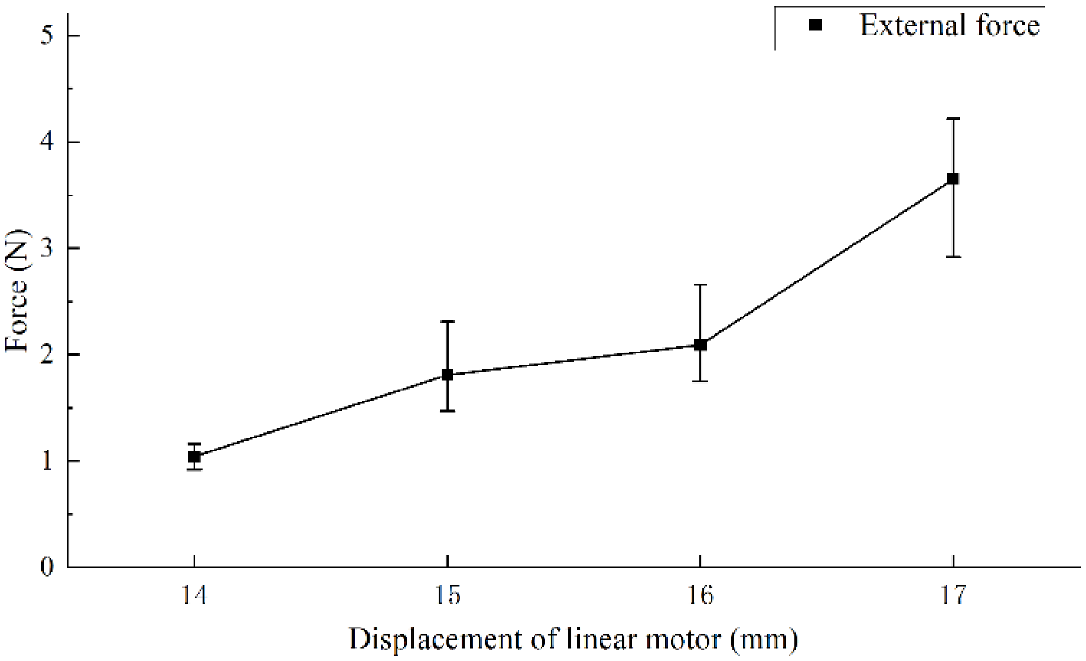


Fig. 9. External force when precise grasping is not stable.

北京航空航天大学 BEIHANG UNIVERSITY

- The above design reduces the weight of the prosthetic hand and makes it more convenient for ULAs to use.
- To further improve the grasping performance of the prosthetic hand, the stiffness of the finger needs to be adjustable to improve the compliance of the prosthetic hand to the stiffness of the grabbed object.
- The optimization of prosthetic hand in the future also includes improving the compliance of EMG control to reduce the operation burden of ULAs.
- The actuation would be improved by using a high torque steering motor to make the structure compact.

CONCLUSION

北京航空航天大學
BEIHANG UNIVERSITY

THANKS FOR LISTENING

THANKS TO RCAE