Final Year Project Presentation—

Robot-guided muscle stretching to measure the range of motion

Student: Guozhi Tang

GUID: 2109630T

CONTENTS

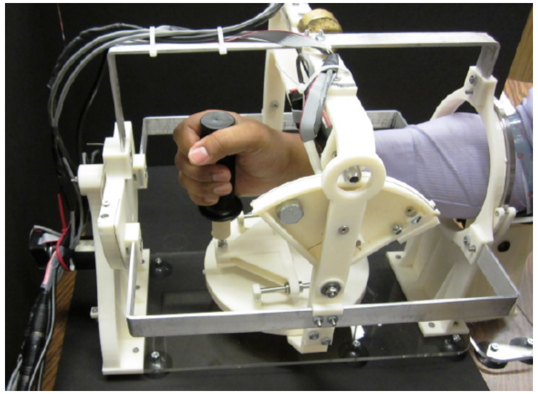
01

Introduction & Literature Research

Problem

A person's range of motion at a joint can be negatively affected by injury, illness, or lack of use.

Current



[1]

Physical therapy is usually necessary to maintain or expand the range of motion.

Barriers

- Some patients are unable to actively participate in the measurement or follow a regiment of exercises because of their affected joints
- The cost of regular appointments and the time required for such kind of appointments

Thus, a type of project which could help patients to recover their negatively affected joints physically and could be operated at anywhere is necessary to be designed.

Experimental Subject: Wooden prosthetic hand

Microcontroller Unit: Arduino Uno R3

Gyroscope module MPU6050

To measure the angle/acceleration/angular velocity in three dimensions.

Gear motor with a Turbo-Worm structure

To move the wooden wrist structure with low revolving speed and large torque.

3-D printing on SOLIDWORKS

To design and fabricate the outer structure for the project.

Motor driver module L298N

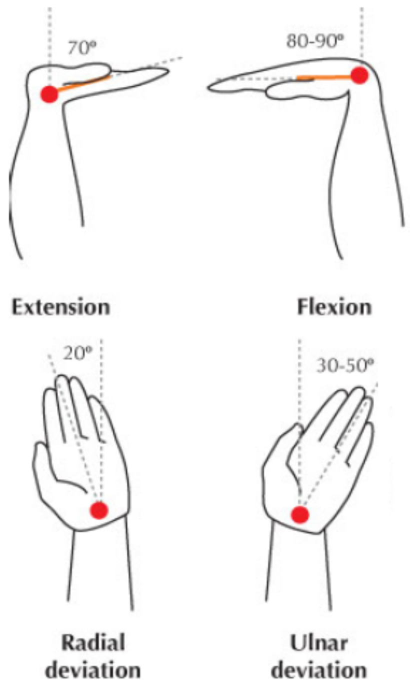
To control and drive the motor (two motors can be driven at the same time).

1960s	1970s	1980s	1990s	2000
CASE operating robot hand	Johns Hopkins University Work Station and Ruprecht-Karls-Universität Heidelberg Work Station cooperated a “Spatacus” Program	De VAR Work Station	“TIDE” Program	MAID
		Cobra RS	Wheelesley Wheelchair	WASTON Exoskelectons
		MANU Arm	ISAC Program	KARES
		RTX Arm	RAIL Arm	Care-0-bot
		“Mater” Program		MATS Smart Chair
		“HANDY1” Program		RFID
				OMW

[2]

Question 1:
Rotation Range?

- Give rotation range measured by gyroscope when designing the Feedback System



[3]

Question 2:
Torque demanded to move the wrist?

- Give exact torque demanded for the motor.

1. 1760*16=28160mNm=28.16Nm
2. $3.77 \times 10^6 Nm$

Reduction ratio: motor: 1:298 (50rpm)

Turbo-Worm: 1:30 ($50 \div 30 = 1.67$ rpm)

Axis	Peak Output Torque (mNm)	Sensor Resolution with Quadrature (deg)	Remarks
Forearm Pronation/Supination	191*15=2865	0.012	Actuator: Maxon Motor RE40 Encoder: Avago HEDL 5540 500CPR Cable drive gear ratio: 15:1
Wrist Flexion/Extension	110*16=1760	0.01125	Actuator: Maxon Motor RE35 Encoder: Avago HEDL 5540 500CPR Cable drive gear ratio: 16:1
Wrist Adduction/Abduction	110*16=1760	0.01125	Actuator: Maxon Motor RE35 Encoder: Avago HEDL 5540 500CPR Cable drive gear ratio: 16:1

[2]

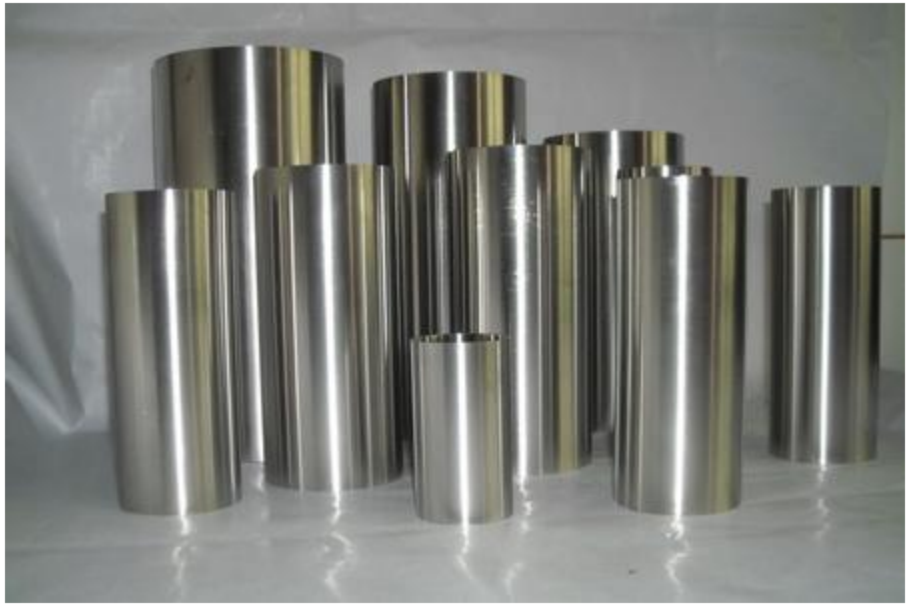
02

Materials and Methods

◆2.1 Materials Selection

PLA (Polylactic Acid)

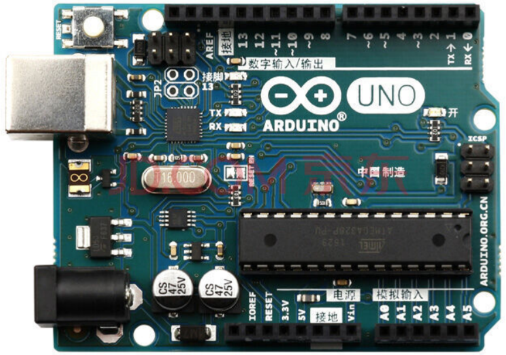
steel No.45 (British BS standard steel IC45)



02 Materials and Methods

◆2.2 Devices Selection

MCU (Microcontroller Unit)

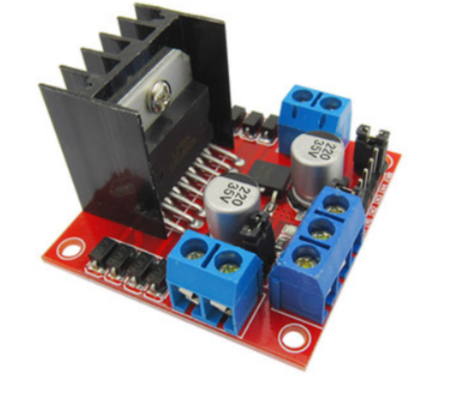


[4]

Prosthetic Hand

Electronic Gyroscope

Motor Driver



Motors

[5]

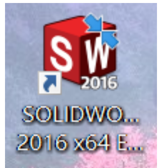
Power Supply

02 Materials and Methods

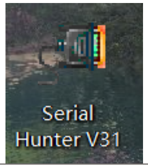
◆2.3 Software Selection

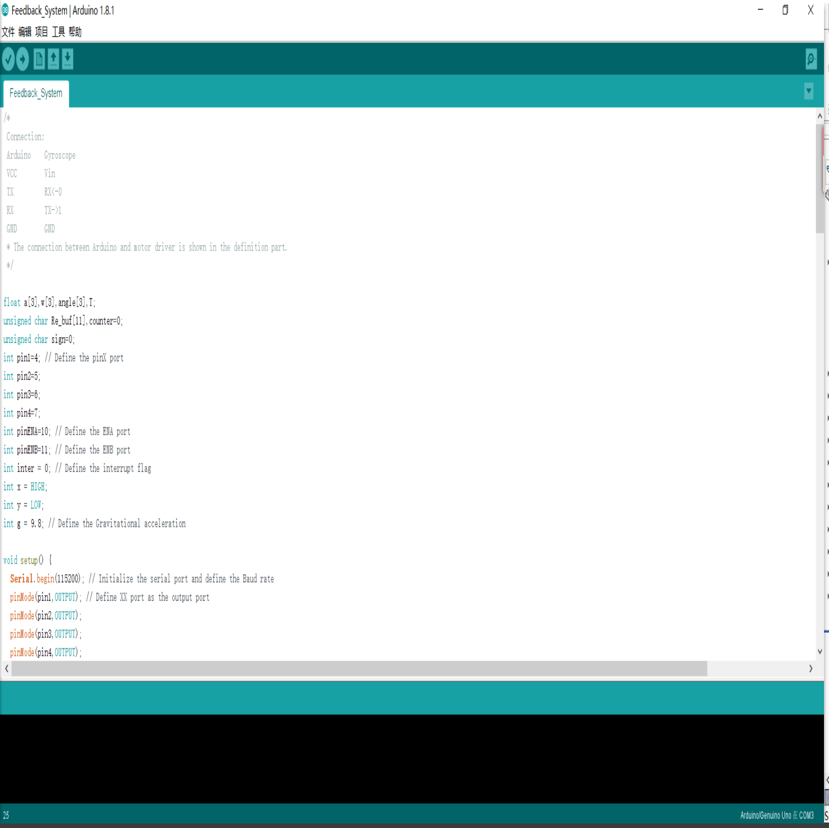
Arduino Compiler

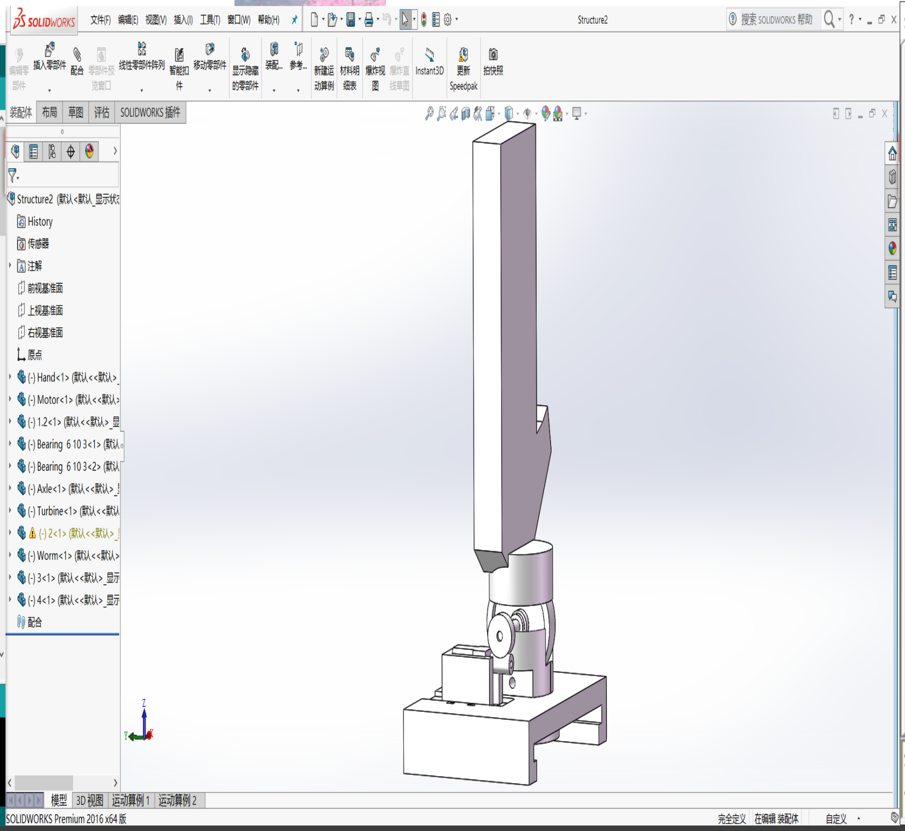
SOLIDWORKS

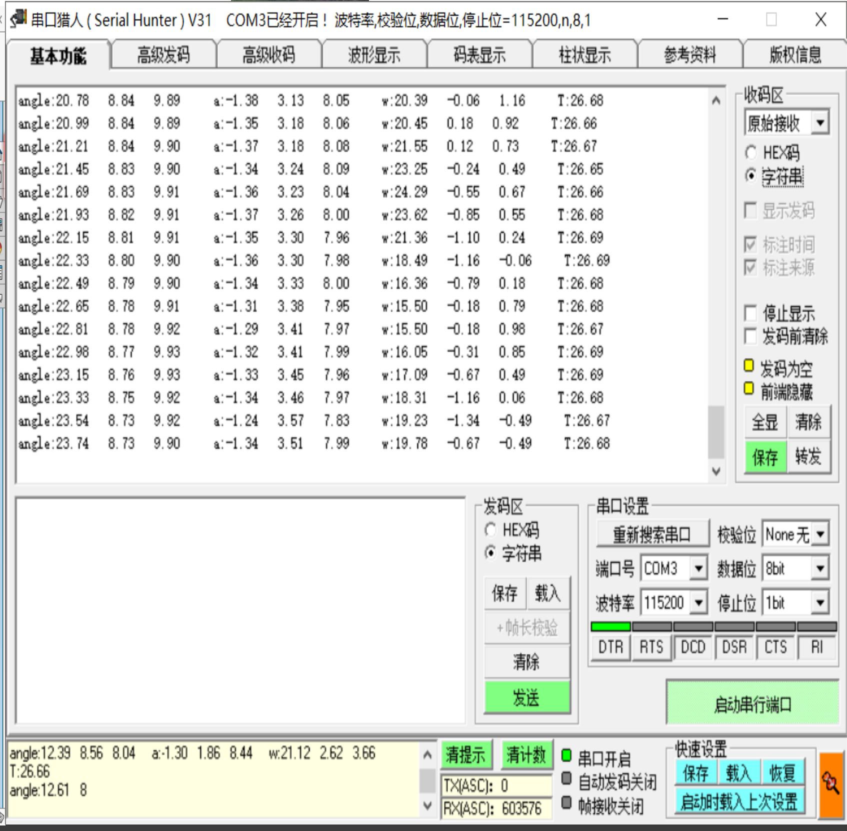


Serial Hunter









◆2.4 Method Selection

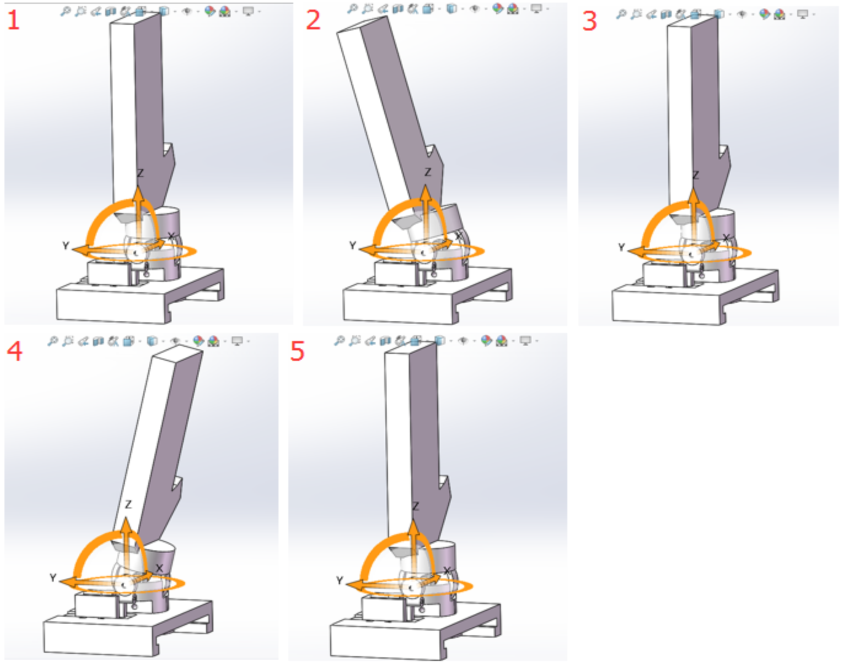
Bang-bang Control

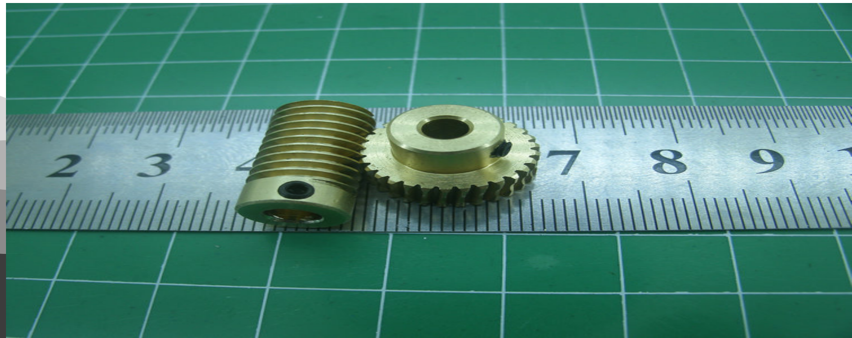
```
int x = HIGH;
int y = LOW;

void motor(){
  digitalWrite(pin1,y); // Let the motor1 rotates in clockwise (counterclockwise) direction
  digitalWrite(pin2,x);
  analogWrite(pinENA,220);

  if (angle[0] <= minimum angle){
   x = !x;
   y = !y;
   digitalWrite(pin1,y); // Let the motor1 rotates in counterclockwise (clockwise) direction
   digitalWrite(pin2,x);
   analogWrite(pinENA,220);
  }

  if (angle[0] >= maximum angle){
   x = !x;
   y = !y;
   digitalWrite(pin1,y); // Let the motor1 rotates in clockwise (counterclockwise) direction
   digitalWrite(pin2,x);
   analogWrite(pinENA,220);
  }
}
```

C Programming

- Interrupt
- Bang-bang Control
- Motor Driver
- Gyroscope

Mechanic Structure



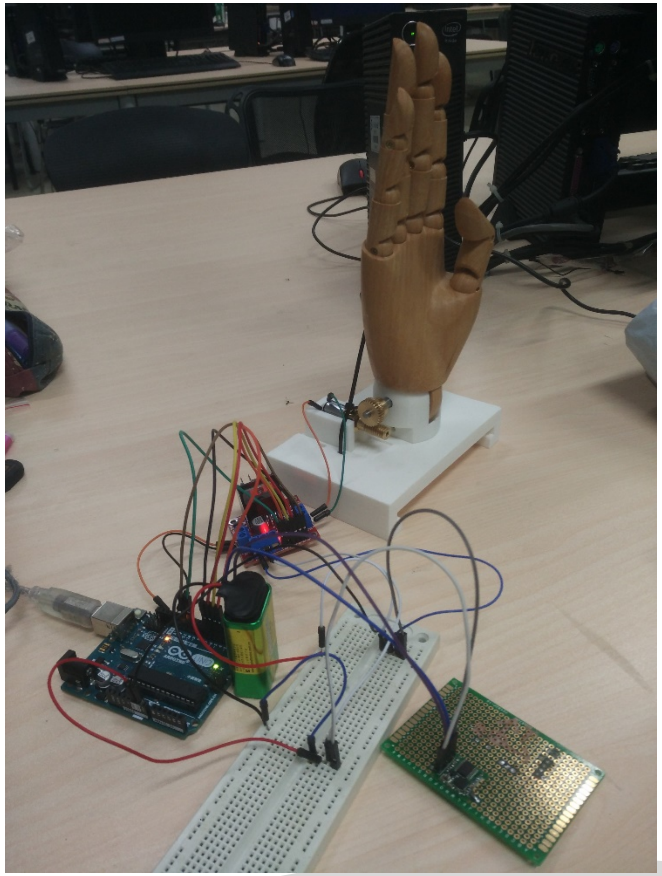


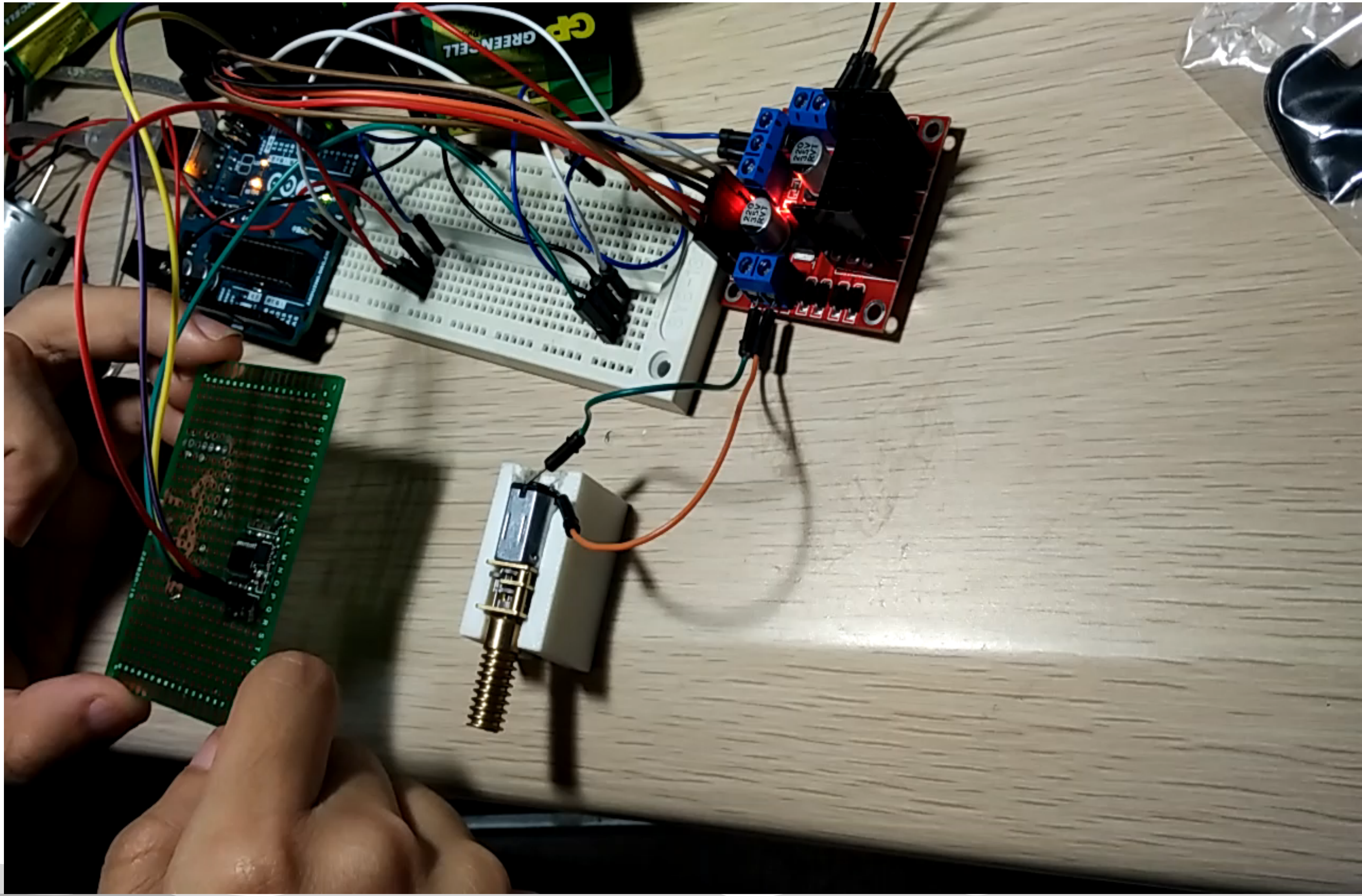
03

Results

03 Results

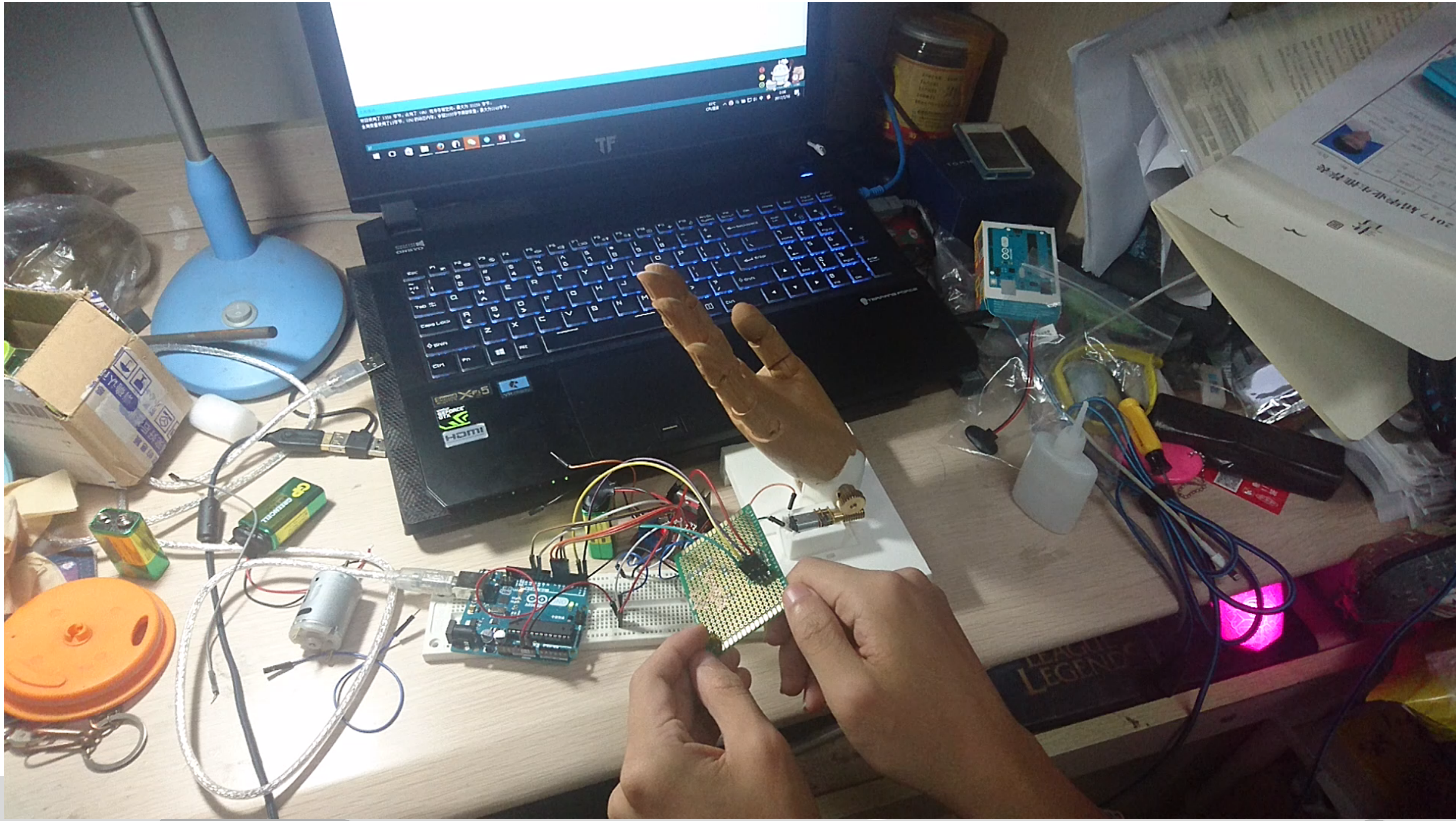
◆3.1 Practical Structure





03 Results

◆3.1 Practical Structure

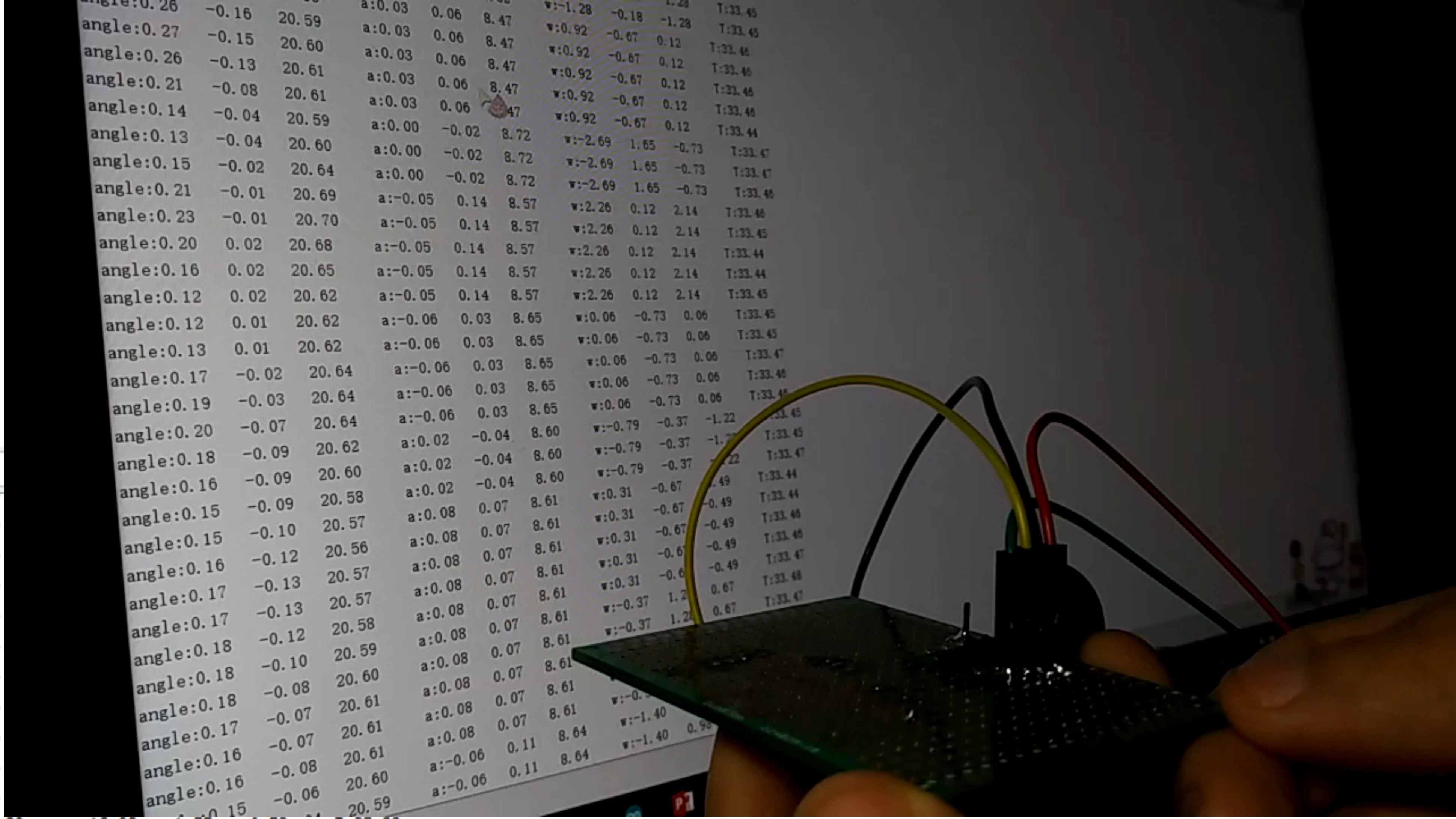


03 Results

◆3.2 Measurement

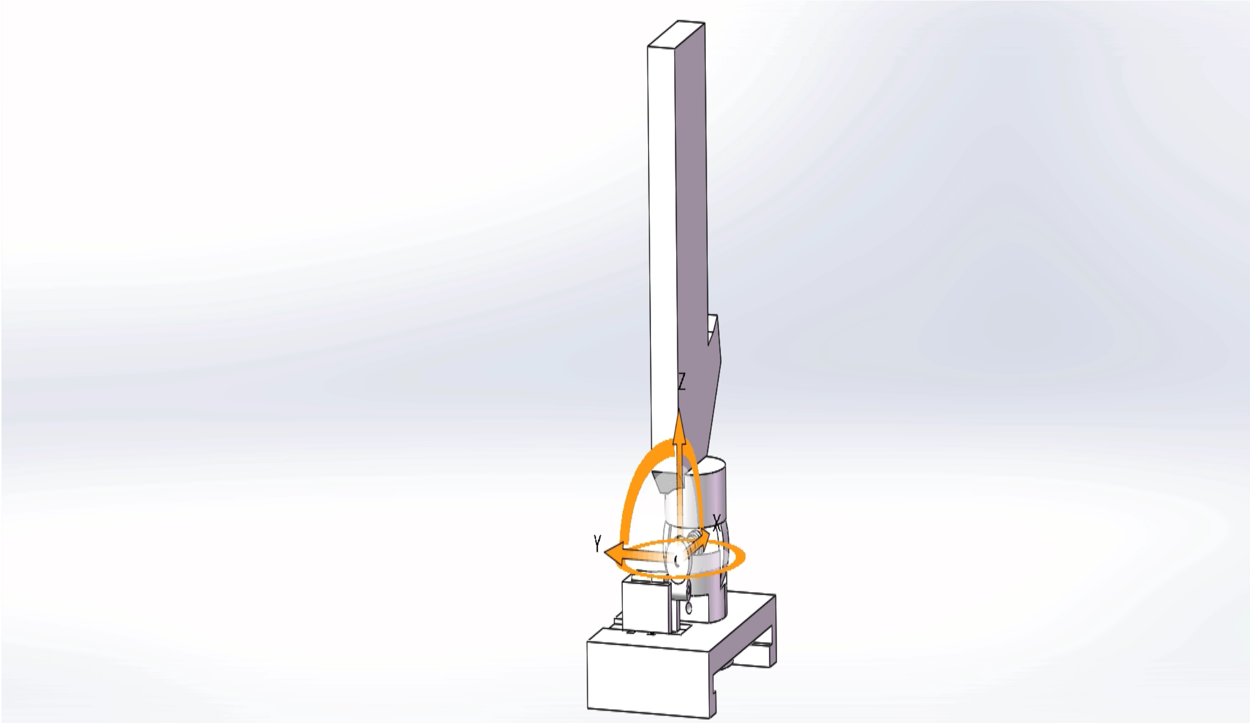
COM3 (Arduino/Genuino Uno)

angle:17.97	-4.15	24.49	a:0.62	2.75	8.				
angle:18.17	-4.14	24.49	a:0.64	2.76	8.				
angle:18.35	-4.12	24.49	a:0.64	2.79	8.				
angle:18.51	-4.10	24.49	a:0.61	2.83	8.				
angle:18.64	-4.10	24.49	a:0.63	2.85	8.				
angle:18.75	-4.10	24.49	a:0.65	2.87	8.				
angle:18.85	-4.11	24.49	a:0.63	2.89	8.				
angle:18.95	-4.13	24.48	a:0.65	2.88	8.				
angle:19.07	-4.15	24.46	a:0.63	2.93	8.				
angle:19.19	-4.16	24.44	a:0.65	2.92	8.				
angle:19.34	-4.18	24.43	a:0.65	2.90	8.29	w:13.98	-1.77	-0.73	T:25.32
angle:19.48	-4.18	24.43	a:0.64	2.92	8.25	w:14.83	-0.24	0.37	T:25.33
angle:19.63	-4.19	24.44	a:0.62	2.93	8.21	w:14.95	0.06	1.10	T:25.32
angle:19.78	-4.19	24.46	a:0.63	2.99	8.26	w:14.47	-0.18	1.65	T:25.32
angle:19.92	-4.20	24.48	a:0.65	3.04	8.21	w:13.79	0.06	1.83	T:25.32
angle:20.06	-4.20	24.49	a:0.66	3.06	8.18	w:13.79	0.18	1.65	T:25.33
angle:20.20	-4.21	24.50	a:0.67	3.12	8.16	w:14.16	-0.37	1.10	T:25.34
angle:20.36	-4.22	24.50	a:0.64	3.09	8.16	w:14.89	-1.28	0.12	T:25.33
angle:20.49	-4.29	24.48	a:1.35	2.48	8.13	w:16.66	-2.01	-0.67	T:25.33



03 Results

◆3.3 3-D Printing Structure



◆3.4 Data Storage

04

Discussion

04 Discussion

◆4.1 Comparison between the History and My Project

- Does not have much advanced technology as other scientists or work stations do.
- A simple structure just like a conceptual model.
- Only can do the measurement and rehabilitation for the wrist in the extension and flexion direction.
- Has necessary basic functions for specific recovery exercises

◆4.2 Learn from the Materials Selection

- The weight of the material
- The hardness of the material.
- The smoothness which would decide the wear capacity.
- The price of the material.

◆4.3 Comparison among Composite Metal and Composite Nylon

- The structure is worn on the wrist, but composite metal is too heavy.
- The composite is very hard and firm, although the ductility of it is not so good, it could be a material with long working life.
- The smoothness of the composite could also be guaranteed.

05

Conclusion and Future Work

05 Conclusion and Future Work

◆5.1 Advantage

- The whole weight is very light and it is very convenient to be carried while nearly all the fundamental functions can be found on it.

◆5.2 Drawbacks

- The device could only rotate in one direction.
- The bearing could not go through a real person's wrist
- The revolving speed of the motor could not be adjusted intelligently.

◆5.3 Future Work

- The structure could be adjusted to realize the measurement and training in other dimensions
- The bearing structure could be adjusted to fit a real person's wrist and hand
- Do the improvement in the code to let the motor driver could adjust the revolving speed intelligently with the help of the negative feedback
- A glove made from elastic materials could be applied when it is applied to the real person's wrist and hand.

06

References

[1] Martinez, J. A., Ng, P., Lu, S., Campagna, M. K. S., & Celik, O. (2013). Design of wrist gimbal: a forearm and wrist exoskeleton for stroke rehabilitation. , *2013*(2013), 1-6.

[2] 王欣宇. (2009). *基于人机工程学的手臂康复训练机构的研究*. (Doctoral dissertation, 长春理工大学).

[3] Hassanin, A. F., Steve, D., & Samia, N. M. (2016). Wrist rehabilitation exoskeleton robot based on pneumatic soft actuators. International Conference for Students on Applied Engineering (ICSAE) (pp.20-21). IEEE

[4] Arduino Uno Boards (2017)[Online]. Available: http://www.arduino.org/products/boards/arduino-uno, Accessed on: April.28,2017.

[5] Tao Bao, "Datasheet for GA12-N20 gear motor,"2016. [Online]. Available: https://item.taobao.com/item.htm?spm=a230r.1.14.27.vJXvTE&id=525167243889&ns=1&abbucket=20#detail.

07

Appendix

07 Appendix

➢Total Code for the Project

```
VCC     Vin
TX      RX<-0
RX      TX->1
GND     GND
* The connection between Arduino and motor driver is shown in the definition part.
*/

float a[3],w[3],angle[3],T;
unsigned char Re_buf[11],counter=0;
unsigned char sign=0;
int pin1=4; // Define the pinX port
int pin2=5;
int pin3=6;
int pin4=7;
int pinENA=10; // Define the ENA port
int pinENB=11; // Define the ENB port
int inter = 0; // Define the interrupt flag
int x = HIGH;
int y = LOW;
int g = 9.8; // Define the Gravitational acceleration

void setup() {
  Serial.begin(115200); // Initialize the serial port and define the Baud rate
  pinMode(pin1,OUTPUT); // Define XX port as the output port
  pinMode(pin2,OUTPUT);
  pinMode(pin3,OUTPUT);
  pinMode(pin4,OUTPUT);
  pinMode(pinENA,OUTPUT);
  pinMode(pinENB,OUTPUT);
  attachInterrupt(inter, motor, CHANGE); // Set the interrupt mode
}
void loop() {
  // Execute the data calculation of the gyroscope first

  if(sign){
    sign=0;
if(Re_buf[0]==0x55) { // Check and select the frame header
     switch(Re_buf [1]){
```

```
case 0x51: // Calculation of the acceleration
        a[0] = (short(Re_buf [3]<<8| Re_buf [2]))/32768.0*16*g;
        a[1] = (short(Re_buf [5]<<8| Re_buf [4]))/32768.0*16*g;
        a[2] = (short(Re_buf [7]<<8| Re_buf [6]))/32768.0*16*g;
        T = (short(Re_buf [9]<<8| Re_buf [8]))/340.0+36.25;
        break;

        case 0x52: // Calculation of the angular velocity
        w[0] = (short(Re_buf [3]<<8| Re_buf [2]))/32768.0*2000;
        w[1] = (short(Re_buf [5]<<8| Re_buf [4]))/32768.0*2000;
        w[2] = (short(Re_buf [7]<<8| Re_buf [6]))/32768.0*2000;
        T = (short(Re_buf [9]<<8| Re_buf [8]))/340.0+36.25;
        break;

        case 0x53: // Calculation of the rotation angle
        angle[0] = (short(Re_buf [3]<<8| Re_buf [2]))/32768.0*180;
        angle[1] = (short(Re_buf [5]<<8| Re_buf [4]))/32768.0*180;
        angle[2] = (short(Re_buf [7]<<8| Re_buf [6]))/32768.0*180;
        T = (short(Re_buf [9]<<8| Re_buf [8]))/340.0+36.25; // Calculation of the temperature
Serial.print("angle:");
        Serial.print(angle[0]);
        Serial.print("   "); // Rotation angle as the center of the x-axis (-180°~+180°)【Facing the direction of the axis, the minus anlge increases in clockwise direction, when it reaches -180 it will change to 180 and then decrease to 0】
        Serial.print(angle[1]);Serial.print("   ");
        Serial.print(angle[2]);Serial.print("    ");
        Serial.print("a:");
        Serial.print(a[0]);Serial.print("   "); // The acceleration when facing the direction of the x-axis【Towards the facing direction, it increases in minus】
        Serial.print(a[1]);Serial.print("   ");
        Serial.print(a[2]);Serial.print("    ");
        Serial.print("w:");
        Serial.print(w[0]);Serial.print("   "); // Rotation angular velocity as the center of the x-axis【Towards the facing direction, the angular velocity is in minus in clockwise direction】
        Serial.print(w[1]);Serial.print("   ");
        Serial.print(w[2]);Serial.print("    ");
        Serial.print("T:");
        Serial.println(T);//模块温度
 break;
      }
     }
  }
```

07 Appendix

```
inter = !inter;  // Flag for the interrupt
}
void motor(){
  // Excute the feedback control next


  digitalWrite(pin1,y); // Let the motor1 rotates in clockwise (counterclockwise)
direction
  digitalWrite(pin2,x);
  analogWrite(pinENA,250);
  digitalWrite(pin3,y); // Let the motor2 rotates in clockwise (counterclockwise)
direction
  digitalWrite(pin4,x);
  analogWrite(pinENB,250);
  if (angle[0] <= -80){
   /*digitalWrite(pin1,x); // Let the motor1 brake
 digitalWrite(pin2,x);
   digitalWrite(pin3,x); // Let the motor2 brake
   digitalWrite(pin4,x);
   delay(2000);*/
x = !x;
 y = !y;
 digitalWrite(pin1,y); // Let the motor1 rotates in counterclockwise (clockwise) direction
 digitalWrite(pin2,x);
 analogWrite(pinENA,220);
 digitalWrite(pin3,y); // Let the motor2 rotates in counterclockwise (clockwise) direction
 digitalWrite(pin4,x);
 analogWrite(pinENB,220);
}


if (angle[0] >= 70){
 /*digitalWrite(pin1,x); // Let the motor1 brake
 digitalWrite(pin2,x);
 digitalWrite(pin3,x); // Let the motor2 brake
 digitalWrite(pin4,x);
 delay(2000); */
 x = !x;
 y = !y;
 digitalWrite(pin1,y); // Let the motor1 rotates in clockwise (counterclockwise) direction
 digitalWrite(pin2,x);
 analogWrite(pinENA,220);
```

07 Appendix

```
digitalWrite(pin3,y); // Let the motor2 rotates in clockwise (counterclockwise) direction
    digitalWrite(pin4,x);
    analogWrite(pinENB,220);
    }
   }
void serialEvent() {
  while (Serial.available()) {

    //char inChar = (char)Serial.read(); Serial.print(inChar); //Output Original Data, use this code

    Re_buf[counter]=(unsigned char)Serial.read();
    if(counter==0&&Re_buf[0]!=0x55) return; // Let the zero data do not be the frame header
    counter++;
    if(counter==11) { // Receive 11 data
       counter=0;     // Value it again and prepare for the receive of the next data frame
       sign=1;
    }

  }
```

Thanks for listening

Robot-guided muscle stretching to measure the range of motion

Student: Guozhi Tang

GUID: 2109630T