Cybernetic Hand: Design and Control

Dion Mariyanayagam

School *of* Computing and Digital Media, Communications Technology, London Metropolitan University

Introduction

The subject matter for this project is the design and control of a 3D printed cybernetic hand that is controlled wirelessly by a user through their hand movements which is captured through the use of a glove. The wireless communication between the glove and cybernetic hand is encrypted using a bespoke logic based cipher and uses a server client model for the wireless communication.

This project began officially in September of 2019 at London Metropolitan University under the school of computing and digital media with Dr Puncham Shukla as the supervisor and Dr Muhittin Onadim as the module leader. However, research for the design of the cybernetic hand was an ongoing learning process throughout the summer in order to gain adequate 3D design, modelling, and programming skills for this project.

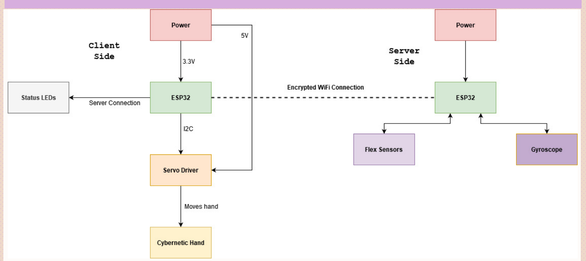
The cybernetic hand has potential applications in areas such as psychotherapy and rehabilitation, controlled operations in hazardous environments, motion models of cinematography, and increasing immersion within a virtual reality environment.

Aim & Objectives

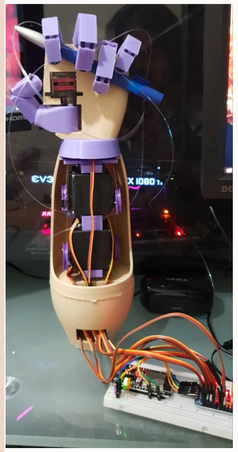
The purpose of this project is to develop a 3D printed cybernetic hand with Wi-Fi-based Client-Server capabilities; therefore, a user can control the hand wirelessly. This project has multiple objectives, such as:

- To Explore and understand the human-machine interface.
- Utilise skills and knowledge of 3D modelling and design.
- To design and develop an electronic interface for hand control.
- To use software development skills for hand control.
- To explore wireless communication between the user and the mechanical hand.
- Exploring and further understanding of LSEP (Legal, Social, Ethical and Professional) issues to improve on the ethical side of the project and how it will affect society.
- Lastly, to enable the dissemination of knowledge through documentation, presentation, and social media.

Method



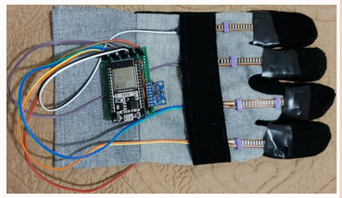
The cybernetic hand is the client-side which will connect to the hand movement capture glove which will be the server-side. Due to the marriage of two systems of this project the method is split unto two aspects; construction of the cybernetic hand, and the construction of the glove.



There are two filaments used for the construction of the hand one is PLA which is a vegetable-based plastic material that is biodegradable and a wood filament which has a PLA base and wood fibres.

The electronics for the mechatronics comprised of MG996R metal-geared servos for the fingers, thumb, and forearm. MG90S micro-servo for the movement of the opposable thumb. ESP32 microcontroller to process, encrypt and send over the built-in WiFi. PCA9685 servo driver that allows I2C communications to all servos

Flex sensors are sewed in place and used to capture the degree of bend for each finger and thumb. The gyroscope rotates the forearm.



The server-side ideally should be turned on before the client side, however, if the any disconnection of the server emerges then the client-side will reset all of the servos back to the idle positions and the status LED will turn red indicating that the client has disconnected from the server.

Results

Various testing was conducted through this project, here are a few:

```
#define SERVOMIN  150 //this is the 'minimum' pulse length count (out of 4096)
#define SERVOMAX  400 //this is the 'maximum' pulse length count (out of 4096)

#define Index_Thumb_Min 450//synced
#define Index_Thumb_Max 100//synced

#define Middle_Min 580//synced
#define Middle_Max 150//synced

#define Ring_Min 200//synced
#define Ring_Max 600//synced

#define Pinky_Min 200//synced
#define Pinky_Max 600//synced

#define Thumb_Rotate_Min 500//synced
#define Thumb_Rotate_Max 100//synced

#define Forearm_Rotate_Min 550//synced
#define Forearm_Rotate_Max 300//synced
```

Servos are defined by its minimum and maximum values for the finger to bend appropriately. Each servo has its unique minimum and maximum values which determined through trial and error testing for the perfect positioning for each finger.

Constant (R2)	Variable (R1)	Voltage out (Vout)	Voltage in (Vin)	Degrees Bend	Pin Reading
10000	30000	2.475	3.3	0	2800
10000	35000	2.566666667	3.3	10	2865
10000	40000	2.64	3.3	20	2879
10000	45000	2.7	3.3	30	2893
10000	50000	2.75	3.3	40	2906
10000	55000	2.792307692	3.3	50	2940
10000	60000	2.828571429	3.3	60	2964
10000	65000	2.86	3.3	70	2988
10000	70000	2.8875	3.3	80	3011
10000	75000	2.911764706	3.3	90	3035

The flex sensor has a conductive paint, and its construction is similar to a voltage divider as it follows Vout=Vin(R1/(R1+R2)) (Duncan, 1985)

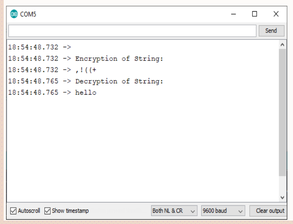
```
void average()
{
  int sum = 0;
  for (int i=0;i<1000;i++)
  {
    filter[i] = AcX;
  }
  for (int i=0;i<1000;i++)
  {
    sum += filter[i];
  }
  filterAvg = sum/1000;
  degreeAvg = map(filterAvg, 1000 ,17000, 0, 180);
  degreeAvg1 = constrain(degreeAvg, 0, 180);
}
```

Taking the raw data had a lot of random spikes of readings, to get rid of any random anomalies; the best form of action is to make a filter to soften the signal output. The moving average filter takes in one thousand readings of the X-axis of the gyroscope and sums all of the values then divides by the number of readings taken.

The real-time code execution achieved by connecting the servo to the client and the flexible sensor to the server. By recording the real-time data from the flexible sensor and saving it locally to the server allows the client to access the data through the get function of the HTTP library.

Analytical testing for the XOR encryption using the key "D" to encrypt the message "hello". The Key "D" in ASCII binary is 01000100. Each character is XOR with the Key resulting in the encrypted message. To decrypt the message, the same process as encryption.

The encrypted messaged is ",!((+" to test the theoretical results, the cypher code uploaded to the ESP32, and the results shown in the serial monitor



D	01000100
h	01101000
Output = ,	00101100
D	01000100
e	01100101
Output = !	00100001
D	01000100
l	01101100
Output = (	00101000
D	01000100
o	01101111
Output = +	00101011

Conclusion

To conclude, this project has explored various engineering disciplines learnt through the bachelor's degree and outside the degree from electronics, mechatronics, 3D modelling, 3D design, wireless networking, encryption, programming, PCB design, SMD soldering and sewing. The achievements of the project correspond to all the deliverables and additional features implemented.

One of the main limitations of this project was the COVID-19 pandemic that significantly limited the time for PCB manufacturing to polish the circuit design of the project; however, staying with the breadboard design still achieved the same effect.

Acknowledgements

Original source of this template

Medical Illustration Unit
Prince of Wales Hospital

Ph: 9382 2800
Email: miunsw@unsw.edu.au
Web: http://miu.med.unsw.edu.au