Sensor Controlled Robotic Hand

COMP 4801 Final Year Project
Interim Report

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Abstract

Many different types of Robots are invented in order to perform dangerous tasks in place of humans. However, in many cases, human workers are still being sent to hazardous environments, seeing as how current robots are not capable of performing complicated tasks. This paper describes the design, implementation and evaluation of a sensor controlled robotic hand that provide haptic feedback. Control over a robotic hand would obviously be most intuitive to the user when actual hand gestures and movements are closely mirrored by the robotic appendage, and this could be achieved with the use of sensor gloves. Haptic feedback also provides more information to the user other than mere visual output, and these features in tandem will allow the robotic hand to handle far more complicated tasks and replace humans in more dangerous scenarios.

Acknowledgement

I would like to express my deep gratitude to Professor Loretta Choi, my research supervisor for her patient guidance, contribution in stimulating suggestion, encouragement and granting me access to the HKU maker lab. Her support assisted me a lot in completing this report. I would also like to thank Mr. David Lee for his advice and assistance in helping my progress on schedule and teaching me 3D modeling techniques.

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List of Abbreviations

Abbreviation	Explanation
PLA	Polylactic Acid
ABS	Acrylonitrile Butadiene Styrene

1 Introduction

Robotics is a rapidly growing field in the past few decades, and the potential uses and functionality of robots have been researched substantially in variety of fields. In recent years, robots are used to perform tasks in dangerous environment in place of humans. For example, many robots have been designed and built to clean up radioactive contaminated places like nuclear facilities, defuse bombs, search for survivors in unstable ruins, etc. However, these robots have a lot of limitations, as their functionality harshly limits flexibility and efficiency when compared to humans. With such restrictions in the application of robots, human workers remain essential for work in hazardous situations, in particular tasks that robots fail to perform satisfactorily. With such shortcomings in mind, the focus of this paper will be a sensor-controlled robotic hand with haptic feedback, which will mimic the gesture of the user wearing the sensor glove. This robotic hand is capable of performing complicated tasks with nearly the same dexterity as a human hand and thus can eliminate the need for human presence in hazardous locations to the greatest possible extent.

In the remainder of this paper, we shall first offer background information on the current robotics and their limitation, and then elaborate more on how this project can solve the challenges and improve upon current practices. Subsequently, we shall discuss the design and approaches for the implementation of this project. We will then address any potential challenges and current progress, with the appended project schedule.

1.1 Background

Contemporary robots usually consist of moving components and one or more robotic arms. [1] These robotic arms are designed for specific purpose. Pliers are attached to the robotic arms for defusing bombs, while a screwdriver might be substituted for maintenance of a machine in radioactive environment. The functionality of these robotic arms is limited to the very specific tasks they are designed for, and the design of controller places another shackle on the flexibility of robots. In most cases, the operator obtains information about the surrounding environment solely through attached cameras, sorely restricting the channel of receiving information.

Several pitfalls emerge from current practice, for instance, unknown challenges are often faced when performing missions in hazardous places. Having robotic arms that are designed for too specific a purpose limit the functionality and flexibility of robots. The robots cannot perform complicated operations and tackle every eventuality. In Fukushima Daiichi nuclear disaster, human workers were sent to stabilize the reactors instead of sending robots because current robots are not qualified for these jobs in terms of functionality and efficiency. Second, the reception of surrounding environment is restricted to sight. The operator cannot feel what the robots touch. Some tasks should be effortless with tactile cues like cutting a wire However, without the pressure feedback, the operator need to apply constant visual confirmation. This increases the cognitive load of the operator and lowers the efficiency and functionality of the robots. Finally, using traditional controllers to control a robotic hand is counter-intuitive and hence necessitates lengthy training on the part of the operator. The effectiveness of robots is also largely dependent on the operator's technique in handling the controller and ultimately the design of the controller.

1.2 Objective

In this project, the robotic hand will mimic the gesture of operator's hand through a pair of sensor gloves. The robotic hand will have adequate strength to hold light instruments and objects but strength will not be the focus of this project. This project will focus on the flexibility and functionality of the robotic hand, which will be able to perform delicate tasks such as operating scissors and screwdriver. The ability to handling different instrument will ensure the multi-functionality of the robots.

The robotic hand will have measure on pressure bearing and provide haptic feedback to the sensor glove so operator can feel the same. Operator can control the robotic hand to perform tasks even with no visual information. The glove will measure the force that operator applies and the robotic hand will apply a similar force. This is important in performing precise tasks such as holding fragile objects like eggs.

Wearable sensor glove instead of traditional controller will be used in this project. This will provide an intuitive way to control the robots. The robotic hand will move in the way that the operator move and consistently smoothen the learning curve of using the robotic hand.

1.3 Deliverables

Robotic hand

Different component of the robotic hand will be 3D printed with PLA as the material and assembled. Several servomotors will be mounted onto the movable part of the hand with strings. Pressure sensors will be installed on different part of the hand to detect the pressure applied on the robotic hand.

Flex sensor glove

Multiple flex sensors will be sewn onto the glove. The flex sensors will be mount together to a circuit. Motors will be attached to the sensor gloves to create a sense of feeling at the user's end. The user will be wearing these gloves in order to control the robotics hand.

Microcontroller

Arduino Uno R3 will to used to link the robotics hand and flex sensor glove. It will be programmed to respond to the signal sent from the flex sensor glove by moving corresponding parts of the robotic hand. If the robotic hand touches an obstacle, Arduino will respond to the signal sent by the pressure sensor on the robotic hand by limiting the movement of sensor glove through the motors on it.

2 Related Works

2.1 InMoov Robotic Hand

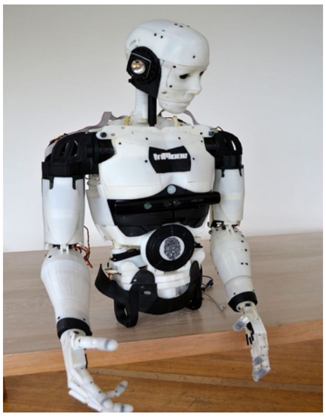

Figure 1: InMoov 3D printed life-size robot

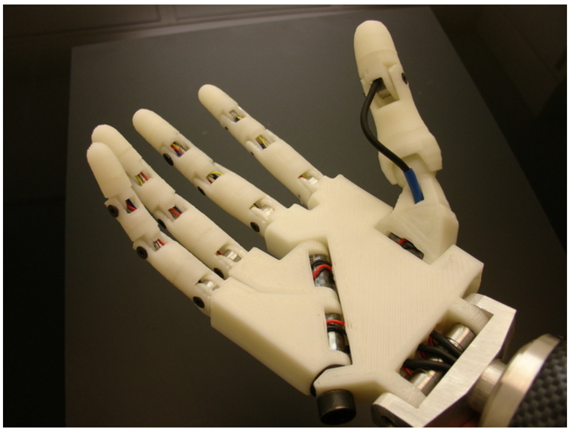

Figure 2: InMoov 3D printed robotic hand

InMoov is an open source humanoid robot that can be 3D printed and controlled by Arduino microcontroller. The robotic hand of InMoov is powered by five servomotors and cables. This is the skeleton used in this project but it is not equipped with haptic feedback.

2.2 Dextrus Hand

Dextrus Hand is a 3D printed robotic hand that is designed to be control by two EMG sensors by placing them on muscles. In Dextrus Hand, different fingers are controlled with an individual string and servomotors which makes the hand can fit to the object that it griped. In contrast, some robotic hands move the fingers in a synchronous way in which all fingers are controlled by only one motor and string. The gesture that those hands can make are limited. It is not equipped with haptic feedback. There is no movable part in the palm which limits its flexibility.

Figure 3: Dextrus robotic hand

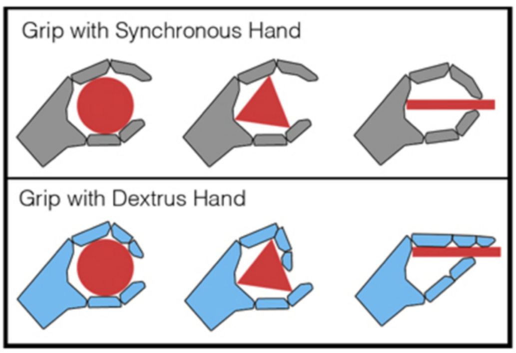

Figure 4: Grip with Synchronous Hand and Dextrus Hand

3 Design

3.1 Abstract

This section is going to explain the design and working principle of the robotic hand from the structure to the programming design. First we will discuss how different component link together. Then we will go through all components of the robotic hand one by one, finally we will go through the working principle.

3.2 Overview

This sensor controlled robotic hand consists of a 3D printed robotic hand, a sensor glove, a power source and a microcontroller that links everything together.
Figure 6 shows how different components are connected.

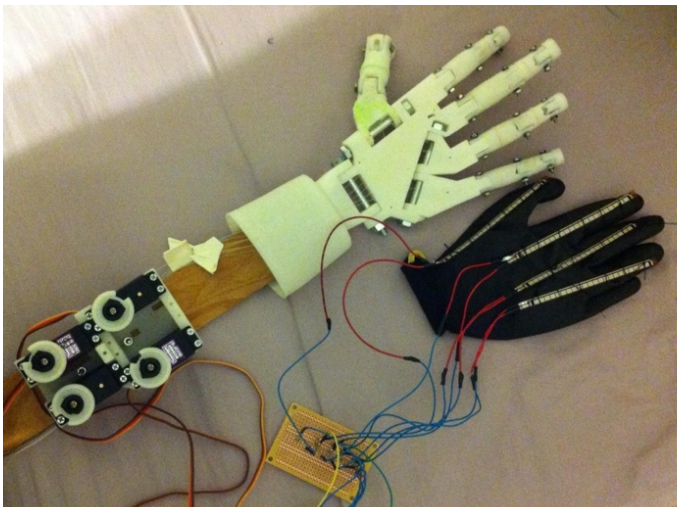

Figure 5: Robotic hand and sensor glove

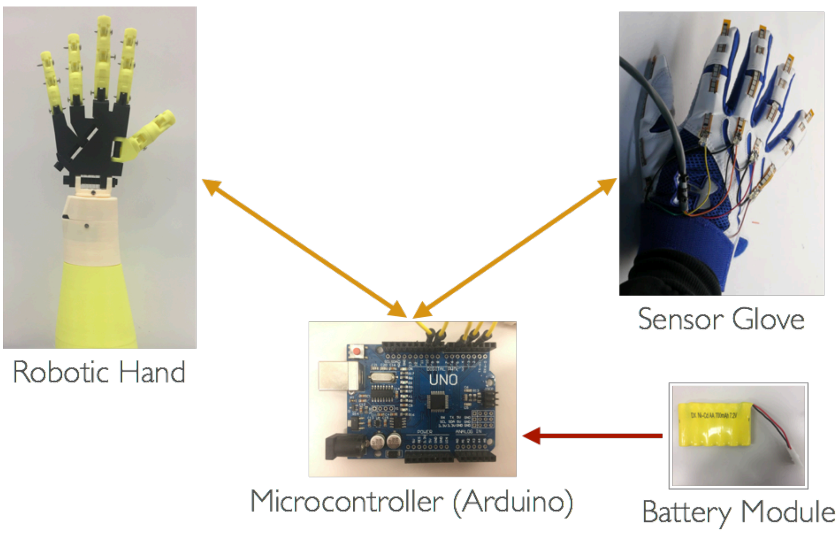

Figure 6: The structure of sensor controlled robotic hand

3.3 Component

3.3.1 Robotic Hand

The robotic hand consists of the skeletons, 5 servomotors and 5 pressure sensors.

3.3.1.1 Skeletons

This robotic hand is built based on open source 3D print robotic hand which is created by InMoov. The 3D models are shown below.

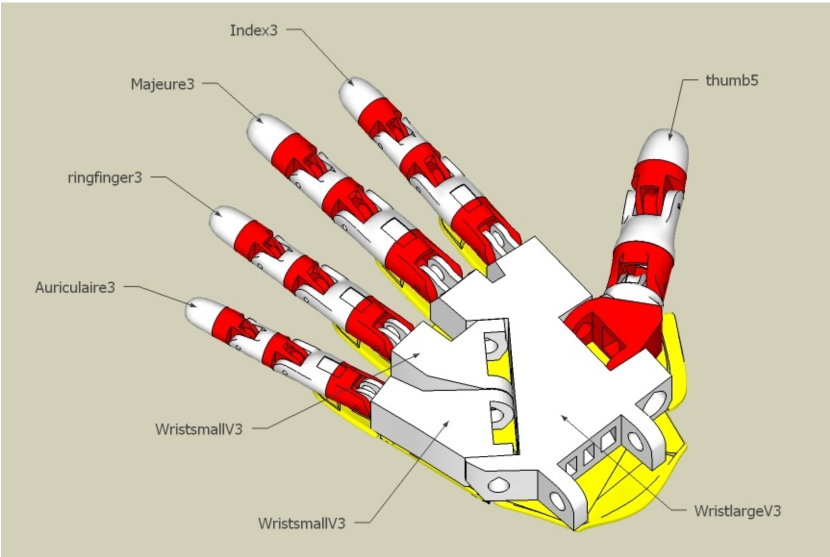

Figure 7: InMoov 3D printed hand

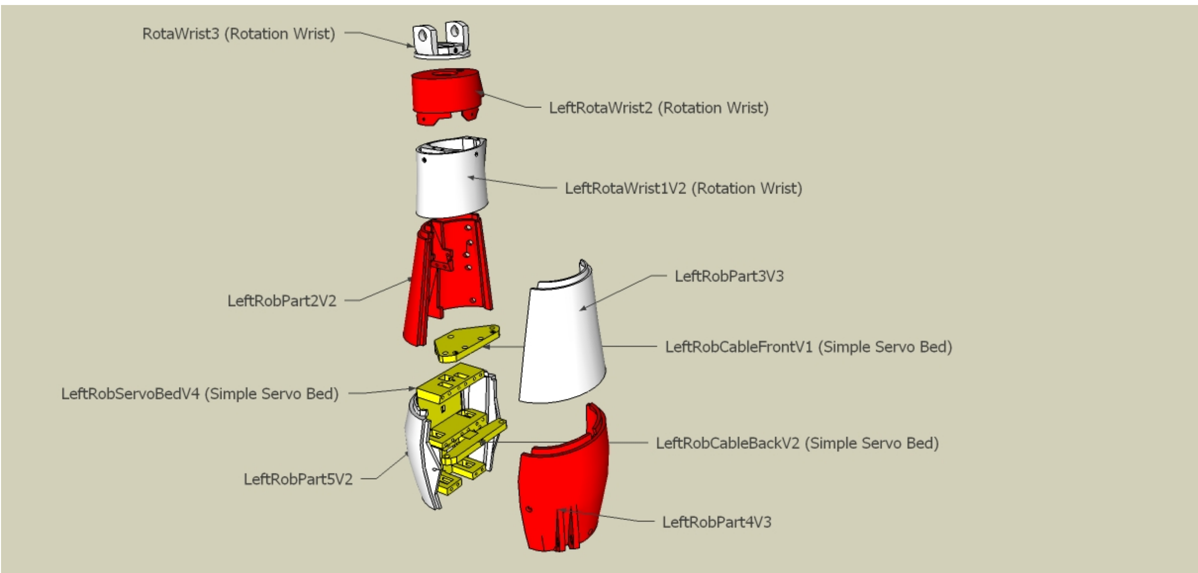

Figure 8: InMoov 3D printed forearm

Most of the robotic hand can be 3D printed. Only Screws are used to act as bolts to connect different parts of the fingers. The robotic hand is 3D printed with 30% infill and 3 shell using Borlee 60wifi 3D printer. Higher infill percentage will provide higher durability but the weight will also increase. The chosen infill percentage and number of shell is optimal after several try on different parameters. PLA is used as the 3D printing material because it is less susceptible to typical 3D printing problems such as warping in comparison to ABS, another common 3D printing material. Figure 9 have shown the effect of warping, the edges of model is bent as the first layer cool down quicker and shrink. The size of the hinges and different parts of the 3D printed component did not fit each other perfectly. This is caused by the quality of the 3D printer and the intention of the creator to allow room for error in 3D printing. Therefore, hinges need to be redrilled and the printed components need to be modified using rasp to make different parts of the robotic hand can fit perfectly and move without resistance.

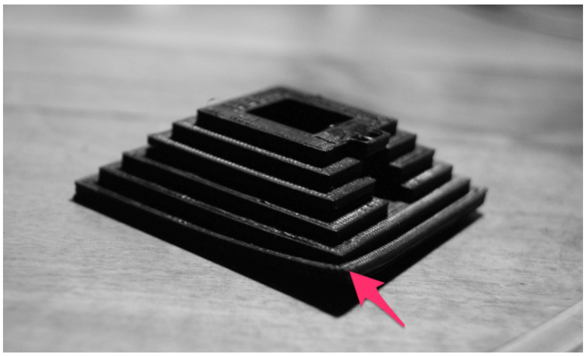

Figure 9: Effect of warping

3.3.1.2 Servomotor

The servomotors that used for the robotic hand are Tower Pro MG946R. They can provide high torque with 13KG and are more accurate in comparison to the previous version MG945 as they are equipped with new PCB and IC control system. These motors have 0 to 60 degree of motion and operate with 4.8v – 6.6v. 5 servomotors are used to control the five fingers of the robotic hand by linking them with 200LB fish line. Figure 5 have shown how the servomotors link to the robotic hand.

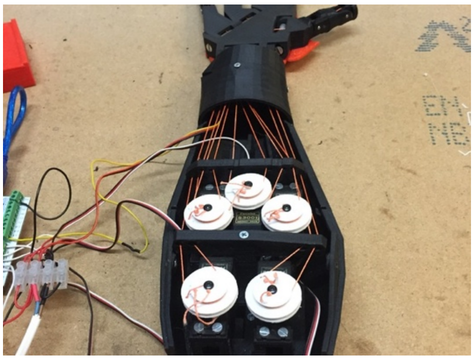

Figure 10: Robotic hand linked with servomotors

3.3.1.3 Pressure Sensor

The pressure sensors used in this project are 5mm Interlink FSR-400 pressure sensor. They can read pressure from 10 g to 10kg by measuring the resistance changes when pressure is applied in the normal direction to the sensors. These pressure sensors will be attached on the finger tips of the robotic hand.

Figure 11: Pressure Sensor

3.3.2 Sensor Glove

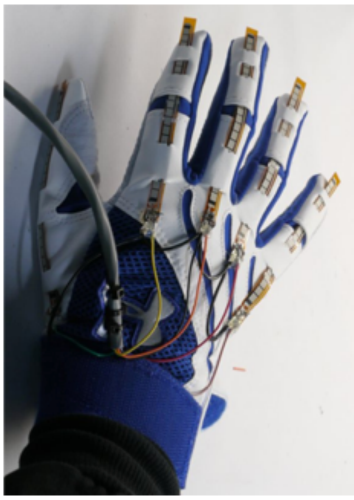

Figure 12: Sensor glove

The sensor glove consists of 5 flex sensors and 5 servomotors. The glove used is general golf glove.

3.3.2.1 Flex Sensor

The flex sensors used here are 2.2” SEN-10264 Flex Sensor. They can measure the degree of bend by measuring the resistance across the sensor. At rest, the applied resistance is 25 k Ohms, they will reach a maximum level of 125 k Ohms depends on the degree of bend. They are sewed into the glove.

3.3.2.2 Servomotors

The servomotors used are the same with the robotic hand. The servomotors are linked to the fingers of glove by 200LB fish line. They are attached to the support on the user’s.

3.3.3 Microcontroller

Figure 13: Arduino UNO R3

The microcontroller used in this project is Arduino UNO R3. It has 14 digital input/output pins, 6 analog inputs and a 16 MHz quartz crystal. Appendix A have shown the pinout diagram of the Arduino UNO R3. It links the robotic hand and sensor glove together by retrieving signal from flex sensor in sensor glove to move the servomotors on robotic hand and retrieving signal from pressure sensor on robotic hand to move the servomotors of sensor glove.

3.3.4 Power Source

In this project, 7.2V battery is used to power the Arduino board and the servomotors of the robotic hand and sensor glove.

3.4 Working Principle

3.4.1 Overview

Microcontroller is used to link the robotic hand and sensor glove. There are two signal paths. As shown in figure 6, one is for the robotic hand to mimic the shape of sensor glove. The microcontroller will get the measured data from the flex sensors of the sensor glove and then move the servomotors at the robotic hand side. Another path is for providing haptic feedback to the user. The microcontroller will get the measured data from the pressure sensor on the robotic hand and move the servomotors on the sensor glove.

Figure 14 have shown the block diagram of the sensor controlled robotic hand that indicates the direction of the two signal paths.

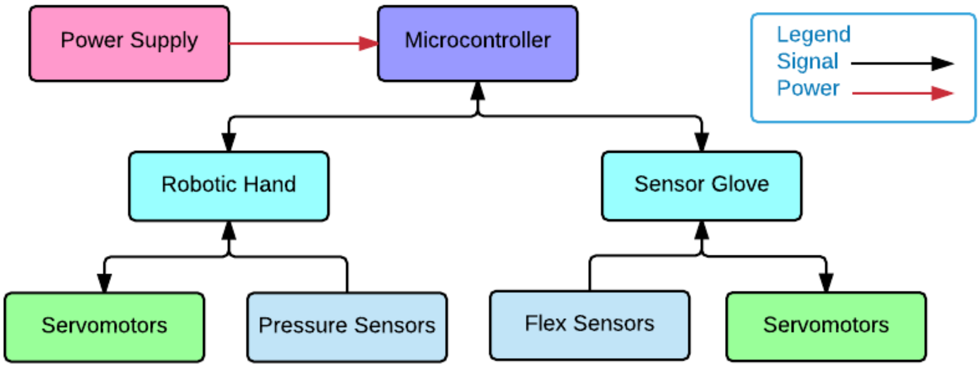

Figure 14: Block diagram of the sensor controlled robotic hand

3.4.1 Movement of robotic hand

5 servomotors are attached on the robotic hand. Each servomotor controls the movement of a finger of connecting them with two strings. One at the palm side of the hand and one at the back side. When a finger is needed to be crooked, the corresponding servomotors will rotate clockwise, pulling the wire on the palm side and the finger will be pulled down. With different position of the fingers, different gestures are formed.

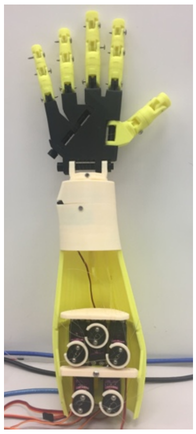

Figure 15: The robotic hand

3.4.2 Capturing gesture

5 flex sensor are attached on the sensor glove. Each flex sensor measures the degree of bend of each fingers. When the user moves his hand, the flex sensor measure the degree of each finger. By combining the data from the flex sensors, the gesture of the user can be captured. The microcontroller can take these data as input and control the servomotors of robotic hand to mimic the user's action.

3.4.3 Haptic feedback

There are 5 pressure sensors attached on the fingertips of the robotic hand and 5 servomotors attached on the sensor glove. Each servomotor is responsible for providing stopping force to each finger. The servomotor and the corresponding finger are connected by two string. When the robotic hand is grabbing something. The pressure sensors on it will be pressed and the data generated will send to the microcontroller. The microcontroller is programmed to control the servomotors to rotate clockwise and this will tighten the string connecting to the finger. The user will experience a stopping force in their fingers and hence able to feel the shape of the object.

Figure 16: Sensor glove with servos

It is important to keep appropriate tension of the strings. If it is too tight, the string will restrain the user's hand. If it is too loose, servomotor will require longer time to tighten the string and provide the stopping force. This will increase the reaction time of the haptic feedback system. Therefore, the servomotors will keep rotating to adjust the tension of the string. If the user closes his hand, the servomotors will loose the string a bit to provide some room for the user to move. If the use open his hand, the servomotors will start tightening the string to shorten the reaction time.

4 Limitation

It is difficult to perform action as precise as human does. For example, picking up an egg require accurate control of strength so that the egg will not be broken or dropped. Tying shoelace require flexible robotic hand and great coordination. Both flex sensor glove and robotic hand need to satisfy certain technical specifications. The flex sensor glove needs to be equipped with enough flex sensors so that not only finger movement is detected but the shape of the palm can also be detected and mimicked. The robotic hand needs to be equipped with many movable parts like knuckles to enable flexible movement.

The robotic hand is made according to the 3D model that is provided on the Internet. However, the robotic hand may be not compatible with other accessories that mounted to it. In this case, the 3D model may need to be fine-tuned or the accessories may need to be modified to suit the robotic hand.

5 Current Status

In the first semester, all materials that need to be used have been acquired such as flex sensors, servos, battery, 3D printing material, etc. The robot hand 3D model from InMoov have been chosen as the robotic hand used in this project since this robot hand model have a good balance between functionality and ease of production. However, the chosen 3D model does not fit perfectly with the servo acquired and some of the parts of the hand are too complicated to make. I have modified the 3D model to make it fit to the parts and lower the difficulties and complexity in assembly the hand. A lot of grinding works are required to make the components move smoothly. I have done all the wiring of the servomotors on the robotic hand. I am currently working on the sensor glove by sewing flex sensor to it and link it to the microcontroller.

In the second semester, I will focus on implementing the haptic feedback function. This included attaching pressure sensor to the robotic hand, attaching servomotors to the sensor glove. 3D modeling is required to fix the servomotors to the user's wrist. After this, the microcontroller will be coded to link the action between the sensor glove and the robotic hand and to provide the haptic feedback. The following table will be the schedule of this project.

Year	Month	Task	Status
2016	September	Research on the feasibility	Completed
		Research on existing 3D models of robotic hand	Completed
		Determine the project scope	Completed
	October	Determine the 3D model of robotic hand	Completed
		Design the project webpage	Completed
		Completed Project Plan	Completed
		Modify the existing 3D model	Completed
	November	Gather required materials	Completed
		3D print the components of robotic hand	Completed
		Assembly the robotic hand	Completed
		Make the sensor glove	In Progress
	December	Link the robotic hand and sensor glove to Arduino board	
		Program the Arduino board	
2017	January	Completed Final year Project Interim Report	
		Functional Robotic hand without haptic feedback	
	February	Attach pressure sensor to robotic hand	
		Attach servomotors to sensor glove	
	March	Program the Arduino board to support haptic feedback	
		Final testing and calibration	
	April	Completed Final Report	
		Completed Robotic hand with haptic feedback	

Table 1: Project Schedule

6 Conclusion

The aim of this project, namely allowing robotic hand to perform precise actions, has immense potential in enhancing the versatility and overall usefulness of robots. This sensor glove-controlled robotic hand with haptic feedback can let user control it intuitively and provides more information about the environment, thanks to the haptic feedback supplementing visual information. This is an economic way to ensure some emergency cases can be handled quickly without on-site human operation. To improve the current design, the robotic hand can be made of more durable materials like steel and have more power so that it can carry out tasks that involve moving heavy objects and can replace human in more dangerous scenarios.

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Appendix A

Arduino UNO R3 Pinout Diagram