Development and Analysis Low-Cost Robotic Prosthetic Arm

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This Project report has been submitted in fulfillment of the requirements for the Degree of Bachelor of Science in Software Engineering.

APPROVAL

This thesis titled on "**Development and Analysis Low-Cost Robotic Prosthetic Arm**", submitted by **Md. Mahmudul Hasan, ID: 181-35-2337** to the Department of Software Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science in Software Engineering and approval as to its style and contents.

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DECLARATION

It hereby declares that this thesis has been done by me under the supervision of Md Hafizul Imran, Lecturer, Department of Software Engineering, Daffodil International University. It also declares that neither this thesis nor any part of this has been submitted elsewhere for award of any degree.

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ABSTRACT:

Being born without arm and losing arm by accident is a common issue. A robotic Prosthetic arm is an important product for handless people. A good robotic prosthetic arm is able to restore the functionality of their lost hand. At present, there are many good-quality prosthetic arm is available in the market at present are very expensive, which is very tough to afford the cost for everyone. And to overcome this problem, in this article we shown the design and development process of a low-cost Prosthetic hand using PLA material with 3D printing technology. The height of this prosthetic arm is usually about 16 inches long. A microcontroller that controls the whole arm and the microcontroller will be controlled by the sensor, the sensor will control the electromyographic (EMG) signal from the user's hand muscle movement. The component list, features and price of our prosthetic arm have been compared with some of the arms in the market. Which has enabled our study to reach the goal.

Keyword: EMG, Prosthetic Arm, Low-Cost Arm, Arm Development, 3D Printed Arm.

CHAPTER 1

INTRODUCTION

1.1 Background

People to complete his daily work every part of the human body is necessary, when any part of the body is absent, human loses his ability to work. The hand is one of the most important parts of the human body, man performs various important functions of his life with the help of hand and this is unchangeable in today's competitive community. Many people lose their hand for a variety of reasons, such as congenital malformations, rail, electric shocks, war-related injuries, road accidents, damage to agricultural equipment, hand injuries during construction, animal or reptile bites, burns, separation from certain diseases: diabetes or trauma, cancer. The impact of amputation is increasing day by day due to the continuous growth of industrialization and lack of safety awareness. which makes human life journey very difficult. Handicapped people are unable to meet their daily work or many times their own needs, which makes them dependent on others. People who are unable to work are burdened by their families and society. So, the robotic prosthetic arm will play an important role in overcoming the functional disability of the handless people.

1.2 Motivation of the Research

There are many prosthetic arms in the international market but these prosthetic arms are very rare in underdeveloped and developing countries. The robotic prosthetic arm that is available in the market at present is very expensive, which is very difficult for most people to afford. The World Health Organization (WHO) reported That about 15% of the global population has a disability, Half of which cannot afford healthcare. There are 10 million amputee people worldwide, of which 30% have their arms amputated. In this context, the aim is to build robotic prosthetic arms using 3D printed technology to make them accessible to low-income people in underdeveloped and developing countries.

1.3 Problem Statement

The prosthetic arms in the market have some specific problems, The biggest problems are:

1. Prosthetic arm is not easily available in the market.
2. People can't buy this product because of the high price.
3. It is difficult to use for overweight.
4. Some prosthetic arms look like an industrial arm.
5. There are some prosthetic hands that are not very functional, Therefore, not all work can be completed in a perfect way.

1.4 Research Questions

1. How will the prosthetic arm solve the problem of handless people?
2. How the Prosthetic Arm in the market are meeting the demand?
3. Is it possible to meet all the needs of prosthetic hand using 3D print technology?

1.5 Research Objectives

1. To solve the problems of handless people.
2. To make a specific weight.
3. To reduce prices compared to the past.
4. To be designed and made in the shape of a perfect hand.

1.6 Research Scope

Organ amputate is a common occurrence, every day anywhere in the world people's organ are being amputate. the United States, an estimated 185,000 organs are amputated each year, and this rate is expected to double by 2050. There were about 20,000 accidents in Bangladesh from 2009 to 2016. In 2017, about 7,397 humans died and 16,193 humans were harmed. And the number of dying in 2018 increased by 7% over the previous year and 10,828 people were injured. There are many among them whose hands have been cut off. The hand is one of the most important organs in the human body. People without hands can be said to be very immobile, because without hands it is difficult to complete daily work. So, at present robotic prosthetic hand is very demandable product.

1.7 Thesis Organization

This thesis is organized as follows: chapter 1 outlines the thesis background, motivation of the research, problem statement, research questions, research objective, research scope and thesis organization. Detailed reviews are provided from previous studies in chapter 2. details of methods such as hand pattern Arm Prototype are explained in chapter 3. And also, Hand size, number of fingers, weight and what material used in this Arm. Mechanical parts such as microcontrollers, sensors, motors, batteries have been discussed. And the circuit diagram, block diagram, component list and each part of the prosthetic arm are shown. and discussed about muscle sensor and muscle signal. Chapter 4 highlight the Result and Discussion. And Chapter 5 discuss Conclusion and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

The hand is one of the most important parts of the human body, man performs various important functions of his life with the help of hand and this is unchangeable in today's competitive community. Therefore, loss of hand function or loss of hand can slow down the life of such people. For this argument, prosthetic hands help them to perform all the tasks in their daily life, for which prosthetic hands have been considered as an alternative means [1]. People lose their limbs for a variety of reasons, such as congenital malformations, rail, electric shocks, war-related injuries, road accidents, damage to agricultural equipment, hand injuries during construction, animal or reptile bites, burns, separation from certain diseases: diabetes or trauma, cancer. The impact of amputation is increasing day by day due to the continuous growth of industrialization and lack of safety awareness [2].

One study found that in the United States alone, an estimated 1.6 million amputees were living as of 2005. And in the United States, an estimated 185,000 organs are amputated each year, and this rate is expected to double by 2050 [3]. There were about 20,000 accidents in Bangladesh from 2009 to 2016. In 2017, about 7,397 humans died and 16,193 humans were harmed. And the number of dying in 2018 increased by 7% over the previous year and 10,828 people were injured [4]. In a recent study, the World Health Organization (WHO) reported That about 15% of the global population has a disability, Half of which cannot afford healthcare. There are 10 million amputee people worldwide, of which 30% have their arms amputated [5].

Although much progress has been made in solving the problem of organ loss and many types of prosthetics hand have been developed over the years, The advancement of this technology is still limited and the cost is very high as it takes a lot of time to make every necessary part of the equipment suitable for use [6].

There are some existing artificial hands available commercially. Those artificial arms include Touch Bionics, Be-bionic, Otto-bock, Steeper, Open Hand Project, and Open Bionics. Existing technology costs from $ 1,000 to $ 120,000 which is very expensive for most people in Bangladesh [4]. A study by the World Health Organization found that only 20% of a group of 30 million people have artificial or other dynamism devices to meet their needs. Humans have 27 degrees of freedom in their hands, Control the hardware with the servo motor here. And prosthetics are made using 3D technology [6].

Myo-sensor will be used as a sensor; these sensors are placed in one or more places on the rest of the patient's hand. When the muscles are raised, the prosthetic arm works, including capturing and augmenting the potential for muscle action [7]. Some previous researchers have found that the most commonly used prosthetic arm movements include: hook grasp (10%), lateral grasp (20%), precise grasp (30%), power grasp (35%) and others (5%). Some of them have studied the requirements of artificial hands and concluded their most worrying features, such as the basic work of adult hands, weight and humanoid appearance. Also, the low cost of prosthetic hand design is considered, as the price can significantly reduce the rate of prosthetic hand adoption [1].

The first step-in low-cost prosthetic arm design is to resolve the basic elements for development, some key elements of the design must be of limited cost. Generally, Prosthetics Arm divided into Four main categories: cosmetic, myoelectric controlled, activated by a cable, and hybrid. In general, wire-activated methods are preferred for making low-cost prostheses. And these are made based on kinematic energy [8].

The hand can be used as a cosmetic in social life and can perform any daily work. The design is easy to control based on the prevention model, and it uses a standard electronic system and is used at low cost for mechanical construction, but there are some limitations to using this type of prosthetics. Again, in some studies there was a tendency to make these artificial hands based on ethnographic designs. And this ethnographic hand had five fingers that looked a lot like a human hand. This type of hand can transmit less and more energy like a human hand. That is, each prosthetic finger of the prosthetic hand controls power individually using a DC servo motor. Therefore, there are more complexities in the design, construction and control algorithms of this type of artificial hand [9].

In recent years the common products of prosthetic hands at home and abroad have adopted two transmission types, the connecting rod drive and the tendon drive.

(1) Stanford University has developed a five-finger simple tendon drive prosthetic arm. (2) US IOWA State University has developed a common connecting rod drive by prosthetic hand. There are also some more advanced quality prosthetic hands in different countries, (3) such as those made by NASA Dextras Hand. But there were some problems with these products, the structure was more complex and controlling the prosthetic hand was difficult for users because of the extra emphasis on finger adaptability [10].

So, this research will focus on creating an advanced, low-cost prosthetic arm [11] [12]. That its structure and hand are easy to use [13]. So, in this study the method of laser cutting can be turned into specific phenomenon through 3D printing instead [14]. The goal of the current work is to design an artificial arm to reduce hand costs using both 3D design software and 3D printing [15]. Since a large number of tasks can be performed by controlling only one sensor [16], whenever a person wishes to move a hand, a small The amount of electrical current produced by muscle fibers [17] [18], Which will measure muscle contraction with a Mayo electric signal and control only the hand using the signal [19] [20]. In this time the artificial hand that is still on the market, because of its low cost and also because of its simplicity [21].

Artificial hands must meet certain criteria: low cost, locally available, technically functional, manual, easy to repair, durable, local production capacity, reproducible by local workers, easy to use, biomechanically suitable, e.g., as lightweight as possible [22].

The compression ratio never exceeded 25% in all previous studies. Recent studies have shown a compression ratio of 80% using the "overtwist phase" [23]. These results constitute an important step towards the development of the prosthetic arm, they may possibly perceive a more natural conception and give the user greater efficiency [24] [25].

2.2 Related paper review 1

The hand is developed with the help of 3D printing technology. The Arduino Mega board is used as a microcontroller. The EMG sensor is used to control the hand. The cost of making the hand is about $ 640. A change will be made from the pin jointed finger to the polyurethane rubber joint which will help to facilitate hand control [3].

2.3 Related paper review 2

The work is an EEG mind-controlled smart artificial arm that is controlled by the order of the brain. With the help of smart sensors obtained from electroencephalography (EEG) headset. The arm is fully 3D printed and a total of nine motors are used in the arm. The components of this project included Raspberry Pi II and EEG-based headset, servo motor, Bluetooth, sensor, two USB battery packs. The cost of the project is estimated at around 1140 USD [5].

2.4 Related paper review 3

Two prototypes were created in this study. A hand with 5 fingers controlled by a flex sensor with a wearable glove. And the other hand is controlled by flexing any muscle in the user's arm and collecting electromyographic (EMG) signals. The fingers are controlled by the servomotor and each servomotor is controlled by the microcontroller. And 3D printing technology has been used to build prototypes. This experiment showed that flex sensors can measure human hand motion smoothly [6].

2.5 Summery

Previous studies have shown that most of the arms are made using 3D printing technology. But five to seven motors have been used for hand control. In some studies, only five fingers have been controlled. Someone has used a motor to control the wrist and fold the hand. Most have used the Arduino Neno as a microcontroller. Some studies have used Arduino Mega, Raspberry Pi. Electromyographic (EMG), electroencephalography (EEG) and flex sensors have been used as sensors. Some studies have been used electromyographic (EMG) and flex both sensors. As a result, the cost of the project increases.

Although, the main objective of this study is to create a good quality prosthetic arm at a low cost.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Model design planning

This hand design includes the little finger, ring finger, middle finger, index finger, thumb finger, palate and base structure. Each finger has three separate parts except for the thumb finger, the thumb finger has two parts. The fingers will be controlled by two servo motors.

little finger, ring finger, middle finger, index finger will be added to one motor and thumb finger will be added to another motor. Servo motors are connected to microcontrollers which will be controlled by sensors. The sensor will control the device by receiving signals from human hands.

3.2 Requirement:

In previous studies, those who have made low-cost prosthetic arms have some requirements are similarities. Although there are differences in design, there are some similarities between the tools.

The tools that will be used in this study:

i. 3D Printer
ii. PLA Material
iii. Arduino Neno Microcontroller
iv. EMG Muscle Sensor
v. Servo Motor
vi. Battery
vii. Jumper wire
viii. Elastic
ix. String
x. Others

3.3 Circuit Diagram

3.3.1 Circuit Diagram of full process

A circuit diagram is a simplified graphical representation of an electrical circuit. in this diagram show full graphical circuit process of prosthetic arm. In this diagram have Arduino neno microcontroller module, muscle sensor, two battery foe sensor and one battery for controller and two MG995 Servo Motor.

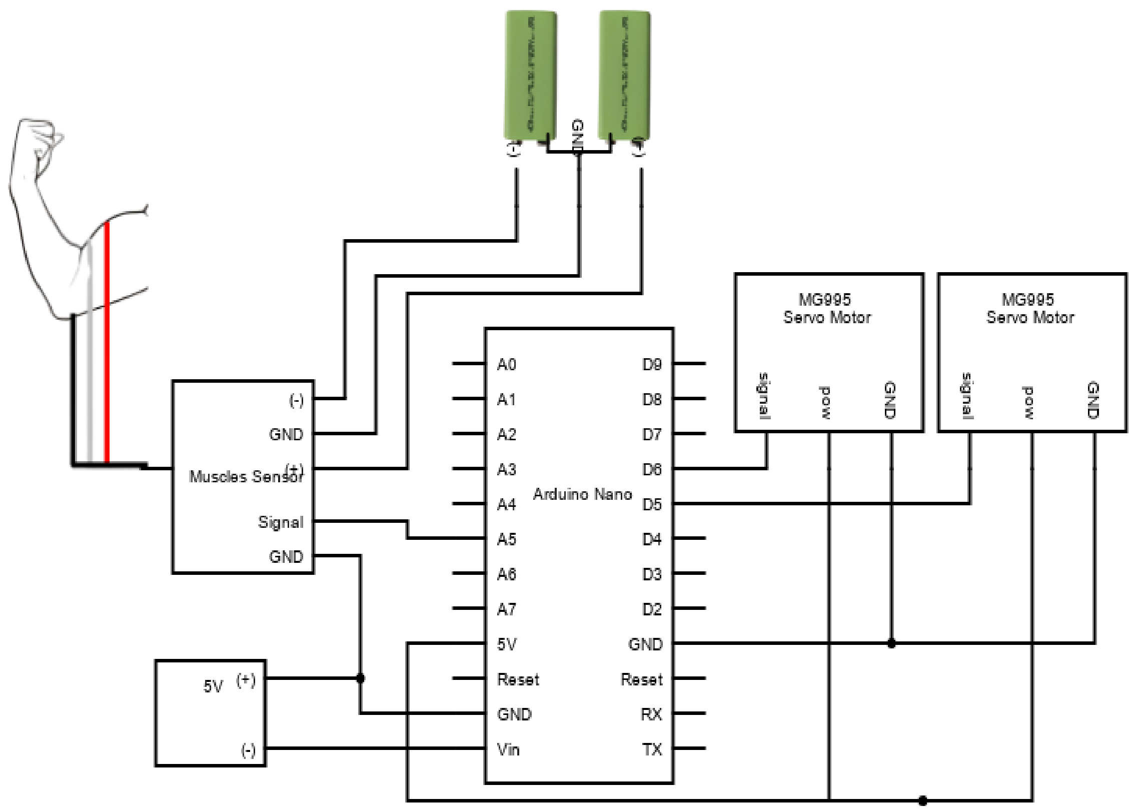

Figure 3.1: Circuit Diagram of Prosthetic Arm

In Figure 3.1 draw a circuit Diagram of prosthetic Arm. This process has an EMG muscle sensor v3 and this sensor has three electrodes fixed on human hand and sensor positive, negative and ground pin connect with 18v battery. Signal and another ground pin connect with Arduino neno ground and analog-5 (A5) pins. Arduino neno vin pin and GND pin connect with a 5-volt battery and two servo motor power and GND also connected Microcontroller 5-volt and GND and signal pin connect with digital pin 5 and 6 (D5, D6).

3.3.1 Circuit Diagram of Arduino Neno

In ATmega328 model Arduino microcontroller circuit diagram shown 8 analog pins,22 digital input/output pin 6 of which are PWM. and this PCB size is 18x45mm.

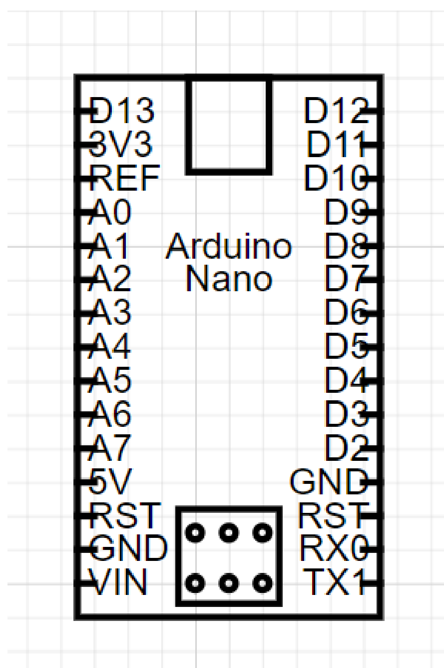

Figure 3.2: Circuit Diagram of Arduino Neno

In figure 3.2 show Arduino neno microcontroller circuit diagram. This diagram has a power and code sending cable port and 8 Analog pin 12 Digital pin one RX 0 pin and one TX 1 pin, one Vin pin and two GND pin and one button for reset.

3.4 Block Diagram

3.4.1 Block Diagram of full Process

In this block diagram Show 18volt battery use for sensor and sensor have 3 pad use human muscle for receiving signal. Microcontroller use 5v battery for power and control two servo motor.

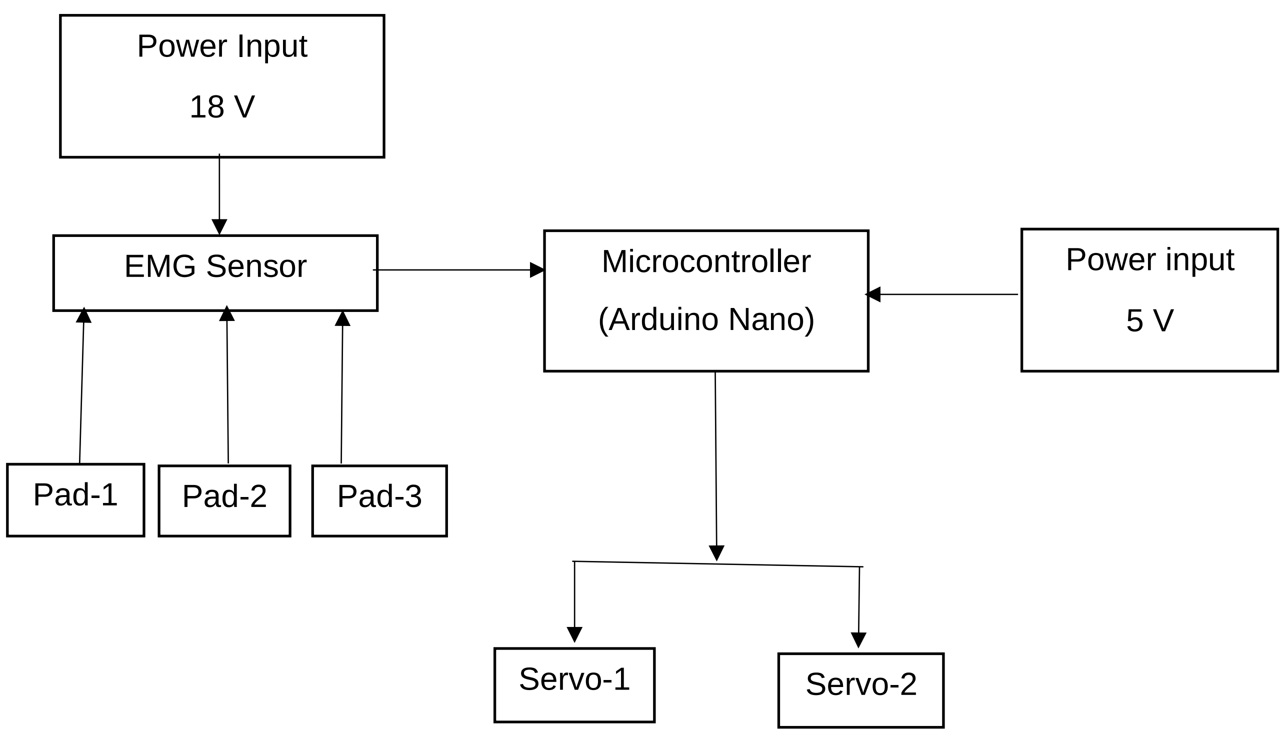

Figure 3.3: Block Diagram of Prosthetic Arm

In figure 3.3 show a Block diagram for prosthetic arm. This diagram shown 18-volt power connected with EMG muscle sensor and 3 electrodes attach with sensor. Muscle sensor and 5-vlot battery also connect with Arduino neno Microcontroller controller. And two servo motor connect with microcontroller.

3.5 Flowchart

This flowchart shows the full process of prosthetic arm. this workflow process with condition and loop use muscle data.

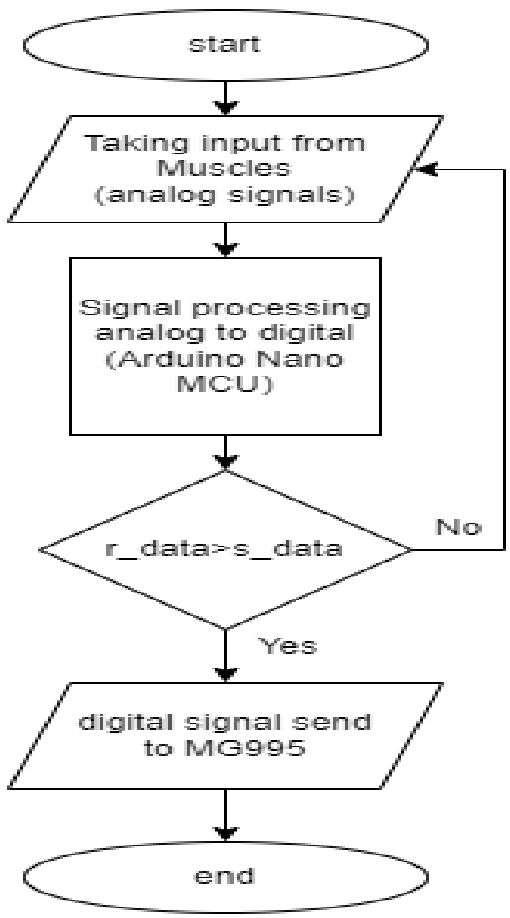

Figure 3.4: Flowchart of Prosthetic Arm

A flowchart is a picture of the sequence of individual steps in a process. In this flowchart shows the continuity of the full function of the prosthetic arm.

After this process starts, the sensor will take the analog signal from the muscle and then convert the signal from analog to digital with the help of Arduino Neno. in condition used random data and signal data, if signal data overcome random data, then process send digital signal in MG995 or Signal Data Do not overcome random data then process back in muscle sensor.

3.6 Description

3.6.1 Description of Arduino Neno

The Arduino Nano is a small microcontroller based on the ATmega328. Arduino Nano has the same effect as Arduino Duemilanove. Although it is in a different package. The Arduino Nano has no DC power jack. It works with a Mini-B USB cable. In Figure 3.1 shows the Arduino Nano Microcontroller.

And in Table 3.1 shown the Description of Arduino Nano Microcontroller Pin, Volt, Memory, Clock speed and other Specifications.

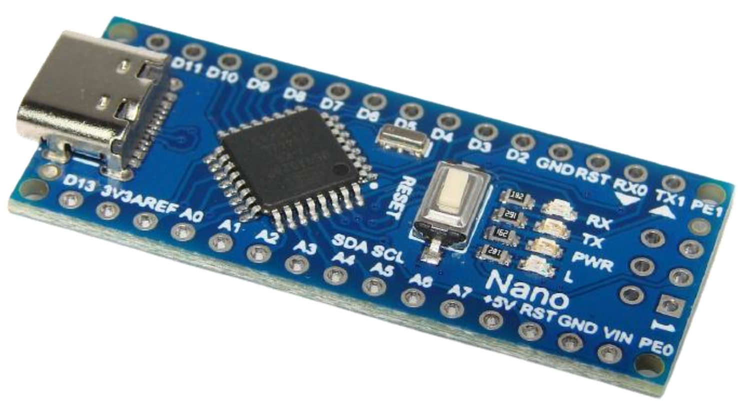

Figure 3.5: Arduino Neno Microcontroller

Table 3.1: Specification of Arduino Neno

Specification	**Description**
MICROCONTROLLER	ATmega328
ARCHITECTURE	AVR
OPERATING VOLTAGE	5V
FLASH MEMORY	32 KB of which 2 KB used by bootloader
SRAM	2 KB
CLOCK SPEED	16 MHz
ANALOG IN PINS	8
EEPROM	1 KB
DC CURRENT PER I/O PINS	40 mA (I/O Pins)
INPUT VOLTAGE	7-12V
DIGITAL I/O PINS	22 (6 of which are PWM)
PWM OUTPUT	6
POWER CONSUMPTION	19 mA
PCB SIZE	18 x 45 mm
WEIGHT	7 g

3.6.2 Description of EMG Muscle Sensor V3

Normally, to control an Arm type machine, press the button, pull the lever, move the joystick. Most of the time it is easier to use the muscles to control the machines. The device is controlled using signals from the muscles. The sensor detects electrical potential by measuring muscle activity, converts it into electromyography (EMG) signal, which is used for medical research.

It is a commercially available electromyography sensor. It uses a microcontroller specifically to receive signals from the human body and control any device. And the device has a power switch, one power LED as LED indicators and one LED is on when the muscle is flexed.

In MyoWare Sensors has two output style,

1. EMG envelop

2. Raw EMG.

In Figure 3.2 shown the EMG Muscle Sensor V3. And in Table 3.2 shown the Description of EMG Muscle Sensor and sensor Specifications.

Figure 3.6: EMG Muscle Sensor V3

Table 3.2: Specification of EMG Muscle Sensor

Specification	**Description**
Dimensions	1.0" x 1.0"
Connector	3.5mm
Design	Specially For Microcontrollers
Breadboard	Compatible
Power supply voltage	minimum +-3.5V

3.6.3 Description of Battery

In this study, a 9-volt size battery was selected to run the device. 9-volt batteries are usually of a certain size but there are some differences between 9-volt batteries, such as: ampere, rechargeable and non-rechargeable. This battery size is commonly used in walkie-talkies, watches, Toys and Selected for smaller devices.

In Figure 3.3 shown the Battery. And in Table 3.3 shown the Description of Battery and Battery Specifications.

Figure 3.7: 9-volt Battery

Table 3.3: Specification of Battery

Specification	**Description**
Voltage	9V
Rechargeable	Yes / No
Dimensions	4.9 cm x 2.6 cm x 1.7 cm
Weight	1.23 oz (35 g)

3.6.4 Description of Servo Motor

The MG995 servo motor is the most famous servo made by TowerPro. The MG995 is a metal gear high torque servo used for aircraft, helicopters and many RC models of RC-cars. Two MG995 servo motors have been used in the prosthetic arm, With the help of which the fingers will be controlled.

In Figure 3.4 shown the TowerPro MG995 Servo motor. And in Table 3.4 shown the Description of MG995 Servo motor and Servo motor Specifications.

Figure 3.8: TowerPro MG995 Servo motor

Table 3.4: Specification of MG995 Servo Motor

Specification	**Description**
Weight	55g
Dimension	40.7×19.7×42.9mm
Stall torque	9.4kg/cm (4.8v); 11kg/cm (6v)
Operating speed	0.20sec/60degree (4.8v) and 0.16sec/60degree (6.0v)
Operating voltage	4.8~ 6.6v
Gear Type	Metal gear
Temperature range	0- 55deg

3.6.5 Description of Jumper Wire

Jumper Wire has been used to assemble each part of the prosthetic arm. There are three types of jumper wires:

1. Male to Male

2. Male to Female

3. Female-Female

Jumper wires are usually 20 cm long. The jumper wires can be connected side by side with a 2.54 mm header. In Figure 3.5 shown the Jumper Wire.

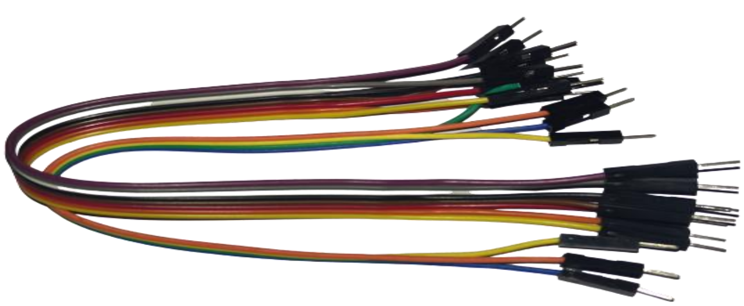

Figure 3.9: Jumper Wire

3.6.6 Description of Elastic and String

Elastic and String have been used in the low-cost prosthetic arm project. Because each part of the finger is different, Elastic has been used to assemble each part. And it helps keep the finger in its position.

String helps to move the finger up and down. The string is attached to the Servo Motor from the top of the finger. And completes the work with the help of Servo Motor. In Figure 3.6 shown the Elastic and String.

Figure 3.10: Elastic and String

3.6.7 Description of PLA Filament

3d Printer and PLA Filament are used to make the whole part of the Prosthetic Arm. With the help of 3d Printer, the prosthetic Arm is printed according to the design with PLA Filament. PLA filament purity and shrinkage are low. No bubbles in this Filament, suitable for use in a variety of 3D printers. In this PLA Filament diameter is:1.75 mm (dimensional accuracy +/- 0.05 mm). In Figure 3.7 Shown the PLA Filament.

Figure 3.11: PLA Filament

3.7 Arm prototype

The prototype of the prosthetic arm is designed based on the human hand. This is an open-source design. The five fingers, the palm of the hand, and the entire base structure are designed to measure the full size of the hand. The height of this arm is usually about 16 inches long. The base structure is designed in different parts, this base structure has a specific location for two servo motors, Arduino Nano Microcontroller and Battery.

The prosthetic arm is then printed with a 3D printer, using PLA Plastic Material during printing. The motors are arranged in the base structure of the hand. The name of this motors is TowerPro MG995. These are Micro Metal maximum force motor. Stall torque of this servo is 9.4kg/cm (4.8v); 11kg/cm (6v) and Operating speed is 0.20sec/60degree (4.8v) and 0.16sec/60degree (6.0v).

little finger, ring finger, middle finger, index finger will be added to one motor and thumb finger will be added to another motor. Elastic has been used to assemble each part of finger. And the maximum force that can be applied on the fingers. The string emitted from the servo motor is attached to the head of the finger to get maximum power to the finger. And the fingers will always be the main one-way force which is a limitation of this prosthetic arm.

This device will be controlled by Arduino Nano Microcontroller. The model of this Microcontroller is Atmel ATmega328. It has a total digital input / output pin of 14, whereas 6 PWM output pins. And there are 4 Analog Input Pins. Servo motors are attached to pins 3 and 5 of the Arduino Nano Microcontroller. And sensor is attached to an analog pin of microcontroller. The Arduino Nano Microcontroller is controlled by a code and upload to the computer.

This code from the microcontroller will control every part of the prosthetic arm. For example, the controller pins of motors will send signals to the motors through which the motors will move the fingers up and down.

The sensor used in this prosthetic arm is called MyoWare Muscle Sensor. The microcontroller will connect Myo-Ware Muscle Sensor, and through this sensor the microcontroller will control all the work by taking the signal from the muscle. When three surface electrodes of the MyoWare Muscle Sensor are used on the upper skin of the body and based on hand torque the muscle is compressed and expanded, the human hand can apply an average force of 100N. This will torque according to the force,

$$T=F*R$$

$$\text{If, } F= 100N$$

$$R= 20$$

$$\text{So, } T= 37.46$$

Equation 3.1: torque according to the force

In this project, the surface of MyoWare Sensor is placed in different places of the muscle. The MyoWare Sensor can measure the electrical potential of the muscle. And the sensor is paired with the Arduino Nano microcontroller to control survival. And the signal received from the sensor is stored in the Arduino Nano microcontroller. The Arduino Nano microcontroller will then control the entire prosthetic arm with the help of the stored signals from the MyoWare Muscle Sensor. And the whole device will control 18-volt battery.

3.8 Implementation

In Figure 3.8 the marked part of the Mechanical Part, battery, Towerpro MG995 Metal Gear 2 Servo Motor and above its ARDUINO NANO V3 ATmega328P model microprocessor has been set up. The two servo motors are connected by a string with five fingers through the palm. Index finger is attached to motor one and Middle finger, Thumb finger, Ring finger, Pinky finger are attached to motor two.

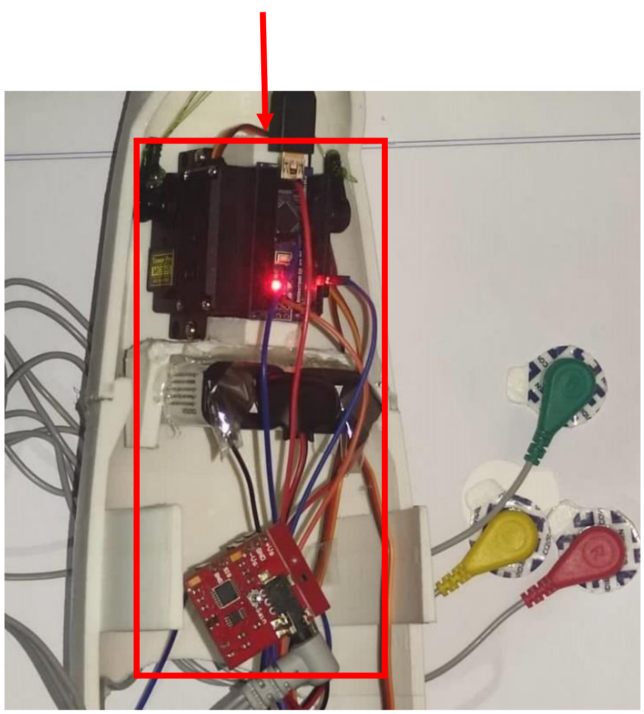

Figure 3.12: Mechanical Part of Prosthetic Arm

The motor one is connected to pin 3 of the microcontroller and the motors two are connected to pin 5. Servo motors with microcontroller will be controlled by a 9V battery. And the EMG Muscle sensor will be attached to the A0 analog pin of the microcontroller. And the EMG Muscle sensor will be controlled by 18V battery. The sensor part will be attached to the hand And EMG sensor will be attached below the sensor part and will send signal. In Figure 3.9 Shown the Full Prosthetic Arm.

Figure 3.13: Full Prosthetic Arm

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Discussion of PLA filament

The main component of the prosthetic Arm project was the PLA filament. The price of PLA Filament per kg is 24 dollars. This project 280.6g PLA filament has been used to make the prosthetic arm. The PLA filament cost 6.73 dollars to make the entire prosthetic arm.

Table 4.1: Discussion of PLA filament Length, Width, Weight

Finger	Length	Width	Filament
Index	69.4 mm	12.1 mm	4g
Middle	100.0 mm	15.0 mm	8g
Thumb	60.0 mm	17.0 mm	6g
Ring	90.0 mm	14.0 mm	6g
Pinky	65.0 mm	13.0 mm	4g
Palm	98.9 mm	96.8 mm	67.6g
Mechanical Part and Cover	181.4 mm	122.1 mm	93g
Sensor Part and Cover	116.7 mm	105.1 mm	92g

4.2 Discussion of Required Component prices

The list of Required Component used in Prosthetic Arm is shown along with the price.

Used in prosthetic arm, One ARDUINO NANO V3 ATmega328P CH340C With Cable, White PLA 1.75mm 280.6g Printer Long Filament Printing Consumables Accessories for 3D, Two Towerpro MG995 Metal Gear Servo Motors, one MyoWare Muscle Sensor V3, three 9v Battery with Charger, Elastic and String and Jumper Wires.

Table 4.2: Components and Price of prosthetic arm

Components	**Cost**
ARDUINO NANO V3 ATmega328P CH340C With Cable.	$6
White PLA 1.75mm 280.6g Filament	$6.73
Towerpro MG995 Metal Gear 2 Servo Motor.	$11
MyoWare Muscle Sensor V3	$38
Battery with Charger	$15
Elastic and String	$3
Jumper Wire and others	$6
Total	$85.73

4.3 Price Discussion and Compared

In this study, created a prosthetics hand phenomenon with PLA material. It is a soft plastic material used for 3D printing. It is cheap in price and fairly strong. In this design, most of the material cost was used to buy DC motors, battery and PLA material. In most cases, the cost of making this 3D prosthetics arm was $350. A study by Krausz et al suggested that they design an open-source prosthetic arm worth $2,221 [9]. The Dextrus robotic hand offered their price of $1000 [14]. in Table 4.1 mentioned the all components of this prosthetic arm. The prices of prosthetic hands have been mentioned in some previous studies:

Table 4.3: Prosthetic Arm Price Comparison

Prosthetic hand	**Cost**
The Dextrus robotic hand	$1000
Surehab Carbon Fiber, Aluminum Alloy Prosthetic Hand [26]	$866
3D Printed prosthetic Hand [27]	$134.20
Functional Prosthetic Carbon Fiber and Silicon Upper Limb Prostheses [28]	$466
Development and Analysis Low-Cost Robotic Prosthetic Arm	$85.73

4.4 Experimentation

The maximum output signal collected from the sensor depends on the voltage of the sensor. The muscle signal is a raw EMG signal that is exhibit, temper, and compact into the sensor transducer. An illustrative example of this signal is shown in Figure 4.1.

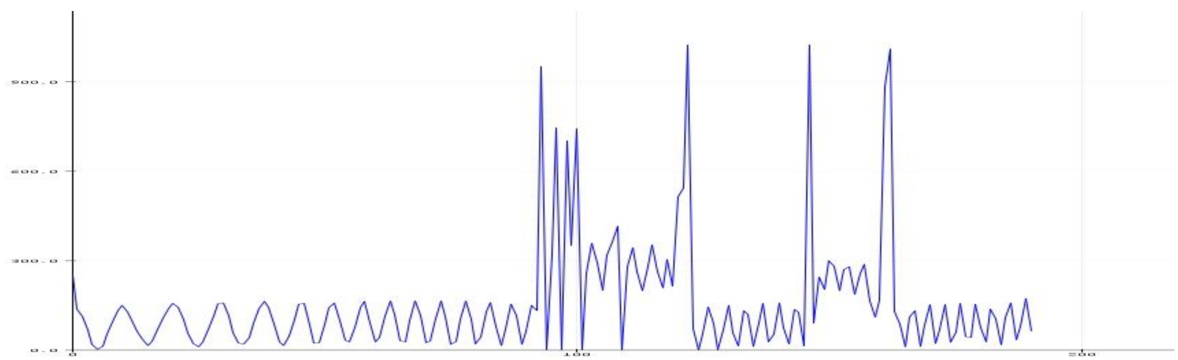

Figure 4.1: Raw EMG Signal

The signal from the sensor can be used directly by the converter from analog signal to digital signal with the help of micro-controller (Arduino neno). A proportional control was applied to gain the ability to slowly control the closing and opening of the arm prototype. The advantage of proportional control is that it automatically scales the level of the input signal to the required values of the actuators. Thus, the movement of the arm is slowed down as the muscle becomes flexible. Figure 4.2 shows the image of the sensor placement in the hand.

Figure 4.2: Sensor placement in the hand

The accuracy between the correct and incorrect actions of the test is shown based on the ratio of the number of correct actions to the number of tests. The results obtained show a lot of precision and control for the Prosthetic arm depending on the position of the sensor. in figure 4.3 shown the image of experiment.

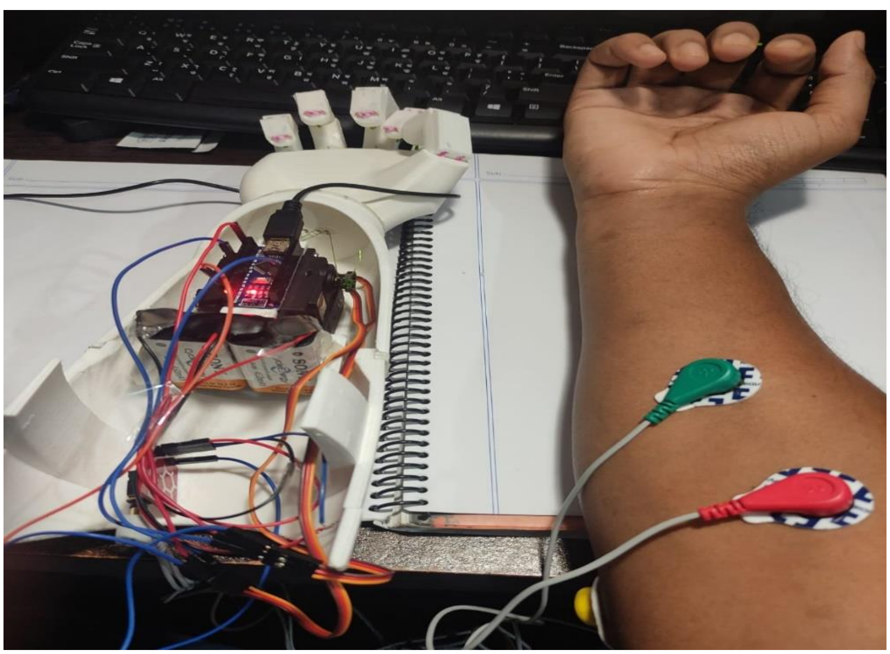

Figure 4.3: Prosthetic arm with sensor attached hand

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Findings and Contributions

The main objective of this study was to create a robotic prosthetic arm whose cost would be comparatively low and would be equally effective. The phenomenon of the robotic prosthetic arm follows a perfect hand feature. From the design of the 16-inch-long arm to the hardware, software focuses on features that make it usable and accurate in real-life applications. It is possible to reduce the price of the hand by making it using the cheapest ingredients in the market. The robotic prosthetic arm has become like a full human hand due to the 3D Design and 3D printing. Because the prosthetic arm is made of PLA filament, the weight of the hand is relatively less, the weight of the whole hand including the sensor is about 500g.

The parts of the finger are joined together using elastic so that the parts of the finger are not Strong. As a result, the prosthetic arm does not stay strong when carrying heavy objects. Two servo motors have been used in the prosthetic arm, which has reduced the cost and weight of the prosthetic arm. But to have four fingers in one motor, it is not possible to move Middle finger, Thumb finger, Ring finger, Pinky finger separately. And having a separate motor on the index finger gives much more power than the middle finger, thumb finger, ring finger, pinky finger.

5.2 Recommendations for Future Works

For future work, the material of the prosthetic arm can be changed, used in this project PLA Material here and it is a low melting point material and unable to carry high loads. Sensor activity can be increased, as the EMG signal depends on physical conditions, such as sweating and muscle fatigue. Use some alternatives of the elastic on the finger parts so that the finger parts are Strong.

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Development and Analysis Low-Cost Robotic Prosthetic Arm Submitted by Md. Mahmudul Hasan 181-35-2337 Department of Software Engineering Daffodil International University Supervised by Md. Hafizul Imran Lecturer Department of Software Engineering Daffodil International University This Project report has been submitted in fulfillment of the requirements for the Degree of Bachelor of Science in Software Engineering. © All right Reserved by Daffodil International University APPROVAL This thesis titled on "Development and Analysis Low-Cost Robotic Prosthetic Arm", submitted by Md. Mahmudul Hasan, ID: 181-35-2337 to the Department of Software Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science in Software Engineering and approval as to its style and contents. BOARD OF EXAMINERS -- Chairman Dr. Imran Mahmud Associate Professor and Head Department of Software EngineeringDaffodil International University ---Internal Examiner 1 Afsana Begum Assistant ProfessorDepartment of Software Engineering Daffodil International University --- Internal Examiner 2 Tapushe Rabaya Toma Senior Lecturer Department of Software Engineering Daffodil International University --- External Examiner Prof. Dr.

Md. Saiful Islam Professor Institute of Information and Communication Technology (IICT) Bangladesh University of Engineering and Technology (BUET) DECLARATION It hereby declares that this thesis has been done by me under the supervision of Md Hafizul Imran, Lecturer, Department of Software Engineering, Daffodil International University. It also declares that neither this thesis nor any part of this has been submitted elsewhere for award of any degree.

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Hafizul Imran Lecturer Department of Software Engineering Faculty of Science & Information Technology Daffodil International University ACKNOWLEDGEMENT We are very grateful to our supervisor Md Hafizul Imran, Lecturer Department of Software Engineering, Daffodil International University. Behind the project, we had to deal with some implementation issue, the encouragement and guidance of our supervising teacher in those moments was truly unparalleled. His excellent scholarly guidance and encouragement and enthusiastic supervision have made in the completion of this project possible. It would not have been possible without his endless cooperation. We are very grateful to Rony Shaha, Research assistant of Daffodil International University. For his in-depth knowledge of Robotics, who encourages us and helps us with many related issues. we truly thanks daffodil international university's FAB Lab authority for allowing the use 3D printing machine and material. Thanks a lot, to my classmates who have been helping me and encouraging me during this project. finally, and most importantly, our hearts are grateful for this blessing of God Almighty. And a lot of respect for our parents for their heartfelt support. iii | P a g e TABLE OF CONTANT APPROVAL

ABSTRACT: Being born without arm and losing arm by accident is a common issue. A robotic Prosthetic arm is an important product for handless people. A good robotic prosthetic arm is able to restore the functionality of their lost hand. At present, there are many good-quality prosthetic arm is available in the market at present are very expensive, which is very tough to afford the cost for everyone. And to overcome this problem, in this article we shown the design and development process of a low-costProsthetic hand using PLA material with 3D printing technology. The height of this prosthetic arm is usually about 16 inches long. A microcontroller that controls the whole arm and the microcontroller will be controlled by the sensor, the sensor will control the electromyographic (EMG) signal from the user's hand muscle movement. The component list, features and price of our prosthetic arm have been compared with some of the arms in the market. Which has enabled our study to reach the goal. Keyword: EMG, Prosthetic Arm, Low-Cost Arm, Arm Development, 3D Printed Arm. CHAPTER 1 INTRODUCTION 1.1 Background People to complete his daily work every part of the human body is necessary, when any part of the body is absent, human loses his ability to work. The hand is one of the most important parts of the human body, man performs various important functions of his life with the help of hand and this is unchangeable in today's competitive community. Many people lose their hand for a variety of reasons, such as congenital malformations, rail, electric shocks, war-related injuries, road accidents, damage to agricultural equipment, hand injuries during

construction, animal or reptile bites, burns, separation from certain diseases: diabetes or trauma, cancer. The impact of amputation is increasing day by day due to the continuous growth of industrialization and lack of safety awareness. which makes human life journey very difficult. Handicapped people are unable to meet their daily work or many times their own needs, which makes them dependent on others. People who are unable to work are burdened by their families and society. So, the robotic prosthetic arm will play an important role in overcoming the functional disability of the handless people. 1.2 Motivation of the Research There are many prosthetic arms in the international market but these prosthetic arms are very rare in underdeveloped and developing countries. The robotic prosthetic arm that is available in the market at present is very expensive, which is very difficult for most people to afford. The World Health Organization (WHO) reported That about 15% of the global population has a disability, Half of which cannot afford healthcare. There are 10 million amputee people worldwide, of which 30% have their arms amputated. In this context, the aim is to build robotic prosthetic arms using 3D printed technology to make them accessible to low-income people in underdeveloped and developing countries. 1.3 Problem Statement The prosthetic arms in the market have some specific problems, The biggest problems are: 1. Prosthetic arm is not easily available in the market. 2. People can't buy this product because of the high price. 3. It is difficult to use for overweight. 4. Some prosthetic arms look like an industrial arm. 5. There are some prosthetic hands that are not very functional, Therefore, not all work can be completed in a perfect way. 1.4 Research Questions 1. How will the prosthetic arm solve the problem of handless people? 2. How the Prosthetic Arm in the market are meeting the demand? 3. Is it possible to meet all the needs of prosthetic hand using 3D print technology? 1.5 Research Objectives 1. To solve the problems of handless people. 2. To make a specific weight. 3. To reduce prices compared to the past. 4. To be designed and made in the shape of a perfect hand. 1.6 Research Scope Organ amputate is a common occurrence, every day anywhere in the world people’s organ are being amputate. the United States, an estimated 185,000 organs are amputated each year, and this rate is expected to double by 2050. There were about 20,000 accidents in Bangladesh from 2009 to 2016. In 2017, about 7,397 humans died and 16,193 humans were harmed. And the number of dying in 2018 increased by 7% over the previous year and 10,828 people were injured. There are many among them whose hands have been cut off. The hand is one of the most important organs in the human body. People without hands can be said to be very immobile, because without hands it is difficult to complete daily work. So, at present robotic prosthetic hand is very demandable product. 1.7 Thesis Organization This thesis is organized as follows: chapter 1 outlines the thesis background, motivation of the research, problem statement, research questions, research objective, research scope and thesis organization. Detailed reviews are provided from previous studies in chapter 2. details of methods such as hand pattern Arm Prototype are explained in chapter 3. And also, Hand size, number of fingers, weight and what material used in this Arm. Mechanical parts such as microcontrollers, sensors, motors, batteries have been discussed. And the circuit diagram, block diagram, component list and each part of the prosthetic arm are shown. and discussed about muscle sensor and muscle signal. Chapter 4 highlight the Result and Discussion. And Chapter 5 discuss Conclusion and recommendations. CHAPTER 2 LITERATURE REVIEW 2.1 Background The hand is one of the most important parts of the human body, man performs various important functions of his life with the help of hand and this is unchangeable in today's competitive community. Therefore, loss of hand function or loss of hand can slow down the life of such people. For this argument, prosthetic hands help them to perform all the tasks in their daily life, for which prosthetic hands have been considered as an alternative means [1]. People lose their limbs for a variety of reasons, such as congenital malformations, rail, electric shocks, war-related injuries, road accidents, damage to agricultural equipment, hand injuries during construction, animal or reptile bites, burns, separation from certain diseases: diabetes or trauma, cancer. The impact of amputation is increasing day by day due to the continuous growth of industrialization and lack of safety awareness [2]. One study found that in the United States alone, an estimated 1.6 million amputees were living as of 2005. And in the United States, an estimated 185,000 organs are amputated each year, and this rate is expected to double by 2050 [3]. There were about 20,000 accidents in Bangladesh from 2009 to 2016. In 2017, about 7,397 humans died and 16,193 humans were harmed. And the number of dying in 2018 increased by 7% over the previous year and 10,828 people were injured [4]. In a recent study, the World Health Organization (WHO) reported That about 15% of the global population has a disability, Half of which cannot afford healthcare. There are 10 million amputee people worldwide, of which 30% have their arms amputated [5]. Although much progress has been made in solving the problem of organ loss and many types of prosthetics hand have been developed over the years, The advancement of this technology is still limited and the cost is very high as it takes a lot of time to make every necessary part of the equipment suitable for use [6]. There are some existing artificial hands available commercially. Those artificial arms include Touch Bionics, Be-bionic, Otto-bock, Steeper, Open Hand Project, and Open Bionics. Existing technology costs from $

1,000 to $ 120,000 which is very expensive for most people in Bangladesh [4]. A study by the World Health Organization found that only 20% of a group of 30 million people have artificial or other dynamism devices to meet their needs. Humans have 27 degrees of freedom in their hands, Control the hardware with the servo motor here. And prosthetics are made using 3D technology [6]. Myo-sensor will be used as a sensor; these sensors are placed in one or more places on the rest of the patient's hand. When the muscles are raised, the prosthetic arm works, including capturing and augmenting the potential for muscle action [7]. Some previous researchers have found that the most commonly used prosthetic arm movements include: hook grasp (10%), lateral grasp (20%), precise grasp (30%), power grasp (35%) and others (5%). Some of them have studied the requirements of artificial hands and concluded their most worrying features, such as the basic work of adult hands, weight and humanoid appearance. Also, the low cost of prosthetic hand design is considered, as the price can significantly reduce the rate of prosthetic hand adoption [1]. The first step-in low-cost prosthetic arm design is to resolve the basic elements for development, some key elements of the design must be of limited cost. Generally, Prosthetics Arm divided into Four main categories: cosmetic, myoelectric controlled, activated by a cable, and hybrid. In general, wire-activated methods are preferred for making low-cost prostheses. And these are made based on kinematic energy [8]. The hand can be used as a cosmetic in social life and can perform any daily work. The design is easy to control based on the prevention model, and it uses a standard electronic system and is used at low cost for mechanical construction, but there are some limitations to using this type of prosthetics. Again, in some studies there was a tendency to make these artificial hands based on ethnographic designs. And this ethnographic hand had five fingers that looked a lot like a human hand. This type of hand can transmit less and more energy like a human hand. That is, each prosthetic finger of the prosthetic hand controls power individually using a DC servo motor. Therefore, there are more complexities in the design, construction and control algorithms of this type of artificial hand [9]. In recent years the common products of prosthetic hands at home and abroad have adopted two transmission types, the connecting rod drive and the tendon drive. (1) Stanford University has developed a five-finger simple tendon drive prosthetic arm. (2) US IOWA State University has developed a common connecting rod drive by prosthetic hand. There are also some more advanced quality prosthetic hands in different countries, (3) such as those made by NASA Dextras Hand. But there were some problems with these products, the structure was more complex and controlling the prosthetic hand was difficult for users because of the extra emphasis on finger adaptability [10]. So, this research will focus on creating an advanced, lowcost prosthetic arm [11] [12]. That its structure and hand are easy to use [13]. So, in this study the method of laser cutting can be turned into specific phenomenon through 3D printing instead [14]. The goal of the current work is to design an artificial arm to reduce hand costs using both 3D design software and 3D printing [15]. Since a large number of tasks can be performed by controlling only one sensor [16], whenever a person wishes to move a hand, a small The amount of electrical current produced by muscle fibers [17] [18], Which will measure muscle contraction with a Mayo electric signal and control only the hand using the signal [19] [20]. In this time the artificial hand that is still on the market, because of its low cost and also because of its simplicity [21]. Artificial hands must meet certain criteria: low cost, locally available, technically functional, manual, easy to repair, durable, local production capacity, reproducible by local workers, easy to use, biomechanically suitable, e.g., as lightweight as possible [22]. The compression ratio never exceeded 25% in all previous studies. Recent studies have shown a compression ratio of 80% using the "overtwist phase" [23]. These results constitute an important step towards the development of the prosthetic arm, they may possibly perceive a more natural conception and give the user greater efficiency [24] [25]. 2.2 Related paper review 1 The hand is developed with the help of 3D printing technology. The Arduino Mega board is used as a microcontroller. The EMG sensor is used to control the hand. The cost of making the hand is about $ 640. A change will be made from the pin jointed finger to the polyurethane rubber joint which will help to facilitate hand control [3]. 2.3 Related paper review 2 The work is an EEG mind-controlled smart artificial arm that is controlled by the order of the brain. With the help of smart sensors obtained from electroencephalography (EEG) headset. The arm is fully 3D printed and a total of nine motors are used in the arm. The components of this project included Raspberry Pi II and EEG-based headset , servo motor, Bluetooth, sensor, two USB battery packs. The cost of the project is estimated at around 1140 USD [5]. 2.4 Related paper review 3 Two prototypes were created in this study. A hand with 5 fingers controlled by a flex sensor with a wearable glove. And the other hand is controlled by flexing any muscle in the user's arm and collecting electromyographic (EMG) signals. The fingers are controlled by the servomotor and each servomotor is controlled by the microcontroller. And 3D printing technology has been used to build prototypes. This experiment showed that flex sensors can measure human hand motion smoothly [6]. 2.5 Summery Previous studies have shown that most of the arms are made using 3D printing technology. But five to seven motors have been used for hand control. In some studies, only five fingers have been controlled. Someone has used a motor to control the wrist and fold the hand. Most have used the Arduino Neno as a microcontroller. Some studies have used Arduino Mega, Raspberry Pi. Electromyographic (EMG), electroencephalography (EEG) and flex sensors have been used as sensors. Some studies have been used electromyographic (EMG) and flex both sensors. As a result, the cost of the project increases. Although, the main objective of this study is to create a good quality prosthetic arm at a low cost. CHAPTER 3 RESEARCH METHODOLOGY 3.1 Model design planning This hand design includes the little finger, ring finger, middle finger, index finger, thumb finger, palate and base structure. Each finger has three separate parts except for the thumb finger, the thumb finger has two parts. The fingers will be controlled by two servo motors. little finger, ring finger, middle finger, index finger will be added to one motor and thumb finger will be added to another motor. Servo motors are connected to microcontrollers which will be controlled by sensors. The sensor will control the device by receiving signals from human hands.

3.2 Requirement: In previous studies, those who have made low-cost prosthetic arms have some requirements are similarities. Although there are differences in design, there are some similarities between the tools. The tools that will be used in this study: i. 3D Printer ii. PLA Material iii. Arduino Neno Microcontroller iv. EMG Muscle Sensor v. Servo Motor vi. Battery vii. Jumper wire viii. Elastic ix. String x. Others 3.3 Circuit Diagram 3.3.1 Circuit Diagram of full process A circuit diagram is a simplified graphical representation of an electrical circuit. in this diagram show full graphical circuit process of prosthetic arm. In this diagram have Arduino neno microcontroller module, muscle sensor, two battery foe sensor and one battery for controller and two MG995 Servo Motor. Figure 3.1: Circuit Diagram of Prosthetic Arm In Figure 3.1 draw a circuit Diagram of prosthetic Arm. This process has an EMG muscle sensor v3 and this sensor has three electrodes fixed on human hand and sensor positive, negative and ground pin connect with 18v battery. Signal and another ground pin connect with Arduino neno ground and analog-5 (A5) pins. Arduino neno vin pin and GND pin connect with a 5-volt battery and two servo motor power and GND also connected Microcontroller 5-volt and GND and signal pin connect with digital pin 5 and 6 (D5, D6). 3.3.1 Circuit Diagram of Arduino Neno In ATmega328 model Arduino microcontroller circuit diagram shown 8 analog pins,22 digital input/output pin 6 of which are PWM. and this PCB size is 18x45mm. Figure 3.2: Circuit Diagram of Arduino Neno In figure 3.2 show Arduino neno microcontroller circuit diagram. This diagram has a power and code sending cable port and 8 Analog pin 12 Digital pin one RX 0 pin and one TX 1 pin, one Vin pin and two GND pin and one button for reset. 3.4 Block Diagram 3.4.1 Block Diagram of full Process In this block diagram Show 18volt battery use for sensor and sensor have 3 pad use human muscle for receiving signal. Microcontroller use 5v battery for power and control two servo motor. Power Input 18 V EMG Sensor Microcontroller Power input (Arduino Nano) 5 V Pad-1 Pad-2 Pad-3 Servo1 Servo-2 Figure 3.3: Block Diagram of Prosthetic Arm In figure 3.3 show a Block diagram for prosthetic arm. This diagram shown 18-volt power connected with EMG muscle sensor and 3 electrodes attach with sensor. Muscle sensor and 5-vlot battery also connect with Arduino neno Microcontroller controller. And two servo motor connect with microcontroller. 3.5 Flowchart This flowchart shows the full process of prosthetic arm. this workflow process with condition and loop use muscle data. Figure 3.4: Flowchart of Prosthetic Arm A flowchart is a picture of the sequence of individual steps in a process. In this flowchart shows the continuity of the full function of the prosthetic arm. After this process starts, the sensor will take the analog signal from the muscle and then convert the signal from analog to digital with the help of Arduino Neno. in condition used random data and signal data, if signal data overcome random data, then process send digital signal in MG995 or Signal Data Do not overcome random data then process back in muscle sensor. 3.6 Description 3.6.1 Description of Arduino Neno The Arduino Nano is a small microcontroller based on the ATmega328. Arduino Nano has the same effect as Arduino Duemilanove. Although it is in a different package. The Arduino Nano has no DC power jack. It works with a Mini-B USB cable. In Figure 3.1 shows the Arduino Nano Microcontroller. And in Table 3.1 shown the Description of Arduino Nano Microcontroller Pin, Volt, Memory, Clock speed and other Specifications. Figure 3.5: Arduino Neno Microcontroller Table 3.1: Specification of Arduino Neno Specification Description MICROCONTROLLER ATmega328 ARCHITECTURE AVR

OPERATING VOLTAGE 5V FLASH MEMORY 32 KB of which 2 KB used by bootloader SRAM 2 KB CLOCK SPEED 16 MHz ANALOG IN PINS 8 EEPROM 1 KB DC CURRENT PER I/O PINS 40 mA (I/O Pins) INPUT VOLTAGE 7-12V DIGITAL I/O PINS 22 (6 of which are PWM) PWM OUTPUT 6 POWER CONSUMPTION 19 mA PCB SIZE 18 x 45 mm WEIGHT 7 g 3.6.2 Description of EMG Muscle Sensor V3 Normally, to control an Arm type machine, press the button, pull the lever, move the joystick. Most of the time it is easier to use the muscles to control the machines. The device is controlled using signals from the muscles. The sensor detects electrical potential by measuring muscle activity, converts it into electromyography (EMG) signal, which is used for medical research. It is a commercially available electromyography sensor. It uses a microcontroller specifically to receive signals from the human body and control any device. And the device has a power switch, one power LED as LED indicators and one LED is on when the muscle is flexed. In MyoWare Sensors has two output style, 1. EMG envelop 2. Raw EMG. In Figure 3.2 shown the EMG Muscle Sensor V3. And in Table 3.2 shown the Description of EMG Muscle Sensor and sensor

Specifications. Figure 3.6: EMG Muscle Sensor V3 Table 3.2: Specification of EMG Muscle Sensor

Specification Description Dimensions 1.0" x 1.0" Connector 3.5mm Design Specially For Microcontrollers Breadboard Compatible Power supply voltage minimum +-3.5V 3.6.3 Description of Battery In this study, a 9-volt size battery was selected to run the device. 9-volt batteries are usually of a certain size but there are some differences between 9-volt batteries, such as: ampere, rechargeable and non-rechargeable. This battery size is commonly used in walkietalkies, watches, Toys and Selected for smaller devices. In Figure 3.3 shown the Battery. And in Table 3.3 shown the Description of Battery and Battery Specifications. Figure 3.7: 9-volt Battery

Table 3.3: Specification of Battery Specification Description Voltage 9V Rechargeable Yes / No Dimensions 4.9 cm x 2.6 cm x 1.7 cm Weight 1.23 oz (35 g) 3.6.4 Description of Servo Motor The MG995 servo motor is the most famous servo made by TowerPro. The MG995 is a metal gear high torque servo used for aircraft, helicopters and many RC models of RC-cars. Two MG995 servo motors have been used in the prosthetic arm, With the help of which the fingers will be controlled. In Figure 3.4 shown the TowerPro MG995 Servo motor. And in Table 3.4 shown the Description of MG995 Servo motor and Servo motor Specifications. Figure 3.8: TowerPro MG995

Servo motor Table 3.4: Specification of MG995Servo Motor Specification Description Weight 55g

Dimension 40.7×19.7×42.9mm Stall torque 9.4kg/cm (4.8v); 11kg/cm (6v) Operating speed

0.20sec/60degree (4.8v) and 0.16sec/60degree (6.0v) Operating voltage 4.8~ 6.6v Gear Type Metal gear Temperature range 0- 55deg 3.6.5 Description of Jumper Wire Jumper Wire has been used to assemble each part of the prosthetic arm. There are three types of jumper wires: 1. Male to Male 2. Male to Female 3. Female-Female Jumper wires are usually 20 cm long. The jumper wires can be connected side by side with a 2.54 mm header. In Figure 3.5 shown the Jumper Wire. Figure 3.9: Jumper Wire 3.6.6 Description of Elastic and String Elastic and String have been used in the low-cost prosthetic arm project. Because each part of the finger is different, Elastic has been used to assemble each part. And it helps keep the finger in its position. String helps to move the finger up and down. The string is attached to the Servo Motor from the top of the finger. And completes the work with the help of Servo Motor. In Figure 3.6 shown the Elastic and String. Figure 3.10: Elastic and String 3.6.7 Description of PLA Filament 3d Printer and PLA Filament are used to make the whole part of the Prosthetic Arm. With the help of 3d Printer, the prosthetic Arm is printed according to the design with PLA Filament. PLA filament purity and shrinkage are low. No bubbles in this Filament, suitable for use in a variety of 3D printers. In this PLA Filament diameter is:1.75 mm (dimensional accuracy +/- 0.05 mm). In Figure 3.7 Shown the PLA Filament. Figure 3.11: PLA Filament 3.7 Arm prototype The prototype of the prosthetic arm is designed based on the human hand. This is an open-source design. The five fingers, the palm of the hand, and the entire base structure are designed to measure the full size of the hand. The height of this arm is usually about 16 inches long. The base structure is designed in different parts, this base structure has a specific location for two servo motors, Arduino Nano Microcontroller and Battery. The prosthetic arm is then printed with a 3D printer, using PLA Plastic Material during printing. The motors are arranged in the base structure of the hand. The name of this motors is TowerPro MG995. These are Micro Metal maximum force motor.

Stall torque of this servo is 9.4kg/cm (4.8v); 11kg/cm (6v) and Operating speed is 0.

20sec/60degree (4.8v) and 0.16sec/60degree (6.0v). little finger, ring finger, middle finger, index finger will be added to one motor and thumb finger will be added to another motor. Elastic has been used to assemble each part of finger. And the maximum force that can be applied on the fingers. The string emitted from the servo motor is attached to the head of the finger to get maximum power to the finger. And the fingers will always be the main one-way force which is a limitation of this prosthetic arm. This device will be controlled by Arduino Nano Microcontroller. The model of this Microcontroller is Atmel ATmega328. It has a total digital input / output pin of 14, whereas 6 PWM output pins. And there are 4 Analog Input Pins. Servo motors are attached to pins 3 and 5 of the Arduino Nano Microcontroller.

And sensor is attached to an analog pin of microcontroller. The Arduino Nano Microcontroller is controlled by a code and upload to the computer. This code from the microcontroller will control every part of the prosthetic arm. For example, the controller pins of motors will send signals to the motors through which the motors will move the fingers up and down. The sensor used in this prosthetic arm is called MyoWare Muscle Sensor. The microcontroller will connect Myo-Ware Muscle Sensor, and through this sensor the microcontroller will control all the work by taking the signal from the muscle. When three surface electrodes of the MyoWare Muscle Sensor are used on the upper skin of the body and based on hand torque the muscle is compressed and expanded, the human hand can apply an average force of 100N. This will torque according to the force, T=F*R If, F= 100N R= 20 So, T= 37.46 Equation 3.1: torque according to the force In this project, the surface of MyoWare Sensor is placed in different places of the muscle. The MyoWare Sensor can measure the electrical potential of the muscle. And the sensor is paired with the Arduino Nano microcontroller to control survival. And the signal received from the sensor is stored in the Arduino Nano microcontroller. The Arduino Nano microcontroller will then control the entire prosthetic arm with the help of the stored signals from the MyoWare Muscle Sensor. And the whole device will control 18-volt battery.

3.8 Implementation In Figure 3.8 the marked part of the Mechanical Part, battery, Towerpro MG995 Metal Gear 2 Servo Motor and above its ARDUINO NANO V3 ATmega328P model microprocessor has been set up. The two servo motors are connected by a string with five fingers through the palm. Index finger is attached to motor one and Middle finger, Thumb finger, Ring finger, Pinky finger are attached to motor two. Figure 3.12: Mechanical Part of Prosthetic Arm The motor one is connected to pin 3 of the microcontroller and the motors two are connected to pin 5. Servo motors with microcontroller will be controlled by a 9V battery. And the EMG Muscle sensor will be attached to the A0 analog pin of the microcontroller. And the EMG Muscle sensor will be controlled by 18V battery. The sensor part will be attached to the hand And EMG sensor will be attached below the sensor part and will send signal. In Figure 3.9 Shown the Full Prosthetic Arm. Figure 3.13: Full Prosthetic Arm CHAPTER 4 RESULTS AND DISCUSSION 4.1 Discussion of PLA filament The main component of the prosthetic Arm project was the PLA filament. The price of PLA Filament per kg is 24 dollars. This project 280.6g PLA filament has been used to make the prosthetic arm. The PLA filament cost 6.73 dollars to make the entire prosthetic arm. Table 4.1: Discussion of PLA filament Length, Width, Weight Finger Length Width Filament Index 69.4 mm 12.1 mm 4g Middle 100.0 mm 15.0 mm 8g Thumb 60.0 mm 17.0 mm 6g Ring 90.0 mm 14.0 mm 6g Pinky 65.0 mm 13.0 mm 4g Palm 98.9 mm 96.8 mm 67.6g Mechanical Part and Cover 181.4 mm 122.1 mm 93g Sensor Part and

Cover 116.7 mm 105.1 mm 92g 4.2 Discussion of Required Component prices The list of Required Component used in Prosthetic Arm is shown along with the price. Used in prosthetic arm, One ARDUINO NANO V3 ATmega328P CH340C With Cable, White PLA 1.75mm 280.6g Printer Long Filament Printing Consumables Accessories for 3D, Two Towerpro MG995 Metal Gear Servo Motors, one MyoWare Muscle Sensor V3, three 9v Battery with Charger, Elastic and String and Jumper Wires. Table 4.2: Components and Price of prosthetic arm Components Cost ARDUINO NANO V3 ATmega328P CH340C With Cable. $6 White PLA 1.75mm 280.6g Filament $6.73 Towerpro MG995 Metal Gear 2 Servo Motor. $11 MyoWare Muscle

Sensor V3 $38 Battery with Charger $15 Elastic and String $3 Jumper Wire and others $6 Total $85.73 4.3 Price Discussion and Compared In this study, created a prosthetics hand phenomenon with PLA material. It is a soft plastic material used for 3D printing. It is cheap in price and fairly strong. In this design, most of the material cost was used to buy DC motors, battery and PLA material. In most cases, the cost of making this 3D prosthetics arm was $350. A study by Krausz et al suggested that they design an open-source prosthetic arm worth $2,221 [9]. The Dextrus robotic hand offered their price of $1000 [14]. in Table 4.1 mentioned the all components of this prosthetic arm. The prices of prosthetic hands have been mentioned in some previous studies: 26 | P a g e Table 4.3: Prosthetic Arm Price Comparison Prosthetic hand Cost The Dextrus robotic hand $1000 Surehab Carbon Fiber, Aluminum Alloy Prosthetic Hand [26]

$866 3D Printed prosthetic Hand [27] $134.20 Functional Prosthetic Carbon Fiber and Silicon Upper Limb Prostheses [28] $466 Development and Analysis Low-Cost Robotic Prosthetic Arm $85.73 4.4 Experimentation The maximum output signal collected from the sensor depends on the voltage of the sensor. The muscle signal is a raw EMG signal that is exhibit, temper, and compact into the sensor transducer. An illustrative example of this signal is shown in Figure 4.1. Figure 4.1: Raw EMG Signal The signal from the sensor can be used directly by the converter from analog signal to digital signal with the help of micro-controller (Arduino neno).

A proportional control was applied to gain the ability to slowly control the closing and opening of the arm prototype. The advantage of proportional control is that it automatically scales the level of the input signal to the required values of the actuators. Thus, the movement of the arm is slowed down as the muscle becomes flexible. Figure 4.2 shows the image of the sensor placement in the hand. Figure 4.2: Sensor placement in the hand The accuracy between the correct and incorrect actions of the test is shown based on the ratio of the number of correct actions to the number of tests. The results obtained show a lot of precision and control for the Prosthetic arm depending on the position of the sensor. in figure 4.3 shown the image of experiment. Figure 4.3: Prosthetic arm with sensor attached hand CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS 5.1 Findings and Contributions The main objective of this study was to create a robotic prosthetic arm whose cost would be comparatively low and would be equally effective. The phenomenon of the robotic prosthetic arm follows a perfect hand feature. From the design of the 16-inch-long arm to the hardware, software focuses on features that make it usable and accurate in real-life applications. It is possible to reduce the price of the hand by making it using the cheapest ingredients in the market. The robotic prosthetic arm has become like a full human hand due to the 3D Design and 3D printing. Because the prosthetic arm is made of PLA filament, the weight of the hand is relatively less, the weight of the whole hand including the sensor is about 500g. The parts of the finger are joined together using elastic so that the parts of the finger are not Strong. As a result, the prosthetic arm does not stay strong when carrying heavy objects. Two servo motors have been used in the prosthetic arm, which has reduced the cost and weight of the prosthetic arm.

finger,finger,Ring finge, Pinky finger separately. And having a separate motor on the index finger gives much more power than the middle finger, thumb finger, ring finger, pinky finger. 5.2 Recommendations for Future Works For future work, the material of the prosthetic arm can be changed, used in this project PLA Material here and it is a low melting point material and unable to carry high loads. Sensor activity can be increased, as the EMG signal depends on physical conditions, such as sweating and muscle fatigue. Use some alternatives of the elastic on the finger parts so that the finger parts are Strong. REFERENCES 1. Y. Zheng, X. Li, L. Tian and G. Li.: Design of a Low-Cost and Humanoid Myoelectric Prosthetic Hand Driven by a Single Actuator to Realize Basic Hand Functions. 2018 IEEE International Conference on Cyborg and Bionic Systems (CBS),

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