Development of 3D Printed Bionic Arm Controlled by EMG Sensor

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Abstract- Man is a one-of-a-kind creation that only God could have made. They are an invaluable asset to the human body, with each component serving a purpose that is distinct from the others. Because of the significant impact that they have on a person's day-to-day and professional activities, a person's fingers, lower arm, and forearm are the body parts that should be preserved following an amputation the most. The primary goal of this bionic arm is to regain fundamental control of the hand at a price that will enable amputees with limited financial resources to purchase a bionic arm. This technology is utilized in the production of many of the artificial arms that are currently available for purchase around the world; however, these arms come at a very high cost. This study demonstrates the design, manufacturing, and functioning of a 3-D printed prosthetic hand that employs an electromyography (EMG) sensor in order to imitate the fundamental motions that are carried out by human hands (holding an object, lifting an object, shutting and opening fingers).

Keywords- Bionic Arm, Electromyography (EMG), Mesh, Stress, Deformation, Polylactide (PLA)

1. INTRODUCTION

Human is a unique creature created by God. For human, their body is like a valuable asset of which each part has a different importance. Just as a robotic platform requires actuators, sensors and microcontrollers, similarly the human body requires arms, legs and brain. When a person is amputated due to some reason, an accident or birth itself, such as a hand, leg, finger or claw, then the person's ability to do the work of daily life is reduced or completely lost and along with this in many cases it makes him dependent on others. But due to the excellence of science, some artificial organs have been developed to make life a little easier for such people.

The most valuable body part in an amputated human is its fingers, lower arm and forearm which affects its daily life as well as professional life [1]. A human hand amputation has a severe detrimental effect on a person's professionalism and disqualifies them from participating in a number of sports and jobs. At present, many such robotic arms or bionic hands are available, which try to meet the needs of disabled people in this way. A bionic arm is a mechatronically designed device that works like a normal human arm in certain limits and is a boon for amputees. Different types of technology, materials and sensors are used to make this artificial hand, but due to not being budget friendly and not having fast availability, these hands are not affordable for poor and middleclass amputees. Over the past twenty years, major advances have been made in the creation of revolutionary prosthetic hands and terminal devices that utilize advantage of the most rapid technological advancements, resulting in the construction of more dexterous hand devices [2].

Ahmed.et al. [3] fabricated a prosthetic hand, in which servo motor was connected along with the flex sensor which develop an affordable five degree of freedom (DOF) and two joints in each finger. Aayush Kumar et al. [4] created a 3-D printed robotic arm using PLA material along with muscle sensors that detect changes in strain and act according to the bionic hand. Dunai L. et al. [5] created a 3D printed robotic arm that simulated hand touch pressure using the FSR sensor. Samara M. et al. [6] told about, prosthetic hand and fingers, which were modeled using (Petg-CR) material, are subjected to stress and strain analysis and determine the impact of various load circumstances on the intended hand. Wattanasiri. et al. [7] proposed a prosthetic hand developed in SIM-Mechanics environment, which has different kind of patterns of grip and a tactile switch was used on the back side of the artificial hand. This switch was used to select desired grip on the hand by pressing it.

Research work presented here, explains the design, fabrication and operation of a 3-D printed prosthetic hand which uses EMG sensor for imitating the basic movement done by human hands with lower arm and closing, opening and turning of fingers like holding an object, lifting the object. The main advantages of this hand are that the it is portable, inexpensive and lighter in weight compared to the modern bionic arm available.

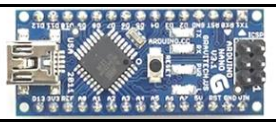
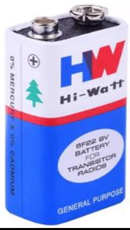
2. DESIGN AND DEVELOPMENT

Different types of technology, materials and sensors are used to make this artificial hand. According to the characteristics of various bionic arms, in this current arm system design we uses the following modules and components:

Table: 1 Characteristic of Some Popular Bionic Arms in India [8, 9, 10, 11, 12]

S.N.	1	2	3	4	5
Producer	Otto –Bock	Touch Bionics	Robo Bionic Hand	Deka Bionic Arm	Open Bionics Labs
Battery Used	Lithium- ion	Lithium Polymer	lithium-ion	Lithium- ion	Lithium Polymer
Weight (Approx.)	500 g	600 g	800 g	1.3 kg	950 g
Grips/ hand positions	14	8	6	6	9
Feed Back-System	No	No	Yes	No	No
Sensor Used	EMG	EMG	MMG	Foot Control, Myo-electrode	EMG
Operating Voltage	12 Volt	7.5 Volt	12 Volt	9 Volt	12 Volt

Table: 2 Components used in Robotic Arm

SN	Main-Component	Figure	Specification
1	Arduino Nano Board		Microchip ATmega328P 5 Volts 8 Analog input pins
2	Servomotor		60g,Metallic Gear 1ms Pulse 6 Volt
3	Battery		9 Volt,82g Model: HLW 6F22M
4	EMG - Sensor		Supported with Arduino, 30g
5	I. PC 3D Printer Filament		Strength :61.5MPa Melting Temperature: >155°C

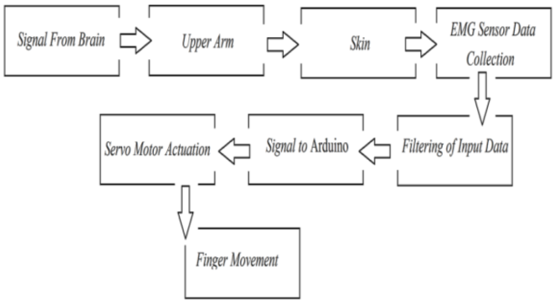


Fig. 1: Block Diagram of the Proposed System

3. FABRICATION OF BIONIC ARM

Material Used

PLA is a well-known name in the world of 3D printing, a material most commonly used to make 3D printed components. PLA material is popular because it is easily available, environment friendly and cheap. PLA is a biodegradable material obtained from food crops such as sugarcane, corn and jowar. Some important features of PLA are as follows:

Table: 3 Features of PLA

S.N.	Property	Value
1	Melting Point	Low
2	Low Thermal Expansion	Low
3	Layer adhesion	Good
4	Heat Resistance	High
5	Strength	High
6	Dimensional accuracy	High

3D printing

3D printing is a manufacturing process that creates a physical object from a digital model file. The technology works by adding layer upon layer of material to build up a complete object [13]. In this current work we use the Max200-3D printer with Ultimaker CURA software for making the mechanical components of the robotic arm. Some important features of 3D Printer are as follows:

Table: 4 Features of 3D Printer [14]

S.N.	Property	Value
1	Model Name/Number	Max-200
2	Material	Polyamide (PLA)
3	Software / Supporting	Ultimaker CURA/ STL
4	Technology	FDM
5	Connectivity	USB
6	Build Plate Temperature	600
7	Total Time for Printing	35 Hrs. Approx.

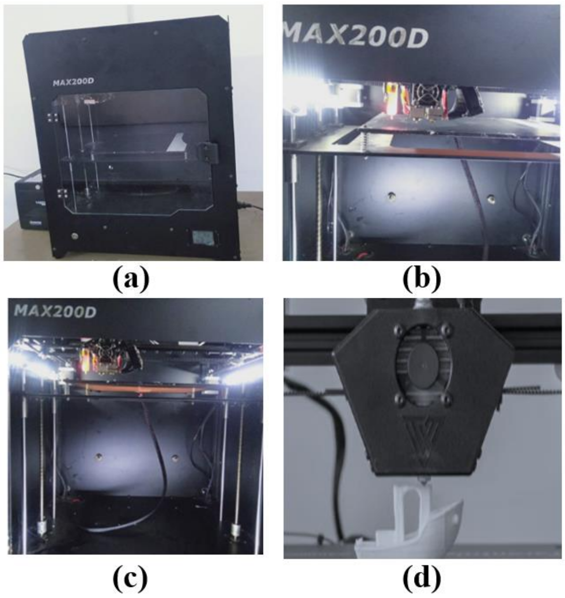


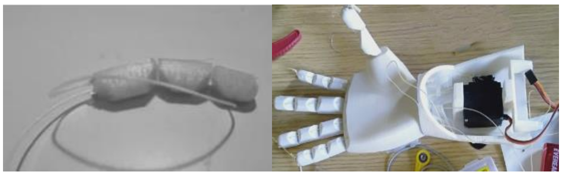
Fig. 2 (a), (b), (c) and (d): 3D Printing Under Process
[*Source: SKIT, M &G College, e-Yantra Lab*]

Fig. 3: Fabricated 3D Printed Parts of Bionic Arm

4. ASSEMBLY OF ROBOTIC ARM

In this bionic arm all the mechanical parts made from 3D printing are integrated with the electrical components. The bionic arm needs to be made cheaper, lighter and accessible than the bionic arm already available in the market. So all the electric components were selected based on the obtained output and requirements. At first all parts of fingers are connected to one another with the help of nylon or fishing wire with palm of the bionic hand.

All the finger parts connected through the servo motor for desired action. Servo motor and EMG sensor are then connected to the Arduino-Nano. When we stretch or move our muscles, the EMG sensor detects this change and sends signal to Arduino.



(a) (b)

Fig. 4 Assembly of Fingers Parts, Palm, Lower Arm

Fig. 5: Assembly of Servo Motors, Arduino, EMG Sensor, Battery and Circuitry Board

Fig. 6: Whole Assembly of Bionic Arm Components

4. RESULT

The system suggested in this work is designed with a five-finger structure, but each finger is modularized, allowing it to be designed with end-effectors of varied shapes based on the palm shape. Actually, as soon as we mentally decide to move or extend our hand or fingers, our brain sends out a signal that travels through the neural system to the nerves in our hand. When we stretch or move our muscles, the EMG sensor detects this change when it is placed on the skin as seen in figure 7. The EMG detects the target muscle group's contraction and relaxation, and a potential is created.

Our Muscle Sensors are designed to be used directly with a microcontroller. Therefore, our sensors do not output a RAW EMG signal but rather an amplified, rectified, and smoothed signal that will work well with a microcontroller's analog to digital converter (ADC). Because it is programmed to be capable of reading the signal which is received from the EMG, the Arduino can easily read the signal received on the analog pin. By comparing the signal with the predefined value in Arduino, the signal is sent to the motors (actuators) and the desired action of the finger is executed. To evaluate the item gripping capabilities of the bionic arm, as depicted in Figure 10, we have identified the six grasp kinds listed below. The precision grab is a test of manual dexterity and sensibility.

Program/ Source Code

```
void setup()
{
  Serial.begin(9600);
}

void loop()
{
  float sensorValue = analogRead(A1);
  float millivolt = (sensorValue/1023)*5;

  Serial.print("Sensor Value: ");
  Serial.println(sensorValue);

  Serial.print("Voltage: ");
  Serial.print(millivolt*1000);
  Serial.println(" mV");
  Serial.println("");
  delay(1);
}
```

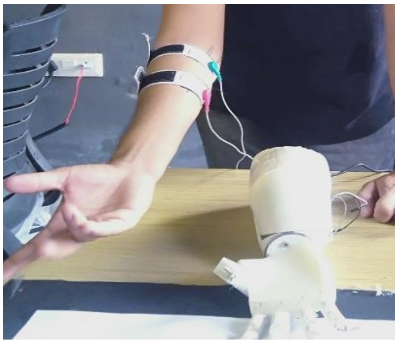


Fig. 7: Opening and Closing of Fingers in Prototype

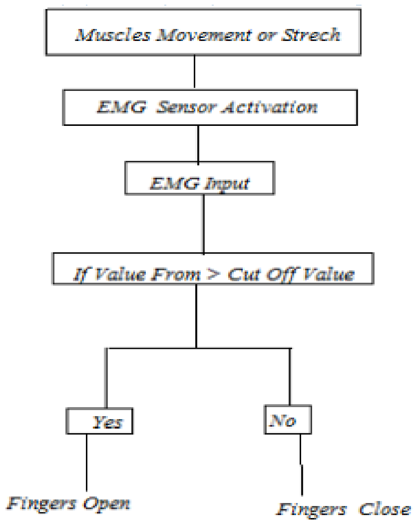


Fig.9: Flow Chart of Action of Bionic Arm with EMG Input

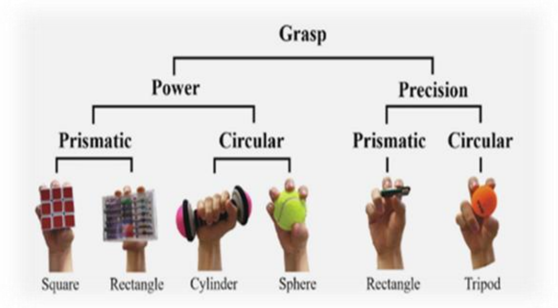


Fig. 10: The grasp taxonomy [15]

5. CONCLUSION

The major goal of this work was to create a bionic arm that is affordable and durable along with easily accessible to everyone. Both the goals of this project were achieved and new directions for future study in this area have been developed.

1. The bionic arm's fingers were capable of performing out daily tasks with good grip.
2. The model for the bionic arm and its fingers help support
3. The fabricated bionic arm is more readily available, lighter, and less expensive than the bionic arm that is currently on the market.

Although bionic arm implants provide many advantages, they also pose serious health hazards. Technology for bionic arms is constantly developing, with a focus on better control systems, richer sensory feedback, and quicker response times. These gadgets are still sometimes quite delicate.

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Appendix

Table: 1 Action of BionicArm Pose with respect of Real Hand

SN	The Real Hand Pose	Action	The Bionic Arm Pose
1		***One Finger Open***	
2		***Two Finger Open***	
3		***All Five Finger Open***	
4		***Fist (Grasp)***