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RESEARCH ARTICLE

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3D PRINTED PROSTHETIC ARM

SONAL SALI[1], SANDESH BHAT[2], ROHAN BATE[3]

[1]Assistant professor, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Mumbai University, Navi Mumbai, India

[2,3] UG student, Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Mumbai University, Navi Mumbai, India

ABSTRACT

Amputees and people deformed at birth miss an important part of their body. They try and make do with what they have but still nothing can beat the convenience of a natural hand. There are many Prosthetic limbs available in the market but they are all quite expensive. 3D printing is a new technology that gives a cheap and replaceable alternative to many parts in industries. Automations are a boon to the industries. They make repetitive task easy to perform. Closing and opening of a hand are repetitive as well. So automating a prosthetic arm is but logical. We have tried to incorporate 3D printing and automation into a prosthetic arm to give it some higher functionality.

SONAL SALI

SANDESH BHAT

ROHAN BATE

I. INTRODUCTION

Human beings have always craved for more. Be it ideas or technology, man has always been curious about things that were new to him. Even a healthy and whole human being fantasizes about what is being known as superpowers. We ourselves have a vague idea of what we would do if we had a superpower. The same goes for a person who doesn't have an arm. Having an amputated arm replaced with a working arm is not less than a miracle for an amputee. This is evident from sci-fi films like star wars and terminator. We, as human beings, are largely reliant on our hands. There are many daily activities that we won't be able to do without our hands. But there are many individuals who are born with a deformity or just half a hand. Scientists around the world have been trying to create a perfect robotic arm. Though the bionic arms can be tweaked to deliver more power than a human hand, till this date the functionality of a real hand isn't matched by any robotic arm.

The human hand took several centuries to evolve into its present form. Robotic arms took a fraction of that time to be innovated into what they are today. There is a wide range of robotic arm each created for a specific task. Not only are they being used as a replacement for human hands, they are also used in industries and workplaces where there is a danger to human life viz. outer space, radioactive environment, bomb diffuser etc.

Prosthetic limbs were made using wood and metal hooks till the 80's. With development in the materials and manufacture department, easier and cheaper methods are no available. 3D printing is a

revolutionary technique that can be used to create complicated models with ease. It is also a cheap and reliable method. We wish to make a prosthetic arm that is cheap and easy to build.

II. METHOD

We used a button as our input. The button is connected to the microcontroller which in turn is connected to a servo motor. Push of the button actuates the servo. The servo motor alternates in motion with every push of the button.

III. DESIGN

While designing a hand we did some preliminary research in how the bones in the hand are arranged. The bones are divided into many segments to ensure free movement. Each finger has dedicated muscles for various movements. To make a robotic arm perform all these motions is simple but costly. A cost effective way is to prioritize the movements. A human hand performs the grab motion about 60% of the times it is moved. So the flexion and adduction movements are the most important. Of course this hugely depends from person to person. But the basics for every induced movement will be the same.

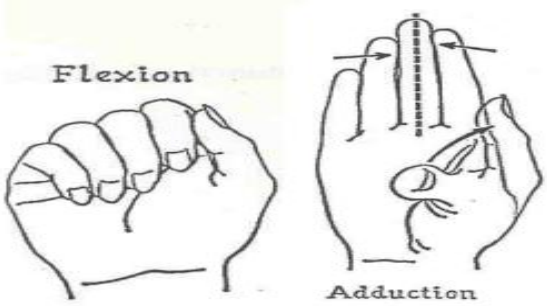

Fig. 1 Movement of the fingers.

The Flexyhand by Gyrobot [1] is a simple enough 3D printed hand that has individual finger movement capability. It's a free to download model on thingiverse.com. Given a good 3D printer, it is a strong and easy to assemble prosthetic arm. The Flexyhand has the thumb at 30˚ and 50˚ from the index finger. We found this orientation of the thumb suitable for the grabbing motion.

Fig. 2 Flexy hand by Gyrobot.

The forearm part must be designed by using the patients measurements. An example of the forearm is shown in fig. 3 and 4.

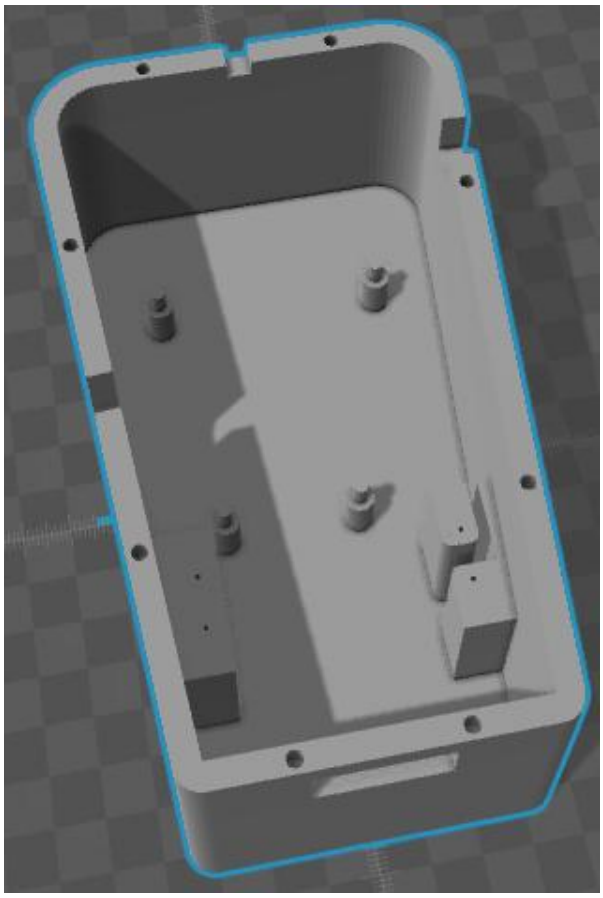

Fig. 3 Forearm with servo motor and microcontroller holders

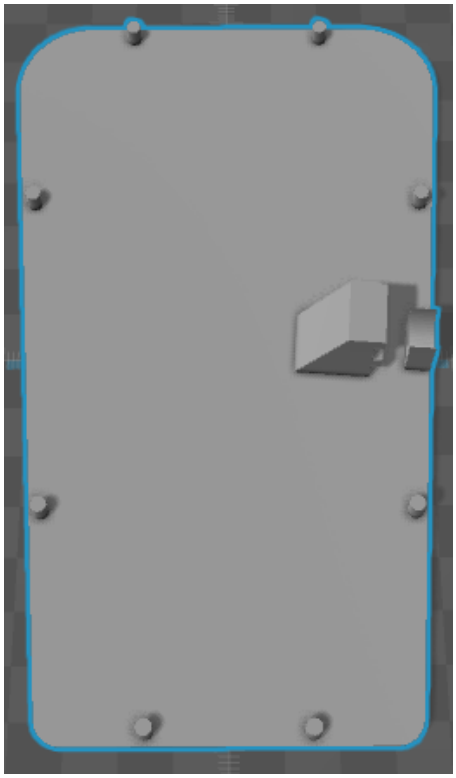

Fig. 4 Cover for the forearm with a button holder

IV. MATERIAL SELECTION

For the hand we shortlisted two materials on the basis of easy availability and then selected ABS material over PLA. The comparison of the materials is given in the following table

TABLE I: MATERIAL PROPERTY AT 23° C [10], [11]

Property	ABS	PLA
Tensile Modulus	1697- 2827 N/mm^2	3500 N/mm^2
Tensile Strength	34- 52 N/mm^2	50 N/mm^2
Elongation at break	8%	6%
Flexural Modulus	2100-7600 N/mm^2	4000 N/mm^2
Flexural Strength	69-97 N/mm^2	80 N/mm^2
Strength to Weight ratio	31-80 kN-m/kg	40 kN-m/kg

We came to a conclusion that ABS has a wider range of strength and hence was sturdier than PLA and completed the criteria of our hand.

V. CIRCUIT DIAGRAM

We made the following circuit for the servo motor and microcontroller integration. We used a software called Fritzing to design the circuit. The following table shows the components used in the circuit

TABLE II: COMPONENT LIST

Sr. No.	Name	Specification
1	Lead Acid Battery	12 V, 1.3 Ah
2	Microcontroller	Arduino Uno
3	Servo motor	10 kg-cm
4	Resistance	220 Ω
5	Button	4 pin
6	Wires	Single strand, 3 m
7	Charger port	-
8	Slide Switch	3 pin

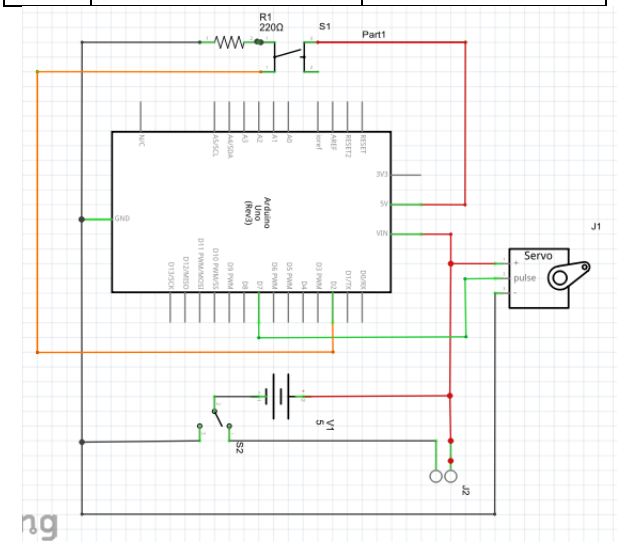

Fig. 5 Circuit diagram.

VI. PROGRAMING

Arduino use a embedded C type of programming language which needs to be input in the Arduino Integrated Development Environment (IDE). We used the following program to integrate the servo motor with the microcontroller:

```
#include <Servo.h>
Servo servo1;
int inPin = 2;
int outPin = 13;
int state = HIGH;
int reading:
int previous = LOW;
```

```
long time = 0;
long debounce = 200;
void setup()
{
 pinMode(inPin, INPUT);
 pinMode(outPin, OUTPUT);
 servo1.attach(7);
}
void loop()
{
 reading = digitalRead(inPin);
 if (reading == HIGH && previous == LOW && millis()
-   time > debounce)
 {
  if (state == HIGH)
   {state = LOW;
    servo1.write(180);
    }
  else
   {state = HIGH;
    servo1.write(20);}
    time = millis();
    }
  digitalWrite(outPin, state);

  previous = reading;
}
```

The above program uses a debounce function that relates to the button input. Usually the button input is spurious and scattered. The signal we need is a single ON or OFF signal but a push button gives many signals at just one push. This is read as multiple pushes by the controller. To avoid this we must debounce the push button signal so as to make it a single signal. All the signals within the debounce time are considered as one signal. Hence by using debounnce we get a predictable result.

VII. ASSEMBLY

The circuit is installed into the forearm. Buttons and switches go into their predetermined place. The assembled flexy hand has threads that can be used to move the fingers. These threads are tied to the servo motor arm so that the servo motor can pull on them to move the fingers. The program takes the button press as input and turns the motor according to the no. of press. For example, first press turns it clockwise, the second press moves it counter clockwise and so on.

Fig. 6 Assemble hand

The hand is indeed cheap and we incurred the following costs for making the hand:

TABLE III: COST REPORT

Part	Cost	Quantity	Total
Servo motor	600.00	1	600.00
Vm 230	90.00	1	90.00
M seal rtv	40.00	1	40.00
Arduino uno	500.00	1	500.00
A to b	40.00	1	40.00
Resiband	30.00	1	30.00
12 v/1.3 amp battery	350.00	1	350.00
Rv 2amp	150.00	1	150.00
BATTERY connector	4.00	2	8.00
Bread BOard	60.00	1	60.00
3D printing HAND	1346.00	1	1346.00
3D Printing joint	1275.00	1	1275.00
Sub total			4489.00

VIII. DISCUSSION OF RESULTS

Other 3D printed hands available have a higher price than our model. Our hand is simple in construction and working and hence even an amateur can build it. Every part of the hand is replaceable and hence maintenance is easy.

IX. CONCLUSIONS

Our main goal was to build a prosthetic arm that was affordable and had as many motions as possible. We would like to say that we were successful in meeting our goals as the hand has the one motion that is needed. We were very successful in the cost department as the hand only cost us Rs. 4489/- which is very less than the ones currently available.

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AUTHORS BIOGRAPHY

SONAL SALI, completed her M.Tech in CAD CAM and Automation. She currently is an assistant professor in the mechanical department of Bharati Vidyapeeth college of Engineering, Mumbai

SANDESH BHAT Undergraduate student. He has presented a few papers before and wishes to push forward into the world of knowledge and technology with new innovations.

ROHAN BATE Undergraduate student. He has worked with the business plan presentation team of a formula student team.