2020 IEEE 15th International Conference on Industrial and Information Systems (ICIIS) | 978-1-7281-8524-8/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICIIS51140.2020.9342659

3D Printed Prosthetic Arm

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Abstract—*From last ten years, human beings have restructured themselves on the far side of their current physical and mental limitations. This development is understood as transhumanism. Where, in robotics and biomimetics, they are exploiting the distinctive styles of the physical structure with the intent to develop turbulent humanlike artificial appendages. While lower extremity medical specialty has evolved to such an extent that lower leg amputees are competitive against skilled runners within the world, there is a significant difference between upper extremity medical specialty and real hands. This work intends to develop a low price, lightweight and sturdy 3D printed prosthetic arm. This paper narrates the prosthetic arm, its mechanical device development and full movement integration. Moreover, the paper presents a walkthrough of our information classification, giving us the flexibility to regulate the prosthetic arm exploitation diagnostic technique using Electromyography (EMG) signals from the arm. This paper intends to contribute to associate ever-increasing human-golem combination by exalting students to interact in transhumanism studies through additional refined technologies and ways.[1]*

Keywords—prosthetic, electromyogram, 3D printing

I. Introduction

A. Background of the project topic

Protheses are devices that are applied externally to help people with disabilities, according to the WHO standards for Prosthetics and Orthotics, so that their functioning can be enhanced and increase their prospective to live independent and august lives. A prosthesis is an artificial device that is used to replace a missing body part, wholly or partly, which may be lost through trauma, disease or congenital (birth) defects. Typical examples are artificial legs and arms. There are at least 33 million people, with amputations, residing in third world countries, and 85% of those cannot afford to buy prosthetics. Across the globe, amputation is a growing issue. 1.4% of population of the world comprises of amputees, of which 33% are arm amputees. As seen in Fig. 1, about 58% of the populace of amputees suffers from amputation under the elbow. This makes it incredibly difficult for them to select things out and clutch them.[12]

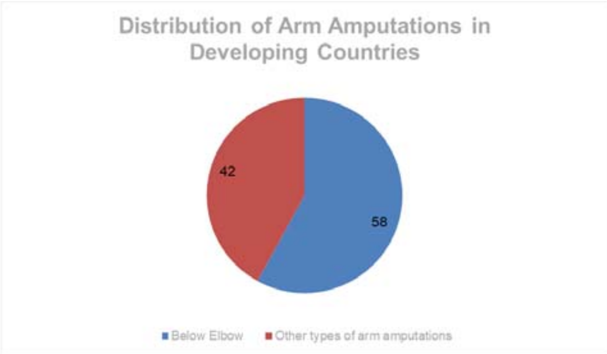

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Fig. 1. *Distribution of Arm Amputee in developing countries*

B. *Scope and Motivation*

The ability to purchase a prosthetic hand is not possible for more than 55% of the amputee population. We had the motivation to design a prosthetic hand that was relatively cheap and easy to manufacture on the market. A 3D Printed Prosthetic Arm will be the proposed prototype, which will be a reasonable solution without compromising efficiency [9].

TABLE I. WORLD POPULATION OF AMPUTEES

Total World Population	7.4 billion
Rate of Amputation	1.6 per 1000
World population of amputees	17 million
Percentage of arm amputees	33%
Population of arm amputees	6 million
Arm amputees in developing countries	3.5 million

C. *Salient Contributions*

- A cost-effective prosthetic arm that is readily available for amputees
- 3D printed and environmentally sound
- Meticulous enough to grab and place objects
- Can be controlled by body movements

II. LITERATURE SURVEY

A. *Feature Extraction*

Kawano et al. found a method for differentiating wrist motion and finger movements from EMG picked up from surface electrodes. EMG coming from deep layers has a propensity to shift the frequency domain to low frequency. EMG coming from upper layers displays a magnitude comparison according to the difference in distance between differential stimuli.

Rami N. Khushaba et al. proposed a novel set of feature extraction technique - Time Domain Power Spectral Density (TD-PSD) method which shows significant reduction in classification error rates in comparison to other feature extraction method.

B. *Pre-processing*

Rubana H. et al. reviewed two prominent areas [16]. the The various ways of analyzing EMG signals, in terms of their performance is studied and compared in this paper.

C. *Classification*

Emi Nakanish., et al. proposed a signal processing method to use electromyographic (EMG) signals to categorize 17 voluntary movements [17].

Geethanjali P., et al. comparing various types of classifiers for machine learning, simple logistic regression (SLR), logistic model tree,J48 algorithm, linear discriminant analysis, support vector machine, and neural network[18].

D. *Signal Acquisition*

Brunelli, Davide, et al. Controlling a prosthetic hand, based on acquiring and processing of surface electromyography signals (sEMG) is a well-established method that uses the electric potentials evoked by one or more muscles' physiological contraction processes.

Ghapanchizadeh, Hossein, et al. Present a technique to improve the acquisition of sEMG signals using better electrode positions from upper limb muscles. Mainly focused to acquire sEMG signal from flexor and extensor Capri radialis muscles and use of statistical features for classification.

E. *Amputee Preference*

Schaffalitzky, Elisabeth, et al. explored preferences and values that recipients have of their prosthetic devices, investigates the views of users on other prosthetic options and demonstrated.

F. *Hand Design*

Atasoy., et al. proposed a hybrid prosthetic hand controlled by electromyogram (EMG), with an anthropomorphic structure and 24 degree of freedom (DOF).

G. *Grip Force*

The grip force exerted via way of means of a hand on an item is the hand configuration, the feature of the actuation, transmission method of the hand and the dimensions of the item. In a precision draw close, the human hand can exert a mean of 95.6 N of pressure [15]. In different grasps, along with the energy draw close, the forces can attain as much as 400N [15]. According to [15], an average Human Hand requires 68N to carry out day to day activities. It is suggested a minimal grip pressure of 45N for prosthetic fingers for realistic use.

H. Inference

Our research made us realize that there were four major problems, to be tackled, while working on this project, namely

I. *Building a cost-effective prosthetic arm which has high accuracy*
II. *Controlling the arm by using the movement of muscles [13]*
III. *Designing a customizable arm*
IV. *Using a lightweight material[12]*

III. Problem Statement

Building the cheapest possible Prosthetic Hand which is easy to customize and use

- Cost
  Selection of the correct components and their quantities was of utmost importance in order to reduce the cost.
- Customization
  Using the dimensions of the amputated arms (in case of bilateral amputees, i.e. both hands are amputated) or of the functional arm (in case of unilateral amputees, i.e. amputation on one side) to recreate a prosthetic arm is very important. The amputee must feel like it is his/her own arm instead of rejecting it.
- Use
  Ease of usage is a must in order to make life easier for the amputee.[4]

IV. Methodology

A. Electronic Circuit Design

The electronic circuit was designed first to understand the size of the circuit, since this data would be helpful in designing the entire prosthetic arm. A sensor was required to control the arm using muscles. Motors were required to move the fingers and the election of the motor was done primarily based on size, ease of programming and accuracy. Then, the microcontroller had to be selected and, finally, the battery was selected.

I. *Selection and placement of sensor:* An EMG sensor was selected. It is a sensor that measures electrical signals generated by the movement of the muscles. This includes simple movements like moving a finger and much more complex ones like clenching a fist and lifting an arm. Surface EMG electrodes were selected as they do not need to be inserted into the skin either with the use of needles or surgery. As seen in Fig 2., sensor positioning is incredibly significant because there is a tremendous impact on the signal intensity due to the location and orientation of the muscle sensor electrodes. Position of the receptor is the middle of the muscle body and should be aligned with the orientation of the muscle fibers. The strength and quality of the signal from the sensor will be reduced by placing the sensor in other locations.

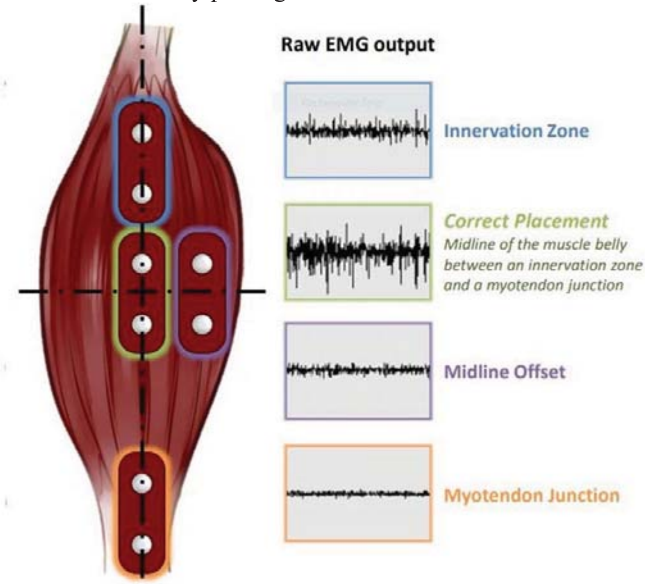

Fig. 2. *Input of Raw EMG*

II. *Selection of type and quantity of motor:* The servo motor was selected, which is commonly used in robotics, as it is small, powerful, easily programmable, and accurate. The quantity of servo motors was decreased from one in each joint of each finger (14 motors) to one for each finger (5 motors) to one for the thumb and one for the remaining fingers (2 motors). This helped to make the arm lightweight and to reduce costs.
III. *Selection of microcontroller:* An Arduino development board was selected as it is easy to acquire, code and use Arduino boards. The Arduino nano board, which contains a microcontroller, was selected as it is smaller, cheaper and has almost no difference to the Arduino uno [11].
IV. *Selection of battery:* An 11.1V and 2200 mAh battery was selected based on the power requirements.

B. Mechanical Design

For the mechanical design to be as real as possible, the exact dimensions of the hand of group member Akshay Fulzele were taken. The design had to accommodate a way to move the arm and have space for the electronics components, while still trying to look like a real arm. 3D printed parts were selected instead of mass-produced factory parts due to ease of customization in the elements. Using factory-produced parts may reduce costs, but it is tough to customize and change the dimensions according to the need of every customer.

I. *CAD Modelling:* A software called DesignSpark was used for CAD Modelling. According to the person's hand dimensions and requirements, the CAD files are very adaptable. As seen in Fig 3 and 4.

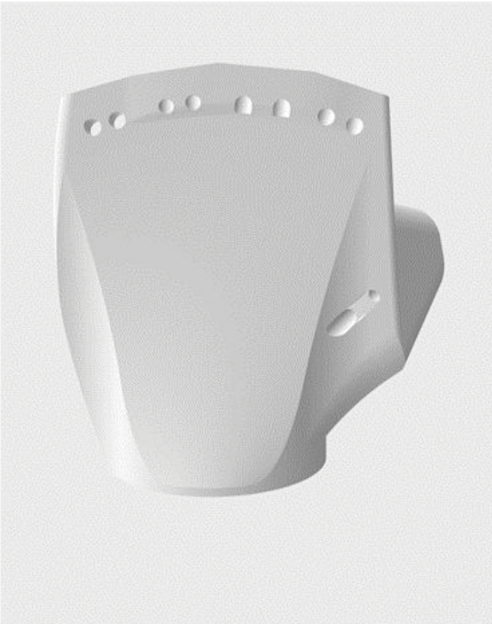

Fig. 3. *Palm Design*

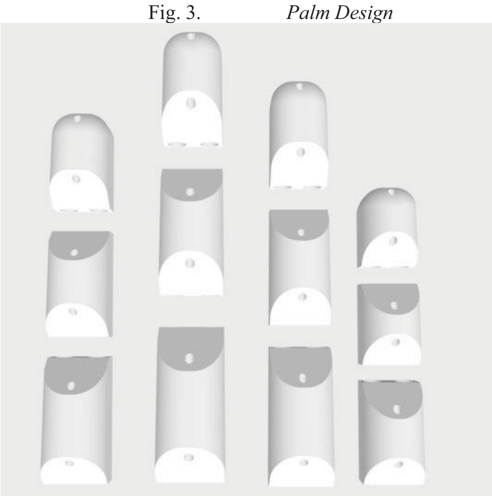

Fig. 4. *Design of fingers*

II. *3D Printing:* 3D printed parts are preferred over mass-produced factory parts due to easy customization. A component called PLA, which is a biodegradable polymer, was used. As seen in Fig 5. This is a lightweight and environmentally friendly material which is cheap and helps to maintain the build cost in the budget. An FDM 3D printer, developed by Stratasys, was used to print the material. The print time was around 50 hours, and the components required only 75 meters of the material. Thus, this method is rapid, efficient, and mass friendly.[9]

Fig. 5. *3D Printed Arm*

V. TECHNICAL SPECIFICATIONS

A. *Block diagram of system*

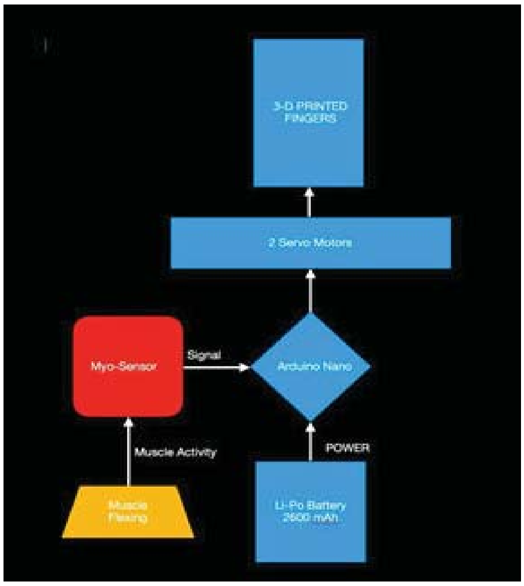

Fig. 6. *Basic Block Diagram*

B. *Components used*

I. Arduino Nano
II. Arduino Nano IO Expansion Board
III. Battery
IV. EMG Sensor
V. Fishing Line
VI. Nylon Paracord
VII. PLA filament
VIII. Servo motors (2)
IX. Wires

VI. Implementation

A. Mechanical

The mechanical system involves the fishing line, nylon paracord, servo motors and the 3D printed parts, i.e. the hand and fingers. The motors have servo horns attached to it, which are connected to the fingers with the help of fishing line. The fishing line is glued to the servo horns. As seen in Fig 6. Since there is tension in the fishing line, the fingers move whenever the servo motors turn, but the servo motors used would have to turn in one direction and return in the opposite direction, which is why the 180-degree rotation motors were used instead of the 360-degree rotation motors.[6] .When the hand is closed, the fingers close but when the hand opens, the fingers may not go back to their original position. This is where the nylon paracord comes into play [8]. It is strong and helps to retain the original shape. As seen in Fig 9

B. Electronics

In the electronic system, the battery is used to power everything. The EMG sensor is used to extract the electrical activity produced by the muscles. When the muscles are flexed, the EMG sensor gets a signal. This is sent to the Arduino nano. Since the Arduino nano does not have enough space to accommodate all the connections, an Arduino nano IO shield expansion board was used to provide the appropriate space required by all the connections. The nano acts as a microcontroller and classifies the output.[5]. If the signal is above the set value, it relays the appropriate information to the servo motors by asking them to turn. If the signal is below the set value, it does not send a signal. The use of only 2 motors restricts the amount of gestures that can be done but it allows he use to perform simple grabbing operations.[2]

C. Software

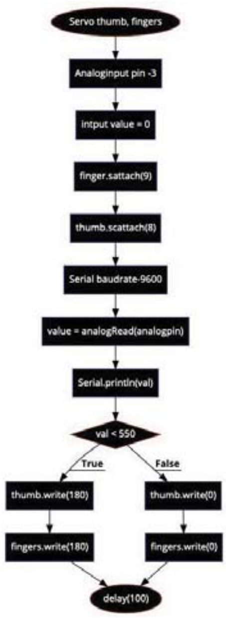

Fig. 7. *Flowchart of code*

After running the code into the Arduino Nano, we need to connect the servo motors with fishing wire which will help operate the 3D arm. The Arduino nano plays a vital role of a microcontroller.[7]. The muscle flexing results can be observed in the below image, Fig. 7 and 8.

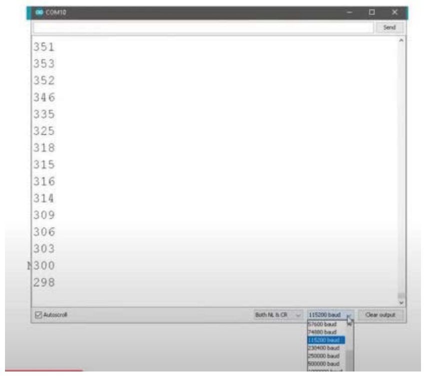

Fig. 8. *Serial Monitor Values*

D. Testing and Final Assembly

Fig. 9. *Testing of the arm*

Fig. 10. *Final Assembly (without cover*)

Fig. 11. *Final Assembly (with cover)*

VII. Conclusion

The result involves a prosthetic arm which is not only light weight (at around 250 grams), has a significant grip force of 55N, but also significantly cheaper in the current market. The prosthetic arm involves a design tweak that makes it easily adaptable for manufacturing it according to the customer's hand dimension and requirement as seen in Fig 10 & 11.Implementation of Machine Learning will be the next step in development of a far superior prosthetic Arm.

Acknowledgment

We share our profound sense of appreciation and indebtedness to our NMIMS University, Mukesh Patel School of Technology Management and Engineering. We are thankful to them for their valuable support, and their cooperation during the period of our project. This project would not have been possible without the support of the 3D printing lab in charges. We are indebted to them for providing their time and patience. We would like to express our special gratitude and thanks to our colleagues for helping us with the development of this project.

References

[1] M. More and N. Vita-More, The Transhumanist Reader: Classical and Contemporary Essays on the Science, Technology, and Philosophy of the Human Future. John Wiley & Sons, 2013.

[2] S. Tachi, Telexistence. Cham: Springer Int. Publishing, 2015, pp. 229–259.

[3] J.L. Pons, Wearable Robots: Biomechatronic Exoskeletons. J.W. & S, 2008.

[4] R. Bogue, "Exoskeletons and robotic prosthetics: a review of recent developments," Industrial Robot, vol. 36, no. 5, pp. 421–427, 2009.

[5] Y. Bar-Cohen, Ed., Smart Structures and Materials 2002: Electroactive Polymer Actuators and Devices (EAPAD), vol. 4695, 2002.

[6] Bicchi A (2000), Hands for dexterous manipulation and robust grasping: A difficult road toward simplicity, IEEE Transactions on Robotics and Automation 16(6): 652-662.

[7] Butter fass J, Hirzinger G, Knoch S, et. al (1998), DLR's multi-sensory articulated hand part I: Hard- and software architec- ture., in: Proceedings of the IEEE International conference on robotics and automation, pp. 2081-2086.

[8] A five fingered robotic hand prototype by using twist drive, Ivan Godler, Takashi Sonoda, ISR/ROBOTIK 2010

[9] P. G. Weyand, M. W. Bundle, C. P. McGowan, A. Grabowski, M. B. Brown, R. Kram, and H. Herr, "The fastest runner on artificial legs: different limbs, similar function?" J. of App Phys, pp. 903–911, 2009.

[10] D. A. Zlotolow and S. H. Kozin, "Advances in upper extremity pros-thetics," Hand clinics, vol. 28, no. 4, pp. 587–593, 2012.

[11] R. M. Krauss, Y. Chen, and P. Chawla, "Nonverbal behavior and nonverbal communication: What do conversational hand gestures tell us?" Advances in experimental social psychology, vol. 28, pp. 389–450,

[12] S. T. Venkataraman and T. Iberall, Dextrous robot hands. Springer Science & Business Media, 2012.

[13] B. Massa, S. Roccella, M. C. Carrozza, and P. Dario, "Design and development of an underactuated prosthetic hand," in Robotics and Automation, 2002. ICRA'02, pp. 3374–3379.

[14] Joseph T. Belter and Aaron M. Dollar, Performance Characteristics of Anthropomorphic Prosthetic Hands, IEEE International Conference on Rehabilitation Robotics, 2011

[15] R. F. Weir, "Design of Artificial Arms and Hands for Prosthetic Applications'" Standard Handbook of Biomedical Engineering and Design, Chapter 32, pp. 32.1-32.59, McGraw-Hill 2004.

[16] Chowdhury, Rubana & Reaz, Mamun Bin Ibne & Mohd Ali, Mohd & A Bakar, Ahmad Ashrif & Chellappan, Kalaivani & Chang, Tae-Gyu. "Surface Electromyography Signal Processing and Classification Techniques", Sensors , 2013.

[17] E. Nakanishi, T. Jiralerspong, A. Kambayashi and J. Ishikawa, "Classification of 17 voluntary movements using principal component analysis for myoelectric prosthetic hand," *IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, Budapest, pp. 1346-1352, 2016.

[18] P. Geethanjali and K. K. Ray, "A Low-Cost Real-Time Research Platform for EMG Pattern Recognition-Based Prosthetic Hand," in *IEEE/ASME Transactions on Mechatronics*, vol. 20, no. 4, pp. 1948-1955, Aug. 2015.