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Design and Fabrication of Prosthetic Arm Using EMG Sensor and 3D Printing Technology: A Review

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Abstract-*Around globe, many people suffer from arm amputation caused by natural disease or due to accidental causes. The limb amputation ceases the day-to-day activities of the amputees and may cause frustration to the working person. In the survey of National Center for Health Statistics, the ratio of upper limb to lower limb amputation is 1:4. Therefore giving a solution to lower limb amputation is much prior. Thus there is need to provide a quick fix for this issue and hence implementation of such system is required. This paper gives brief information about the various methods to implement a prosthetic arm. The various methodologies include the use of EMG Sensors, 3D printing technology and use of actuators. In this paper the merits and demerits of these approaches have been discussed thoroughly. By analyzing the previous research articles, this paper aims toward suggesting an effective, efficient and economical solution to the stated problem.*

Keywords-*Prosthetic, Amputee, EMG, 3D Printing*

I. Introduction

The most crucial part in the routine life of a human is its hands. The loss or absence of even one hand can change the way things work normally. The people with such misfortune are called amputees. According to a research of Amputee Coalition, there are nearly 2 million amputees in the United States. It is predicted that the number will increase by the year 2050 to probably 3.6 million American amputees. Few amongst this number are born without hands and some may have lost their limb in accident or due to any disease. The main causes of amputation found are vascular diseases, diabetes, arterial disease and cancer. This ailment can happen randomly to any person. Due to which they are unable to perform there day to day work and their life becomes frustrated. This matter of concern aspire us to write this review and provide a solution to this problem. It discusses the evolution of Prostheses, its use and the advancements in technology providing comfortable, safer and more efficient prostheses. The review will conclude on the best achievable and desirable method to design one such prosthetic hand. This includes the finest procedures to deal with the Electromyography (EMG) signals. A functional prosthetic arm costs around $20,000-$100,000, which is very expensive and hence only few people will be able to buy it. Also this prosthetic limb needs to be changed many times during a patient's lifetime. Thus, the replacement and maintenance cost is unaffordable. The methods to reduce its cost are also analyzed and one amongst it can be the 3D printing technology which makes fabrication of the arm cheaper.

II. Literature Survey

In this paper, we have studied about the detection of EMG signals from the muscles. The author has explained the various processes that are implemented on the EMG Signals like modification, filtration, rectification, smoothening and acquisition. A method is given in which the electric signals are generated by the upper arm muscles which are used to control this artificial limb. The electric signals generated are the electromyography signals which can be detected using two methods: invasive and non-invasive [1].The prosthetic arm has evolved since the civil war from prosthetic hook to the current prosthetic arm containing all fingers, as in real hand. The discussion further moves towards the functioning of various robotic prosthetic hands with individually articulated fingers as well as their limitations. The author has given the detail analysis of the different grip mode selections, including the thumb gearbox which gives the articulated thumb roll its actuation. The use of myoelectric sensors for controlling the hand has also been highlighted. In this paper, the main focus is on making the cost of prosthetic hand cheaper [2]. The prosthetic hand is specially designed for the use of children by proposing a distance-fitting methodology for easy attachment. The author studied the complexity and one of the objectives of the author was to propose a distant-fitting procedure for the children who couldn't visit laboratory for measurements. This procedure involved measurements of the hand just by taking photographs of it. The image editing software helps in the measurement and design of the arm by using 3D printing technology with the use of CAD modeling software program and manufacturing in the research

laboratory using desktop 3D printers [3]. This paper illustrates that for a forearm amputee, the upper arm muscle movements can be used to control the prosthetic hand using the EMG signals generated by them. The author also mentions that several servo motors can be used as the replacement for the finger and wrist movements [4]. In this paper the main objective of the author was to fabricate a prosthetic arm whose functionality should be close to that of the actual hand. The controlling of the hand is done using the EMG signals generated by the Muscle units of the upper arm. Various methods were used by the author for modeling of the fingers and finally chose the reliable method. These methods included the use of impressions of actual hand on moulds and the use of 3D scanner to create files of actual hand for 3D printer. Lastly the selected method was the use of SolidWorks software for designing the hand part by part [5]. The paper discusses about the advancements in computer-aided design (CAD) programs, additive manufacturing and the image editing software. It emphasizes on the way by which 3D printing technology has emerged as a revolutionary way to enhance this medical device by avoiding traditional negative impacts. This paper suggests the various steps involved in designing of the 3D printed prosthetic hand. This includes the detailed analysis of temperature required for designing and the material involved for the printing of the hand [6].

III. Methodology

The objective of this review was to provide the best possible solution to deal with the problem of limb loss that is amputation. For this, literature survey was done from our end which is discussed already in the above section. As the use of the Prostheses is being made since early ages, it has seen variance in its evolution. A variety of methodologies has been implemented or suggested till date. These may have its advantages and disadvantages. Our study has analysed all the issues and came to the suitable and affordable methodology that should be implemented.

The use of Arduino Nano as central controlling unit will give a better result. This is because Arduino Nano is a small, complete and breadboard friendly board based on ATmega328P. The Nano has an inbuilt Atmega328P microcontroller. Using Nano will also be a benefit because the programming of this is very simple. It is programmed using a software application called Integrated Development Environment (IDE).

The input to the Nano will be the EMG signals i.e. Electromyography signals. These EMG signals will be detected from the amputees upper arm muscles. These signals are the biomedical signals which measures the electrical potential generated in the amputees muscles during its contraction and relaxation. The advantage of using EMG signal is that the signal will be acquired from the patient's body only and will be controllable according to the need of user.

These signals will be detected using an EMG sensor directly. It will beneficial to use this sensor because it gives an accurate value to be straightly given to the Nano. If otherwise the signals are taken directly from muscles they will require a large amount of signal processing which may cause loss of accuracy and precision and may not give a perfect output.

The processed EMG signals from the sensor are received by the Nano as analog signals. The Nano is programmed in such a way that it will convert these signals into pulsated form to drive the servo motor attached at its output. The servo motor will receive this signal representing a desired output position for the servo shaft and will apply power to its DC motor until its shaft turns to that position.

The servo motors are coupled to the fingers and wrist of the prosthetic arm. The functioning of the artificial hand needs to be closer to the actual hand. For this it should be able to move any object from one point to another at different speeds. So, while doing this the speed and position of that must be precisely controlled. For this to achieve servo motor is an efficient tool. For good results and proper functioning of the fingers, 5 servo motors for each and 1 for the wrist should be used. The servo motor can be controlled easily by using simple pulse controlling. The wrist servo motor will be controlled by the accelerometer. An accelerometer is an electromechanical device used to measure acceleration forces. These are continuous forces. It interprets the voltage to determine the velocity. These servo motors will be having the nylon threads on its shafts connected to the artificial fingers. When stretched, these threads will produce motion in the fingers. Nylon threads are durable and cause less fatigue.

The most preferable method for fabricating the complete hand model is the use of 3D printing technology. This is because 3D printing is done using a plastic material which is very light weighted. The cost of it is also less when printed in bulk making the product affordable.

IV. Conclusion

The literature survey is focused towards understanding advantages and disadvantages of the previously implemented methodologies. Thus, it has been found that the most effective solution can be given by designing a low cost 3D printed prosthetic arm which would be controlled by the EMG signals generated in the upper arm muscles using EMG sensor. This can be thought of as the best solution to the problem but its adaptation still

remains unclear due to the user acceptance. No written evidence has been found regarding the durability of the prosthetic hand i.e. no author has claimed the long term lifespan of the hand. As per the user, the work can be done towards having excellent functionality and real appearance. Fabricating a prosthetic hand is not always cheap. The material cost, development, designing, assembling and fitting increases its cost. The hands designed by most of the authors have not been tested with the real afflicted person rather it has been tested with healthy individuals. Thus, the results are uncertain but with the help of proper programming, precise calibration can be done. The prosthetic hand cannot be scaled i.e. the size of the hand is fixed and can be used for either only adults or for kids. Addition of more hand gestures using precise and sensitive sensor will improve the performance of the product. As the mechanical specifications of the prosthetic arm are not specific, modifications can be done as per requirement. Therefore, by outlining the review it can be concluded that this product can accomplish the basic goals for an amputee, but still there is a scope for future works on it.

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