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Research Article

Design & Analysis of Prosthetic Hand with EMG Technology in 3-D Printing Machine

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Abstract

Prosthesis is an artificial extension that replaces a missing body part. Prostheses are typically used to replace parts lost by injury or missing from birth or to supplement defective body parts. One of the main requirements of artificial arm is that functionally, it should be as near to the natural hand as possible. Various designs of artificial arm are available in the market, categorized as mechanical, electrical and Electro-Mechanical. Myo-Electric arm is stimulated by muscle signal available from the stump of amputee. In this method the EMG signals are picked from the surface and the time domain features associated with the intended motion are extracted using suitable technique. The Goal behind this project is low-cost objective was achieved by developing an inexpensive EMG control platform Prosthetic hand that is designed to be produced inexpensively on a 3D printer. This EMG Technology Prosthetic hand User Interface also reduces the chance of a stray muscle impulse causing unintended actuation of the hand and reducing the mental task load for the user of the device. In this project first prepare a design in solid works with proper dimensions and then converted into Three Dimensional Object, after complete the entire design then the design can be adopted in to 3D Printer, it will take few hours of time to prepare the final object. Once we compare the current prosthetic hand with this advanced EMG prosthetic hand cost is drastically decreased and user can feel very comfortable to wear this because of less weight and EMG Sensor technology.

Keywords: *Prosthetic hand, EMG-Technology, Myo-Electric arm, Solid Works, 3D-Printing.*

1. Introduction

Accidents can occur to anyone, and sometimes people receive serious injuries such as losing a limb because of one. Losing a limb can affect the patient's everyday life and their autonomy. Nowadays, different medical companies provide numerous solutions for those who have unfortunately gone through one of these accidents including different kinds of prosthetics. Most of these very in aesthetics, range of movement, and change extensively depending on the quality of performance (i.e. speed, durability, choice of material). Prosthetics can also use different approaches to mimic the movement of human fingers and the conditions that cause them to move. However, prosthetics that include more functions or have better performance prove more expensive and sometimes require surgery to attach to the patient, only increasing the overall cost even more. Most prosthetics can cost up to thousands of dollars not including all of the fees associated with purchasing one (i.e. doctors, tutorials), which some patients in the United States and in developing countries can't afford. Prosthetic fingers can provide patients with the ability to pick up a pencil and write, play piano, hold up a glass of water, type on a keyboard, and much more. Using electromyography to evaluate signals generated in the muscles by brain activity and 3D printing for the design of a prosthetic, one can create an affordable yet durable and fully functioning prosthetic. This would give patients another opportunity to perform activities on a regular basis that may have become more difficult as a consequence of a limb-severing accident. We hope to work on and add later developments to the Go-Go Finger with help of EMG in the future in order to improve sensitivity to the finger (i.e. better movement performance), more degrees of freedom, amplified strength of brain control, smaller components, and a quicker response time between sensors and servos. Furthermore, the use of removable fingertips with this prosthetic adds to the overall functionality. The tips can help perform other tasks easily; a removable screwdriver could help the user tighten or loosen screws, a laser pointing device for use during presentations, a bottle opener to open soda pops, a flash drive to keep important files anywhere, or a blade

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to open new packages. These removable tips resemble innovative additions to a regular prosthetic targeted to those who want to have the extraordinary and prepare to do even more tasks than explained above. However, these additions may also come as options for the patient in order to maintain affordability, and would result in differently priced products.

2. EMG signals and their applications in prosthetics

The process of recording and interpreting changes in electrical potential produced by contracting skeletal muscles is called Electromyography or (EMG). EMG signals can be used to detect when a muscle, or group of muscles have contracted. This makes EMG a very good candidate for upper limb prosthetic device control. EMG allows myoelectric hand users to manipulate their artificial limbs using muscles on their residual limb that would otherwise remain unused.

2.1 Fundamentals of Surface Electromyography

The basis of skeletal muscle organization is the motor unit (MU). Each MU is composed of a motor nerve fiber attached to a bundle of muscle fibers. A MU is the smallest muscle component that can be activated voluntarily. The activation of a single MU manifests itself as a distributed bio potential due to the superposition of action potentials of all of the muscle fibers in the bundle. Depending on the size of a MU, the amplitude of a measured EMG signal also known as a myoelectric signal is between 20_V and 2000_V [6, p. 145]. The frequencies of interest when recording EMG signals are about 30Hz to 300Hz. When intramuscular probes and proper signal filtering are employed, it is possible to contract the muscle in such a way that the distinctive activation of a single MU can be observed here.

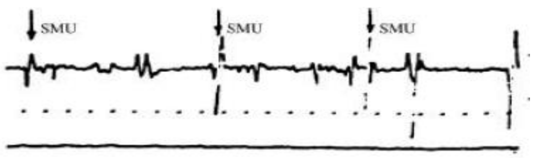

Fig.2 Single Motor Unit Activation Clearly Visible

As the force of contraction increases, it becomes impossible to distinguish an individual MU in the time domain signal. The reason for this is a combination of increased MU recruitment (more MUs _ring) and increased MU activation rate. The result is a time domain signal that resembles stochastic noise as illustrated in Figure.

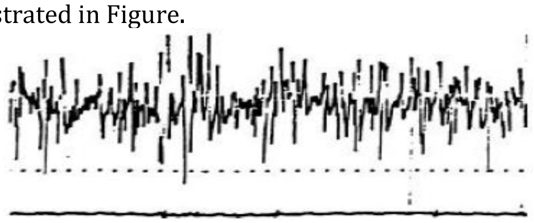

Fig.2 Time domain signal that resembles stochastic noise

2.2 Multiple Motor Unit Activation Appears Extremely Noisy

3 Application of electromyography in prosthetics

A myoelectric hand is an artificial hand whose control system is based on Electromyography. Myoelectric prosthetic devices are controlled by purposeful muscle contractions, usually in the user's residual limb. Tight fitting prosthetic sockets hold dry electrodes against prominent superficial muscles or groups of muscles in the user's residual limb.

These electrodes register surface EMG signals. By carefully controlling muscle contractions, myoelectric arm users are able to open and close basic myoelectric hands and switch between active functions in multi-function hands. The control loop employed in a myoelectric arm is shown in figure.

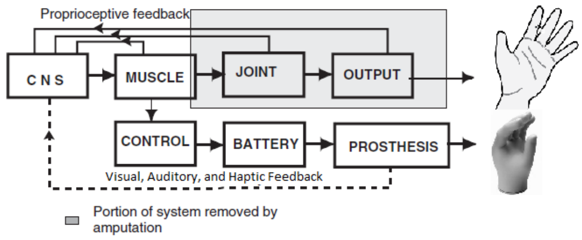

Fig.4 Myoelectric Arm Control Loop

Myoelectric control systems come in single and multi-channel configurations. Typically, children and those with little muscle in their residual limb are fitted with single channel control systems, while most adults are fitted with two-channel control systems.

4. Mechanical design requirements

In order to meet the functionality objectives our team set out for the prosthetic hand, we had to set several design requirements for the mechanical hand component. First, the hand had to be printable using a fused deposition modelling (FDM) 3D printer. FDM provides the most robust physical product of all 3D printing technologies and it is also the technology most widely available in inexpensive consumer grade printers. This makes FDM the most accessible type of 3D printing. Second, the hand must be capable of preforming multiple functions, such as pinch, bat grip, and index point. To accomplish this, at least the thumb and index finger must be actuated independently of any other fingers. Ideally, each finger should be actuated independently. Third, the design should strive to accurately reproduce the look and style of a human hand. There should be four parallel fingers, at least one of which is directly opposed by the thumb, so they can come together in a pinch.

5. Preliminary design work

The concept of wire actuated fingers came from a simple toy that we were introduced to at the start of the project. Cables running down the palmer side of each finger in the toy caused the fingers to curl toward the palm as tension was applied. When tension on a finger cable was released, the finger associated with that cable was extended due to the elastic force of the bent plastic which was now free to return to its original shape.

Prior to modelling the mechanical hand in a solid modelling suite, several cardboard mock ups of the final hand were developed to get a sense of how the final mechanical system would behave. In these mock-ups, plastic zip-ties were employed to act as both the palmer cables and the elastic recoil mechanism. In a final mock-up, elastic bands were run the length of each finger on the dorsal side of the hand. This is the configuration that was employed in the final prototype design. Figure illustrates the design principles that were employed in this final mock up and in the prototype hand.

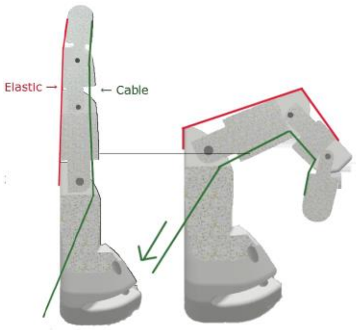

Fig.5 Basic Mechanical Hand Operation

During the course of assembling these mock-ups, it appeared as though it would be possible to implement an antagonistic force scheme for finger actuation. In this scheme, two cables would run the length of each finger; one down the palmer side of the finger and a second down the dorsal side of the finger. Both of the cables would be secured to the same servo, on opposite ends of the actuator arm. When the servo rotated, tension would be applied to the palmer cable while the dorsal cable would be supplied with slack. The advantage of this scheme is that the motors would not be required to work against an elastic force that was constantly working to retract the fingers. The final prototype hand design did include the holes on the dorsal side of each finger that are required to configure this type of actuation system. However, in order to be effective, an additional cable suspension system would have been required as the displacement of the palmer cable was not equal to the displacement of the dorsal cable. This or a similar system of antagonistic actuation will be incorporated into the next design iteration of the prosthetic hand.

6. 3D Modelling

Solid modelling of the 15 unique hand components was performed in Auto Desk In venter. The index, middle, ring and pinkly fingers are each made up of a tip segment, a middle segment and a base segment, which is connected to the palm of the hand. The thumb is composed of just two segments but sits on a raised platform away from the palm, allowing it to directly oppose the other fingers when contracted. Figure shows the assembly of the printed hand as well as the hands major design features.

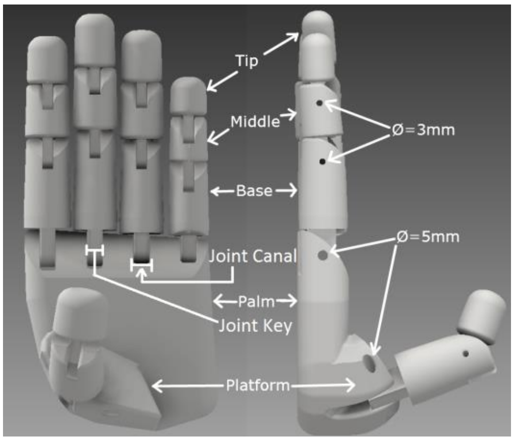

Fig.6 Part modelling

The axel holes for each of the joint is 3mm, except for where finger segments interface with the palm, in which case the axel holes were 5mm. The joint channel width differed from joint to join and ranged in size from 1cm to 1.5cm. Each joint key was 1mm narrower than its corresponding joint channel to reduce friction between the channel wall and the channel key.

7. Requirements & specifications

Making our product affordable falls as our number one requirement. We must choose cheap sensors, mechanical components, and mold materials in order to not drive up the cost. In addition to an inexpensive mechanical motor of some sort, this part must also function in a complete range of motion. To assist with the range of motion, two myoelectric sensors detect all types of movements in the hand. Lastly, additional molds created for interchangeable fingertips assist with various tasks and swap out easily. The entire prosthetic receives power from a self-contained battery power source to make our product both portable and efficient. Overall, we must ensure the safety of our user by properly testing the types of materials, the power source, and the mechanical components.

Table 1 Engineering Specifications

Engineering Specifications	Justification
Total production cost less than $300	After researching potential parts for the motor, 3D printing/material, and sensors, Our project doesn't exceed $300.
Material that can withstand	A cheap durable plastic that

13N of force	lasts throughout daily use and outdoors Conditions. This material gives the molds a finger like appearance.
Fingers bend in complete 90 degree Motion	Must have a mechanism that operates in a complete 90-degree motion.
Two sensors account for a complete range of movements	One sensor measures the muscle twitches form the flexor while the other measures the extensor. These twitches correspond to actual movement of the Fingers.
Utilizes a 9 V Battery to power the device	The battery powers the device for up to 12 hours. Each finger requires a battery
Interchangeable tips such as screwdrivers (Regular, Phillips), bottle opener, laser pointer	The ability to swap fingertips allows the User to perform various tasks right from the tips of their fingers. For example the user may switch between a screwdriver, pointer, or bottle opener.
A glove secures the prosthetic fingers to the user's hand.	The user wears a comfortable glove that securely connects the prosthetics to the hand while impacting their operation.
1.5x1/3x1/4 (inches) fingertip dimensions	Carefully sized fingertips represent proportionality to human fingers.

Fig.7 Overall Design of EMG Prosthetic Arm

As shown in the above figure, it's wanted to be incorporate moving joints and strings as the primary mechanism to move this artificial hand. This image served as an example of the type of model I wanted to make.

8. The finger modelling and printing

The first thing decide upon was how to make the model for the finger that planned on using. I brainstormed and experimented with various methods while reaching this determination, in the end, it came down to cost, viability, and availability as factors that affected my decision. I decided on using a 3D printer to make the actual model. To create the mold that the printer would read I thought about using a mold of the user's hand. This would work by using a molding kit that would leave the impression of a person's hand in a type of putty and then hardening clay was used to fill in the mold and create the figure. After attempting this several times, we came to the realization that this method was ineffective because the hand did not form properly many of the times. Since I felt that this would lead to noticeable inaccuracies later on, I decided to try another method instead.

Another method I considered was using a 3D scanner to create the model of the human hand and use that as the file the 3D printer would use. Unfortunately I faced trouble with the availability of a scanner and also felt there were better options to explore. Finally, I decided to use the modelling software SolidWorks to create the file of the hand I desired to use. This would entail the team learning the basics of SolidWorks to gain an understanding of how the program worked and how I could alter files to fit our specifications.

Here found a file that, felt would be perfect for needs, and proceeded to alter this file to fit to my desires. This is where our knowledge of SolidWorks came in handy to be able to alter the file and certain parameters such as orientations, lengths, diameters, etc. here shows the file, altered and used for the project and also used SolidWorks to create other objects such as enclosures.

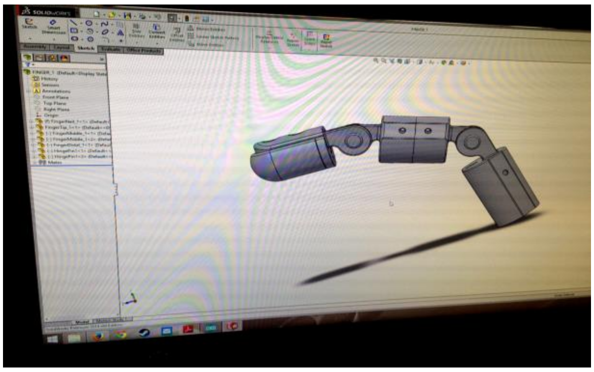

Fig. 8 SolidWorks file of the hand used for the 3D printer

9. 3D printing

Upon completion of virtual mechanical simulations, the hand was ready for manufacture. The method of manufacture selected was rapid prototyping on a Fused Deposition Modelling (FDM) 3D printer. Fused Deposition Modelling, also known as Fused Filament Fabrication is a type of additive manufacturing where a thread of molten plastic is used to trace out a layer of a part in the X-Y plane. Once an entire layer is traced, the print platform is lowered and the next layer is printed.
The prototype hand model was converted into stereo lithography (STL) files in Auto desk Inventor. These STL files were loaded into the printer's software, arranged for printing, and converted to G code. G code is the control code that provides the printer with

instructions regarding the velocity of the print head, extruder temperature and the filament extrusion velocity. The hand parts were printed in 18 hours on a Dimension SST 3D printer. The plastic used to print the prototype hand was Acrylonitrile Butadiene Styrene (ABS) Plastic. The Dimension SST has a layer thickness of 0.256 mm.

10. Benefits of a 3D printed hand

There are two major advantages to producing prosthetic hands with 3D printers. First, it is very inexpensive. The accelerating adoption of consumer grade printers and the decrease in the price of feed stock means that replacement and upgraded parts can now be printed in many materials for only tens of dollars. Second, 3D printing allows for mass customization, a sought after quality in prosthetics. Using this technology, every hand can be designed to meet a specific user needs, including the size of the hand and its complexity. The size of each hand can inexpensively be modeled to match the proportions of the opposite hand. Also, some people lack the _ne motor skills, experience or need for an advanced hand with many degrees of freedom and a myriad of functions. Due to the modular nature of the hand design, these users can use a simpler hand and upgrade individual components as they grow and their abilities or preferences change

Conclusion

By the end of this project successfully create a product that fulfilled what it was originally intended to do. Main two primary goals are to keep it cheap and affordable and also ensure that the user's daily living would be improved by the use of this prosthetic hand.

Even though the result is not highly consistent and varies on the position and other movement of the hand. Originally worried that the hinges in our design would inhibit the hand from extending out all the way. However, after numerous printings and adjustments made in SolidWorks, made this product that moved exactly how it intended. Finally this advanced EMG Technology Prosthetic hand prepared on 3D Printer by using some special type of low weight fiber material because of this special features user can feel very comfortable to wear it and it also respond to do any action like a normal human hand due to EMG Sensors.

And another big assert is as per market survey the present prosthetic hand is very economic it is approximately 15 lakhs but this advance type prosthetic hand can available in the market under the cost of 50 thousand rupees only with the help of government support so in our country this prosthetic hand can available to all category of people.

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