A Study on the Development of Robotic Prosthesis

by

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Abstract

This paper is a multi-analysis study of the development of robotic prosthesis. There are many types of robotic prosthesis, some of which are already in circulation. However, true robotic prosthetics which can move in the exact fashion of the original limb are still in the early stages of prototyping. In experimenting there have been problems found in the methods of communicating movement and the manufacturing of sensory recording material. Using a comparison of the failed and successful experiments it is possibly to approximate the material that will be used and the cost of future market ready robotic prosthesis.

A Study on the Development of Robotic Prosthesis

The development of robotic prosthesis is an innovative field of study, bridging the gap between prosthesis and robotics. There are prosthetics already in circulation that use robotic elements to help motion, but it is not their pure functionality to replace the amputated limb. A robotic prosthetic in this paper will be defined as a prosthetic that is able to conform with all the functionalities possible by the pre-amputated limb. This paper compares some of the leading successes and failures to map out the progress of the field and gastrulate where the field might end up.

Literature Review

Prosthetics in their earliest form were wooden sticks fashioned into a usable form. Then over time the crafting of prosthetics became an art form. Every prosthetic was unique and matched the appearance of the user. Over even more time prosthetics have evolved from being an artisan skill to a scientific field of study (Pogarasteanu & Barbilian (2014)). According to Pogarasteanu and Barbilian the United States is behind as Iasi, Cluj and Bucharest prove to be pioneers in the field of prosthesis (2014). Pogarasteanu and Barbilian look at a new method of recording myoelectric signals called “circumferential osteoneuromioplasty” (CONM). CONM is an invasive surgery in which electrodes are placed at the end of muscles to record the exiting signals. In Bucharest there are already prosthetics which use these signals to provide motions that are accurate above the 90% margin.

According to *Effect of clinical parameters on the control of myoelectric robotic prosthetic hands* having a rate of over 90% being predictable is close to being able to completely map out the movements of electrons (Atzori, et al (2016)). In their study with the use of sEMG, surface electromyography, the amount of time that 90% of an action was unique was less than

80% of the time (Atzori, et al (2016)). In their study they did testing on men with a variety of amputation levels. Those who were amputated no farter than their wrist gave more data on unique signals in arm movements.

This backs up the *Robotic lower limb prosthesis design through simultaneous computer optimizations of human and prosthesis costs* study by Handford, M. L., and Srinivasan, M. (2016). In Handford and Srinivasan study they observed the ability to correlate data from none amputated subjects and amputees. By recording the signal usage of non-amputees there was a ground work to place electrodes on amputees. The more of the limb that was retained the more helpful the data acquired. Through experimentation Handford and Srinivasan found that by using non-amputee movement as an example for prosthetic design it not only helped with phantom pains but also ease of movement. On the other hand, it was found that using gait technology to manufacture lower extremities was not accurate. The loss or difficulty to use the limb had already changed the walking gait of the individual. According to Hahne, J. M., Markovic, M., & Farina, D. in their own study with electromyography, clinical motor prosthetics in their current state are rarely used outside of clinical studies as they have problems with their reliability (2017). Through their testing a system called retrogression was found to help the patient with fine motor control of robotic limbs. Though they were not still not as effective as brain-machine interfacing, being non-invasive was its primary benefit.

In addition to this study, Abd Razak, N. A., Abu Osman, N. A., Gholizadeh, H., & Ali, S wrote the *Biomechanics principle of elbow joint for transhumeral prostheses: Comparison of normal hand, body-powered, myoelectric & air splint prostheses* (2014). This was a study on the effect of 3 different types of prosthetic hands on their respective elbow joints using kinematic equations. They believed that finding the kinematic force applied to the elbow joint and comparing it with the force applied by a normal can greatly improve the development of prosthetics. It was found that by mathematically testing prosthetics before clinical trials it was possible to predict friction points which could make the use of future prosthetics painful. Studying prosthetic design, even if it will not be on the market was found to help inspire and bring to light design flaws to some not yet marketable prosthetists.

In their other study, Development and performance of a new prosthesis system using ultrasonic sensor for wrist movements: A preliminary study, Abd Razak, N. A., Abu Osman, N. A., Gholizadeh, H., & Ali, S broached aa new design of wrist prosthetic was created using motors and electronic sensors to cause hand movement. They discuss the different types of hand prosthetics, "body powered prosthesis (uses tension cable) and externally powered prosthesis (electrically powered)" (Abd Razak, et al (2014)). In their paper they went over a new design of externally powered prosthesis. The designed used ultrasonic sensors to record synapse discharge and motors to control movement. The new design went through trials showing that it could move to accommodate daily tasks with a 45-55% range of motion. In future studies it will be possible to see the same method being expanded on in medical fields for physical therapy

Another way to connect signals is through brain-machine interfaces (BMI) which have been widely studied and are being developed. BMI's like all other methods of control have some specific flaws, like that current BMI's only use motor function centers of the brain and lack the cognitive function ability. In Astra, Athanasiou, and Gogoussis' Study towards brain-computer interface control of a 6-degree-of-freedom robotic arm using dry EEG electrodes a hybrid BCI-harness system was tested using a harness and electrode sensing headset to function an artificial limb (2013). The set consists of one exoskeletal position sensing harness (EPSH) connected to the robotic are one BMI which reads the neural pathways to control the robotic limb. When going through trials the device was found to meet requirements and was usable with a small learning curve through in its state was too large to be easily carried. And although most simply commands were met any complex movements were not possible to recreate. The brain is always connected and with study scientists have found that fine not all motor commands come from the motor-related parts of the brain (Byoung-Kyong, Chavarriaga, & José del (2017)). In the future placing studies into the frontal lobes use of limbs can better accentuate and accommodate for BMI's current misgivings.

Liu, H., Yang, D., Fan, S., & Cai, H. found in their study *On the development of intrinsically-actuated, multisensory dexterous robotic hands*, which was a study of actuated prosthetics, the use of embedding motor functions in prosthetic hands have many uses (2016). From therapeutic to ease of use the design and movement of the prosthetic can be personalized and allow for better patient-prosthetic communication. They study previously made anthropomorphic hands and compared the opinion of users to find that dexterous robotic hand is preferred (2016).

In the end, the patient preferred sensory unit was the non-invasive sEMG's. Although they were less accurate it was found that the surgery and expenses of having an implanted electrode scared most of the prospective users. Oritz-Catalan, Branemark, Håkansson, and Delbeke went over the long-term use of algorithm based prosthetics and how it has not been actualized since outer electrodes are environment based (2012). They emphasized that focusing on using internal electrodes can give the amputee the ability to have natural hand control without losing signal. In this study specifically, epimysia and cuff electrodes are related. Although both devices are invasive, imbedded under the skin, cuff electrodes are closer to the surface and cause less damage to the body upon implantation and removal, epimysia electrodes are not easily removable and can cause serious damage to the muscle around its implantation.

Discussion

In my study I considered the benefits and negatives of the various sensory methods as well as the types of prosthetics being used. I found that the difficulty of factoring in robotic elements to the prosthetics without having access to confidential data was impossible. Instead I focused on the material I knew was used for regular prosthetics and tried to find any correlations where they could continue being used. Through contact with prosthetists in the Tyler area I obtained this chart.

Material	**Average price per pound**	**Rigidness**	**Durability**	**Flexibility**
Acrylic	$125-130	High	Low	Average
Composite Carbon Fibers	$15*	Very High	High	Very Low
Ethyl-vinyl acetates (EVAs)	$1.07*	Low	High	High
Polyethylene	$120-146	Low	High	High
Polypropylene	$72-118	Very High	Low	Low
Subortholen (HMW-HDPE)	$62-85	Low	High	High

I originally theorized that my main material for base prosthetics would be a metal alloy. However, with research into the subject I found that prosthetics are now made of plastic polymers. I went into some research into Abd Razak, N. A., Abu Osman, N. A., Gholizadeh, H., and Ali, S. works to look at their design layout where they mention some of these materials and followed the thread through most of my other sources (2014).

I found that the reasons plastics were preferred included their mold ability, changing physicality and their look. Plastics could be molded into a plethora of shapes and sizes with very little difficulty. Plastics also has the special ability to change physical capabilities with minimal addition of other plastics making the price affordable. All that is required it to design a model including the motors and electronic wiring and most of the prosthetic can be made using a 3D printer.

Conclusion and Future Studies

I have concluded that now acquiring household robotic prosthetics is unachievable. Even with the use of imbedded electrode the only available prosthetics must be in constant communication with a network to use fine motor control with over 90% accuracy. There is simply not enough known about the human brain and neural pathways to recreate movement in a robotic limb. However, in future studies when more information on the mechanics of robotic prosthesis are available to the public the study of sEMG with be crucial to the success of making robotic prosthesis a common occurrence.

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