Application of Artificial Intelligence and 3D Printing in Prosthetics : A Review

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Abstract

There are between 10 and 15 million amputees around the world. The field of prosthetics has opened a new world to the people who have lost limbs by giving them an option to regain some functionality or normalcy. Prosthetic limbs are very important to amputees as they can help restore some of the capabilities lost with the amputated limb. Although they cannot equal the functionality provided by biological limbs, they can provide significant capabilities.

People who lose a limb go through a lot of pain, and a prosthetic limb that allows them to function again is a big challenge. It is a difficult and expensive process. Prosthetics is a very interesting area with a range of fields like Artificial Intelligence, Biomedical Engineering and Neuroscience. Huge innovations and developments of technology have inserted in the field of the prosthetics. In this paper we will review the history behind, the first prosthetic limbs made, with the impact on Artificial Intelligence and meeting Bionic limbs that would fully replace a biological limb. We will also review the latest researches in this field. It is surprising that a bionic hand would not merely mimic the movement but would also substitute the brain-hand communication with constant feedback information. There are many which serve the needs of the amputees.

3D Printing is one of the recent innovations which can provide an artificial limb for lower cost. The importance of the field of prosthetics is analyzed and highlighted, resolving the affording problem.

Keywords : Artificial Intelligence, Prosthetics, 3D Printing

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Introduction

The first commercially available microprocessor controlled prosthetic knee, the Intelligent Prosthesis was released by Chas. A. Blatchford & Sons of Great Britain, in 1993. It made walking with the prosthesis look and feel more natural. An improved version, name Intelligent Prosthesis Plus was released in 1995. Blatchford also released another prosthesis, the Adaptive Prosthesis in the year 1998, which utilized hydraulic controls, pneumatic controls, and a microprocessor. It provided the amputee with a gait which was more responsive to changes in speed of walking.

Components of the prosthesis

Components of the prosthesis include terminal devices like artificial fingers, hands, feet, toes etc. and joints like wrists, elbows, hips, and knees. They also include other working parts like metal or carbon fiber shafts, which function as bones.

Nowadays, components that are controlled by microprocessors and powered myoelectrically are replacing the older hydraulic, body-powered models. Myoelectric prosthesis create movement using the electrical charges naturally produced when a muscle contracts. These electrical charges are then sent to an electric motor that moves the limb. These new components are more efficient causing lesser stress to users.

At present, Bionic components are becoming available, which enable people to function much better. Bionic components are moved similarly to natural limbs as if by thinking. Such a movement is made possible by rerouting the nerves that once went to the amputated limb and connecting them to healthy muscle in the body. These nerves direct impulses which were once sent to the amputated limb through electrodes on the surface to the microprocessors in the prosthetic limb, thereby enabling the user to move the limb.

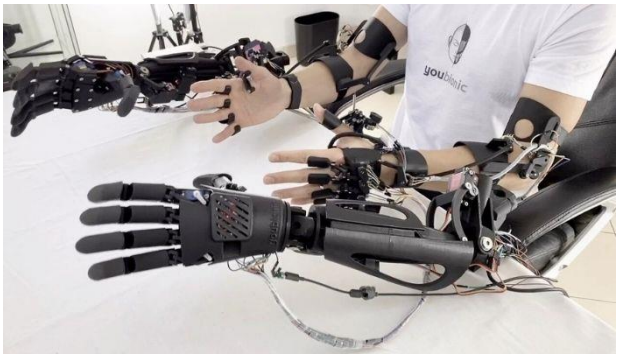
The prosthetist explains the options which are available to the user and helps them choose the type of prosthesis and also the options they need to accomplish their goals. People who swim can get a prosthetic leg designed for swimming that can withstand water, salt, and chlorine. For runners, there are prosthetic feet designed specifically for running.

Prosthetic lower limb types

Prosthetic knee systems are one of the most complex of all components, as they give support when people stand, allow smooth motion when people walk, and also permit movement when people sit, bend or kneel. AI plays a very significant role in this field of Prosthetic knees analysis. Prosthetic knees range from simple systems that were used earlier to advanced computer-based systems popular today. While the perfect prosthetic knee has not been invented yet, research shows great promise with various new types of technology. Today, there are over many types of knee systems to choose from. Doctors, prosthetists and rehabilitation specialists consider various factors like an amputee's age, health, activity level, and lifestyle to make suggestions about which types of knees and their options for stability and motion control would work best for them. There are two major types of prosthetic knees which are mechanical and computerized. Every type has its own advantages and disadvantages.

Computerized (Microprocessor) Knees

Computerized knees are relatively newer type of prosthetic technology. There are many types now available, and various others are in development. Each model may slightly differ in terms of performance characteristics, yet all computerized knees have certain features. For example, they are usually smaller and more lightweight than mechanical knees. They are initially programmed to "learn" the user's walking characteristics and have sensors like timing, force, and swing that take readings 50 times per second or faster. They can adjust the fluid control system accordingly and take less effort to control timing, which means that amputees have a more natural gait, longer walking endurance, and better control on uneven surfaces. They are appropriate for moderately to very active amputees.



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3D Printing

The recent development of 3D printers and innovations in prosthetic design, manufacturing and distribution offer a viable solution for the millions of people living with limb loss across the world.

These technological developments have introduced new abilities, including propulsion systems, sensors and advanced algorithms that work together to automate a more natural joint movement. Prosthetics, in future, will move with more fluidity to mimic natural movement, allowing people to control them in part with their brains and bodies by using direct natural touch input systems.

3D printers are now becoming compatible with many new materials, like lightweight titanium, providing more durability and strength. Prosthetics are also becoming more comfortable with the use of multi-material 3D printing methods for creating more natural sockets that better interface with the human body.

How 3D Printing works

3D printing is the process of creating a three dimensional object by applying, or adding material in successive layers with the help of a computer.

The process of 3D printing includes the following steps:

1. A digital model of the object to be produced is created by using a computer-aided design (CAD) program and employing 3D scanning.

2. The CAD model is converted into file format which is appropriate, like STL .

3. The STL file is transferred to the computer which directly controls the 3D printing device.

4. The 3D printer is prepared for the job by loading containers with the appropriate printing materials such as polymers and binders and a foundation tray for the finished object is set up.

5. The printer constructs the desired object, layer by layer. This process can take a few hours, or days, depending on the size and complexity of the object and the materials used to create it.

6. After the 3D printer completes the building process, the object is removed from the machine and can be further refined by using various post-manufacturing actions, like brushing, polishing etc. Sometimes, the object may need some time to cure before use.

We can find a large number of open-source 3D-printable prosthetic designs on the Internet. There are many advantages of using 3D printers to manufacture prosthetic limbs. 3D-printed prosthesis are considerably cheaper than the traditional prosthesis, which makes the limbs especially useful for children in low-and middle-income countries who can grow out of their artificial limbs rather quickly. Printed prosthetic limbs can also be customized easily, allowing users to design the aesthetics as they want. Printed prosthetics is relatively quick to manufacture and maintain. With the use of 3D-printing technology we can do rapid testing and design.

Challenges to 3D printed prosthetics

Although 3D-printed prostheses are great, but there are certain challenges to 3D printed prosthetics which hinder their widespread adoption.

Traditional prosthetics are made from lightweight materials with high strength such as polyethylene, acrylics, titanium, aluminum, and even carbon fiber. Commonly found 3D printers do not have the capability to print with such materials and they use more common plastics such as ABS. However, it is found that ABS 3D-printed prosthetics have much lower strength of injection molded plastics. In recent years, with innovation in 3D printing materials, carbon-reinforced and flexible filaments like

thermoplastic polyurethane are also becoming popular , along with ABS and PLA filaments.

3D printers that use metals such as titanium exist and are becoming more popular in additive manufacturing. However, they require a large capital investment, and their consumables are more expensive than desktop plastic-printing 3D printers.

Also, printed prosthetics are fragile and require more maintenance than the traditional prosthetics. Lower limb printed prosthetics break more frequently as they are unable to support large weights for long period of time. After printing the prosthetic parts, they need to be assembled, fitted and adjusted to the user by a trained professional. These trained professionals are hard to find in low-income countries.

3D printers are not easily accessible in low-income countries, in the health sector. However, 3D printing is gaining popularity low- and middle-income countries, and larger populations increasingly recognize its benefits. There are no standard operating procedures in the prosthetic printing field to address the variance in printed components. These procedures are required so that the final product is in compliance with national and international standards. Despite these challenges, the future of printed prosthetics seems bright and may transform the lives of millions of people. Also the modern day prosthetic devices can be embedded with IoT devices which can be remotely monitored and controlled.

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