Biomimetic Robotics Applications in Prosthetics

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Over the past decade, as new technologies in materials and actuation strategies have emerged, prosthetics designs have begun to re-shape amputees experiences. Today, amputees are able to achieve amazing feats with the use of their prosthetic devices; however, there still remains a significant gap between the most advanced prosthetics and the human body. Therefore, a great need for innovation remains in the prosthetics and orthotics fields. This advancement must be ever mindful that in prosthetic design it is important to provide a system that is durable, cost effective, and capable of meeting the needs of a wide variety of user's abilities and desires.

Only within recent years have computer controlled technologies been found in clinical prosthetic products. This melding of robotics into the field provides many possibilities that recently were not possible, including artificial intelligence based control, positive power input, and enhanced safety and capability. We at OrthoCare Innovations have a history of working on several key issues that surround this emerging synergistic relationship between clinical prosthetics and orthotics, sensor/computer integration, control system, and mechanical design for practical rehabilitation robotics within the prosthetics and orthotics fields. Our work in these areas of control system strategies and haptic feedback, as well as first hand knowledge of actuation methods combined with practical clinical experience has earned honors such as being involved with the DARPA Revolutionizing Prosthetics 2009 initiative.

What makes these prosthetics increasingly difficult to develop, when compared to purely robotic systems, is the component of meshing man and machine. Control of the system is arguably one of the largest technical barriers, as the limb's movement requires precise accommodation for a wide variance of factors, and the ability for the prosthesis to think, respond, and react to these environmental changes. Our bodies are not merely mechanical based systems, as prosthetics have long solely relied on; rather, we have an advanced controller (brain) to adapt our actuators (limbs) to the surrounding environment. The use of intelligent prosthetics is therefore essential to fully mimic the natural conditions for all environments on ambulation and dexterous movement.

Advanced Control Strategies and Actuation Methods in Lower Extremity Designs

To accomplish such coordinated movement in advanced prosthetics requires highly specialized senor inputs and a comprehensive understanding of adapting those for artificial control to mesh the device with its anatomical counterpart effectively. One such method being developed in devices at OrthoCare Innovations is computational intrinsic control (CIC) systems.

At OrthoCare we have utilized this CIC control strategy in bionic prosthetic ankle prototypes. This ankle offering first of its kind control through all phases of gait is an example of the opportunities afforded by robotic prosthetics. Through the implementation of movement derived algorithms combined with multiple environment sensor inputs we are able to accommodate for force, speed and terrain variations effectively with real-time control.

Another factor that affects the capabilities of a prosthetic is the available actuation strategies. While early computer controlled lower extremity prosthetics devices used semi-active resistive control of a hydraulic damper unit, new generations of designs are currently being investigated and developed by our team that demonstrate the practicality and benefits of offering fully autonomous and powered control of these lower extremity limbs. Our prosthetic ankle design incorporates this actuation strategy and allows amputees to perform activities not previously possible. This strategy offers control across the full anatomical range of motion, thus allowing the user to traverse “real-life” obstacles with much greater safety and symmetry.

One of the latest trends in prosthetics is the inclusion of powered devices. Semi-Active powered devices provide actuation power levels for certain times during the gait cycle, but lack in their ability to have the full accommodation as the anatomical limb in accommodating for real-world variables. Active powered devices provide positive energy into the prosthetic acting to mimic concentric muscular contractions found during certain ambulation activities, but are usually large, heavy, and require greater energy input than are practical.

Aware of these limitations we are investigating the use of actuators that are capable of nearly equivalent strength to human muscles, while maintaining a size ratio that allows for their adoption into the field. While early results have proved promising it is this area of actuation methods that will need a greater investigation in the future to provide for full automation robotics adoption.

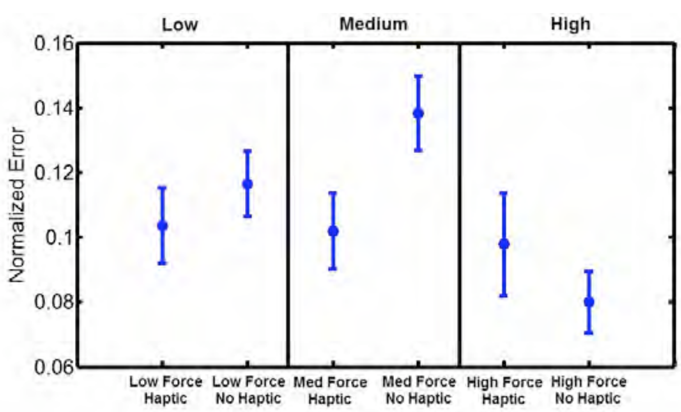
Neural Signal Capture for Prosthetics Control

Additionally, the use of communication methods between the prosthesis and human brain may prove effective in offering greater control capabilities to the user than purely autonomous control methods. Interactive extrinsic control, uses human-interacting methods of determining appropriate movement and function of the prosthetic device. These methods utilize efferent information from the user by means such as: EMG sensors, pattern recognition systems, cortical or peripheral nerve sensors, and may be used in conjunction with feedback mechanisms to provide afferent information to the user through haptic feedback, or cortical or peripheral nerve feedback.

Recognizing the need for greater neural input from the user, we at OrthoCare are investigating the ways in which this usable data can best be extracted and utilized for the most effective outcomes. Understanding the complexities of invasive measures for practical clinical use, we have focused on non-invasive data extraction within the interface environment. By creating a sensor network that covers the entire limb surface, we are working to gather large numbers of inputs signals of musculature contraction and extrapolate a larger number of intended outcomes for greater control of the device. It is this collection of usable signals that will drive the next generation of robotic prosthetics for both upper and lower extremity designs.

Haptic Feedback Mechanisms for Prosthetics

To effectively achieve these new capabilities offered to the user through greater neural integration, a closed loop sensory feedback control system is currently under development at OrthoCare Innovations. The user must be able to communicate intended movement information to the device, and also sense proprioception, tactile, and temperature feedback from the device. Our work in this area has lead to the creation of a haptic test bed used in small scale clinical trials for the evaluation of this technique. Early testing shows this technique to be beneficial after a required learning time to adapt to the use of the system.



It is evident that technology is increasing in nearly every facet of medicine and robotics, as well as the combination of the two. There remains a number of milestones that have not yet been met in the prosthetics research and development community – all requiring evidence based research and novel product developments for practical clinical outcomes. If our nation wishes to catalyze the growth of technical innovation, it is imperative to look into the future and see that the knowledge gained from research will play an integral role in enabling future products coming to fruition.