Wearable EMG-Controlled Robotic Arm-Exoskeleton

Brain-Computer Interfaces: How society reacts to revolutionary medicine

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

What encompasses a “person”? Some of the most important technological developments in recent history, like cell phones and the internet, have centered on becoming . Cell phones, laptops, tablets, smartwatches, and the immense array of personal online services have all evolved not just to become devices that people in developed countries use, but devices that play large roles in memory, communication, creativity, and health. Losing one’s access to their phone means lost access to these memories and can negatively affect our health; should this be considered an injury? Now the focus has shifted to truly making these devices extensions of selves by creating more complex interfaces between these devices and the brain. This momentum has the potential to radically shift the way that humans interact with each other and with the environment as a whole in radical ways. Given how much cell phones have already affected society, the ripples that Brain-Computer Interface (BCI) technology may imbue upon society in terms of treatment and perception of disability is the focus of the research paper presented in this portfolio.

The power of BCI technology has the potential to improve peoples’ daily lives in ways not possible to date. One area in which this is the case is accessibility. The underlying reason for paralysis is a breakdown in communication between the brain and the actuators that control movement, our muscles. This understanding motivates research into technologies that would restore this communication between the brain and the existing muscles or between the brain and external hardware. More specifically, our research into using Electromyography (EMG) sensors to control a wearable arm-muscle-like device is centered on restoring the pathway from the nervous system to the actuators, circumventing the arm muscles. Such a device would allow a wearer, for instance a physical trauma victim, to move their arms without having control of their muscles. Our Capstone project seeks to develop a prototype using physical actuators and wearable EMG sensors.

Capstone Project

Around 17,810 Americans every year have their lives altered dramatically by spinal cord injuries every year (Statistics, n.d.). In many cases, the victim partially or completely loses function in their extremeties. While this damage is often permanent, in two-thirds of cases, the paralysis is considered “incomplete,” meaning that some pathways remain intact (What is a complete vs incomplete injury?, n.d.). Physical therapy has emerged as a powerful method to help patients recover partially or even totally from a traumatic injury (Larson, 2013). Unfortunately, this process takes months to years, and often causes undue burden on families both financially, in terms of support and lost ability to work, and emotionally . The numerous problems laid out motivates the search to facilitate ways to relieve this burden by allowing people with traumatic nervous system injuries to regain some function either during recovery or permanently using wearable technology. The goal of our research team’s technical project is to create a prototype wearable device which will detect muscle signals using sensors to control actuators that will manipulate the sleeve to move the arm.

The device being constructed is a system composed of two main components: the sensors and the actuators. The sensors being used are Electromyography (EMG) sensors. They detect changes in electric potential that occur when nerves send signals to the muscles. These signals are then amplified and filtered to be interpreted by a microcontroller, a small programmable interface device, using either logic circuitry or an algorithm on the microcontroller. The Arduino must be able differentiate between different muscle actions and different desired magnitudes of force that the muscle signals correspond to. Extensive testing and research will be conducted to determine the best signal processing methods required to achieve this goal. Other parameters that must be defined are the locations on the muscles where EMG sensors will be placed and the number of sensors to be used.

Once the signals have been generated, the Arduino then sends signals to linear actuators that exert forces on the wearable sleeve which causes the arm to move without requiring the use of the muscles in the arm. Research will be done on the structure and type of actuators that will be used. The goal is to mimic as closely as possible the natural dynamics of human muscles using actuators, or mechanical devices that produce linear motion. A leading candidate is a pneumatic actuator design known as a McKibben type pneumatic, or air-powered, actuator. This actuator contracts when the air inside a reservoir is compressed, and relax when the air is emptied. The Arduino microcontrollers will manipulate these pneumatic muscles by electric air pumps that operate in both directions. In order to finely control movement, the Arduino will make use of inverse kinematics to correctly actuate the muscles in order to achieve a desired arm position. Additional questions that must be answered include the number of actuators to be used and the power source for the pumps.

This project achieves the goal of relieving the burden on those affected by traumatic nervous system injury by enabling arm movement without the use of muscles so long as there is some degree of nerve activity in the muscles that can be detected by EMG sensors. Our prototype design, in principle, enables the user to perform otherwise untenable tasks, and in some cases, be able to return to work and normal life faster. Our goal is to manufacture this prototype and to co-author and publish a technical report discussing associated research conclusions to be included in this portfolio.

STS Research Project

It was once a science fiction dream to control and interact with our environment directly with our mind. But now, Brain-Computer Interfaces (BCIs) are slowly making this dream into reality. Concretely, BCIs are devices that serve to create a direct digital pathway between a person's brain and a computer. This bridge is typically made through the use of a small implant or multiple implants directly to nerves or areas of the brain. By measuring electrical signals in the brain, the interface allows its user to perform tasks using only brainpower (Shih, 2012). Importantly, this direct pathway cuts out the need for any use of the spinal cord, the peripheral nervous system, or the musculoskeletal system. The potential implications of technology like this are far-reaching. People living with paralysis or other disabilities may be able to control devices like their phones or computers (Neuralink, 2021). Further into the future, this principle may be extended to enabling people to control robotic exoskeletons directly with their mind which would more or less restore the motor capabilities that they lost or never had. Many other groups stand to benefit as well, including the elderly, who lose function in many areas involving motor control and senses (Belkacem, 2020). Additionally, BCI technology may be approved in shorter terms in order to facilitate rehabilitation after traumatic injury (Chaudhary, 2016). Eventually, it is possible that these interfaces be used for general use, allowing humans to push the capabilities of their flesh through sophisticated control of their environment using direct brain pathways.

Modern research is also looking to develop sophisticated interfaces which send signals from a digital device to the brain. This type of interface has already been implemented in the widely-available cochlear implant (Cochlear Implants, n.d.). Experiments demonstrating the efficacy of directly stimulating the auditory nerve were performed in the 1950s and the device was being manufactured for general use by the 1970s. Today cochlear implants are a popular and successful treatment for deafness. But the principle of making digital connections between the brain and a person's environment can be pushed further. There is ongoing research into analogous treatments for blindness in which an electrode implant to the visual cortex is wired to a camera in order to send basic light signals straight to the user's brain. Even more ambitious concepts involve enhancements to the brain's other senses, for instance integrating digital information displays directly into people's visual cortexes (Juskalian, 2020).

The widespread implementation of BCIs is analyzed in the context of Paradigm Shift Theory. Developed by Thomas Kuhn in his book, *The Structure of Scientific Revolutions*, Paradigm Shift theory describes how science reacts in the context of revolutionary discoveries (Kuhn, 1962). The theory explains such a discovery leads to a radical change in how the particular field views problems and can lead to a whole host of discoveries by viewing things from this new example (McLeod, 2020). A prime example of a paradigm shift is Darwinian Evolution. Since its introduction, evolution has been used universally within the field of biology to explain a whole host of phenomena and eventually spawned a subfield dedicated to studying Darwinian evolution. Paradigm shift is criticized of belittling the hard science behind new discoveries like evolution and quantum mechanics through comparisons to the opinions of experts which may change over time or fall out of fashion. It also assumes a certain fallibility of hard facts that is characteristic of human beliefs.

Coproduction is a useful framework for understanding how BCIs as a technology may cause changes in society and vice versa. In particular, it analyzes how technological evolution causes changes in societal structures, and in turn how societal structures shape technological evolutions by highlighting societal needs and values (Jasanoff, 2004). This theory is often used to relate changes in society that often coincide with technological development by understanding how the technology encourages and discourages certain human behaviors that in turn shapes societal structures and values. These changes in turn change societal needs and encourage technological growth in new areas.

Given the many causes for non-adoption, a world with BCIs may have to contend with new and familiar controversies. The Paradigm Shift Theory will be useful in analyzing how certain communities may react to the widespread introduction and usage of sophisticated BCIs. Comparisons can be drawn between this and the introduction of cochlear implants. In the case of deafness, a community has developed among people who are deaf who celebrate the culture that has developed around what it means to be deaf in modern society (The Deaf Community, n.d.). While the broader public accepts and celebrates medical advances like the cochlear implant, it has been met with resistance within the Deaf community (The Cochlear Implant Controversy, n.d.). Additionally, class issues may also drive non-adoption due to healthcare costs and whether or not it is perceived as a necessity. The Inverse Equity Hypothesis details this phenomenon in terms of more general healthcare procedures, and it is worthy of significant consideration in this case as well (Victora, 2018). This analysis may be extended to further revolutions due to the personal nature of BCI applications. Paradigm shift theory is useful in understanding how the prevailing realities about disability and personhood may be challenged in a world where widespread adoption of BCIs has made the lack of adoption not just an unpopular stance but a borderline unethical stance given the hardships of disability (Clark, 2020).

The theory of coproduction will aid in understanding how the progression of technology will affect society. Through analyzing case studies, the effect that BCIs or related technology has on different groups can then be extrapolated to draw conclusions for how society might respond. Studies on reactions to related technologies will be collected and analyzed. Keywords like “Brain-Computer Interfaces,” “Disability,” and “Paralysis” will be used to find such sources.

The paradigm shift theory will allow for analysis of societal reactions by studying what fundamental concepts are affected by BCIs and how different minority groups evolve in response.

Conclusion

The aims of both the above projects are to advance the field of biomechanics in terms of developing new technologies to aid in traumatic nervous system rehabilitation and contributing to the understanding of the societal impacts of BCI technology. Through the development of a wearable EMG-controlled external actuator, this project would advance understanding of EMG signal detection, signal processing, and actuator design. Additionally, the STS research paper hopes to build understanding of BCI technology by expoloring its role as a paradigm-shifting technology by understanding iats effect on certain groups.

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