Soft Robotic Exoskeleton for Elbow Assistance
(Technical Paper)

Effect of User Groups on Co-Production Cycle of Wearable Exoskeleton Technology

(STS Paper)

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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

A wearable robotic exoskeleton (WRE) is a fascinating piece of technology that enhances the physical capabilities of its user, making it comparable to the suits imagined in hero movies that allow the wearers to lift great weights that no normal human could. Even though the possibilities presented by wearable exoskeletons seem great, the negative aspects of them should not be overlooked. This prospectus will discuss both the Technical and STS project and their overarching focus on wearable exoskeleton technology. The technical aspect of this thesis is the designing and development of an upper limb wearable exoskeleton. The STS portion will examine the social implications of this technology and the effects it will have on the lives of those who require the use of a wearable exoskeleton for independent mobility through the use of the three philosophies of technology methodology.

The term "exoskeleton" was first used in the robotics field in the 1960s when the first powered exoskeleton, Hardiman, was invented by the US Armed Forces and General Electric for the purpose of strength augmentation for human limbs. Since then, wearable exoskeletons have been used in multiple fields in ways such as medical applications, military equipment, and industrial practices (Bao et al., 2019). In the STS portion of this paper, I will examine the wearable robotic exoskeleton technology's co-production cycle in medical applications and how it is influenced by the needs of user groups. The ability for wearable exoskeletons to provide mobility to those who can not move independently due to muscular disorders and old age is a positive outcome, but as the industry grows, use of this technology has the potential for negative social repercussions. Though the technology may provide independence, which would in turn help social interaction, the design may also continue to restrict sociability of the user because of discomfort with wearing it both from a physical and mental standpoint. Without truly addressing society's problematization of disability, the design may contribute to the stigmatization and ableism (Kapeller et al., 2020).

Technical Project

My senior capstone project is to design a wearable upper limb exoskeleton that integrates wearable electronics, pneumatic actuators, and feedback control. A wearable robotic exoskeleton is a mechatronic system, which typically consists of six components: sensors, analog circuits, digital circuits, control module, actuators, and mechanical system. Within the context of this capstone, there are two main components of the design: the sensor and the actuator.

Electromyographic (EMG) signals created by muscle activity will be measured through the use of wearable and flexible sensors placed on the user's arm. An EMG signal is a biomedical signal that measures the electric currents generated by contraction of a muscle. A sensor will convert the activity it measures into an estimated force output of the arm (Raez et al., 2006). The actuators we will be using to create our upper limb exoskeleton are McKibben artificial muscles. These actuators consist of an air pump connected to an elastic inner tube that is encompassed by a double-helix woven sheath. Pumping air into the inner tube causes the sheath to contract linearly and expand circumferentially, then in contrast, the sheath expands linearly when air is pumped out of the tube (Tondu, 2012). For this project we will be creating our own McKibben artificial muscles and deriving control algorithms so that we will be able to accurately model them. When deciding on our design we had to be conscious of the social ramifications for the user. We wanted to provide a lightweight and non-bulky exoskeleton that would allow the user to complete daily activities independently. Using pneumatic actuators rather than a DC motor-based robotic arm will allow the exoskeleton to be more lightweight, flexible and portable. It is necessary for the design to meet these requirements for patients with neuromuscular disorders. The patient will be able to use the exoskeleton for a longer amount of time and potentially use it outside of a clinical environment (Proietti et al., 2021).

This project will last the duration of two semesters. The first semester will be used to design the upper limb exoskeleton and create a finished model in CAD. The second semester will be used to make the final product and conduct adjustments on the design. We will possibly bring the prototype to the UVA University Hospital and have patients with physical impairments test it out to receive feedback on it. The first semester is split into two parts. The first half is used to teach team members the basic skills required to conduct this design project, such as writing programs to collect EMG sensor data and how to develop an actuator. In the second half, the class is split into two groups to physically design the two major parts of the exoskeleton. The actuator is split into two subgroups: one for degrees of freedom of the elbow, and one for the degrees of freedom of the shoulder.

STS Project

The ethical, social, and legal implications must be taken into account when designing a wearable robotic exoskeleton before allowing it to be used by patients. The human-robot interaction is quite prominent with technology due to its requirement for use. The robot must be worn on the chosen limb and have points of contact with the user's skin in order to receive accurate signals that will permit the robot to work in tandem with the user. Ableism is a significant social issue that must be addressed when talking about WREs. Designs can often be rejected due to reasons such as discomfort, lack of cosmetic appeal, social restriction, stigma and lack of functionality (Kapeller et al., 2020). There is both a physical and mental discomfort that can be felt when using this technology. People who have to use an exoskeleton for mobility may feel that they do not want to be “fixed” by this technology and that it would just isolate them more from able-bodied people. “General social concerns relate to the personal and psychological impact on disabled individuals and their families. And as a society, we may need to reconsider ableness, in light of these and other technological opportunities for overcoming our limitations” (Greenbaum, 2016). Development of WREs may contribute to the technologization and dehumanization of human life in the general sense (Felzmann et al., 2020). Engineers have to be conscious of social factors and not focus solely on the problem-solving approach that engineers typically subscribe to. Most guidelines for WRE developers do not typically address the societal implications that pertain to the development of WREs (Kapeller et al., 2021).

My study will be conducted through the use of cases where exoskeleton designs were rejected due to the discomfort they caused the patient and had to be reexamined through a more socio-philosophical lense. One such study is titled *Wearable robotic exoskeletons: A socio-philosophical perspective on Duchenne muscular dystrophy research*, which discusses how exoskeleton’s research focuses mainly on looking at disability as a challenge and something that needs to be fixed, rather than questioning views that problematize disabilities. By looking at socio-philosophical aspects, principles may be developed that avoid stigmatization and increase acceptability of wearable robotic exoskeletons (Kapeller et al., 2020). A contrasting research article is *A Brief Review on Robotic Exoskeletons for Upper Extremity Rehabilitation to Find the Gap between Research Prototype and Commercial Type*, it is stated that there is a need for commercialization of WREs and the paper delves into the reasons that use of exoskeletons is so rare, but the paper focuses more on the physical and mechanical issues, rather than possible ethical and social issues as well (Islam et al., 2017). The two articles agree that WREs are necessary, but the second one does not take into account social issues associated with them. The WRE actually functioning properly is something that needs to be taken into account, but it cannot be looked at as the sole reason for possible failure. Addressing both physical and social issues before commercialization of WRE technology will ensure that designs do not negatively impact the user in a social context.

Research Question and Methodology

With the commercialization of wearable exoskeleton technology, how will the needs of user groups affect the co-production cycle of this technology?

The methodology used to answer the research question are the three philosophies of technology: technological determinism, social constructivism, and co-production. Technological determinism is the theory that technology drives society and social progress. In contrast, social constructivism is the theory that technological progress is driven by society. The theory of co-production is a combination of the two where society and technology are in a cycle in which society produces technology that is then influenced by the society continuously. Society and technology are internally related and they need one another to progress (Harbers, 2005). The goal of this thesis is to examine how more widespread use of wearable exoskeletons will affect the lives of those who use them and how they progress in society. In turn, this outcome will determine future research and design of wearable exoskeleton technology. The exoskeleton design and the user of the exoskeleton affecting one another creates a cycle as stated in the Co-production concept where the technology influences how the user is viewed in society and how they act in society, which then determines the changes needed for the technology to be more successful.

Conclusion

The Technical project will center around the design and development of a functional wearable robotic exoskeleton using EMG sensors and pneumatic actuators. The philosophy of technology co-production framework will be used in the STS project. The social progress driven by wearable exoskeleton technology, and the technological progress driven by society's needs, will be examined. My Technical and STS projects are very closely related since they both center on wearable robotic exoskeleton technology, which will help me view the topic from different perspectives. When developing an upper limb exoskeleton for my Technical project, my STS project's focus on the social concerns of the technology will aid me in being more aware of the social repercussions of my group's design as it is developed. After the development of our upper limb exoskeleton, we will begin testing with actual patients, giving me first-hand experience of what social concerns may arise during the design process and how the needs of the user group will affect the co-production cycle of the wearable exoskeleton. If societal and ethical implications are not taken into account when designing WREs, then there is the possibility that social progress of the user may be hindered, which would in turn hinder technological progress.

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