EXOSKELETON PROJECT

EVALUATING VALUE SENSITIVE DESIGN OF HUMAN ORTHOTIC DEVICES

A Thesis Prospectus In STS 4500

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By

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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

Now more than ever, individuals, companies, and groups are realizing the importance of including societal and personal values and norms into the design process. Value sensitive design (VSD) is an approach for foregrounding human values in the technical design process (Friedman & Hendry, n.d.). With the aim of ensuring that the values we hold to inform the products and systems we design. In the field of biomedical devices, where users have an intimate relationship with the technology they use, this integration of values and what is important to the user with the designed product is particularly relevant. One such category of biomedical devices is orthotics, orthotics are externally applied devices used to help a person go about their daily life. They are used in a wide variety of applications from helping people walk to play sports to get out of bed, etc. Patients rely on their orthotics on a daily basis to go about normal actions, so designing them in a way that fit the user's lifestyle and values is critical. This paper investigates the application or lack thereof of VSD by designers and engineers in the design and creation of orthotic devices to discover what methods of VSD work best and can be applied to the capstone team's design of an upper limb exoskeleton. With the goal of ultimately answering the question "What design practices might we use to design orthotics that maximize the wellbeing of the user?". Friedman and Hendry's paper on the value and future of value sensitive design will serve as a framework for VSD principles and a lens by which to examine past products and the design processes utilized.

Exoskeletons are a form of powered orthotic utilizing both mechanical and electrical components in order to assist the user with a particular movement or action. The project team will design, prototype, and build a human controlled wearable upper limb exoskeleton specifically to assist patients with neuromuscular disorders. Given their capability to capitalize on the robustness of motors and pneumatics and the sensory feedback of electrical sensing technologies, exoskeletons have the potential to enable patients to do things a traditional orthotic never could. The STS study examining value sensitive design's applications to orthotics will inform and aid the project team in designing an upper limb exoskeleton best fitted to meet the needs of its target patients.

Design of an Upper Limb Exoskeleton

For many daily physical tasks, humans are limited by their own muscle strength, which declines with age, and is frequently impaired by illness or injury. In contrast, humans are excellent at controlling complex and coordinated movements, and this cognitive ability does not diminish with muscle loss. Robots on the other hand are capable of tremendous physical strength, fast motions and complex movements (*Utilizing Exoskeleton Robots for Industrial Applications - Technical Articles*, n.d.). But controlling them requires immense computing power and advanced algorithms, and even the most advanced systems are nowhere close to what even a small child is capable of (Losbichler & Lehner, 2021). Exoskeletons, broadly speaking, are an attempt to combine the pros of robotics with the pros of human control, overcoming the weaknesses of each system (Rosen & Perry, 2007). The project team will be specifically focusing on the design of an exoskeleton that utilizes these strengths in order to assist patients with neuromuscular disorders. Neuromuscular disorders are diseases that originate in the musculoskeletal system, the nervous system, or the interface between the two systems (*Neuromuscular Disorders*, n.d.). Patients gradually lose muscle control to the point where they eventually cannot perform simple activities such as grabbing a drink, lifting a box, etc. Making this application a tremendous opportunity for the capabilities of exoskeletons to better the lives of these people.

To create an exoskeleton requires two major components, the design of the physical mechanism itself, the frame, motors and actuators which will be providing physical assistance and structure to the user, and the sensors integrated into the design, reading the user’s movements in order to control the motion of the exoskeleton.

Our group will be splitting into two teams to tackle these two problems, the mechanical design team, which I am on, will be further broken down into two sub teams working in close communication, one on the elbow joint of the exoskeleton, and one on the shoulder joint. In order to design the physical joints, the design team must first establish the requirements for the system. This will include deciding how many degrees of freedom (DOF) for each joint, the manner in which the system is worn by the user, the power supply, and the type of actuators used.

On the electrical / sensing team side, the primary task will be evaluating what sensors to use, and how/where to attach them to the user. Electromyography or EMG sensors read the electrical signals sent by human muscles when a person flexes or contracts a muscle group. Using these sensors will enable the exoskeleton to act directly in parallel with the movements of the user. The sensing team will determine what model of EMG sensors to use, and most importantly where and how to attach them to the user. Finally, the team will test and experiment with different data filtering methods, both through the design of the electronics and through software methods to extract the most useful data for controlling the exoskeleton.

Next semester as both teams complete these initial goals, the focus will pivot towards the integration and optimization of the union between the sensing and actuating systems. Actual testing of the device will be performed in order to improve and iterate on the design. The success of the system will be evaluated through this testing in the form of user surveys conducted with groups of test patients in cooperation with the UVA Hospital. Their feedback will inform the team on the success of the design and points for improvement in the iterative design process.

Evaluating Value Sensitive Design of Human Orthotic Devices

Value sensitive design is a framework for helping the moral and ethical values we hold to, what is most important to us, inform the design process for the betterment of human beings and the natural world. VSD does this through providing theory, method, and practice for accounting for human values throughout the design process (Friedman & Hendry, n.d.). Approaching design with this framework enables engineers and creators to consider the wider implications and effects of their products, in particular the relationship users will have with the product. An example of VSD in practice can be seen in the design of robotic dog toys for kids. Engineers conducted studies on the way the kids interacted with the robots in contrast to real dogs and stuffed dogs. The children expected the robotic dogs to reciprocate the affection showed in a way a real dog would, but obviously this was not what occurred (Friedman & Hendry, n.d., pp. 128-130). This consideration spurred new questions informing the design of these toys, how do we want children to interact with robotics? What is the role that these toys should play in the lives of the children? This focus on the values and implications of the technology enabled the engineers to adapt the functionality and characteristics of the robotic dogs to in response to these questions.

In the design of orthotics this intentionality and focus on the values involved and the wellbeing of the user is particularly needed. Wrist-driven orthoses are devices used by individuals with spinal cord injury to improve hand function. Current designs focused purely on the utility of the hand movement are heavy, uncomfortable, and time-consuming to fabricate (Portnova et al., 2018). Faculty and students at the Department of Mechanical Engineering at the University of Washington set out to solve this problem through the application of 3d printing technology and a focus on having user feedback inform the design process (Portnova et al., 2018). The authors state that “While functionality is the primary goal of many assistive technologies, aesthetic appeal and comfort levels of a prescribed device are critical for many users and have a great impact on device acceptability” (Portnova et al., 2018). Why are aesthetic appeal and comfort influencing factors in the device’s acceptability? What values in the user do comfort and aesthetics align with? How might the wrist orthoses be better designed to fulfill the patient?

In the design of orthotics, companies overwhelmingly focus on their own device goals and requirements, leaving user input and feedback as an afterthought. This leads the the creation of a new orthotic to be purely an engineering design problem. Duante and co. investigate this state of the industry and propose a better way, asserting that “The design process should consider the physical, mental and psychological traits of its intended users” (Duarte et al., 2017). The authors seek to develop a design process that prioritizes these other important factors, factors central to the value sensitive design process. An examination of their proposed processes and evidence will help illuminate where facets of VSD are most sourly needed in the biomedical field and where they are being successfully implemented.

Across the multitude of different orthotics there is one thing they all have in common, being attached to a person's body, and an integral part of some motion or action, they are more than just an accessory. VSD provides the opportunity to better make orthotics a true extension of one's self, not only in function, but in utility and lifestyle. This study will examine the existing design processes used to create several modern orthotics to discover how VSD can be better implemented into the design process, and how other design strategies are already implementing facets of the value sensitive design framework in ways that consider and optimize the human-technology relationship.

Next Steps

- Review case study on orthotic, 3d printed wrist-driven orthoses device (Portnova et al., 2018)
- Read and better familiarize self with value centered design through the study of Friedman's book on Value Sensitive Design
- Review and analyze case study on optimizing orthotic design practices
- Tie together case studies and VSD analysis, using techniques learned to extract tactics of VSD that were successful or counterproductive in the case studies
- Apply lessons learned and key aspects of the VSD design process to the technical capstone project of building an upper limb exoskeleton
- Create a chart of how VSD can come into play in the team's design of the upper limb exoskeleton
- For capstone, begin prototyping of physical design for exoskeleton

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