Thesis Project Portfolio

S.U.R.E: Soft Upper-Limb Rehabilitation Exoskeleton

(Technical Report)

Exploring Relations Between Investor Goals and Exoskeleton Diversification

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

A human exoskeleton is any wearable structure or device that supports a person and their activities. Exoskeletons are generally designed for four primary applications: military, industrial, consumer, and medical. They take a wide variety of forms across these industries. They can be comprised of soft or hard components, support different areas of the body, and have varying degrees of freedom. The support they provide can be active or passive, and can come in different forms. For example, different exoskeletons might support impeded mobility, improve the sustainability of a motion, or enable an additional motion a person would not be able to perform independently. The capabilities and prevalence of this technology have grown significantly in the past two decades due in part to factors such as the improvement of control algorithms, including the implementation of artificial intelligence, and increased efficiency of key mechanical components such as motors and batteries. As this field continues to grow, research must be continued to facilitate the development of devices that address the needs of those who will use them for support. Furthermore, this growth process can be studied to gain insight into the directions researchers and developers are exploring for this technology.

The goal of my technical project was to develop an upper-body exoskeleton to assist with stroke rehabilitation. Strokes are a leading cause of disability and can limit mobility of the arm and hand. A 2020 study found upper-limb robotic therapy increased positive recovery outcomes and was more cost effective compared to traditional therapy. In spite of this, we found many contemporary devices are uncomfortable for the wearer or are limited to one motion. To address this gap my group designed a soft exoskeleton that supports elbow flexion and extension as well as hand grasping and ungrasping. This was accomplished using motor and cable actuation, fabric components, and PID motor control. We ensured the design was ergonomic and easy a patient to use independently. The device also weighed less than five pounds and cost less than five hundred dollars to assemble. We hope that developing a device to these specifications will provide a basis for further research on how assistive robotics can be developed to serve rehabilitation patients.

My STS project explored trends in the general development of exoskeleton designs. While human exoskeletons are not a new concept, it is only thanks to recent developments in mechanics and controls that they have become practical for widespread adoption. My goal was to identify how the goals of large-scale investors have been impacting design differentiation during this process. For my research project, I studied designs produced by Sarcos, Lockheed Martin, and Ekso Bionics, three leaders in the American exoskeleton industry. For each design I identified major sources of external funding in its development and the industry it has been marketed towards. I then categorized the designs by the area of the body they target and the function they support. Finally, I was able to use this assembled information to draw conclusions about the influence of investor goals on exoskeleton development. There was a strong correlation between investment provided by the Department of Defense to support soldiers and lower body designs. Furthermore, I was able to argue that this influence created a predilection for similar designs in a company's future products, even if those products had a different purpose or were geared towards a different area of the exoskeleton market. I hope this will support more research on the long-term impact of investors on this expanding market.

My technical and STS projects are closely related. They share the common topic of human exoskeleton development. In the process of actualizing a design for the technical project, I learned firsthand about the challenges of implementing this technology, including the selection of part that are comfortable and adjustable, as well as functional, providing sufficient power to support the user, and implementing adaptive and user-friendly controls. The STS project gave me the opportunity to explore the broader research area the technical project falls under. Researching the context in which other exoskeletons were developed provided me with a solid reference to develop a wider view of this topic and how the technical project fits within it. The combination of these two projects made each more impactful towards my learning and promotes a more in depth understanding of the broader topic.