Thesis Project Portfolio

The Squat Bot: A Minimally-Invasive, Low-Cost Exoskeleton for Sitting and Standing

(Technical Report)

Function Augmented by Beauty: Assistive Medical Devices for Patient Empowerment

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

Medical devices are continuously designed and redesigned to best serve patients. My work focuses on the creation of those that are worn by a patient to supplement or supplant everyday bodily functions. It approaches the issue from the lens of a critical consumer, evaluating the effectiveness of highly visible medical devices and how they could be improved. It also approaches device design from scratch, proposing a novel design for a sit-to-stand assistive exoskeleton. This is no simple task. It's so difficult to create functional devices that frequently all other features are pushed to the side, which has led to the acceptance of technology that is effective but not beautiful. No matter the method of approach, the top priority of medical device design is the patient experience. People in need of wearable medical devices deserve technological solutions that improve their physical and psychological well-being.

The technical research project was created with the guidance of Professor Sarah Sun, whose research focuses on biomechanical designs to aid human movement. The proposed design is a lower-limb exoskeleton for assistance standing and sitting with a specific focus on elderly patients. As humans age, they become significantly more at risk of falling due to a loss in muscle and balance control, and also adopt more sedentary lifestyles. Elderly patients provided with an assistive device for everyday use will be healthier and at a lower risk for injury. Developed with data from test subject motions and widely-accepted kinematic models, the proposed design utilizes stepper motor actuators to provide assistive torque to the knee and hip joints when standing and sitting. All electrical components are stored in a backpack for full portability of the system. The design is also low-cost and minimally invasive compared to those on the market. Customization and testing of the device was performed on a single subject to varying degrees of success according to predetermined specifications.

The STS Research Paper seeks to dismantle the age-old dichotomy between form and function. Specifically, it considers form vs. function as it applies to medical devices that are worn every day by patients. It asks: “How can aesthetics add to the function of highly visible assistive medical devices?” Manufacturer catalogs, propositions of new designs in academic journals, and online sale pages were scoured for examples of the aesthetic status quo in highly visible device design—and how it is being broken. This was conducted for three case studies: hearing aids and cochlear implants, orthotic braces, and diabetes management devices. A number of themes emerged. The additional functions granted by aesthetically minded device design include serving as a desirable accessory, augmenting feelings of agency, and increasing the regularity of use. Perhaps most importantly, better design for devices actively fights negative perceptions of disability. The investigation reveals the importance of co-designing with patients and keeping in mind their self-esteem.

The projects combine in a nearly ironic manner. One extols the virtues of considering aesthetics during the design process of assistive medical devices, and the other presents a device design with a preeminent focus on function. I am pleased with my results considering the timeframes for each, however. As I critiqued engineers who neglect the appearance of their creations, while simultaneously struggling to pull together control systems for elaborate linkages, I understood firsthand the difficulty of following my own advice. Still, this challenge does not reduce the potential benefits laid out in the STS research. If given a timeframe more realistic to industry and the scope of the technical project, I am confident that adjusting for a more pleasing appearance would significantly improve the design.

The technical research, as it stands, is a design proposal and an early-stage prototype. A subsequent version of the prototype should critically examine its “wearability.” The metal frame

supporting the leg is uncomfortable when sitting on a solid surface, and the current design has no way for the gears to disengage for easy everyday movement. Future work includes the addition of biometric sensing to automatically operate the device, absolute encoders to confirm movement, and more advanced position and speed control.

Future research into the aesthetics of highly visible assistive devices could enrich the topic in a number of areas. For one, three case studies are not nearly enough to understand the device market as a whole. There still exists a gap in current research when it comes to co-design with engineers and patients: What is the ideal methodology for such a partnership? How precisely can and should patients contribute in the process?