Undergraduate Thesis Prospectus

Creating Wearable Upper Extremity Robotics: Soft Components in Assistive Technologies

(technical research project in Mechanical Engineering)

The Struggle for Affordable Healthcare in the United States

(sociotechnical research project)

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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General research problem

How can the effectiveness of healthcare be improved in the United States?

Accessing effective healthcare is a critical challenge for many Americans. Not only does American healthcare have a staggeringly high cost: $4.1 trillion in 2020, the stakes are life and death (CMS, 2022). Patients all across America, particularly the poor, struggle to find affordable healthcare (Keisler-Starkey & Brunch, 2021). Even patients with high quality insurance, cannot be cured due to limitations in science and medicine. Today about 40 million Americans have chronic illnesses (NHC, 2014). Advancements in technology may provide researchers with new opportunities to treat these conditions in fields such as wearable robotics. While technology continues to advance and provide new solutions, it is not the sole answer to fixing the American healthcare crisis. Americans must also seek to innovate on the social side of the healthcare spectrum in order to form a system that fulfills the needs of all.

Creating Wearable Upper Extremity Robotics: Soft Components in Assistive Technologies

How can soft electronics and actuators be used to make a practical arm orthosis for patients with amyotrophic lateral sclerosis?

The project department is Mechanical Engineering under the guidance of Professor Sarah Sun of the Mechanical and Aerospace Engineering and Electrical and Computer Engineering departments. Bill Williams, Ellianna Bailey, Lilly Xu, Patrick Evans, and Priti Patel will collaborate on the capstone project.

Wearable, electronically controlled, assistive technologies have generally been made from rigid components. However, these exoskeletons can be described as "heavy" and requiring "tremendous corporeal literacy" (Butnaru, 2021). Patients must remain stationary while using them, or must transport the equipment when moving. For those with amyotrophic lateral sclerosis (ALS), muscle deterioration is gradual. Many have weakened, but still partially functional upper body muscles and do not need cumbersome exoskeletons. For the estimated 31,000 people living with ALS in America, devices made from soft, lightweight electronics and actuators may be a viable alternative (CDC, 2022).

Although the soft robotics field is promising, it is still young. Publications regarding “soft robotics” only began to rise around 2008, but have grown significantly in recent years (Bao et al., 2018). A variety of different approaches have been studied including pneumatic actuators and motor-cable systems, but these methods require rigid pumps, motors or actuators, which can be impractical to wear on a daily basis. Thus, there is a need for a textile-based, lightweight, electronic device which provides the user with motion control assistance, while allowing for free movement during use.

The project group seeks to accomplish this via novel twisted and coiled polymer actuators (TCPA). Specifically, the goal of the project is to create a microcontroller controlled wearable robotic device that assists an ALS user’s elbow joint in flexion and extension by reading electromyography (EMG) signals from the user’s arm. The brace will be designed to help the user with daily tasks such as eating, drinking, and carrying mid-sized items. The greatest constraint to the project is the novelty of TCPAs. TCPAs have not been thoroughly researched or optimized. The limited publications suggest that high amounts of current must be applied to heat the actuator’s surface. Both heat and current can be dangerous, even fatal, if not properly managed.

The current state of the art designs in soft robotics are pneumatic or motor-cable-based. One example from a group at Harvard University uses an inflatable Y-shaped balloon beneath the arm to support the user using EMG and inertial measurement unit (IMU) sensors (Chen et al., 2020). Researchers also created a similar soft device capable of articulating the user's wrist with a series of pneumatic actuators via a microcontroller (Liu et al., 2021). Another group used a motor-cable system with a body mounted harness to raise and lower the forearm (Xiloyannis et al., 2019). While there is no current research on using TCPAs in wearable robotics, there are documents which demonstrate known TCPA capabilities. A 2018 study regarding TCPAs claims that the material is easily fabricated, lightweight, durable, and realizes a high power density (Motoya, 2018). This is supported by another study which demonstrates an actuator controlling a plastic finger (Cho et al., 2016). While these projects and studies are all noteworthy steps toward the future of soft robotics, they lack practicality in some form: weight, size, or aesthetic design. The capstone group will seek to reconcile these components into a single pragmatic design.

To do this, TCPAs must be extensively tested for optimal coil design and current flow. Once the actuator has been resolved, it will be controlled using inverse kinematics programmed onto a microcontroller. Additional components will need to be fabricated including the sleeve on which the actuators are positioned. The design may be iterated upon. When a safe, effective design is made, it may be tested on human patients. Feedback will be gathered and more iterations may be made with the possibility of an eventual market release.

If the goals are met, the design will be fully textile-based, with EMG sensors and TCPA actuators, programmed to assist ALS users with daily tasks of living in a practical, comfortable, and safe manner. If achieved, it will mark a breakthrough in the soft robotics field and could benefit many ALS patients in the United States and worldwide.

The Struggle for Affordable Healthcare in the United States

In the United States, how are social groups competing to influence efforts to improve access to affordable healthcare?

In 2019 an estimated 34 million Americans could not afford their yearly drug prescriptions and 13% of adults knew someone who had died because they could not continue to pay their medical bills (Witters, 2019). With rising deductibles, copays and overall insurance costs, even those who have access to some form of healthcare often cannot get treatment they need. Nearly 10% of Americans have no insurance at all; the majority of which are impoverished (Keisler-Starkey & Brunch, 2021). Many jobs that low-income populations work do not offer health insurance benefits. And usually, the poor cannot afford private insurance due to low wages (Castañeda et al., 2011). This healthcare crisis has long sparked debate and advocacy for change among Americans, yet the problem persists today. The current American healthcare system is broken at the core.

To Champlin and Knoedler (2008), healthcare is fundamentally a shared responsibility, and efforts to improve access to care must begin on this basis. They claim that this responsibility is not fully recognized by the main participants: individuals, employers, and the state. Instead, to alleviate the burden, intentionally ambiguous copays, deductibles, and premiums are introduced. Knowledge of the responsibility can be shifted instead of recognized. Thus, the illusion of lower costs is created, while overall costs and inefficiencies rise. Champlin and Knoedler conclude that because of a lack of shared responsibility on all levels, the entire system cannot adequately support everyone (2008). In a study of homelessness, Shlomo and Benjamin (1976) reached analogous conclusions. They found that because responsibility for homelessness is shared across agencies, each agency could invoke “the principle of somebody else’s problem” to excuse inaction. Nadeem and Kaiser (2022) attribute disparities in healthcare to resource inequalities correlating with race, economic status, and location. According to Lancaster (1995), however, “specialty medical and hospital care” take precedence in the U.S. over “population-based services designed to keep people healthy,” raising costs and impairing access.

In a study of income inequality and health, Kawachi and Kennedy (1999) warned that “high income disparity may translate into lower social spending” when “the interests of the rich begin to diverge from those of the typical family.” They found better public health in societies with less income inequality (fig. 1).

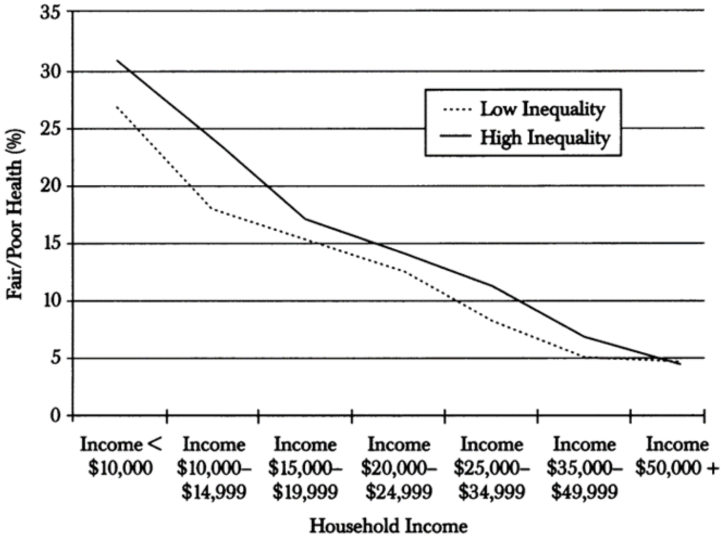

Figure 1: Relationships of self-rated health according to levels of individual income and levels of income inequality (Author; data from Atkinson, Rainwater, and Smeeding 1995)

Responses to inequalities in healthcare access are diverse. The National Health Law Program (NHeLP) uses litigation and advocacy “to protect and expand health rights of low-income individuals, families and underserved communities” and to promote mandated healthcare services (NHeLP, 2020). Families USA promotes extension of health insurance coverage to underserved populations. Through an article warning of “the deadly cost of being uninsured," it demands public programs that extend insurance coverage (Families USA, 2012). While many medical professionals support expanded healthcare access, they generally defend private insurance. In 2019 the American Medical Association's House of Delegates resolved to "boost its push for universal coverage by improving the Affordable Care Act (ACA) while maintaining the Association's opposition to a single-payer approach to health system reform" (O'Reilly, 2019).

Some advocacies oppose mandates to improve healthcare access, citing principles such as free enterprise and personal liberty. Americans for Prosperity (AFP) claims to be a broad-based grassroots advocacy that opposes "unsustainable government spending." An AFP press release reads, "NEW POLL: Americans strongly prefer personal option in healthcare to single payer or public option" (Holtzman, 2022). Partnership for America's Health Care Future also opposes government funded universal health care. It urges policymakers to "build on what's working" (PAHCF, 2022) by improving private plans and the Affordable Care Act.

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