Undergraduate Thesis Prospectus

Tongue Drive System: An Alternative Control System for Quadriplegics

(Technical Research Project in Computer Engineering)

The Struggle for the Right to Repair 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 engineered systems better empower their users?

Systems are engineered to better empower users, but this aspiration doesn't always translate into an advancement for users. Improvements in technology can be a force for good, such as research into assistive technologies for the disabled which has helped many overcome their disadvantages (Nichd, 2018). This drive to better serve users and push engineered systems to new heights can also be its own pitfall by causing unintended consequences. One of these consequences is difficulty in device reparability which actually inhibits users and deteriorates the environment (Ramirez & Duffy, 2021). Exploring this question holds significant importance as it impacts the effectiveness and inclusivity of technology in our lives, ensuring that individuals can fully harness the potential of these systems to improve their experiences and opportunities.

Tongue Drive System: An Alternative Control System for Quadriplegics

How can the limited mobility of quadriplegics be improved through an accessible system?

This is part of my 4th year capstone project and will be advised by Adam Barnes in the Electrical and Computer Engineering Department. In collaboration with Nicholas Talton, Dhruv Batra, and Micahal Kinsel, we aim to create an alternative control system that can be used on electric wheelchairs, for quadriplegics that are unable to use conventional systems.

Spinal cord injury(SCI) affects 200,000 to 500,000 people each year globally (Bennett et al., 2022). In the United States, there are approximately 17,000 new cases of SCI each year, and roughly 282,000 persons estimated to be living with SCI, 60 percent of which suffer from Quadriplegia, paralysis below the neck (Bennett et al., 2022; Cleveland Clinic, 2022). Quadriplegics face the issue of not being able to use traditional motorized wheelchair controls

such as joysticks instead requiring assistive devices. The most popular assistive device is called ”Sip and Puff” which is a system where a user can inhale/exhale into a tube and the strength of the inhale/exhale along with the direction of airflow determines whether a user goes left, right, forwards, or backward in their wheelchair. This system has limited control precision, since one sip/puff is mapped to one corresponding movement, as well as can be tiring to use (Mougharbel et al., 2013). Thus we have decided to explore control methods based on tongue utilization. Using the tongue to control wheelchairs for quadriplegics has been explored by various researchers and the range and ease of motion for a tongue can be compared to a finger so it’s easy to see why this medium is an attractive approach.

One such group of researchers from Georgia Tech developed the Tongue Drive System (TDS), a system that uses sensors placed on both sides of the face to interact with the fields generated by a magnet on the tongue (Huo et al., 2008). This design allows for greater control while being easy to maintain since the electronics are all external. Our project builds on this research by trying to implement the methods described in the paper on a fully embedded system in-order to avoid the need for an external computer for data processing, which their implementation required. We will be following a similar, but simplified, process as the one described in the Georgia Tech research. First, there will be a calibration process for the user to map positions of the tongue to different commands. Following calibration, the microcontroller we’re using, MSP 432, will continuously grab sensor readings and determine the command the user is trying to perform using the data from the calibration process and the K-Nearest Neighbors classification algorithm. The predicted command can then be used to control the application of choice. In order to meet the budget and time constraints, we will be testing this system through a simulation software and not an actual electric wheelchair. At the conclusion of the project, we

expect to have a prototype headset that holds the magnetic sensors by the user's face, software to perform the described operation, and simulation software to show its capabilities. This project is important because being able to reproduce this work on a low power embedded device will prove that the methods used can be run on a simple low power device which would reduce the cost and increase portability. Future iterations of the project could work on reducing latency and making the system wireless.

The Struggle for the Right to Repair in the United States

In the US, what interests, ideas and values do critics and proponents of the Right to Repair Movement invoke in defense of their respective agendas?

"It's odd to be a computer repairman and feel like the kid in high school that was selling weed out of the fourth stall of the lunch bathroom"(2021) stated Louis Rossman in a WSJ interview. This is the issue that the Right to Repair Movement advocates to remedy. The movement argues that once a consumer has bought a product they should have the right to use it, modify it, and repair it however they wish, but currently they are often denied the information and parts needed to do this. Advocates for this movement believe giving consumers these tools will allow for cheaper repair options and develop a more sustainable product design (Hernandez et al., 2020). Critics of the movement push back saying, among other things, the right to repair policies will infringe on companies' intellectual property which will stunt innovation (Fang et al., 2017).

Participants include at least three classes of advocates. First, small shop owners like Louis Rossman who stated the following when asked about what he wants legislation to include, "the bare minimum, which is get us access to schematics, to board views, and to be able to buy

these chips" (Wall Street Journal, 2021). Small repair shops are currently extremely limited on how much they can help customers as a result of companies restricting access to device parts and schematic information with company leaks being their primary source of this necessary information. Second, nationwide interest groups such as Environmental America whose, "campaign is working to reduce waste, protect fragile ecosystems, and reduce greenhouse gas pollution by making the parts, tools and information we need available so we can fix our stuff and keep it in use for longer." (n.d.). Environmental interest groups such as these fight both locally and nationally to make device reparability easier in order to fight against the business practice of Planned Obsolescence which they believe is a major cause of environmental damage (Guiltian, 2009). As well as, Right to Repair interest groups such as the Repair Association whose objective is, "to shape pro-repair policies, guidelines, and regulations across federal, state, and local governance structures." (n.d.). The Repair Association has been a major force for the movement primarily focusing on pushing legislative change. The repair association doesn't only fight for electronic devices, but also other industries ranging from Automotive, Farm Equipment, and Medical Equipment. Lastly local and online communities such as iFixit which states "As the world's largest online repair community, we help thousands of people fix their broken stuff every day. We also have everything you need to fix your electronic devices yourself " (n.d.). iFixit is one of the largest e-commerce companies that sells repair parts as well as serves as a community hotspot providing free wiki-like repair guides for consumer electronics and forums for users to discuss and teach each other how to repair their devices.

Participants also include critics of the movement. This includes manufacturers such as Apple that cited issues of securing intellectual property when lobbying Nebraska Lawmakers "to kill 'right to repair' legislation, telling them unauthorized repair will turn the state into a "mecca"

for hackers" (Koebler, 2017). Another set of participants are trade groups such as TechNet that represent several large tech firms. The vice president of TechNet, Carl Holshouser, stated in a recent FTC hearing, "Allowing unvetted third parties with access to sensitive diagnostic information, software, tools, and parts would jeopardize the safety and security of consumers' devices and put consumers at risk for fraud" (TechNet, 2021). Many major technology companies and trade groups have been reluctant to allow the release of design schematics stating that this will allow malicious actors to find vulnerabilities in systems, this is an issue since these documents are a necessity in order to make repairs as Louis Rossman stated. Finally, individuals that don't disagree with the movement but hold some nuanced opinion on some of the points activists make are also participants. A group researchers said the following in an article in the Harvard Business Review, "The key is that manufacturers might strategically adjust new product prices to mitigate their foreseeable profit loss from the right-to-repair legislation. Will manufacturers follow a margin strategy and raise new product prices to capitalize on easier repair? Will manufacturers follow a volume strategy and cut new product prices to lure consumers into replacing instead of repairing a glitchy product?" (Yang et al., 2023). In this article Yang and his colleagues argue enabling reparability doesn't directly mean a win for the environment and consumer pricing, but instead it depends on how companies react. Many hold a similar view that it's not a black and white issue and that the right to repair legislation can have major implications on the political landscape of consumer products.

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