Modularity and its Application in the Modern Consumer Prosthesis

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BME 1501: Innovations in Prosthetics

Goal

Outline the infrastructure/capital to support the creation and production of modular upper-arm prosthetics to enable unprecedented customizability for the end user.

Impact

Enabling modularity in prosthesis will enable third parties to manufacture and innovate on an established base. Prosthesis users will be able to customize their prosthesis with cheap, readily available parts.

Literature Review

Standardization is one of the great modern innovations but has been present within human societies since the early Indus Valley Civilization as a mode of having a common system of mass measurement. This idea was then translated by the towns of Harrappa, Mohenjo-daro, and others into standardized angular measurement for the planning and construction (Yoke et al., 1997). Since then we have advanced considerably, implementing the basis of standardization into all manner of technical products from the basic USB port to the Windows operating system. This is primarily due to the economic benefits experienced by all parties involved (Xie et al. 2016). Because of this economic benefit, there is a wide third-party market for most standardized products. This alleviates the pressure on the original innovator and vastly improves the experience for the end user. Unfortunately, despite the innovation in the field of prosthetics, standardization has had no real presence. For the most part, prosthesis are one-off products, custom made for an end-user. The lack of standardization is a major hurdle for introducing a modular prosthesis.

The benefits of modular prosthesis have been explored very early, prior to modern modular prosthesis being conceived. Even then, the benefits of modular prosthetics such as advantages in repair and maintenance, interchangeability, etc. has been recognized (Staros, 1879). But it has been only recently that the means to achieve the goal of modular prosthesis have been revealed. Modular prosthesis have been heavily explored and have demonstrated "ability to control a greater number of motions, utilize multiple task-appropriate grasps, and describe a more intuitive control experience than currently available with conventional prostheses" (Yu, et al. 2017). In another study, a modular prosthesis was fitted to multiple patients with an industry socket followed by multiple training sessions. The users demonstrated a high degree of freedom when manipulating the prosthesis as well as good specificity in sensitive controls (Perry, et al. 2018). Despite the clear advantages, modular prosthetics have little to no commercial presence this is due primarily to the complexity involved in designing a modular system. In the designing phase of a modular prosthetic, the designers must anticipate levels of flexibility far into the future. This requires more skill than a common prosthetic system, a custom prosthetic.

This proposal will seek to outline the goals and innovations necessary to bring the modular prosthetic to market in a form that is widely available to the masses. These innovations include high-power density batteries, a unified connector, and a market-standard neural-prosthesis interface.

Design Process Outline

1. Unified Connector
    a. Design (~1 month)
    b. Create working prototype (~1 month)
2. Market-standard neural prosthesis interface
    a. Find and purchase (~1 month)
    b. Adjust unified connector to accommodate interface (~1 month)
3. Test for integration
    a. output signal fidelity through synthetic signals (~1 month)
    b. input signal fidelity through synthetic signals (~1 month)

4. Recruit human test subjects-transradial amputees with existing upper arm functionality (~1 month)
5. Perform and adjust for select human trials
    a. Human test subjects-transradial amputees (~3 months)
    b. Human test subjects-transhumeral amputees (~3 months)
    c. Human test subjects-forequarter amputees (~3 months)

References

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