Improving Embodiment and User Control of Myoelectric Prosthetics Using Sensory Feedback

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Introduction

- The sense of touch is an often overlooked aspect of our daily lives
- Necessary for interacting with objects, other people, and our environment
- People who undergo upper extremity amputations lose their sense of touch
- Currently zero clinical applications of sensory feedback
- Consequently, people view their prosthetic as an artificial tool instead of an extension of their body
- Experience dissociation and decreased confidence manipulating objects they cannot feel
Introduction

• The ideal control and feedback system would work the same as a natural limb
• EMG signals travel through the nervous system to cause muscle activation, while sensory feedback is provided by the peripheral nerves and interpreted in the brain
• Myoelectric prosthetics utilize EMG signals (efferent pathway) as control inputs
• Do nothing to create or utilize the existing afferent pathway in the peripheral nerves

Myoelectric Prosthesis

Myoelectric prostheses have better grip patterns when compared to body powered prosthesis due to the control of electric signals from muscles

- Lack sensory feedback and rely on visual cues
- Only about half of amputees use prostheses on a daily basis*
- Replacement is necessary about every five years and even more with a growing child

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Purpose

• Develop a way to improve sensory feedback based on previous research and technological developments
• Maximize prosthetic embodiment and user control
• Make people happy to use their prosthetics, making operation less conscious and easy to perform daily activities
• Make prosthetics more lifelike, and increase quality of life (for the vets!)
Background

• Myoelectric-controlled prosthetics (both simple and advanced) already exist, but offer little or no sensory feedback
• Nerve cuff electrode implants meant to stimulate the median, ulnar, and radial nerves also already exist
• Current methods to produce sensory feedback are electrotactile, mechano-tactile, or vibrotactile
• Different types of commercial sensors or “tactors” which measure normal force, temperature, and shear force have been developed
• These sensory feedback systems have been designed to work with existing prosthetics
Previous Research

Cuff implants with peripheral nerve stimulation systems of two separate upper extremity amputees to provide sensory feedback

- Calibrated sensors by applying weights and having subjects open and close prosthetic hand
- Functional tests (3) administered to prosthetic hand to examine addition of sensory feedback
- The two subjects were blindfolded during test one and two
- Types of feedback for tests: without sensory feedback, with pressure feedback, with hand aperture feedback
Previous Research

Functional Tests of prosthetic hand included:

- Determining whether a wooden block was placed in hand
- Locating and removing magnetic blocks from a table
- Completing Southampton Hand Assessment Procedure (SHAP)
  - Assess ability of daily living and time to complete tasks

Results:

- Subjects performed significantly better with sensory feedback and with increased confidence in their answers
- Sensory feedback decreased error to success ratio by 96%
- Previous success ratio < 50%
- Improved results of SHAP tests
a. Non-amputee
c. Amputee
Proposed Research

- Natural limbs provide all types of sensations (position, pressure, temperature, stretch, etc.)
- Our proposed research involves the combination of multiple sensory feedback techniques (force and position)
- We want to create a more lifelike prosthetic experience
- Our experimental participants will need to have myoelectric prosthetics
- Be willing to undergo a minimally invasive procedure to place the nerve cuff electrodes and vibrotactile motors
Proposed Research

• Evaluating the combination of force feedback and position feedback
• Position feedback will utilize nerve cuff electrode implants and strain gauges placed on the joints of the myoelectric prosthetic
• Different hand positions will correlate to strain measurements
• Stimulation will be provided to the medial, ulnar, and radial nerves in different combinations based on hand position
• Force feedback will utilize pressure sensors on the fingertips and four small coin motor implants for vibrotactile feedback
• Motor activation and vibration will correspond to the amount of force on the fingertips
Methods and Testing

- 5 Groups, 5 - 13 Participants
- Natural limb (comparison), myoelectric prosthetic with no feedback (control), only force feedback, only position feedback, and both types of feedback
- Both types of sensory feedback will need to be calibrated after implantation and users will need to be trained to associate stimulations
- Participants will be asked to perform multiple tasks
- Moving light and heavy weights from point A to point B (with evaluation of applied force)
- Lifting light and heavy weights while blindfolded (to take out visual cues)
- Force and position targets and evaluation of accuracy
Methods and Testing

- Participants will be asked a variety of questions relating to force feedback, position feedback, and experienced sensations.
- Where is pressure being applied to the prosthetic?
- What position is the grasping hand in?
- Blindfolds and headphones to reduce visual and some auditory cues.
- Does the same prosthetic feel more like your natural limb?
Potential Obstacles

- Invasiveness
- Calibration of the system to provide appropriate sensations
- Interference of sensors on prosthetic operation
- Training period which teaches the user to associate specific forces and hand positions to specific sensations
- Interference between multiple types of sensory feedback
- Sensations distracting user from tasks
Optimal Outcome

- Improved grip control and task performance
- Reduced error in movement and grip
- Reduced reliance on visual cues
- Increased embodiment and ownership of prosthetic
- Reduced phantom pain

https://www.voltaicsystems.com/blog/solar-to-power-prosthesis/
Conclusion

• Current users of myoelectric prosthetics have little or no sensory feedback
• Previous research has demonstrated multiple possible methods of sensory feedback, and that feedback improves prosthetic control
• We are proposing further research in the combination of multiple types of sensory feedback
• Will result in improved control and embodiment
• Improved quality of life during daily activities
• Funding
Questions?
References


References

