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Perspectives on Use of Resistive Force Sensing to Improve the Control and User Experience of Hand Prostheses

Daniel Andreas[1], Mehmet Ege Cansev[1], Anany Dwivedi[1], Philipp Beckerle[1,2]
[1] Chair of Autonomous Systems and Mechatronics, Department of Electrical Engineering, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany,
[2] Department of Artificial Intelligence in Biomedical Engineering, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany
daniel.andreas@fau.de

Summary:
Human hands help us to learn about the environment via haptic sensation and thus facilitating effortless interactions. A hand amputation can disrupt the life of persons with amputation in carrying out everyday tasks. In this paper, we provide our perspective on employing force sensing methods to improve the acceptance rate of the prosthetic limbs by providing haptic feedback.

Keywords: force sensing resistors, robotic prosthesis, affective touch, human-machine interface, data glove

Introduction

Humans learn about the environment by interacting with it. The human hand is a powerful tool that enables us to perform a wide range of tasks, from interacting with objects used in daily living to executing gestures in social activities. According to [1], approximately 540,000 persons with amputation suffer from upper limb loss in the US with the expected projections to be doubled by 2050. Europe approximately has 4.66 million persons with amputation, with up to 431,000 amputations performed each year [2]. The loss of a limb can have a detrimental effect on the quality of life, preventing people from performing critical activities of daily living [3].

The latest technological advancements have led to increasingly dexterous devices for persons with amputation. However, the use of such devices is still not widespread, as there are still challenges to be overcome. The control algorithms that utilize traditional biosignals-based sensing methods (e.g. electromyography) for control of prosthetic hands can be complicated as they require sophisticated electronics, frequent gelling on the skin electrodes to reduce noise, and can also be expensive [4]. Another challenge with prosthetic devices is that use of prosthetics is a cognitively intensive task due to absence of proprioception information, forcing the wearer to visually monitor the artificial limb [5]. For enhanced feeling of proprioception, researchers are exploring affective touch for integration of the prostheses into the bodily self of the wearer and to foster more natural interpersonal interactions [6].

In this paper, we present our perspective on the use of force sensing resistors (FSR) for improving the state-of-the-art of upper limb prosthetic devices by focusing on the above-mentioned challenges. To do this, we consider low-cost solutions for predicting the user intentions using alternate myography methods like an FSRs-based wearable glove and forcemyography (FMG) for acquisition of data for developing the decoding models. We also discuss employing affective touch methods to improve the feeling of proprioception leading to greater embodiment with the device and thus increasing the acceptability of the prosthesis.

Force Sensing based Data Acquisition

Acquiring ground truth data from persons with hand amputation to train machine/deep learning models to decode hand motions for prosthesis control is particularly difficult due to the missing limb [7]. Generally, there are two ways to overcome this challenge. The first option provides a simulated hand motion to guide the user through the movements to be performed [7,8]. Alternatively, people with hand amputation can perform tasks bilaterally while wearing a sensor glove on the intact limb to record ground truth data [7,8].

Such sensor gloves typically contain flex sensors that change their resistance while bending and thus work very similar to FSRs. The acquired signal can then be translated into finger joint angles. We developed a sensor glove that contains eleven flex sensors with five additional FSRs mounted to the fingertips in order to measure the exerted force between the respective finger and the object. The added FSRs can be used as an additional input to improve the reliability of the decoder and to enable force control, given the hand prosthesis contains corresponding sensors.

FMG is a cost-effective alternative to electromyography (EMG) and is based around FSRs to measure muscle motion that result from hand movements. The acquired data can be used to decode finger and hand motions. In the past, decoding hand motions from FMG data outperformed EMG in many instances and is thus a promising way to acquire muscular activity [8].

Force Sensing for Enhanced Embodiment

In addition to physiological factors, psychological effects, e.g., embodiment, presence, pleasantness, and agency, play a critical role in acceptance of prosthetic devices. Although being a recently considered phenomenon in assistive and prosthetic robotics, affective touch has the potential to support the acceptance process [6].

To reveal the potential benefits of affective touch, we developed a prototype that stimulates either the lower or upper arm of a user so that it can be tested with different amputations [10]. Our design stimulates the mechanoreceptors on the skin in a realistic human-like manner as if fingers are touching the skin by using linear actuators and silicone coating. However, one of the most important factors that determines the realism of touch feeling is the contact force. Thus, we used FSRs to measure and control the contact forces to fit them into the suggested range of affective touch. Therefore, our design can be controlled by the sensor glove mentioned above to precisely apply the forces detected on the fingertips of the glove for further experiments.

Conclusion

Owing to the cost-effectiveness of the force sensitive resistors and flex sensors, they have found applications in various fields. In this paper, we present our perspective on the use of these sensors for development of an interface to acquire high quality data in a reliable way to decode hand motions from muscular activity. Future works could investigate the benefits of combining FMG with EMG in a single device for hand motion decoding. Furthermore, benefits of affective touch can be tested on persons with amputations by designing prosthetic sockets using modular linear actuators or vibration motors with force feedback to improve the user experience with robotic hand prostheses.

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