EMG feedback for improved control of myoelectric hand prostheses

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***Abstract*—Myoelectric prostheses can compensate for the motor functions that are lost due to an amputation. However, none of the commercial prostheses restores somatosensory feedback to their users. A conventional approach to providing the missing sensory information is to read the data from the sensors embedded in the prosthesis and transmit this information back to the subject by stimulating the skin of the residual limb mechanically or electrically. However, we have proposed a substantially different approach to closing the control loop. In this scheme, the tactile feedback does not convey the output of the prosthesis (sensor data) but its command input, namely, the magnitude of the myoelectric signals generated by the user (so-called EMG feedback). In this lecture, we will explain that this method facilitates the natural proprioceptive feedback from the muscles (sense of contraction) and thereby allows predictive control of prosthesis grasping force. We will also present results illustrating that EMG feedback outperforms conventional force feedback in terms of accuracy and robustness. Finally, we will outline the potential for further developments of this approach.**

***Index Terms*—myoelectric prostheses, tactile feedback, electrotactile and vibrotactile stimulation, EMG feedback, grasping force control.**

I. Conventional approach to closing the loop

To fully reconstruct the limb that is lost due to an amputation, a bionic prosthesis should restore both motor and sensory functions. Myoelectric control allows an intuitive connection between the brain of the user and his/her prosthesis; however, commercial devices do not transmit somatosensory feedback. Therefore, the amputees do not "feel" their bionic limbs, which might impair performance during prosthesis use as well as the sense of embodiment.

Modern hand prostheses are equipped with sensors and the feedback can be restored by translating sensor data into stimulation profiles that are delivered to the residual limb using mechanical or electrical stimulation [1]. For instance, the magnitude of the grasping force can be associated with the frequency or intensity of electrical stimulation applied to the surface of the skin. The prosthesis user can then learn to interpret the elicited sensations – faster or stronger stimulation indicates larger forces.

Recognizing the importance of sensory feedback in able-bodied subjects, the expectation was that providing such artificial force feedback to an amputee user would significantly improve the performance. The results in the literature are however contradictory [2]. Some studies indeed show an improvement, while in some, the addition of feedback was not beneficial.

II. EMG feedback: an approach inspired by human motor control

In this lecture, we will first explain that the controversial results in literature can be understood by approaching the topic of artificial sensory feedback from the perspective of human motor control [2]. We will then use the same framework to introduce a different approach to closing the loop, so-called EMG feedback [3]. In this method, the tactile stimulation is not used to convey sensor data (prosthesis output); instead, it transmits the magnitude of the myoelectric signal generated by the user as the command input for the prosthesis. Since the prosthesis responds proportionally to the input signal, EMG feedback enables the subject to control the grasping force predictively.

The usual approach for the implementation of EMG feedback is to divide the myoelectric signal into ranges, where each range is indicated by a simple stimulation pattern, e.g., activation of a specific vibration motor from an array of motors placed around the residual limb [4], [5]. To produce a specific force level, the subject then needs to activate his/her muscles and increase the muscle contraction until he/she feels that the desired motor is on. Then, the subject maintains that contraction level, while the prosthesis closes and produces the desired force. Contrary to the conventional approach, the feedback is in this case available even before the prosthesis makes contact with an object, giving enough time for adjustments.

We will present the results from our recent experiments illustrating this approach and showing that EMG feedback outperforms the conventional method in terms of both accuracy and robustness. We will then present the ideas for the further developments of EMG feedback.

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