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Sensory Feedback in SEMG Prosthetic Hand

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Abstract. Active hand prostheses controlled using electromyography (EMG) signals have been used for decades to restore the grasping function. Amputees with myoelectric hands wish to control the prostheses according to their own will and act like human hands as much as possible. Therefore, substantial research efforts have been put forth to advance the control of myoelectric hands. However, the sensory feedback from the prosthesis to the user is still missing, terous end-effector and a sophisticated instrument for sensory exploration. After an amputation, these important motor and sensory functions are abruptly lost. Which results in a disability with possibly enormous consequence for activities of daily living and quality of life [1].Myoelectric hand prostheses can be used to restore grasping. The control signal driving the prosthesis hand is obtained by applying simple processing to the electromyography (EMG) signals recorded from the user muscles. and it seems that little attention has been paid to restoring the sensory functions of tactile feedback. This paper introduces the basic theory of SEMG signals and presents an overview of the sensory feedback employed to prosthetic hand. Some further researches and developing trend of sensory feedback are indicated.

Introduction

Human hand is a dex But such prostheses do not provide feedback of the interaction forces, or other kind of information from proprioceptive or exteroceptive sensors to the user. This lack of sensory feedback does not help to operate efficiently with these robotic devices.

Providing feedback to the user would help to operate a prosthetic device more efficiently, and the control of grasping largely depends on tactical feedback, in humans [2]. Therefore, a common thought is that prostheses would function better if used closed-loop control, making use of proprioceptive and exteroceptive information. To achieve this goal, the prosthesis should be able time convey such information to the user in a perceivable and possibly effortless manner. Various researches and designs of sensory feedback systems have been presented over the years, but it seems that none has yet been convincingly proven usable and thus been made commercially available. In this paper, we review the important features describing sensory feedback in myoelectric hands as well as summarize significant work carried out in the field.

SEMG Signals

The electromyographic (EMG) signal is the summation of the action potentials discharged by the active muscle fibers in the proximity of the recording electrodes [3].

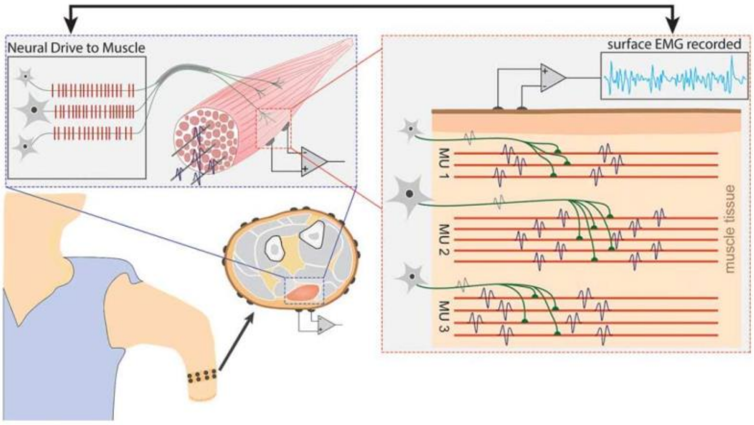

Figure 1. Finite Generation of the surface EMG signals. Source from [4].

Fig. 1 demonstrates the generation of EMG signals. As described by Farina [5], the EMG signal can be seen as a neural recording from a peripheral muscle that biologically amplifies neural signals of tens to hundreds motor neuron. A single motor neuron and its corresponding muscle fibers constitute a muscle unit (MU).The surface EMG (SEMG) obtains EMG signals by placing electrodes on the skin. It’s a kind of bioelectric signal recorded and included by electrodes when neuromuscular system is active. The activity of motor neurons activates the generation of muscle fiber action potentials and a compound action potential is recorded at the skin surface is the SEMG recording. When the SEMG signals are recorded from the muscles, they will be processed and analyzed for activating certain prosthetic functions of the prosthesis. SEMG acquisition and processing are shown in Fig. 2 The purpose of signal analysis and processing is to discuss the possible cause of SEMG signals change and reflect activity and function of muscles effectively by the change of SEMG signals.

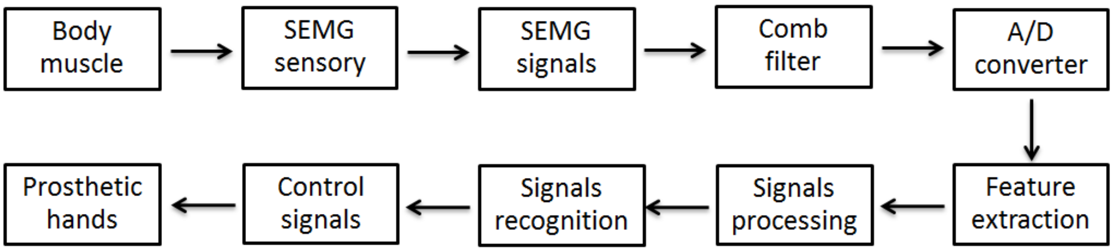

Figure 2. Finite The frame diagram of SEMG acquisition and processing

Sensory Information and Feedback

The somatic cell receptor is divided into skin and subcutaneous mechanical receptors, muscle and skeletal mechanical receptors, nociceptors and heat receptors. This complex sensory system is encoded and transmitted to the central nervous system (CNS). There are four major ways of information: tactile, ontological sensation, pain and temperature. Sensory feedback system uses a prosthetic instrument (or sensor) to detect external stimulation. The instrument timely drives the output of a tactile feedback device (also known as a reactor) that communicates information about external stimuli to the prosthetic user. Various types of actuators have been reported in the literature, and external stimulation are conveyed to the user by means of vibration or electrical stimulation. For an amputee, after the loss of receptors and the disruption of the physiological channels, there are two potential pathways that trigger sensory feedback:(1)invasively, by direct contaction with the physiological neural structure in the peripheral nervous system (PNS) or CNS.(2)non-invasively, by providing feedback to intact sensory systems. Invasive system may can pose an infection risk where the cables emerge from the skin, but non-invasive tactile feedback methods involving temperature, vibrations or electro-mechanical force feedbacks have been shown to improve both the use and the sense of ownership of the prosthetic hand by making it feel less like a tool and more like a natural part of the amputee’s body[6]. The sensory feedback systems reviewed in this paper have been divided into substitution feedback and modality-matched feedback.

Sensory-Substitution Feedback

Sensory substitution is a method to provide sensory information to the body, through a sensory channel different from that normally used (e.g. substitute touch with hearing), or through the same channel but in a different modality (e.g. substitute pressure with vibration). The success of the approach depends on the user’s ability to interpret the type and location of the stimulus and associate it with the prosthesis. The most common methodology has been to translate tactile information from the prosthesis to the amputee using vibration, electrotactile or auditory substitution.

Vibrotactile Feedback. Just as shown in the literature [7], vibrotactile feedback involves communicating sensory information from the prosthesis to the user through the application of mechanical vibration to the user’s skin at forearm. The main features of the stimulus are vibration frequency, amplitude and duration of vibration, and they can be modulated to convey different kinds of information like grasping forces and pressures present in the prosthesis. The vibrotactile feedback in prosthetic was firstly proposed by Conzelman in 1953 [8].And then, it has been widely researched due to its higher compatibility with EMG control and acceptability compared to electrotactile stimulation. Explore on Vibrotactile sensory substitution has been mostly applied to communicate tactile information during grasping tasks. Vibrotactile feedback systems have been used in research with the Otto Bock, Motion control and iLimb myoelectric prostheses. Recent studies [9] have reported that vibratory feedback was shown to improve user performance through a better control of grip force and success rates in performing grasping tasks. As a mechanism for providing sensory feedback, vibration is often a baseline standard to which other feedback methods are compared [10]. Vibrotactile tactors are advantageous in that they are relatively inexpensive, with small size and weight; important factors for prosthetic applications. However, prior to successful implementation, it must be demonstrated that the vibration induced into the residual limb tissues does not contaminate the motor control signals. Furthermore, analysis is warranted as to whether the vibration will affect socket movement or cause separation of tissue from the EMG electrodes.

Electrotactile Feedback. One of the earliest methods of creating sensation in an artificial hand was to use electrotactile stimulation for feedback. Electrotactile feedback system is comprised of force sensors, that are placed on the fingers and palm of a prosthetic hand, interface circuits for processing the sensor data and electrodes that are placed on nearby skin [11].It communicates sensory information to the prosthetic user via electrodes placed on the user’s skin. Electrotactile feedback can be used to elicit pressure and lip feedback. Sensory communication is most often achieved through modulation of the electrical current parameters: amplitude, frequency and pulse rate to single or multiple electrode sites. Through the experimental method, the relationship between electrical stimulation parameters and the grasping force in prosthesis should be determined to make user feel comfortable and safe, and have a clear sense of excitement. In testing with amputee populations, improvements in user confidence, control and grasp force discrimination have also been demonstrated with electrotactile feedback [12].

Despite many advantages, electrotactile feedback is not ideal because it can evoke a range of sensations that have been qualitatively described by participants as a tingling, itch, vibration, buzz, touch, pressure, pinch and sharp or burning pain. Some studies do not report the specific sensations experienced by the participants as a result of the electrocutaneous feedback; rather, they identify the range between initial sensation and pain [13]. Additionally, another major drawback of electrotactile stimulation is its interference with electromyography (EMG) signal and electroencephalography (EEG) signal, although there are cases which tested electrotactile stimulation with EMG-based and EEG-based rehabilitation system[14 15].

Auditory Feedback. Auditory feedback has been demonstrated as a technique to convey contact of a robotic hand to an object as well as the position of the hand’s digits and intended grasping pattern[16]. Methods of auditory feedback provide information on the state of a robotic or prosthetic hand through varying frequencies of tones or sounds. Gonzalez et al. designed an experience to explore the effect of using an auditory display as a sensory feedback system for reaching and grasping movements for prosthetic applications. The results showed that the usage of an auditory display to monitor and control a robot hand improved the temporal and grasping performance greatly, while reducing mental effort and improving their confidence[17].

Alison Gibson presented a method of sensing tactile information in dexterous manipulation by multi-frequency auditory signals. By grasping several objects of varying stiffness and weight with EMG prosthetic hand, the tactical information was provided in time through the proposed auditory feedback. Results showed that users were able to adapt and learn the feedback technology after short use, and could eventually use auditory information alone to control the grasping forces of a prosthetic hand[18].

Modality-Matched Feedback

Modality-matched feedback is the method that the output stimulation is felt in the same modality as the sensory input. For example, touch to the prosthesis is felt like touch to the skin. But the generated stimulation in the user's area is different from the original stimulation. In modality-matched methods, mechanotactile feedback is the represent of feedback paradigm.

Mechanotactile feedback is commonly used to communicate tactile information of touch and grasp to the users. It can provide force, pressure or position feedback for the user through the actuator or vibrator in prosthetic hand. Compared with other feedback systems, mechanotactile feedback is able to generate a natural feeling of force or pressure. But current mechanotactile devices consume more power and still have often larger size and heavier weight than vibrotactile or electrotactile devices. And some methods are desired to be developed to minimize these disadvantages.

A light and simple wearable device called CUFF, has been presented to provide the grasp force of a hand by applying a normal force to the skin and the aperture of the prosthesis by applying a tangential force to the skin[19]. But in the evaluation study[20], using the CUFF did not indicate significant efforts in regulating grasp force. Additionally, further improvements such as longer training with CUFF or customization of the feedback have been suggested and might enhance the performance.

Conclusions

The SEMG prosthetic hands have been widely applied to deliver functionality of grasp or manipulation for decades. However, the performances have been limited by an inability to provide a reliable sensory feedback. This paper presented the basic theory of SEMG signals, followed by a review of available sensory feedback systems which have potential to be applied in hand prostheses. Various sensory feedback systems have been proposed, and most have shown that users can improve their ability to manipulate the prostheses with feedback. There are still much challenges and opportunities in the field of tactile sensation restoration. Therefore, it is expected that an effective sensory feedback which can generate natural tactile perception will facilitate clinical use in prosthetic hands or other application in virtual reality.

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