Relationship Between Delay Time and Sensation in Tactile Feedback for Myoelectric Prosthesis

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Abstract

In this paper, we aim to develop a new tactile feedback method for myoelectric prosthetic hands and model the relationship between delay time and sensation in vibration stimulation. For myoelectric prosthetic hands, the tactile sensation can be expressed by vibrating an oscillator attached to the socket based on information obtained from tactile sensors attached to the prosthesis's fingertips. In this case, if there is a time gap between the sensory input and the stimulus, there is a possibility of causing discomfort. Therefore, in the experiment performed, a delay time, D_{u} [s], is set between the start of contact with an object and the start of vibration using a tactile sensor and conducted NRS evaluation. The results showed that the discomfort was generated up to $D_{\mathrm{u}} = 0.4$ [s] and then decreased according to the delay time. The results showed that the discomfort was induced by controlling the timing of the vibration stimulus.

Keywords: electromyogram, prosthetic hand, tactile feedback, tactile sensation.

1. Introduction

Although there are various studies on myoelectric prosthetic hands to compensate for the lost functions of upper limb amputees, to create a truly human prosthetic hand, it is necessary not only to realize control that mimics human hand movement, but also to equip the prosthetic hand with a means of obtaining sensory information such as the tactile sensation that is inherent in the human arm. One of the reasons why there are so few myoelectric prosthetic hand users, despite the development of various advanced prosthetic hands, is that there is little sensory feedback to the user.

To solve this problem, research has been conducted to feed back the information obtained when the prosthetic hand comes in contact with an object to the operator. Feedback for myoelectric prosthetic hands can be divided into invasive and non-invasive methods, among which it is important to know what kind of stimuli to use and how to use them. Various types of stimuli such as vibration [1-2], temperature, pressure [3-4], electrical stimulation [5], and phantom limb stimulation [6] have been studied as possible feedback. On the other hand, there is research that uses electrical stimulation to present the pain of a localized strong stimulus, and research that combines image recognition to present the texture of an object. Pain, for example, may be useful for presenting contact with objects that should not be touched with a prosthetic hand, such as hot or sharp objects, but it is usually difficult to provide direct feedback of pain to the user.

The proposed method aims to present pain sensation, and to clarify the relationship between the timing of vibration stimuli and human sensation.

2. Method

The time taken for the sensory stimuli to be recognized as contacting an object is approximately 50 to 300 [ms].

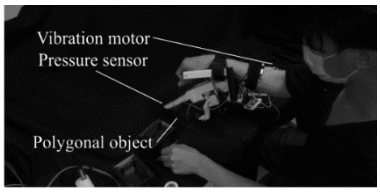

Fig. 1. Overview of the myoelectric prosthetic hand feedback system.

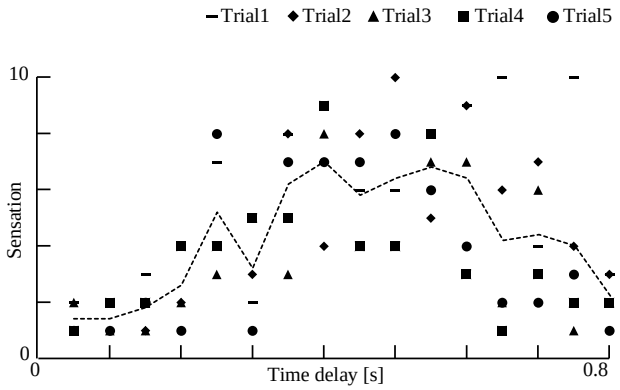

Fig. 2. Experimental results.

In a music game, the timing of the button operation and its feedback was varied, and the results were evaluated by questionnaire, and the larger the deviation from the operator's expected timing, the greater the discomfort. Therefore, when the pressure sensor value exceeds the object contact judgment threshold $\mathrm{th_s}$ and the threshold value $\mathrm{th_u}$ during the contact judgment time S, the vibration stimulus is given after the delay time D_u [s] from the end of the contact judgment time S, and it is verified whether the operator feels discomfort against the unexpected stimulus. Figure 1 shows an overview of the myoelectric prosthetic hand feedback system using an oscillator. A tactile sensor is attached to the fingertip of the myoelectric prosthetic hand, and feedback using an oscillator is possible according to the sensor value.

3. Experiments

In order to verify the optimal delay time D_u for expressing pain as discomfort using the proposed method, an experiment was conducted on a healthy university student. In the experiment, when the subject initiated feedback at an arbitrary timing, the vibration stimulus generation was delayed by a total of 10 random delay times D_u between [0.1, 1.0] [s] in 0.1 [s] increments. In this experiment, the subject was asked to evaluate how much discomfort he felt by a questionnaire with a 10-point scale. In the experiment, the subject presses a button to generate the feedback once and the vibration stimulus ends as one trial. In this experiment, all the delay times of 10 steps are presented 10 times. In addition, the vibration stimulus is set to 2.0 [s].

Figure 2 shows the results of the experiment. The vertical axis is the evaluation value of the questionnaire, and the horizontal axis is the delay time D_u. From the graph, the optimal delay time for expressing discomfort by feedback is 0.4 [s].

4. Conclusion

This paper verified a time-delay of tactile stimulation whether it is possible to express the discomfort to the operator. In the experiment, the time-delay of vibratory feedback after contact determination to the feedback was evaluated. The time at which the feedback by the vibration stimulus started was varied in 10 steps of 0.1 [s] between [0.1, 1.0] [s], and presented randomly. The time-delay that caused the most discomfort was 0.4 [s] for the participant.

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References

1. T. Rosenbaum-Chou, W. Daly, R. Austin, P. Chaubey and D. A. Boone, Development and real world use of a vibratory haptic feedback system for upper-limb prosthetic users, J. Prosthetics. Orth., vol. 28, no. 4, 136-144, 2016.
2. F. Clemente, M. D 'Alonzo, M. Controzzi, B. B. Edin and C. Cipriani, Non-invasive temporally discrete feedback of object contact and release improves grasp control of closed-loop myoelectric transradial prostheses, IEEE Trans. Neural Syst. Rehabil. Eng., vol. 24, no. 12, 1314-1322, 2016.
3. M. Aziziaghdam and E. Samur, Providing contact sensory feedback for upper limb robotic prosthesis, Proc. IEEE Haptics Symp. (HAPTICS), 575-579, 2014.
4. T. Morita, T. Kikuchi and C. Ishii, Development of sensory feedback device for myoelectric prosthetic hand to provide hardness of objects to users, J. Robot. Mechatron., vol. 28, no. 3, 361-370, 2016.
5. M. A. Schweisfurth, M. Markovic, S. Dosen, F. Teich, B. Graimann and D. Farina, Electrotactile EMG feedback improves the control of prosthesis grasping force, J. Neural Eng., vol. 13, pp. 056010, Oct. 2016.

6. Osborn, Luke E et al., Prosthesis with neuromorphic multilayered e-dermis perceives touch and pain, Science robotics vol. 3, 19, 2018.

Authors Introduction

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