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Development of myoelectric hand that determines hand posture and estimates grip force simultaneously

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ABSTRACT

The purpose of this study is to develop a myoelectric hand that determines hand posture and estimates grip force simultaneously like human hands. Methods for simultaneous hand posture determination and grip force estimation typically yield unsatisfying results because of the complex characteristics of electromyogram (EMG) signals. In this study, the authors developed a myoelectric hand that is able to control both force and posture using a method proposed in our previous study. Tests of the grasp ability of the myoelectric hand conducted with healthy men and an amputee showed that the proposed method can be used to control both grip force and hand posture simultaneously with sufficiently accuracy in a real environment. In conclusion, it was suggested that the hand that control posture and force simultaneously improve the dexterity of amputees.

1. Introduction

A myoelectric hand is a prosthetic hand controlled by electromyogram (EMG) signals, which are the potentials that occur over muscles when muscles contract. A myoelectric hand is said to be the closest type of prosthetic hand to a human hand in terms of functionality and appearance because a wearer can control a myoelectric hand based on his or her intentions and because most myoelectric hands have five fingers, like human hands. Therefore, many amputees want to use myoelectric hands.

EMG signals are measured as convolutional signals of impulses because they are neural signals. It is difficult to use these signals, but EMG signals have some features that can be used to estimate wearers' intentions. The relationship between EMG signal and grip force is illustrated in Fig. 1. The amplitudes of the EMG signals increase with the grasp force. Furthermore, the type of muscle used and the frequency of EMG signals are changed by the hand posture. Therefore, EMG signals possess information on both the grasp force and the hand posture. However, it is difficult to control both the grasp force and the hand posture of a myoelectric hand by EMG signals because EMG signals are very weak and fragile, and because EMG signals are affected by fatigue, sweating, and many other factors. Thus, with traditional myoelectric hands, a change in the EMG signal is regarded as a change in either force or posture that can be controlled by controlling the EMG signal.

The grasp control features of traditional myoelectric hands are summarized in Fig. 2. Most traditional hands belong to either one of the two groups; single-degree-of-freedom (DOF) hands that control the force or multi-DOF hands that control the posture.

Geethanjali et al. classified myoelectric control schemes into seven: on-off myoelectric control, proportional myoelectric control, direct myoelectric control, finite state machine control, pattern recognition-based myoelectric control, posture myoelectric control, regression myoelectric control [1].

On about single-DOF hands, on-off myoelectric control and proportional myoelectric control are often used. On-off myoelectric control is the most simple control scheme based on a threshold of EMG amplitudes. Hands can run at a constant speed. In proportional myoelectric control, hands convert the contraction level of EMG signals into the force, the velocity, or the position. One of the most famous myoelectric hands of this scheme is DMC plus, produced by Ottobock [2]. Regression myoelectric control is the control strategy developed recently. This scheme control multiple DOF of hand and wrist proportionally at the same time, but currently, it is not possible to realize a lot of hand postures.

On about multi-DOF hands, various studies are being conducted. Direct myoelectric control is the scheme to achieve individual control of fingers. However, it is difficult to control without implantable

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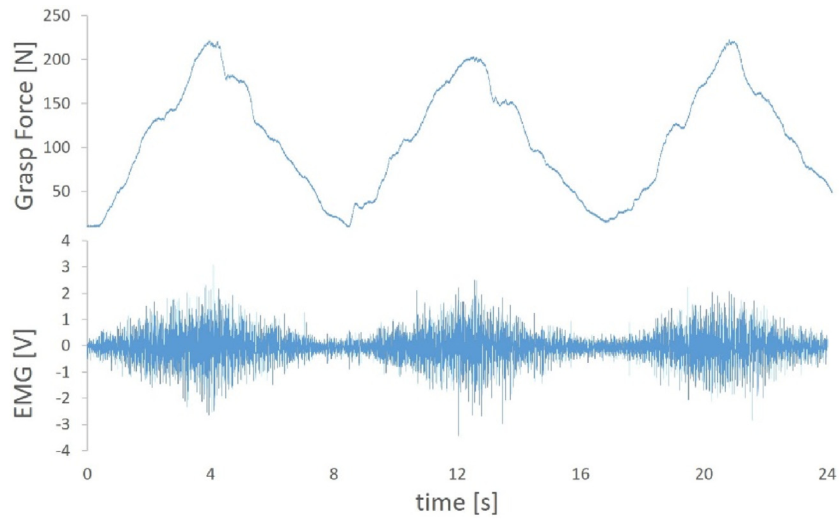

Fig. 1. Relationship between EMG signal and grip force.

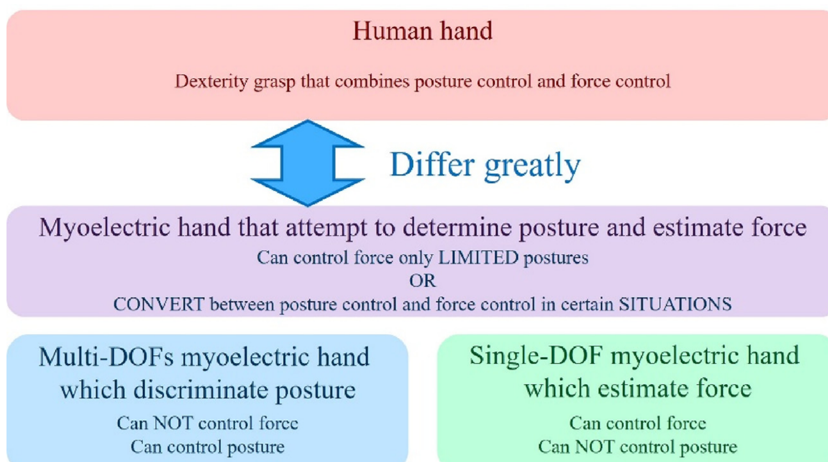

Fig. 2. The problem of traditional myoelectric hands.

myoelectric sensors. Finite state machine control predefine the postures as states and transit the states by commands. The combination of postures is limited, because it is necessary to transit the state several times till the desired posture is selected. The SSSA-MyHand and bebionic use this scheme [3,4]. Pattern recognition-based myoelectric control learn the hand posture and then determine the posture by pattern recognition. Many kinds of machine learning like linear discriminant analysis (LDA), artificial neural network (ANN), support vector machine (SVM), and so on are used in this scheme [5,6]. In pattern recognition, the force is also a factor in the patterns, so the pattern determined is affected by the force. Therefore, it needs to keep the force stable in order to identify correctly. In posture myoelectric control, EMG signals are mapped in the principal component domain [7]. This scheme enables simultaneous control of multiple DOF of hand, but it do not considered the force control.

There are a few myoelectric hands that attempt to perform both hand posture determination and grip force estimation. However, most of these hands can estimate grip force only when limited postures are considered or can convert between posture control and force control in certain situations [4,5]. The grip control of such myoelectric hands differs from that of human hands, which integrate posture control and force control. It is difficult to divide EMG signals into posture and force features independently. Therefore, it is important to develop the pattern recognition method with consideration of grasp force.

2. Methods

EMG signals are fragile biological signals, so EMG features extracted from EMG signals are often used in the control of myoelectric hands. Two types of EMG features, the mean absolute value (MAV) and the power spectrum (PS), were used in this study. MAV is a time-domain feature that reflects the amplitude average of the EMG signal. We can obtain information on the grasp force from the amplitudes of EMG signals. PS is a frequency-domain feature that reflects the strength of each frequency band. Using frequency-domain features allows determination of many postures by a few sensors.

We examined the relationships among three factors: EMG features, grasp force, and hand posture. We measured EMG signals while the hand posture and grasp force were changing. As a result, two types of EMG features appeared to increase monotonically with the grasp force. In addition, the form of the increase was different for each posture shown in Fig. 3. Based on these results, the authors developed the method described below for determining the hand posture and estimating the grip force simultaneously [8]. An overview of this method is presented in Fig. 4. This procedure