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The Robot Hand System that can Control Grasping Power by SEMG

Tsubasa Seto, Kentaro Nagata, Kazushige Magatani

***Abstract*—**SEMG (Surface Electromyogram) is one of the bio-signals and is generated from the muscle. And there are many research results that use forearm EMG to detect hand motions. In this paper, we will talk about our developed the robot hand system that can control grasping power by SEMG. In our system, we suppose that muscle power is proportional to the amplitude of SEMG. The power is estimated and the grip power of a robot hand is able to be controlled using estimated muscle power in our system. In addition, to perform a more precise control can be considered to build a closed loop feedback system as an object to a subject to pressure from the edge of hand. Our objectives of this study are the development of a method that makes perfect detection of the hand grip force possible using SEMG patterns, and applying this method to the man-machine interface.

***Keywords*—**SEMG, multi electrode, robot hand, power control

I. Introduction

SEMG is measuring the electrical signal associated with the activation of the muscle. Electromyography can be used for a lot of studies (e.g., clinical, biomedical, basic physiological, classical Neurological, and biomechanical studies). Recently, in order to describe the neuromuscular activation of muscles within functional movements, kinesiological electromyography deserves attention and is established as an evaluation tool for various applied research. In order to apply it simply, the surface electromyogram (SEMG) which is measured from the skin surface, is widely used as a control source for human interface such as myoelectric prosthetic hands[1-5]. The SEMG related system has many practical examples of applications in various fields such as human interfaces. Human interfaces are reported by many researchers, and we call them "SEMG interfaces". Our study also aims to develop the SEMG interfaces like myoelectric prosthetic hands. In our study, our target machine controlled by SEMG is a robot arm that is made for industrial use. This is shown in Fig. 1. About an SEMG interface, it is desirable to operate it with the same feeling as the sensations of real body movement. In order to achieve this objective, accuracy recognition of motion, which is an essential requirement, and estimation of muscular strength are both important factors. However, conventional SEMG interfaces have mainly focused on how to achieve the accuracy using sophisticated signal-processing techniques which are represented by a neural network model and a nonlinear one.

Tsubasa Seto is with the Department of Electrical and Electronic Engineering, Tokai University, Japan(e-mail: 1bdpm008@mail.tokai-u.jp).

Kentaro Nagata is with the Advanced Reserch Center for Human Sciences, WASEDA Univesity, Japan.

Kazushige Magatani is with the Department of Electrical and Electronic Engineering, Tokai University, Japan (e-mail: magatani@keyaki.cc.u-tokai.ac.jp).

We think the ability to estimate muscular strength is also an important factor in controlling it. In our SEMG system, we suppose that muscle power is proportional to the amplitude of SEMG. The power is estimated and the grip power of a robot hand is able to be controlled using estimated muscle power in our system. In addition, we think perform more precise control by letting a force feed back when a robot arm grasped something. In this study, our objective is to develop the control system with sense feedback using SEMG by building a robot arm grip force control system having a closed feedback system.

Fig. 1 A robot arm that is made for industrial use

II. Methodology

A. SEMG Measurement System

Fig.2 shows a developed multi channel electrode that includes 48 Ag electrodes. As shown in this figure, 48 Ag electrodes are set on a silicon rubber sheet. This electrode is wrapped around the forearm and 48 channels SEMG are measured from these electrodes. Fig. 3, also shows the construction of a multi channel electrode. In our system, a SEMG amplifier that can amplify 48 channels SEMG is necessary. A developed SEMG amplifier is shown in Fig. 4. Measured SEMG is amplified about 2000 times and noise reduced in this amplifier. A block diagram of the signal flow of measured SEMG is shown in Fig. 5. As shown in this figure, EMG signal is amplified and noise reduced by active filters. And then analog to digital converted by a 12 bit A/D converter. Digitized SEMG data is analyzed in a personal computer. It is very important for our system to select suitable electrode positions. And it is thought that if the user of this system is different, suitable electrode positions are different for each user. Therefore, suitable electrode positions for each user are decided from the 48 electrode positions of a right forearm in our system.

As following, the selection method of suitable electrode positions is described. First of all, 48 channels SEMG of a user are measured for each hand motion. In our system, canonical discriminant analysis is used to recognize hand motion. The SEMG feature extraction *X*i is given by the following expression.

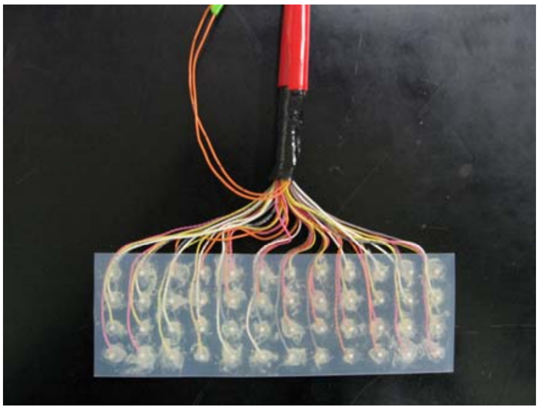

Fig. 2 A multi-channel electrode

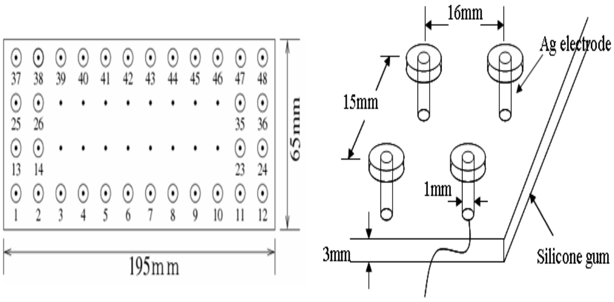

Fig. 3 Construction of a multi channel electrode

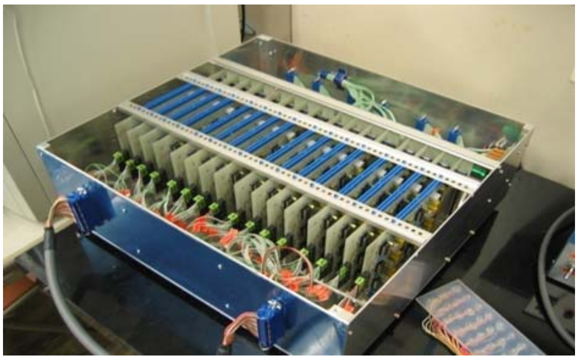

Fig. 4 A 96 channels SEMG amplifier

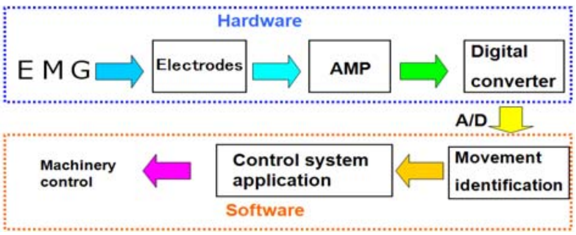

Fig. 5 A block diagram of the signal flow of measured SEMG

$$Xi = C\sum_{n=1}^{N}\left|X_i\left(n\Delta t\right)\right| \qquad (1)$$

Where $xi(t)$ is the SEMG signal value of *i* channel at time t and Δt is sampling period. *C* is the constant used to normalize patterns. In our system, integrated time $N\Delta t$ is set to 300ms. In order to select suitable electrode positions, Monte Carlo method is used. In other word, many electrode sets which consist as 4 electrodes are generated randomly, and the set that can establish highest recognition rate is selected as a suitable electrodes set. About the number of measurement electrodes, our current work shows “four channel electrodes” are satisfactory to our objective [7].The recognition rate for each hand motion is calculated applying pre-measured SEMG to canonical discriminant analysis. In our system, this trial is repeated 1000 times, and the set of electrodes that acquires highest mean value of recognition rate for every hand motions is chosen as the suitable electrode set. After this selection, electrode positions that are indicated in the suitable electrode set are used as the suitable electrode positions. As mentioned earlier, four channels SEMG that are measured from a right forearm are used to control a robot arm in our system.

B. Grasp Force Measurement System

In order to estimate a grasp force based on an SEMG signal, it is necessary to determine the relationship between the SEMG characteristic of grip and a real grasp force for every individual. In most dynamo meter for grasp force, the measured value is indicated by a needle that moves over a dial gauge, and as a result the acquired grasp data cannot be stored into a personal computer (PC). To analyze the relationship using a PC, we developed a grasp force measurement system that provides a real time grasp force measurement and the output data is stored on a PC with the SEMG simultaneously. A potentiometer is attached to the axis of rotation of the indicator, and translates the indicated value on the dynamometer into a resistance value. The resistance is converted to voltage using a resistance-to-voltage converter which we made. And the analog output voltage is converted to digital value for PC input. Most dynamometers indicate only the maximum grasp force, but our equipment directly indicates the change of grasp. Fig. 6 shows measuring equipment for grasp force and the resistance-to-voltage converter. In our system, we use FSR (Force Sensing Resistor) for sensing robot hand grasp power.

FSR is connected to the edge of the hand of the robot arm. FSR is a polymer thick film (PTF) device which exhibits a decrease in resistance with any increase in force applied to the active surface. The resistance is converted to voltage using a resistance-to-voltage converter which we made. Next, The voltage found in FSR is analyzed by Peripheral Interface Controller (PIC). In addition, we made a logarithm circuit to simplify data processing with PIC.

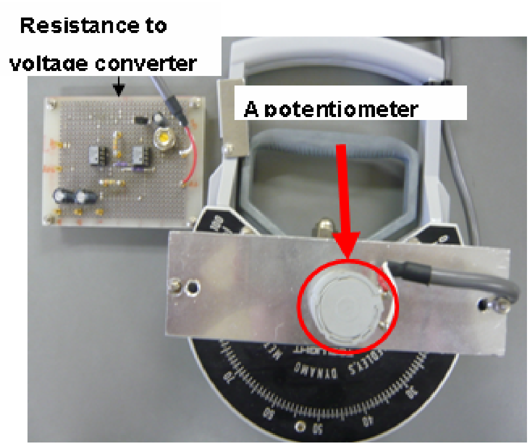

Fig. 6 A potentiometer and resistance to voltage converter

We made device that used a pull solenoid for a notice of the pressure. Fig. 7 shows the grip force feedback system that we made. The power of absorption of the solenoid is proportional to the square of the input current. Therefore we change power of absorption by changing the input current of the solenoid according to the pressure that we measured from robot arm. The power of absorption of the solenoid reproduces feedback by a subject grasping this device.

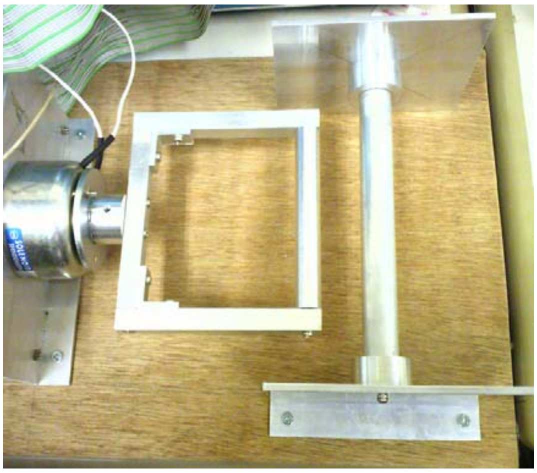

Fig. 7 A device that used a pull solenoid for a notice of pressure

III. Experimental Results

Three normal male adult subjects were tested with our developed system. In this paper we show the results of one subject.

All subjects were equipped with a multi-channel electrode on a right forearm and 48 channels SEMG were measured for each hand motion. Suitable four channel electrode positions were decided by Monte Carlo method as mentioned above. After detecting electrode positions, we measured and memorize relationship between SEMG properties of the grip and a real grasp force and estimated the grasp force using this result. The object to grasp of the robot arm is an aluminum rectangular case (8cm×5cm×3.5cm). Requested motions were set to three types which were composed of two motions and one state (Grasping, Releasing, and Rest state). The rest state is relaxed and there is no motion. This is the initial state and recognition of the three motions is started after this state. The recognition was performed by every 300 ms, and once a grasp motion is recognized, our system moves to the grasp force estimation mode. While a grasp motion is recognized, our system keeps evaluating the grasp force. As for the motions, each subject received training to get used to the control of our system.

The experiment was set up as follows to evaluate our system

1. Evaluation of the estimate of the grip force.
2. The measurement of the reaction power from the object which did the grasp of the robot arm.
3. Evaluation of a device of the grip force feedback system.

Fig. 8 shows the comparison results of grasp force data between the estimated value and the real measurement one. The horizontal line shows the time series and vertical line shows the grasp force [kgf]. From Fig.9, the estimated value of the grasp force is a good approximation to the real one.

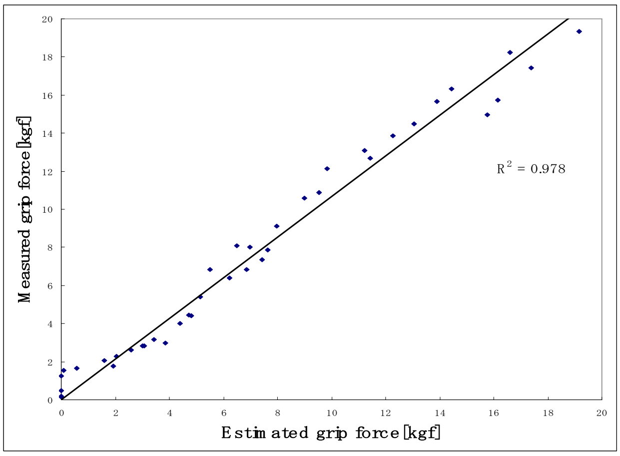

Fig. 8 The grasp force data of the estimated value and the real measurement value

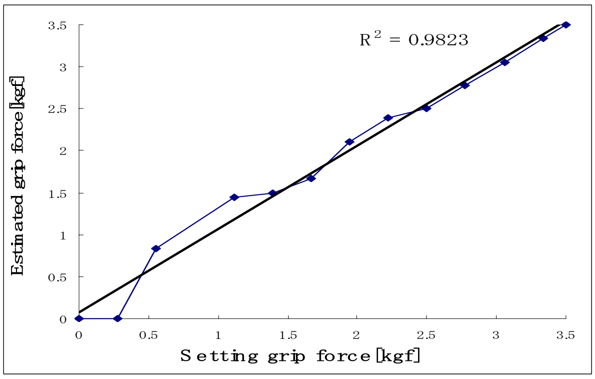

Fig. 9 Relationship between the real measured value of the grip force and the estimated value of the grip force

Fig. 9 shows the comparison results of robot arm grip force data between the setting value and the estimated one. The horizonal line shows the setting grip force (kgf) and vertical line shows the grip force of the estimated reaction power from the object[kgf]. From Fig.10, there are few errors with a low value, but the estimated reaction power from the object is associated with a setting grip force.

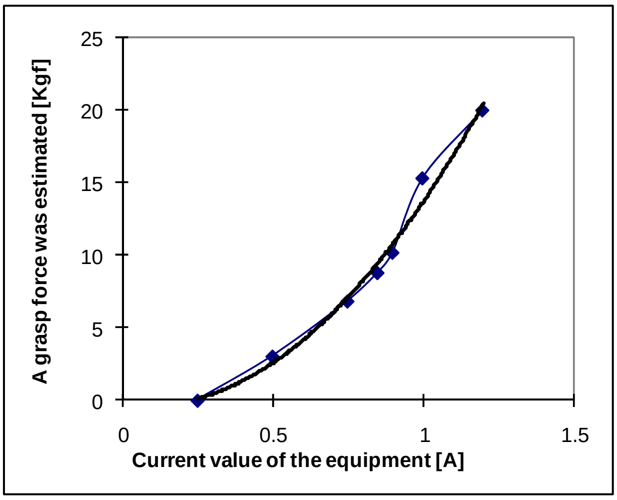

Fig. 10 Relationship between the current value of the device of grip force feedback and estimated value of the grip force

Fig. 10 shows the result that changed an input current level during a subject gripping our feedback unit. From Fig.11, we understand that it draw a quadratic function curve for an input electric current. Therefore, we can express reaction power from a object by the input current of our feedback unit.

Using these results, we built a robot arm control system having a feedback system. It is different from the individual result, but a subject adjustment of precise power control was possible. From these results, we are convinced that a new man-machine interface can be made by improving our system.

IV. Conclusion

In this paper, we described about our developed man-machine interface using SEMG. In our system, we suppose that muscle power is proportional to the amplitude of SEMG. The power is estimated and the grip power of a robot hand is able to be controlled using estimated muscle power in our system. In addition, it is possible to perform more precise control by letting a force feedback when a robot arm grasped something. From our results of experiment, we can estimated of the grasping power of a subject and control a robot arm. We can estimated of the reaction power from the object which did the grasp of the robot arm. And we can express reaction power from a object by the input current of our feedback unit. Therefore, we concluded that our developed system will be a valuable one for the man-machine interface using SEMG.

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