Study of Optimum Surface Electrode Positioning for Myoelectric Signal Detection of Typical Human Grasping

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***Abstract*—Recently, commercially available myoelectric prosthetic hands have complied with advanced technology direction. Unfortunately, there are many customers from middle to low-income groups who emphasize on affordability, especially those living in developing countries. There is a need to build low cost myoelectric prosthetics that use more affordable material, easily operated mechanism, and simple myoelectric control by few channels of myoelectric module. Myoelectric hand uses myoelectric signal from the muscle to activate and control the movement of finger. Typical prosthetic receives the myoelectric signal by placing electrodes on the skin surface of human arm so that it can only capture small magnitude compare to implanting the electrodes inside the muscles. With only a few electrodes, detecting myoelectric signal on the skin surface should take proper and careful procedure. In this research, we used three channels to detect signals from the groups of muscles, which activate the hand to perform grasping flexion as well as its extension. This paper provides a preliminary study of electrode positions that given the best signal strength for five basic hand grasping. Three position scenarios was used to place each channel electrodes set on the top of muscle spots. They are pollicis longus muscles, extensor digitorium superficialis muscle, and between both of the muscles. A biopotential amplifier based on AD620 was used to amplify the signal. Finally, the raw signals were analyzed using DSSF3 software. We identified the position mapping and concluded that all of the three electrode positions are important. To build a hand with the capability of basic grasps, the three electrode positions are needed.**

***Index Terms*—AD620 Bi-Potential Amplifier; Basic Grasp; DSSF3; Electrode; Myoelectric Signal; Surface Electromyography.**

I. INTRODUCTION

Advanced myoelectric prosthetic hands, such as iLimb form Touch Bionics, bebionics, and Michelangelo from Ottobock, have been developed and commercialized around the world. Even though the hands can function almost similar to a real hand, the price of these hands are still expensive. On the other hand, low cost prosthetic hands using myoelectric signal for motor activation have also been intensively developed for the middle to low customers. Myoelectric prosthetic hand uses myoelectric signal from the muscle to activate and give direction for the movement of the fingers. Physiological variation in the state of master fiber membranes forms the myoelectric signal [1]. Study of muscle function through the inquiry of electric signal muscle emanate is referred to the Electromyography [2].

Surface Electromyography (SEMG) is a non-invasive technique for detecting or measuring electrical signal activation from muscle contraction and relaxation cycle [3]. Myoelectric signal is measured through the surface of the skin. Although surface electrodes are easy to apply and their application does not involve physical pain, there is more potential for crosstalk from adjacent muscles and only the signals from surface muscles can be adequately measured [4].

The three channels of this research refers to the three independent modules, wherein each module captures signal from the muscle with a specific function on the moving part of the hand, namely the thumb, fore finger, and three other fingers. This channeling strategy is suitable for supporting a simple operation prosthetic hand [5]. From six basics of human grasping [6], a simple operation of the hand can produce five movements, by using a few channels that can accommodate almost all of human hand activities. Therefore, there should be three muscle which are targeted for surface electrode placement. The first channel assigned to detect thumb movement will face the most diffcult detection because the muscle position is very deep in the hand. The second channel for the fore finger will also encounter some problems because the muscle of this finger is located in the intermediate layer of the human hand. The third channel for the other three fingers will get the easiest task because the muscle of these fingers is located on the superficial layers of the hand muscle.

The upper limb of human body consists of the shoulder girdle, arm, forearm, wrist, palm of hand, and finger [7]. Some muscle spots of the hand that are targeted for detecting myoelectric signal are the anterior deltoid, lateral deltoid, posterior deltoid, biceps brachii, brachioradialis, wrist flexor, and wrist extensor [8]. Not all of the hand muscle produce the optimum myoelectric signal. Thus, a study of electrode position on surface skin needs to give a guide for capturing optimum myoelectric signal.

Other researches have been conducted to study the characteristic of the myoelectric signal, but there is no study that focuses on electrodes positioning to capture optimum signal strength. There are some evidences that show the potential of frequency-based parameter for distinguishing grasping type [9]. Mean power is one of the parameters that can distinguish several type of human grasp [10]. From eight frequency-based parameters, the mean power is considered as one of the best parameters to distinguish grasping [11].

II. EXPERIMENTAL

Myoelectric signal power, which is generated by the muscle in the arm has a small magnitude. Thus, there should be a proper and careful procedure to detect the myoelectric signal.

A. Subject Preparation

This study involved six male normal subjects. The subjects were marked as subject A to F in this research. The subject was between 21-23 years old with the height ranged between 165cm-175cm, and weighed between 65kg - 75kg. Every subject has the same grsping power. Normal subjects with intact upper limb used to get myoelectric signal data, in the hope that they are able to describe the function of the myoelectric according to expectations.

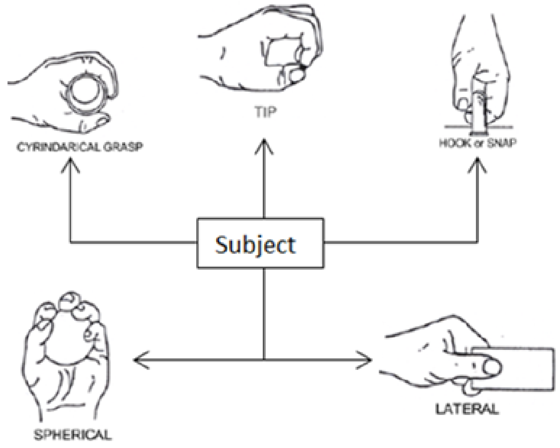

Figure 1: Five basic grasp based. Source: Design of TU AT/ Karlsruhe Humanoid Hand

As shown in Figure 1, the subject chosen was treated with five different grasping movements, namely lateral, cylindrical, tip, hook, tip, and spherical. For the lateral grasping movement, the subject was directed to grasp and release a flat object using the right hand. In this study, a card was used as the object. The subject was directed to grasp and release a bottle to identify the cylindrical grasp movement. For the tip movement, the subject was directed to grasp a small cable. To perform the hook movement, the subject was directed to grasp a flop plier. In the last movement, the spherical grasp movement, the subject was directed to grasp a tennis ball.

The subject used his/her right hand on every movement, with constant speed and did one grasp per two second. Every grasp movement was repeated thirty times. Before teh five grasp movement were performed, the subject was directed to train every grasping movement using the different objects.

B. Three Custom Made Ad620 Bi-Potential Amplifier

AD620 bipotential amplifier was used because it is very cheap, although it has high capability. It is better than 3 instrumentation amplifier in Homebrew configuration [12]. AD620 is also capable to produce a wide range of magnification: 1-10000 times, with wide range power supply between 2.3V-18V, and low noise [13]. Four sets of battery were used with the voltage of -3 Volt, neutral, +3 Volt. The amplification was set 100 times with ± 500Ω of gain resistance. Table.1 shows the required values of gain resistor. It calibrated using sinus signal that was generated using the function generator. The output signal was checked using the oscilloscope.

Ag-AgCl was used as positive and negative electrodes. This electrode was attached at the surface of the skin. The positive electrode was attached at the flexor digitorium superficialis muscle, pollicis longus and between them. The negative electrode was attached at the extensor digitorium at the forearm.

Table 1
Required Values of Gain Resistor (Analog Device, 2011)

1% Standard Table of Rg (Ω)	Calculated Gain	0.1% Standard table Value of Rg (Ω)	Calculated Gain
49.9 k	1.99	49.3 k	2.002
12.4 k	4.984	12.4 k	4.984
5.49 k	9.998	5.49 k	9.998
2.61 k	19.93	2.61 k	19.93
1.00 k	50.4	1.01 k	49.91
499	100	499	100
249	199.4	249	199.4
100	495	98.8	501
49.9	991	49.3	1,003

C. Electrodes Placement

Every electrode was attached to the surface skin based on the muscle position and muscle anatomy of the human body, especially on the human upper limb. This muscle placement was based on the electrode placement for the upper extremity [9]. The muscle placement is as shown in Table 1. Four muscles were targeted for the electrode placement and one for the ground (elbow). The Extensor digitorium was used as a negative electrode as shown in Figure 2. This electrode detects the myoelectric signal for the extensor movement, especially the finger's extension. This electrode was placed 13.5 cm from the wrist.

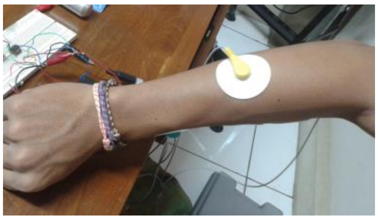

Figure 1: Negative electrode placement (Extensor digitorium)

Electrode to detect flexion movement was attached and targeted on three muscles: They were the pollicis longus muscles (position 1), extensor digitorium superficialis muscle (position 3) and between pollicis longus-extensor digitorium superficialis muscle (position 2). Figure3 shows the extensor muscle for the electrode placement. Position 1 electrode was attached 5 cm from the wrist. Position 2 was placed 14 cm from the wrist and Position 3 was located 20 cm from the wrist.

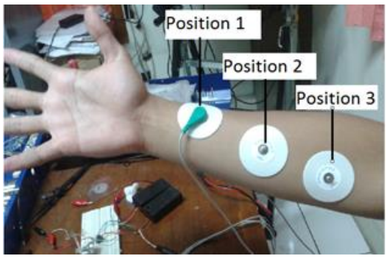

Figure 3: Electrodes placement position

Electrode placement on Figure 3 was applied to all subjects to determine the optimum electrode placement in capturing the myoelectric signal. Signal detection signal used five electrodes that were placed on the surface of the skin. The position of the electrode was the same for each subject. Pollicis longus is the flexor muscle with the function to move the thumb for flexion. This muscle was targeted by the first electrode with a distance of 5cm from the wrist. This was the first position. The superficial flexor digitorium was a muscle with the function to move a finger. This musle moved the finger in flexion. This muscle was targeted by the electrode as the third position. This electrode was placed 20 cm from the wrist. The second electrode was placed on the muscle between the pollicis longus and the flexor digitorium superficialis muscle. This was located 14 cm from the wrist.

D. Signal Acquistion

Custom AD620 bi-potential amplifier must be calibrated before it is ready to use. AD620 circuit must be checked using a function generator before being used to capture the signal. Function generator was used to generate a magnitude of signal input. The magnitude of the signal must be the same as the output signal displayed with an oscilloscope before the signal amplifier. The signal from the function generator was amplified using potentiometers. The magnification can be set flexibly, 10x, 100x, or more. The result of the enlargement signal was displayed by the oscilloscope.

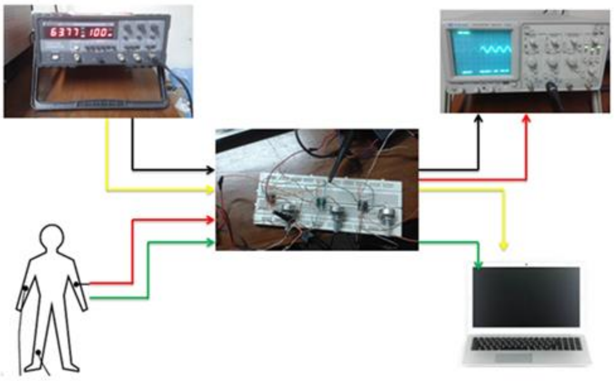

Figure 4: AD620 testing scheme

Considering that AD620 is still not ready to be used, the output signal must be checked on software DSSF3. The objective of this step is to see that the signal is read by the software. If AD620 worked, the acquisition of the myoelectric signal using a real subject can be done.

AD620 instrumentation was tested using a function generator as the input signal (black line). The electrodes then captured the signal from AD620 and showed it on an oscilloscope. The magnitude of the signal frequency was amplified by AD620. The oscilloscope as the output was changed to DSSF3 software. The magnitude of the signal was displayed on the PC screen (yellow line).

Next, the electrodes were placed on the surface of the skin as input. Since the skin of the subject must be cleaned, alcohol was used to clean the surface of the skin. Hence, the skin hair needs to be shaved, if needed. Electrodes were captured myoelectric signal from the muscle, which was then displayed on an oscilloscope (red line). The output was changed to DSSF3 (green line) and the instrumentation of AD620 was ready to be used.

E. DSSF3 Analyzer

Frequencies spectral of the captured myoelectric signal were shown using DSSF3 FFT Analyzer. Octave frequency resolution was set at 1/24 octave. The sampling rate was set in 48.000Hz and the time resolution was 1x. The output of the myoelectric signal from AD620 bi-potential amplifier was connected to the laptop using 3.5 mm stereo jack cable. The output signal was analyzed to get the optimum output of myoelectric signal and determined the electrode placement on the surface of the skin. An output signal shown in FFT software was analyzed by considering the position of the skin surface. Every signal output was compared based on the type of grasp to find the optimum position of each grasp type. The output of this software was derived by grouping the number of data as the result of the subject's grasp movement. The data were based on the frequency domain. The output of this software can be saved on many formats such as text, excel, csv, etc. In this research, format used was the text that was converted to excel format.

III. RESULTS AND DISCUSSION

A. Mean Power

Mean Power (MNP) is the average power of EMG power spectrum [14]. Total power of EMG spectrum divided with total ribbon of the power spectrum. The calculation is defined as:

$$\text{MNP} = \sum_{j=1}^{M} Pj/M \tag{1}$$

B. Peak Captured Signal

DSSF3 captured signal based on frequency. Table 2 shows the output signal from subject A. This table shows the average mean power flexion for every type of grasp. The mean power indicates the power of signal power for every grasp movement.

Table 2
Average Mean Power Flexion subject A

Average Mean Power Flexion subject A			
Grasp Type	Position 1	Position 2	Position 3
Cylindrical	-80.542*	-85.745	-97.482
Hook	-95.070	-87.335*	-86.177*
Spherical	-98.724	-83.270*	-83.824*
Lateral	-95.416	-87.978*	-88.644
Tip	-85.752*	-86.563*	-86.167*

*Recomended position

Table 2 shows that the cylindrical grasp position 1 was the most optimal position. The magnitude of this signal position was strongest in comparison to the others. Position 3 was the most appropriate place of electrode placement for the hook grasp. Spherical grasp has two electrode positions. It can take position 2 or 3 because the magnitude of the myoelectric signal was not significantly different. The optimal position for lateral grasp was on position 2 and 3. All of the positions can be placed with electrode for tip grasp. The optimal electrode position could not be decided using one subject. The other subject was used to compare and insure optimal electrode position. Table 3 and Table 4 represent the power of EMG signal captured from subject B and subject C.

Table 3
Average Mean Power Flexion subject B

Average Mean Power Flexion subject B			
Grasp Type	Position 1	Position 2	Position 3
Cylindrical	-80.499*	-79.647*	-80.790*
Hook	-84.713*	-84.475*	-84.426*
Spherical	-91.921*	-96.296	-104.073
Lateral	-87.106	-83.564*	-90.339
Tip	-94.537*	-94.698*	-95.849*

*Recomended position

Myoelectric signal power for subject B is shown in Table 3. The electrode can be placed in all positions for cyindrical and lateral grasp. Spherical grasp has totally different electrode position compared to subject A. Electrode position for optimal spherical grasp for subject B was at position 1. Based on Table 2, the optimal electrode position was placed in position 2 and every position for tip grasp.

Table 4 represents the power of the myoelectric signal from subject C. The optimal electrode placement for cylindrical grasp was at position 2 and position 1 for hook grasp. Position 3 was the optimal electrode placement for spherical grasp and lateral grasp. Electrode placement for tip grasp was placed at position 3.

Table 4
Average Mean Power Flexion subject C

Average Mean Power Flexion subject C			
Grasp Type	Position 1	Position 2	Position 3
Cylindrical	-90.243*	-89.226*	-100.501
Hook	-95.797*	-98.766	-94.375*
Spherical	-91.250	-96.296	-88.671*
Lateral	-99.534	-96.927	-90.339*
Tip	-94.537	-94.698	-89.890*

*Recomended position

The next subject is subject D. Table 5 represents the average mean power for subject D. Position 1 was the cylindrical flexion for optimal electrode position. Position 3 was the optimal electrode position for hook flexion movement. Position 1 was the recomended position for spherical grasp movement. Position 2 was the recomended position for lateral grasp movement, and the strongest electrode position for tip grasp movement was at position 3.

The average mean power flexion for subject E is shown in Table 6. Position 1 was recomended for every grasp type on subject E. Position 3 was recomended for cylindrical, spherical and tip grasp.

Table 5
Average Mean Power Flexion subject D

Average Mean Power Fleksi subject D			
Grasp type	Position 1	Position 2	Position 3
Cylindrical	-84.889*	-87.423	-87.244
Hook	-86.123	-89.776	-84.412*
Spherical	-85.294*	-92.505	-86.813
Lateral	-92.629	-89.776*	-91.539
Tip	-88.151	-90.002	-85.640*

*Recomended position

Table 6
Average Mean Power Flexion subject E

Mean Power Flexion Subject E			
Grasp type	Position 1	Position 2	Position 3
Cylindrical	-81.395*	-83.639	-80.709*
Hook	-81.000*	-89.888	-95.894
Spherical	-82.347*	-86.327	-83.633*
Lateral	-86.854*	-89.888	-95.894
Tip	-87.348*	-90.639	-88.583*

*Recomended position

Subject F is the last subject, and the average mean power for five types of grasp is presented in Table 7. Position 3 was the optimal electrode placement for cylindrical grasp. Hook grasp and spherical grasp recommended electrode placement at position 1. Position 3 was the recommended electrode placement for lateral grasp and tip grasp.

From the mean power flexion of basic grasp movement of subject A-F, we classified the mean power based on the subjects to compare the mean power. Electrode position with the most star mark (*) was the recomendation position of electrodes placement considering that the star mark (*) indicates the strongest mean power/peak signal of grasping movement.

Table 8 shows is the recomendation electrode placement of cylindrical grasp.

Table 7
Average Mean Power Flexion Subject F

Average Mean Power Flexion Subjek F			
Grasp Type	Position 1	Position 2	Position 3
Cylindrical	-89.611	-89.344	-81.195*
Hook	-84.743*	-85.209	-86.498
Spherical	-81.328*	-83.106	-83.645
Lateral	-88.244	-87.078	-85.994*
Tip	-88.677	-86.136	-85.449*

*Recomended position

Table 8
Electrode Recomendation Position of Cylindrical Grasp

Subject	Cylindrical Grasp Flexion		
	Position 1	Position 2	Position3
1	*		
2	*	*	*
3	*	*	
4	*		
5	*		*
6			*
Recomendation position	Position 1 and Position 3		

The recomended positions for electrode placement of cylindrical grasp were position 1 and position 3. Based on Table 8, we can see and count the star mark (*) for every position. Position 1 and 3 were the most recomendation position with 5 and 3 of six star marks (*). Similar way was used to determine the electrode recomendation position of the hook, lateral, spherical and tip grasp.

All electrode recomendation position are shown in Table 9. This electrode recomendation position was determined based on the number of star mark of every basic grasp type from all subjects.

Table 9
Electrode Recomendation Position for Typical Human Grasp

No	Basic Grasp	Movement Flexion		
		Position1	Position2	Position3
1	Cylindrical	*		*
2	Hook	*		*
3	Lateral		*	*
4	Spherical	*		*
5	Tip			*

IV. CONCLUSION

Mean power was used to determine myoelectric signal power for every grasp movement. This mean power Electrode position on the skin surface detected the myoelectric signals with variation magnitude. Three subjects described above can be used as a guide to place electrodes on the right muscle to get an optimal myoelectric signal. Table 9 shows the optimal electrode position for cylindrical, hook and spherical grasp was at position 1 and 3. Position 2 and 3 were recommended for lateral grasp. Position 3 was recommended for tip grasp electrode placement. Considering that cylindrical grasp, hook grasp and spherical grasp group as power grip while lateral and tip as precision grip, there seems to be no dominant position based on the grasp type. From that position mapping, it can be concluded that all of three electrode positions are important. To build a hand with the capability of basic grasps, the three electrode positions are needed. However, if one of the electrodes must be eliminated to simplify the design, position 2 is the most potential because all of the information in that position can be drawn from the other two positions.

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