Analysis of EMG based Arm Movement Sequence using Mean and Median Frequency

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Abstract* — This paper present the studies of analysis arm movement sequence which dedicated for upper limb rehabilitation after stroke. The recovery of the arm could be optimized if the rehabilitation therapy is in a right manner. Upper limb weakness after stroke is prevalent in post-stroke rehabilitation, many factors that can deficit muscle strength there are neural, muscle structure and function change after stroke. Rehabilitation process needs to start as soon as after a stroke attack, repetitive and conceptualized. On the other hand monitoring of muscle activity also need in the rehabilitation process to evaluate muscle strength, motor function and progress in the rehabilitation process. The objective of this research is to analysis arm movement sequence using the feature frequency domain. In this study deltoid, biceps and flexor carpum ulnaris (FCU) muscles will be monitored by surface electromyography (sEMG). Five healthy subjects male and female become participants in data recording. Mean frequency (MNF) and median frequency (MDF) domain are two signals processing technique used for arm movement sequence analyzing. The analysis result showed that MNF is better than MDF where MNF produced higher frequency than MDF from each segment. From the data analysis, this movement sequence design more focuses on deltoid and FCU muscles treatment. This movement sequence has five condition movements. First undemanding, second difficult, third moderate, fourth moderate and the last cool-down movements. The best movement sequence minimum has four condition movements warming up – moderate – difficult – cool-down.

Keywords— Electromyography (EMG), rehabilitation, mean frequency, median frequency, movement sequence

I. INTRODUCTION

A Stroke is a "brain Attack". Based on the cause stroke divide into two, the first is hemorrhagic stroke it occurs when there is a blood vessel leak in an area of the brain and the second is a blood vessel carrying blood to the brain is blocked by a blood clot (ischemic). When blood flow to an area of the brain is cut off, so brain cells are deprived of oxygen and begin to die. When brain cells die during a stroke, abilities controlled by that area of the brain such as memory and muscle control are lost [3]. In 2017 World Health Organization (WHO) published that the second leading of death is stroke accident where more than 15 million people have strokes every year and two-thirds of them have the permanent disability [1]. Rehabilitation after post-stroke is an important and ongoing part of treatment. With the right treatment and the rehabilitation procedures, stroke patients can enjoy normal life is possible. Physical therapy is one of the most important parts in the rehabilitation process where it can help a person relearn movement and coordination. It is important to stay active, even if it is difficult at first [2]. Rehabilitation upper limb after post stroke is indispensable because upper limb motion is very important for the human daily activities such as eating, drinking, brushing teeth, combing hair and washing face [4]. In this time many therapies do the post-stroke rehabilitation using fundamental movement and a play traditional equipment like table and glass. This technique needs more time and there is no feedback from rehabilitations proses.

One of the major objectives of post-stroke rehabilitation is to improve patient's motor function as it is critically elated to the ability of independent living [5]. The previous scientist explained that motor impairment and muscle strength can be covered or treated with active movement in the oriented and repetitive task, with combinations movement which can improve motor skills and muscular strength by avoiding a muscle and joint pain [6][11]. Studies in post-stroke rehabilitation reported that the most important in process rehabilitation is the monitoring of muscle activity during recovery [7]. Much information can be obtained from the muscle and the researchers can use that information in their study by measuring the electromyography (EMG) signal [8]. This research will analyze of EMG signal based arm movement sequence for post-stroke rehabilitation using mean and median frequency domain.

The outline of this research paper consists of four sections, the first section is an introduction and related

researches, in the second section the proposed research methodologies and the third section discusses the finding of the research. The conclusions of this research are discussed in the last section.

II. METHODOLOGIES

Fig. 1 shows the workflow for this research from a preparation of the hardware and software until discussion and conclusion.

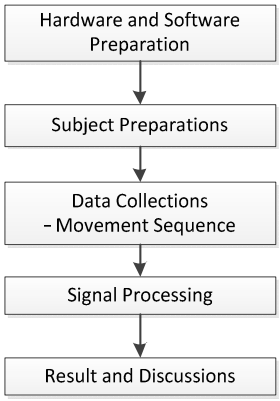

Fig. 1. The flow of the investigation

A. Hardware and Software Preparations

Data collections in this research used DELSYS Bagnoli EMG system with 8 input channels and EMG works 4.3.2 software used to communicate with a personal computer. Muscle activity in this movement will detect using surface electromyogram sensor type single differential. Raw EMG signal will analyze using software MATLAB r2016a.

B. Subject Preparation

Five students between the ages of 23 and 30 years old include male and female in good conditions were prepared for this experiment. The participants were graduate or undergraduate students of University Malaysia Perlis. Before data collecting, every subject briefed on experimental procedures and their signature used as approval to be participants. Using healthy subjects caused this research is a laboratory prototype for EMG signal studying and movement sequence were used in this research is applicable for post-stroke patients.

C. Data Collection

I. EMG Signal Acquisition

EMG data were recorded by three surface electrodes on upper limb muscle include deltoid, biceps and FCU muscles. Data recording was done for 30 seconds with frequency 1 kHz using EMG acquisition system.

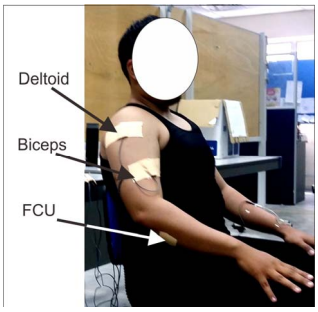

Fig. 2. Sensor placement

II. Movement Sequence

Arm movement sequences were designed based on the fundamental arm movements to stimulate the weak muscle of post-stroke patient [6]. Repetitive rehabilitation exercise based on fundamental movement is one of the method used in the treatment, the combination of some fundamental movement which produces a movement sequence can increase treatment timing. Motor impairment and coordination between one muscle with another muscle can be treated by movement sequence repetitively [11][14].

Arm movement sequence designed based on fundamental movement which involves flexion, extension and grasp. Design of movement sequence use of three objects as targets, the design of functional movement shows in fig 3. Target number one located on the right patients, target two located on the top of patients and target three located on the left of patients. Firstly participants put their hand at the start point for five seconds after rehabilitation begins, then participants take an object in the start point and move it to target one and back to start point then rest about five seconds. Next targets have the same steps as target one.

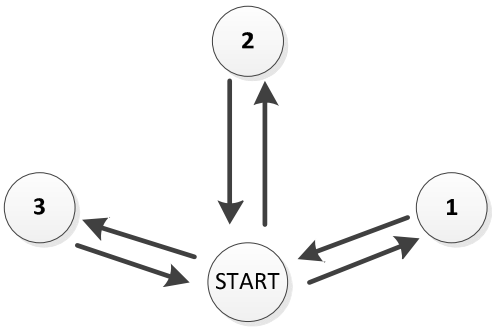

Fig. 3. Movement Sequence [6]

D. Signal Processing

I. Power Spectral Density

Power Spectral Density (PSD) is defined as the amount of power per frequency interval. To transform signal EMG based on time domain to frequency domain need a furrier transform. To search frequency signal components which brought by time domain signal. The most commonly used PSD estimator in the EMG signal analysis is the periodogram. Calculation of PSD in MATLAB used Welch method (1) ie looking for DFT based on calculations with the FFT algorithm, then squaring the magnitude [12][13].

$$P_{XX}(w) = \frac{S\left(e^{fw}\right)}{2p} \quad (1)$$

Where,

P_{XX} (w) = Power spectrum density at a window
$S\left(e^{fw}\right)$ = Power spectrum using FFT
p = Estimation of spectrum value using periodogram
w = Sampling window
f = frame window

The estimation of spectrum value (p) will be close to the true value if sampling window is very large, this means that the number of periodograms is made as much as possible but the resolution of the observed frequency is decreased.

II. Mean and Median Frequency

Features-based time domain and frequency domain are two important features. Generally, time domain feature used for the muscle force detection but their performance is a major drawback for detecting muscle fatigue. On the other hand, frequency domain has good performance to detect muscle fatigue [9][10]. Mean frequency (MNF) is an average frequency which is calculated from a total of the product EMG power spectrum and the frequency divided by the total of the power spectrum. The definition of MNF is given by

$$MNF = \frac{\sum_{j=1}^{m} f_j P_j}{\sum_{j=1}^{m} P_j} \quad (2)$$

Where,

f_j = frequency value at a data sampling j
Pj = EMG power spectrum at a data sampling j
m = length of data sampling j

Median frequency (MDF) is a frequency at which the EMG power spectrum is divided into two regions with equal amplitude. The definition of MDF is given by

$$\sum_{j=1}^{MDF} P_j = \sum_{j=MDF}^{m} P_j = \frac{1}{2}\sum_{j=1}^{m} P_j \quad (3)$$

Where,

Pj = EMG power spectrum at a sampling j
m = length of data sampling j

III. EMG signal

Raw EMG signal generated by EMG acquisition hardware has a data length of 66000 data. These data were divided into five segments to make it easier to analyze. Segment one is start position, segment two is reached target one, segment three is reached target two, segment four is reached target three and the last segment is finished positions. Fig. 4 showed a sample of Raw EMG signal from a deltoid muscle by subject #1. Fig. 5 showed a sample of power spectrum density (PSD) using the Welch method from a deltoid muscle by subject #1 for the second segment.

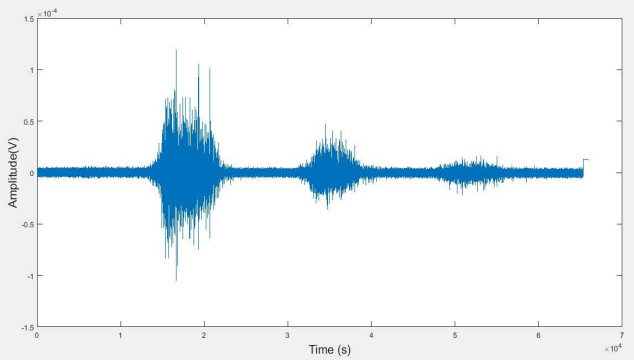

Fig. 4. The sample of Raw EMG signal

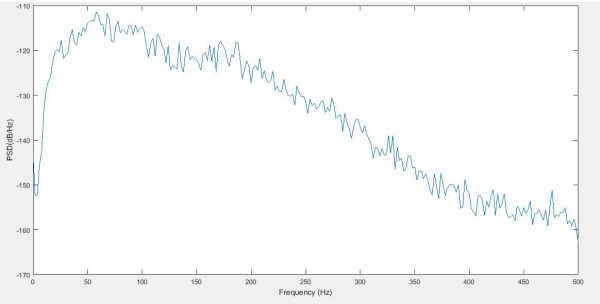

Fig. 5. The sample of PSD using Welch method

III. Result and Discussion

The EMG signals were analyzed in frequency domain to obtain the feature extraction. A total of two frequency domain features were selected and used to analyze EMG signal from deltoid, biceps and FCU muscles. Table I shows the values of the mean frequency (MNF) for the purpose movement sequence. The frequency at the start position and finish position has almost the same value because in this condition there are no movements so there are no muscle contractions. Deltoid muscle, the biggest frequency when the subjects reach target 1 and the value decreased slowdown when subjects reach target 2 and 3 because when subjects move to target 1 the muscle produces more contractions than subjects move to target 2 and 3. Be evidenced by subject #1, #2 and #5. Biceps muscle, the frequency produced by biceps muscle from this movement sequence inconsistent value where this conditions due to there are not contractions from biceps muscle. FCU muscle, the frequency produced by the FCU muscle from this movement sequence is consistent where this conditions due to there are same contractions from target 1, target 2 and target 3.

TABLE I. Value of MNF domain feature extractions

Subject		MNF (Hz)				
		Start	Target 1	Target 2	Target 3	Finish
#1	d	38	92	83	65	40
	b	39	53	42	43	41
	f	50	70	82	74	65
#2	d	40	74	69	56	41
	b	37	55	53	49	37
	f	74	84	75	75	65
#3	d	42	73	75	48	42
	b	40	48	45	43	39
	f	48	89	86	86	58
#4	d	42	65	67	58	45
	b	38	48	53	44	34
	f	72	82	77	74	65
#5	d	36	94	85	62	37
	b	37	50	42	40	37
	f	46	75	70	78	67

*d=deltoid, b=biceps, f=flexor carpum ulnaris (FCU)

Table II shows the values of median frequency domain features for the purpose movement sequence. Median frequency is similar with mean frequency but the value of median frequency is too small than mean frequency so median frequency difficult to analyze.

TABLE II. VALUE OF MDF DOMAIN FEATURE EXTRACTIONS

Subject		MDF (Hz)				
		Start	Target 1	Target 2	Target 3	Finish
#1	d	25	76	67	40	25
	b	25	37	26	30	25
	f	25	54	68	49	26
#2	d	25	63	59	34	25
	b	25	42	39	33	25
	f	34	70	63	64	27
#3	d	25	60	61	35	27
	b	25	27	26	26	25
	f	25	76	73	73	25
#4	d	25	50	53	36	25
	b	25	26	40	26	25
	f	26	66	61	62	26
#5	d	25	81	73	36	25
	b	25	35	31	25	25
	f	25	54	51	55	26

*d=deltoid, b=biceps, f=flexor carpum ulnaris (FCU)

Frequency obtained from muscle have inconsistent value depends on arm movement. In this movement sequence design, a frequency obtained from deltoid muscles decreased frequency value, when subjects move their hand to target 1 frequency produced by deltoid muscles is higher than target 2 and 3. Biceps muscles produce inconsistent values but mostly when subjects reach target 2 biceps muscle produce the highest value than the other. At the same time, FCU muscles tend to be more constant, this is due to the same movement ie grasp object.

Difference values of frequency at every target due to the direction of arm movement, the power of contractions and the distance between object and arm. Beside this muscle fatigue also can influence signal which generated by muscle when contractions. Muscle fatigue occurs when muscles contract too long without rest.

Difference value from mean and median frequency feature extraction showed at Fig. 6. Actually in this movement sequence had three condition movements with five segments: warming up, moderate, difficult, moderate and cool-down movement. From the graph forms the following sequence: warming up – difficult – moderate – moderate – cool-down.

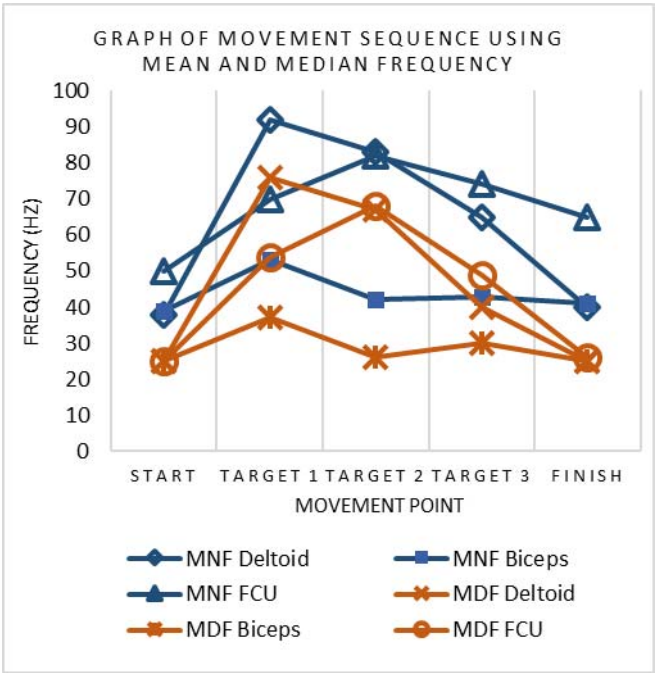

Fig. 6. The sample of graph MNF and MDF from subject #1

IV. CONCLUSIONS

The main objective of this research is to analyze movement sequence based on EMG signal using mean and median frequency domain feature extractions. Generally, frequency feature extraction used to analysis of muscle fatigue after post-stroke rehabilitation, in this section mean and median frequency used for analyzing arm movement sequence. From this research obtain some conclusions:

1. Feature extraction using mean frequency domain is better than the median frequency for analyzing movement sequence.
2. From the data analysis, this movement sequence design more focuses on deltoid and FCU muscles treatment.
3. Refer to fig. 6 shows, this movement sequence has five condition movements. First undemanding, second difficult, third moderate, fourth moderate and the last cool-down movements.

Recommendations for the next research (1) Addition virtual reality based on a game in the rehabilitation process can motivate subjects. (2) Showing feedback to screen and saving data to the server can make it easier therapist to data analyzing.

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