Analysis of EMG-based Muscles Activity for Stroke Rehabilitation

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Abstract— **This paper presents 18 fundamental movements for the rehabilitation of the stroke patient. The objective of this research is to develop the movement sequences which are suitable for the rehabilitation process and is focused on hemiparesis sufferers which are the most common among stroke patients. The muscle activities are analyzed using electromyography (EMG). 12 electrodes are attached to the right arm of the subject includes deltoid, bicep, tricep, flexor and extensor. The experimental results proof that it is likely to produce movement sequence for stroke rehabilitation based on each muscle activity.**

Keywords: ***Fundamental arm movement; rehabilitation; stroke patient; electromyography (EMG); motion sequence;***

I. INTRODUCTION

Arm rehabilitation in an important process after stroke to regain movement skill lost. The main goal of stroke rehabilitation is to regain independence and improve life's quality. Arm rehabilitation must begin as early as possible after a stroke attack, right after completing all other priorities such as stabilize the patient medical condition.

Various approaches that have been used formerly on hand rehabilitation such as virtual reality rehabilitation [1,2], robotic rehabilitation [3,4], electrical simulation and data glove [5]. Sandeep Subramanian et al. proposed a virtual reality rehabilitation system by providing feedback to the system, the virtual elevator scenes are suitable for the movement distance of patient and related to human body segment [6]. Meanwhile Shih Ching Yeh et al. suggest using rehabilitation items of upper limbs includes three exercise of shoulder and elbow, the difficulty of the virtual game are adjustable to allow patient using different gesture [7].

In this research, fundamental of arm movement data are recorded using EMG system and the movements is performed by a healthy subject. The output raw signals are analyzed using Matlab to study the features of the signal.

The outline of this research paper consists of section 2 for related research, section 3 for methods which present the methodologies of the proposed works. Section 4 includes the experimental result and the conclusion of this research is expressed in Section 5.

II. RELATED RESEARCH

Recently, researchers had been using EMG (electromyography) device to study the activity of skeletal muscle contraction for various purposes for example for motion recognizing, hand rehabilitation [8], classification etc. EMG (electromyography) is an instrument able to transmit or detect the electrical signal generated by electrically or neurologically energized muscle cells. The output signals can be analyzed to detect the muscle activity level and medical abnormalities even to analyze the biomechanics of human.

Some of researcher studies the surface electromyography of the upper arm of human to verify the variability in different muscle location and different age group. The age group consists of three groups which are adolescents, vicenarian and tricenarian. The researcher analyzed the mean, standard deviation and coefficient of variations to study the muscle activities which are useful for rehabilitation concerns [9].

Other researcher performs EMG signal analysis on specific functional movements which are shots and passes during playing basketball. The subjects are basketball players with different level of experience in playing basketball. Flexor and extensor muscle were taken into consideration for each activity. The research proved that EMG activation signal depends on the type of activity done by muscle [10].

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III. Methods

A. Flow chart

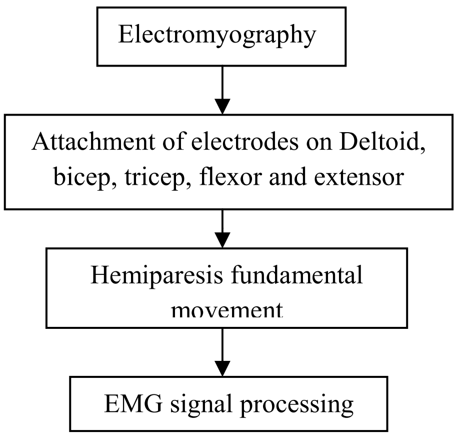


Fig. 1. Flowchart of the propose work

B. Signal Rectification

Signal rectification is the process of translating the raw EMG signal to a positive polarity frequency. Two types of rectification include full wave rectification and half wave rectification. Full wave rectification converts all negative values into positive values, this method preserves the energy signal for further analysis. While half wave rectification deletes the negative signal leaving only the positive signal and still can be used for statistical analyses [11].

C. Low Pass Filter

Filtering a raw signal is an important process since the signal consists of many source of noise such as movement artifact, electrodes, cable movement artifact, electrostatic and radio waves. Suitable selection of filter is necessary to avoid losing important information from the signal. Butterworth low pass filter is an ideal filter and able to get the closer approximation of the wanted frequency with the right values of filter elements. The cut off frequency [12] selection is also necessary to make sure we only eliminate the unwanted signal.

The formula of the Butterworth frequency response [13] is given by

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{1+(f/f_c)^{2n}} \quad (1)$$

Where V_{out} is the output voltage, V_{in} is the input voltage, f stand for frequency, f_c is the cut off frequency and n is the elements filter number. The equation also can be written as the transfer function $|H(jw)|$ as given below

$$|H(jw)| = \frac{1}{\sqrt{1+(w/w_c)^2}} \quad (2)$$

In this experiment, the EMG signal is sample at the rate of 1000 Hz/s with five repetition of rehabilitation movement [14]. 5th order Butterworth low pass digital filter is used to remove noises in the signal which the cut off frequency of 10 Hz and 0.001 normalization value.

IV. Result

A. Experimental setup

TABLE I. FUNDAMENTAL MOVEMENTS FOR DATA COLLECTION

No.	Body part	Fundamental Movements
1	Shoulder	Shoulder Elevation
2		Shoulder Depression
3		Flexion and Extension
4		Abduction and Adduction
5		External Rotation and Internal Rotation
6		Horizontal Abduction and Horizontal Adduction
7	Elbow	Flexion and Extension
8		Supination and Pronation
9		Extension
10		Flexion
11	Wrist	Radial Deviation
12		Ulnar Deviation

Table 1 shows the muscle activities used in the experiment as the rehabilitation movement. All the movements were acquired by using EMG system as shown in figure 2.

Fig. 2. EMG system

The ADInstruments EMG system used to acquire each movement signal consists of 16 channels but only four channels were designed for EMG, the capturing of the EMG signal was done by using LabChart. Figure 3 shows the electrode placement for the fundamental movement experiment. For the shoulder movement, 8 electrodes were placed on deltoid, biceps and triceps. While for elbow and wrist movements, 8 electrodes were placed on biceps, triceps, flexor and extensor. Each parts of muscle need a pair of electrodes and one ground which is located at another hand.

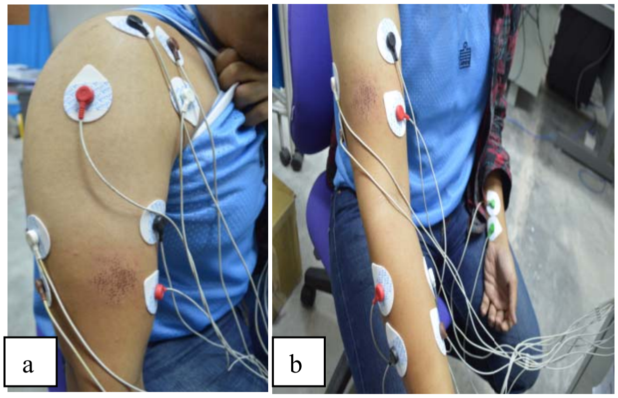
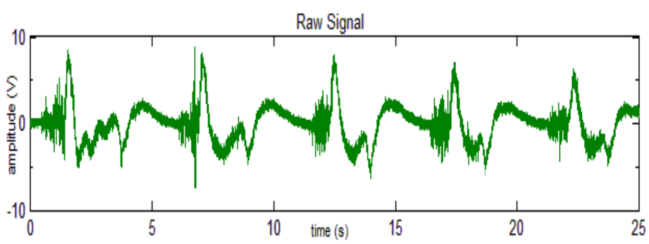


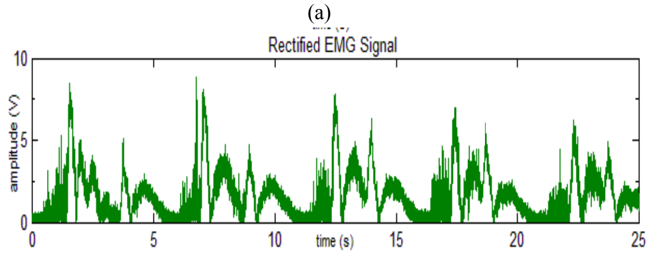
Fig. 3. (a) Electrode placement for shoulder movement (b) Electrode movement for elbow and wrist movement

The subject who performed the stroke rehabilitation movement is a healthy man in 24 years old. Figure 4 show the processing steps of EMG signal for elbow flexion involving the bicep. The signal was rectified to obtain the signal which flow in positive direction and then was low pass filter to smooth the signal. It can be seen that the signal after low pass filter is smoother and less repetition of data. Rectified and filtered signal can be use for further analysis. In this experiment, the most suitable filter is 5th order Butterworth low pass filter of 10 Hz cut off frequency.

B. Experimental Results



(a)



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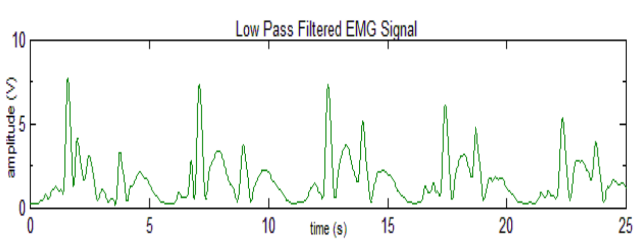
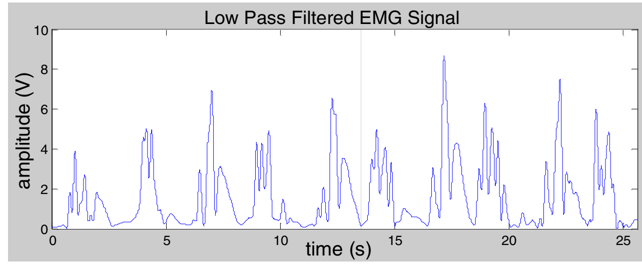
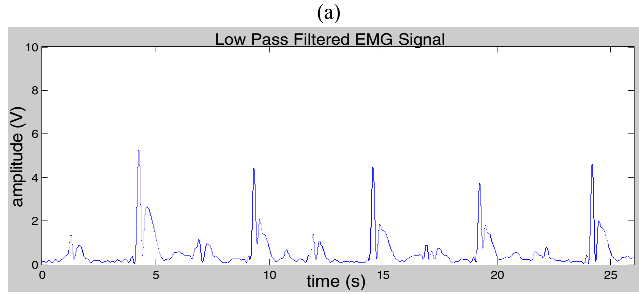


(c)

Fig. 4. (a) Original unfiltered EMG signal (b) Rectified EMG Signal (c) Low pass filtered EMG signal



(a)



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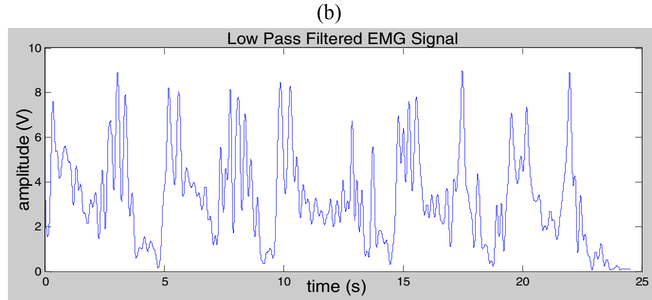

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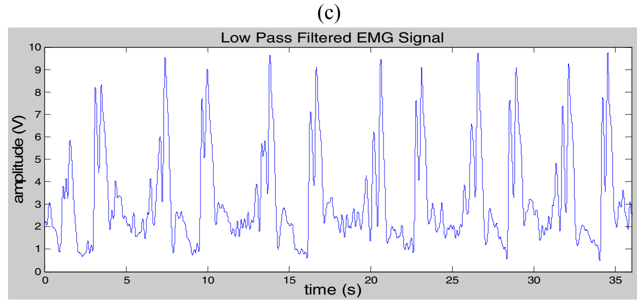

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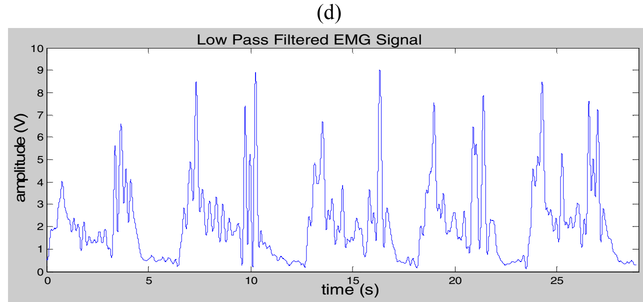

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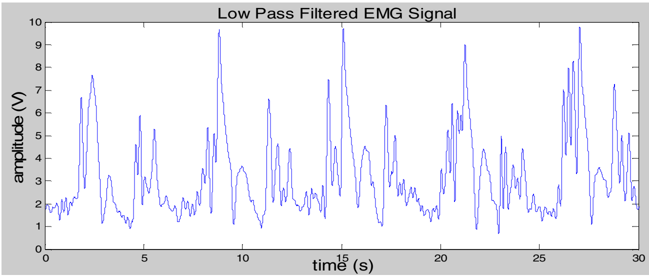

(f)

Fig. 5. (a) Elbow flexion and extension (b)elbow pronation and supination (c) Shoulder Abduction and adduction (d) Shoulder external and internal rotation (e) Shoulder flexion and extension (f) Shoulder horizontal abduction and horizontal adduction

Five times repetition for each rehabilitation movement can be observed clearly from the signals pattern. The peak voltage shows the energy level of muscle contraction. Figure 5 show the signals of deltoid obtained from several rehabilitation movements which are elbow flexion and extension, elbow pronation and supination, shoulder abduction and adduction, shoulder external rotation and internal rotation,shoulder flexion and extension finally the shoulder horizontal abduction and horizontal adduction. The movements were performed in pair according to suitability.

V. CONCLUSION

This research paper presents 18 fundamental arm movements for stroke rehabilitation which was acquired using ADInstrument Electromyography. A healthy subject was chosen to perform the arm rehabilitation movements provided and guided by experience stroke therapist.

The sampling frequency which is 1000 Hz is suitable for arm movement activities, the low pass filter with 10 Hz cut off frequency also able to remove noise and artifact in the signals. The experimental results are useful to design a most suitable motion sequence for stroke patient. In the future, the functional movement based virtual environment will be develop for the stroke patient to perform the rehabilitation activities without stroke therapist.

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REFERENCES

[1] Damasceno, E. F., Cardoso, A., & Lamounier Jr, E. A. (2013, March). An Middleware for Motion Capture Devices Applied to Virtual Rehab. IEEE Virtual Reality, pp. 171-172

[2] Nguyen, K. D., Chen, I. M., Luo, Z., Yeo, S. H., & Duh, H. L. (2011) A Wearable Sensing System for Tracking and Monitoring of Functional Arm Movement, IEEE/ASME Transactions On Mechatronics, 2011, Vol. 16, No. 2, pp.213-220

[3] Nanda, P., Smith, A., Gebregiorgis, A., & Brown, E. E. (2009) Design and Development of an Upper Extremity Motion Capture System for a Rehabilitation Robot, 31st Annual International Conference of the IEEE EMBS Minneapolis, 2009, pp. 7135-7138

[4] Jochen Radmer, Sami Hussein and Jorg Kruger. (2010) Depth Data Based Human Motion Capture for Assessment of Robot Assisted Gait Rehabilitation, IEEE Medical Technology Conference on individualized Healthcare

[5] Nazrul H. ADNAN, Khairunizam WAN, Shariman Ab and Juliana A. Abu Bakar., Principal Component Analysis For The Classification Of Fingers Movement Data Using DataGlove "GloveMAP"., International Journal of Computer Engineering & Technology (IJCET), Vol. 4, No. 2, 79-93, 2013

[6] Sandeep Subramanian, Luiz A Knaut et al. (2007) Virtual reality environments for post-stroke arm rehabilitation, Journal of NeuroEngineering and Rehabilitation 2007,**4**:20 doi:10.1186/1743-0003-4-20

[7] Shih-Ching Yeh, Si-Huei Lee et al. (2012) Virtual Reality for Post-Stroke Shoulder-Arm Motor Rehabilitation: Training System & Assessment Method, 2012 IEEE International Conference on E-Health Networking, Applications and Services, Beijing, 2012, pp 190-195

[8] K. Y. Ang, Y. Y. Huang, K. H. Low (2009) Electromyography Analysis for Pre-clinical Trials off hand Rehabilitation Tasks using Design of Experiments, IEEE ICMA Proceedings, Changchun, China, 2009, pp 915-920

[9] Ahamed, N. U., Sundaraj, K., Ahmad, R. B. et al. (2012). Variability in surface electromyography of right arm biceps brachii muscles between male adolescent, vicenarian and tricenarian with distinct electrode placement. In *Sustainable Utilization and Development in Engineering and Technology (STUDENT), 2012 IEEE Conference on* (pp. 24-28). IEEE.

[10] Pakosz, P. (2011). EMG signal analysis of selected muscles during shots and passes in basketball. *J Health Promotion Recreation*, *1*, 9-14.

[11] Information at http://en.wikipedia.org/wiki/Electromyography#Rectification

[12] M.Yoshida and M. Terao (2003) Suitable Cutoff Frequency of Low-pass Filter for Estimating Muscle Forceby Surface Electromyogram, Proceedings of the 2Sh Annual lnternational Conference of the lEEE EMBS, Mexico, 2003, pp 1709-1711

[13] Information at http://www.radio-electronics.com/

[14] Rash, G. S. (2003). Electromyography fundamentals. *Retrieved February*, *4*.