Faculty of Electrical Engineering

ELECTROMYOGRAPHY (EMG) SIGNAL ANALYSIS OF MANUAL LIFTING USING TIME-FREQUENCY DISTRIBUTION

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ELECTROMYOGRAPHY SIGNAL ANALYSIS FOR MANUAL LIFTING USING TIME-FREQUENCY DISTRIBUTION

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DECLARATION

I declare that this thesis entitle “Electromyography Signal Analysis of Manual Lifting using Time-Frequency Distribution” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for award of Master of Science in Electrical Engineering.

Signature : …….....

Supervisor Name : Prof. Madya Dr. Abdul Rahim Bin Abdullah

Date : .....

DEDICATION

I dedicate my dissertation work towards my family, supervisor, co-supervisor, examiners, collaboration lecturer and all my friends especially from Advanced Digital Signal Processing Group (ADSP) for their support cooperation in helping me to complete this research and thesis.

Thanks to the Ministry of Education (MOE) and Universiti Teknikal Malaysia Melaka (UTeM) for the financial support of my study.

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ABSTRACT

In manufacturing industries, manual lifting is commonly practiced by workers in their routine to move or transport objects to a desired place. Manual lifting with higher repetition and loading using biceps muscle contribute to the effects of soft tissues and muscle fatigue that affect the performance and efficiency of the worker. Electromyography (EMG) is a device to detect the signal's muscle that is use to investigate muscular disorder. Fast-Fourier transform is the common technique used in signal processing. However, this technique only present spectral information and have the limitation to provide the time-frequency information. EMG signals is complicated and highly complex which is consists of variable frequency and amplitude. Thus, time-frequency analysis technique is needed to be employed to provide spectral and temporal information of the signal. This research presents the analysis of EMG signal using Fast-Fourier Transform and time-frequency distribution (TFD) which is spectrogram to estimate the parameters. Manual lifting activities is repeated to five times with the different load mass and lifting height are performed until achieve muscle fatigue to collect the data. From experiments, the raw data of EMG signals were collected via Measurement Configuration Data Collection of NORAXON INC. The parameters are extracted from EMG signal such as instantaneous root mean square (RMS) voltage, mean of RMS voltage and instantaneous energy to determine the information of manual lifting behaviour such as muscle fatigue, strength and energy transfer for the subject's performance evaluation. The results show the relationship between all the parameters involve in manual lifting activities and its behaviour. The higher subjects is easier to handle manual lifting with the higher lifting height, but tough body have advantage to handle higher load mass. The increasing of load masses and lifting height are highly proportional to the strength and energy transfer, however inversely proportional to reach muscle fatigue. The overall results conclude that, the application of spectrogram clearly give the information of the subject's muscle performance based on the manual lifting activities.

ABSTRAK

Dalam industri pembuatan, pekerja biasanya angkatan secara hanya secara dalam rutin mereka untuk bergerak atau mengangkut objek ke tempat yang sepatutnya. Angkatan manual yang berkekerapan tinggi akan memberi kesan kepada tisu yang lembut dan otot akibat mengalami kepenatan dan ini memberi kesan kepada prestasi pekerja untuk bekerja dengan lebih cekap. Electromyography (EMG) adalah alat untuk mengesan signal daripada otot yang digunakan untuk menyiasat gangguan yang berlaku pada otot. Fast-Fourier transform adalah teknik yang biasa digunakan dalam pemprosesan isyarat. Walau bagaimanapun, teknik ini hanya memberikan maklumat spektrum sahaja dan mempunyai had untuk memberikan maklumat dalam frekuensi masa. Isyarat EMG adalah rumit dan sangat kompleks kerana ia terdiri daripada pelbagai bentuk frekuensi dan amplitud. Oleh itu, teknik analisis frekuensi masa perlu digunakan untuk memberikan maklumat dalam bentuk isyarat spektrum dan masa. Kajian ini membentangkan analisis EMG isyarat yang menggunakan Fast-Fourier transform dan taburan masa frekuensi (TFR) iaitu spectrogram untuk membuat anggaran parameter. Data asal isyarat EMG dikumpulkan dengan menggunakan Pengukuran Konfigurasi Koleksi Data NORAXON INC. untuk membuat angkatan yang berlainan ketinggian dan jisim beban. Parameter kemuadian diekstrak daripada isyarat EMG seperti instantaneous root mean square (RMS) voltage, min bagi RMS voltage dan instantaneous energy yang memberikan maklumat keadaan angkatan manual yang dijalankan seperti keletihan otot, kekuatan dan pemindahan tenaga untuk seiap subjek seterusnya dapat ketahui keseluruhan prestasi subjek. Hasil keputusan jelas menunjukkan hubungan antara semua parameter yang terlibat dalam tingkah laku angkatan manual. Peningkatan jisim beban dan ketinggian angkatan berkadar terus dengan kekuatan dan pemindahan tenaga, tetapi berkadar songsang dengan masa mencapai keletihan otot. Ia boleh disimpulkan bahawa, penggunaan spectrogram mampu memberikan maklumat tingkah laku angkatan manual terhadap prestasi subjek. Oleh itu, hasil kajian ini berjaya menunjukkan bahawa teknik yang dicadangkan itu boleh digunakan untuk memberi maklumat berdasarkan aktiviti mengangkat manual.

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LIST OF ABBREVIATIONS

AIF	-	Average Instantaneous Frequency
ECG	-	Electrocardiogram
EEG	-	Emergency electroencephalography
EMG	-	Electromyography
FFT	-	Fast-Fourier Transform
MSDs	-	Musculoskeletal Disorders
RMS	-	Root Mean Square
sEMG	-	Surface Electromyography
SENIAM	-	Surface Electromyography for Non-invasive Assessment of Muscle
STFT	-	Short-time Fourier transform
TFD	-	Time-frequency Distribution
TFR	-	Time-frequency Representation
WT		Wavelet transform

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LIST OF SYMBOLS

$E(t)$		Instantaneous energy
E_{thres}		Global threshold
f_{max}		Maximum frequency
F_r		Frequency resolution
F_s	-	Sampling frequency
$f(t)$		Frequency to Analyse
$h(\tau)$		Input Signal
$M(t)$		Thresholded
N	-	Number of singal length
N_s	-	Number of sample shift
N_w	-	Number of window length
t	-	Time
$S(t,f)$		Time-frequency distribution
$S_x(t,f)$		TFR of the signal
T_r		Time resolution
$V_{rms}(t)$		Instantaneous Root Mean Square Voltage
$w(t)$		Window Observation
$\bar{x}$		Mean of Instantaneous RMS Voltage
$X(f)$	-	Continuous frequency response
$Xs(t)$		Segmented of raw signal

$\Sigma V_{rms}(t)$	Summation of $V_{rms}(t)$
$x(t)$	Time domain Signal

LIST OF PUBLICATIONS

A. Journal

1) **T. N. S. T. Zawawi**, A. R. Abdullah, E. F. Shair, I. Halim, S. M. Salleh., 2015. EMG Signal Analysis of Fatigue Muscle Activity in Manual Lifting. *Journal of Electrical Systems*, 11(3), pp.319–325. **(ISI Journal)**

2) **T. N. S. T. Zawawi**, A. R. Abdullah, I. Halim, E. F. Shair, S. M. Salleh, 2015. Application of Spectrogram in Analysing Electromyography (EMG) Signals of Manual Lifting. *ARPN Journal of Engineering and Applied Sciences*, 11(6), pp.3603 – 3609. **(Scopus Journal)**

B. Conference

1) **T. N. S. T. Zawawi,** A.R. Abdullah, E.F. Shair, I. Halim, and Rawaida, O., 2013, December. Electromyography signal analysis using spectrogram. In *Research and Development (SCOReD), 2013 IEEE Student Conference* on, pp. 319-324. **(IEEE Conferences)**

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2) E. F. Shair, **T. N. S. T. Zawawi**, A. R. Abdullah & N. H. Shamsudin., (2015). sEMG Signals Analysis Using Time-Frequency Distribution for Symmetric and Asymmetric Lifting. In *2015 International Symposium on Technology Management and Emerging Technologies (ISTMET), August 25 - 27, 2015, Langkawi, Kedah, Malaysia*, pp. 233–237.**(IEEE Conferences)**

C. Other

1) Kasim, R., Abdullah, A.R., Selamat, N.A., Abidullah, N.A. and **T. N. S. T. Zawawi**, 2015, August. Lead Acid Battery Analysis Using Spectrogram. In *Applied Mechanics and Materials* (Vol. 785, pp. 692-696). Trans Tech Publications. **(Scopus)**

CHAPTER 1

INTRODUCTION

1.1 Introduction

In industrial workplaces, manual lifting is a prevalent choice that needed to perform a material handling task, although mechanized and automated equipment are provided (Chang et al., 2003 and Halim et. al., 2014). Manual lifting is commonly practiced by workers in industrial workplaces to move or transport the object to a desired place (Waters et. al., 1994 and Halim et. al., 2014).

Manual lifting is one of the manual handling activities. Improper manual handling becomes the common causes of injuries at work (Arif et. al., 2013). National Safety council (NSC) indicated that the estimation of safe load limit for manual handling operations should be judged scientifically to reduce the rate of industrial accidents (Maiti and Bagchi, 2006).

Skeletal muscles are critically implemented to perform the manual lifting task. It is important to handle a suitable load mass and lifting height to ensure the muscles properly used to achieve muscle fatigue. Inappropriate lifting techniques will contribute to work-related musculoskeletal disorders (MSDs) in workplace injuries (Lu et. al., 2016). In general, the repetition of manual lifting tasks frequently may expose worker to the high risk of (MSDs) (Arif et al., 2013, Halim et. al., 2014 and Nurhayati, et. al., 2015)

MSDs can be divided into two parts which are upper limb and lower limbs. Statistic data of prevalence (total cases) from 2001 to 2014 shown that back pain was recorded as a common complaint in Malaysia (Veerapen et. al., 2007). It will cause absenteeism at work and lead to direct loses like the increasing of medical and compensation cost, and indirect loses as contribute to low the productivity, miserable due to the soreness and absenteeism (Veerapen et. al., 2007 and Sterud, T. and Tynes, T., 2013). Electromyography (EMG) will relate to the MSDs.

EMG signal is widely used and applied as a control signal in numerous man-machine interfaces' applications. It has also been deployed in numerous clinical and industrial applications (Phinyomark et. al., 2012). The EMG is known as biomedical signal that consist of electrical current. It is generated during contraction and relaxation phase of muscles (Gokgoz and Subasi, 2015 and Ruchika and Dhingra, 2013). Moreover, it is originally developed for investigating muscular disorder and EMG recording has also been used for studying the functional state of the muscle during various motions (Rekhi et. al., 2009).

However, EMG signal is complicated and non-stationary signal with highly complex time and frequency characteristics (Kamaruddin, Khalid, and Shaameri, 2015). It is controlled by nervous signal because it always responsible the muscle activity (Ruchika and Dhingra, 2013 and Canal, 2010). During data collection and recording process, it become difficult because of EMG signal that really sensitive to noise and easier distorts while travelling through different tissues in the body muscle (Gokgoz and Subasi, 2015 and Reaz et. al., 2006). Feature extraction and function classification is the key in processing and analysing the EMG signals (Rekhi et. al., 2009).

A lot of studies have been done in EMG signal investigation especially in extraction of EMG signal (Bekka and Chikouche, 2003, (Gokgoz and Subasi, 2015 ; Reaz et. al., 2006 and Wu, Talmon, and Lo, 2015). The previous researchers have been used fast Fourier