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Behavioral Modeling of Mechanomyogram Signals
Detection and Decomposition System

By

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A Dissertation

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Abstract

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The analysis of the Mechanomyogram (MMG) signals of the muscles is a promising technique in order to evaluate the muscles effort and diagnose the different neuromuscular disorders. In this dissertation, we use virtual muscle model and MEMS based accelerometer model to construct model based detection system. We propose to use the Empirical Mode Decomposition (EMD) method in order to analyze the MMG signal of the biceps brachii muscle. The EMD decomposes the MMG signal into a finite set of band-limited signals termed intrinsic mode functions (IMFs). The mean power frequency (MPF) for each IMF has been computed. The MPF measure of the IMFs has been used as a feature in order to discriminate between normal, myopathic and neuropathic cases. It has been shown that the MPF feature of the IMFs has provided statistically significant difference between the different cases. The obtained classification accuracy using linear discriminant analysis (LDA) between these three cases illustrated the effectiveness of the proposed method.

The proposed MMG analysis system is hardware realized via two stages. The first stage is the detection stage which is formed of muscle stimulation, MMG measurement and MMG signal conditioning. The experiment is done on the biceps brachii muscle, as a case study. The second stage is FPGA implementation of Hilbert Huang Transform (HHT) core which relies on EMD. Before FPGA implementation, the HHT core was simulated and statistically tested to prove the discrimination capability of the decomposition technique after hardware implementation. The results

showed that the imaginary component of the HHT is statistically significant. The classification resultsshowed that the imaginary component of the HHT could be considered an effective discriminator among different neuromuscular disorders for the biceps brachii muscle.

Key Words:mechanomyogram, accelerometer, empirical mode decomposition, Hilbert Huang transform, myopathy, neuropathy.

Summary

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This dissertation consists of the following chapters:

Chapter One introduces the MMG signals, its origin, history and characteristics. Different detection techniques and comparison between them are illustrated. The motivation for investigating MMG as a control signal, previous work and contribution that demonstrate the potential of MMG as a control signal are mentioned.

Chapter Two gives an overview about the nerves and muscles. The organization of the nervous system and its main components are illustrated. The resting and action potentials are well discussed. The muscle structure, physiology and contraction mechanism are demonstrated. Muscle behaviors in neuromuscular diseases are presented and myogram techniques such as EMG and MMG are discussed.

Chapter Three presents the used muscle model with brief explanation regarding its operation and equations. The MEMS based accelerometer is explained with its theory and significance. The specifications and behavioral model of the used MMG sensor are also illustrated.

Chapter Four introduces the proposed MMG signals analysis algorithm. Firstly, the experimental protocol is clarified. Then, the concept of Empirical Mode Decomposition (EMD) and Hilbert Spectrum (HS) is presented. After that, the MMG

feature to be tested is selected and the decomposition results and spectrums are illustrated and discussed. The decomposition results are statistically analyzed to test the discrimination capability of the proposed algorithm between normal and different pathological cases. Finally, Linear Discriminant Analysis (LDA) classification technique is demonstrated as the classification technique for the system. The classification accuracy is also determined statistically.

Chapter Five implements the proposed MMG detection and decomposition system in hardware. The experiment is done on biceps brachii muscle. The detection stage is constructed by using muscle electrical stimulator, MEMS based accelerometer sensor and signal conditioning circuits. The decomposition stage introduces HHT core which is simulated and statistically tested to prove the discrimination capability of the decomposition technique after hardware implementation. The presented HHT core is implemented on FPGA.

Chapter Six concludes this dissertation and proposes future work.

List of publications

1. **Hisham Gamal Daoud** and **Hani Fikry Ragai** "Mechanomyogram Signal Detection and Decomposition: conceptualisation and research design," 1st International Conference on Electrical and Computer Systems Engineering , Nov. 2010, Cairo, Egypt and International Journal of Healthcare Technology and Management (IJHTM), 2012 Vol.13, No.1/2/3, pp.32-44.

2. **Hisham Gamal Daoud**, **Hani Fikry Ragai** and **Hassan El Shahaly** "Mechanomyographic Signal Analysis for Biceps Brachii Based on Empirical Mode Decomposition". ICECE 2013: International Conference on Electronics and Communication Engineering, Apr. 2013, Paris, France and World Academy Of Science, Engineering and Technology Journal, 2013, Issue 76, Pages:564-570.

Table of contents

1 Introduction.....	1
1.1 Introduction.....	1
1.1.1 Mechanomyogram Signals	1
1.1.2MMG Detection Techniques	2
1.1.3MMG Signal Characteristics	4
1.1.4Motivation for investigating MMG as a control signal	6
1.1.5MMG as a control signal	7
1.2 Dissertation Outline	7
2 Nerves and Muscles.....	10
2.1 Introduction.....	10
2.2 The Nervous System	11
2.2.1 Organization of Nervous System.....	11
2.2.2The Nerve Cell	13
2.2.3Resting and Action Potentials	15
2.3 Muscles	18
2.3.1 Muscle Structure.....	18
2.3.2 Muscle Physiology	22
2.3.3 Muscle Contraction	27
2.3.4Muscle Behaviour in NeuromuscularDiseases	30
2.3.5Muscle of Study: Biceps Brachii	31
2.4 Myogram Techniques	32
2.4.1 Electromyogram	32
2.4.2 Mechanomyogram.....	38
2.5 Summary	39
3Modeling of Muscle and MMG Sensor	41
3.1 Introduction.....	41
3.2 Muscle Model	41
3.2.1Biceps Brachii Muscle Model	51
3.2.2MMG Extraction 52	
3.3 MMG Sensor.....	53

3.3.1 MEMS Based Accelerometer	54
3.3.2 MMG Sensor Model	60
3.4Summary	63
4 MMG Signal Decomposition and Classification	64
4.1 Introduction.....	64
4.2Experimental Protocol	65
4.3 Decomposition Technique	66
4.3.1 Empirical Mode Decomposition.....	66
4.3.2Hilbert Spectrum Generation.....	72
4.3.3Proposed Analysis Algorithm.....	73
4.3.4 Statistical Analysis and Results.....	81
4.4 Classification Technique.....	83
4.4.1 Linear Discriminant Analysis.....	83
4.4.2 Statistical Analysis and Results.....	89
4.5Summary	90
5Hardware Implementation.....	91
5.1 Introduction.....	91
5.2 MMG Detection	92
5.2.1 Muscle Stimulator	92
5.2.2MMG Sensor	93
5.2.3PSoC Configuration.....	95
5.2.4 Measurement Hardware.....	102
5.2.5 Experiment and Results.....	105
5.3 MMG Decomposition	107
5.3.1 HHT IP Core and Simulation Result.....	107
5.3.2Statistical Analysis and Results.....	112
5.3.3FPGA Implementation.....	113
5.4 Summary	114
6 Conclusions and Future work.....	116
6.1Conclusions.....	116
6.2Future work.....	118
References.....	120

List of Figures

Figure 1.1 Motor unit recruitment strategy reflected in MMG. Typical MMG RMS and MPF curves during isometric contraction showing (A) recruitment of ST fibers, (B) increase in force with no change in frequency due to increased recruitment of ST fibers, (C) increased frequency and RMS due to recruitment of FT fibers, (D) increase in force with increased motor unit firing rate and decrease in RMS due to motor-unit fusion.	5
Figure 1.2 Dissertation overview.	9
Figure 2.1 Nervous system components	11
Figure 2.2 Organization of nervous system	12
Figure 2.3 Structure of neuron	14
Figure 2.4 Formation of an action potential based on changes in Na^+ and K^+ ion flow	17
Figure 2.5 Structure of skeletal muscle.....	19
Figure 2.6 Structure of sarcomere.....	20
Figure 2.7 Structure of skeletal muscle fiber	20
Figure 2.8 Motor units	23
Figure 2.9 Twitch contraction.....	24
Figure 2.10 Motor unit recruitment	24
Figure 2.11 Contraction types (a) isometric contraction, (b) isotonic contraction	26
Figure 2.12 Contraction process (a) axon branch to a single muscle fiber, (b) neuromuscular junction.....	27
Figure 2.13 The sliding filament theory, (a) muscle relaxation case, (b) muscle contraction case.....	29
Figure 2.14 Neuropathy in: (1) motor unit, (2) motor neuron axon, (3) neuromuscular junction, myopathy in: (4) muscle fibers	30
Figure 2.15 Biceps brachii muscle.....	32
Figure 2.16 EMG and frequency spectrum measured from the tibialis anterior muscle during a constant force isometric contraction at 50% of maximum voluntary contraction	Error! Bookmark not defined. 3
Figure 2.17 EMG differential amplifier configuration. The EMG is represented by m and the noise signal by n.....	Error! Bookmark not defined. 4

Figure 2.18 The preferred electrode location is between the motor point or (innervation zone) and the tendinous insertion	Error! Bookmark not defined.
Figure 3.1 Modified Hill-type model.....	43
Figure 3.2 Schematic diagram of the model function.....	43
Figure 3.3 Fiber types creating and editing in virtual muscle model.....	50
Figure 3.4 Muscle types creating and editing in virtual muscle model	50
Figure 3.5 Simulink model block diagram of the muscle.....	50
Figure 3.6 Biceps brachii muscle parameters	51
Figure 3.7 Simulink model block diagram of the biceps brachii muscle.....	52
Figure 3.8 Simulink model of the MMG generation process	53
Figure 3.9 Accelerometer structure. Proof mass is attached through springs(k_s : spring constant) at substrate. It can move only up and down. Movable and fixed plates construct capacitors	57
figure 3.10 a) Electric circuit that measures acceleration through capacitor changes. b) if acceleration is zero, voltage output is also zero. c)→ e) when acceleration isn't zero, we get with the voltage follower square wave with the right amplitude and after demodulator voltage output V_{out} with the right amplitude and the right sign.....	59
Figure 3.11 ADXL203 accelerometer die photo.....	61
Figure 3.12 Behavioral model of one axis of ADXL203 accelerometer	62
Figure 4.1 Block diagram of the proposed model based system	66
Figure 4.2 Flow chart of the proposed EMD algorithm.....	71
Figure 4.3 MMG signal and its IMFs for the first normal case	75
Figure 4.4 MMG signal and its IMFs for the first myopathic case.....	76
Figure 4.5 MMG signal and its IMFs for the first neuropathic case.....	77
Figure 4.6 MMG signal and its HS for the first normal case.....	78
Figure 4.7 MMG signal and its HS for the first myopathic case	79
Figure 4.8 MMG signal and its HS for the first neuropathic case	80
Figure 4.9 The box plots of the MPF with its mean indicated for (a) IMF1 for both normal and myopathic cases and (b) IMF8 for both normal and neuropathic cases	82
Figure 4.10 Projections of samples onto two different lines in the direction marked w.....	84
Figure 5.1 Muscles electrical stimulator.....	92
Figure 5.2 Functional block diagram of ADXL203 dual axis accelerometer.....	93

Figure 5.3 ADXL203 evaluation board	94
Figure 5.4 PSoC family cores	96
Figure 5.5 PSoC digital system distribution	99
Figure 5.6 PSoC analog system distribution.....	100
Figure 5.7 CY3210-PSoCEVAL1 evaluation board.....	101
Figure 5.8 Block diagram of PSoC based MMG measurement circuit (first implementation)	102
Figure 5.9 Block diagram of the MMG measurement circuit (second implementation)	104
Figure 5.10 The MMG measurement experiment setup	106
Figure 5.11 Screenshot of MMG signal measurement of the biceps brachii muscle	106
Figure 5.12 The analytic filter structure	109
Figure 5.13 Plots of the filter $H_{A1}(e^{j\omega})$, (a) normalized magnitude response, (b) phase response	111
Figure 5.14 Block diagram of the HHT core simulation process	112
Figure 5.15 Modelsim simulation result of the HHT core.....	112
Figure 5.16 Altera DE1 board.....	114

List of Tables

Table 2.1	Characteristics of skeletal muscle fibers.....	21
Table 2.2	Factors that influence surface EMG	37
Table 3.1	Equations and coefficients of the virtual muscle model	45
Table 3.2	Symbols and definitions.....	47
Table 3.3	Specifications of dual axis accelerometer ADXL203.....	61
Table 5.1	Filter capacitor selection C_x and C_y	94

Abbreviations

ADC	: Analog to Digital Converter
Af	: Activation–Frequency
AGND	: Analog Ground
ALS	: Amyotrophic Lateral Sclerosis
AM	: Amplitude Modulation
ANOVA	: Analysis of Variance
ANS	: Autonomic Nervous System
API	: Application Programming Interface
BW	: Band Width
CMRR	: Common Mode Rejection Ratio
CNS	: Central Nervous System
CPU	: Central Processing Unit
CRC	: Cyclic Redundancy Check
CT	: Continuous Time
DAC	: Digital to Analog Converter
DBB	: Digital Block for Basic Purposes
DC	: Direct Current
DCB	: Digital Block for Communication Purposes
EEPROM	: Electrically Erasable Programmable Read Only Memory
EMD	: Empirical Mode Decomposition
EMG	: Electromyogram
FL	: Force–Length
FM	: Frequency Modulation
FPGA	: Field Programmable Gate Array
FT	: Fast-Twitch
FV	: Force–Velocity

GPIO : General Purpose Input and Output
 HHT : Hilbert Huang Transform
 HPF : High Pass Filter
 HS : Hilbert Spectrum
 I2C : Inter-Integrated Circuit
 IMF : Intrinsic Mode Function
 INSAMP : Instrumentation Amplifier
 IO : Input and Output
 IP : Intellectual Property
 IrDA : Infrared Data Association
 ISSP : In-System-Serial-Programming
 LCD : Liquid Crystal Display
 LDA : Linear Discriminant Analysis
 LED : Light Emitting Diodes
 LPF : Low Pass Filter
 M8C : 8 bit Microcontroller
 MCU : Microcontroller Unit
 MDF : Median Frequency
 MEMS : Micro Electro-Mechanical Systems
 MHS : Marginal Hilbert Spectrum
 MIPS : Million Instructions Per Second
 MMG : Mechanomyogram
 MNF : Mean Frequency
 MPF : Mean Power Frequency
 MU : Motor Unit
 MUAP : Motor Unit Action Potential
 MVC : Maximum Voluntary Contraction
 Opamp: Operational Amplifier
 PGA : Programmable Gain Amplifier