Ain Shams University
Faculty of Engineering
Electronics and Communications Engineering Department

Behavioral Modeling of Mechanomyogram Signals Detection and Decomposition System

By

Hisham Gamal Mohamed Daoud

A Dissertation

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Under the Supervision of

Prof. Dr. Hani Fikry Ragai
Dept. of Electronics & Communications,
Faculty of Engineering,
Ain Shams University

Prof. Dr. Hassan El Shahaly
Dept. of Rheumatology & Rehabilitation,
Faculty of Medicine,
Suez Canal University

Cairo, Egypt
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AinShams University

Faculty of Engineering

Electronics and Communications Engineering Department

Examiners Committee

Name: HishamGamal Mohamed Daoud

Thesis: Behavioral Modeling of MechanomyogramSignals Detection and Decomposition System

Degree: Doctor of Philosophy in Electrical Engineering

Title, Name, AffiliationSignature

Prof. Dr. AhmedMohamed El-Bialy-------------------
Systems and Biomedical Engineering Dept.
Faculty of Engineering-CairoUniversity

Prof. Dr. Ismail Mohammed Hafez-------------------
Electronics and Communications Engineering Dept.
Faculty of Engineering-Ain Shams University

Prof. Dr. Hani FikryRagai------------------
Electronics and Communications Engineering Dept.
Faculty of Engineering-Ain Shams University

Date: 2/2/2014

Abstract

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The analysis of the Mechanomyogram(MMG)signals of the muscles is a promising technique in order toevaluate the muscles effort and diagnose the differentneuromuscular disorders. In this dissertation, we use virtual muscle model and MEMS based accelerometer model to construct model based detection system. We propose to use theEmpirical 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-limitedsignals termed intrinsic mode functions (IMFs). The meanpower 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 neuropathiccases. It has been shown that the MPF feature of the IMFs hasprovided statistically significant difference between the different cases. The obtained classification accuracy usinglinear discriminant analysis (LDA) between thesethree casesillustrated 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 Oneintroduces 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 Twogives 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 andmyogram techniques such as EMG and MMG are discussed.

Chapter Threepresents 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 Fourintroduces 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 Fiveimplementsthe 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.**HishamGamalDaoud**andHani FikryRagai"Mechanomyogram SignalDetection and Decomposition: conceptualisation andresearchdesign,".1st InternationalConference on Electrical and Computer Systems Engineering , Nov. 2010, Cairo,Egypt and InternationalJournalofHealthcareTechnology andManagement(IJHTM), 2012 Vol.13, No.1/2/3, pp.32-44.

2.**HishamGamalDaoud**,Hani FikryRagai and Hassan El Shahaly"Mechanomyographic Signal Analysis for Biceps Brachii Based on Empirical ModeDecomposition".ICECE 2013: International Conference on Electronics and CommunicationEngineering, Apr. 2013, Paris, France and World Academy Of Science, Engineering and Technology Journal,2013, Issue 76, Pages:564-570.

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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