Computational Intelligence based EMG for Automated Classification of Foot Drop Rehabilitation

By

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Certificate of Original Authorship

I, Sahar Adil Abboud, declare that this thesis, is submitted in fulfillment of the requirements for the award of Doctorate of Philosophy in the School of Biomedical Engineering at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. IN addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

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Abstract

Foot drop is a complication that arises from the weakness that occurs in specific muscles in the ankle and foot; such as the Anterior Tibialis muscle (AT) during the foot flexion and extension. A lesion in the Lower Motor Neuron (LMN) will cause Foot Drop. Foot drop has been found to arise in 52% to 67% of patients with spinal Upper Motor Neuron (UMN) pathology. Foot Drop (FD) is a common disorder and is not specific to age; it affects around 1% of women and 2.8 % of men. The affected muscles impact on the motion of the ankle and foot both downward and upward. To overcome this problem and to improve rehabilitation devices, this thesis introduces several methods to improve the performance of the Myoelectric Pattern Recognition (M-PR) in both the offline and real data experiments. The thesis proposes a new M-PR system that will work satisfactorily on both the healthy and non-healthy leg by classifying movements in the offline experiments. The thesis describes the state-of-the-art procedures for M-PR and studies all the conceivable structures for the best M-PR features and classifiers.

This thesis presents new classifiers to develop the performance of the M-PR. The Self-Advised-Support Vector Machine (SA-SVM) modified from a single class to multi-class. Developments in methodology lead to more significant applications for overall use. The thesis adapted and altered label classification methods resulting in a new classification named Label Self- Advised-Support Vector Machine LSA-SVM. Further, a development to LSA-SVM is to upgrade from a single class into Multi-LSA-SVM and then to evolve the methodology to match Extreme Learning Machine (ELM) with LSA-SVM to acquire a new rapid method, named ELM-LSA-SVM. For the real data experimental option, a collected data from using the sEMG device from Foot Drop Patients in Metro Rehabilitation Hospital in Sydney, Australia using Ethical Approval (UTS HREC NO.ETH15-0152).

The collected used to apply the latest and fastest method to FD patients to use the myoelectric pattern recognition (M-PR) for leg movement detection. The experimental results for the EMG dataset and benchmark datasets exhibit its benefits. Furthermore, the experimental results on UCI datasets indicate that ELM-LSA-SVM achieves the best performance when working together with LSA-SVM and SVM. The whole sets of experimental results are encouraging as recorded and reported in the thesis.

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Dedication

This thesis dedicated to the five most important people in life, without their support, this journey would have been just a dream. Special thanks to mother, Sammera A.Gh., father, Adil Abboud (Allah place him in heaven), bother Jameel, Daughter Noor and my very best friends for being my inspiration and encouraging me throughout my career.

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List of Abbreviations

AFO Ankle Foot Orthotic
ANN Artificial Neural Network
AR Auto-Regressive (model)
SA-SVM Self Advised Support Vector Machine
BCI Brain-Computer Interfaces
BPF Band-Pass Filtering
CNS Central Nervous System
COM Center of Mass
CPN Common Peroneal Nerve
CSA Cross-Sectional Area
DOF Degree of Freedom
DSP Digital Signal Processor
DM Data Mining
ECG Electrocardiograph
eCGS Comfortable Gait Speed
EEG Electroencephalography
EI Efficiency Index
EMG Electromyography
ES Electrical Stimulation
ESCS Epidural Spinal Cord Stimulation
FES Functional Electrical Stimulation
FLC Free Fuzzy Logic Controller
GRF Ground Reaction Force
GRNN General Regression Neural Network
HGO Hip Guidance Orthotics
HRF Handle Reaction Force
IEMG Integrated EMG
iFES-LCE isokinetic Leg Cycle Ergometer
IOFL Input Output Feedback Linearised
KAFO Knee-Ankle-Foot Orthosis

KNN K Nearest Neighbour

MA Moving Average

macro MUP macro Motor Unit Potential

MeCFES Myoelectrically Controlled Functional Electrical Stimulator

MFPV Muscle Fibre Propagation Velocity

MGH FAC Massachusetts General Hospital Functional Ambulation Classification

MLD Multi Labelling Dimensionality

NFES Non Function Electrical Stimulation

NIH National Institutes of Health

NMES Neuromuscular Electrical Stimulation

PCI Physiological Cost Index

PD Parkinson’s Disease

RF Rectus Femoral

RGO Reciprocating Gait Orthotics

RMS Root Mean Square

ROM Range Of Motion

RTS Randomly Timed Stimulation

RTT Robotic Treadmill Training

SCI Spinal Cord Injury

SCKAFO Stance-Control Knee Ankle Foot Orthosis

SCS Spinal Cord Stimulation

SD Standard Deviation

sEMG surface EMG

SOMF Second Order Moment Function

SThD Single Threshold detection

TA Tibias Anterior

TLSI Thoracolumbar Spinal Injury

TO Toe-Off

VL Vastus Lateralis

VM Vastus Medialis

VR Virtual Reality

VSNR Virtual Signal-to-Noise Ratio

WPT Wavelet Packet Transform

WSTT Weight-Supported Treadmill Training.