DETECTION OF FREEZING OF GAIT AND GAIT INITIATION FAILURE IN PEOPLE WITH PARKINSON'S DISEASE USING ELECTROENCEPHALOGRAM SIGNALS

By

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I, Quynh Tran Ly, certify that the work in the thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the content of this thesis is my own work. Any help that I have received in my research work and the preparation of the thesis itself has been duly acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abbreviations

3D: Three Dimensions

ANN: Artificial Neural Networks

BSS: Blind Source Separation

BNN: Bayesian Neural Networks

CF: Centroid Frequency

CWT: Continuous Wavelet Transform

DWT: Discrete Wavelet Transforms

ECG: Electrocardiography

EEG: Electroencephalography

EMG: Electromyography

EW: Effective Walking

FFT: Fast Fourier Transform

fMRI: function Magnetic Resonance Imaging

FOG: Freezing of Gait

FOGQ: Freezing of Gait Questionnaire

H&Y: Hoehn and Yahr stage

GIF: Gait Initiation Failure

GS: Good Start

GT: Good Turn

ICA: Independent Component Analysis

ICA-EBM: Independent Component Analysis Entropy Boundary Maximization

ICs: Independent Components

MMSE: Mini-Mental State Examination

PD: Parkinson’s disease

PSD: Power Spectral Density

PSE: Power Spectral Entropy

pSMA: pre-Supplementary Motor Area

SVM: Support Vector Machine

ST: S-Transform

TF: Turning FOG

TUG: Timed Up and Go

UPDRS: Unified Parkinson’s disease Rating Scale

WE: Wavelet Energy

WCS: Wavelet Centroid Scale

WEE: Wavelet Energy Entropy

Abstract

Parkinson's disease (PD) is the second most common age related neurodegenerative disorder, affecting approximately 1-2% of the elderly population. Freezing of Gait (FOG) is a very disabling feature of PD that causes frequent falls. During FOG, patients are suddenly unable to take a step despite the intention to walk or continue moving forward. The neural mechanisms of FOG are unclear and treatments have only limited effectiveness.

Based on contexts of behavioural measures in daily life, different types of FOG have been observed including: freezing when turning (TF); freezing when getting through narrow doorways; freezing when reaching a target; freezing when straight walking or freezing when initiating gait to start a movement (GIF). TF and GIF are recognized to be the most frequent triggers of FOG seen in PD patients.

To detect FOG, using parameters extracted from the Electroencephalogram (EEG) is one of the most promising methods. In the comparison of using "body-worn" sensors technique, EEG measures the activity of the brain where the root of FOG is occurring. Therefore, EEG will be quicker to detect FOG than "body-worn" sensors because of the time the neural signal has to travel all the way to the legs to be measured, thus offering the most optimal time window for intervention to overcome FOG.

The research in this thesis introduces advanced algorithms for FOG detection using EEG signals. These algorithms have been developed and applied successfully to detect FOG and its two common subtypes (GIF, TF) based on various features extractions and classifiers, providing high accuracy for detection. It was found that the combination of Independent Component Analysis Entropy Boundary Minimization (ICA-EBM), S-Transform (ST) and Bayesian Neural Networks (BNN) proved to be a very robust and effective method for freezing detection.

In the first study, abnormal changes of EEG signal to detect FOG were investigated. By using Fast Fourier Transform as the feature extraction and Artificial Neural Networks

(ANN) as a classifier, the EEG data of FOG could be detected effectively from seven PD patients with sensitivity, specificity and accuracy of 72.20%, 70.58% and 71.46%, respectively. Furthermore, FOG episodes were found to be associated with significant increases in the high beta band (21-38Hz) across the central, frontal, occipital and parietal EEG sites.

In the second study, the dynamic brain changes underlying a GIF episode and its detection were investigated in four PD patients. This research studied the brain activity underlying GIF by analyzing Wavelet Transform (WT) of EEG signals. Using ICA-EBM for EEG source separation, WT for feature extraction and Support Vector Machine (SVM) for classification, the correct identification of GIF episodes was improved with sensitivity, specificity, and accuracy of 83.94%, 89.39% and 86.67%, respectively.

The final classification results produced by this dissertation indicated that by applying source separation ICA-EBM for pre-processing EEG data, time-frequency ST techniques for feature extraction and BNN for classification, a freezing event can be successfully detected using EEG signals. The results for the TF detection were achieved with sensitivity, specificity, and accuracy of 83.00%, 87.60% and 85.40%, respectively. The results for the GIF detection were relatively similar with sensitivity, specificity, and accuracy of 88.96%, 90.26% and 89.50%, respectively.

With the final performance (ICA-EBM, ST, BNN) achieved by this thesis, future work will be carried out to pursue the eventual aim of the current research, which is developing an EEG-based system for detecting FOG that can be applied in real-time.