



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Computer and Systems Engineering

Event Related Potential-based Applications with Limited Number of Trials

A Thesis submitted in partial fulfilment of the requirements of the degree of
Master of Science in Electrical Engineering
(Computer and Systems Engineering)
by

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Cairo - (2018)



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Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

Brain-Computer Interface (BCI) is one of the most promising fields nowadays in hope to assist individuals with cognitive or sensory-motor disabilities. It facilitates human interaction with modern technologies and tools through brain activity. This could grant some communication capabilities back to severely disabled individuals. The P300 speller is one of the most successful BCI communication applications that employs one type of event related potentials; the P300 signal. A typical P300 speller is presented to the user as a 6-by-6 matrix whose cells contain the essential alphanumeric characters that are randomly flashed. By analyzing the recorded Electroencephalography (EEG) signals, the character to spell is identified. The usage of this application typically takes a significant amount of time due to the need to perform multiple trials to accurately recognize the target cell. This thesis introduces two deep neural network approaches for P300 recognition from limited number of trials. The first approach consists of a deep neural network with multiple stacked autoencoder layers and a softmax classifier, while the second approach consists of a convolutional neural network. Two sets of recorded signals were used through the present study; the BCI Competition III benchmark dataset, in addition to EEG data that we recorded from two subjects using the Emotiv Epoc neuroheadset. We compared the proposed approaches to the traditional approach for P300 recognition which employs principal component analysis for feature reduction followed by linear classifiers. Our results revealed that the stacked autoencoder approach achieves a remarkable increase of 4.5% in accuracy compared to the traditional approach when applied to averaged 5 trials P300 data. More importantly, a significant enhancement of 8% is achieved when applied to

single trial P300 data. The obtained results elucidate the significant effect of deep learning techniques in this paradigm.

Keywords: BCI, EEG, P300 speller, deep learning, convolutional, neural network, Autoencoder

Summary

The severely disabled people are facing major challenges to live a normal life with the ability to interact with the surrounding environment which can be achieved by the brain-computer interface technique. The word interaction between the patients and their families and friends is the most important and essential ability that is needed to be granted to them. The P300 spellers provide such ability but with a long and exhausting training procedure. In this thesis, the long-time consumed in order to use the spellers is reduced significantly using the deep learning approach of the neural networks with a remarkable time reduction from 2 minutes per character to just 8 seconds or 40 seconds according the respective solution.

The chapters of this thesis can be divided into seven chapters, explained as follows

Chapter 1, an introduction to this thesis

Chapter 2, a literature review of the history of brain-computer interface, electroencephalography, positive-evoked potentials.

Chapter 3, a detailed description of the datasets collection and the experimental design.

Chapter 4, a detailed explanation of the used pre-processing techniques.

Chapter 5, a detailed explanation dimensionality reduction techniques and classifiers.

Chapter 6, all approaches and their corresponding results.

Chapter 7, the summary and the future work.

Acknowledgment

I would like to thank my thesis supervisors; Prof. Gamal M. Aly and Dr. Seif Eldin M. Eldawlatly for their continuous support and guidance through the process of researching and writing this thesis.

My research would have been impossible without the aid of my family and my partner. I must express my very profound gratitude to each and every one of them. Their unfailing support and continuous encouragement for the past years are the reasons to this accomplishment. Thank you.

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September 2018

Table of Contents

CHAPTER 1 Introduction.....	1
1.1 Research Scope.....	2
1.2 Research Objectives	2
1.3 Research Contributions.....	3
1.3.1. Develop a Deep Neural Network Approach for P300 Recognition	3
1.3.2. Performance Analysis and Comparison to Traditional Approaches	3
1.4 Thesis Outline.....	4
CHAPTER 2 Literature Review and Background.....	6
2.1 History and Background.....	6
2.1.1 Brain Structure	6
2.1.2 Brain Activity Recording Approaches	9
2.1.3 Electroencephalography (EEG).....	10
2.1.4 EEG Signal Acquisition Approaches	11
2.1.5 EEG Signal Frequency Spectrum.....	15
2.2 Brain-Computer Interface (BCI) Structure.....	17
2.2.1 BCI System Architecture	17
2.3 EEG Signal Modalities	19
2.3.1 Evoked Potentials Signals	19
2.3.1.1 Steady State Visually Evoked Potentials (SSVEP)	19
2.3.1.2 Event Related Potentials (ERP).....	19
2.3.2 Spontaneous Signals.....	23
2.3.2.1 Sensorimotor Rhythms	23
2.3.2.2 Motor Imagery.....	23