P300 BRAIN WAVE DETECTION USING EMOTIV EPOC HEADSET FOR COMMUNICATION AIDS

By

Fatma El-Zahraa Mohamed Labib Hassan Farag

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Biomedical Engineering and Systems

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Title of Thesis:

P300 Brain Wave Detection using Emotiv Epoc Headset for Communication Aids

Key Words:
BCI; P300; Offline System; Online System; Machine Learning Algorithms

Summary:

The interface way that enables direct link between an external device and the brain is the Brain-computer interface system. Two systems are presented: offline and online systems. Comparing the performance of the various investigated machine learning systems, within the primary dataset it's found that SVM (4th method) and BLDA classifiers yield the best performance for both participants 'A' and 'B'. Dealing with online system, five participants were subjected to different sessions. Two classification methods were employed to detect the target character: (SVM) and (LDA). The feasibility and capability of the Emotiv Epoc neuroheadset to detect the P300 signals is validated by the results.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Fatma El-Zahraa Mohamed Labib Date: ../../…

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Dedication

I would like to dedicate this work to my kind husband Dr. Islam Abdel-Azeem and my lovely kids Mohamed, Fouad, and Sara.

Acknowledgments

I am writing these acknowledgments at the end of my master study journey. I have the pleasure to thank numerous people who contributed to the success of this research in many ways after thanking my God for making this happen, and for all the gifts I have had in my life.

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Nomenclature

ALS	Amyotrophic Lateral Sclerosis
AP	Action Potential
A/D	Analog to Digital
BCI	Brain Computer Interface
BLDA	Bayesian Linear Discriminant Analysis
ECG	Electrocardiography
EEG	Electroencephalograph
EGG	Electrogastrography
EMG	Electromyography
EOG	Electrooculography
ERD	Event Related Desynchronization
ERP	Event Related Potential
fMRI	Functional Magnetic Resonance Imaging
fNIR	Functional Near InfraRed
FT	Fourier Transform
LDA	Linear Discriminant Analysis
MEG	Magnetoencephalography
PET	Positron Emission Tomography
PSP	Postsynaptic
Rbf	Radial Basis Function
SNR	Signal to Ratio
SOFNNs	Self Organizing Fuzzy Neural Networks
SSVEP	Steady State Visual Evoked Potential
SVM	Support Vector Machine
TWSVM	Twin Support Vector Machine

Abstract

The interface way that enables direct link between an external device and the brain is the Brain-computer interface BCI system. This type of interface uses electroencephalography (EEG) which allows the recording of brain activity by focusing on the temporal content of the EEG. These models are event-related and are based on the P300 wave signal, denoted as a potential related event (ERP) aroused in the process of choosing a rare event. This is done using the oddball paradigm, where there is a low probability of obtaining a rare target and a high probability of obtaining a desired target.

In particular, Brain-computer interface allows subjects in whom a degenerative disease has been diagnosed, such as subjects with amyotrophic-lateral sclerosis - ALS, non-muscular communication. In this thesis, two systems are presented: offline and online.

In the presented offline BCI system, two different datasets are handled; the first dataset was posted freely available at 2004 and the second most recent dataset was at 2019. First, a preprocessing step is applied on both datasets to enhance the EEG signal and to extract the important features before applying the proposed machine learning techniques; Linear Discriminant Analysis (two different approaches of LDA), Support Vector Machine (four different approaches of SVM), Twin Support Vector Machine (TSVM), linear regression (LREG), and Bayesian Linear Discriminant Analysis (BLDA).

Comparing the performance of the various investigated machine learning systems, within the primary dataset it's found that SVM (4^{th} method) and BLDA classifiers yield the best performance for both participants 'A' and 'B'. BLDA yields accuracy of 98% and 66% for 15th and 5th sequences respectively, while for 15th and 5th sequences the SVM (4^{th} method) yields accuracies of 98% and 54.4%, respectively. While within the second dataset, it's obvious that BLDA classifier achieves accuracy of 90.115% for both subjects '1' and '2', which yields the best performance.

Dealing with online system, five participants were subjected to different sessions of the 6x6 matrix. The rows and columns of the matrix were randomly flashed at a rate of 200 ms. The experiments were conducted using Emotiv Epoc neuroheadset interfaced with the OpenViBE platform, that is used to run the P300 speller. Two classification methods were employed to detect the target character: Support Vector Machine (SVM) and Linear discriminate analysis (LDA).

The feasibility and capability of the Emotiv Epoc neuroheadset to detect the P300 signals is validated by the results. Additionally, the online results show that participants reached accuracy up to 90% and 70% after only two training sessions for Linear discriminate analysis (LDA) and support vector machine (SVM) classifiers, respectively.

The significance of the suggested system is to demonstrate that such a transportable and affordable headset might be useful to design and implement a robust and reliable online P300-based BCI system. The work discusses the proposed system, compares the classification methods performances, and considers some aspects for the long run work to be handled. The results show high accuracy and fewer computational time.