Machine learning based framework for EEG/ERP analysis

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Introduction

Event Related Potential (ERP) analysis of Electroencephalography (EEG) data has been widely used in research on language, cognition, and pathology [1,2]. The high dimensionality (time × channel × condition) of a typical EEG/ERP dataset makes it a time-consuming prospect to properly analyze, explore, and validate knowledge without a particular restricted hypothesis. This study proposes an automated, empirical, and greedy approach to the analysis process to determine an EEG dataset for the location, robustness, and latency of ERPs, if any present in a given dataset.

Objectives

Provide an automated reliable analysis method that is capable of replicating traditional analysis techniques. The framework should also be capable of reducing averaging requirements and providing insight on main aspects of detected ERP signals.

Framework

Design Scheme

A given EEG/ERP dataset with more than one experimental condition should show a significant difference across latencies and sites that contain information on a differing signal (ERP). This can be attained by simplification to a binary classification problem. Also, this can be extended to classification between experimental groups across a particular set of conditions [3].

Preprocessing

Raw data is filtered, passed through a semi-automated artifact rejection algorithm, corrected for ocular artifacts using ICA, and lastly referenced to linked mastoids. Data is segmented for all relevant stimulus triggers and sorted into experimental conditions.

Feature Extraction

Observations are taken to be a single-trial or an average of 2,4,8, or 16 randomly sampled trials from a class. Features fed into the classification algorithm are the preprocessed amplitudes in addition to the mean, skewness, variance, and kurtosis of said values.

Classification

Linear classification support vector machines [4] using the libsvm (v3.21, [5]) implementation in MATLAB (2016a).

Validation

Monte-Carlo bootstrapping was set to yield 95% confidence intervals on each model's prediction accuracy on the testing set [3].

Framework (Cont.)

Analysis Outputs
- Latency of detected signal across an epoch's time axis
- Topography of signal detected across the scalp utilizing the dense electrode arrays (64+) needed by the proposed framework
- Size and consistency of signal provided by accuracies across both modalities and the five trial-averages per observation settings (see feature extraction)

Significance Criteria
- Accuracies before stimulus presentation is expected to yield chance (50%) and hence is used as a baseline
- Confidence intervals at a significant point must not intersect with respective intervals from the baseline
- Confidence intervals must not intersect with chance accuracy

Datasets

Dataset 1: P300 [6]
- Standard tones (82%)
- 3 deviant types (6% each)
- Active response
- 20 healthy participants

Dataset 2: MMN [7, 2]
- Standard tones (82%)
- 3 deviant types (6% each)
- Passive listening with silent video
- 19 healthy participants

Data Acquisition

EEG was recorded on 64 electrodes placed in accordance with the international 10/20 system using a bandpass of 0.01 Hz to 100 Hz.
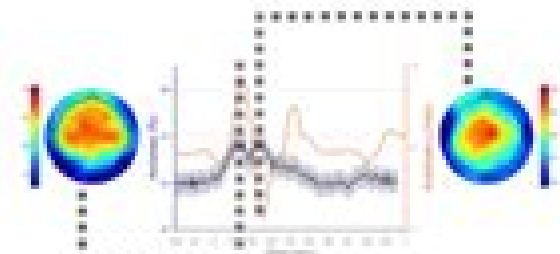
Results

A) P300 dataset

Classification accuracy between frequent deviants and standard tones (blue), with 95% confidence intervals (shaded region), difference wave (red), and the topography accuracy lines based on the two detected peaks corresponding to the MMN (left), and the P300 (right).

Results (Cont.)

B) MMN dataset

Classification accuracy between frequency deviants and standard tones (blue), with 95% confidence intervals (shaded region), difference wave (red), and the topography accuracy lines based on the two detected peaks corresponding to the MMN (left), and the P300 (right).

Discussion

The proposed framework was capable of providing clear indications of the latencies and topographies of ERPs in their respective datasets. The mined information closely followed what can be found in the literature in regards to each of the ERPs in question.

Automatically analyzing the three datasets was also capable of highlighting other discrepancies between tested conditions which would not have been normally detected when using traditional analysis methods.

The analysis scheme produced models capable of accurate discrimination of ERPs utilizing only a small number of trials and minimal use of averaging.

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EEG/ERP Analysis Kamel Nidal,Aamir Saeed Malik,2014-10-23 Changes in the neurological functions of the human brain are often a precursor to numerous degenerative diseases Advanced EEG systems and other monitoring systems used in preventive diagnostic procedures incorporate innovative features for brain monitoring functions such as real time automated signal processing techniques and sophisticated amplifiers Highlighting the US Europe Australia New Zealand Japan Korea China and many other areas EEG ERP Analysis Methods and Applications examines how researchers from various disciplines have started to work in the field of brain science and explains the different techniques used for processing EEG ERP data Engineers can learn more about the clinical applications while clinicians and biomedical scientists can familiarize themselves with the technical aspects and theoretical approaches This book explores the recent advances involved in EEG ERP analysis for brain monitoring details successful EEG and ERP applications and presents the neurological aspects in a simplified way so that those with an engineering background can better design clinical instruments It consists of 13 chapters and includes the advanced techniques used for signal enhancement source localization data fusion classification and quantitative EEG In addition some of the chapters are contributed by neurologists and neurosurgeons providing the clinical aspects of EEG ERP analysis Covers a wide range of EEG ERP applications with state of the art techniques for denoising analysis and classification Examines new applications related to 3D display devices Includes MATLAB codes EEG ERP Analysis Methods and Applications is a resource for biomedical and neuroscience scientists who are working on neural signal processing and interpretation and biomedical engineers who are working on EEG ERP signal analysis methods and developing clinical instrumentation It can also assist neurosurgeons psychiatrists and postgraduate students doing research in neural engineering as well as electronic engineers in neural signal processing and instrumentation *Quantitative EEG Analysis Methods and Clinical Applications* Shanbao Tong,Nitish V. Thankor,2009 This authoritative volume provides an overview of basic and advanced techniques used in quantitative EEG qEEG analysis The book provides a wide range of mathematical tools used in qEEG from single channel discriptors to the interactions among multi channel EEG analysis Moreover you find coverage of the latest and most popular application in the field including mental and neurological disease detection monitoring physiological and cognitive phenomena research and fMRI Neurofeedback and Neuromodulation Techniques and Applications Robert Coben,James R. Evans,2010-11-25 The study of neurofeedback and neuromodulation offer a window into brain physiology and function suggesting innovative approaches to the improvement of attention anxiety pain mood and behavior Resources for understanding what neurofeedback and neuromodulation are how they are used and to what disorders and patients they can be applied are scarce and this volume serves as an ideal tool for clinical researchers and practicing clinicians in both neuroscience and psychology to understand techniques analysis and their applications to specific patient populations and disorders The top scholars in the field have been enlisted and contributions offer both the breadth

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Techniques in Psychophysiology Irene Martin,Peter Henry Venables,1980 EEG Signal Processing Saeid Sanei,Jonathon A. Chambers,2013-05-28 Electroencephalograms EEGs are becoming increasingly important measurements of brain activity and they have great potential for the diagnosis and treatment of mental and brain diseases and abnormalities With appropriate interpretation methods they are emerging as a key methodology to satisfy the increasing global demand for more affordable and effective clinical and healthcare services Developing and understanding advanced signal processing techniques for the analysis of EEG signals is crucial in the area of biomedical research This book focuses on these techniques providing expansive coverage of algorithms and tools from the field of digital signal processing It discusses their applications to medical data using graphs and topographic images to show simulation results that assess the efficacy of the methods Additionally expect to find explanations of the significance of EEG signal analysis and processing with examples and a useful theoretical and mathematical background for the analysis and processing of EEG signals an exploration of normal and abnormal EEGs neurological symptoms and diagnostic information and representations of the EEGs reviews of theoretical approaches in EEG modelling such as restoration enhancement segmentation and the removal of different internal and external artefacts from the EEG and ERP event related potential signals coverage of major abnormalities such as seizure and

mental illnesses such as dementia schizophrenia and Alzheimer s disease together with their mathematical interpretations from the EEG and ERP signals and sleep phenomenon descriptions of nonlinear and adaptive digital signal processing techniques for abnormality detection source localization and brain computer interfacing using multi channel EEG data with emphasis on non invasive techniques together with future topics for research in the area of EEG signal processing The information within EEG Signal Processing has the potential to enhance the clinically related information within EEG signals thereby aiding physicians and ultimately providing more cost effective efficient diagnostic tools It will be beneficial to psychiatrists neurophysiologists engineers and students or researchers in neurosciences Undergraduate and postgraduate biomedical engineering students and postgraduate epileptology students will also find it a helpful reference **How Do Brains Work?** Theodore Holmes Bullock,1993 I ll bet it will turn out that brains use both mechanisms in different centers Much of my waking life and that of many of my friends is spent racking our brains over how brains work This book claims that good science is often a form of betting on the outcome of research the stakes being time and reputation and someone s money Some scientists to be sure claim they avoid leaning this way or that in the name of keeping an open mind I recommend making expectations explicit in order to design controls against unconscious influence formulate alternative outcomes more clearly and to add zest Both the immediately upcoming experiment and the expected result of many long years of work by many people after one is gone are proper subjects for betting or the most informed and serious guessing The working title for this collection of new and old papers was for some time Betting on how brains work and then Betting on brains It goes without saying that the book will not answer the title question but will speak to it in particular making a series of propositions that I think are more likely to be confirmed by future research than the alternatives we can presently recognize It follows that a significant message implied in many chapters of the book is this **Proceedings of the 1992 International Biomedical Engineering Days, August 18-20, 1992, İstanbul, Turkey** Yekta Ülgen,1992 *Third International Conference on Photonics and Imaging in Biology and Medicine* Qingming Luo,2003 **CSA Neurosciences Abstracts** ,1999 *The 13th Convention of Electrical & Electronics Engineers in Israel, Tel Aviv, 22-24 March 1983* ,1983 **Cognitive Neuroscience** Jamie Ward,2009

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