Feature Reduction Using Genetic Algorithm for Cognitive Man-Machine Communication

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ABSTRACT

Electroencephalographic (EEG) signals are usually comprised of high-dimensional feature space. This work aims to assess the effect of reducing the number of features extracted from EEG recordings. A methodology is proposed that combines brain imaging and machine learning techniques to predict the cognitive state of the subjects whether they are feeling themselves in a safe or dangerous environment. The changes in the brain state are correlated with power modulations of oscillatory rhythms in recorded EEG signals called ERD / ERS (Event-related De-synchronization / Synchronization). In order to determine the optimized number of features, Genetic Algorithm (GA) will be used. GA has played instrumental role in solving optimization problems from diverse fields. In various studies and researches for Cognitive Man-Machine Communication, the algorithm has been used as an effective method to extract an optimal set of features.

Keywords: Cognitive Computing, Cognitive Machine Learning, Electroencephalography, Emotiv, Event Related Desynchronization, Event Related Synchronization, Genetic Algorithm, Signal Processing

1. INTRODUCTION

A brain-computer interface (BCI) or a Cognitive man-machine communication interface can be defined as a communication system used to translate the brainwaves of a user into commands interpretable by a computer, bypassing the usual muscular channels. It enables movement-free communication where an EEG signal modulated by the user performing a particular cognitive task e.g., imagined movement or observing visually or auditory stimuli can be used to determine the user’s intent.

The most common method towards BCI is to analyze, categorize and interpret electroencephalographic signals (EEG), in such a way that they alter the state of a machine. The electrical activity of the brain is comprised of six different oscillatory rhythms characterized by their frequency bands. The rhythms are divided on the basis of their frequency ranges and location

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of origin namely delta (less than 4 Hz), theta (4-7 Hz), alpha (8-15 Hz), beta (12- 30 Hz), mu (8-12Hz) and gamma (32+Hz). Numerous existing studies have been performed to explore and investigate the inter-relationship between behavioral decisions and choices and oscillatory dynamics that accompany them (Dähne et al., 2014; Jatupaiiboon, Pan-ngum, & Israsena, 2013).

On the other hand, several existing studies have been reported working on BCI for bio medical applications (Lantz, Grave de Peralta, Spinelli, Seeck, & Michel, 2003; Pfurtscheller, Müller-Putz, Pfurtscheller, & Rupp, 2005). In an application, a subject with complete paralysis of his left hand is equipped with an FES (Functional Electrical Stimulation) system. The system uses electrodes placed on the forearm of the subject, in order to send him an electrical current which forces his muscles to get tense, a task that the subject is not able to perform voluntarily (Pfurtscheller et al., 2005).

The Berlin group in Germany has worked on the development of a BCI based application known as Hex-O-Spell or the P300 speller which is a brain actuated spelling application (Blankertz et al., 2007). In this application, the subject has to control the movement and size of the arrow displayed on the screen using motor imagery to select a cell in a Hexagon consisting of 6 cells where each cell contains a group of letters or a letter.

In order to allow EEGs performed in one laboratory be reproduced in another, the 10-20 system, an international system of electrode placement, was introduced during the 1950s (Herwig, Satrapi, & Schönfeldt-Lecuona, 2003). This system uses several distinctive landmarks to help researchers record EEG signals related to the tasks of interest. Figure 1 shows a top view.

In the proceeding part of this section, various terminologies and concepts associated with EEG based BCIs are discussed. The next section 2 focuses on the problem statement. Along with this, the aim of the proposed work will also be stated. Section 3 describes the proposed methodology and Section 4 covers the conclusion and future directions of the proposed approach.

### 1.1. Event Related Desynchronization / Synchronization

Changes in user intentions or his cognitive state causes either an attenuation or increase in the oscillatory activity termed as Event related Desynchronization and Synchronization (ERD/ERS) respectively. Since its launch, many cognitive studies utilizing the ERD/ERS technique have been performed (Krause, 2006). In one study on a child population, Krause et al. auditorily elicited 4–12 Hz EEG ERD/ERS responses were assessed in children (having average age of 12 years) while they were asked to perform the same auditory cognitive / memory task as previously performed by adult populations. In the lower EEG frequency bands (4–6 Hz, 6–8 Hz, and 8–10 Hz), it was observed that the children’s ERD/ERS responses were different from the adult population especially while retrieving from memory (Krause, Salminen, Sillanmäki, & Holopainen, 2001).

Pesonen et al. conducted a study for dynamic ERD/ERS responses for EEG frequency range between 1–30 Hz during multiple phases of an auditory Sternberg memory scanning task. The ERD/ERS responses were examined and analysed separately for four successive memory tasks and for two conditions of recognition either YES or NO. Power Synchronization i.e. ERS observed in the alpha and theta oscillations accompanied by desynchronization in beta band (Pesonen, Björnberg, Hämäläinen, & Krause, 2006).

The observation from one more study is depicted in Figure 2 that shows the temporal behavior of ERD and ERS during a voluntary movement experiment that involves brisk finger lifting (Nicolas-Alonso & Gomez-Gil, 2012). The mu band desynchronization is initiated at 2.5 s before movement on-set, and then it reaches the maximal ERD just after movement-onset, and recovers its previous level during few seconds. Contrary to this the beta wave shows a short ERD during the initiation of movement, which is followed by synchronization which reaches the highest
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