EEG-based Classification of Epileptic and Non-Epileptic Events using Multi-Array Decomposition

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ABSTRACT

In this paper, the classification of epileptic and non-epileptic events from EEG is investigated based on temporal and spectral analysis and two different schemes for the formulation of the training set. Although matrix representation which treats features as concatenated vectors allows capturing dependencies across channels, it leads to significant increase of feature vector dimensionality and lacks a means of modeling dependencies between features. Thus, the authors compare the commonly used matrix representation with a tensor-based scheme. TUCKER decomposition is applied to learn the essence of original, high-dimensional domain of feature space. In contrast to other relevant studies, the authors extend the non-epileptic class to both psychogenic non-epileptic seizure and vasovagal syncope. The classification schemes were evaluated on EEG epochs from 11 subjects. The proposed tensor scheme achieved an accuracy of 97.7% which is better compared to the spatiotemporal model even after trying to improve the latter by dimensionality reduction through principal component analysis and feature selection.

KEYWORDS

Electroencephalography, Multi-array Decomposition, Multi-linear Data Structures, Seizure-like Events, Tensors

1. INTRODUCTION

One of the most challenging medical cases a clinician usually faces in everyday practice is that of patients reporting episodes of transient loss of consciousness (TLoC or blackout), altered awareness, abnormal limb movements or incontinence. The common causes of such episodes are mainly that of epileptic seizures, possible psychogenic non-epileptic seizures (PNES) and vasovagal syncopal attacks (VVS) (Hoefnagels, Padberg, Overweg, Van der Velde, & Roos, 1991; Moya, et al., 2009). The similar seizure-like reactions of both epileptic and non-epileptic events make their diagnosis a difficult task. In clinical practice, the diagnosis is based on historical information assisted by specific tests (Brigo,
Nardone, & Bongiovanni, 2012). However, since patients may have limited or no recall of the event and a witness report might not be available clinical information can be either missing or fragmented.

Diagnostic uncertainty may have costs in terms of patients’ distress, unnecessary lifestyle changes, social exclusion and financial deprivation associated with hospitalization and repeated investigations (Smith, Defalla, & Chadwick, 1999). In the worst case scenario, a misdiagnosis of epilepsy can result in mistreatment, with potentially important side effects from the use of antiepileptic drugs and also may have significant medical implications if a serious condition remains undiagnosed or untreated. Furthermore, the financial burden on health services accompanied by an incorrect diagnosis is significant. Taking into account the estimated proportion of the worldwide population with active epilepsy (according to WHO, it is estimated between 4 to 10 per 1000 people) and the unnecessary treatment costs, the estimated annual cost of epilepsy misdiagnosis only in England is around £189 million (Chapman, et al., 2011).

The most common diagnostic issue that medical experts routinely deal with, is the differentiation between an epileptic seizure commonly manifested by generalized spike wave discharges (GSW), a psychogenic non-epileptic seizure (PNES) (Krumholz, 1998) and a vasovagal/vasodepressor syncope (VVS) (Lewis, 1932). Figures 1 to 3 show examples of the different epileptic and non-epileptic events investigated in our study.

Figure 1. Generalized Spike Wave (GSW) example. The first marker indicates the beginning of the GSW event and the second marker its end.