Expert Systems with Applications 42 (2015) 3227–3233

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Seizure detection using EEG and ECG signals for computer-based monitoring, analysis and management of epileptic patients

Iosif Mporas [a,*], Vasiliki Tsirka [b], Evangelia I. Zacharaki [a], Michalis Koutroumanidis [b], Mark Richardson [b], Vasileios Megalooikonomou [a]

[a] Multidimensional Data Analysis and Knowledge Management Laboratory, Dept. of Computer Engineering and Informatics, University of Patras, 26500 Rion-Patras, Greece
[b] Dept. of Clinical Neurophysiology and Epilepsies, Guy's & St. Thomas' and Evelina Hospital for Children, NHS Foundation Trust/King's College, London, United Kingdom

ARTICLE INFO

Article history:
Available online 12 December 2014

Keywords:
Seizure
Electroencephalogram
Electrocardiogram
Support vector machines

ABSTRACT

In this paper a seizure detector using EEG and ECG signals, as a module of a healthcare system, is presented. Specifically, the module is based on short-time analysis with time-domain and frequency-domain features and classification using support vector machines. The seizure detection module was evaluated on three subjects with diagnosed idiopathic generalized epilepsy manifested with absences. The achieved seizure detection accuracy was approximately 90% for all evaluated subjects. Feature ranking investigation and evaluation of the seizure detection module using subsets of features showed that the feature vector composed of approximately the 65%-best ranked parameters provides a good trade-off between computational demands and accuracy. This configurable architecture allows the seizure detection module to operate as part of a healthcare system in offline mode as well as in online mode, where real-time performance is needed.

1. Introduction

More than fifty million people worldwide, approximately 1% of the world population, suffer from epilepsy, which is the third most common neurological disorder in the United States after Alzheimer's disease and cerebrovascular events (Hauser, 1997). Moreover, more than 30% of the epileptic patients suffer from seizures that are refractory to medication (Kwan & Brodie, 2000). Epilepsy can directly influence patients' quality of life because of treatment-related side effects, cognitive and particularly memory dysfunction or injuries associated to seizures, potential psychiatric co-morbidities and social isolation due to stigma, especially when it runs as a long term disease (Begley et al., 2000). Moreover, there are indications that the members of the family or the caregivers of patients are also experiencing multiple psychological or social difficulties in the form of depression and social restriction (Ellis, Upton, & Thompson, 2000). Apart from these negative effects to personal and social parameters of life, the high annual budget spent for the healthcare activities related to the cost of investigation, treatment and hospitalization of epileptic patients cannot be disregarded (Ali, Elliott, & Tata, 2014; Begley et al., 2010; Hunyadi et al., 2012). The highly negative socioeconomic impact of epilepsy justifies the need for further investigation and development of technology-supported diagnostic and therapeutic systems.

This disease is manifested through recurrent epileptic seizures, resulting from an abnormal synchronous activity in the brain involving a large network of neurons (Le Van Quyen et al., 2005; Valderrama, Nikolopoulos, Adam, Navarro, & Le Van Quyen, 2010). The epileptic seizures are not randomly occurring events but they are instead the product of highly non-linear dynamics in the brain circuits evolving over time (Corsini, Shoker, Sanei, & Alarcon, 2006). The underlying process of seizures occurrence is not completely understood yet, thus making their study and prediction a difficult task (Corsini et al., 2006; Mohseni, Maghsoudi, & Shamsollahi, 2006).

The progress of technology over the last decades has provided the means for shifting from qualitative to quantitative clues, related to the unknown process that produces a seizure. Seizure investigation is mainly performed with quantitative analysis of the electroencephalogram (EEG) (Gotman, 1982; Nasehi & Pourghassem, 2012; Tong & Thankor, 2009; Valderrama et al., 2010). The detection of epileptic seizures is based on visual analysis of the multidimensional EEG signal (typically consisting of time-synchronous recordings captured from a 10–20 scalp electrodes system), which is performed manually by expert neurologists for the detection of patterns of interest such as spikes or spike wave complexes (Mohseni et al., 2006). This procedure is

* Corresponding author.
E-mail address: imporas@upatras.gr (I. Mporas).

http://dx.doi.org/10.1016/j.eswa.2014.12.009
0957-4174/