Evaluation of Time and Frequency Domain Features for Seizure Detection from Combined EEG and ECG signals

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ABSTRACT
In this paper, a large scale evaluation of time-domain and frequency domain features of electroencephalographic and electrocardiographic signals for seizure detection was performed. For the classification we relied on the support vector machines algorithm. The seizure detection architecture was evaluated on three subjects and the achieved detection accuracy was more than 90% for two of them and slightly lower than 90% for the third subject.

Keywords
Seizure, electroencephalogram, electrocardiogram, support vector machines.

1. INTRODUCTION
Approximately 1% of the world population suffers from seizures, while more than 20% of the epileptic patients suffer from seizures that are refractory to medication [1, 2]. Epilepsy is manifested through recurrent seizures, resulting from an abnormal synchronous activity in the brain involving a large network of neurons [3]. 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 [4]. The underlying process of a seizure occurrence is not completely understood yet, thus making the study and prediction of it a difficult task [4, 5].

Over the last decade clues to the unknown process that produces seizure have began to emerge from quantitative analysis of the electroencephalogram (EEG) [2, 4]. The detection of epileptic seizures is based on visual analysis of the multidimensional EEG signal (usually consisting of time-synchronous recordings of more than 20 electrodes), which is performed manually by expert neurologists for the detection of patterns of interest such as spikes or seizures [5]. This procedure is tedious, time-consuming (especially for long time recordings) and expensive since investigation from experts is needed. Furthermore, due to the lack of knowledge on the seizure formation mechanism the annotation and labeling of the EEG signals is highly subjective and thus in many cases there is disagreement between expert neuroscientists for the same recording.

Additionally to the EEG signals, it has been shown that seizures are often associated with cardiovascular and respiratory alterations [4, 6, 7, 8, 9]. Specifically, the study of electrocardiographic (ECG) signals can offer valuable information related to the seizure discharges [4]. Due to the difficulty of manual investigation of multiparametric recordings (in this case time-synchronous EEG and ECG) and in combination with the progress of signal processing and pattern recognition technology, approaches for automatic detection of seizures have been proposed in the literature.

In most of the parametric approaches found in the literature the analysis is based on the estimation of the EEG channels' spectral magnitude [4, 5, 6, 7]. Other EEG features that have been reported are the autoregressive filter coefficients, the continuous and discrete wavelet transform, as well as energy per brain wave (delta, theta, alpha, beta, gamma) bands [4, 6]. In addition, time domain features have been proposed, such as zero-crossing rate [3] and statistics of the EEG samples per channel [4, 6]. The ECG features are mainly based on the heart rate estimation (based on R-R intervals) and statistics of it, i.e. heart rate variability [4, 6, 7, 8, 9]. Morphological features of the ECG signal have also been used [8].

Several powerful machine learning algorithms have been proposed in the literature for detection of seizures. The most widely used are the artificial neural networks [5, 6], the support vector machines [1, 3, 4], and other less popular methods [6, 7, 8, 10].

In this paper we evaluate a large scale set of time-domain and frequency domain EEG and ECG features for seizure detection. This evaluation is part of ongoing work for constructing online and offline tools for seizure detection and analysis for the needs of the ARMOR project [11]. The rest of this paper is organized as