Applied Computing and Informatics (2016) **12**, 70–89

Saudi Computer Society, King Saud University

Applied Computing and Informatics

(http://computer.org.sa)
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ORIGINAL ARTICLE

A machine learning system for automated whole-brain seizure detection

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Received 13 October 2014; revised 27 January 2015; accepted 27 January 2015
Available online 9 February 2015

KEYWORDS

Seizure;
Non-seizure;
Machine learning;
Classification;
Electroencephalogram;
Oversampling

Abstract Epilepsy is a chronic neurological condition that affects approximately 70 million people worldwide. Characterised by sudden bursts of excess electricity in the brain, manifesting as seizures, epilepsy is still not well understood when compared with other neurological disorders. Seizures often happen unexpectedly and attempting to predict them has been a research topic for the last 30 years. Electroencephalograms have been integral to these studies, as the recordings that they produce can capture the brain's electrical signals. The diagnosis of epilepsy is usually made by a neurologist, but can be difficult to make in the early stages. Supporting para-clinical evidence obtained from magnetic resonance imaging and electroencephalography may enable clinicians to make a diagnosis of epilepsy and instigate treatment earlier. However, electroencephalogram capture and interpretation is time consuming and can be expensive due to the need for trained specialists to perform the interpretation. Automated

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.aci.2015.01.001

detection of correlates of seizure activity generalised across different regions of the brain and across multiple subjects may be a solution. This paper explores this idea further and presents a supervised machine learning approach that classifies *seizure* and *non-seizure* records using an open dataset containing 342 records (171 *seizures* and 171 *non-seizures*). Our approach posits a new method for generalising seizure detection across different subjects without prior knowledge about the focal point of seizures. Our results show an improvement on existing studies with 88% for *sensitivity*, 88% for *specificity* and 93% for the area under the curve, with a 12% global error, using the *k-NN* classifier.

1. Introduction

Epilepsy is a chronic condition of the brain, and causes repeated seizures, commonly referred to as fits. Epilepsy is said to affect 70 million people worldwide [19]. The risk of developing epilepsy is greatest at the extremes of life with incidences more common in the elderly than the young [18] and is the cause of premature mortality for those suffering with the condition [19].

Seizures can be focal (partial) and exist in one part of the brain only, or they can be general and affect both halves of the brain. During a focal seizure, the person may be conscious and unaware that a seizure is taking place, or they may have uncontrollable movements or unusual feelings and sensations. A diagnosis of epilepsy is made with the help of an electroencephalogram (EEG). *EEG* recordings are commonly visualised as charts of electrical energy produced by the brain and plotted against time [16].

The majority of previous works on seizure detection and prediction have focused on patient-specific predictors, where a classifier is trained on one person and tested on the same person [13,10,25,26,63,9]. In this paper, the emphasis is on using EEG classification to generalise detection across all regions of the brain using multiple subject records.

A whole-brain seizure detection approach supports para-clinical evidence obtained from magnetic resonance imaging and EEG to make a diagnosis of epilepsy and instigate treatment earlier. It helps to mitigate the difficulties associated with the capture and interpretation of electroencephalogram by neurologists. In this paper, a robust data processing methodology is adopted and several classifiers are trained and evaluated, using 342 EEG segments extracted from the EEG records of 24 patients suffering with epilepsy.

The structure, of the remainder, of this paper is as follows. Section 2 describes the underlying principles of EEG and the type of features extracted from EEG signals. Section 3 discusses machine learning and its use in *seizure* and *non-seizure* classification, while Section 4 describes the evaluation. The results are discussed in Section 5 before the paper is concluded in Section 6.