Available online at www.sciencedirect.com
ScienceDirect
Applied Soft Computing 7 (2007) 343–352
Applied Soft Computing
www.elsevier.com/locate/asoc

Genetic programming for epileptic pattern recognition in electroencephalographic signals

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Received 27 September 2004; received in revised form 12 May 2005; accepted 11 July 2005

Abstract

This paper reports how the genetic programming paradigm, in conjunction with pattern recognition principles, can be used to evolve classifiers capable of recognizing epileptic patterns in human electroencephalographic signals. The procedure for feature extraction from the raw signal is detailed, as well as the genetic programming system that properly selects the features and evolves the classifiers. Based on the data sets used, two different epileptic patterns were detected: 3 Hz spike-and-slow-wave-complex (SASWC) and spike-or-sharp-wave (SOSW). After training, classifiers for both patterns were tested with unseen instances, and achieved sensibility = 1.00 and specificity = 0.93 for SASWC patterns, and sensibility = 0.94 and specificity = 0.89 for SOSW patterns. Results are very promising and suggest that the methodology presented can be applied to other pattern recognition tasks in complex signals.

Keywords: Genetic programming; Pattern recognition; Epilepsy; EEG

1. Introduction

According to the World Health Organization (WHO) [1], up to 5% of the world population may have some kind of epileptic event during lifetime. Epilepsy is the commonest neurological disorder of the brain and its incidence is not limited to a specific age, race or geographical location. Epilepsy can have several physical, psychological and social consequences, including mood disorders, injuries and sudden death. When correctly diagnosed, up to 70% of epileptic patients can respond satisfactory to the clinical treatment. Thus, efforts toward its diagnosis and treatment are always of great importance.

This paper has a multidisciplinary nature, in the crossroads of evolutionary computation, pattern recognition and biomedical signal processing. It is reported the application of the genetic programming (GP) paradigm [2] to evolve a classifier capable of recognizing epileptic patterns in human electroencephalogram (EEG) signals recorded from the scalp of real patients. This work was also motivated by the difficulty in the interpretation of clinical EEG tests.

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1568-4946/$ – see front matter
doi:10.1016/j.asoc.2005.07.004

Hopefully, this method can be useful in the automatic detection of epileptic events, not only in the clinical setting, but also in long-term electroencephalographic monitoring.

Since around the 1980s, many researchers have proposed methods for the quantitative analysis of the EEG. Many statistical, syntactic or artificial intelligence based techniques were used for pattern recognition, together or not with a variety of digital signal processing methods. Due to the complexity of the task, up to now, no method yet gave a widespread support to identify consistently every possible pattern of interest in the EEG. Therefore, proposed methods are usually applied to particular patterns or conditions. Some works related to the detection of epileptic events in the EEG are cited below. There is no intention to compare methods themselves or them with the current work, but it is interesting to illustrate the diversity of techniques previously used.

Many different approaches of neural networks to detect epileptic patterns in the EEG were reported, for instance, using simple multilayer perceptrons [3], simple Kohonen maps [4], or self-organizing maps with time–frequency analysis techniques [5,6]. Adaptive filtering based on digital signal processing techniques were used by Stelle [7]. Wavelets were used by Khan and Gotman [8], and also by Geva and Keren [9], who hybridized wavelets with fuzzy techniques. Gotman and co-workers [10,11] have proposed an heuristic mathematical method, based on the graphical similarity between EEG patterns that has been cited frequently in the literature.

The objective of this work is to present a methodology for pattern recognition, based on classifiers evolved by using genetic programming. The paper is organized as follows: first, an brief description of EEG and epileptic patterns is presented so as to allow readers to understand the nature of the application. Then, some basic aspects of the genetic programming are presented, since this is the technique used for problem solving. Next, it is described in detail the methodology for the application of GP to pattern recognition, including database handling, data reduction and supervised training. In the sequence, results of the application of the proposed methodology for two different epileptic patterns are shown. Finally, results are discussed and conclusions are drawn, pointing future directions of research and other possible applications.

2. Epilepsy and electroencephalography

The EEG signal is the recording of the electric activity of the brain at the scalp, usually taken concurrently with several electrodes. The EEG is a very complex and nonstationary signal and its characteristics are spatio-temporal dependent. The EEG is different at every point of the scalp where it is being recorded, and it is function of the underlying brain activity of the region. Although nonstationary, the EEG can be divided into epochs in which its statistical properties are reasonably constant, according to some specific criteria [12]. This is a key point since, in this work, the analysis of the EEG is based on predefined epochs in which the pattern of interest can be present.

EEG may be rich of different patterns that are superimposed with the background activity and noise from many sources, like the electrooculogram, the electromyogram and movement artifacts. Many diseases and clinical conditions can induce specific categories of patterns in the EEG, as well as normal events like mental activity, sleeping and eyes closure. Due to the large biological variability from individual to individual and other environmental influences, little progress has been done in establishing clear patterns found in the EEG [13]. Notwithstanding, the analysis of the EEG is still a valuable diagnostic procedure for the clinician. The EEG is helpful in the diagnosis of many diseases related to the central nervous system, and particularly, to epilepsy. Briefly, epilepsy can be defined as an excessive and uncontrolled activity of part (or the whole) of the central nervous system. Epileptic seizures can be caused by several diseases, mainly in the brain, as well as brain damage due to external injury or tumor. Also, some extra-cerebral transitory events like prolonged fever, hyperventilation or hypoglycemia, eventually can lead to epileptic seizures [14].

Epileptic seizures can cause a large variety of patterns in the EEG, and there is no general method for their identification. The objective of this work is to detect some particular epileptic patterns in the EEG. Amongst many different types of epileptic patterns, two categories of such patterns are focused: the 3 Hz spike-and-slow-wave-complex (SASWC) and the spike-or-sharp-wave (SOSW). The first case is well-known as characteristic of the ''petit-mal'' epilepsy, and the