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Computers in Biology and Medicine 36 (2006) 195–208

Computers in Biology and Medicine

www.intl.elsevierhealth.com/journals/cobm

Comparison of subspace-based methods with AR parametric methods in epileptic seizure detection

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Received 8 March 2004; accepted 1 November 2004

Abstract

Electroencephalography is an important clinical tool for the evaluation and treatment of neurophysiologic disorders related to epilepsy. Careful analyses of the electroencephalograph (EEG) records can provide valuable insight and improved understanding of the mechanisms causing epileptic disorders. The detection of epileptiform discharges in the EEG is an important component in the diagnosis of epilepsy. In this study, we have proposed subspace-based methods to analyze and characterize epileptiform discharges in the form of 3-Hz spike and wave complex in patients with absence seizure. The variations in the shape of the EEG power spectra were examined in order to obtain medical information. These power spectra were then used to compare the applied methods in terms of their frequency resolution and the effects in determination of epileptic seizure. Global performance of the proposed methods was evaluated by means of the visual inspection of power spectral densities (PSDs). Graphical results comparing the performance of the proposed methods with that of the autoregressive techniques were given. The results demonstrate consistently superior performance of the proposed methods over the autoregressive ones.

Keywords: EEG; Epileptic seizure; Spectral analysis; Burg; Yule–Walker; MUSIC; Eigenvector

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doi:10.1016/j.compbiomed.2004.11.001

1. Introduction

About 1% of the people in the world suffer from epilepsy and 30% of epileptics are not helped by medication [1]. Research is needed for better understanding of the mechanisms causing epileptic disorders. Careful analyses of the electroencephalograph (EEG) records can provide valuable insight into this widespread brain disorder. The detection of epileptiform discharges occurring in the EEG between seizures is an important component in the diagnosis of epilepsy. In this work, two autoregressive (AR) methods (Burg and Yule–Walker), and two subspace-based methods (Multiple signal classification, and eigenvector methods) were used to analyze epileptiform discharges in recorded brain waves (EEG) for patient with absence seizure (petit mal). Absence seizure is one of the main types of generalized seizures and the underlying pathophysiology is not completely understood. Neurologists make the absence seizure epileptic diagnosis primarily through visual identification of the so-called 3-Hz spike and wave complex [1].

Performing EEG analysis by human readers is a time-consuming, high-cost activity, thus devising programs for semi-automatic analysis started a number of years ago. When treating epileptic pathologies, the development of dynamical, long-term EEG recording techniques has allowed to detect sporadic events and to evaluate the percentage of critical episodes during all-day activity. On the other hand, such long EEG recordings have enlarged the amount of data to be analyzed, thus increasing the demand for automatic analysis devices. Since the early days of automatic EEG processing, representations based on a Fourier transform have been most commonly applied. This approach is based on earlier observations that the EEG spectrum contains some characteristic waveforms. A number of spectral estimation techniques have recently been developed and have been compared to the more standard fast Fourier transform (FFT) method that have been widely studied in the literature [1,3–5]. AR spectra can be computed by different algorithms such as the Burg method and Yule–Walker method [3–8]. So far subspace-based methods have been used for estimating frequencies of different signals. Multiple signal classification (MUSIC) [8–17], and eigenvector [17–21] methods are subspace-based methods that can be used for obtaining PSD estimates of signals.

In this study, we have proposed subspace-based methods for determination of epileptic seizure. PSDs of EEG signals obtained from healthy and unhealthy (epileptic patient) subjects were computed by using subspace-based methods. Burg AR, Yule–Walker AR, MUSIC, and eigenvector methods were compared with each other in terms of their frequency resolution and the effects in determination of epileptic seizure.

2. Materials and method

2.1. Subject and data acquisition

The EEG data used in our study was downloaded from 24 h EEG recorded from both epileptic patients and normal subjects. The following bipolar EEG channels were selected for analysis: F7-C3, F8-C4, T5-O1 and T6-O2 (Fig. 1). In order to assess the performance of the classifier, we selected 500 EEG segments containing spike and wave complex, artifacts, and background normal EEG. Twenty absence seizures (petit mal) from five epileptic patients admitted for video-EEG monitoring were analyzed. EEG signals recorded from a patient with absence seizure epileptic discharge is shown in Fig. 2, and normal EEG signal is shown in Fig. 3. The subjects consisted of three males and two females, age 28.87 ± 15.27