Epileptic Seizure Detection: Approximate Entropy and Discrete Wavelet Transform based method

Tarek LAJNEF*, Sahbi CHAIBI*, Abdennaceur KACHOURI** & Mounir SAMET

*National School of Engineering of Sfax, Research Laboratory on Electronics and information Technologies: LETI, Sfax, TUNISIA
lajnef.tarek@gmail.com
ciahbi.sahbi@yahoo.fr
Mounir.Samet@enis.rnu.tn

**Higher Institute of industrial systems of Gabes
Abdennaceur.Kachouri@enis.rnu.tn

Abstract: Epilepsy is one of the most common neurological disorders and affects almost 60 million people worldwide; many techniques were used to detect epileptic seizures in the EEG recording. In this study we have implemented the new non linear epileptic seizure detection, proposed by H.Ocak, the method is based on discrete wavelet analyse and Approximate Entropy. The detection technique is divided on four steps, the data is firstly divided on different epochs, and secondly a third level DWT decomposition was used. Then ApEn values were computed for D1 level in both normal and epileptic EEG, finally a threshold is used to detect epileptic activity. Epochs with ApEn values less then threshold (1.7) are considered as epileptic ones. Two data bases were used in this study; the first one is an EEG record for epileptic patient and the second is for a normal subject. The mean values of ApEn were respectively 1.3177 and 1.9138. The results obtained, led us to conclude that epileptic epochs are much predictable (less complex) then normal ones.

Key words: Approximate entropy, DWT, EEG, Epilepsy,

INTRODUCTION

Epilepsy is one of the most common neurological disorders and affects almost 60 million people worldwide. The International League Against Epilepsy (ILAE) and the International Bureau for Epilepsy (IBE) defines an epileptic seizure as “a transient occurrence of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity in the brain”, [ILAE 05a] Since its invention in 1929 by Hans Berger, the electro encephalogram (EEG) record, witch is a summation of electrical activities generated by cortical neurons, have been widely used in epilepsy seizure detection. Since these records are a long, visual detection becomes more difficult, so it is increasingly necessary to develop a practically applicable method to detect epileptiform waves automatically.

The first automatic analysis of interictal spikes in epilepsy patients was proposed by Gotman and Gloor in 1976 using mimetic based method then a multitudes of techniques were used; (i) techniques based on time domain analyse, (autocorrelation in the eeg record [Liu, A. 92]) , (ii) frequency domain techniques (finding the difference between normal and epileptic frequency domain [Gotman, J 97]) (iii) time frequency domain; (specially wavelet analyse [Latka M 03]) , (iv) Artificial neural networks [Gabor AJ 96], and (v) non linear measures techniques; correlation dimension (CD), largest Lyapunov exponent (LLE) and approximate entropy (ApEn), Renyi entropy [N. Mammon 08a] these values reflect the complexity and predictably of EEG records. [Kannathal, N 05b ]

In this study we try to implement the technique proposed by H.Ocak [H.Ocak 09], using two different data bases of both epileptic and normal EEG record. The technique is based on a multilevel DWT decomposition of epochs extracted from the data base used, unlike Ocak study, the choice of wavelet function and level was based on study done by (K.P. Indiradevi, 2007), then the complexity of the sub bands is analysed using Approximate Entropy (ApEn).

1. Approximation entropy

Approximate entropy (ApEn) is a recently developed statistic quantifying regularity and complexity that appears to have potential application to a wide variety of physiological and clinical time-series data. To compute the ApEn of a time series, x[i], i = 1, . . . , N, first the state vectors in the embedding
space, $R^m$, is constructed using the method of delays,

$$x_i = \{y_{i}, y_{i+\tau}, y_{i+2\tau}, \ldots, y_{i+(m-1)\tau}\}; \quad (1)$$

$$1 \leq i \leq N - (m - 1)\tau$$

Where $m$ and $\tau$ are the embedding dimension and time delay, respectively.

Next, we define for each $i$,

$$C^m_i(r) = \frac{1}{N - (m - 1)\tau} \sum_{j=1}^{N - (m - 1)\tau} \theta(r - d(x(i), x(j))) \quad (2)$$

where $h(x) = 1$ for $x > 0$, $h(x) = 0$, otherwise is the standard Heavy side function, $r$ is the vector comparison distance and $d(x(i), x(j))$ is a distance measure defined by,

$$d(x(i), x(j)) = \max_{k \in \{1, 2, \ldots, m\}} |x(i + (k-1)\tau) - x(j + (k-1)\tau)| \quad (3)$$

Then, we define $\Phi^m(r)$ as,

$$\Phi^m(r) = \frac{1}{N - (m - 1)\tau} \sum_{i=1}^{N - (m - 1)\tau} \log(C^m_i(r)) \quad (4)$$

For fixed $m$, $r$ and $\tau$, ApEn is given by the formula

$$ApEn(m, r, \tau, N) = \Phi^m(r) - \Phi^{m+1}(r) \quad (5)$$

Which is basically the logarithmic likelihood that runs of patterns of length $m$ that are close (within $r$) will remain close on next incremental comparisons.

2. Methods

2.1 Databases

The data base we use in this study is an EEG recording for an epileptic patient done at Katholieke Universities Leuven (KUL) (Belgium) in collaboration with the department of Clinical and Experimental Neurology, available in their web site [De Clercq 06- Vergult, A 07a].

A second database used in this study is token from the eeglab databases available for free download on their web site, this data is an EEG recording for heathy person doing a visual task, the data were sampled at 250Hz [Delorme A 07b].

2.2 Spike detection

Given an epileptic signal $s(t)$, the process of spike detection with Approximate Entropy used by (H.Ocak 2009) can be described in fig1.

(I): to , EEG data, (from one electrode) is divided on 30 epochs, as the data base contain 600sec of EEG recording, then every epochs contain 5000 sample (250 Hz sampling rate)

(II): then, the epochs were analysed using DWT transform.

(III): after that, values of the approximation and detail coefficients at each level of the wavelet decomposition were computed.

(VI): finally, a threshold is used to detect epileptic activity.

2.2.1 DWT pre-processing

In order to choose the basis function that matches the spike shape, a correlation between different basis functions and spike shape, was described by K.P. Indiradevi, [K.P. Indiradevi 07c]. The highest correlation coefficients were found for the daubechies4 functions, in this study, third level of wavelet decomposition is used, for both epileptic and normal EEG epochs. The structure for this wavelet decomposition along with the corresponding frequency bands of the approximations and detail coefficients at each level are presented in Fig.2. Approximation and detail coefficients of sample EEG epochs taken from both data1 (epileptic data), and data2 (normal data) are presented in Fig.3 and Fig.4, respectively.

Figure 2: Third level wavelet decomposition of the signal
Figure 3: Wavelet decomposition of a sample EEG epoch during seizure activity
(Respectively, EEG data, A3, D1, D2, D3)

Figure 4: Wavelet decomposition of a sample EEG epoch for normal data
(Respectively, EEG data, A3, D1, D2, D3)
2.2.2 ApEn analyse

ApEn values of the approximation and detail coefficients at each level of the wavelet decomposition for the two data base were computed. For computing the ApEn, the embedding dimension (m), vector comparison distance (r) and time delay (s) were set to 2, 0.15 times the standard deviation of the data and 1, respectively based on suggestions by Pincus [Pincus, S. M. 91].

Spike detection is done then by applying a threshold value (1.7) [H.Ocak 09], epochs with ApEn less then threshold are considered us epileptic activity.

3. Results

As shown in Fig2, third level DWT decomposition of our data allows decomposing the EEG data into 6 sub bands frequency ; A1(0-62.5 Hz), A2(0-31.5Hz), A3(0,15.625 Hz), D1(62.5_125 Hz), D2(31.25-62.5 Hz) and D3(15.625-31.25 Hz).

As H.Ocak, proved [H.Ocak 09], D1 outperformed all the other sub-bands in separating epileptic activity in the first data set, witch can be clearly seen in Fig 3.

Then, ApEn values for the D1 sub bands, was computed, in both epileptic data base and normal one, Fig 5 and Fig 6 illustrate the ApEn values for D1 coefficients of the 26 epochs of the normal and Epileptic EEG, respectively, values less then the threshold plotted on the same figure (1.7) are considered as epileptic activity.

The mean ApEn value for the epileptic EEG is 1.3177 however this value was 1.9138 for the normal one, witch means that epileptic EEG is more predictable (less complex) then the normal one.

4. Conclusion

Several automatic seizure detection techniques were used to overcome the difficulty in visual seizure detection in long term EEG recording. In this study we have implemented a technique based on non linear analyse of both normal and epileptic EEG records; the results led us to conclude that epileptic activity is less complex then normal one. Since that we can simply use an appropriate threshold to detect epileptic activity. Epochs with ApEn values less then threshold are considered as epileptic activity, in this study the mean value of the ApEn for epileptic data was 1.3177 however this value was 1.9138.

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