Reccurence plots parameters during epileptic seizure patterns onset

Anton Popov, Oleksandr Topikha

Biomedical Electronics and Signal Analysis Group,
Physical and Biomedical Electronics Department, National Technical University of Ukraine "Kyiv Polytechnic Institute",
off. 423, Politekhnichna Str., 16, Kyiv, 03056, Ukraine,
E-mail: anton.popov@ieee.org

***Abstract* – The purpose of the paper is to investigate the applicability of recurrence plots paremeters for early detection of epileptic seizures. Trends of Recurrence Rate and Determinism of electroencephalogram recurrence plots are calculated for different time windows. Experiments show that both parameters start to grow approximately 250 seconds in advance of epileptic seizure activity onset for time window of 5 minutes.**

Key words – epilepsy, seizure prediction, recurrence plots.

I. Introduction

Epilepsy is one of the most common neurologic disorders worldwide. It is characterized by repeated unpredictable seizures caused by excessive abnormal synchronous activity of neuronal groups in the brain. Clinical manifestations of epilepsy are unforeseen and abrupt motor phenomena, loss of consciousness, psychic and sensory symptoms etc., causing the low everyday life quality of sufferers. Despite the availability of variety of antiepileptic drugs, one third of patients have intractable seizures. Due to this fact, the need for automated techniques for epileptic seizures prediction and control is of great interest [1]. The most widespread way to analyze brain functioning in healthy and epileptic conditions is to apply various signal analysis techniques to the electroencephalogram (EEG) signal.

This paper is aimed to demonstrate the application of EEG reccurence plots analysis to the prediction of seizure onset.

II. Detection of epileptic patterns using recurrence plots

Reccurence plot (RP) is the graphical tool allowing to explore the *m*-dimensional phase space trajectory of the nonlinear system through a two-dimensional representation of its recurrence and, therefore, to see a dynamic picture. This approach was introduced in [2, 3] and is used in the investigations of nonlinear systems parameters and behavor.

Let point $x(i)$ corresponds to *i*-th point of the phase trajectory ($i = 1...N$) describing dynamical system in *m*-dimensional space. Then recurrence plot for this system is an array of $N \times N$ elements, where a nonzero element with the coordinates (i, j) corresponds to the case when $x(i)$ is sufficiently close to $x(j)$.

The closeness between different paiont in phase space is usually depicted by the black and white points on the recurrence picture, where black color corresponds to the presence of reccurence (closeness of system states in phase space) and white color means that the states of the system are signifacanltly different. Reccurence of the states is defined by

$$R_{j,i} = \theta(\varepsilon_i - \left\| x(i) - x(j) \right\|),$$

where $x(i) \in L^m$, $i, j = 1...N$, ε_i – minimal distance between pionts interpreted as a radius of *m*-dimentional sphere around the points in phase space, $\|\cdot\|$ – norm, $\theta(\cdot)$ – Heaviside step function.

To characterize the system behaviour a number of recurrence plots parameters are proposed, see e.g. [4-6]. They are used to go beyond visual inspection of the plots and to measure the complexity of underlying system. In this paper the following are used to study possibility of epileptic seizures pattern prediction:

– *Reccurence rate*

$$RR = \frac{1}{N^2} \sum_{i,j=1}^{N} R_{i,j}^{m,\varepsilon} ;$$

– *Determinism* of the system

$$DET = \frac{\sum_{l=l_{\min}}^{N} lP(\varepsilon, l)}{\sum_{l=1}^{N} lP(\varepsilon, l)},$$

where

$$P(\varepsilon, l) = \sum_{i,j=1}^{N} \left(1 - R_{i-1,j-1}(\varepsilon)\right)\left(1 - R_{i+l,j=l}(\varepsilon)\right) \prod_{k=0}^{l-1} R_{i+k,j+k}(\varepsilon).$$

The aim of experimental part is to investigate the applicability of recurrence plots paremeters for early detection of epileptic seizures. Example of one EEG channel containing burst of seizure activity is given in Fig.1. Seizure is started after 1850 second on this fugure and characterized by the change in EEG magnitude without significant alternation of oscilatory behavior. The onset of seizure activity should be predicted as early as possible before changes.

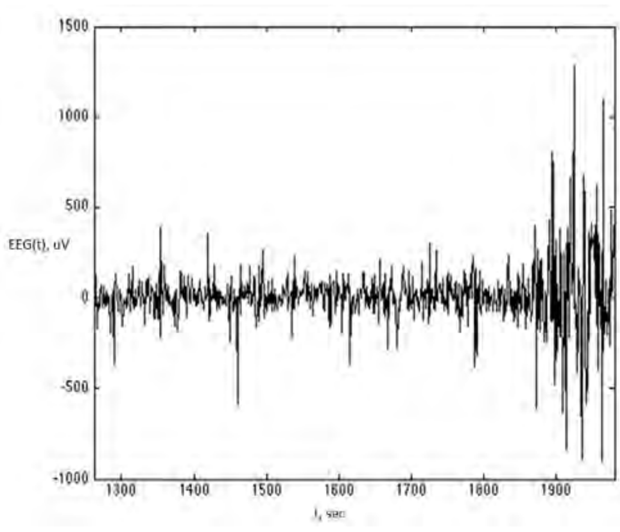

Fig. 1. Part of one EEG channel with seizure activity

III. Experimental Results

The main idea of the presented work is to find out if the chosen RP parameters change their value prior to the siezure onset. For this purpose the EEG signals containing epileptic patterns were selected from public available database [7].

To study the RP parameters trends, several time windows were chosen (durations from 1 second to 5 minutes) and RP parameters were calsulated in sliding windows. Resulting plots are given in Fig. 2-3 for window duration of 1 second, and for 5 min. window.

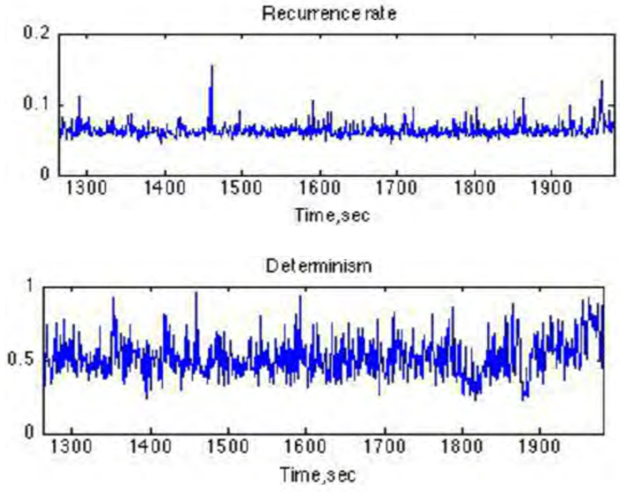

Fig. 2. RP parameters for window of 1 sec duration

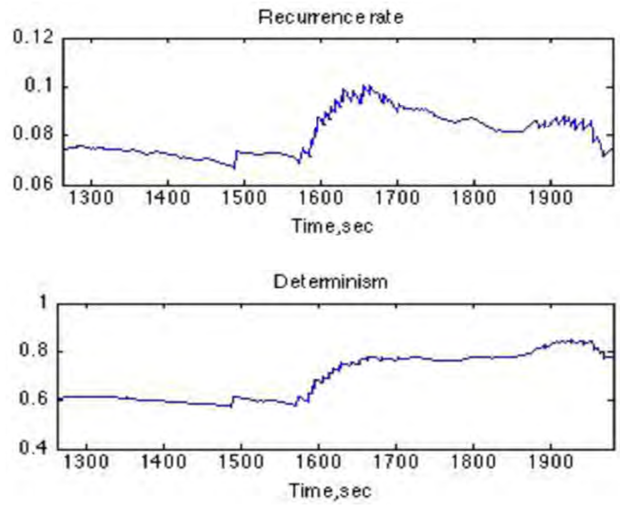

Fig. 3. RP parameters for window of 5 minutes duration

It can be seen that depending on the time window duration, the trends of the parameters value are different. In case of 1 sec. there is no change in parameters neither before seizure nor during siezure. The behavior is the same for both recurrence rate and determinism, thus these parameters cannot be used for prediction and even for detection of seizure onset.

The opposit behaviour occures for the case whet time window is 5 minutes. There are prominent change in RP parameters values for both recurrence rate and determinism: thy start to grow approximately 250 seconds in advance of seizure onset and keeps large up to the seizure time. This time period is sufficient to forestall the epileptic seizure.

The drawback in this approach is significant time for calculations of RP parameters, thus further research is needed to adjust recurrence plots parameters calculation procedure and investigate other parameters feasible for epileptic seizure prediction.

Conclusion

In this paper recurrence plots of EEG signals containing epileptic patterns were obtained and their parameters were calculated in sliding time window during background activity and seizure onset. It is shown that some parameters, namely recurrence rate and determinism of reccurence plots have changed drastically prior to the seizure onset and thus are promising for epileptic seizures prediction.

References

[1] L.D. Iasemidis, “Epileptic seizure prediction and control,” IEEE Trans. Biomed. Eng., vol. 50, no. 5, pp. 549-558, May 2003

[2] F. Takens, “Detecting strange attractors in turbulence,” Lecture Notes in Mathematics. Springer, vol. 898, pp. 366-381, 1981.

[3] N.H. Packard, J.P. Crutchfield, J.D. Farmer, R.S. Shaw, “Geometry from a time series,” Phys. Rev. Lett., vol. 45, pp. 712-716, 1980.

[4] N. Marwan, M.C. Romano, M. Thiel, J. Kurths, “Recurrence plots for the analysis of complex systems,” Physics Reports, vol. 438, iss. 5–6, pp. 237-329. Jan. 2007.

[5] C.L. Webber Jr., J.P. Zbilut, “Dynamical assessment of physiological systems and states using recurrence plot strategies,” J. Appl. Physiol., vol. 76, pp. 965–973, 1994.

[6] J.P. Zbilut, C.L. Webber Jr., “Embeddings and delays as derived from quantification of recurrence plots,” Phys. Lett. A, vol.171, pp. 199–203, 1992.

[7] A.L. Goldberger, L.A.N. Amaral, L. Glass, J.M. Hausdorff, P.Ch. Ivanov, R.G. Mark, J.E. Mietus, G.B. Moody, C.K. Peng, H.E. Stanley, “PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals,” Circulation, 101 (23), e215-e220, 2000.