Permutation entropy applied to the characterization of the clinical evolution of epileptic patients under pharmacological treatment

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Overview

Introduction

- An electroencephalogram (EEG) is a graphic representation of the neural activity. An EEG is a fundamental tool for the diagnosis of many neurological diseases, for example epilepsy and sleep disorders.
- The quantitative analysis of an EEG has been based, mainly, in the use of classical techniques of signal processing:
  - Spectral analysis (Fast Fourier Transform),
  - Topographic mapping,
  - Compressed spectral arrays,
  - Significance probability mapping

  Recently new approaches for quantifying an EEG were achieved by using techniques and methods from Information Theory and Nonlinear dynamics.

Motivation

- Usually clinical interpretations of an EEG record are achieved by Visual Inspection and Pattern Recognition .

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  But the visual inspection of the EEG is **subjective** , and it does not allow easily any systematization.
- There has been a marked interest in Characterizing the Therapeutical Effect of Drugs by means of quantities arising in the theory of non - linear systems.

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  For example: **Permutation Entropy (PE)**.

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  PE describes complexity, through a phase space reconstruction that takes into account non - linear behaviour, of a time series.

Permutation Entropy

Let us consider a real-valued discrete-time series $\{X_t\}_{t\geq 0}$.

- From $\{X_t\}$ we introduce a d-dimensional vector

$$\mathbf{Y}_t^{(d,t)} \mapsto (X_{t-(d-1)\tau}, ..., X_{t-\tau}, X_t)^T; \quad t \geq (d-1)\tau \tag{1}$$

The integer d and τ are called the embedding dimension and the time delay, respectively.

- We sort (in ascending order) the components of the phase-space trajectory $\mathbf{Y}_t^{d,\tau}$.
- Then we can define a permutation vector (pattern or motif), $\Pi_{\mathbf{Y}_t}^{d,\tau}$, with components given by the position of the sorted vector.
- We estimate the probability distribution for each pattern: $P_i = P(\Pi_i^{(d,\tau)})$; $i \leq d!$.
- Then the permutation entropy for the time serie is given by the Shannon entropy of the probabilities P_i.

$$h_{PE}(X_t) = \frac{-\sum_{i=1}^{d!} P_i \log_2 P_i}{\log_2 d!} \tag{2}$$

Permutation Entropy

Step 1

An sliding window of width $\Delta > 0$ and position k (which indicates the position of the left side of the window) is defined.

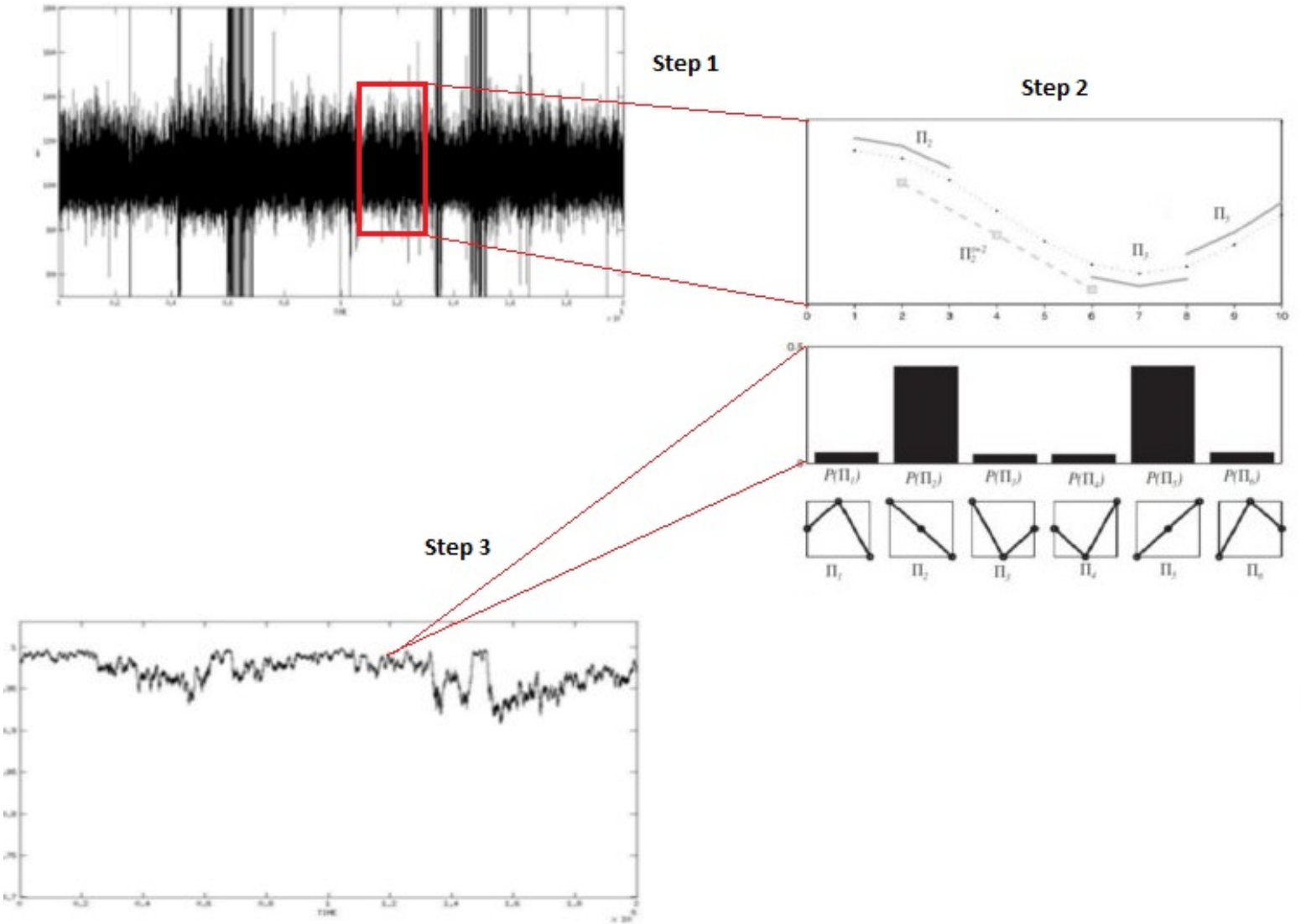
Block 2

For each position of the window we evaluate the permutations vectors as explained before. We denote this set of patterns by $\Pi_t^{(d,\tau)}(\Delta, k)$

Block 3

We can evaluate the associated PE as a function of the cursor position (pointer) k.

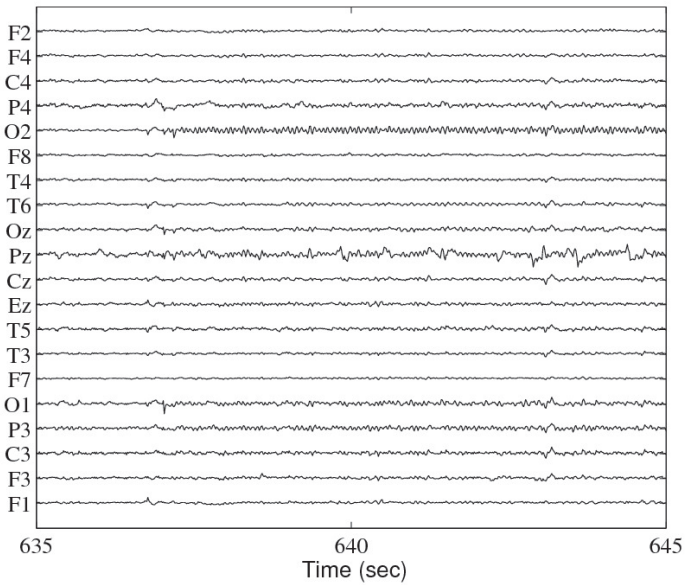
Permutation Entropy

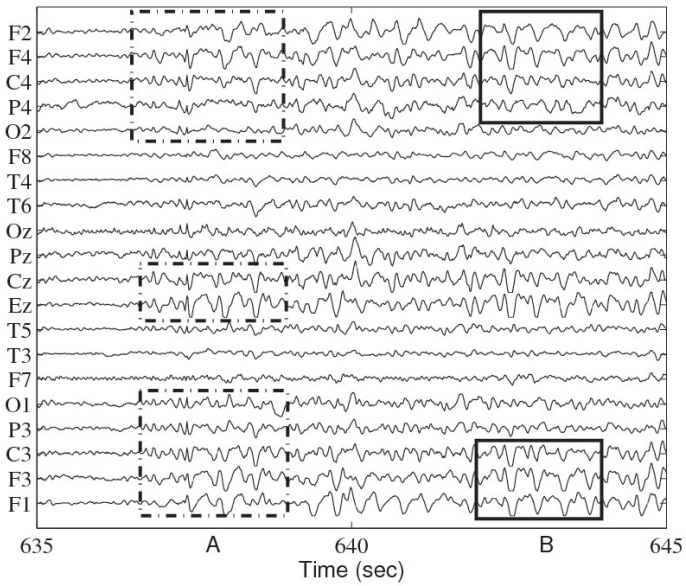


Case Study

Patient 20 years old, woman suffering Paroximal Frontal Bilateral Dysfunction.

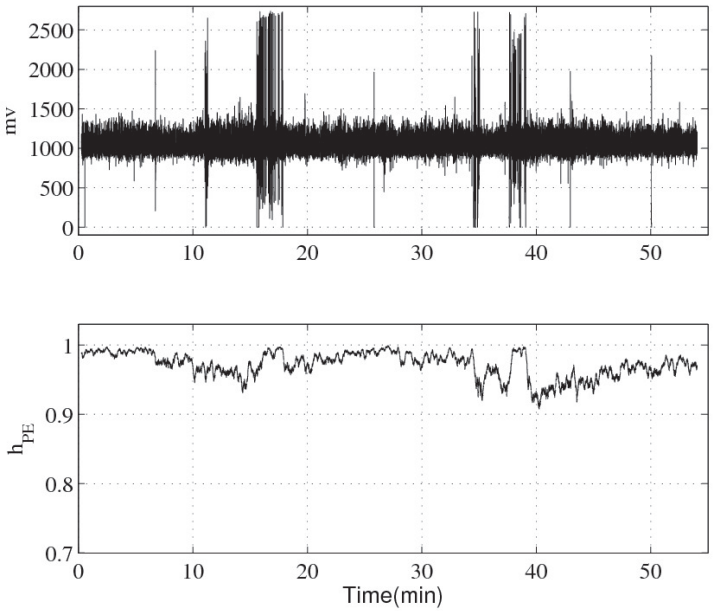
EEG Records

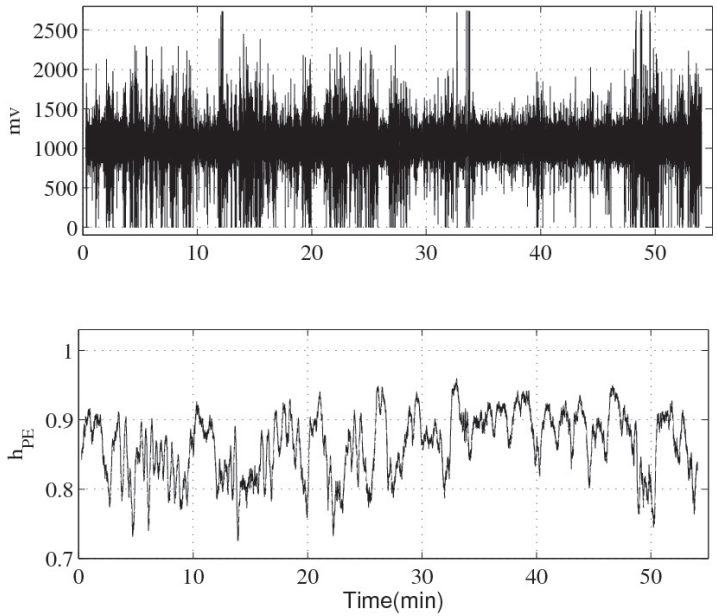




Case Study

PE Analysis

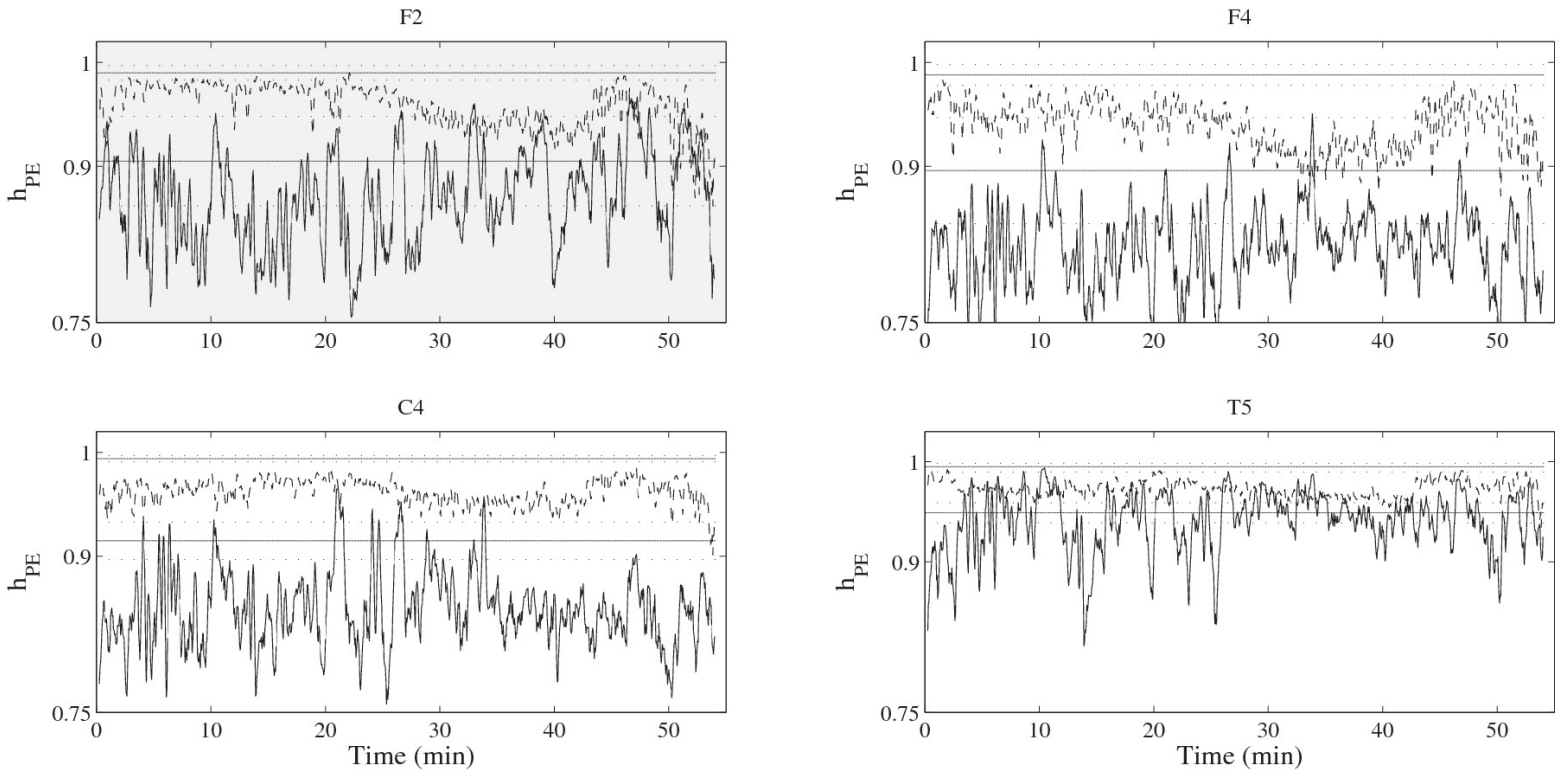




Results

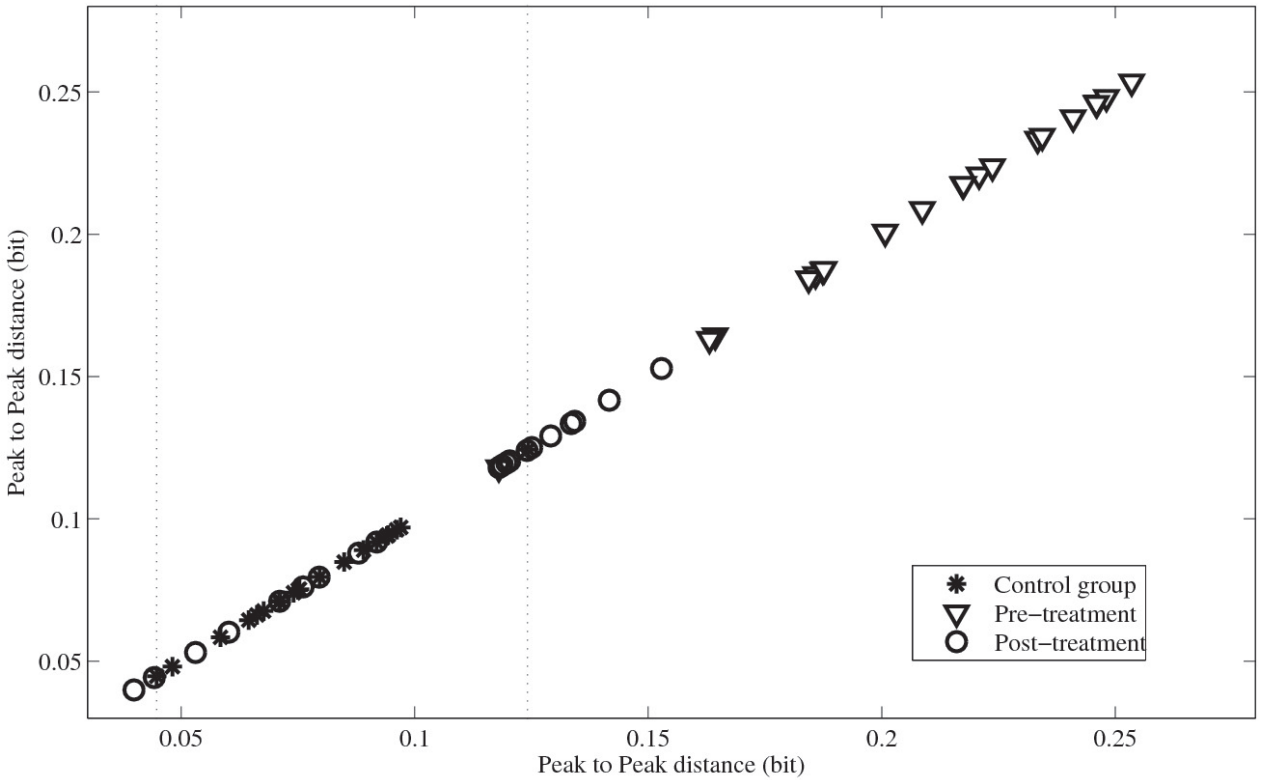
Pharmacological treatment for one year:
carbamazepine 400 mg valproic acid 1 g per day

Pre and Post Treatment



Statistics

Control group: 20 healthy patients. After the treatment a tendency to normality is observed!



Results and Conclusion

- The proposed scheme shows to be useful to quantify the effects of the pharmacological treatment
- A dynamical analysys of the pre and post treatment signals, is required!

References


Niedermeyer E. and Lopes da Silva F. Electroencephalography: Basic Principles, Clinical Applications, and Related Fields, Lippincott Williams and Wilkins, Pennsylvania **2005**.


Tong S. and Thakor N (Eds). Quantitative EEG Analysis Methods and Clinical Applications, Artech House, Boston, **2009**.


Sanei S. and Chambers J.A. *EEG Signal Processing* Wiley **2007**.


Blanco S., Figliola A., Quian Quiroga R., Rosso O.A. and Serrabo E. Time - frequency analysis of electroencephalogram series. III. Wavelet packets and information functions. *Phys. Rev. E* **57**, 1: 932-938 **1998**.


Bandt C. and Pompe B. Permutation entropy - a complexity measure for time series, Phys. Rev. Lett. **88**, 174102 **2002**

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Questions?