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Assessment of Measures of Scalar Time Series Analysis in Discriminating Preictal States

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Abstract. We evaluate a large number of measures used in the statistical and nonlinear analysis of EEG as to their discriminating power of different preictal stages. Some new measures are proposed and the analysis involves also feature time series, such as local minima and maxima, the time between them, as well as interspike intervals. The measures are computed on consecutive non-overlapping segments of 30sec of multichannel EEG at the preictal stage of several hours. The discrimination power of each measure is assessed by the receiver operating characteristic (ROC) curve computed on measure values grouped in different preictal stages. The results on 4 epileptic EEG records show that simple measures have the same, and at cases better, power in discriminating preictal stages than other more sophisticated measures.

Keywords: Preictal EEG; feature time series; nonlinear analysis; correlation; complexity; receiver operating characteristic

1. Introduction

The prediction of epileptic seizure from electroencephalograph recordings (EEG) is an open issue and there is still no method that can reliably provide such predictions besides the varying success of many measures stemming from diverse fields, such as nonlinear dynamics and chaos, synchronization, networks, and statistical testing [Andrzejak et al., 2003; Stam, 2005; Iasemidis et al., 2005]. Critical reviews have pointed that there is a long way to go before we can establish statistical significance for the predictability of any measure in terms of its sensitivity and specificity [Mormann et al., 2006; Gudmundsson et al., 2007]. Along these lines, recently we examined a number of different measures in discriminating early and late preictal stages in [Kugiumtzis et al., 2006]. Here, we extend this study and include most of the measures used in univariate EEG analysis as well as some new measures that can capture different characteristics of the oscillating EEG signal and are computationally efficient.

2. Material and Methods

The EEG data are provided by the Department of Neurodiagnostics, Rikshospitalet University Hospital, Norway. They comprise of four preictal multi-channel scalp EEG records of single episode from different patients, covering at least 3h prior to a seizure onset. The three first seizures (A,B,C) are generalized clonic-tonic and the fourth (D) is complex partial seizure. Recordings with 63 channels, according to the 10-10 system are used for A and B and 25 channels according to the 10–20 system with added low rows are used for C and D. Fronto-polar channels are excluded. The data are high-pass filtered at 0.3Hz, low-pass filtered at 40Hz, and sampled at 0.01s without any other pre-processing.

Each record is split into consecutive non-overlapping segments of duration 30s. From each segment $\{x_t\}_{t=1}^N$, where N=3000, the "Gaussianized" time series $\{y_t\}_{t=1}^N$ is formed to have Gaussian amplitude. A large number of measures are computed on each $\{y_t\}_{t=1}^N$: correlation measures at different lags as well as the respective cumulative correlation (Pearson, Spearman and Kendall autocorrelation, bicorrelation, and mutual information), complexity, entropy and dimension measures (correlation integral at fixed distance and embedding dimension, approximate and spectral entropy, energy in certain frequency bands, algorithmic complexity, dimension from false nearest neighbour, largest Lyapunov exponent, Hjorth parameters, Hurst exponent and detrended fluctuation analysis index) and measures of the improvement of goodness of fit with linear and nonlinear (local linear) models at different orders.

The following seven time series of features are extracted from $\{x_t\}_{t=1}^{N}$: local maxima, local minima, time between consecutive local maxima, time from local maximum to next minimum, difference of local maxima and minima and inter-spike intervals compute in two ways. Simple statistics (e.g. median) and some of the above-mentioned measures were computed also on the feature time series adjusting accordingly the method-specific parameters, giving a total of 284 measures.

3. Results

An example of the profile of two measures for two channels is shown in Fig.1. Samples for each measure over a period of 30min (20 values) just before seizure onset are compared to other periods longer before seizure by mean of the area under the receiver operating characteristic curve (AUC). Better discrimination of late from earlier preictal stages is found here using a simple measure (median local maximum) as opposed to a more involved measure (largest Lyapunov exponent). Results of AUC are accumulated for all measures and the measures are ranked in terms of the AUC score over the four episodes.

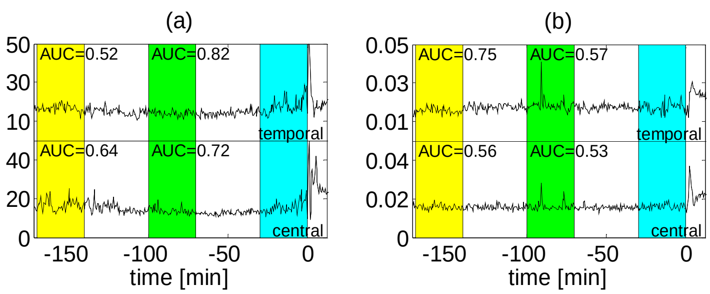

Figure 1. *Profiles of the median of local maxima in (a) and the largest Lyapunov exponent in (b) for a temporal and central channel (upper and lower panel). The AUC values displayed at each panel regard the comparison of the periods in first and second shaded areas to the third period ending at seizure onset.*

4. Discussion and conclusion

The results do not show clear discrimination of late preictal state (last 30min) from earlier periods (from about 3h to 1h prior to seizure onset). Earlier preictal stages as well as interictal periods should be included in the analysis. The ranking of measures shows that simple measures discriminate preictal stages best with the proposed measures, such as statistics on feature time series, being among the best. This work is in progress and results on new seizure episodes are being accumulated. At this stage, many measures are used but on few preictal EEG records, so the results cannot be taken as conclusive.

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