

New methods, that combine non-linear data analysis techniques with elements from graph theory are applied to standard EEG recordings in the context of epilepsy. The correlation between these synchronously obtained time series is quantified by means of measures derived from information theory. The resulting quantities form the basis of a hierarchical clustering analysis that characterises the spatio-temporal ordering and the degree of synchronisation of brain activity.

A precise localisation of the origin of epileptic seizures based on surface electroencephalograms (EEGs) is still a challenge. In interictal periods (time between epileptic attacks) visual inspection of EEGs often shows no epileptic signs. Therefore it is desired to find characteristics that allow the recognition of an epileptic disease in interictal EEG-recordings even if typical pathological patterns are missing. The non-invasive scalp-electrodes are placed according to the standardised 10-20-International System of Electrode Placements. So every single EEG-recording consists of 21 synchronous channels. We apply several correlation measures to pairs of time series. For every time step ($t_{step} \approx 1-2 s$) we end up with a correlation matrix. We observe that the use of non-linear distance measures based on e.g. mutual information is most appropriate to distinguish between normal and pathological brain activity. For clustering purposes these correlation measures have to be transformed to dissimilarity metric measures (“distances”). To assess the spatio-temporal dynamics of brain activity a hierarchical tree is generated based on this metric.

Fig. 1 shows the development of the derived parameter (mean mutual information) for patient A suffering a frontal lobe epilepsy (red symbols) and a reference case B. An effective therapy in patient A yields values which are comparable to the reference patient. The observed distinctive feature could be confirmed in a small study with more than 30 EEGs from eight patients.

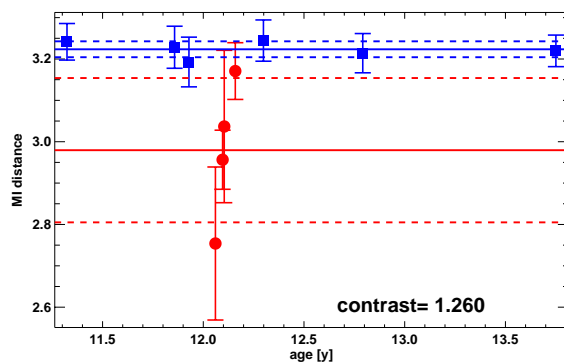


Fig. 1: Mean mutual information for patient A (red) and B (blue). The filled circles denote the mean mutual information, the vertical lines indicate the standard deviation of the single EEG-recordings. The horizontal lines label the mean mutual information for patient A and patient B, the dashed lines mark the respective standard deviations. As a consequence of medication patient A “approaches” the region where patient B resides during a longer time of observations.

Comparison of the panels in Fig. 2 reveals significant differences in the spatial structuring of both patients: The aggregation levels of the hierarchical trees indicate the much stronger coupling of the EEG-channels in patient A. Also the different spatial distributions of dependencies between the time series are striking.

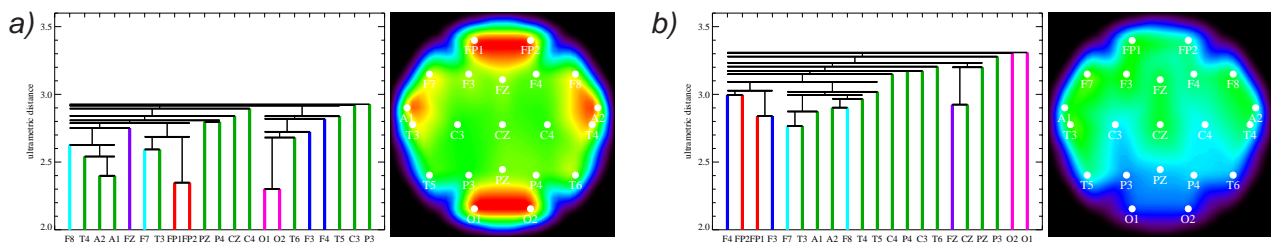


Fig. 2: Characterisation of Clustering behavior of patient A during an epileptic seizure (a) and patient B as a reference (b). In the left part of each panel the exact hierarchical tree is shown, while at the right side a two dimensional approximation of the cluster behaviour is displayed. High synchronisation is colour coded in red, low in blue.

Even though some indications for the location of the epileptic focus could be found with this methods, it is so far not possible to define this area exactly. In future work we hope to narrow down the search area by optimising this technique.

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