Visualization of Dynamic Processes Recorded during Epileptic Seizures

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Abstract
A visualization system dedicated to the analysis of spatio-temporal dynamics of epileptic processes recorded by stereoeletroencephalography (SEEG) is presented. It is based on the representation in a same anatomical scene of relevant measures (computed from SEEG signals) that characterize both intra-structure activities and inter-structures relationships. Several propagation and synchronization mechanisms between brain structures are revealed by the visualization system.
Keywords - visualization of processes, spatio-temporal dynamics, epilepsy.

1. Introduction

Epilepsy is the result of abnormal brain electric activities which mainly appear as synchronous (paroxistic) discharges within large populations of neurons belonging to brain structures implied during seizures. Investigation methods used in epileptology are aimed at defining and understanding the organization of the epileptogenic zone[1] (from the areas originating the discharges to those secondarily affected by their propagations). Among these methods, Stereoeletroencephalography (SEEG) provides signals recorded with intra-cerebral electrodes. These signals bring major information not only on the dynamics of processes inside the brain structures but also on their interactions.

The visual analysis of SEEG signals is aimed at understanding the spatio-temporal dynamics of epileptic processes. More precisely, it tries to exhibit: 1) the existence of one or more areas generating independent activities, 2) propagations of paroxystic activities from one cerebral structure to another and 3) phenomena of synchronization or time delays between activities from subsets of structures.

However, the standard representation of these signals (as scalar plots of amplitudes vs. time) is difficult to use for an accurate analysis. In this paper, a system dedicated to the visualization of relevant measures extracted from SEEG signals is proposed.

2. Visualization of paroxystic processes

SEEG gives information on the electrical activity in the structures. However, neither the dynamics of the process nor the relations between structures appear explicitly in the standard representation of SEEG signals. The aim of the proposed visualization system is to bring forward this information which can be extracted from signals. Among the possible statistics that can be deduced from signals, Energy and Rhythm[2] provide relevant information about intra-structure activity and Simple Coherence[3] can be chosen to characterize the relationships between structures (synchronization, de-synchronization and delay).

In a first step, a model has to be constructed from data that characterize the processes to be displayed. We chose to represent the area explored by SEEG as a network of structures modeled by a relational graph in which each node corresponds to an anatomical structure and each link to a relation between two structures. This approach is close to Network Visualization[4]. The visualization objects (graphemes) that encode the information are the following: i) a node is represented by a disk whose diameter is related to the Energy whereas its color follows the Rhythm, ii) a link is represented by a line whose thickness is proportional to the value of the Coherence. The dynamic evolution is rendered as an animation, the time step being one of the parameter of the visualization system. The anatomical aspect is fundamental for the understanding of phenomena. At the present time, the system does not provide a realistic description. However, the spatial arrangement of graphemes tries to match the cerebral topology as better as possible.

3. Architecture of the visualization system

The visualization system is implemented on a NextStep station. Its object-oriented programming language (Objective C) has been used to define two main classes collecting the parameters and the procedures respectively common to the Structures (name, location, Energy and Rhythm signals,...) and the Connection between structures (name of the structures connected together, Coherence signal,...). Each object can be parameterized interactively through a graphic interface.

From these parameters, the dynamic process can be drawn in a visualization window referred to as the scene (see figure 2). The visualization parameters (color scale, size, position of graphemes, ...) are chosen and driven through a graphic interface.

A toolbox allows the user to manage the visualization system. More precisely, this toolbox can be used to: i) display the list of displayed objects, ii) display the processes (Rhythm, Energy and Coherence signals are plotted vs. time ; a cursor showing the current time instant can be moved by the user), iii) change the color scales (luminance or saturation color scales are available in order to encode the Rhythm), iv) change the navigation mode (step by step or continuous mode, forward, backward, etc.), v) define a Period Of Interest and vi) show the main parameters of the scene (topology, color and size scales of the graphemes).

4. Results

The visualization system has been supplied with signals recorded from a patient suffering from a temporal lobe epilepsy. The SEEG electrodes implantation allows to analyze activities from the inner limbic system as well as from structures of the neocortex. The sampling frequency of signals is 200 Hz. In this paragraph, only two cases are presented where the visualization system gives a good insight into the displayed processes.

Activities on a subset of structures.

During the period preceding the seizure (pre-ictal activity), the system reveals important changes of activities within structures of the limbic system. More precisely, it clearly shows a "propagation effect" from the amygdala (Amyg.) to the Hippocampus (Anterior Cornu Amonis CA_ant) (see figure 1). It is important to notice that this propagation is not easily perceivable by a direct visual analysis of the classical plots vs. time.

Inter-structures relationships

During the seizure several increase/decrease phases of the coherence between the limbic and neocortex structures can be observed. These phases seem to reveal some hyper- or hypo-synchronization mechanisms. After the seizure, the activities within the limbic system are almost inhibited but, and this is generally not visible, the coherence remains very high (figure 2). This is also the case for neocortical structures.

5. Conclusion

A visualization system dedicated to the analysis of spatio-temporal dynamics of epileptic processes recorded by stereoeletroencephalography (SEEG) is presented. It is based on a relational graph where the anatomical structures and the relations between structures are symbolized by simple geometrical shapes. Results report situations in which the visualization improves the perception and the understanding of epileptic phenomena compared to the classical representation of signals.

References

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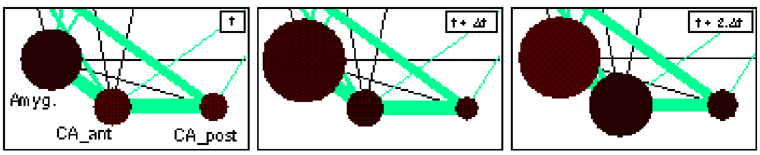

figure 1 : Propagation effect within the lymbic system

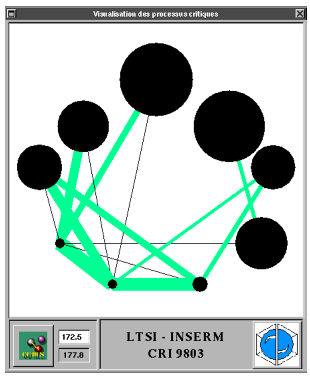

figure 2 : Activity after a seizure