MULTI-AGENTS SYSTEM ON EPILEPTIC NETWORK

Abel Kinie, Jean-Jacques Montois
LTSI-INSERM/GRAID - IUT de Saint-Malo, Bd déportés BP 195, Saint-Malo Cedex, France

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Abstract: This work is focused on the study and interpretation of *epileptic signals*, based on the analysis of stereo electroencephalographic (SEEG) signals with signal processing method and multi-agent approach. The objective is to use this technique to improve information extraction, representation and interpretation as well as the implemented control strategies in the different processes. Our approach deals with the information recorded during the intercerebral exploration and it exploits a dynamic selection of the interest's information to optimize the processing without truncating the information. We associated signal processing algorithms (spectrum analysis, causality measure between signals) approved in the analysis of the epileptic signal in a multi-agent system.

1 INTRODUCTION

The paroxysmal discharges are initiated by a network (epileptogen network) distributed in different cerebral structures linked by dynamic connections and abnormally facilitated (Chauvel et al., 1987). The identification of this network, in a given patient, leads to the definition of an optimal surgical procedure, that is to say minimizing the size of the resection of the region of origin of the crisis (Bartolomei et al., 2005).

The proposed methods for treating the signal could lead to a better definition of the complex concepts of the irritative and the epileptogenic zone (Wendling et al., 1999) as well as those of the topography *("where is the source of the signal?")* and of synchronicity *("these two signals are they synchronic, therefore reflecting a functional connectivity?")* The response elements only quantify a part of the information contained in these signals. These methods rely generally on a downward approach and realize with difficulty the dynamic of interactions between cerebral structures implied in the epileptic process. The problem of analyzing the propagation of epileptic activity is difficult to solve with these approaches because the system must face varied and unforeseeable situations (epileptic seizures).

The problem is tackled here by a cooperative distributive system. (J. Ferber, 1995), (G. Weiss, 1999). the first generation of distributive systems appears in the middle of the 1970's with the development of artificial distributed intelligence (AID). This generation of systems is characterized by a distribution of knowledge and processing whilst conserving a centralized control. The most important contributions were those of Erman and Roth Hayes (Erman et al., 1980) with Hearsay II, a system of word recognition those of Lesser (Lesser and Corkill, 1983) and actors of Hewitt [8. The second generation of systems appearing in the 1990's, brought the decentralization of control, reutilization and autonomous cooperative agents (J. Ferber, 1995) and (G. Weiss, 1999). The cooperative distributed system relies on a formalism agent who aims to organize and control the scalar processes and to insure its coordination by best integrating the specifics of each process to make the combination of interests appear between explored cerebral regions. We hope through analysis by an independent agent, for better adaptability to the erratic signal changes and an effective management of complexity (by local approach). It is therefore the control (Altman et al., 2002) and follows up of the evolution of activities from agents which will clarify the evolution of the activities of explored cerebral structures.

Paragraph two explains the formal framework of the planned study. It poses the problem treated. The methodological approach undertaken is then exposed

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in detail in the third part which presents the experimental platform of the multi agents system (MAS) dedicated to the analysis of SEEG signals. The fourth paragraph discusses the experimental results obtained and compares them to traditional clinical analysis made by a clinician and the last part proposes a discussion of the potential benefits of this original approach in the analysis of SEEG signals and monitoring of epileptic patients.

2 THE MULTI AGENT SYSTEM IN EPILEPSY

The MAS technical are often used in the artificial intelligence field, the distributed information processing systems and the software genius. It is a discipline which is interested in the collective behaviours produced by interactions of several autonomous and flexible entities called agents. These interactions suppose a co-operation between these agents. The multi agent systems and signal processing applying to epilepsy present a close links according to the entities which compose them.

Indeed, the multi agent systems can allow modelling and simulation of neurons aggregates or systems based on autonomous entities and distributed interactions. However the signals processing (applying to epilepy) model the mechanisms which govern the propagation of the electric activities in the brain (distributed mechanisms) and also the structure and the interactions of the nervous cells.

Our paper brings out the common interests to study the association of these two research fields.

Scalar analysis of the epileptic signal by the computation of the relations between signals (Bartolomei et al., 2005), (Wendling et al., 1999) highlighted the existence of mutual interactions between the EEGs. In the same way the concept of epileptogenic network developed by Professor Patrick CHAUVEL (Chauvel et al., 1987) give raise to the existence of a co-operation between cerebral areas in epileptic processes.

In order to take into account the specificity of each signal and to compute the co-operations between them, we evaluate 9 descriptors per signal around a distributed system. These 9 descriptors evaluated starting from the spectral power density (PSD) in various frequencies bands from the epileptic signals which correspond to various physiological or pathological cerebral cortex states.

These descriptors and the various frequencies bands used are detailed in paragraph 3.

The MAS from their innovative aspect and their non-traditional approach (behavioural approach) of the realization of distributed systems propose an original method of vectorial processing by associating existing signal processing scalar methods. With the MAS technical in the signal processing study we hope to compute the epileptic processes mechanism during the paroxysmal discharge propagation.

3 AGENTIFICATION OF THE PROBLEM

The experimental platform used in this work is MadKit (Multi-agent development Kit) (J. Ferber, 1995). The implementation of MAS requires using iterative algorithms to define the behaviours of the various agents which composed the system. For conveniences reasons we used a ready to employment platform (MadKit). In this model, an organization is regarded as a structural relationship between collections of agents. Thus, an organization can be described only on the basis of its structure. MADKIT is conceived by Jacques FERBER and al (J. Ferber, 1995). It implements its three central concepts Agent, Groups and Role.

Our approach is built starting from several groups of agents whose properties and missions must allow:

- To classify the signals having the same SEEG activities and/or contained similar spectral components (groups).
- to classify the signals whose activities change in the same temporal interval (segmentation)(groups).
- To represent the seizure as a coloured image allowing locating in space and in time the SEEG signals having the pathological or the similar activities (groups and roles...).
- To associate all these partial results to bring out a global behaviour of the analyzed seizure (groups and roles).

To formalize the problem we consider a vectorial signal S (t) made up of a recording SEEG signals on N channels and an interval [0, T]. S (t) = [S1 (t)...... SN (t) $S_k(t) \in \mathbb{R}$. k = 1...... N, t = {0, 1/Fe... T-1/Fe}, N is the number of explored cerebral structures and Fe is the sampling rate.

Our architecture is made of a reactive agent's community which is made up of various agents groups whose are able to analyze, in parallel, the signals coming from N recording SEEG channels (N ≈100). In this approach, to each SEEG channel (epileptic signal) we associated a "Descriptor" agent. Its role is to analyze the spectral components of the segment of signal recorded on this channel and to seek possible links with his/her "colleagues" on the [t, t+Δt] interval. All the "Descriptors" agents communicate the results of their analysis to a "Classifying" agent which is in charged to compute the components of each SEEG segment then to classify it according to its a priori knowledge. Indeed no exhaustive trainings classes were built and transmitted to the "Classifying" agent for each epileptic activity. When T described the [0, T] interval (T being the total recording duration), a "Visualization" agent produces a coloured space time and spectral tablecloth representation, with each agent at the t moment. Parallel to each activity class identified by the "Descriptors" agent on the [t, t+Δt] interval we associated a "Causality" agent whose role is to evaluate the degree of relationship between brain's entities bound by affinities.

3.1 Descriptors Agent

The agent associated with each SEEG channel uses the energy of the signal calculated in various frequencies bands to characterize the activity during the computation time. To take into account the specificity of SEEG signal, we chose the 9 bands classically used in the field (δ1, δ2, θ1, θ2, α1, α2, β1, β2, γ). Energy is calculated starting from the power spectral density (psd to see (1) and (2)) estimated starting from the periodogram method A characteristic vector (9 parameters representing the agent state at the t moment) is produced for each SEEG channel for the current segment.

$$dsp = \sum_{f=0}^{f=nbPtsFFT} \left\| S(f) \right\|^2 \quad (1)$$

$$S(f) = \sum_{n=0}^{nbPtsFFT} s(n)\, e^{\frac{-i2\pi fn}{N}} \quad (2)$$

Where S (f) is the Fast Fourier Transform the s(t) signal.

3.2 Classifying Agent

During each cycle, the "Classifying" agent receives the characteristic vector produced by each "Descriptors" agent and associates a scalar code to the segment considered. . From this agent state (its scalar code) and its “neighbours” state (information on the proximity between SEEG sensors), a decision is taken according to the identification of all agents components (strong probability of being in the same state as its “neighbours” belonging to the same brain‘s structure).

3.3 Visualization Agent

It associates during the computation time a colour to each "Descriptors" agent and produces a space time and spectral tablecloth representation of the spectral components of each SEEG signal. The colour attribution is carried thanks to each agent state (spectral components). “Cold "and" hot "colours then respectively code the "low frequencies activities and the "high frequencies" activities and the black colour codes the not classified activities.

Figure.1: Association between activity and colour.

3.4 Causality Agent

The agent associated with each class and activity identified on the [t, t+Δt] interval uses the nonlinear coefficient of regression h^2_{XY} calculated on a pair of X(t) and Y(t) observed signals on the limited temporal support [t, t+Δt]. It makes it possible to characterize the functional couplings between cerebral structures and to consider a time delay of propagation possible between these two observations.

The Load Agent (Scheduler) is charged to plan the execution order and to activate in a synchronized way all the operated agents. The principle is rather simple to each agent or agents groups (G) equipped with a role (R) we associated an activator (A_{GR}) on the level of Scheduler. Scheduler is useful of these activators to plan the tasks while launching to each activators (A_{GR}) cycle the ones after the others according to the desired execution order. A cycle corresponds to a full rotation of the various activators which one need to activate.

The global architecture of the establishment is summarize in 3 phases (A Phase, B Phase and C Phase)

A Phase

The Server agent (data base) feeds the Descriptors agents and "Rate/rhythm" in signal samples. The Descriptors, the "Rate/rhythm» and the Causality (the signal processing algorithms) are charged to carry out the traditional computation of low level. The "Rate/rhythm" deals with the segmentation (detections of the moments of rupture in the analyzed signal).

B Phase

Observant agents (Watcher) (Erman et al., 1980) are charged to recover the data (results provided by the agents of low level. They also provide a more elaborate processing on these data and contribute to the emergence of a global organization. The Classifying agent allows the junction of the other agents with the Descriptors agent, it also orders the results generated by the latter. The Visualization agent provides a representation of the seizure where information is made available. The observers "Rupture" and the Causality respectively represent for the agents "Rate/rhythm" and "the Causality what "To classify it" represents for the Descriptors agent. Load Agent (interface) allows choosing the patient seizure to be analyzed, to create and to parameterize the execution architecture. It also manages the scheduling of the spots to be carried out by the agents.

C Phase

This phase which is not presented here will have to join together information resulting from phases A and B to order the seizure propagation. It will have to consider the evolution of the interactions between agents (affinities) to raise the evolution of the couplings between brain's structures during the seizures.

4 RESULTS

The SEEG signals are recorded by a BMSI-NICOLET system which allows a simultaneous acquisition of SEEG signals on 128 channels, at a sampling rate of 256Hz. The studs of the electrodes are numbered from 1 to 15 from the internal end to the external end. Each electrode is located by a letter (A, B, C....), affected of a "premium" (A', B', C '...) if it is established on the left dimensions of the brain.

We obtained a complete image of the analyzed epileptic seizure where each activity is well identified according to the frequencies activities of its localization SEEG sensors and its appearance moment (time).

The x-axis corresponds to the temporal space (time in second), the y-axis space (studs or signals), the various electrodes are separated by white features and each electrode studs is presented at the extreme right-hand side of the diagram. The following paragraphs propose the results analysis.

In a patient presenting temporal lobe epilepsy, according to the clinician; the brain's structures involved in the initiation of its seizure are the internal temporal pole (TP), the former hippocampus (B), the posterior hippocampus (C) and the entorhinal cortex (TB).

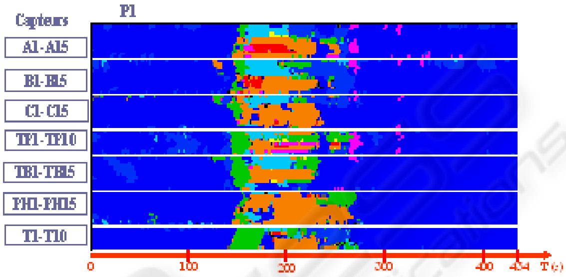

Figure 2: Space –time and -spectral representation of P1.

Figure 2 shows the localization of various activities (ictal and normal) but also allow identifying for each SEEG sensor, the activity type. It also highlights about several initiating brain's structures. We observed quite localized ictal activities and this clearly highlight again about the implication of a great number of SEEG channels in the propagation of the paroxysmal discharge during the computation time.

5 CONCLUSIONS

On patients study the results highlight a zone initiating the seizures including the internal temporal brain's structures (former and posterior hippocampus, entorhinal cortex) and confirm the key role of these structures in the partial temporal lobe epilepsy.

Our work formalization problems and an analysis made of each entity's behaviour towards co-operation, association and competition which bring out these relevant images, can lead us to a better understand some epileptic observed phenomena. Difficulty to interpret some others phenomena come from the artefacts strongly present in the signals and a good management of these measurements noises can improve the results.

The technological platform thus created is situated at the borders of several research domains (signal processing, computer engineering and artificial distributed intelligence) and opens the perspectives notably for monitoring epileptic patients. The original procedure proposed and the first results obtained give us hope to go further in the exploitation of MAS techniques to help with the diagnosis of epilepsy by means of the description of the propagation of the discharge during epileptic seizures and the vectorial processing of the signal in its entirety. In the long term we envisage to place more interactivity between the system and its user so as to better link the clinical symptoms to the evolution of certain physiological parameters.

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