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A Review on Methodologies for detection of Epilepsy using EEG Signals

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***Abstract*- In this paper we are working on literature review of EEG Signals. In our paper synchronization analysis is also done on driven oscillators and it is used to know whether the oscillators are in Phase Synchronization (PS) or in non-Phase Synchronization (non-PS). The application of the PS is done on biomedical signals and how the biomedical signals can be distinguished based on PS is studied. Synchronization analysis also includes Generalized Synchronization (GS) based on recurrences and its application to driven oscillators and biomedical signals is observed.**

***Keyword*- Biomedical Signals, CRP, EEG Signals, Recurrence Plots.**

1. Introduction

Recurrence is a fundamental characteristic of many dynamical systems. This recurrence property is exploited to characterise the system's behaviour in phase space. The concept of recurrence is used for the analysis of data and to study dynamical systems. It is a powerful tool for the visualisation of dynamical systems and analysis which was introduced by Poincare in 1890 [1]. Thus recurrences contain all relevant information about the system's behaviour. The method of Recurrence Plots (RPs) is extended to the CRPs. The method of CRPs enables us the study of synchronization or time differences between two different time series and this is emphasized in a distorted main diagonal in the CRP called the LOS. Thus, first we introduce the definition of Recurrence plot and Cross Recurrence plot and then LOS and its applications to the biomedical signals. Complexity measures based on CRPs are introduced in the thesis and their applications to biomedical signals is studied. In this manner we are able to distinguish biomedical signals based on the CRP plots and complexity measures values. Next, synchronization analysis is also done on driven oscillators and it is used to know whether the oscillators are in Phase Synchronization (PS) or in non-Phase Synchronization (non-PS). The application of the PS is done on biomedical signals and how the biomedical signals can be distinguished based on PS is studied. Synchronization analysis also includes Generalized Synchronization (GS) based on recurrences and its application to driven oscillators and biomedical signals is observed.

2. Literature Review:

The study of coupled systems goes back to the 17th century and begins with the analysis of synchronization of nonlinear periodic systems. Well known examples are the synchronization of two pendulum clocks that hang on the same beam (it was through this system, that Huygens discovered synchronization), the synchronized flashing of fireflies, or the peculiarities of adjacent organ pipes which can almost annihilate each other or speak in unison. But the research of chaotic synchronization does not begin until the eighties where it was shown that two chaotic systems can become completely coupled, i. e. their time evolution becomes identical. This finding has had very important consequences for the design of secure communication devices. The synchronized chaotic trajectories can be used to mask messages and prevent their interception. In the notion of complete synchronization of chaotic systems was generalized, allowing the non identity between the coupled systems. And some time later, Rosenblum et al. [1] considered a rather weak degree of synchronization between chaotic oscillators, of which their associated phases become locked, whereas their amplitudes remain almost uncorrelated. Hence, they called this kind of synchronization, phase synchronization. Not only laboratory experiments have demonstrated phase synchronization of chaotic oscillators, such as electronic circuits, lasers and electrochemical oscillators, but also natural systems can exhibit phase synchronization. For example, the dynamics of the cardio respiratory system, an extended ecological system, and the electroencephalographic activity of Parkinson patients display synchronization features.

On one hand it is important to investigate the conditions under which coupling of chaotic systems occurs, and on the other hand, to develop tests for the detection of coupling. In this work, it has been concentrated on the second task for the cases of phase synchronization (PS) and generalized synchronization (GS). Several measures have been proposed so far for the detection of PS and GS. However, difficulties arise with the detection of coupling in systems subjected to rather large amounts of noise and/or non-stationarity, which are common when analyzing experimental data. The new measures that will be proposed in the course of this report are rather robust with respect to these effects. They hence allow to be applied to data, which have evaded coupling analysis so far. The proposed tests for synchronization in this work are based on the fundamental property of recurrences using order patterns.

The planned structure of whole project work starts with concept given by Andreas Groth from his paper named as *Visualization of coupling in time series by order recurrence plots* [34]. Previous to this work in the analysis of coupled systems various techniques have been developed to detect cooperative behaviour from observed time series in the following literatures:

Depending on the nature of the systems, there are different requirements to the above methods. While linear methods based on correlations are not sufficient to deal with nonlinear dependencies, most nonlinear methods require sufficiently long stationary time series. For the case that stationarity holds only for short observation time, cross recurrence plots CRPs were introduced in following literatures:

N. Marwan and J. Kurths, (2002) they use the extension of the method of recurrence plots to cross recurrence plots (CRP) which enables a nonlinear analysis of bivariate data. To quantify CRPs, we develop further three measures of complexity mainly basing on diagonal structures in CRPs. The CRP analysis of prototypical model systems with nonlinear interactions demonstrates that this technique enables to find these nonlinear interrelations from bivariate time series, whereas linear correlation tests do not. Applying the CRP analysis to climatological data, we find a complex relationship between rainfall and El Nino data.
Thay have modified the method of cross recurrence plots (CRPs) in order to study the similarity of two different phase space trajectories. Local similar time evolution of the states becomes then visible by long diagonal lines. The distributions of recurrence points and diagonal lines along the main diagonal provides an evaluation of the similarity of the phase space trajectories of both systems. We have introduced three measures of complexity based on these distributions. They enable to quantify a possible similarity and interrelation between both dynamical systems. We have demonstrated the potentials of this approach for typical model systems and natural data. In the case of linear systems, the results with this nonlinear technique agree with the linear correlation test. However, in the case of nonlinear coupled systems, the linear correlation test does not find any correlation, whereas nonlinear techniques, as the mutual information, and the proposed complexity measures clearly reveal
this relation. Additionally, the latters determine the kind of coupling as to be an even function. The application to climatological data enables to find a more complex relationship between the El Ni˜no and local rainfall in NW Argentina than the linear correlation test, the mutual information or the power spectra analysis yielded.
Our quantification analysis of CRPs is able to find nonlinear relations between dynamical systems. It provides more information than a linear correlation analysis and the nonlinear technique of mutual information analysis. The future work is dedicated to the development of a significance test for RPs and the complexity measures which are based on RPs.

However, the method of CRP is based on taking distances of trajectories, which is conceptually difficult on physically different systems. A general problem in studying multivariate data from natural systems, for instance electroencephalogram EEG data, is that measurement conditions change with time. Among others offset and amplitude range can vary differently within the channels.
To overcome this problem we consider a special symbolic dynamics of the system, where the time series is encoded by order patterns. This yields further symbol sequences, which are invariant with respect to certain distortions in amplitude.
The concept of symbolic dynamics was proposed by Bandt and Pompe [4], they suggested that the symbol sequence should come naturally from the time series, without further model assumptions, and that one should therefore take partitions as given by comparisons of neighbouring values of the series. With this symbolic dynamics Bandt and Pompe suggested a method of complexity measure and successfully applied to epileptic seizure detection in paper given below:

Y. Cao, W. Tung, J. Gao, V. Protopopescu, and L. Hively, (2004) they worked on timely detection of unusual and/or unexpected events in natural and man-made systems has deep scientific and practical relevance. We show that the recently proposed conceptually simple and easily calculated measure of permutation entropy can be effectively used to detect qualitative and quantitative dynamical changes. We illustrate our results on two model systems as well as on clinically characterized brain wave data from epileptic patients.
In this work, they have explored the possibility of using the PE to detect dynamical changes in a complex time series. By analyzing two simple models, namely a transient logistic map and transient Lorenz system, as well as a number of clinical EEG data, we have shown that the PE can indeed be effectively used to detect bifurcations in model systems as well as the onset of epileptic seizures in intracrannial EEG data. Certainly there is no reason to expect that the PE is universally and indiscriminately applicable. Most likely, no such measure exists; instead, various measures would have to be used in a complementary fashion, to take best advantage of their respective merits within their ranges of applicability. We conclude though by emphasizing that the most attractive features of the PE, namely its conceptual simplicity and computational efficiency make it an excellent candidate for a fast, robust, and useful screener and detector of unusual patterns in complex time series.

Following the idea of CRPs Andreas Groth [6] introduce a visualization tool based on the recurrence of order patterns.
Thomas Schreiber in his paper, *Measuring Information Transfer* [5], describes a method based on transfer entropy approach using the Markov property. The purpose of this paper is to motivate and derive an alternative information theoretic measure, to be called transfer entropy, which shares some of the desired properties of mutual information but takes the dynamics of information transport into account. With minimal assumptions about the dynamics of the system and the nature of their coupling one will be able to quantify the exchange of information between two systems, separately for both directions, and, if desired, conditional to common input signals. The concept of this is used in our work to generate a modified form of ORP and RP based on Markov property.

In addition to detection of coupling we have used symbolic dynamics and recurrences to find direction of coupling. The concept of recurrence has been used to detect relationships between interacting systems in [7], where the so-called synchronization likelihood has been introduced. This method allows for a multivariate analysis of generalized synchronization. Moreover, the concept of recurrence has been used to quantify a weaker form of synchronization, namely phase synchronization. Here, we extend these measures in order to detect the direction of the coupling. The proposed method is rather straightforward to compute, in contrast to the more complicated information theory approaches. Furthermore, it has the advantage that it is applicable to both weak and strong directional coupling, as well as to structurally different systems. For evaluating direction of coupling the literatures used are based on mean conditional probability of recurrence or directionality index based on mutual information. In these papers several methods have been compared from other literatures to estimate the direction of the coupling. Most of these methods can be divided into the following three categories: (i) methods based on a functional relationship between the phases, (ii) state-space based methods and (iii) information theory based methods.

3. Conclusion:

we can conclude that this method of order patterns based on Markov property can also be used over biomedical signals for finding short time dynamics and they can be more accurate in diagnosis of pathological condition that can be detected from strength of interactions between recorded signals obtained from two structurally different systems like ECG and heart rate variability, breathing patterns and EMG or in between different EEG channels for the patients of Parkinson disease or to analyze sleep disorders by studying EEG during various sleep stages.

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