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FACULTY OF ELECTRONICS, TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY

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PhD. THESIS

NEURONAL SIGNAL ANALYSIS INVOLVED IN SENSORY PROCESSING

SUMMARY

Scientific Coordinator :
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Contents

Key Words

Transfer Entropy, interaction lag, source imaging, TE_{SPO} estimator, neuronal signal processing.

Introduction and motivation of the thesis

Human kind would have not evolved so much if it had not been the "spark" that made us unique among all the living creatures of earth. What made us unique is the ability of judgment, to have a perception about the world we are living in and to be able to self-teach. All this is due to the evolution over time of the brain, a very complex and important anatomical part that helped us, as a species, reach the amount of knowledge we have today.

Although we have a high amount of knowledge about the anatomy of the brain, only a small part of its function can be explained today. In order to understand better the brain, we need to study how its functional processes give rise to awareness and judgment-making, the role of brain regions and how these regions interact with each other. It is not enough to know the very basic functions of brain cells, how they are chemically connected and how they are chemically interacting. We need to understand the brain at a macroscopic level, to understand how rather small regions can influence other larger functional regions. We can describe the brain as one complex system, where different functions of different areas emerge from low-level physical mechanisms. This allows the brain to produce more outcome (ie. high level processes, intelligence, behavior) than the sum of individual neural activities.

If we can measure the neuronal activity and their effects we will obtain information which will permit a more detailed view of what is happening in the brain. This is not possible without methods from signal processing, an evolving domain that can help us understand of the neuronal processes at macroscopic level. Techniques from this domain can be used to detect and measure synchronized activities or temporal correlation of different brain areas.

One problem of interest is to identify of the causal relations between several areas. These relations can provide information about the communication mechanisms from a complex neuronal network. It is desired that signal processing techniques are adapted to detect directional interactions, information transfer and system lag for neuronal data. The ability to estimate these parameters is crucial in the study of brain functions.

Thesis Objectives

First objective of this thesis is to show an overview about the interaction measuring methods both linear and non-linear. More, it must present an overview about causal measuring methods. These includes Information Theory methods for measuring transfer of information between random systems.

The second objective of the thesis is to present and test a new estimator for Transfer Entropy (TE_{SPO}), estimator which represent a measurement technique for information transfer, directivity and lag between random processes. The testing of the estimator TE_{SPO} has a role of identifying of the behavior in some situations, like non-linear systems with unidirectional, bidirectional and self feedback interactions.

The third objective is the testing of the TE_{SPO} estimator on real Electroencephalografic and Magnetoencephalografic signals. This also includes the reconstruction of neuronal source activity in corresponding brain areas and estimate the interaction using the TE_{SPO} estimator.

The last objective of this thesis is to analyze and interpret the resulted interactions, to find the correctness of these results compared to with previous neuronal studies.

Thesis structure

The thesis is divided in three parts, with a total of 5 chapters as :

– First part (chapter 1,2 and 3) contains general information about neuronal activity, how it can be measured and the methods that can be used to detect interactions and connectivity.
– The second part (chapter 4) contains description of the new estimator TE_{SPO} and its testing on non-linear systems.
– The third part (chapter 5) treats the analysis and reconstruction of source activity from real experimental data using EEG and MEG from two paradigms. The reconstructed source time courses were used to estimate the interactions directivity and delays with TE_{SPO} method.

Personal Contributions

The work that has been done for this thesis permits the statement of the following contributions in the neuronal signal processing :

1. The study and improvement for transfer entropy method (TE_{SPO} estimator), a new method based on the information theory which can measure interactions in non-linear in time series :
   – the implementation of the algorithm ;
   – non-linear system generated based on Autoregressive and Lorenz processes ;
   – testing the algorithm using the simulated systems ;
   – algorithm improvement and parallelization
2. EEG and MEG data recording using the experimental paradigms "Dots" and "Mooney"
3. Reconstruct of the corresponding neuronal source activation locations for both EEG and MEG data
4. Source state space reconstruction from the significant source locations in both experiments
5. Lag interaction estimation for the above source locations using TE_{SPO} estimator.
6. Analyzing the source locations and estimated interactions, comparing them with other neuronal studies.
7. Bibliographic study for the synthesis of the techniques used in the domain of neuronal signal processing, more exact techniques for interaction estimation.

Publications List

Articles

Published Articles

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