ENS DE LYON

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

M2 INTERNSHIP PROPOSAL

CHARACTERIZATION OF CAUSALITY RELATIONSHIPS BETWEEN SCALES OF TIME PROCESSES: APPLICATIONS TO TURBULENCE AND OCEAN DYNAMICS

Keywords : Signal processing ; Causality ; Multiscale analysis ; Information Theory ; Turbulence ; Ocean dynamics

1. Context

Today, the huge amounts of collected data in the framework of Earth sciences is revolutionizing the way scientific advances are propelled in this field. Thus, analyzing the available datasets (remote sensing images, in-situ observations) with the suitable signal processing methodologies produce nowadays new understandings on topics such as climate change, ocean dynamics or ocean atmosphere interactions. These analyses also allow to call into question and/or validate existing physical models as well as to improve them.

Causality interactions are fundamental to correctly comprehend the connections between the parts of a complex system such as the Earth [1] and they can be crucial for the correct modeling and forecasting of such a system. However, correlation and linear regression techniques are still used to characterize these interactions, so leading to incorrect conclusions (correlation is a measure of linear dependencies not causality) [2]. In the last years, a large number of causality measures have been developed presenting different advantages and counterparts [1], among them the Information Theory based approaches appear as promising [2]. However, complex systems, and more precisely the Earth, are most of the time multi-scale, and consequently this Information Theory framework should be adapted to characterize relationships and interactions among scales.

From several years the team composed by S. G. Roux, N. B. Garnier and C. Granero-Belinchon has been working on the development of a statistical description of multi-scale couplings and interactions based on Information Theory [3]. Since information can be directly linked to complexity and then to the structure and state of complex systems, and since multi-scale approaches of Information Theory started to emerge in the last years, this framework appears as novel and original.

The main goal of this internship is the characterization of causality relationships between the scales of a single time process [3]. Thus, two main methodological aspects should be confronted : first, the definition and generation of scales from a time series [4], and second, the definition of an adapted measure of causality across scales. Furthermore, this methodological study presents also an applicative section with relevance in the understanding of ocean dynamics and turbulence.

2. Main tasks

First, the student will make a bibliographic work to understand the different kind of causality measures existing in the literature with a focus on the Information Theory based approaches. Simultaneously, the student will familiarize with a set of existing codes developed within the team by N. B. Garnier to estimate causality relationships between time series. Then, the student will familiarize with multiscale analysis and multiscale decomposition methodologies. Finally, the student will study causality interactions between the scales of time series. During this task, the student will study both synthetic time series with known causality properties as well as more complex synthetic processes and experimental signals.

3. Eligibility Criteria

Candidates are required to be in the Master 2 (or third year engineering school) level education in the field of either applied mathematics, physics or signal processing. Good knowledge of Python programming language with previous experiences in programming is required, as well as previous experience in signal processing. Background in Information Theory, causality interactions, fluid dynamics and/or turbulence will be a plus.

4. Supervision

The internship will be advised by Carlos Granero-Belinchon, Thierry Chonavel (IMT Atlantique), Stéphane G. Roux and Nicolas B. Garnier (ENS de Lyon). Motivated students should send a CV and a motivation letter to : carlos.granero-belinchon@imt-atlantique.fr.

Depending on the sanitary conditions, the internship could take place at IMT Atlantique, ENS de Lyon or by teleworking. Expected duration is 5-6 months.

5. Perspectives

This internship could lead to a subsequent PhD contract funded by ANR SCALES. The PhD will focus on the development of methodological aspects of causality characterization between scales with applications to surface ocean dynamics.

References

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[4] Cohen, L. **The scale representation**, IEEE Trans. Signal Process. 41 3275-3292 (1993). https://www.ee.columbia.edu/~dpwe/papers/Cohen93-scale.pdf