Subject of the internship:
Information measurements in neural networks

Thanos (Athanasios) MANOS (LPTM, CY Cergy Paris Université, email: thanos.manos@cyu.fr)
Mathias QUOY (ETIS, CY Cergy Paris Université, email: mathias.quoy@cyu.fr)

State of the art:

Our understanding of how the different distributed networks, such as in the mammals' brain, function, relies largely on the use of proper methods to measure their ability to integrate and transfer information [1]. Signals from different functionally groups of neurons (different brain regions) are integrated to generate a coherent and multimodal landscape [2] associated to cognitive abilities. In order to understand the underlying mechanisms of the latter ones, one has to investigate how the information is integrated upon arrival as signal to a network node and how it is further conveyed.

Several theoretical and computational tools have been developed over the past year aiming to capture, describe and predict the information transfer within networks, as this quantity is straight-forwardly associated with the information processing. Information transfer can be measured by a variety of directed information measures of which transfer entropy is being broadly used in the literature. For example, applications of transfer entropy are found in neuroscience, physiology, climatology, complex systems theory, economics and elsewhere (see e.g., [3] and references therein), demonstrating its importance in better understanding complex processes in different scientific fields [2].

Complex neural networks (one example of which is the human brain) are able to self-organize into different emergent states crucial for its healthy vs. pathological functioning (e.g., via external stimulus [4;5;6]) and cognition [7;8]. To investigate the role and impact of the network's topological and its information transfer due the interactions between network modes, one can employ a dynamical model to simulate the activity of each node of the network and then study its collective behavior [9;10]. Evidently this global activity is being driven by the underlying nodes connectivity pattern (presence of hubs) [11]. Firing rate models such as the Wilson-Cowan model (see e.g.,[12]) can well capture the main dynamical features and generate simulated data to mimic the activity of a brain network.

Goal of the internship:

The initial goal of the internship will be to prepare numerical codes for the model and the setup of simple (at first) networks to generate simulated time-series and study the information transfer within a simple network. This task may be implemented either by preparing new "in-house" scripts or by using one of the available open-source neural network simulator, like for example the BRIAN platform [13] or The Virtual Brain [14]. Then, we aim to explore the impact of different types of topological network architectures (e.g., fully connected, randomly connected, small-world connection and scale-free connections). For each architecture, we will investigate the directional functionality (causal effects) and communication efficiency between nodes by measuring different information transfer quantities such as transfer entropy, mutual information etc., see e.g. [15; 1].

Total Duration: 6 months with internship funding

Requirements for the students: knowledge of either Python or MATLAB/OCTAVE or Fortran, C or C++ (numerical integration methods for systems of ODEs)

Contact: mathias.quoy@cyu.fr and thanos.manos@cyu.fr

References

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