Master 2 Internship

Title: ***Oscillator dynamics synchronization***

Type: **theoretical**

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PhD funding (if any):

Project:

Oscillatory systems, in particular biological oscillators have been studied since the beginning of last century and their ability to synchronize has been well established. The entrainment of periodic self-sustained oscillators by external periodic forcing, or mutual synchronization is well understood [1]. Many exemples of oscillator synchronization have been reported, for exemple circadian rhythm, locomotion rhythms, animal gaits, human insulin secretion and glucose infusion, synchronization of heart and/or brain rhythms [2]with external audio or visual stimuli…. A less understood domain is that of synchronization of chaotic and noisy oscillators (e.g . of cardiac and respiratory systems through the autonomic nervous system, brain rhythm synchronization on distant areas of the cortex ...). This project aims at unraveling the nature and origin of the couplings that produces such synchronization effects. The main difficulty comes from our ability to distinguish chaotic dynamics from noisy dynamics in real data. In vitro experiments in cardiac and neural tissue have clarified the effects of periodic stimulation in biological systems. Heart and nerve tissue are examples of excitable tissues. This means that in response to a stimulus that is sufficiently large they will generate an event called an action potential. Following the action potential, for a time interval called the refractory period, a second stimulus does not elicit a second action potential. During periodic stimulation there are both periodic synchronized rhythms and aperiodic rhythms. Periodic stimulation of biological systems can give also give rise to aperiodic rhythms. For weak stimulation, it is common to find quasiperiodic rhythms, in which two rhythms with different frequencies superimpose through each other with little interaction. Other aperiodic rhythms of higher complexity are classified as chaotic.

Objectives :

- carry out a state-of-the-art review of the literature; with the support of the book of Pikovsky & Rosenblum [1]
- test and adapt open-source numerical codes accessibles on github (python Brainpy), in particular the library of Susin and Destexhe [3]
- compare various types of synchronization processes, such as external forcing, mutual oscillator synchronization (with or without noise), phase synchronization ...
- Compare these simulations with real physiological signals (EEG, ECG, respiration), in particular for the interpretation of brain rhythms [2] and cardio-respiratory synchronization effects

Expected profile :

We are looking for a student with a background in computer science, data science, physics or applied mathematics, who is curious and open to applications in transdisciplinary fields and complex systems.

References :

[1] A. Pikovsky, M. Rosenblum & J. Kurths, Synchronization. A universal concept in nonlinear sciences, Cambridge Nonlinear Science Series, 2003

[2] G. Buszacki, Rhythms of the brain, Oxford University Press, 2006.

[3] E. Susin, Eduarda & A. Destexhe. "Integration, coincidence detection and resonance in networks of spiking neurons expressing gamma oscillations and asynchronous states." PLoS computational biology 17.9 (2021): e1009416