Master 2 Internship

Title: Time-frequency analysis of complex physiological signals

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PhD funding (if any): no

Project:

During the past decades, the possibility to capture in real time physiological signals from many tissues and organs (brain, heart, muscles, breath, vessels, intestines, lungs, blood ...) has pushed physicians and clinicians to revisit their approach of human beings. From their original view of segmented bodies with separate parts who would require a treatment by a specialized physician, they progressively turned to a global holistic view of human being as a complex and multi-scale network of interactions, where all the parts work in close synergy and contribute to the preservation of health. Physiologic signals are not only unsteady in time but they also pave several frequency decades. Their complexity and their interest for physicist community comes from their combination of stochastic and rhythmic dynamics, where nonlinear feedback loops across scales have to adapt continuously to ensure an efficient homeostatic control. To correctly handle such processes it is required to use multifractal a formalism [1–3]. Moreover their high variability cannot be assessed by classical spectral analysis or averaging methods. In that context time-frequency estimators have been proposed based on temporal or spectral windowing [4], short time Fourier transform (STFT) [5, 6] or wavelet transform (WT) [7, 8].

Following our recent study on the cross-correlation of heart, respiratory and brain rhythms during sleep and sleep apnea [8], this thesis project will address the question of the intermittent character of the temporal variability of these cross-coupling between organs, to characterize to which extent the loss of sleep multi-rhythmic characteristics can be a marker of cognitive impairment [9]. Cross-frequency couplings (CFC) have been proposed as a key mechanism for the coordination of neural dynamics across spatial and temporal scales [10]. For that purpose, it is important to improve temporal and spectral methods to detect and discriminate amplitude-to-amplitude, phase-to-amplitude and phase-to-phase couplings. The relevance of wavelet-based phase and amplitude time-frequency decompositions on electroencephalogram (EEG) signals has recently been highlighted [11], giving a solid ground for this thesis project. At first, the PhD student will concentrate on linear time-frequency decomposition methods (correlation, coherence, Granger causality) to acquire a mastery of these analytical tools and of the brain physiology complexity. Because the human nervous system connectivity is effectively nonlinear, the extension of linear identification methods to nonlinear time-frequency identification tools will be achieved in the second year [12,13]. Multi-spectral generalized coherence and nonlinear causality analysis will be implemented on EEG signals either from databases which we have access to from the web or from the two collaborations in Bordeaux - J. Taillard from the USR CNRS 3413 SANSPY Sommeil, Addiction and NeuroPsychyatrie [9]

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