Project Title: Data-driven and adaptive decomposition of multi-variate signals
Principal Investigator: Dr. Pietro Bonizzi
Promotor: Prof. Ralf Peeters
Collaborators: Dr. Joël Karel
Faculty/Department: Faculty of Science and Engineering, Department of Advanced Computing Sciences
Proposal (250 words):

Introduction: Multi-variate signal analysis plays an important role in our understanding of a variety of complex systems in engineering, physics, biology, and medicine. A major challenge is to achieve a data-driven and adaptive decomposition of a multi-variate signal in a set of components that can accurately capture the nonlinear and nonstationary dynamics typical of complex systems. Current approaches have limitations in terms of their ability to properly separate the information in a multi-variate signal while minimizing leakage of information over several components, or generation of spurious components. Moreover, some techniques are computationally expensive, and cannot scale efficiently to large datasets.

Objectives: Our objective is to develop accurate and efficient data-driven and adaptive multi-variate signal decomposition techniques, starting from state-of-the-art univariate signal decomposition methods.

Setting and Methods: Recently, we proposed singular spectrum decomposition, an adaptive and data driven method for the decomposition of univariate signals (Bonizzi et al., 2015). This method is based on standard matrix factorization techniques like singular value decomposition, and on the concept of trajectory matrix, which links to recurrence analysis of complex systems. Modification of these techniques, also by means of tensor-based decomposition methods, may help in achieving a more physically meaningful separation of the unknown components hidden in the signals.

Impact: This project will impact several fields of research, among which the analysis of brain signals, of gravitational wave signals from multiple detectors, of complex networks, and of recurrence in complex systems, and improve the spatio-temporal analysis of weak and transient components in a multi-variate signal.

Requirements candidate: Student with solid mathematical background (at the level of M.Sc.) in either applied mathematics, physics, or engineering. Good English and communication skills. Basic knowledge in signal processing and machine learning.

Keywords: Signal Decomposition, Signal Processing, Matrix Factorization, Machine Learning.

Top 5 selected publications:

1. P. Bonizzi, J. Karel, O. Meste, R. Peeters. Singular spectrum decomposition: A new method for time series decomposition. Advances in Adaptive Data Analysis, 2014, 6(4): 1450011. Citation score after 2016: 85.
2. E. Lowet, M. Roberts, P. Bonizzi, J. Karel, P. De Weerd. Quantifying neural oscillatory synchronization: a comparison between spectral coherence and phase-locking value approaches. PloS one, 2016, 11(1): 1-37. Citation score after 2016: 111.
3. P. Bonizzi, O. Meste, S. Zeemering, J. Karel, T. Lankveld, H. Crijns, U. Schotten, R. Peeters. A novel framework for noninvasive analysis of short-term atrial activity dynamics during persistent atrial fibrillation. Medical & Biological Engineering & Computing, 2020, 58 (9), 1933-1945. Citation score after 2016: 6.
4. S. Zeemering, A. van Hunnik, F. van Rosmalen, P. Bonizzi, B. Scaf, T. Delhaas, S. Verheule, U. Schotten. A novel tool for the identification and characterization of repetitive patterns in high-density contact mapping of atrial fibrillation. Frontiers in physiology, 2020, 11, 570118. Citation score after 2016: 9.
5. M. Cluitmans, P. Bonizzi, J. Karel, M. Das, B. Kietselaer, M. de Jong, F. Prinzen, R. Peeters, R. Westra, P. Volders. In vivo validation of electrocardiographic imaging. JACC: Clinical Electrophysiology, 2017, 3(3): 232-242. Citation score after 2016: 92.