Control and learning methods for anesthesia patients monitoring

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Post-Doc founded by LabEx PERSYVAL-Lab (ANR-11-LABX-0025-01), starting on autumn 2022

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Keywords: Complex dynamical systems, biological systems, optimal and predictive control, machine learning, formal methods.

Required skills: Skills in applied mathematics and advanced control; skills in data-oriented and optimization programming (Matlab, Phyton, pandas, sklearn, C/C++, etc)

Post-Doc subject: General anesthesia plays a fundamental role to provide surgeons with adequate conditions for operation and avoid discomfort or pain for the patient while reducing the negative post-operation effects of anesthesia. In medical practice, anesthesia concerns the monitoring and controlling of the evolution of the areflexia (lack of movement), analgesia (lack of pain) and hypnosis (lack of consciousness) of the patient. Based on several physiological signals, like the Bispectral Index (BIS), the electroencephalogram (EEG) and the pain and neuromuscular blockage indicators, the anesthesiologist modulates the different drugs perfusion rates to reach and maintain the adequate anesthesia levels. Besides controlling the patient's sedation level, the anesthesiologist is designated to monitor the hemodynamic state, measured by the mean arterial pressure (MAP) and the cardiac output (CO), since the cardiovascular system strongly interacts with the multi-drug anesthesia process.

The main objective of anesthesia is to maintain the desired level of hypnosis, areflexia and analgesia to facilitate the surgeon's tasks by avoiding both drug overdosing and underdosing and their potentially extremely severe consequences on the patient. Pursuing this aim, automatic feedback control theory, formal verification and machine learning can be of great help not only to increase the control efficiency and the monitoring reliability, but also to preserve the vigilance of anesthetists on potential critical events. Several sources of complexity, though, contribute to make the problem of monitoring, predicting and controlling the anesthesia process extremely challenging. Although some works have been appearing proposing automatic control application to the anesthesia process, several key issues are worth to be further addressed.

Objectives and scheduling: The objective of the project is to apply analytical and data-based methods from *advanced control theory*, *formal verification* and *machine learning* to the problems of *modelling, monitoring and controlling the anesthetic process*. Based on both dynamical models, available in the literature, and regression and classification learning techniques, the aim will be to design a numerical tool for estimating the patient state and inferring the occurrence of undesired critical events, like bleeding or anaphylactic shocks for instance, from the signals available to the anesthesiologist.

A further objective of the project concerns the task of develop a method, based on data and learning, for classifying different prototypes of patients, to capture the intra-patient physiological variability and then improve the accuracy and precision of the patient state evolution models.

Such tools could be subsequently used to predict future dangerous scenarios, providing effective means for risk assessment and prevention in the context of automatic assistance of anesthesia, therefore increasing the anesthesia process efficiency and safety.

This Post-Doc is developed in the framework of an interdisciplinary project that gathers researchers from different fields, as automatic control, information science and anesthesiology, whose synergy will contribute to a deeper understanding of the dynamics involved in the anesthesia process and to design ad-hoc methods for analysis and control synthesis, based on the available *real anesthesia data*.