Control and data-driven modelling in biomedicine

Prof Dr Clara IONESCU
Ghent University, Research group on Dynamical Systems and Control,
Technologiepark 914, 9052 Gent, Belgium
Claramihaela.ionescu@ugent.be

Prof DrLevente KOVACS
John von Neumann Faculty of Informatics
Obuda University, Budapest, Hungary
kovacs.levente@nik.uni-obuda.hu

Summary:

This proposal is for an open invited track (OIT) on the problem of control and data-driven modelling in biomedicine. The **main goals** of this OIT are:

1) To address corner issues in control and modelling of biological and medical data, such as: missing data, intermittent feedback information, triggered response data, event based control, time and dose based treatment, etc.
2) To enable emerging modelling tools such as fractional calculus, e.g.for characterizing anomalous drug diffusion, LPV-based control, TP transformation, etc.
3) To tackle the problem of integrating patient response and medical assist devices within cyber medical systems paradigm, addressing modularity, compatibility, flexibility, emergency response and patient safety.

The topic of this OIT falls within the IFAC TC 8.2 “Biological and Medical Systems”, and the IEEE TCs on Signal Processing and Adaptive Control, on Medical Healthcare Technologies and on CyberMedical Systems.

Description:

Overview of system identification and control in biological and medical systems

This proposal envisages an OIT addressing the challenges of feedback control in living organisms, with application to biology and medicine. Mathematical models of organs and systems of the human body are used to uncover and quantify their dynamical properties in health and disease. The obtained insights are expected to be instrumental in design of innovative and agile tools for modeling, analysis, design, and optimization of biological and medical systems.

Hitherto, control engineering has become an important enabling technology in several areas of biology and medicine. Prominent recent examples are artificial pancreas, closed-loop anesthesia, life support systems, neuromodulation systems, radiation therapies, and individualized drug dosing strategies in neurology, oncology, endocrinology, pathology and psychiatry. The feedback principle ultimately allows for treatment individualization by relating the achieved therapeutical effect and the specified treatment goal to the current regiment. Thus the arrival of feedback control to the clinic makes the visionary concept of "Treat the patient, not the disease" technologically and economically feasible.

Feedback is the basis of homeostasis in biological system. In many cases, the steady state conditions in a system of an organism are oscillatory and dynamical systems theory is indispensable for explaining the nature of those exogenous processes.

Mathematical modeling is a powerful tool widely applied in both biology and medical systems, however for different reasons. In biology, mathematical models are predominately derived from somewhat fragmented descriptions of biological pathways and regulation mechanisms in order to obtain a more general view of a biological system and its dynamical properties. Thus the developed model is perceived as a final product. Fitting such a model to experimental data is in many cases seen as a mundane task.

On the contrary, mathematical modeling in medicine typically aims at individualization of therapies and quantification of effects that cannot be measured directly. For these ends, the biological interpretation of the model structure is less important compared to the model performance on experimental data and its feasibility for the end application.

Although the above issues are well tackled at the moment by the research community, there are corner issues and specific aspects which challenge the achievable end-result. Often, when models are to be identified from real data, one has to deal with missing data, intermittent feedback information. Additionally, disturbances and side effects can originate from triggered response data, event based control, changes in the time and dose based treatment, etc.

As a recent trend, emerging technologies and tools from other disciplines are more and more penetrating the area of biological and medical systems. Of these, we may give the example of fractional calculus, from applied mathematics, with deep roots in physics, chemistry and biology, offering natural solutions to characterize complex processes such as anomalous diffusion. Another example could be the Linear Parameter Varying based control or Tensor Product modeling in order to use linear control methods directly on nonlinear systems.

Yet another element in the current landscape is the integration of multiple systems and data sources and possibly human in the loop response. For instance, one needs to integrate the patient response and medical assist devices within cyber medical systems paradigm, addressing modularity, compatibility, flexibility, emergency response and patient safety.

Specific Aims

Given the context described above, the purpose of this OIT is to bring together researchers working on system identification and automatic control with applications to systems biology and medical/healthcare systems to see what the two communities can learn from each other's experiences. Topics of common interests include but are not limited to the following:

- theoretical and deployment challenges that arise in medical and biological systems,
- control engineering tools for solving specific system design problems in medical technology,
- existing and new data-driven modeling techniques capturing the dynamics of biomedical systems and taking into account intra- and inter-individual variability,

- evidence of successful projects (study-cases) in biomedical technology enabled by system identification and control,
- application areas in healthcare and medical systems, such as assistive devices and therapeutics in medical rehabilitation, mathematical and simulative models of infectious diseases spreading, treatment and management of diabetes, artificial pancreas, closed-loop anesthesia, and control of legged locomotion.

In a nutshell, with this OIT, we are waiting for papers dedicated to technological advances in control engineering with a specific attention to system biology, healthcare,... applications. More specifically, we aim at:

a) pointing out theoretical and practical issues specific to bio-medical and biological systems,
b) bringing together solutions developed under different settings with a specific attention to the validation of these tools in bio-medical and biology settings,
c) introducing significant case studies.