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"La mente è come un paracadute.
Funziona solo se si apre"
A. Einstein

Modern robust control in biomedical control problems. From theory to application.

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Abstract

Due to the continuous development in computer science, control engineering and measurement theory, the possibilities of biomedical engineering are extending. The aim of physiological control—a subdiscipline of biomedical engineering—is to study, model and apply identification and control strategies in order to understand and help the automated treatment of various diseases and injuries of the human body.
In many biomedical systems external controllers provide biosignal input or inject given specific dosage substituting the internal, physiological procedure because patient's body cannot ensure it or produce it. The outer control might be partially or fully automated. The regulation has several strict requirements, but once adequately established, it permits not only to facilitate the patient's life, but also to optimize (if necessary) the amount of the used dosage.
Individualized model-based control gains more and more importance in physiological and pathophysiological control. The investigated models are nonlinear and rather complex by nature. Furthermore, the parameters of the patients slowly change over time. However, despite the difficulties, the controllers have to ensure safety and stability under all circumstances. Hence, not only classical nominal control requirements, i.e. disturbance rejection, good command following and stability are required, but robust performance as well. Modern robust control methods (in terms of linear H_∞, and μ control syntheses) endeavor to provide this safety, and guarantee to handle even the worst case scenario by taking neglected dynamics into account. This is done by exact mathematical formulations, but also by empiricism gained from the expertise of the corresponding control process.
The use of modern robust control methods from physiological point of view will be presented as case study

for two high impact diseases:

- Artificial pancreas: Recent technological advances in diabetes treatment like Continuous Glucose Monitors (CGMs) for the subcutaneous measurement of glucose concentration and insulin pumps for the subcutaneous delivery of insulin allowed investigating the applicability of an external controller. In type 1 diabetes, where the disease can be characterized as a general clinical picture (complete pancreatic β-cell insufficiency) different individualized model-based (mostly model predictive control (MPC) based) solutions have been already formulated and even first clinical trials appeared demonstrating that nocturnal hypoglycaemia can be efficiently avoided. However, during the daytime, due to several uncontrolled and not modeled events (like stress, physical activity, etc.) a robust solution is required handling these uncertainties.
- Antiangiogenic therapy in cancer treatment: Antiangiogenic therapy is a targeted molecular therapy arose in the last decade which aims to stop tumor angiogenesis, i.e. making new blood vessels; hence, minimalizing the tumor's volume. However, the corresponding drugs are very expensive, in high doses may have side effects and currently used clinical protocols are determined empirically. As a consequence, this problem can be seen as a double optimal control problem: on the one hand the aim is to minimize the tumor's volume by a model-based control algorithm, but it is also crucial to inject the corresponding inhibitor (drug) in an optimal way (minimizing costs). Due to the heterogeneous nature of the patients a robust control method is again needed giving modern robust control theory to be a corresponding candidate.

Although modern robust control theory represent linear control methods, their extension into nonlinear cases is an actively researched case nowadays as well. A promising candidate is the Linear Parameter Varying (LPV) methodology, where the nonlinearity can be hidden by adequately choosing variables; hence, being a practical alternative to differential geometric approach-based classical nonlinear control theory.