

Model Predictive Control of Type 1 Diabetes: An *in Silico* Trial

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Abstract

Background:

The development of artificial pancreas has received a new impulse from recent technological advancements in subcutaneous continuous glucose monitoring and subcutaneous insulin pump delivery systems. However, the availability of innovative sensors and actuators, although essential, does not guarantee optimal glycemic regulation. Closed-loop control of blood glucose levels still poses technological challenges to the automatic control expert, most notable of which are the inevitable time delays between glucose sensing and insulin actuation.

Methods:

A new *in silico* model is exploited for both design and validation of a linear model predictive control (MPC) glucose control system. The starting point is a recently developed meal glucose–insulin model in health, which is modified to describe the metabolic dynamics of a person with type 1 diabetes mellitus. The population distribution of the model parameters originally obtained in healthy 204 patients is modified to describe diabetic patients. Individual models of virtual patients are extracted from this distribution. A discrete-time MPC is designed for all the virtual patients from a *unique* input–output-linearized approximation of the full model based on the average population values of the parameters. The *in silico* trial simulates 4 consecutive days, during which the patient receives breakfast, lunch, and dinner each day.

Results:

Provided that the regulator undergoes some individual tuning, satisfactory results are obtained even if the control design relies solely on the average patient model. Only the weight on the glucose concentration error needs to be tuned in a quite straightforward and intuitive way. The ability of the MPC to take advantage of meal announcement information is demonstrated. Imperfect knowledge of the amount of ingested glucose causes only marginal deterioration of performance. In general, MPC results in better regulation than proportional integral derivative, limiting significantly the oscillation of glucose levels.

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Abbreviations: (FHOCP) finite horizon optimal control problem, (HBGI) high blood glucose index, (LBGI) low blood glucose index, (MPC) model predictive control, (PID) proportional integral derivative, (T1DM) type 1 diabetes mellitus

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Abstract cont.**Conclusions:**

The proposed *in silico* trial shows the potential of MPC for artificial pancreas design. The main features are a capability to consider meal announcement information, delay compensation, and simplicity of tuning and implementation.

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