

Safety Constraints in an Artificial Pancreatic β Cell: An Implementation of Model Predictive Control with Insulin on Board

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Abstract

Background:

Type 1 diabetes mellitus (T1DM) is characterized by the destruction of pancreatic β cells, resulting in the inability to produce sufficient insulin to maintain normoglycemia. As a result, people with T1DM depend on exogenous insulin that is given either by multiple daily injections or by an insulin pump to control their blood glucose. A challenging task is to design the next step in T1DM therapy: a fully automated insulin delivery system consisting of an artificial pancreatic β cell that shall provide both safe and effective therapy. The core of such a system is a control algorithm that calculates the insulin dose based on automated glucose measurements.

Methods:

A model predictive control (MPC) algorithm was designed to control glycemia by controlling exogenous insulin delivery. The MPC algorithm contained a dynamic safety constraint, insulin on board (IOB), which incorporated the clinical values of correction factor and insulin-to-carbohydrate ratio along with estimated insulin action decay curves as part of the optimal control solution.

Results:

The results emphasized the ability of the IOB constraint to significantly improve the glucose/insulin control trajectories in the presence of aggressive control actions. The simulation results indicated that 50% of the simulations conducted without the IOB constraint resulted in hypoglycemic events, compared to 10% of the simulations that included the IOB constraint.

Conclusions:

Achieving both efficacy and safety in an artificial pancreatic β cell calls for an IOB safety constraint that is able to override aggressive control moves (large insulin doses), thereby minimizing the risk of hypoglycemia.

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Abbreviations: (ARX) autoregressive exogenous input, (CF) correction factor, (CHO) carbohydrate, (CSII) continuous subcutaneous insulin infusion, (I:C) insulin-to-carbohydrate ratio, (IOB) insulin on board, (MDI) multiple daily injections, (MPC) model predictive control, (SMBG) self-monitoring of blood glucose, (T1DM) type 1 diabetes mellitus

Keywords: artificial pancreas, insulin-on-board, model predictive control, type 1 diabetes mellitus

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