

Glucose Estimation and Prediction through Meal Responses Using Ambulatory Subject Data for Advisory Mode Model Predictive Control

Rachel Gillis,¹ Cesar C. Palerm, Ph.D.,^{1,3,4} Howard Zisser, M.D.,² Lois Jovanovič, M.D.,^{2,3}
Dale E. Seborg, Ph.D.,¹ and Francis J. Doyle, III, Ph.D.^{1,3}

Abstract

Background:

A primary challenge for closed-loop glucose control in type 1 diabetes mellitus (T1DM) is the development of a control strategy that will be applicable during all daily activities, including meals, stress, and exercise. A model-based control algorithm requires a mathematical model that has the simplicity for online glucose prediction, yet retains the complexity necessary to cope with variations in insulin sensitivities and carbohydrate ingestion.

Methods:

A modified Bergman minimal model was linearized for Kalman filter (KF) state estimation on data from T1DM subjects, and multiple methods of parameter augmentation were developed for online adaptation. In addition, model deterioration for glucose prediction was assessed to determine an appropriate prediction horizon for model predictive control (MPC). Furthermore, MPC strategies were validated using advisory mode simulations.

Results:

Twenty days of continuous glucose data, which included 97 meals, were evaluated for three subjects. A constant parameter minimal model was used to predict glucose levels for normal days with meal announcement and with a maximum prediction horizon of approximately 45 minutes. In order to attain this prediction horizon in the absence of meal announcement, parameter adaptation was necessary to capture the glucose disturbance. Evaluation of advisory mode MPC permitted effective tuning for a moderately aggressive controller that responded well to meal disturbances.

continued →

Author Affiliations: ¹Department of Chemical Engineering, University of California, Santa Barbara, California, ²Sansum Diabetes Research Institute, Santa Barbara, California, ³Biomolecular Science and Engineering Program, University of California, Santa Barbara, California, and ⁴Current Affiliation: Medtronic Diabetes

Abbreviations: (CGMS) continuous glucose monitoring systems, (KF) Kalman filter, (MPC) model predictive control, (MRAD) median relative absolute difference, (T1DM) type 1 diabetes mellitus

Keywords: artificial pancreas, model predictive control, patient model, type 1 diabetes

Corresponding Author: Francis J. Doyle, III, Ph.D, Department of Chemical Engineering, University of California, Santa Barbara, Santa Barbara, CA 93106-9611; email address doyle@engineering.ucsb.edu

Abstract cont.**Conclusions:**

Estimation and prediction of glucose were accomplished using a KF based on a modified Bergman model. For a model with no meal announcement, parameter adaptation provided the means for closed-loop implementation. This state estimation and model validation scheme established the necessary framework for advisory mode MPC.

J Diabetes Sci Technol 2007;1(6):825-833