A Simple Modeling Framework For Prediction In The Human Glucose-Insulin System

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In this paper, we build a new, simple, and interpretable mathematical model to describe the human glucose-insulin system. Our ultimate goal is the robust control of the blood-glucose (BG) level of individuals to a desired healthy range, by means of adjusting the amount of nutrition and/or external insulin appropriately. By constructing a simple yet flexible model class, with interpretable parameters, this general model can be specialized to work in different settings, such as type 2 diabetes mellitus (T2DM), intensive care unit (ICU) and type 1 diabetes mellitus (T1DM); different choices of appro- priate model functions describing uptake of nutrition and removal of glucose differentiate between the models. In addition to data-driven decision-making and control, we believe the model is also useful for basic quantification of endocrine physiology. In both cases the available data is sparse and collected in clinical settings, major factors that have constrained our model choice to the simple form adopted.

The model has the form of a linear stochastic differential equation (SDE) to describe the evolution of the blood glucose (BG) level. The model includes a term quantifying glucose removal from the bloodstream through the regulation system of the human body and/or from externally delivered insulin; it also includes another term representing the effect of nutrition. The stochastic fluctuations encapsulate model error necessitated by the simple model form, and enable flexible incorporation of data. The parameters entering the equation must be learned in a patient-specific fashion, leading to personalized models. We present numerical results on patient-specific parameter estimation and future BG level forecasting in T2DM and ICU settings. The resulting model leads to prediction of the BG level as an expected value accompanied by a band around this value which accounts for uncertainties in the prediction. Such predictions, then, have the potential for use as part of control systems which are robust to model imperfections and noisy data.