Abstract

Mathematical models provide a platform for understanding the mechanism and providing insight into various physiological processes. With diabetes reaching epidemic proportions, recent times have witnessed an increased attention in glucose metabolism including modeling the dynamics of the involved physiological processes.

Along with the physiological models some completely data driven empirical models of glucose metabolism are also reported in the literature. Empirical models are only compatible with the input-output data and their parameters do not have any physiological significance. In the present work, a nonlinear autoregressive with exogenous input (NARX) model, which is able to exhibit the input-output behavior of a clinical test and at the same time quantify an index for insulin sensitivity, is developed.

The analysis of the nonlinear glucose regulation system is further carried out using its piecewise affine (PWA) equivalent model. The number of affine subsystems required to represent a nonlinear system is an important consideration in the development of PWA model. In this regard, a fuzzy clustering based technique for the optimal piecewise affine representation of a general class of nonlinear systems is derived. The PWA model analysis mainly involves the behavioral study of the system at steady state for different sets of inputs and physiological parameters. From the PWA representation, it is possible to determine the equilibrium point (basal condition) of the glucose regulation system without solving complex equations. A condition for the existence of a stable limit cycle of plasma glucose concentration as a function of delay in hepatic glucose production is determined from the developed model. This has allowed to determine the point of hopf bifurcation without carrying extensive simulation. The PWA model is further applied to determine a particular profile (characteristics) for insulin sensitivity that would maintain a normal basal glucose level even with retarded insulin secretion characteristics.

Finally, by considering the glucose regulation as a linear quadratic regulator (LQR) problem, a constrained state feedback controller that maintains proper glucose regulation in case of a meal disturbance in type 1 diabetic subjects with the optimal infusion of insulin is proposed. The constrained controller is based on the feedback of plasma glucose and plasma insulin.