Chapter 44
Higher Order Sliding Mode Control for Blood Glucose Regulation of Type 1 Diabetic Patients

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ABSTRACT

Type 1 diabetes mellitus (T1DM) treatment depends on the delivery of exogenous insulin to obtain near normal glucose levels. This article proposes a method for blood glucose level regulation in type 1 diabetics. The control strategy is based on comparing the first order sliding mode control (FOSMC) with a higher order SMC based on the super twisting control algorithm. The higher order sliding mode is used to overcome chattering, which can induce some undesirable and harmful phenomena for human health. In order to test the controller in silico experiments, Bergman's minimal model is used for studying the dynamic behavior of the glucose and insulin inside human body. Simulation results are presented to validate the effectiveness and the good performance of this control technique. The obtained results clearly reveal improved performance of the proposed higher order SMC in regulating the blood glucose level within the normal glycemic range in terms of accuracy and robustness.

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1. INTRODUCTION

Diabetes mellitus (DB) is a metabolic disorder in which insulin cannot properly perform its role (Mandrup-Poulsen, 1998). Insulin is an important hormone needed to facilitate entry of blood glucose to cells where it is converted into energy or stored to be used when the glycemia decrease (Bilous and Donnelly, 2010). The statistics of the World Health Organization (WHO) predate an increase of adult diabetes population from 4% (in 2000, meaning 171 million people) to 5,4% (366 million worldwide) by the year 2030 (Wild et al. 2004). The incidence of type 1 diabetes (T1D) continues to increase in all countries of the world and concern specifically age during childhood and adolescence. Type I, or insulin dependent diabetes mellitus (IDDM), is characterized by absent insulin secretion in the pancreas, resulting in plasma glucose concentrations elevated above the normoglycemic range (70-120mg/dL Current research is mainly aimed at preventing the disease in the years to come. The insulin injection to T1D has the goal to better mimic normal pancreatic release as shown in Figure 1. (Bilous and Donnelly, 2010). A condition of high blood glucose profiles, which is hyperglycemia, results in several complications, such as, blindness, kidney failure, nerve damage, and heart attack. Thus, in order to avoid the hyperglycemia, a continuous supply of exogenous insulin is required, and the insulin dependent diabetic therapy usually does this (Takahashi et al., 2008).

On the contrary, too much insulin supply may lead to a condition of low blood glucose profiles resulting in drowsiness, mental malfunctioning, irritability, and loss of consciousness. This condition is called hypoglycemia and also dangerous to the diabetic. Thus, the insulin dependent diabetic therapy must concern both hyperglycemia and hypoglycemia by providing an appropriate amount of exogenous insulin timely. Therefore, a significant effort has been put toward the development of a device to control glycemia (Fisher, 1991; Ibbini et al., 2004) and the methods are continuously improved. Since diabetic patients show a lack of feedback regulation between blood sugar concentration and insulin secretion, the development of external closed-loop insulin delivery systems is a challenging and hot topic for application-oriented control engineers (Bequette, 2005; Lin et al., 2004; Chee et al., 2003). A closed-

Figure 1. Profiles of plasma glucose and insulin concentrations in individuals without diabetes (Bilous and Donnelly, 2010)