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University of Bahrain
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FUZZY PID (FPID) CONTROL FOR BLOOD GLUCOSE-INSULIN SYSTEM FOR T1DM

Abstract

Blood glucose control for diabetic patients began many years ago, and as the years progressed, various techniques for better and more effective control were developed. The project's aim is to keep type 1 diabetes patients' blood glucose levels within a healthy range by employing an artificial pancreas that uses fuzzy-proportional Integration derivative control algorithm. In this project, the Bergman model was simulated to show the dynamics of glucose-insulin. Controlling blood glucose proposed, using three controllers, starting with the PID and fuzzy controllers, and ending with the project's goal, which is to control blood glucose using a fuzzy-PID controller. By using the fuzzy control system, we can get greater and more precise control of glucose, as the fuzzy logic works with excellent efficiency because it mimics human thinking and analyzing. Also, testing the controllers under inter-intra variability of the patient gives more reliability to the designs and increases safety. The development used in this paper is expected to simplify the insulin delivery, thereby enhancing the quality of life of the patient.

Objective and Motivation

Aim of the project is to design an accurate and effective injection control approach for Type 1 diabetes patients that would allow them to maintain a stable blood glucose level because T1DM patients have no control over the blood glucose in their bodies because of their deficient pancreas. The Bergman Model was used for the simulation in MATLAB/SIMULINK, in which normal and patient responses were obtained for comparison and control of the patient glucose concentration. For exogenous insulin infusion, three control algorithms will be used: PID controller, Mamdani type fuzzy logic controller, and fuzzy-PID controller.

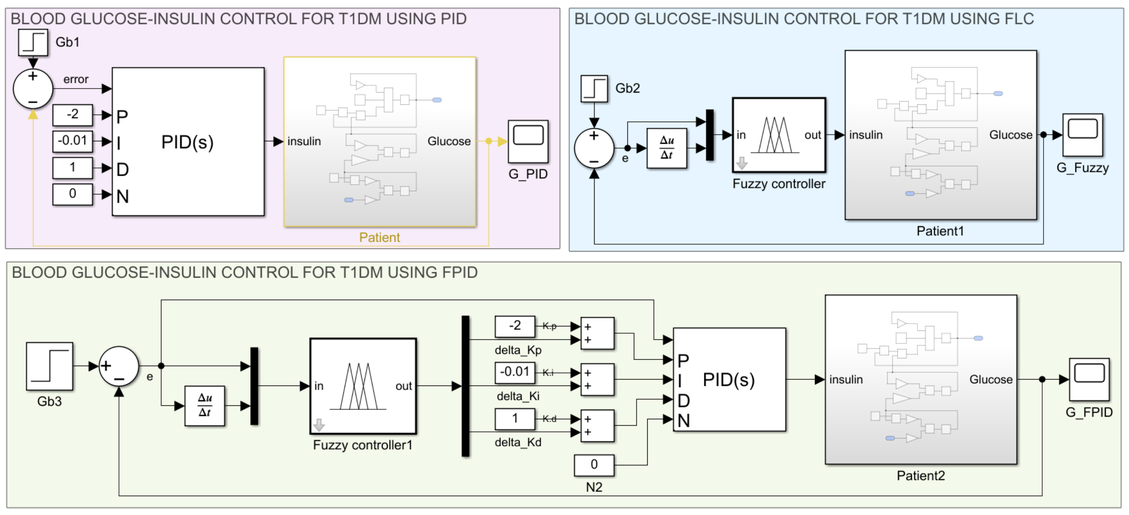
Motivation Diabetes mellitus is a metabolic disease in which the body is unable to generate or respond to insulin in the blood. In T1DM, the pancreas does not release insulin, the key hormone that controls blood glucose content. As a result, type 1 patients require exogenous insulin injections to help with glucose absorption and utilization otherwise the patients will suffer from complications and death at the end. Using control knowledge via simulation to solve this problem will have a great impact on these patients.

Design and Implementation

Three controllers were designed to control T1DM glucose using insulin, which are PID, FLC, and FPID. PID controller was obtained first, then the FLC and the FPID using the Fuzzy designer app, in which the fuzzy sets have been set for inputs and outputs along with the 25 fuzzy rules for each fuzzy controller. The inputs for the FLC and the FPID were both the error and the derivative of error, while the outputs were insulin only for FLC and $\Delta K_p, \Delta K_I, and\ \Delta K_D$ for FPID. The three controllers were designed so that they maintain the glucose concentration within an acceptable range.

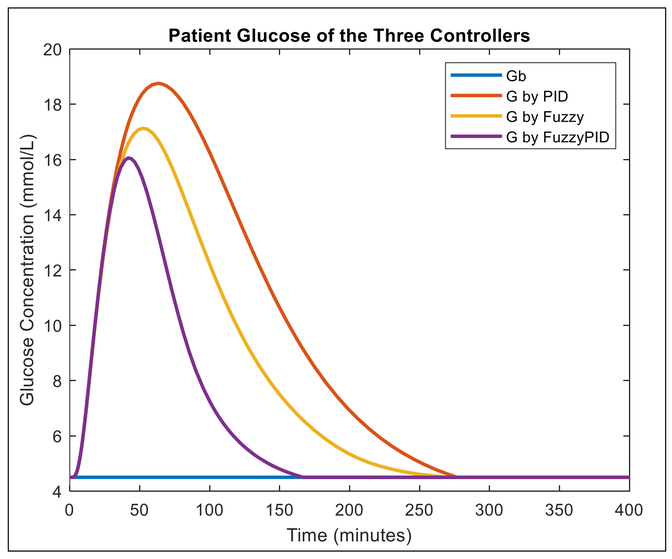
$$u(t) = (\Delta K_p + -2)\, e(t) + (\Delta K_I + -0.01) \int e(t)\, dt + (\Delta K_D + 1) \frac{de}{dt}$$

Where $\Delta K_p = \Delta K_I = \Delta K_D = [-0.5, 0.5]$



Results

The results showed that the PID controller can be used to control the blood glucose of a patient. The Fuzzy controller gave better responses. However, the Fuzzy-PID controller was the best of them all, as expected. The Fuzzy-PID controller settles at 167 minutes, while the PID and Fuzzy controllers settle at 277 and 270 minutes, respectively. For diabetes patients, time is very important. Otherwise, their condition might deteriorate quickly and lead to a serious situation and may even lead to death. The Fuzzy-PID controller also had a lower peak for glucose concentration, measuring 16.05 mmol/L, while the other two controllers had larger values.



The controllers were tested on three different patients, and the results were satisfactory in all three cases, with glucose properly controlled.

Conclusion

Controlling the blood glucose of the T1DM patients was implemented in this project. The Bergman Model was used for the simulation in MATLAB/SIMULINK, in which normal and patient responses were obtained for comparison and control of the patient glucose concentration. To solve this problem, a Fuzzy-PID controller was designed, starting with the PID, then the Fuzzy controller, and finalizing with the Fuzzy-PID. Fuzzy-PID controller present best response among all controller used.

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