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PID CONTROLLER FOR BLOOD GLUCOSE CONTROL

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ABSTRACT
In the current era diabetes has become a common disease among people irrespective of age. Diabetes can even cause loss of life if not treated properly. There are different types of diabetes commonly classified as Type I and Type II. In Type I diabetes insulin is not produced properly and in Type II the insulin produced is not utilized by the body properly. In this paper we are considering Type I diabetes, where no or little insulin is produced and as a result sugar builds up in the blood instead of being used as energy in the body. Here PID controller is used for controlling blood glucose by properly providing insulin. The tuning method used is Imc-chien and Imc-maclaurin.

KEYWORDS: Diabetes, PID controller, Imc-chien, Imc-maclaurin

INTRODUCTION
Diabetes is a particular state that prevents the human body from properly extracting the energy from food we consume. The consumed food is broken down into glucose. The dieticians advise not to include food with too much sugar in the diet, but practically some glucose is required in regulating our metabolism and also to provide us energy. During the digestion process , glucose moves throughout the body through the bloodstream to the blood cells. For transfer of the blood sugar into the cells, insulin is needed, which is produced by the pancreas and pumped into the bloodstream. The pancreas generate alpha cells that release glucagon which in turn is released as glucose into the blood stream by liver to achieve normal level from low blood glucose. They also generate beta cells which release insulin that enables the fatty acids to absorb glucose from blood bringing the high blood glucose level to normal level. The aim is to set the glucose level between 70-180 mg/dl.

MOTIVATION
One of the biggest diseases in the world today is diabetes. Millions suffer from this disease and the number is growing. The grow is mostly due to the use of unhealthy food. Because of this large problem many researchers try to find methods for diagnosing and treating the disease. Patients with long standing Type 1 Diabetes Mellitus produce little or no insulin, leaving the body unable to lower blood glucose (BG) levels without exogenous insulin. One of the mathematical models describes the glucose-insulin system with a few number of parameters is Hovorka model and this was used in this paper. Hovorka is a three compartment model. It has two inputs, meal disturbances and insulin infusions, and simulates the glucose and insulin concentration in the body in response to these inputs.

LITERATURE SURVEY
In the past many authors have discussed about controllers for blood glucose level control and they considered meal as a disturbance Stuart et al.[1], had discussed that minimum amount of premeal boluses would reduce postmeal sugar level during closed loop control (CLC), full closed loop (FCL) and hybrid closed loop (HCL). In FCL technique a system with PID control algorithm was used to take the controlling action once in every 15 minutes. The target glucose level was made to vary from 100 mg/dl during day and at night time 120 mg/dl to reduce false alarm which may be due to sensor malfunction. Based on the sensor input various alarm indications were done to alert the patient about the diet. Marchetti et al.[2] made simulation studies for the Hovorka model

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and demonstrated that set point reduction is the most effective approach. Several new feed forward control strategies have been proposed as alternatives to the standard insulin bolus approach.

PATIENT MODEL

Hovorka model is taken as the patient model shown in figure 1. It is a three compartment model with a few number of parameters.

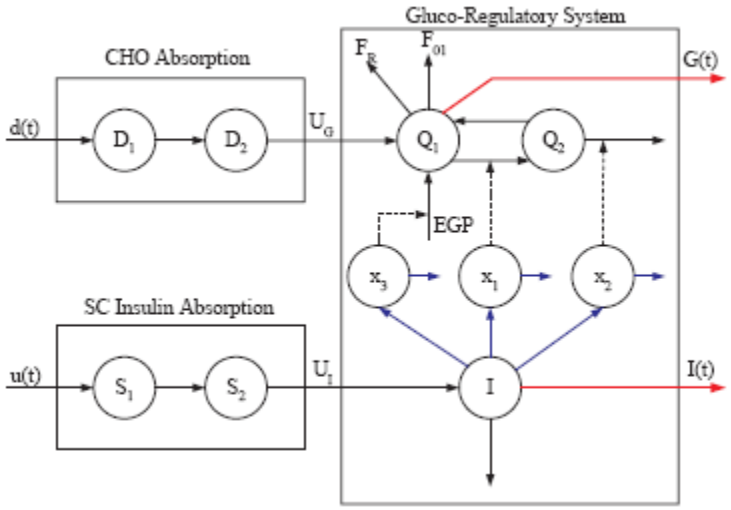

Figure 1: Hovorka model

It has three compartments namely CHO absorption, SC absorption and Gluco-Regulatory system. Hovorka can be represented by second order function with delays.

$$\frac{I(S)}{G(S)} = \frac{5.04 * e^{-0.0282s}}{(S^2 + 347.08\,S + 4585.05)} \quad (1)$$

The pattern of food consumption that the patient follows in a 24-hour period (starting From 7 am) is described in the table 1

Table 1. Meal pattern

Meal	Time of consumption	Amount of CHO (g)	Duration (min)
Breakfast	7 AM	25	10
Lunch	1 PM	40	15
Dinner	7 PM	60	20

PID CONTROL

To design the PID controller the error is determined, where the error is difference between glucose sensors measured value and desired value of glucose. The equation for PID is given by equation 2

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{d}{dt} e(t) \quad (2)$$

Where, u(t) is output response, e is the error(difference between set point of glucose and measured value of glucose) Kp is proportional gain and it depends on the present value of system. Ki is integral gain and it depends on past accumulate value of system. Kd is derivative gain and it depends on future or expected value.

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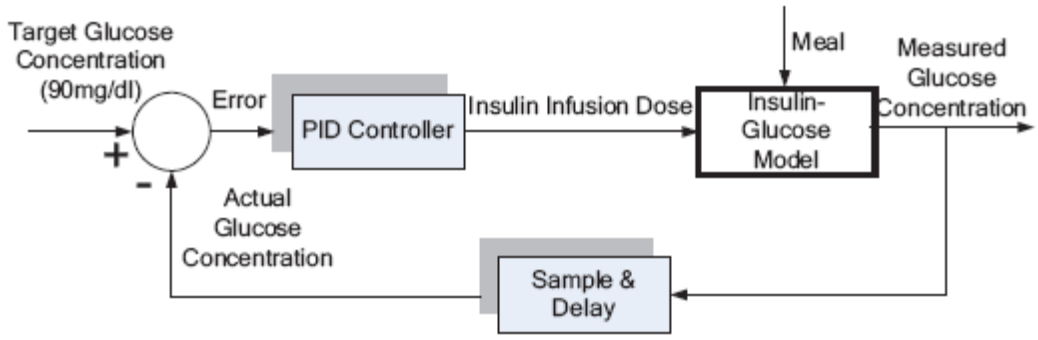

Figure 2: PID Controller

While the PID concepts are relatively straightforward, system optimization can be difficult; for this reason, some degree of tuning is necessary. While experience is certainly valuable, a tuning process such IMC-chien and IMC-maclaurin methods is used.The model is re-written as

$$H(s) = \frac{ke^{-\tau_d S}}{(1+\tau_1 s)(1+\tau_2 s)} \qquad (3)$$

Table 2. Tuning table

	Kp	Ki	Kd
IMC- chien	$\frac{\tau_1+\tau_2}{k(\gamma+D)}$	$\tau_1+\tau_2$	$\frac{\tau_1\tau_2}{\tau_1+\tau_2}$
IMC-maclaurin	$\frac{\tau_1}{k(2\gamma+D)}$	$\tau_1+\tau_2-\frac{2\gamma^2-D^2}{2(2\gamma+D)}$	$\tau_1+2\varepsilon\tau_1 \quad -\frac{2{\tau_1}^2-\frac{D^3}{6(2\gamma+D)}}{\tau_1}$

Where ku= ultimate gain,D= dead time(τ_d),γ=max(0.25D,0.4εw_n)

RESULTS AND DISCUSSION

The step response of the system is given by the figure 3

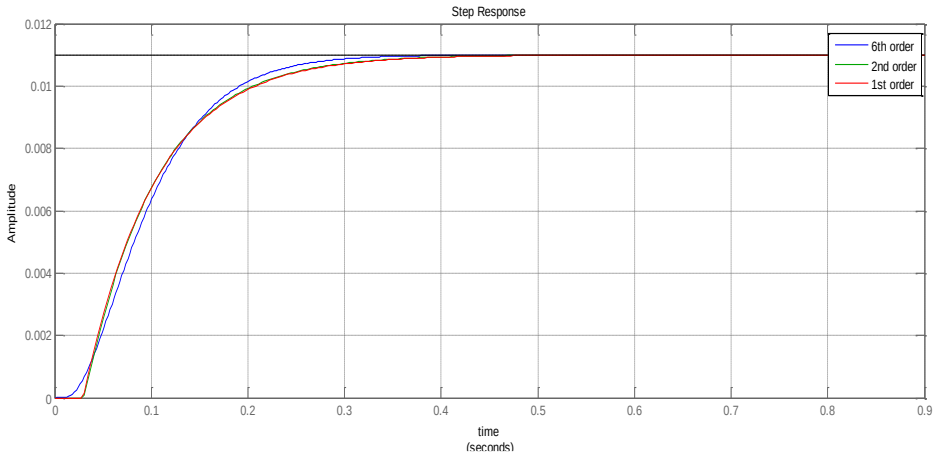

Figure 3: Step response

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The target glucose level is selected as 90 mg/dL. The different methods such as Imc-chien and Imc-maclaurin is selected for tuning of PID. The different methods are simulated with and without the disturbance action.

Imc-chien

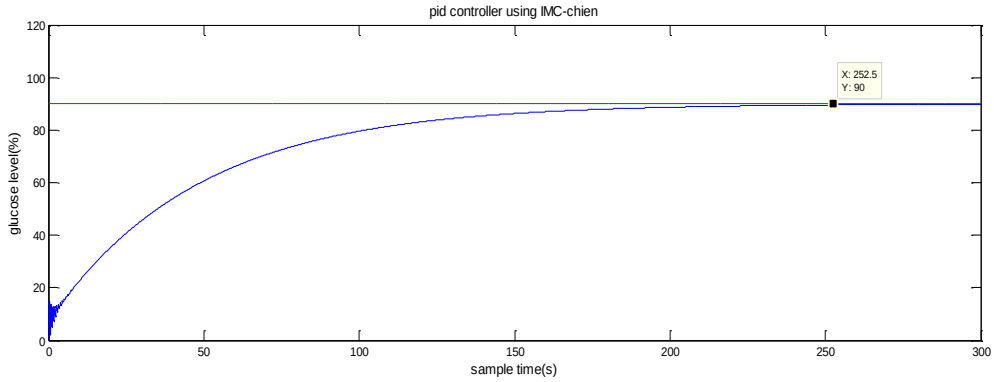

Figure 4: PID tuning using Imc-chien

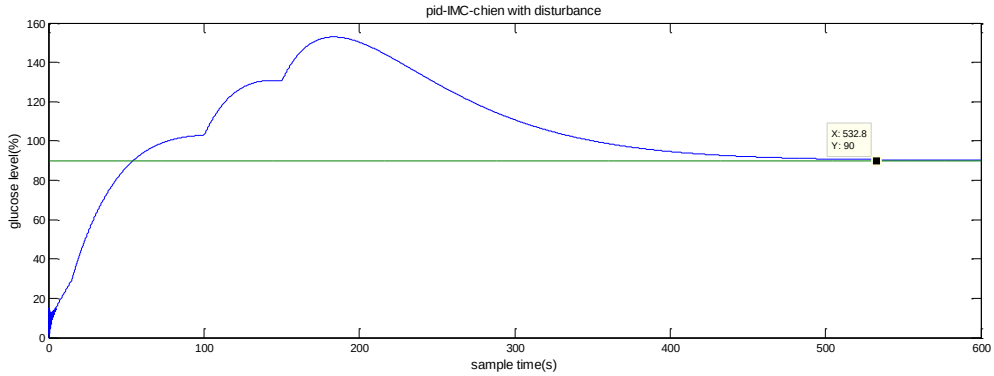

Figure 5: PID tuning using Imc-chien with disturbance

Imc-maclaurin

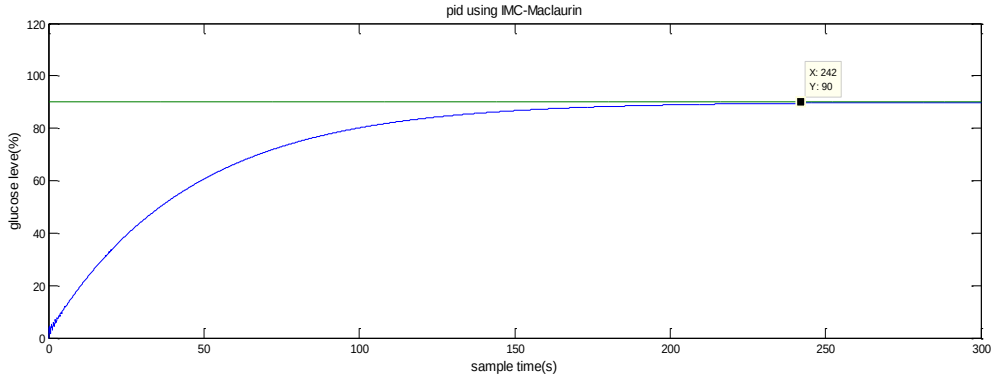

Figure 6: PID tuning using Imc-maclaurin

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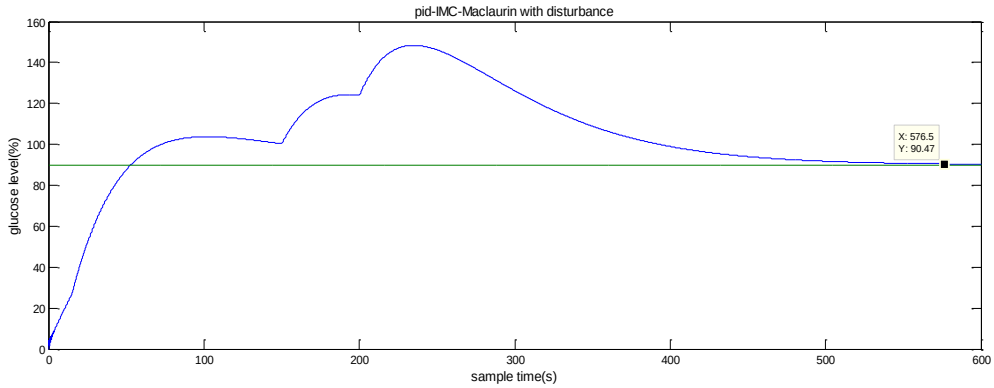

Figure 7: PID tuning using Imc-maclaurin with disturbance

The proposed controller design gives desired output. The disturbance is acting at the time intervals between 100-200 sample time. Even though there is disturbance the system is tracking the setpoint i.e 90mg/dL .

CONCLUSION AND FUTURE WORK

The PID controller gives satisfactory output. The time taken to reach set point is more. These models only react to the glucose concentration that has just been measured, and when there is an increase in insulin, it takes so long to have an effect on the glucose concentration that too much insulin has already been given. Therefore it is necessary to react before the glucose concentration has risen too much. Future glucose concentrations should therefore be predicted, which makes MPC an attractive option for this application. It makes predictions of the glucose concentration, and can therefore react before the actual glucose concentration has changed too much.

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