Nonlinear model predictive control with combined system model of fuzzy predictive and PID controller for managing the blood glucose level in type I diabetes

M NALINI, V BALAJI

Abstract - Diabetes is likewise alluded as diabetes mellitus, is a gathering of metabolic maladies and causes high glucose level over a long stretch. Because of absence of insulin discharge sort 1 diabetes happen and accordingly has a low level of glucose. Insulin must be infused to control the level of blood glucose in the body. In the event that the level of insulin surpasses the farthest point it might bring about death. This paper displayed on controlling the blood glucose level utilizing a nonlinear model prescient control. The blood glucose level is observed for every single moment and anticipated for whenever interim, the insulin infusion level will be resolved if the model finds the framework is in irregular range. The nonlinear prescient control model is ordered into two models. The primary model is alluded as plant model. It decides the diabetic control and the second model is alluded as framework model. It decides the insulin-glucose administrative framework. To decide the prescient control, Fuzzy and PID control technique is utilized. These two control techniques are utilized to decide the prescient control level and they are reproduced and done in MATLAB/Simulink. The aftereffects of the proposed technique uncover the adequacy in changing the blood glucose level by infusing required insulin.

***Keywords**:* Type 1 Diabetes, System model, Insulin-Glucose Regulatory System, PID controller, Nonlinear Model Predictive Control

The authors are with the Sri Sairam Engineering college, West Tambaram, Chennai-44, INDIA

I. INTRODUCTION

Diabetes is regularly called as diabetes mellitus, portrays the gathering of metabolic maladies and it causes the individual a high blood glucose level(blood sugar) because of insufficient emission of insulin or the activity of body cells don't react legitimately for the insulin. Two sorts of diabetes are introduced they are Type 1 and sort 2 diabetes. The Type 1 diabetes does not deliver the insulin; around 10% of instances of diabetes are sort 1. Individuals who are overweight and idle are additionally more prone to create sort 2 diabetes. Sort 2 diabetes happen if the pancreas does not deliver enough insulin; around 90% of individuals are of this sort. To control the blood glucose level a few techniques have been taken after among them, in one strategy a control lead is connected to gauge the information/yield values, for example, insulin/glucose level. In another strategy, the insulin and glucose level is evaluated with a sigmoid bend. The connection between the control factors are gained for the controlling standards and afterward applies bend fitting and concentrates basically the connection between them.

A nonlinear model prescient controller (NMPC) has been utilized. This controller gives ongoing control which utilized nonlinear model with postponements and security. It exhibits a control framework, which can ceaselessly anticipate the blood glucose level and infuse the insulin in a way that the blood glucose level stays in the ordinary range, for all time. Past models were basically organized and straight in which they consider just the insulin and glucose level. A few scientific models have been proposed for the insulin-glucose administrative framework, also.

Nonlinear model prescient controller (NMPC) presented and is made out of two models. One model is called plant, which is diabetic model and the second one is called framework demonstrate, which indicates insulin-glucose administrative framework in an ordinary body.

II. NONLINEAR MODEL PREDICTIVE CONTROL

NMPC controller performs as indicated by framework elements, imperatives including states and controls. The fundamental guideline of model prescient control depends on estimations got at time t, the controller predicts what's to come. The info work at time t=0 for every one of the circumstances t ≥ 0 in the framework, if there were no model-plant bungle and if the advancement issue could be fathomed for limitless skylines. Dynamic way of the framework over an expectation skyline Tp and decides the info to such an extent that a foreordained execution objective practical is streamlined.

The controlled information capacity is gotten and it will be actualized until the following estimation transforms into accessible. The time distinction between the recalculation/estimations can fluctuate, in any case it is ventured to be settled, the estimation will occur each δ examining time-units. Utilizing the new estimation at time t + δ, the whole procedure forecast and enhancement will be rehashed to locate another information work with the control and expectation skylines pushing ahead. The computation of the connected information in view of the anticipated framework conduct permits the incorporation of imperatives on states and contributions and also the enhancement of a given cost work. The adjustment issue for a class of frameworks which presented by the accompanying nonlinear arrangement of differential Equations

x(t) = f(x(t),u(t),x(0)) = x_0 ………………Eq(1)

u(t) and x(t) are represented as inputs and states and these constraints will be given as umin, umax, xmin, xmax constant vectors.

III. PROPOSED SYSTEM DIABETIC MODEL

The insulin-glucose show speaks to the G(t) (Glucose) and I(t) (Insulin) focus in time area t. The mass protection law is characterized in Equation 7 as,

$\{G(t) = G - f_2\big(G(t)\big)f_3\big(G(t)\big)f_4\big(I(t)\big) + f_5(I(t - \tau_2))$

$\{I(t) = f_1\big(G(t-\tau_1)\big) - d_i I(t)$ (3)

A few capacities characterized the utilization of creating insulin and glucose, f1(G) is utilized to remain for the insulin generation which is invigorated by glucose fixation.

$f_1(G)$ = Rm /(1+ exp((c_1-G(Vg)/ a_1)) (4)

The insulin-independent glucose consumer function f2(G) indicating its dependency on the glucose concentration alone.

$f_2(G) = U_b$ /(1- exp(-G/(C_zVg))) (5)

Insulin-dependent glucose uptake is denoted as function f3(G),f4(I).

$f_3(G)$ = G/(C_3Vg) (6)

$f_4(I) = U_0 + (U_m - U_0)$ /(1+ exp(-B ln(I /(C_4(1/V_i+1/(E_i))))) (7)

Glucose is denoted by function f5(I) controlled by insulin concentration.

$f_5(I)$ = Rg /(1+ exp(α(I /VP+Cs))) (8).

Insulin corruption which is meant by positive consistent di, glucose imbuement rate is a steady, indicated by Gin. The time deferral is measured and indicated as τ1 which is the time between the lifted glucose focus level to the minute the insulin has been discharged and τ2 is measured from the time that insulin winds up noticeably remote insulin to the time that a huge change of hepatic glucose creation occur. The component of this model and recreation is depicted after the presentation of the condition 6 and the principle highlight of this model is the swaying of blood glucose level or more two specified time delays.

The first run through deferral is an indication of diabetes, and it is because of the expansion of blood glucose level yet there is no insulin emission accordingly. The second time deferral is because of the postponement of liver glucose creation and lessening which can bring about an expansion in the blood glucose level. By considering these depictions, the diabetic model is outlined from the fundamental model (Eq.3). The NMPC controller execution will be improved, the framework model and plant ought to incorporate the components of the insulin-glucose administrative framework and diabetic, so it is adjusted to Eq.15 to accomplish diabetes demonstrate. As a result of that in typeI diabetes, insulin isn't discharged or creates exceptionally slight and τ1 strongly will build, so Eqs.7 and 8 will change to Eqs.9, 10.

$f_{41}(I) = U_0$ (9).

$f_{51}(I)$ = Rg /(1+ exp(αC_z)) (10).

The blood glucose level of a diabetic model is explained in Equation 15,

$\{G(t) = G_{in} - f_2\big(G(t)\big)f_3\big(G(t)\big)U_0 + f_{51}(I)$

$\{I(t) = f_1\big(G(t - \alpha\tau_1)\big)$ (11)

A. Fuzzy predictive model

The fluffy prescient model is utilized as the framework display in the NMPC controller in which the prescient model is connected and utilized for time arrangement including a period delay. The fluffy prescient model [9] , f(x), is planned in view of the query table and is utilized for building the fluffy framework. The contributions of f(x) are [x(k-n+1),… ..,x(k+ n+1)] for l=0,1,2,… , and the yield is x(k+1) where n characterizes the quantity of information sources. This sources of info/yield sets are utilized to outline f(x) with query table and after that f(x) will be connected to foresee x(k+1). The glucose tests are isolated into 2 sections, one is appointed to preparing and another is doled out to forecast.

In any case, the prescient model has vulnerabilities in the parameter definition, and needs adequate learning about the insulin-glucose administrative framework. The glucose is considered as information yield matches in each time, by picking n as 4. The forecast precision is imperative and can be come to by characterizing more fluffy sets for every variable. By utilizing four progressive flow of glucose, the following element is anticipated and this model prescient is called as four-point show prescient.

B. PID controller

Corresponding Integral-Derivative(PID) controller register the coveted actuator yield by ascertaining the relative, vital and subordinate reactions and summing those three parts to process the yield. PID is likewise utilized as the framework show in the NMPC. The PID controller will send an input and naturally actuator the coveted yield esteem. In the event that the time deferral is expanded naturally the PID controller flags the actuator. Control configuration prepare characterizes the execution necessity. Control framework execution is measured by applying the set point and after that measuring the reaction of the procedure variable. The relentless state mistake is the last distinction between the procedure variable and set point.

The reaction of a framework to a given control yield may change after some time, so a nonlinear framework is connected in which a control parameter deliver a coveted reaction at a point.

IV. IMPLEMENTATION OF NONLINEAR MODEL PREDICTIVE CONTROLLER

The NMPC is utilized as a blood glucose level controller. The contribution of the controller is the measure of the insulin infusion and the yield of the controller is the glucose level. There are two state space in the insulin-glucose administrative framework, 1) I(t) speaks to the insulin and 2) G(t) demonstrates blood glucose level fixation. The execution of the NMPC controller in MATLAB/SIMULINK is appeared in figure 2 and 3. The capacity F is perused and utilized as a contribution to the integrator work in each keep running of the simulink and the outcome is called J. The capacity J can be expected as the proportion of blunder varieties to infusion of the insulin. The infusion measure of the insulin is subtracted from the already infused one at each keep running of the simulink and the new infusion sum is computed. Toward the finish of every usage, the Time interim of the integrator is [t, t + Tp] and one unit is added to this interim and the forecast is proceeded. To control the blood glucose level of a diabetic individual, diabetic model (plant) and a model of insulin-glucose communications (framework model) is required.

The fig. 2 demonstrates the yield of with and without nonlinear model. The nonlinear model is connected to anticipate the time delay. The vulnerabilities are measured utilizing the fluffy and PID controller is appeared in the fig.3. These vulnerabilities are limited and to keep the blood glucose level in the typical range the fluffy and PID controller consistently measure the range and answer to the NMPC show

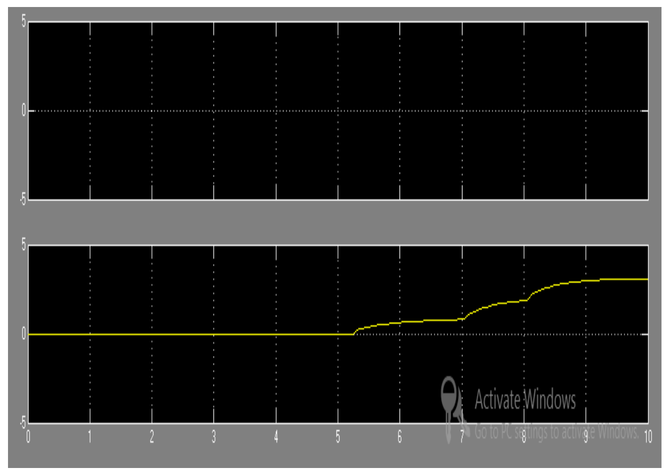

Fig. 2. The result without and with nonlinear model (See the Figure 2 with better resolution in the Appendix at the end of the paper)

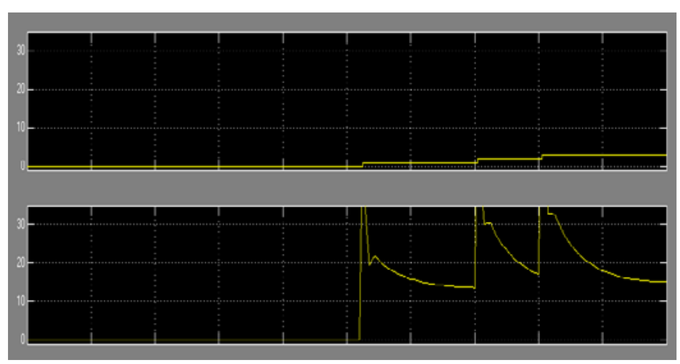

Fig. 3. The comparison output of fuzzy-PID controller output.
(See the Figure 3 with better resolution in the Appendix at the end of the paper)

V. CONCLUSION

The glucose-insulin administrative framework is mimicked utilizing MATLAB/Simulink programming. The proposed framework incorporates fluffy and PID control prescient model and sort 1 diabetic model. Each time the blood glucose level is measured, on the off chance that it is not in the ordinary range the insulin will be infused to keep up the typical range. The proposed NMPC controller measures the blood glucose level and routinely checks the distinction of blood glucose level in plant and framework show. The blood glucose level can be controlled in typical range and constantly check the level utilizing the NMPC controller.

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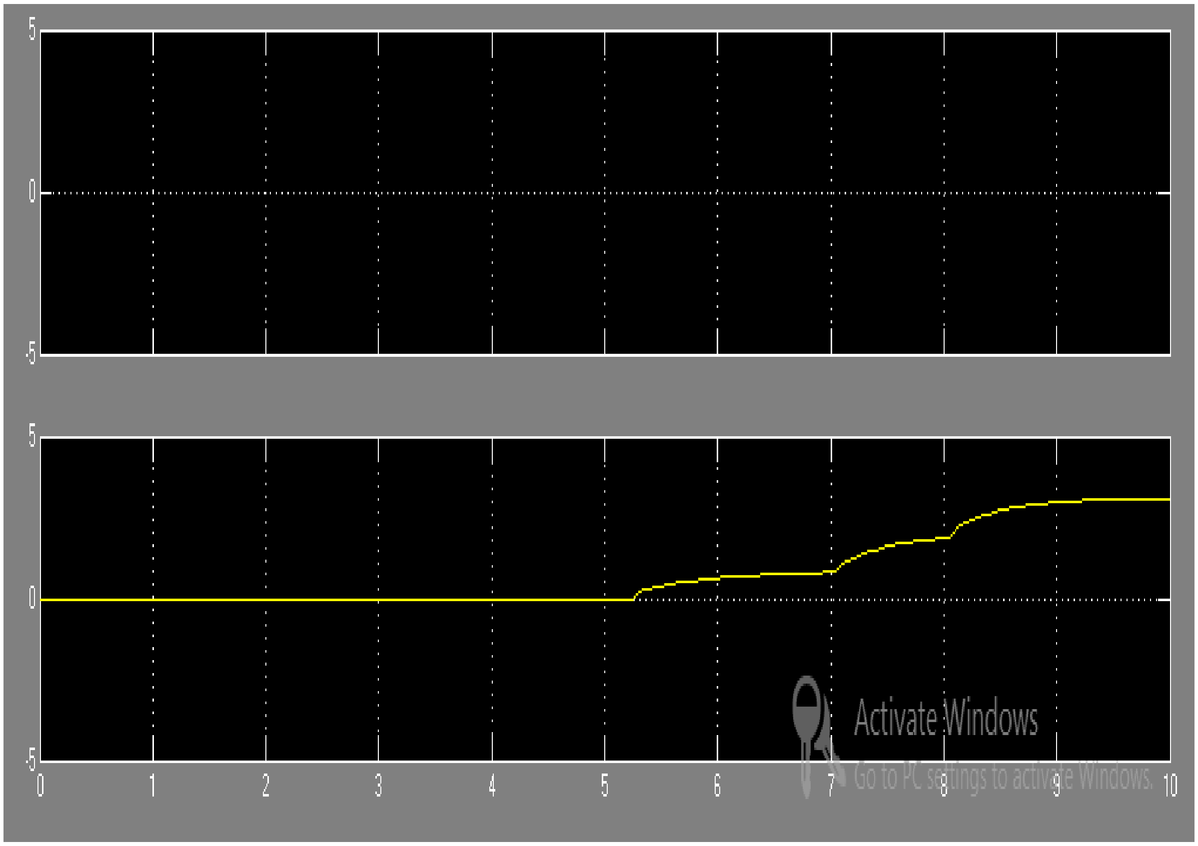
APPENDIX



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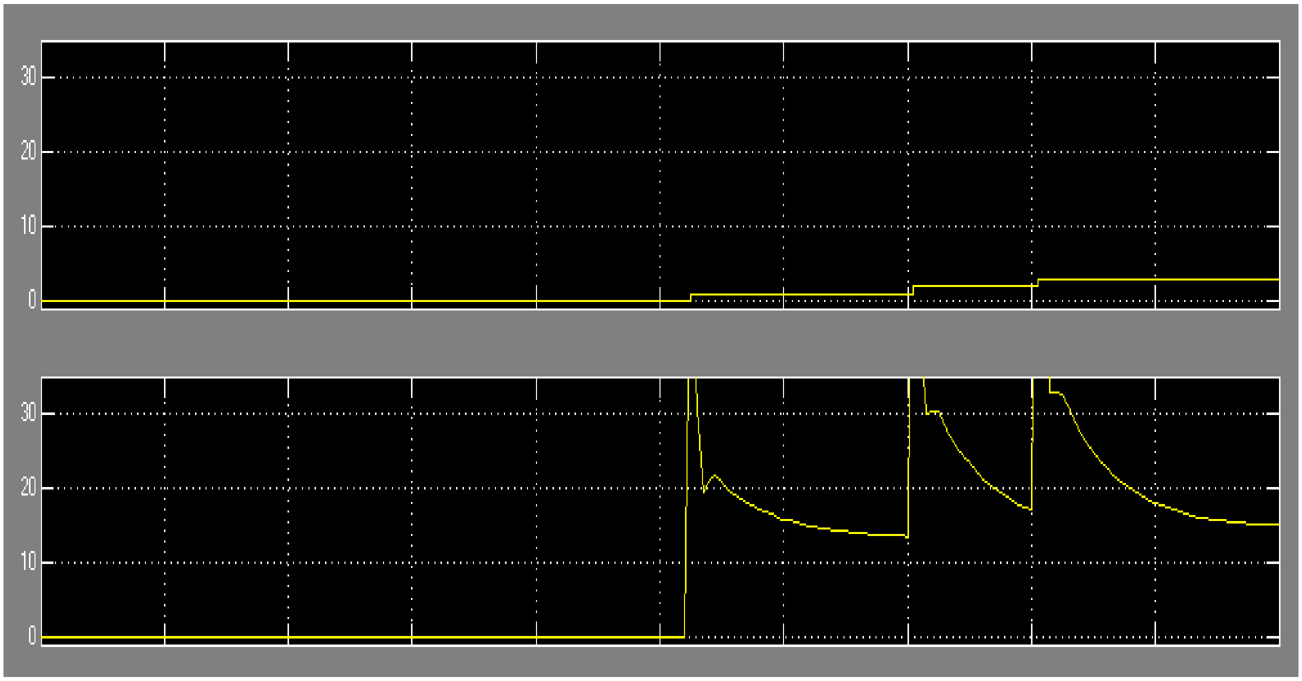

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