Optimal glucose level regulation for Intensive Care Unit patients: CSEDOM approach

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1 Blood glucose level of Intense Care Unit patients

One of the more important problems in ICUs is the control of blood glucose level of patients. Many afflictions like heart attack or multi-organ disorder cause sudden rises in the glucose level. This situation is very dangerous because it increases the risk of infection, hampers blood coagulation and disturbs the metabolic balance. Studies shown, that the rigoristic blood glucose level control substantially reduces the mortality rate in ICUs. Nowadays either frequent testing and insulin shots or automatic insulin pumps are used to avoid hyperglycemia even for patients without history of diabetes. In this paper we propose an algorithm that can be used as an advisory system or as a closed loop control.

2 Mathematical model

$$\begin{aligned}
\dot{G}(t) &= (P_1 - X(t))G(t) - P_1 G_b + \frac{F_G}{V_G} \\
\dot{X}(t) &= P_2 X(t) + P_3(I_1 - I_b) \\
\dot{I}_1(t) &= \alpha \max(0, I_2) - n(I_1 - I_b) + \frac{F_I}{V_I} \\
\dot{I}_2(t) &= \beta\gamma(G(t) - h) - nI_2(t)
\end{aligned} \tag{1}$$

where G and I_1 are the glucose and the insulin concentrations in the blood plasma. The variable X describes the effect of insulin on net glucose disappearance. The variable I_2 does not have a strictly defined clinical interpretation and was introduced for mathematical reasons. Parameters will be described in the full version of the paper. For more deatails see(Van Herpe et al., 2007).

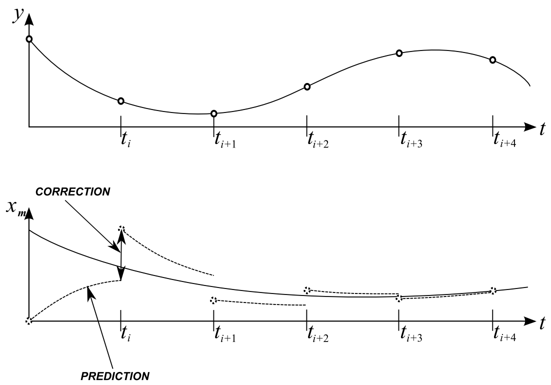

Figure 1: Illustration of CSEDOM concept – a prediction is followed by a correction

3 CSEDOM

Because of all the variables of (1) only glucose level is easily measured, other state variables have to be estimated. Because such measurements are discrete for our problem we need to consider a continuous state estimation from discrete output measurements (CSEDOM) (i.e. Baranowski and Tutaj, 2008) Complete formulation will be included in the full version of the paper. The concept of this algorithm is relatively simple – see figure 1, however the main problem is the choice of a estimation method used in the correction step. That is why we consider a so called Newton Observer (see for example Bıyık and Arcak, 2006).

4 LQ based MPC

For keeping appropriate values of blood glucose levels, we have determined reference values of state and exogenous inputs. Δx and Δu are appropriately deviations from state and control. Optimal regulator (from finite time LQ problem) for tracking this signal is governed from the following equations:

$$\Delta u = -S^{-1}B^{\mathsf{T}}\Big(D(t)(\Delta x(t) - \kappa(t)) + d(t)\Big) \tag{2}$$

$$\begin{aligned}\dot{D}(t) = D(t)BS^{-1}B^{\mathsf{T}}D(t) - A^{\mathsf{T}}D(t) + \\ -D(t)A - W\end{aligned} \tag{3}$$

$$\begin{aligned}\dot{d}(t) = (D(t)BS^{-1}B^{\mathsf{T}} - A^{\mathsf{T}})d(t) + \\ +W(g(t) - \kappa(t))\end{aligned} \tag{4}$$

$$D(T) = Q \quad \text{and} \quad D(t) = D^{\mathsf{T}}(t) \geq 0 \tag{5}$$

$$d(T) = -Q(g(T) - \kappa(T)) \tag{6}$$

$$\dot{\kappa}(t) = A\kappa(t) + \varepsilon(t) \tag{7}$$

Where A and B are matrices of linearised version of (1), Q, W and S are matrices of performance index other symbols will be explained in the full version of paper (see Mitkowski, 2002) This optimal regulator will be used in a model predictive control scheme, using the prediction horizon τ shorter than the finite time of LQ problem - T.

5 Conclusion

In the full version of paper, the model (1) will be fully presented and discussed. A full formulation of CSEDOM will be presented along with description of the Newton observer application. Also the numerical considerations regarding equations (3) - (7) and their use in MPC scheme. The following list of references includes only crucial elements and will be substantially expanded.

References

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