Variable-time impulsive model predictive control: Automated insulin bolusing for type 1 diabetes mellitus

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Introduction

Matching meal insulin to carbohydrate intake is recommended for type 1 diabetes treatment. Calculating an appropiate insulin bolus size several times per day is, however, challenging and time demanding. Food intake increases blood glucose level rapidly and may cause hyperglycemia if sufficient amount of insulin is not infused in an appropriate period of time. hyperglycemic events can occur more frequently in artificial pancreas systems without announcements that trigger insulin boluses[Turksoy et al., 2017, Schmidt and Nørgaard, 2014]. To handle the problem a feedforward model predictive control for computing meal insulin bolus is proposed. The strategy calculates the optimal insulin bolus and the time for the next dosage considering an impulsive system.

Methodology

- Representation of the glucose-insulin dynamics as an impulsive system.

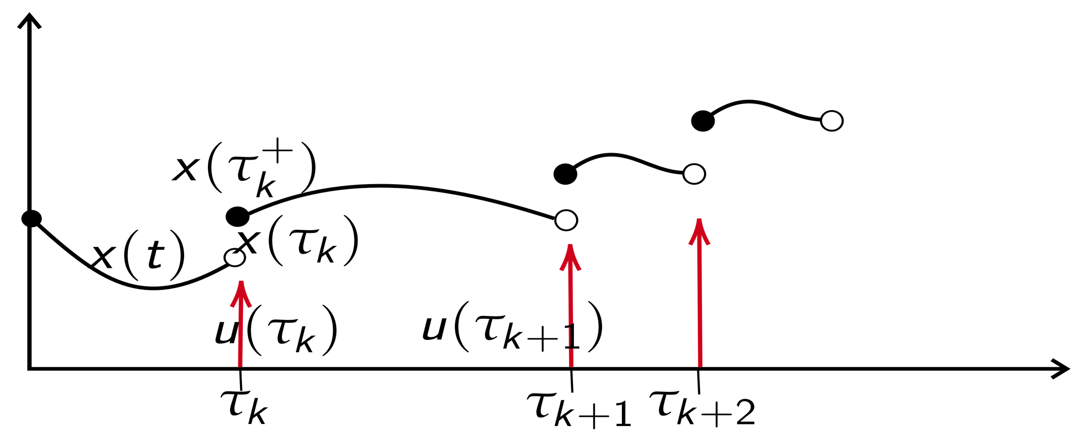
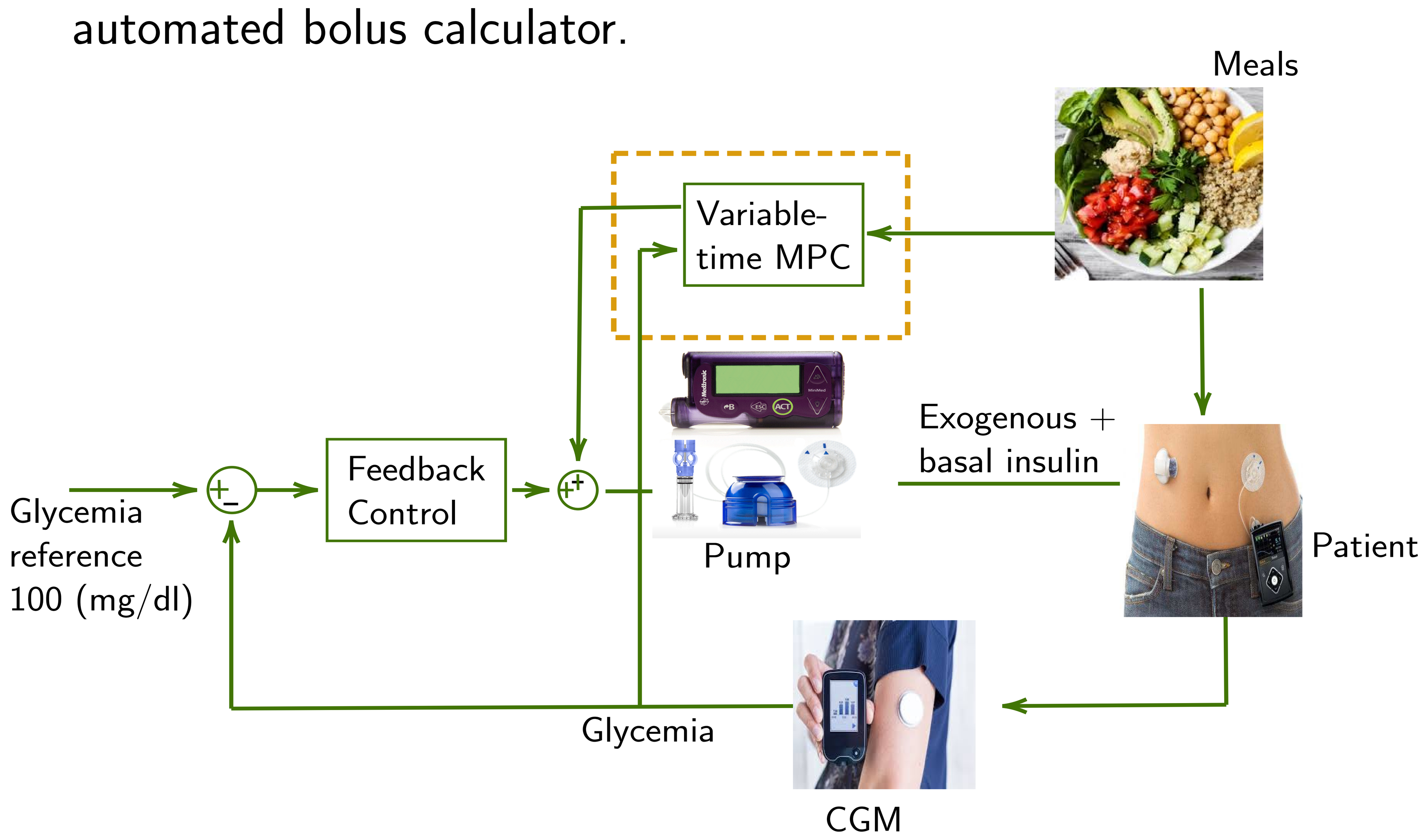


Figure: Impulsive system scheme

- Construction of the impulsive MPC cost function for optimizing time and insulin bolus when a meal is announced.

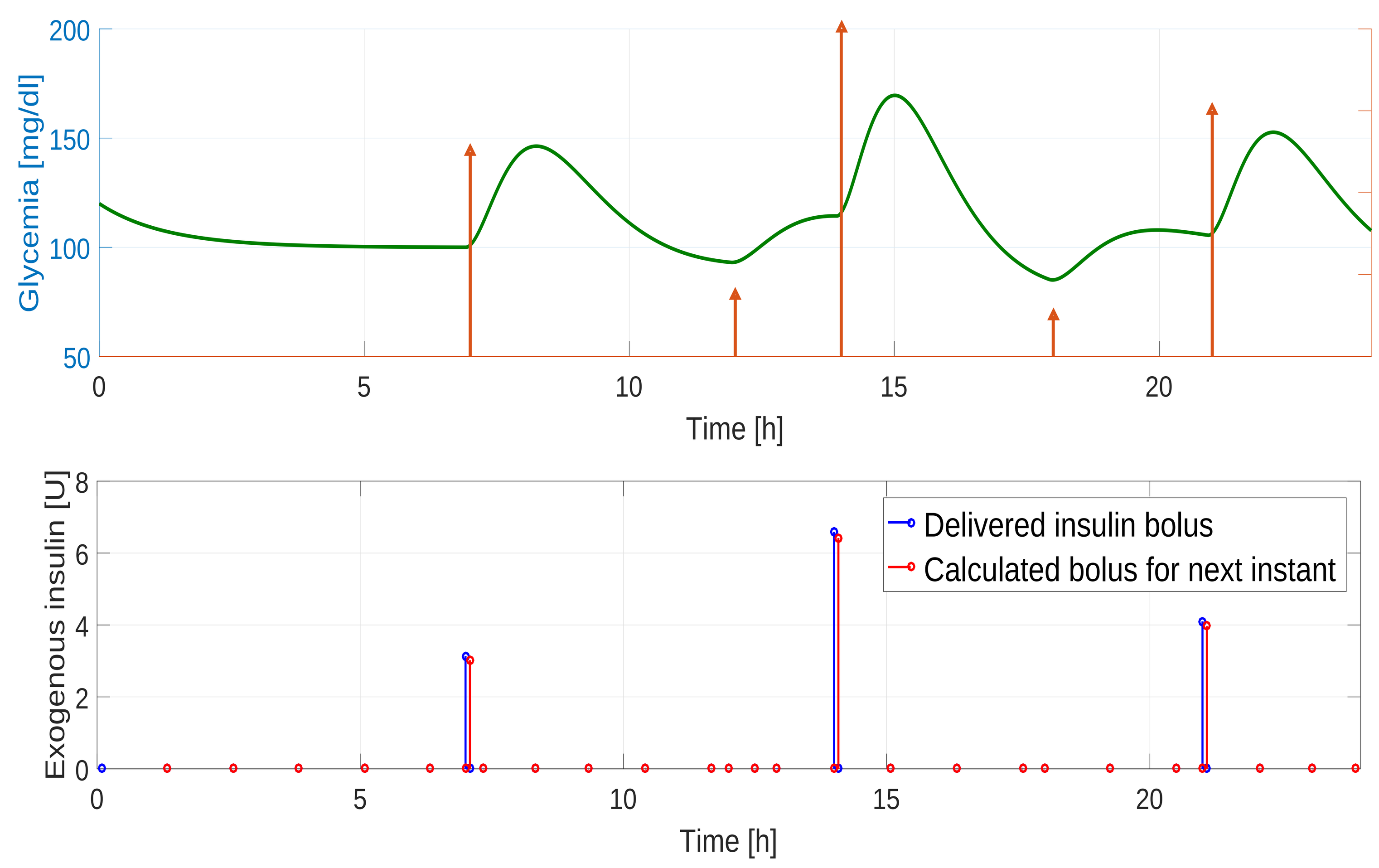
$$\bar{u}^o = argmin\left(\min_{u_{i,t},t_i} J_i(\bar{u}_{i,t_i}, x_{i,t_i}, t_i)\right) \tag{1}$$

- Implementation and simulation of the feedforward scheme as automated bolus calculator.



Results

Simulation of blood glucose levels for optimal insulin bolusing and time calculated using data from [Kanderian et al., 2009]. Performance evaluated under a scenario composed of 5 meals: breakfast (55g), lunch (80g), dinner (60g) and two snacks (15g and 10g).



How does it work?

The MPC solves a optimization problem with constraints. The strategy is the additional set of constraints containing L possible separations between boluses (the one to be delivered and the next one), producing L possible costs. Thus the rest of the L trajectories are forced to be zero. The input trajectory with lower cost is chosen to determine how much insulin is delivered at the time $t = \tau_k$, the separation from the next bolus gives the time $t = \tau_{k+1}$ needed to calculate a new optimization.

Conclusions

- A feedforward MPC for meal bolusing is used to compensate postprandial hyperglycemia considering an impulsive system.
- The variable-time strategy reduces the computation time of using a standard periodic MPC.
- There is still needed a study of the performance of the controller when there is inter and intra-patient variability .

References

- Kanderian, S. S., Weinzimer, S., Voskanyan, G., and Steil, G. M. (2009). Identification of intraday metabolic profiles during closed-loop glucose control in individuals with type 1 diabetes. *Journal of Diabetes Science and Technology*, 3:1047–1057.
- Schmidt, S. and Nørgaard, K. (2014). Bolus calculators. *Journal of Diabetes Science and Technology*, 8(5).
- Turksoy, K., Hajizadeh, I., Samadi, S., Feng, J., Sevil, M., Park, M., Quinn, L., Littlejohn, E., and Cinar., A. (2017). Real-time insulin bolusing for unannounced meals with artificial pancreas. *Control Engineering Practice*, 59:159–164.

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