HYPOGLYCEMIA PREVENTION IN CLOSED-LOOP GLYCEMIC CONTROL VIA CONSTRAINTS IN THE GLUCOSE SLOPE

N. Rosales[1], F. M. León Vargas[3], H. De Battista[1,2] and F. Garelli[1,2]

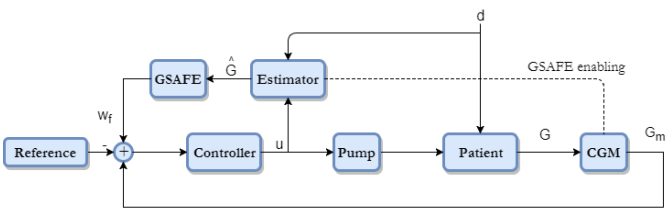
[1] Group of Control Applications, LEICI-Facultad de Ingeniería, Universidad Nacional de La Plata, Buenos Aires, Argentina.
[2] Consejo Nacional de Investigaciones Científicas y Técnicas CONICET, Argentina.
[3] Universidad Antonio Nariño, Bogotá, Colombia
nicolas.rosales@ing.unlp.edu.ar – http://www.gca.ing.unlp.edu.ar

BACKGROUND AND AIMS

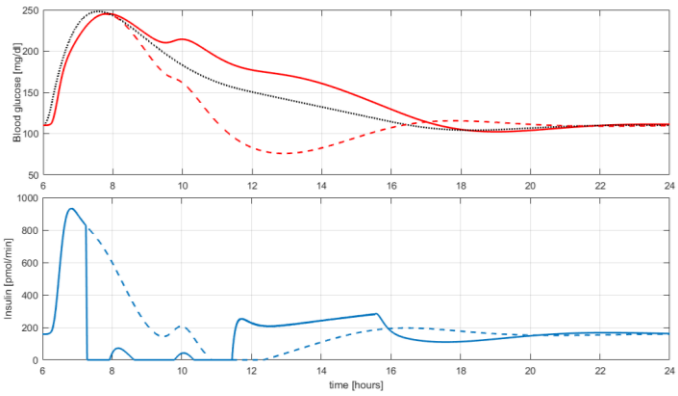
Within the development of closed-loop glucose controllers for type 1 diabetes mellitus, one of the major risks is the insulin induced hypoglycemia that can be produced due to controller overreaction.
Here, a supervisory methodology is proposed for the prevention of hypoglycemia, which differs from previous work (Revert et al., IEEE TBME 2013) by considering a limitation on the controlled variable or output of the system.

METHODS

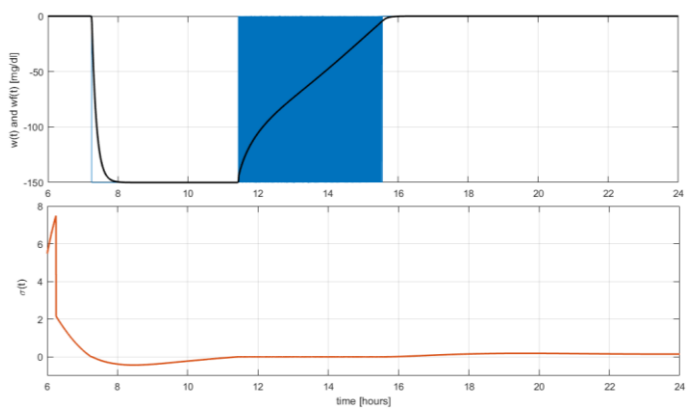
The GSAFE (Glucose-based safety auxiliary feedback element) is a security layer based on the *Sliding Mode Reference Conditioning* technique. By means of a reduced-order glucose estimator, the GSAFE modifies the reference of the main controller to regulate the slope with which the glucose decreases, thereby limiting the insulin delivered by the controller. The proposed technique can be applied to any control algorithm, both PID and MPC.



An illustrative operation of the GSAFE is shown below, including the reference conditioning signal and the switching function.



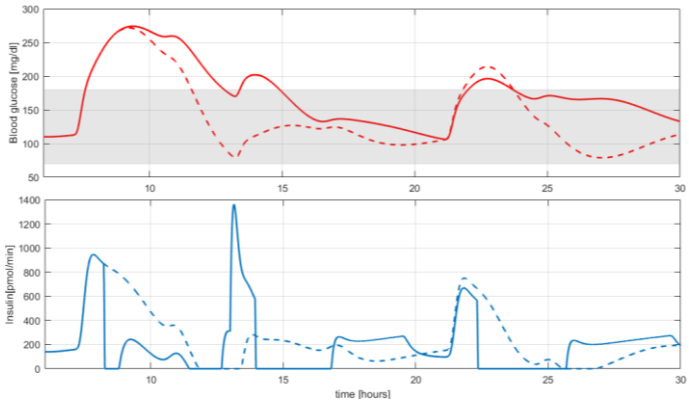
GSAFE operation over the controller given in Palerm CMPB 2011. Upper panel: blood glucose level with (solid line) and without (dashed line) GSAFE and estimated glucose (dotted line). Below: insulin delivered by the closed-loop controller with (solid line) and without GSAFE (dashed line).



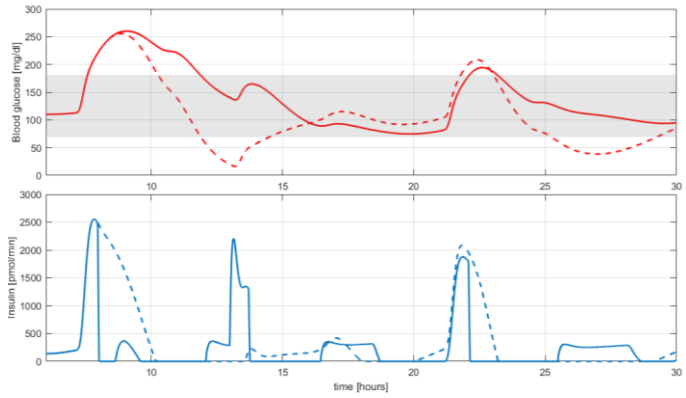
GSAFE switching signal, designed from the blood glucose derivative, and the reference conditioning signal that modulates the controller's input. Upper panel: discontinuous signal w(t) and filtered signal wf(t) (black solid line). Below: switching function σ(t)

RESULTS

The algorithm was tested in a platform based on the UVa/Padova T1D Simulator (3-meals scenario with varying insulin sensitivity) with the controller given in Palerm CMPB 2011. Preliminary results show that the amount of hypoglycemic events and time spent in hypoglycemia were considerably reduced when applying the GSAFE, even for aggressive controller configurations. In particular, low glucose values were avoided in the late postpandrial period.



GSAFE operation over the nominal controller in a 3 meal scenario with insulin sentitivity variability. Upper panel: blood glucose level with (solid line) and without (dashed line) GSAFE. Below: insulin delivered by the closed-loop controller with (solid line) and without GSAFE (dashed line). Grey area indicates euglycemic range ([70 -180]mg/dl)



GSAFE operation over a 3 times more agressive controller in a 3 meal scenario with insulin sentitivity variability. Upper panel: blood glucose level with (solid line) and without (dashed line) GSAFE. Below: insulin delivered by the closed-loop controller with (solid line) and without GSAFE (dashed line). Grey area indicates euglycemic range ([70 -180]mg/dl).

RESULTS

The promising in-silico results obtained with the novel GSAFE methodology allow considering it as a potential safety layer for hypoglycemia prevention in the next clinical trials in Argentina, after the first and successful trial carried out in June 2017 without carbohydrates counting.

REFERENCES

[1] A. Revert, F. Garelli, J. Pico, H. De Battista, p. Rossetti, J. Vehí and J. Bondia, "Safety Auxiliary Feedback Element for the Artificial Pancreas in Type 1 Diabetes", IEEE Transactions in Biomedical Engineering, vol. 60, no. 8, 2013.
[2] C. Palerm, "Physiologic insulin delivery with insulin feedback: A control system perspective", Computer Methods and Programs in Biomedicine, vol. 102, no 2, pp 130—137, 2011.

This work was suppported by CONICET (PIP 0837), MinCyT (PICT 2014-2394), UNLP and ERANET (2015/T09-103).

ATTD Advanced Technologies & Treatments for Diabetes