Simulation Framework to Test Algorithms for the Optimization of Insulin Bolus Parameters in Type 1 Diabetes Therapy

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1. INTRODUCTION

In the open-loop insulin therapy for Type 1 Diabetes (T1D), semi-empirical rules to determine a suitable size of the insulin bolus are commonly employed. The state-of-art rules in particular, are based on two individual parameters [1]:

- the carbohydrate-to-insulin ratio (CR)
- the correction factor (CF)

that are normally tuned by trial-and-error procedures and, in many cases, could result suboptimal. In this context, automatic algorithms for the optimization of the insulin bolus parameters are particularly useful.

2. AIM

The aim of this work is to create a simulation framework to test the different algorithms for CR optimization in a credible real-life scenario.

3. SIMULATION FRAMEWORK

The proposed simulation framework **(Fig. 1)** integrates state-of-art models of variability of patient's physiology and behavior, and technology.

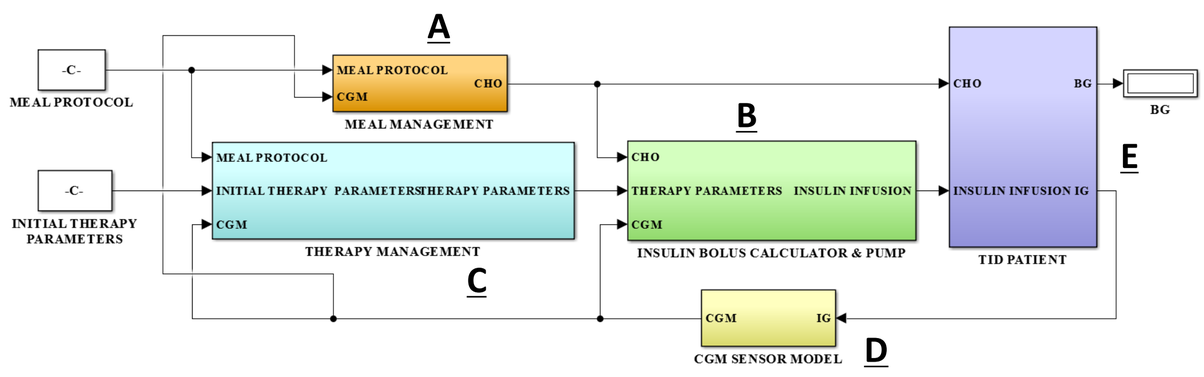

Fig. 1: Simulation Framework for T1D open-loop management (Simulink notation)

A. Meal Management block (orange block in Fig. 1)

- INPUT: meal protocol (see Table 1)
- OUTPUTS: patient's estimate of meal and hypotreatment CHO intake

	Breakfast	Lunch	Dinner
Time	[7, 9]	[12, 14]	[20, 22]
$CHO(g)$	[30, 70]	[60, 100]	[50, 90]

Table 1: Meal protocol. Size and time of meals are uniformly distributed random variables in the intervals in square brackets.

B. Insulin Bolus Calculator & Pump (green block in Fig. 1)

- INPUTS: therapy parameters (CR and CF) and CHO intake.
- OUTPUTS: insulin doses calculation and infusion

It implements the bolus calculator formula:

$$B = \frac{CHO}{CR} + \frac{G_c - G_{sp}}{CF} - IOB \qquad IOB = \sum_{i=1}^{n} B_i exp\frac{-(t - T_{B_i})}{\tau}$$

C. Therapy Management (blue block in Fig. 1)

- INPUTS: meal protocol, CGM measurements and initial therapy parameters
- OUTPUTS: optimized CR and CF values obtained using the optimization algorithm to be tested

D. CGM Sensor (yellow block in Fig. 1)

- INPUT: interstitial glucose concentration
- OUTPUT: CGM measurement generated according to [2].

E. T1D Patient (violet block in Fig. 1)

The block implements the **T1D Uva/Padova simulator** [3] to simulate BG and IG concentration and to describe physiological events related to BG dynamics.

4. TESTED CR OPTIMIZATION ALGORITHMS

The two tested CR optimization algorithms are the run-to-run (R2R) [4] and a new method where the R2R is integrated with case-based reasoning (R2R+CBR) [5].
We simulated four 30-day sessions on 100 virtual patients.

5. RESULTS

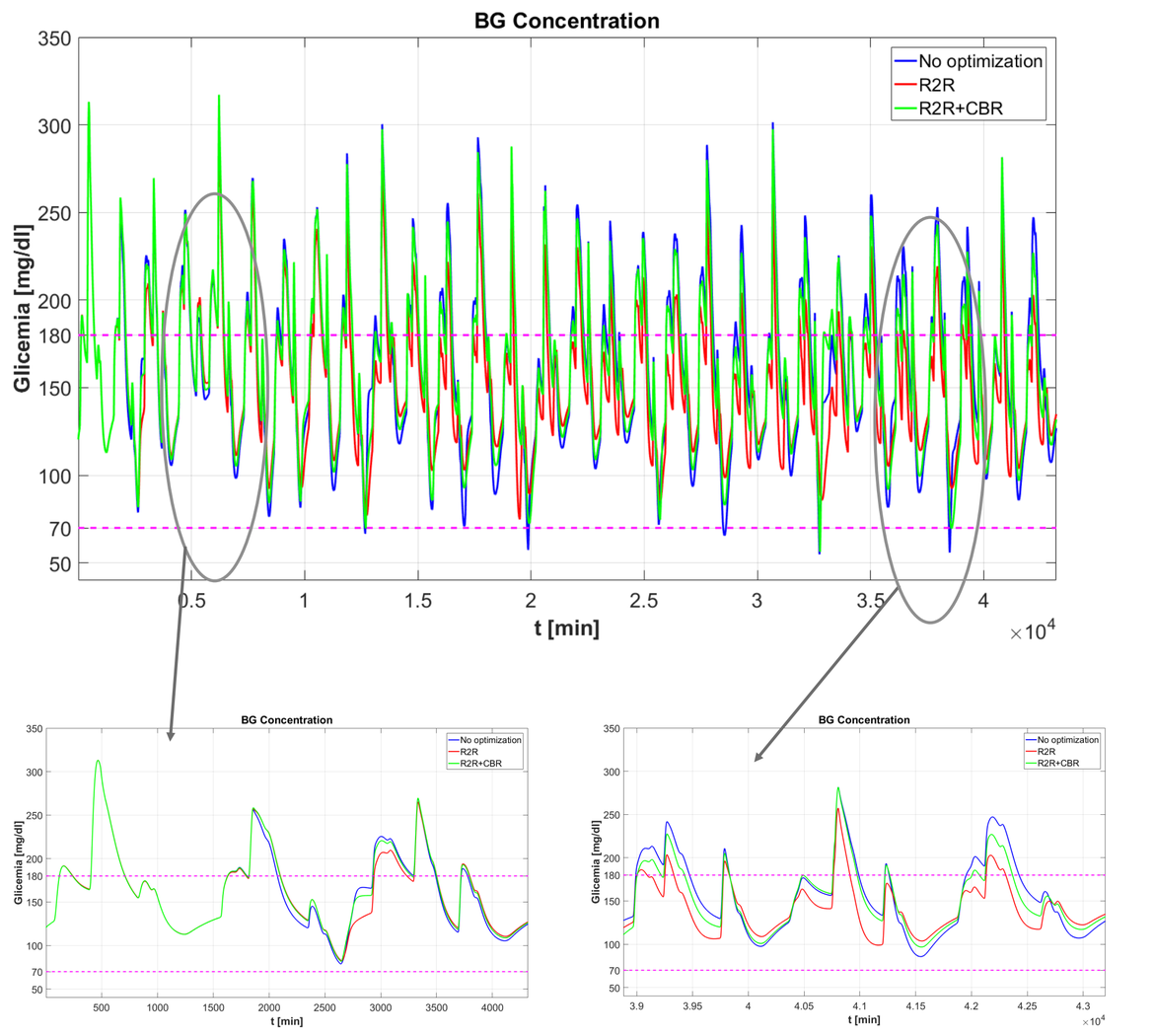

*Fig. 2: Representative results of **BG concentration** of patient#1 for 30-days. In blue, BG profile obtained without optimizing the therapy parameters. In red and green, the same profile obtained with R2R and R2R+CBR, respectively.*

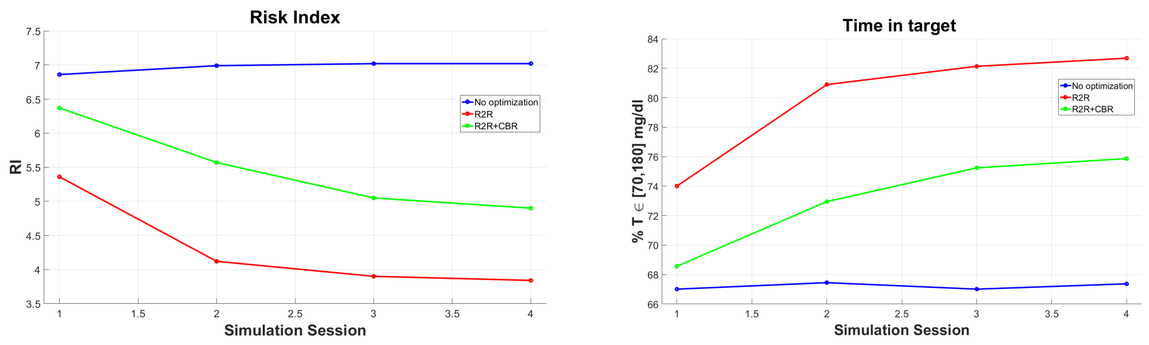

*Fig. 3: **Risk Index** (left) and **Time in Target** (right) results (median). In blue, the results obtained without optimization. In red and green, the same results obtained with the R2R and the R2R+CBR, respectively.*

The results show how both the algorithms improved the therapy performance obtained without optimization session-by-session. On average, in the fourth session, time in target and risk index result, respectively, 82.68% and 3.84 with R2R, 75.87% and 4.90 with R2R+CBR, 67.37% and 7.02 with no optimization.

6. CONCLUSIONS

We developed a simulation framework that allows generating credible scenarios to test existing, and develop new, algorithms for CR optimization in real life conditions.
Both tested algorithms were able to improve the therapy performance.
Future work will involve the expansion of the simulation framework in order to take into account for other factors, e.g. circadian rhythms, physical activity levels and stress.

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