Cukorbeteg döntéstámogató rendszer fejlesztése

Dr. Eigner György

TKP2021-NKTA-36 AZONOSÍTÓSZÁMÚ "INNOVATÍV ÉS DIGITÁLIS EGÉSZSÉGIPARI TECHNOLÓGIÁK FEJLESZTÉSE ÉS ÉRTÉKELÉSE"

ÓBUDAI EGYETEM
ÓBUDA UNIVERSITY

NEMZETI KUTATÁSI, FEJLESZTÉSI ÉS INNOVÁCIÓS HIVATAL

AZ NKFI ALAPBÓL MEGVALÓSULÓ PROJEKT


sugar
hypertension
diabetes
weight reduction
metabolic
obesity
hormone
nutrition
insulin
blood glucose level
diagnosis
overweight
type 1
pancreas
insulin resistance
therapy
disease
hypoglycemia
medicine
syringe
retinopathy
glucose
type 2
diet

blood glucose prediction

artificial pancreas

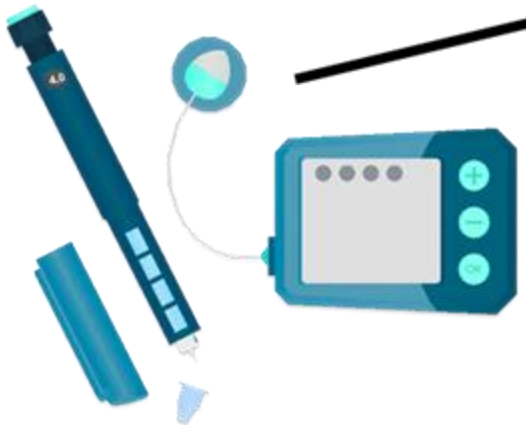
parameter estimation

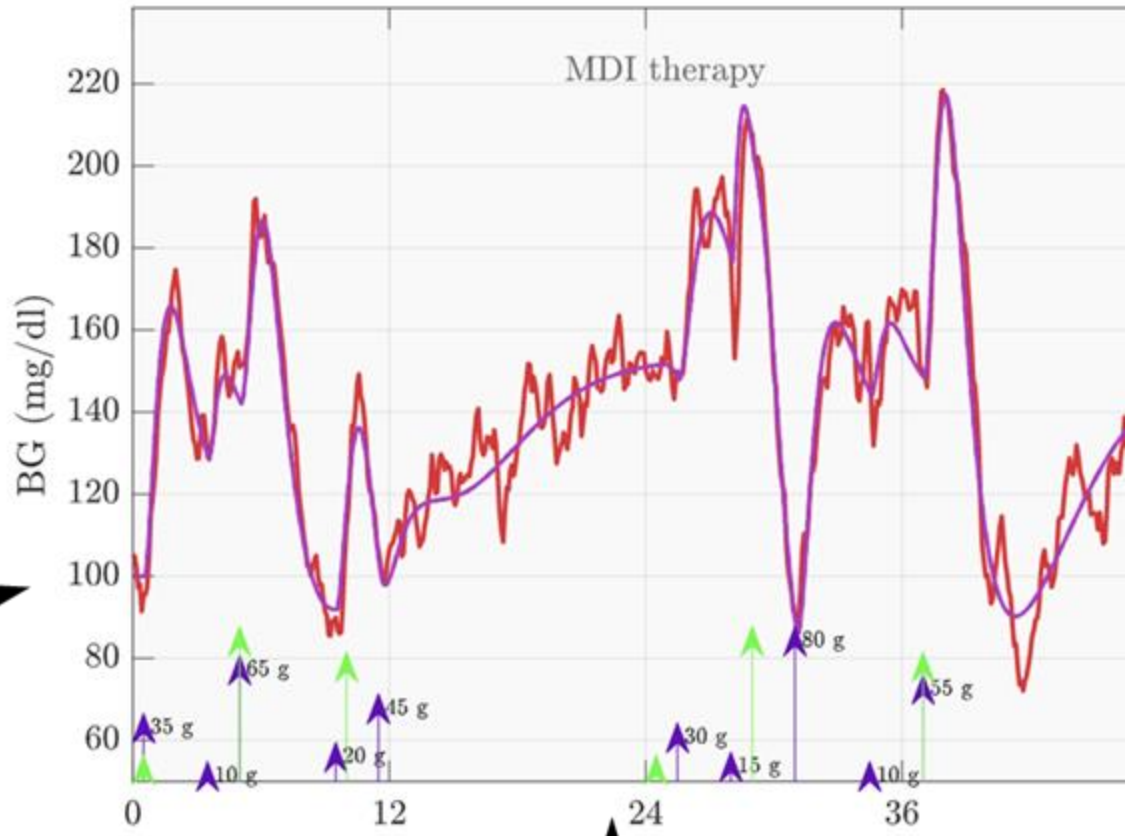
model predictive control

reinforcement learning

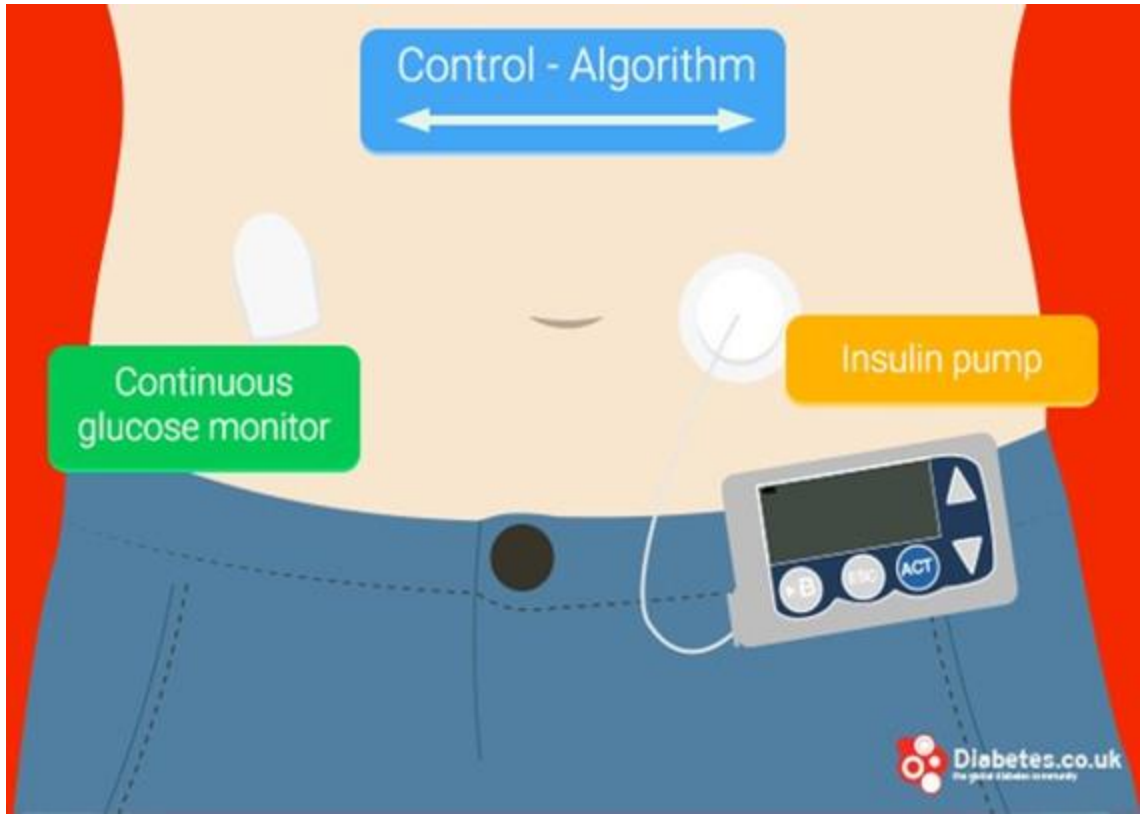
gesture recognition

physical activity modeling




MDI therapy
BG (mg/dl)
220
200
180
160
140
120
100
80
60
0
12
24
36
35 g
10 g
65 g
20 g
45 g
30 g
15 g
80 g
10 g
55 g

Automated insulin dosing – artificial pancreas



Minimed 670G (2016)

Tandem t:slim x2

Minimed 780G

Omnipod 5 (2022)

Gesture detection

Automatic detection vs. manual logging

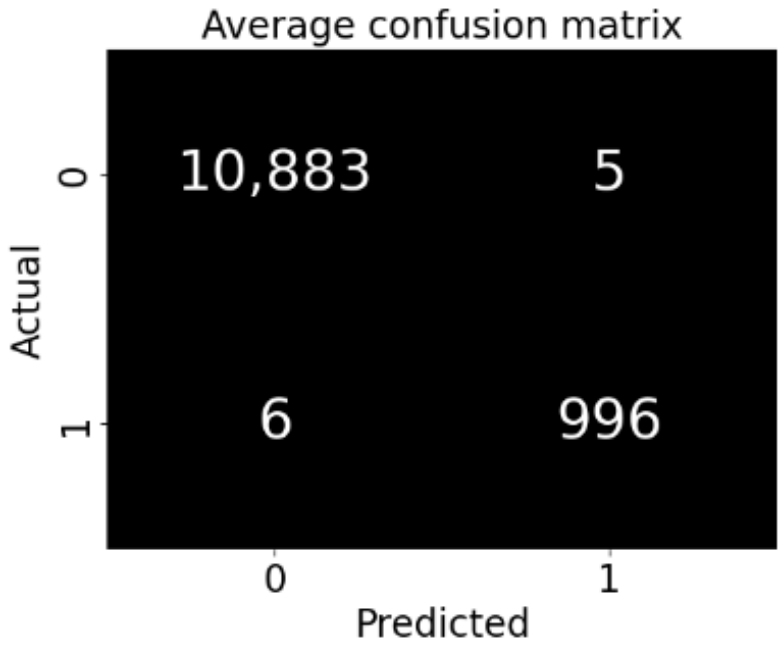
- Need for reducing "administrative burden"

Gesture detection

- Detection based on accelerometer data
- Running experimental application on Android and iOS devices
- Data collected from activity trackers

Gesture detection

- Clemson all-day dataset
  - 351 subjects
  - Accelerometer and gyroscope data
- LSTM neural networks
- Training and testing:
  - Non-overlapping 80%, 20% split



Observational study

- Ongoing, TUKEB approved observational study
  - Title: Explorative study for the analysis of the effect of physical activity on type 1 diabetes and for the development of diabetes decision support system
  - Evaluation of annotated and sensory data
  - Collected data:
    - Pulse rate
    - Intensity of physical activity
    - Insulin
    - Food: macronutritients
    - Blood glucose level

Observational study

- Tools:
  - DiabTrend smartphone application
  - Xiaomi fitness tracker
  - Medtronic CGM sensor
- Telegram Bot sends daily reports on the patients' data
  - Easy daily follow-up

Physical activity

- Possible parameters in models:
  - HR [1/min] – Heart Rate
  - PVO_2^{max} [ml/kg/min] – maximum oxygen uptake
  - PAMM [%] – Percentage of Active Muscle Mass

- Our studies:
  - HR is used through EGP (Endogenous Glucose Production)
  - EGP equation from Ormsbee et al.:

$$EGP = \gamma \cdot HR + \delta \cdot \frac{\alpha \cdot HR}{(220 - HR)^{\beta}}$$

Model predictive control

Dynamic extension of the mathematical model:

$$\dot{u}(t) = -u(t)v(t),$$

$$u(t) = u(0)exp\left(- \int_0^t v(\tau)d\tau \right).$$

$$\dot{I}_{SC}(t) = -\frac{1}{\tau_1} I_{SC}(t) + \frac{1}{\tau_1 C_I} u(t) \quad (1)$$

$$\dot{I}_{P}(t) = -\frac{1}{\tau_2} I_{P}(t) + \frac{1}{\tau_2} I_{SC}(t) \quad (2)$$

$$\dot{I}_{EFF}(t) = -p_2 \cdot I_{EFF}(t) + p_2 \cdot S_I \cdot I_P(t) \quad (3)$$

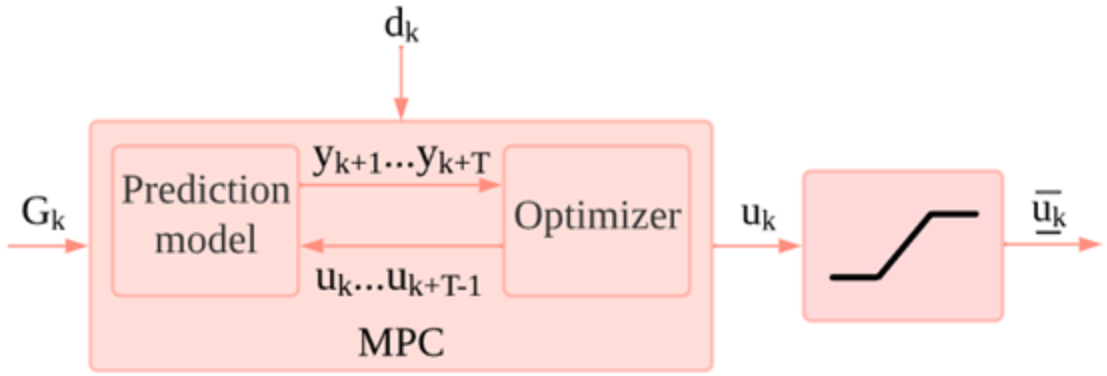
$$\dot{G}(t) = -(GEZI + I_{EFF}(t)) \cdot G(t) + EGP + R_A(t) \quad (4)$$

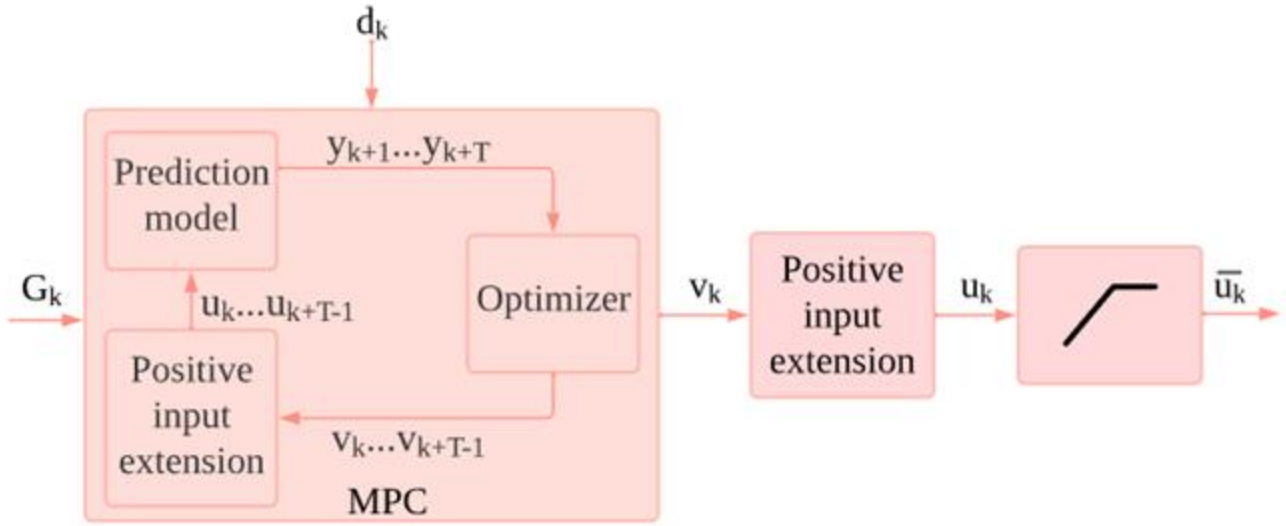
$$R_A(t) = \sum_i^m \frac{d_i}{V_G \cdot \tau_{D_i}^2} t_i \cdot e^{-\frac{t_i}{\tau_{D_i}}} \quad (5)$$

Model predictive control

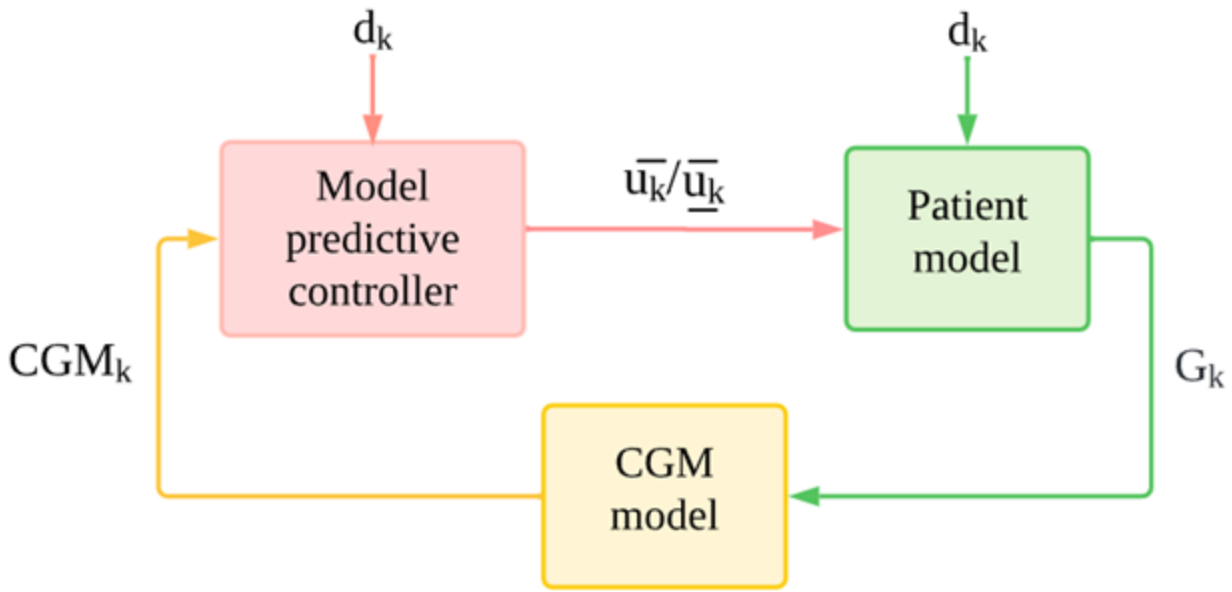
Evaluation:

- Closed-loop scenario
- Controller: Model Predictive Control
- Dynamic model extension compared with saturation

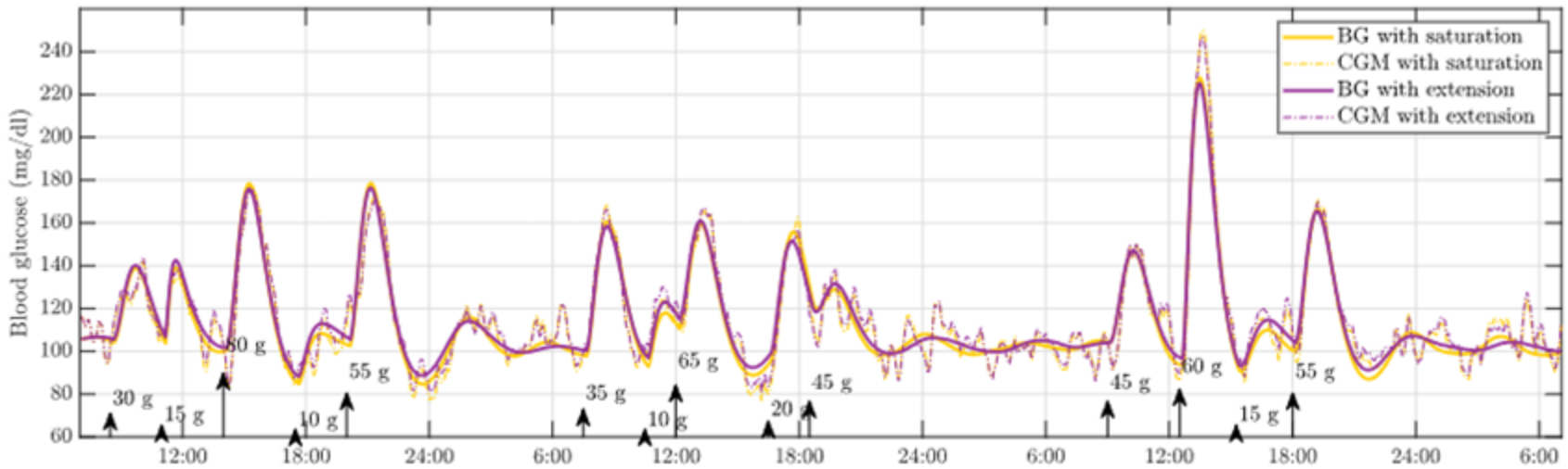


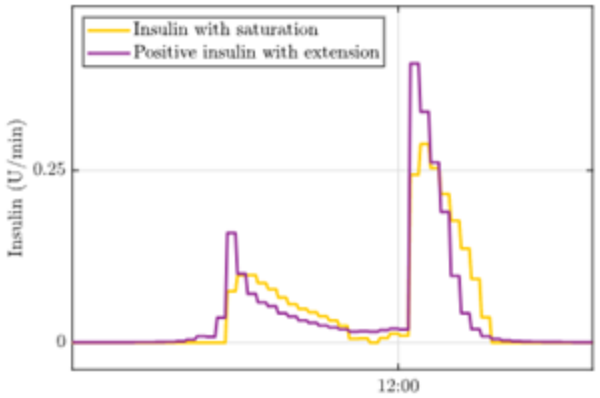


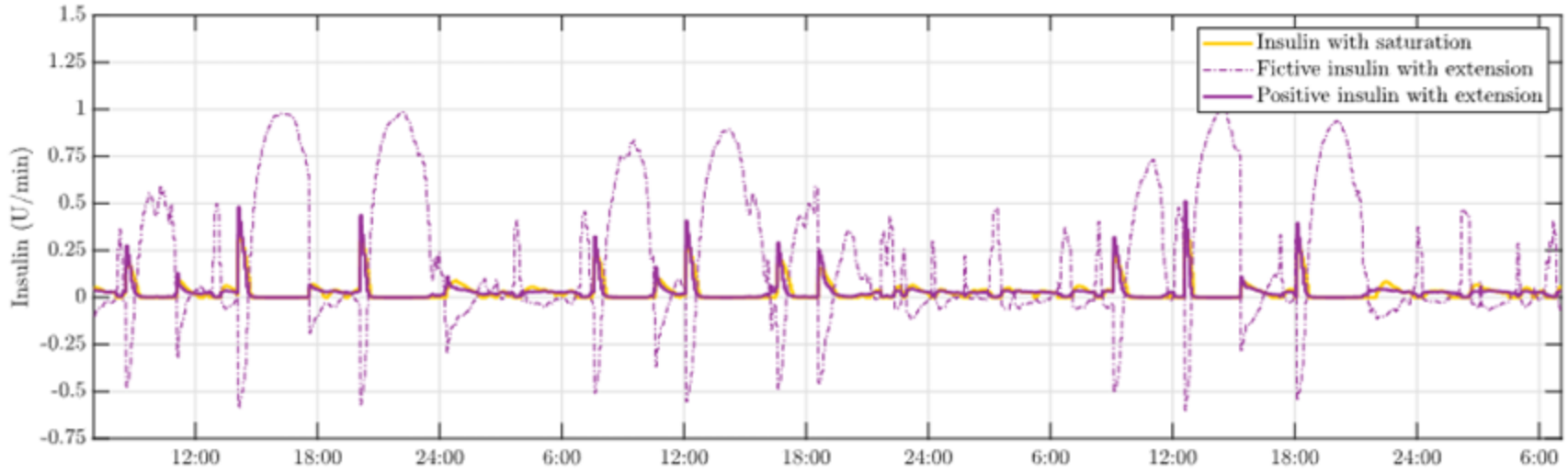
Model predictive control



$$J(\mathbf{y_k}, \mathbf{u_k}) = \underbrace{\sum_{i=k+1}^{k+T} [\hat{\delta}\hat{y_i}^2 + \check{\delta}\check{y_i}^2]}_{\text{Output}} + \underbrace{\sum_{i=k}^{k+T-1} [\hat{R}\hat{u_i}^2 + \check{R}\check{u_i}^2]}_{\text{Input}},$$

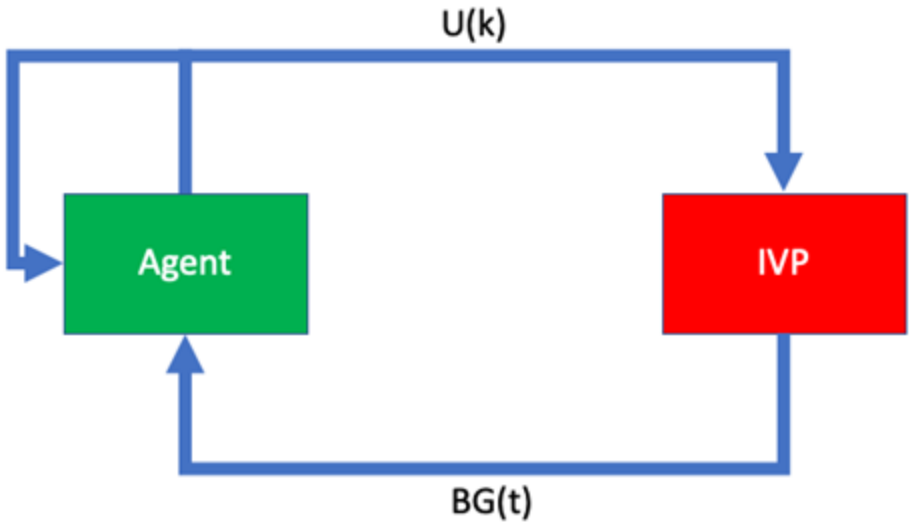

BG with saturation
CGM with saturation
BG with extension
CGM with extension
Blood glucose (mg/dl)
240
220
200
180
160
140
120
100
80
60
30 g
15 g
80 g
10 g
55 g
35 g
10 g
65 g
20 g
45 g
45 g
60 g
15 g
55 g
12:00
18:00
24:00
6:00
12:00
18:00
24:00
6:00
12:00
18:00
24:00
6:00

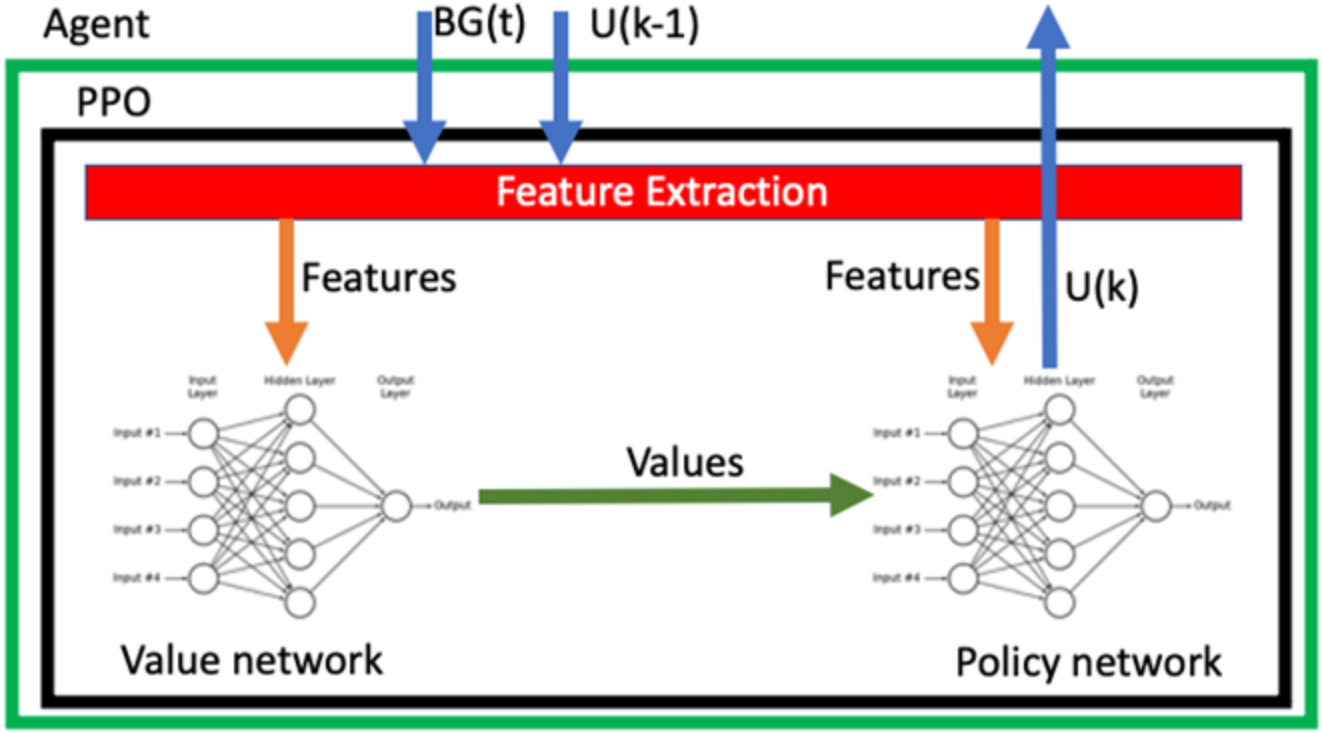

Insulin with saturation
Positive insulin with extension
Insulin (U/min)
0.25
0
12:00


Insulin with saturation
Fictive insulin with extension
Positive insulin with extension
Insulin (U/min)
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
12:00
18:00
24:00
6:00
12:00
18:00
24:00
6:00
12:00
18:00
24:00
6:00

	Saturation	Positive input extension
Mean BG	114.61 mg/dl	115.97 mg/dl
Min BG	76.95 mg/dl	80.65 mg/dl
Max BG	249.86 mg/dl	246.91 mg/dl
RMSE	28.95	28.86
Quadratic cost	22236.93	14572.04
TIR (70-180)	98.38 %	98.38 %
TIR (80-140)	84.97 %	86.12 %
TDI	131.04 U	129.36 U

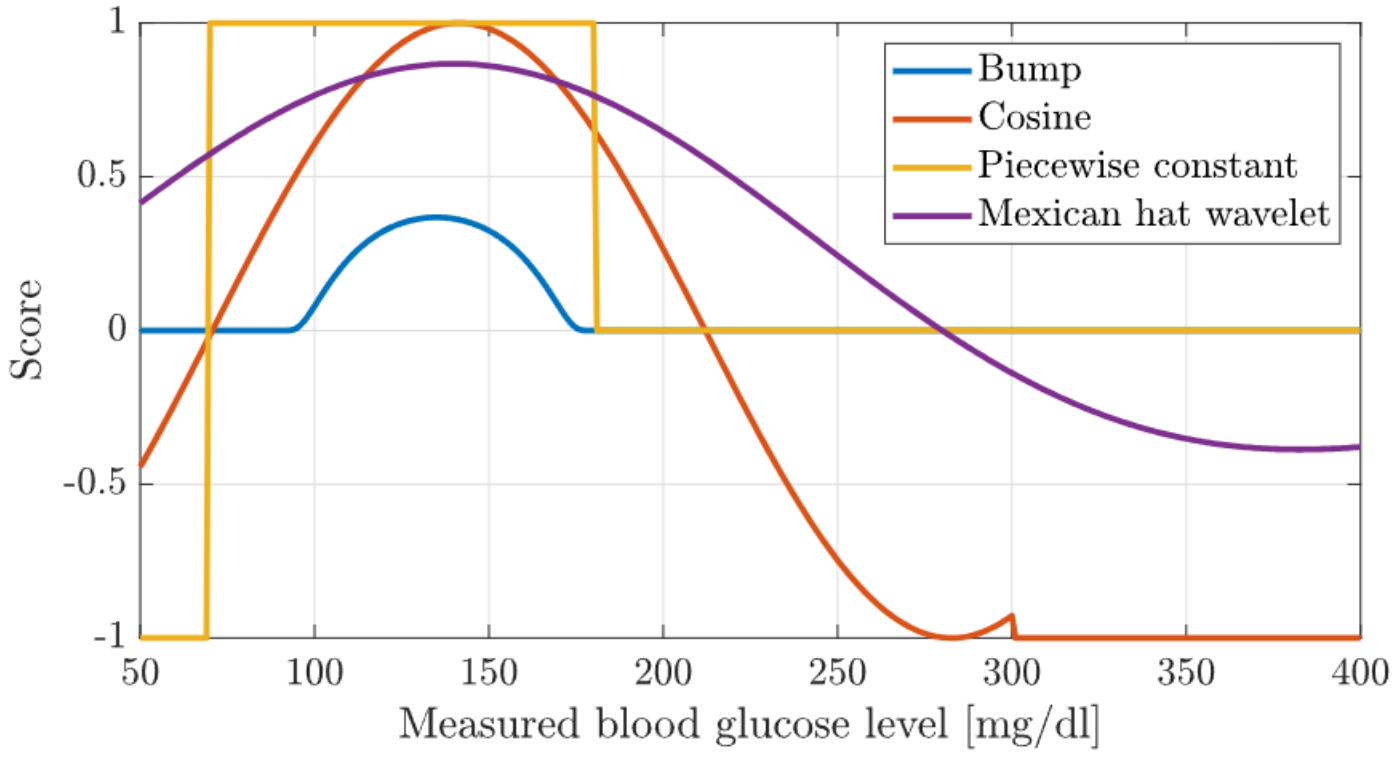
Reinforcement learning



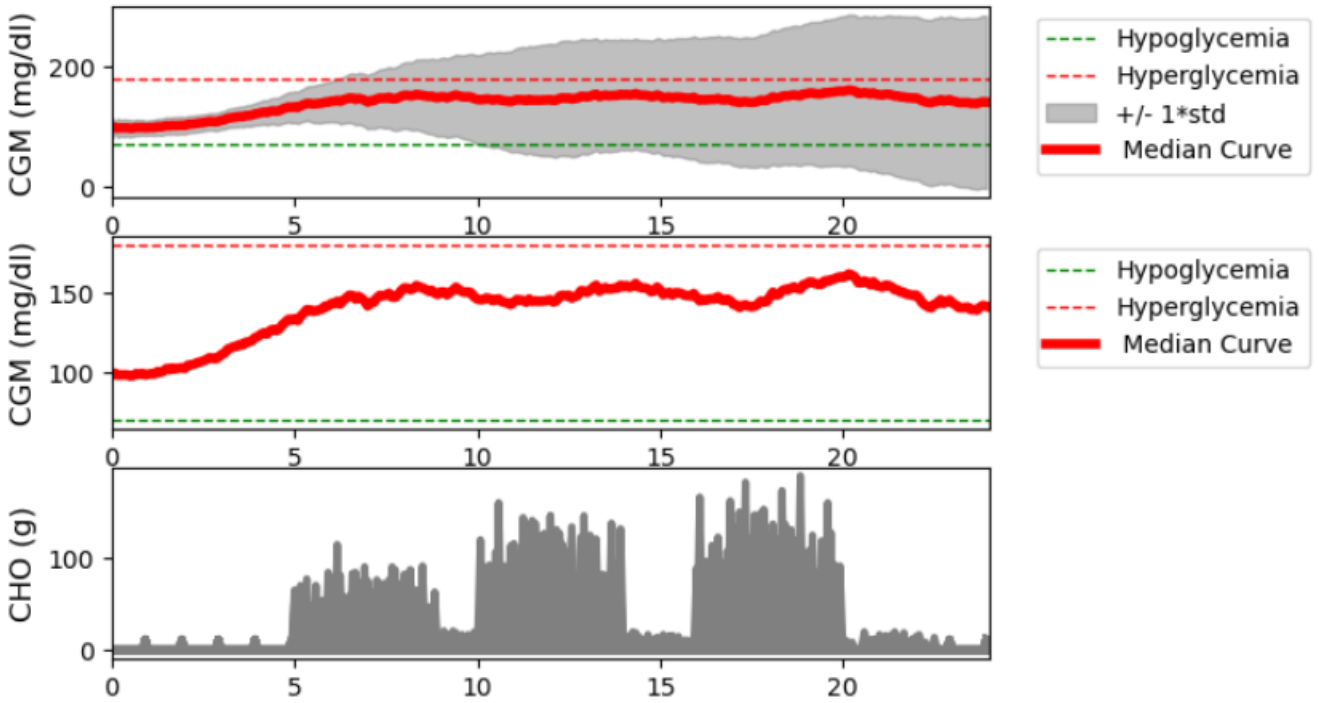


Reinforcement learning

Investigated reward functions



Reinforcement learning

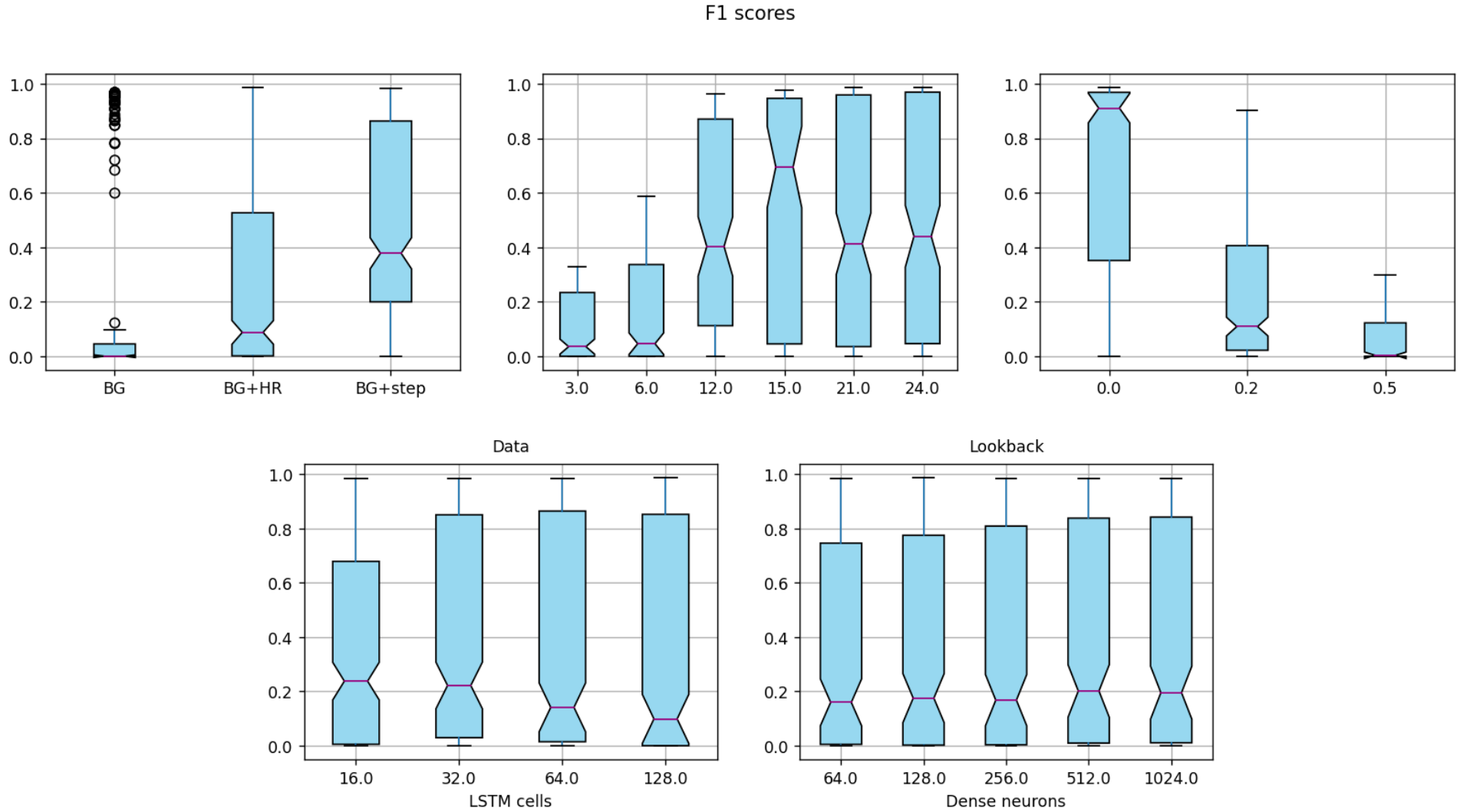


Physical activity detection

- OHIOT1DM dataset:
  - Heart rate, glucose, steps
  - 5-fold cross validation

- Neural networks:
  - Bidirectional LSTM
  - Bidirectional GRU

Physical activity detection



Köszönöm a figyelmet!

www.uni-obuda.hu

Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal

AZ NKFI ALAPBÓL MEGVALÓSULÓ PROJEKT