Joint Moving Horizon Estimation and Model Predictive Control for Type 1 Diabetes

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BYU PRISM
model optimize control

GEKKO
DYNAMIC OPTIMIZATION

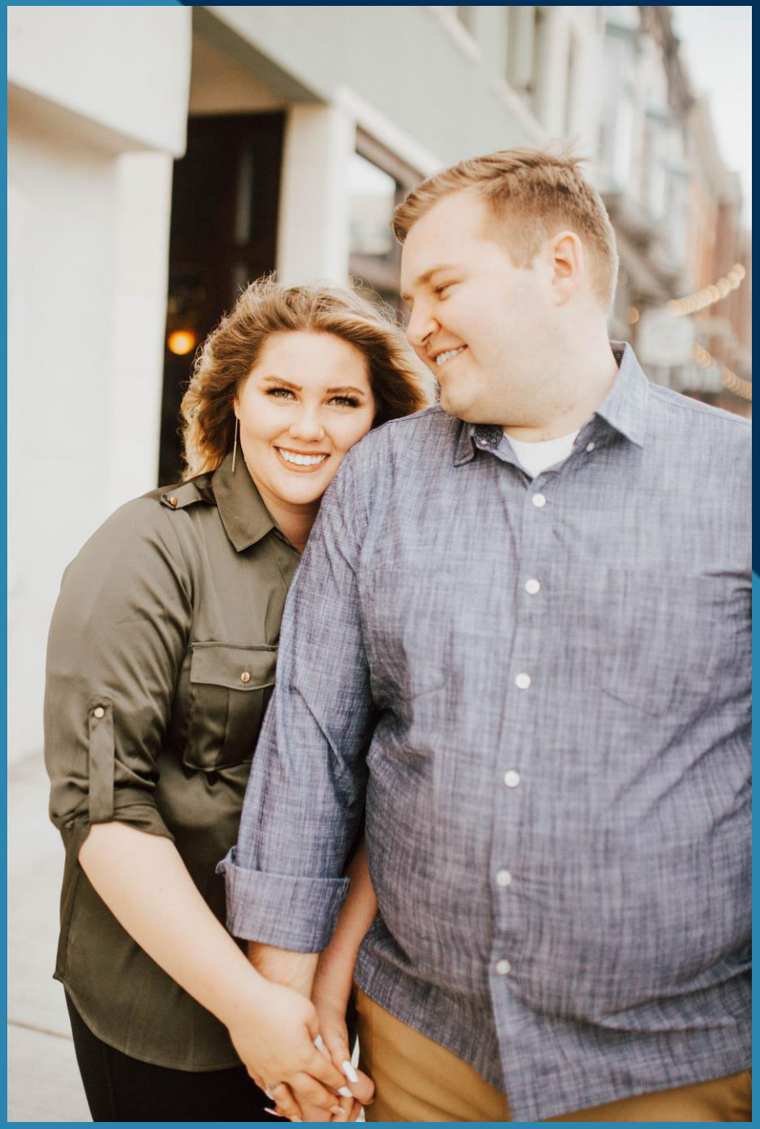
Objective:

i) Proof of concept disturbance and parameter estimation with MHE

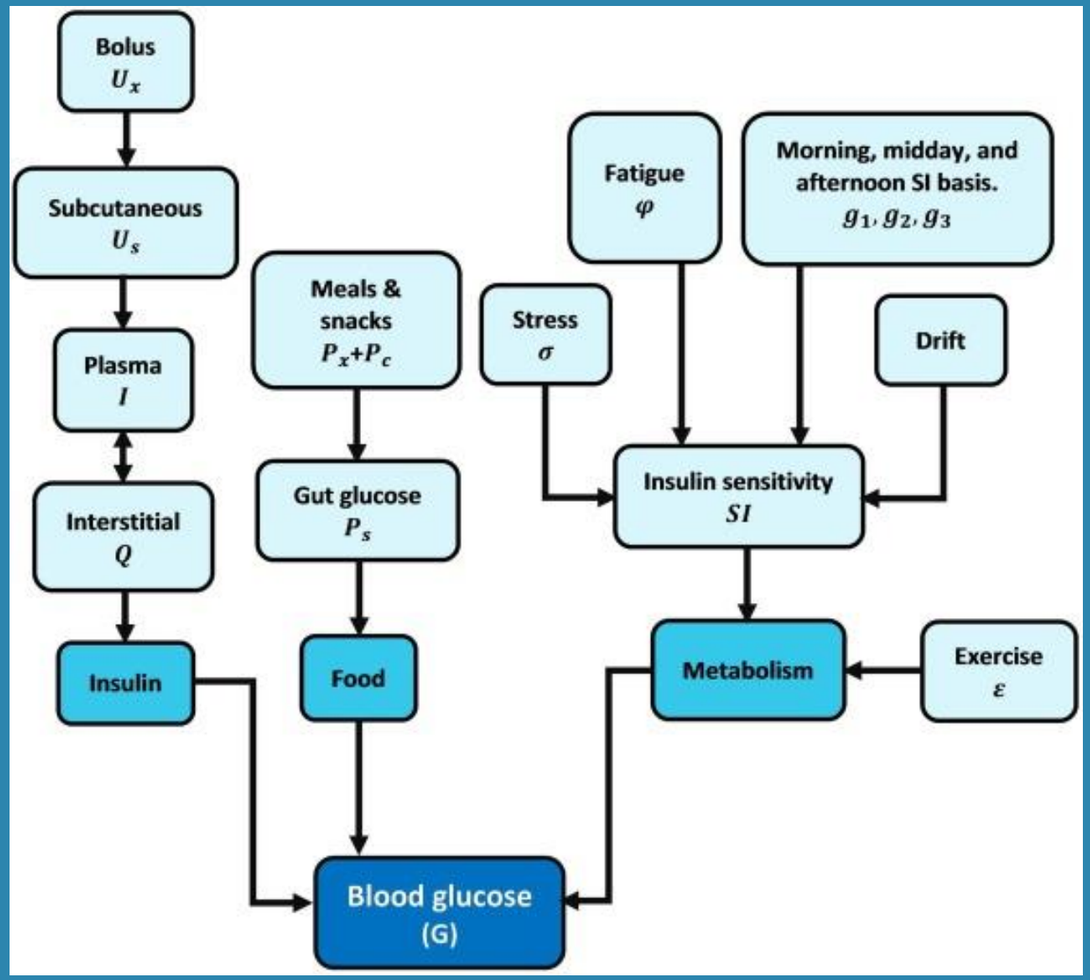
ii) Design an objective function that prioritizes patieny safety

a) avoid hypoglycemic time

b) Target 80 mmol/dL blood glucose



Insulin Dynamics



Bergman Minimum Model

$$\frac{dG}{dt} = -p_1 * (G - bg_s_i * X * G + f * \frac{k_{abs}}{vg} GG + \frac{f}{vg} D$$

$$\frac{dX}{dt} = p_2(I - X)$$

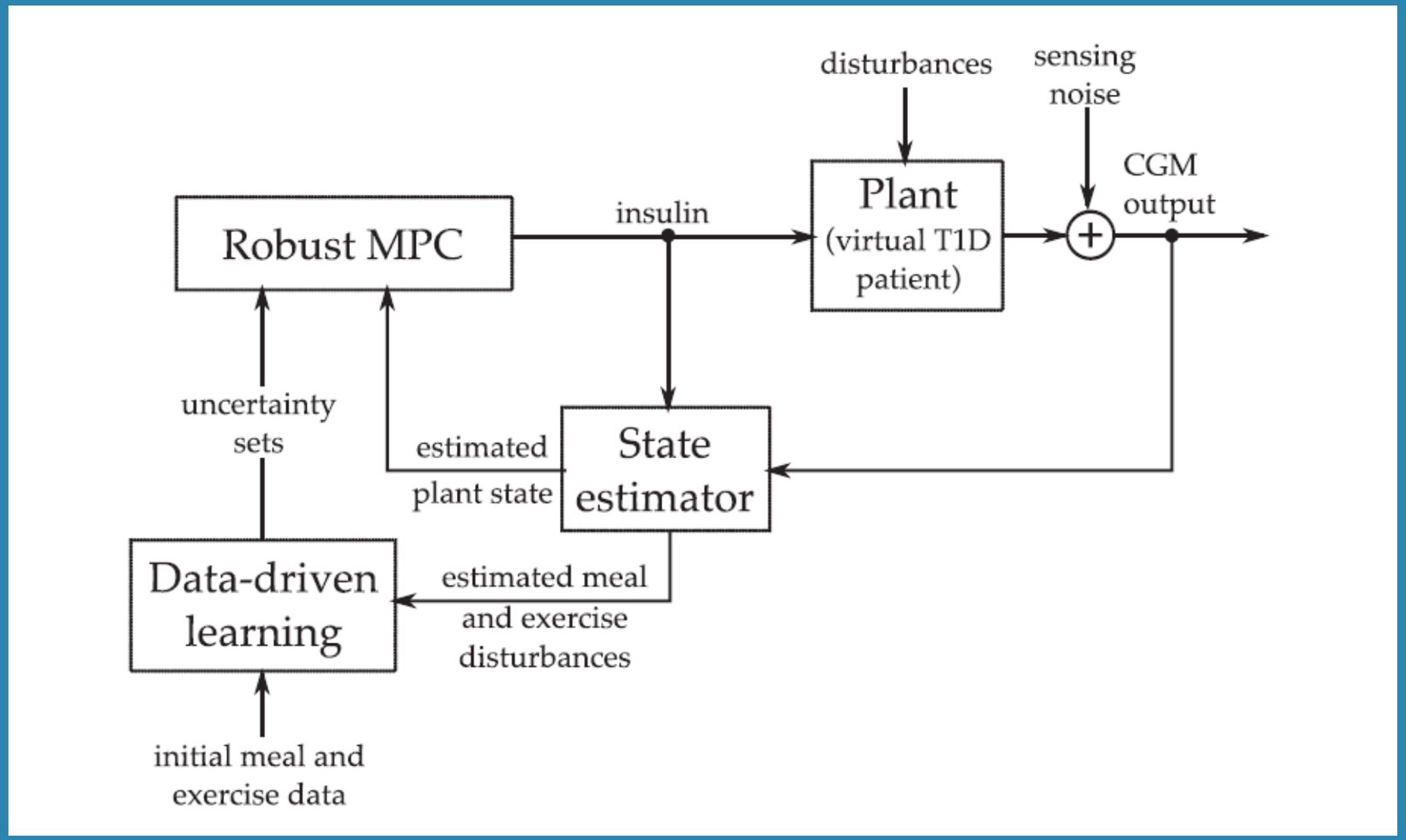
$$\frac{dI}{dt} = -k_e * I * U$$

$$\frac{dS_1}{dt} = U - k_{emp} * S_1$$

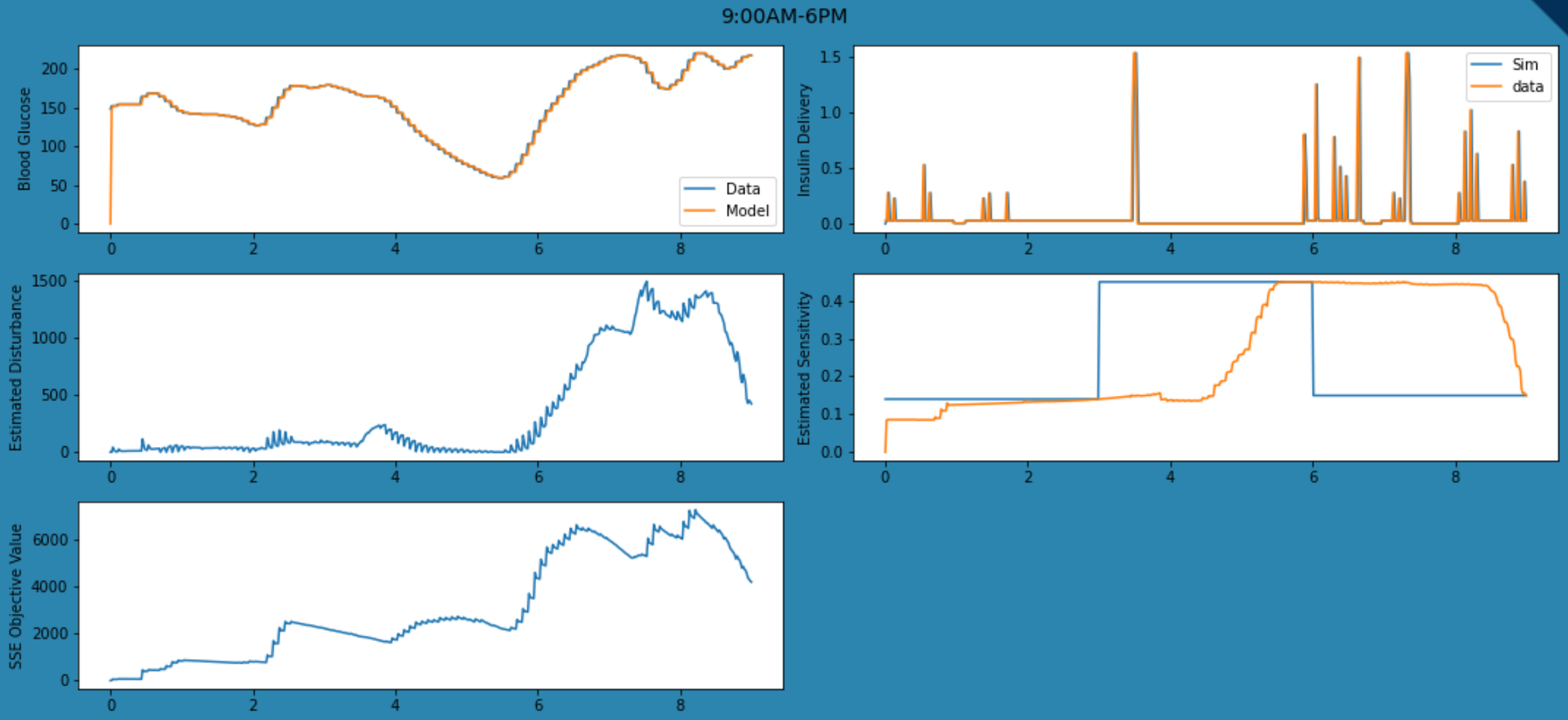
$$\frac{dS_2}{dt} = -k_{emp} * (S_2 - S_1)$$

$$\frac{dGG}{dt} = k_{emp} * S_2 - k_{abs} * GG$$

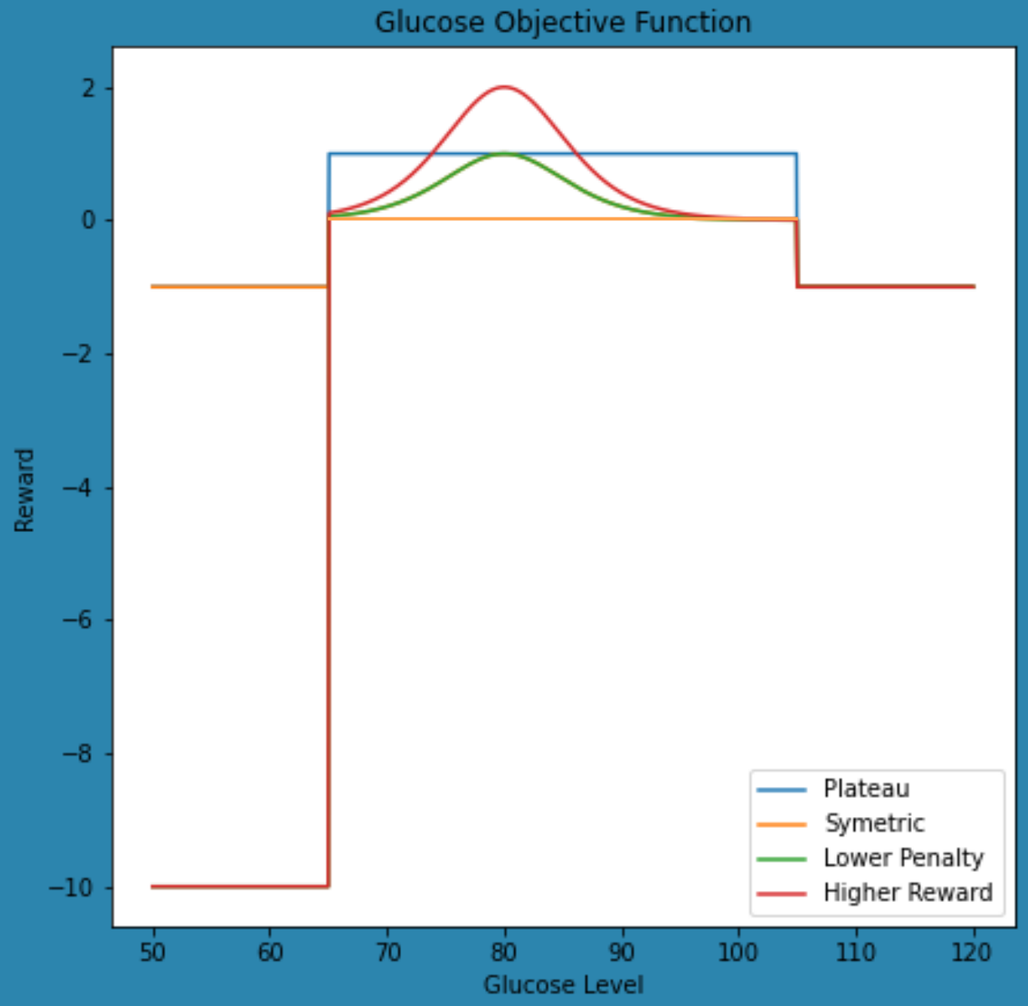
Block Diagram

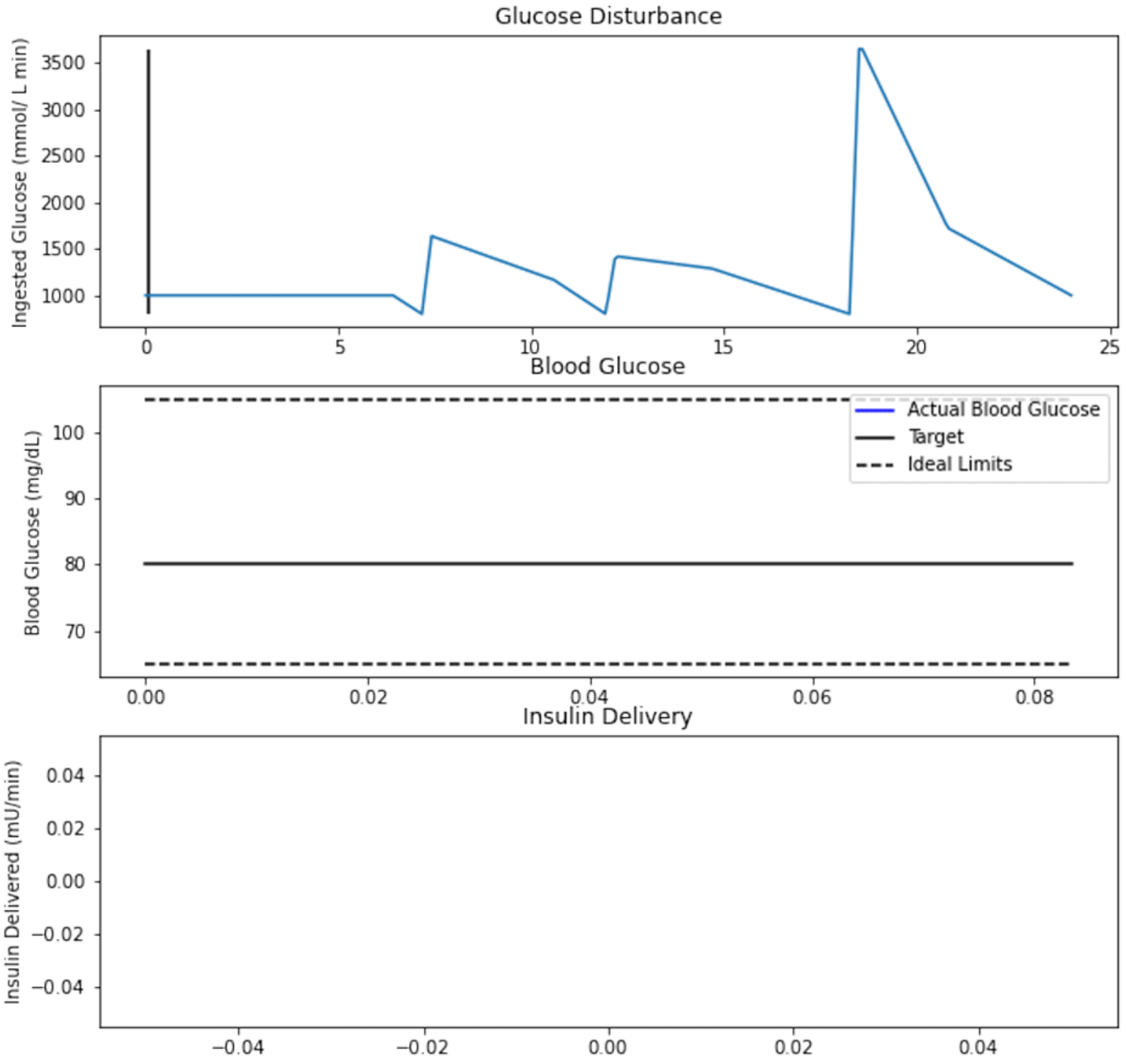


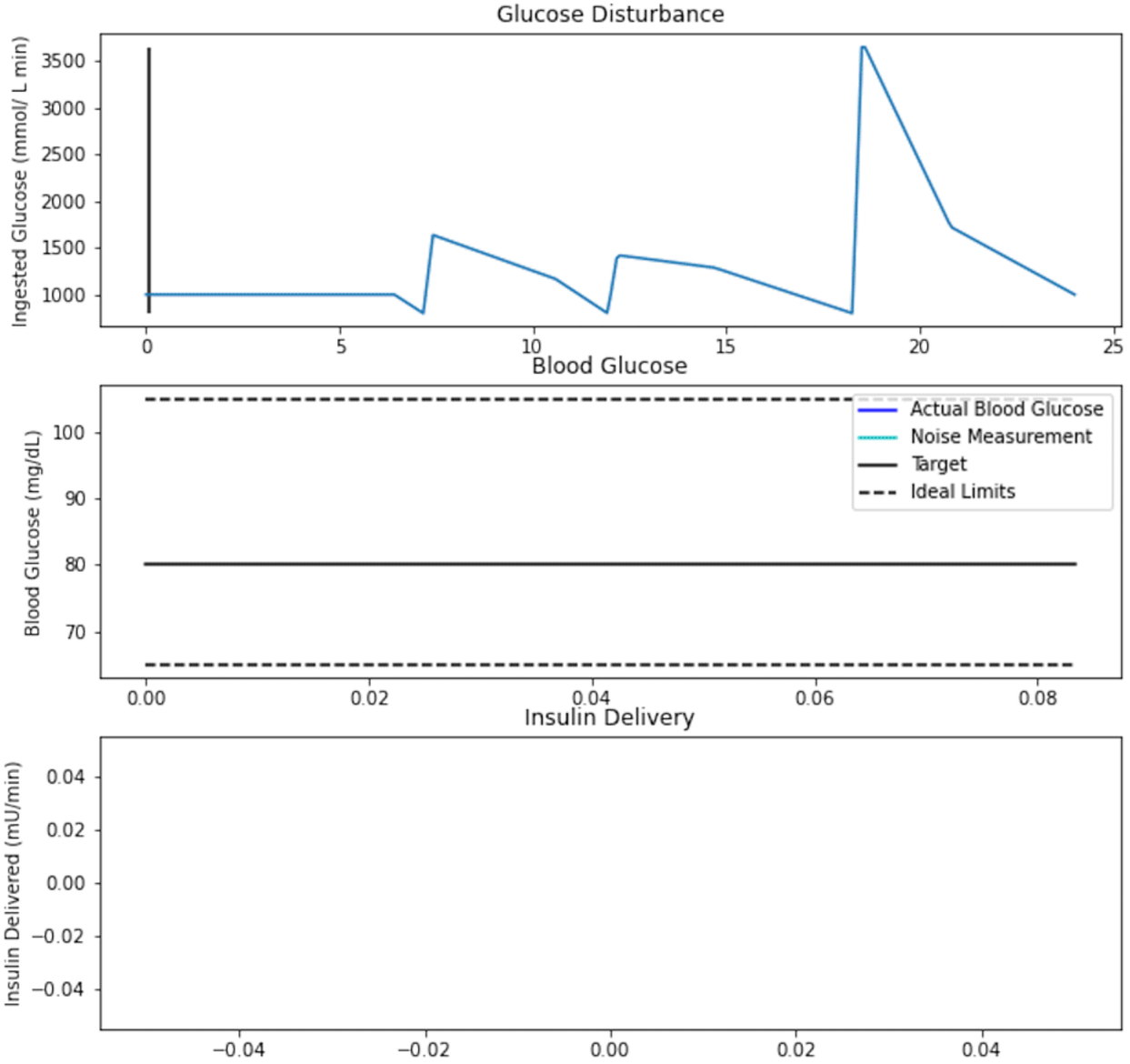
Moving Horizon Estimation



MPC: Objective Function




Glucose Disturbance
Ingested Glucose (mmol/ L min)
3500
3000
2500
2000
1500
1000
0
5
10
15
20
25
Blood Glucose
Blood Glucose (mg/dL)
100
90
80
70
Actual Blood Glucose
Target
Ideal Limits
0.00
0.02
0.04
0.06
0.08
Insulin Delivery
Insulin Delivered (mU/min)
0.04
0.02
0.00
−0.02
−0.04
−0.04
−0.02
0.00
0.02
0.04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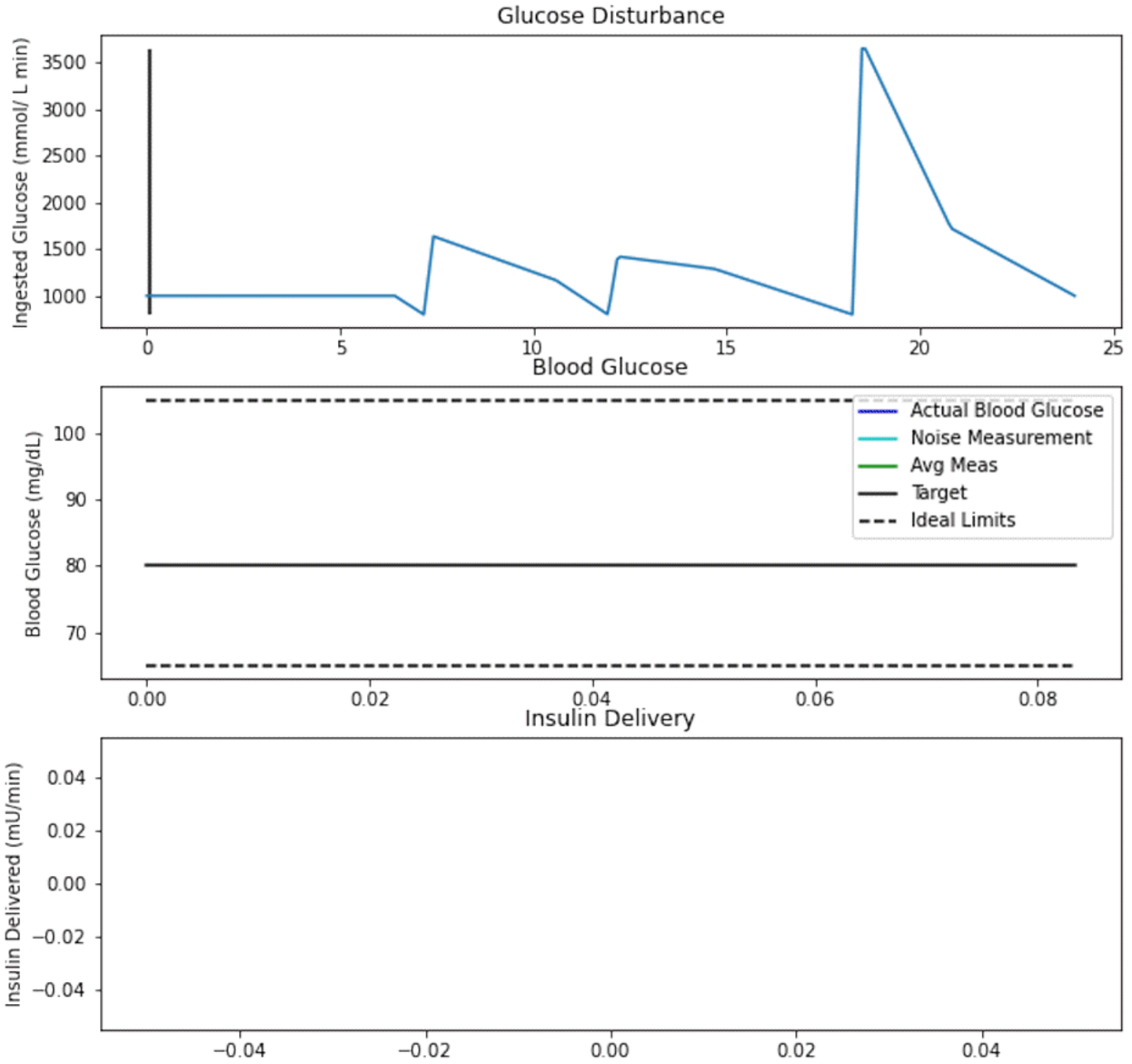
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Insulin Delivered (mU/min)
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Objective Function Results

Objective Function	Average Blood Glucose	Average Time Above 105 mmol/dL per day	Average Time Below 65 mmol/dL per day
Plateau	87.30	133.05	121.25
Tanh	101.93	187.70	8.85
Tanh + lower Penalty	86.34	123.70	10.45
2(Tanh) + Lower Penalty	86.42	124.70	8.70