CH303 Project

TYPE 1 DIABETES (DRUG DELIVERY)

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SYSTEM DESCRIPTION

The objective of this project is to design an automated control scheme to regulate the blood glucose level of a Type 1 diabetes patient, aiming to maintain glucose concentration within an acceptable range. The model employed describes the interaction between blood glucose and insulin concentrations.

MATHEMATICAL MODEL

Glucose concentration (G):

$$\frac{dG}{dt} = -p_1 G - X(G + G_{basal}) + D$$

This equation models the glucose concentration dynamics in the blood (mg/dL) considering the basal glucose level (Gbasal=81 mg/dL, the insulin concentration at the active site (X), and the rate of glucose release into the blood due to external factors (D, in mg/dL-min).

MATHEMATICAL MODEL

Insulin concentration at the active site (X):

$$\frac{dX}{dt} = -p_2 X + p_3 I$$

This equation models how insulin is absorbed and used at the active site. Insulin concentration (I) in the blood is expressed in deviation variables relative to the basal insulin concentration (Ibasal=15mU/L).

MATHEMATICAL MODEL

Blood insulin concentration (I):

$$\frac{dI}{dt} = -n(I + I_{Basal}) + \frac{U}{V_1}$$

This equation describes the rate of change of blood insulin concentration, where U is the flow rate of insulin (manipulated variable in mU/min) and V1=12L is the volume of insulin distribution in the body. The parameter n=0.0926 min−1 represents the rate of insulin clearance from the bloodstream.

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MODEL PARAMETERS

Parameter	Symbol	Value	Unit	Description
Glucose degradation rate	P_1	0.028735	min^{-1}	Rate at which glucose depletes from the bloodstream
Insulin degradation rate	P_2	0.028344	min^{-1}	Rate at which insulin degrades at the active site
Insulin absorption rate	P_3	5.035 x 10 $^{-5}$	min^{-1}	Rate at which insulin is absorbed from the blood to the active site
Insulin clearance rate	n	0.0926	min^{-1}	Rate at which insulin is cleared from the bloodstream
Insulin distribution volume	V_1	12	L	Volume of insulin distribution in the body
Basal glucose concentration	G_{basal}	81	mg/dL	Normal glucose level in the blood
Basal insulin concentration	I_{basal}	15	mU/L	Normal insulin concentration in the blood

CLASSIFICATION OF VARIABLES

Controlled Variables (CV):

- Glucose concentration (G) in the blood (mg/dL)

Manipulated Variables (MV):

- Insulin flow rate (U) in mU/min

Disturbance Variables (DV):

- Glucose intake rate (D) (mg/dL-min)

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OBJECTIVES

Objective 1: Steady State Simulation

Simulate the system to observe steady state behavior.

Objective 2: Dynamic Simulation

Compare responses of output variables (glucose) using:

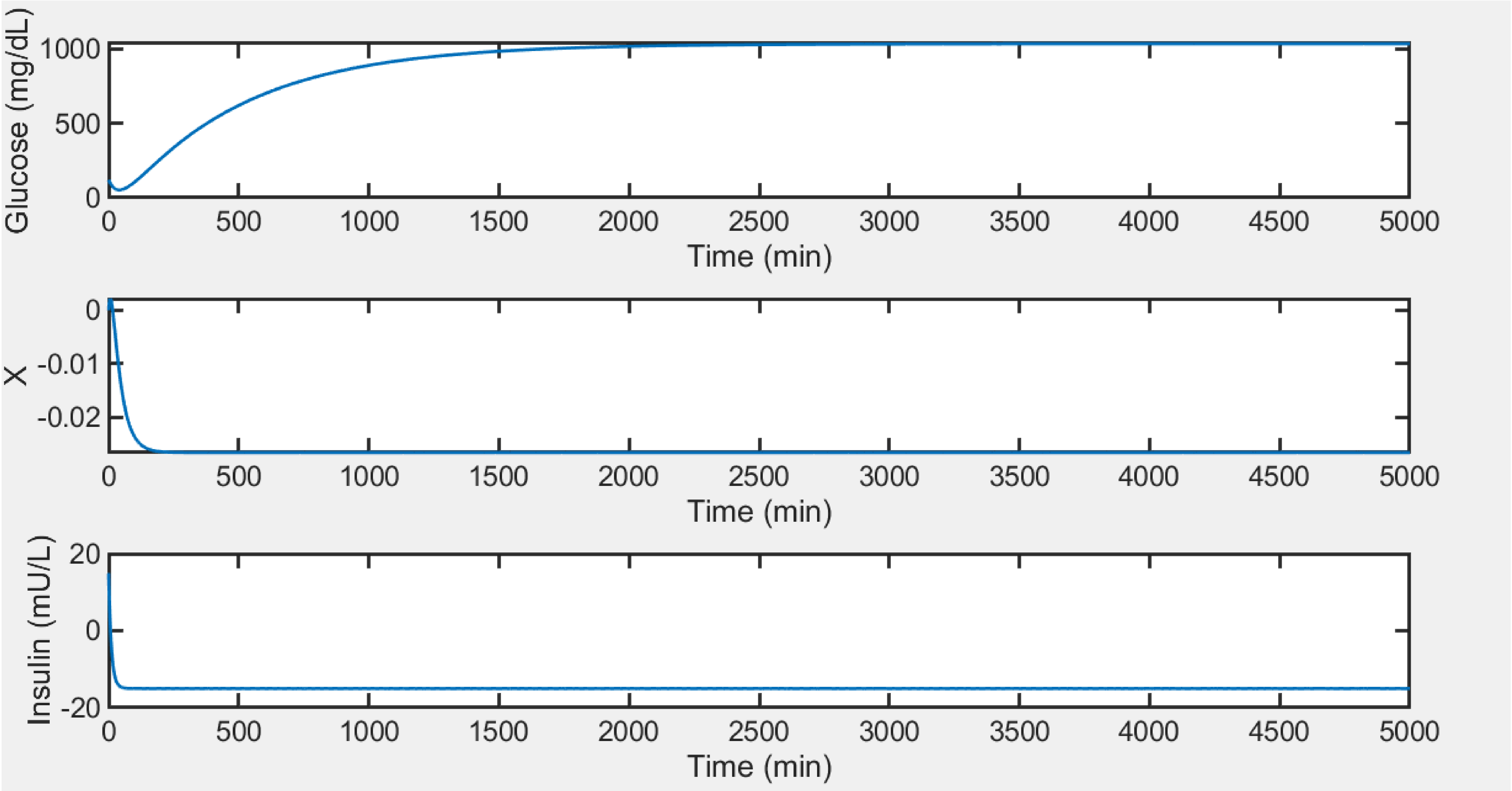
- Nonlinear model simulation (ODE45)
- Linear model simulation

Objective 3: Empirical Model Identification

- Identify a suitable First Order Plus Time Delay (FOPTD) model for the system.
- Report model parameters and validation.

STEADY STATE SIMULATION

Plot steady state graphs for glucose concentration (G) and insulin concentration (I).



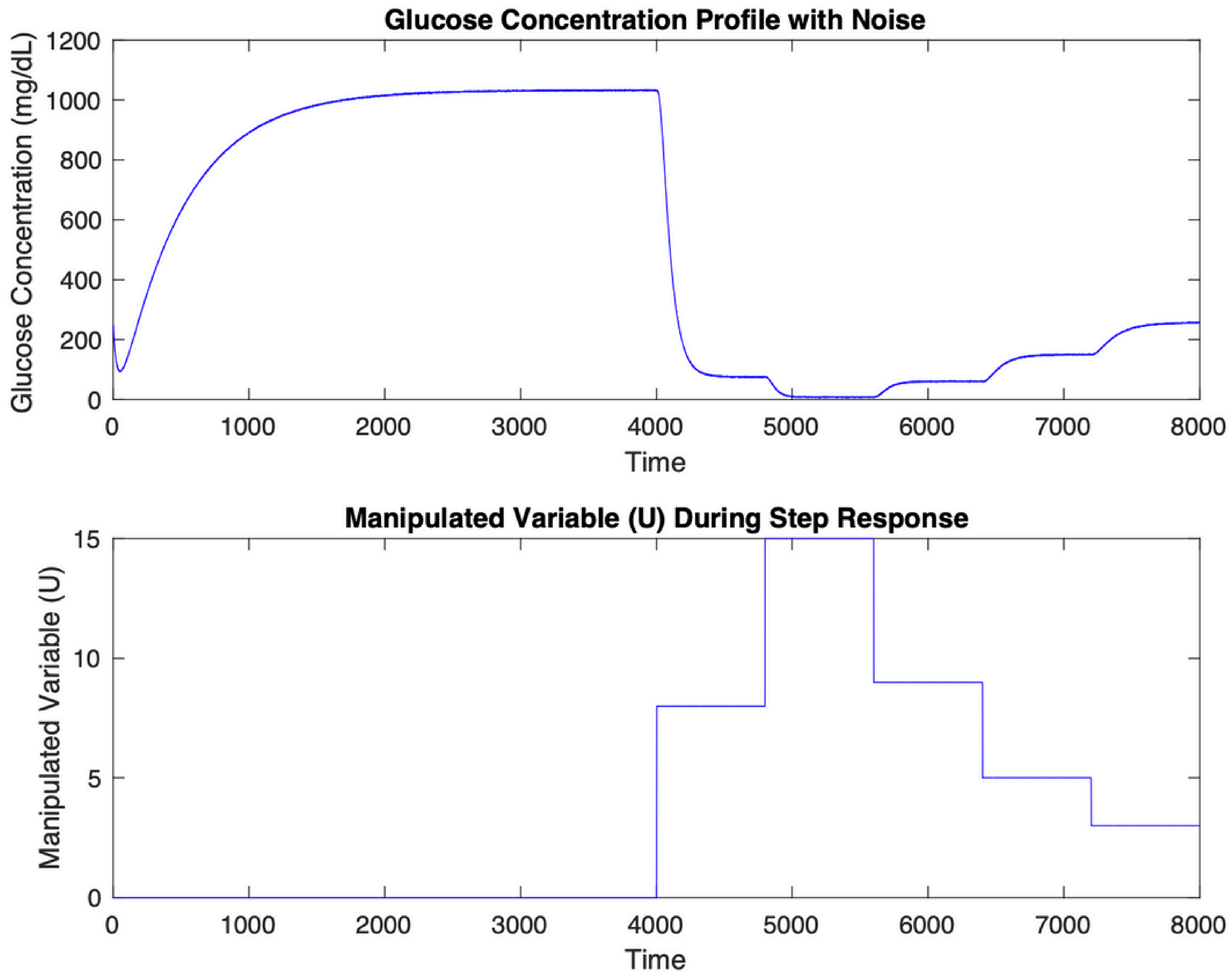
STEADY STATE VALUES

Steady State Values:

- G : 195.5513mg/dL
- I : 11.4382 mU/L
- X : 0.020319 mg/dL

DYNAMIC SIMULATION

Plots comparing glucose responses for different step change magnitudes.



EMPIRICAL MODEL IDENTIFICATION (TRAINING AND TESTING DATA)

- Data for Model Identification:
  - Training Data: Collected over 0 to 100min, covering a range of step inputs.
  - Testing Data: Collected over 100 to 200min, ensuring no overlap with training data.
- Procedure for FOPTD Model Identification:
  - Apply system identification techniques to obtain model parameters (process gain, time constant, time delay).
  - Compare training data to model outputs.

FIRST ORDER PLUS TIME DELAY (FOPTD) MODEL

FOPTD Model Parameters:

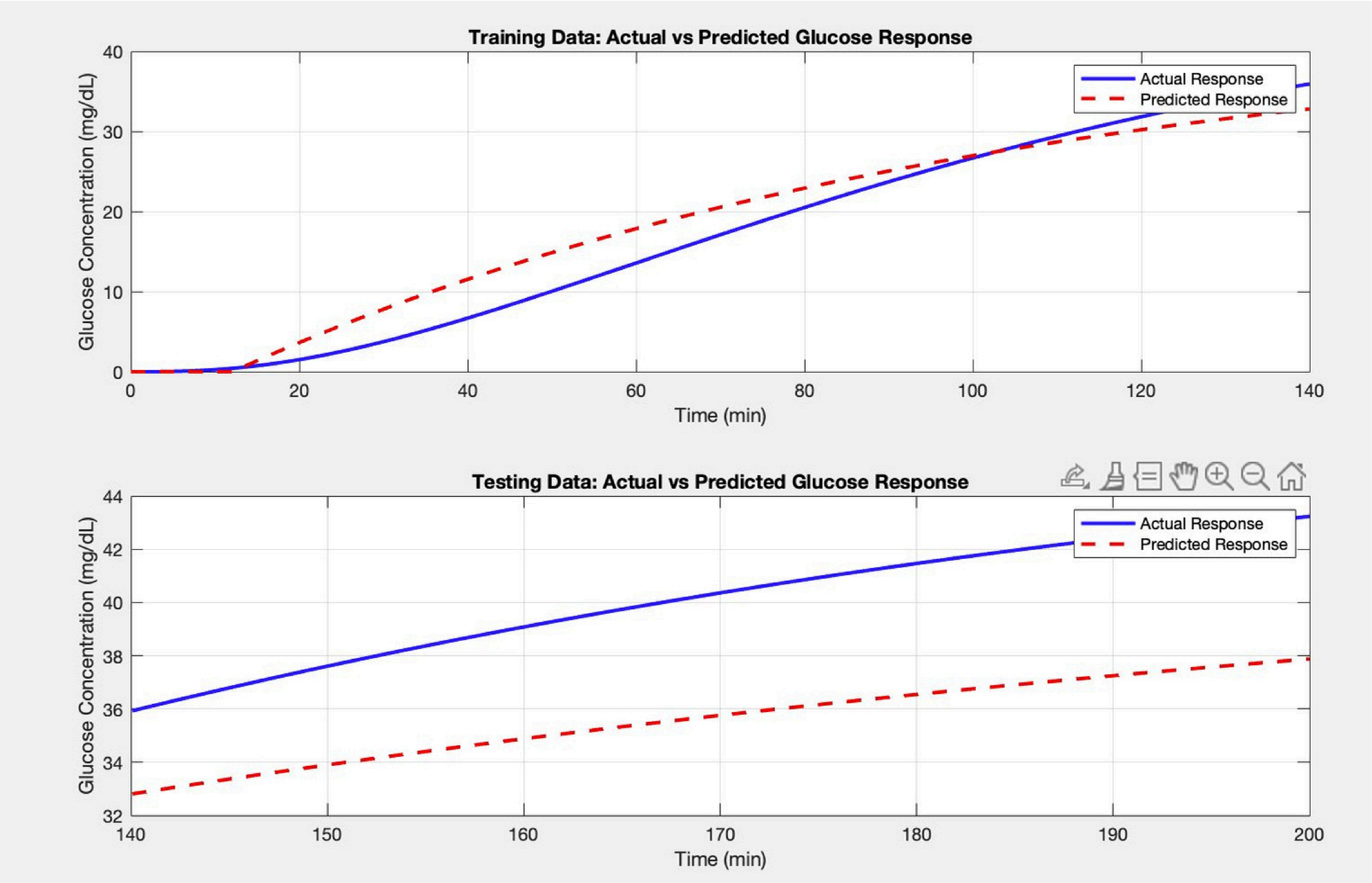
- Process Gain (K): 4.2371
- Time Constant (τ): 100.9505 min
- Time Delay (θ): 0 min

Empirical Model:

$$G(s) = \frac{K\exp(-Ts)}{(\tau_p s + 1)}$$

VALIDATION

Graph comparing validation data and FOPTD model predictions.



CONCLUSION

- Successfully simulated both steady state and dynamic behavior.
- Linear and nonlinear models exhibit different performance under varying disturbances.
- Developed and validated an empirical FOPTD model with reasonable accuracy

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THANK YOU