EENG307: Application Example #2[1]

Lecture 35

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Fall 2022

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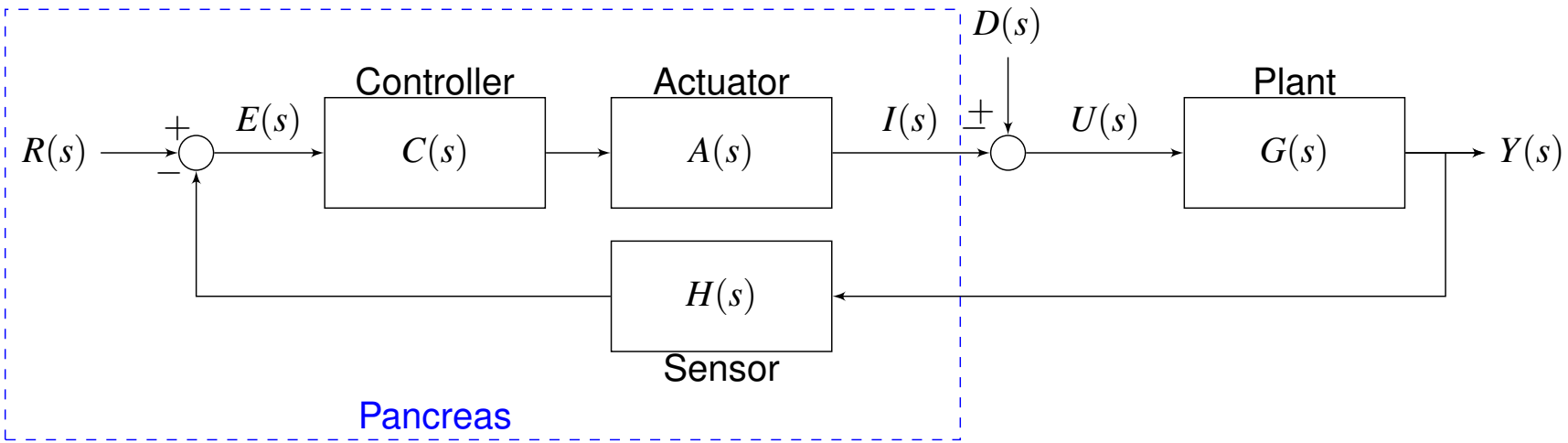
Big-picture questions

What is the problem we are trying to solve?

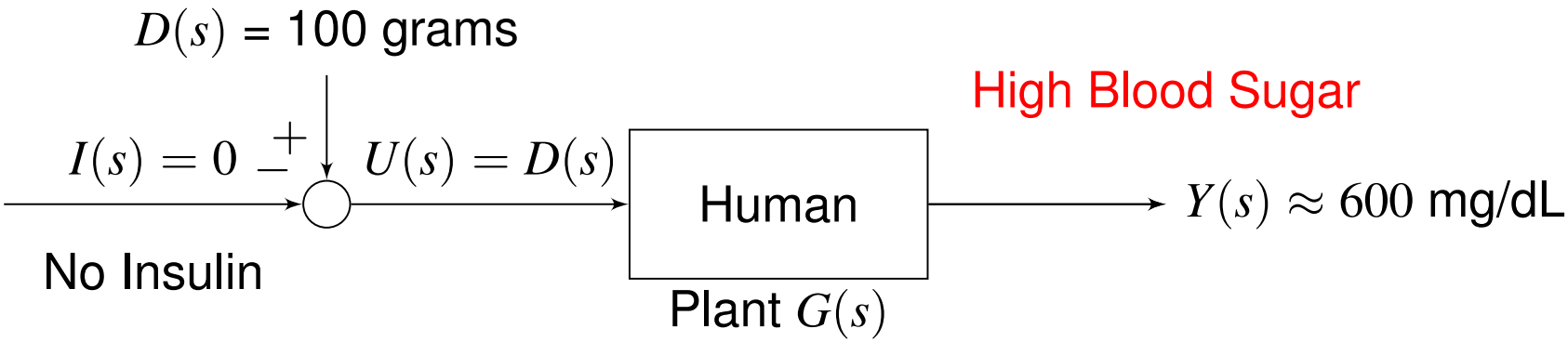
How can we describe (and model) the plant system articulated in the problem definition?

Who is creating the control technology and who are they creating it for? How does that impact the definition of the problem, the plant model, and any control solutions developed?

Conceptual biological feedback loop for blood sugar regulation in a person without diabetes



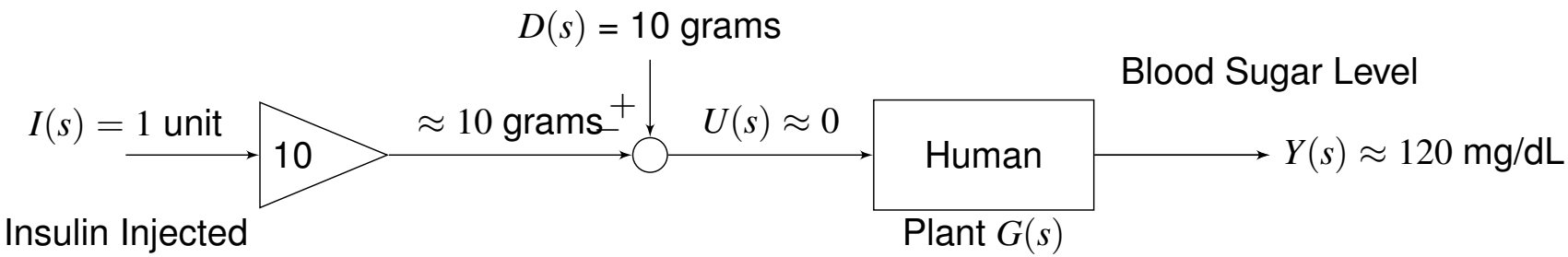
Open-loop system diagram for human with diabetes



Discussion Question

DQ1 If you were to develop an external feedback controller for this open-loop system modeling a person with diabetes, what specifications may you care about and why? Consider both transient and steady-state response as well as robustness (gain and phase margins).

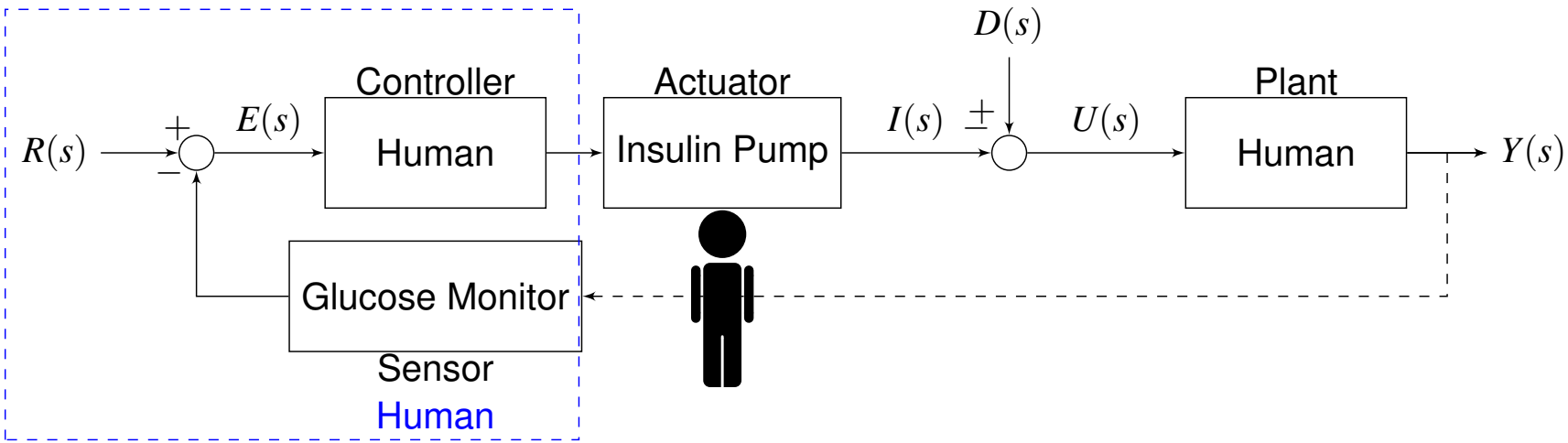
Open-loop (no feedback) blood sugar regulation



Discussion Question

DQ2 How would you augment the open-loop figure (Figure **??**) to consider the case with "feedback" from external reading of a glucose monitor but for which the human must still take action, such as injecting insulin or eating something with a high GI?

Human-in-the-loop feedback control with actuator (insulin pump) and sensor (glucose monitor)

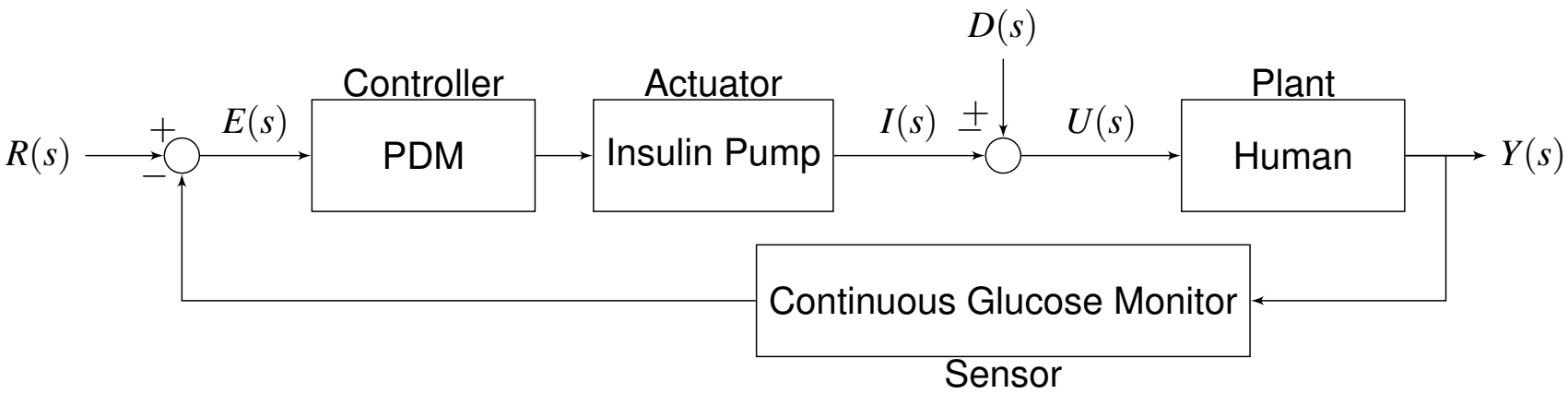


Discussion Questions

DQ3 What acts as the controller, actuator, and sensor in the insulin regulation system for a person with diabetes and how is that different from a person without diabetes?

DQ4 What are the inputs and outputs of each of these subsystems?

Automatic Closed Loop Blood Sugar Regulation using Insulin Pump



Discussion Questions

DQ5 What are some risks or potential issues with the closed-loop system?

DQ6 What kind of disturbances can it account for and not account for?

Cost Considerations

Continuous Glucose Monitor (CGM): *Dexcom G6*

- Transmitter Cost: $600
- 3 pack of sensors (sensors need to be replaced every 10 days): $300-$500
- Transmitter + 3 pack sensor pack: $700-$1000

Insulin Pump and PDM: *Omnipod*

- Pump & PDM: $800
- 5 pack of pods (pods have to be replaced every 2-3 days or 200 units of insulin): $150-$350

Insulin

- 1 vial has 1000 units of insulin: $60-$140
- 1000 units of insulin covers about 10,000 grams of carbs
- recommended daily carb intake is 225-325 grams
- 1 vial of insulin could last 1-1.5 months
- In 2019 insulin had a cost of $0.34/unit

Discussion Questions

DQ7 Who has access to the automatic closed-loop blood sugar regulation technology and who doesn't?

DQ8 How could the "problem" be re-defined to make this technology more accessible? What are other considerations that could be included in the controller design process?

Measured Glucose Dynamics in Person With and Person Without Diabetes

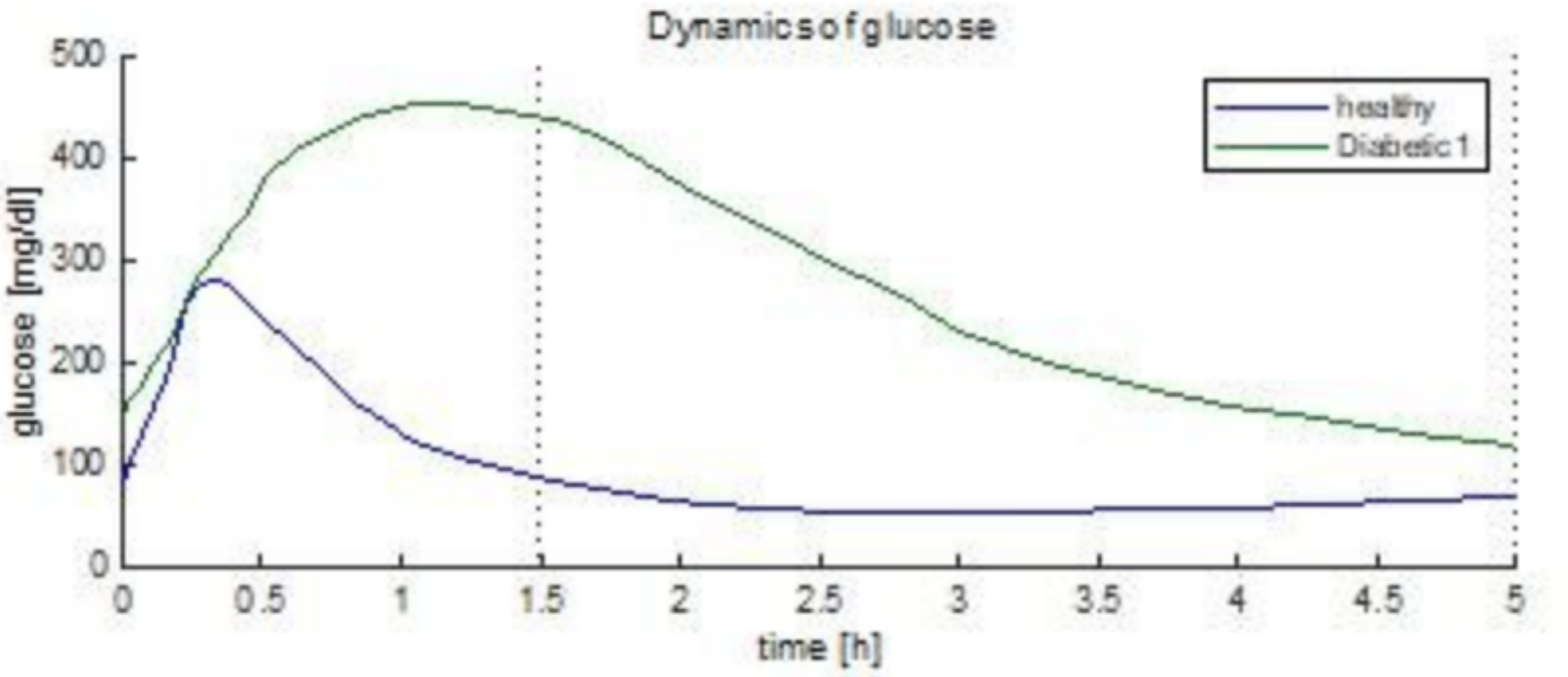
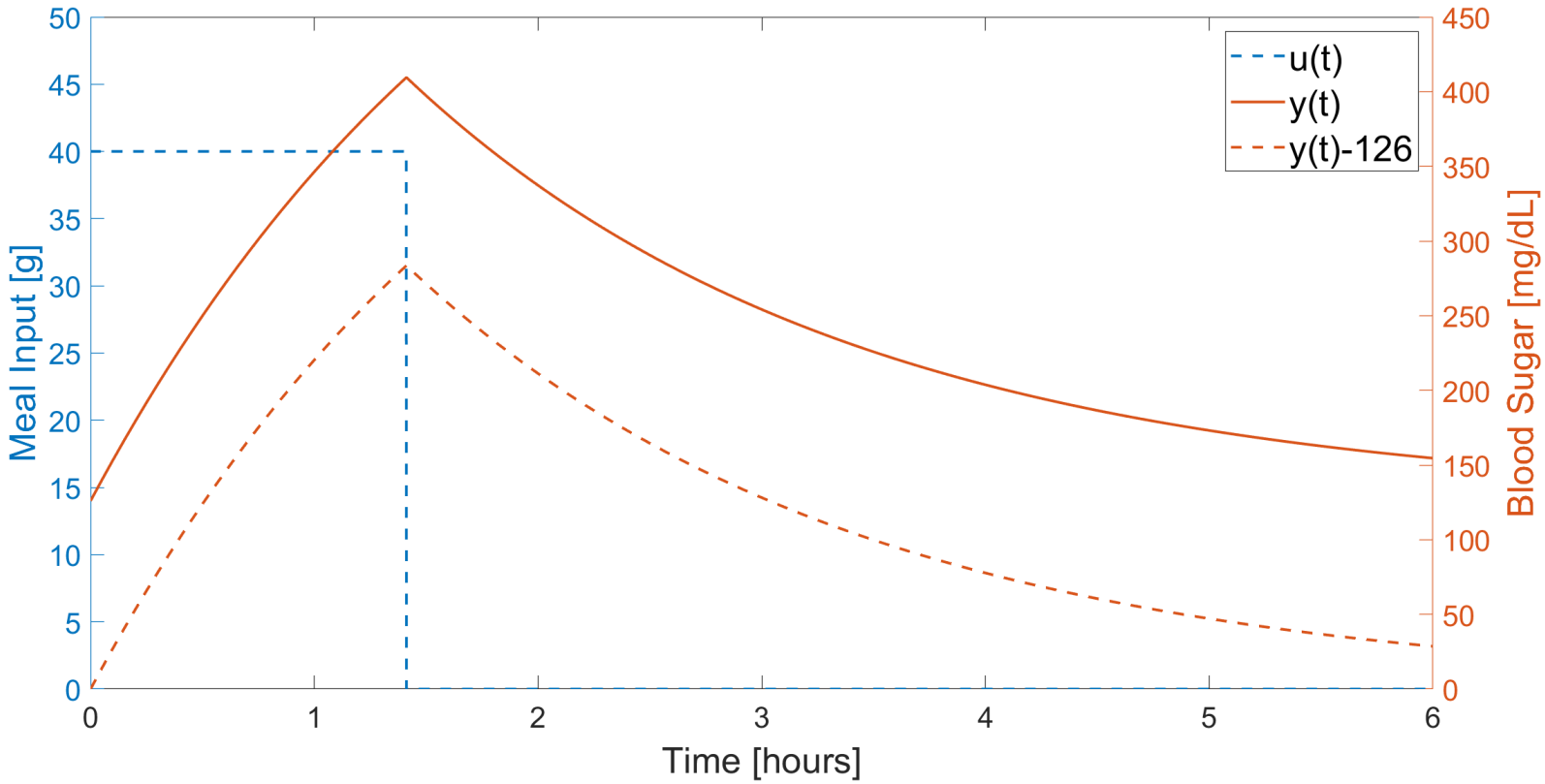


Figure obtained from Meszyski, Sebastian, Sokolov, Oleksandr, Mrela, Aleksandra, "From Compartments to Agents via Fuzzy Models *Modeling and Analysis of Complex Behavior of Physiological Systems," International Journal on Advances in Intelligent Systems, Vol. 11, no. 1-2, 2018.*

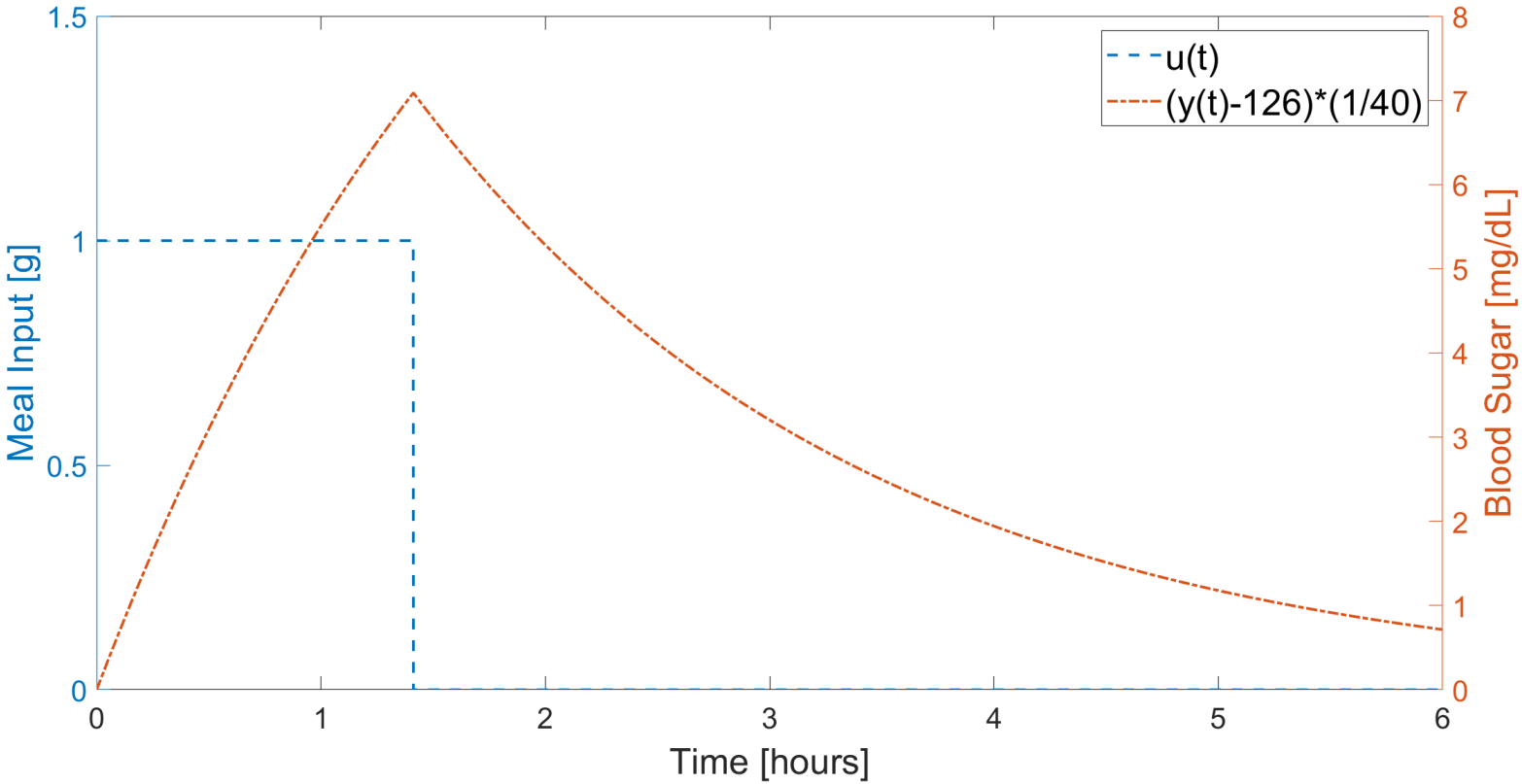
Blood Sugar Response to Meal Disturbance without Insulin – Measured and Corrected for Initial Conditions



Discussion Question

DQ9 Given the "initial condition" of a blood sugar level of $y(t) = 126$ mg/dL and the scaling of the input signal $d(t)$ to a magnitude of 40, how do we need to process our data to perform system ID?

Blood Sugar Response to Meal Disturbance without Insulin - Fully Processed

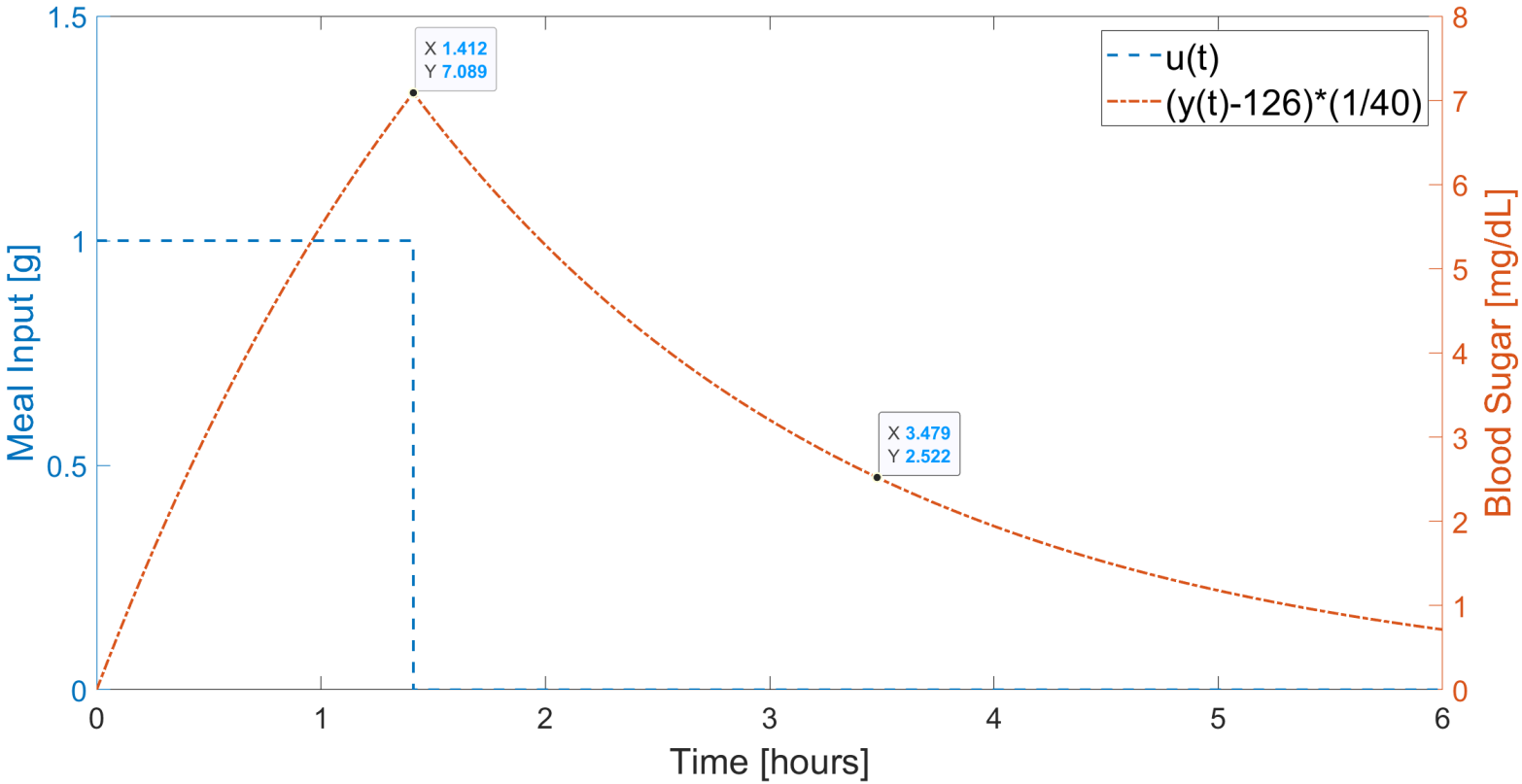


Discussion Questions

DQ10 Can you determine the order of the plant system from net insulin $u(t)$ to blood sugar level $y(t)$? How might knowing (or not knowing) the order impact any system identification?

DQ11 Given the data and your assumptions about the order of the plant system, what may you be able to infer about some of the parameters?

Blood Sugar Response to Meal Disturbance without Insulin - Processed with Data Markers



Discussion Questions

DQ12 If you compare the transfer function from our approximate system identification work and the resulting plot to the original data, what similarities and differences do you see? Do the assumptions discussed make sense?

DQ13 Which value, K or σ, is likely to be less accurate from our "experiment"? What could we do to improve the experiment to get better data?