Computational Control Project Assignment

Spring 2024

Introduction

You are a control expert, and you are asked to act as a consultant for InsulinCo, a company that provides artificial pancreas (AP) care to patients with diabetes. Their AP uses an insulin pump to inject insulin in response to glucose measurements and meal predictions.

InsulinCo would like to know if an advanced control method can improve the performance of their AP. They are interested in a **model-based AP controller**, as well as a **data-driven AP controller**. They want to know if they should pursue a product direction that involves a model that they, perhaps, modify for each patient, or a product direction that relies only upon data from the patient.

To support the model-based approach, InsulinCo has provided a nonlinear model for a specific patient and its linearization at a steady-state operating point. To support the data-driven approach, InsulinCo has provided the time series data for a single sample patient that they would like you to use for the data-driven controller.

To test/validate the controllers you develop, InsulinCo has provided you with the ReplayBg simulator, which simulates the nonlinear dynamics of a human glucose regulation mechanism. For the model-based and data-driven controllers that you design, InsulinCo would like you to just use the ReplayBg simulator for testing, not generating additional data. If you have time, InsulinCo is also curious if they could design a better AP controller if they had a full commercial license for the ReplayBg simulator (i.e., if they use the ReplayBg simulator for more than just testing, such as to generate additional data). We describe this in the “Bonus” bullet point below.

In concrete terms, you are provided with a Jupyter notebook with the following information:

- The simulator ReplayBG of the glucose dynamics of a diabetic patient;
- A nonlinear model of the glucose dynamics derived by their medical specialists;
- A linearization of the nonlinear model for a given patient at a standard operating point;
- A time series data set with the input/output data of a sample patient;
- Insulin injection limitations of the InsulinCo pump;
- Glucose level constraints from their medical specialists;
- The PID controller that InsulinCo currently uses.

Your task

You need to produce **two documents**:

- A 5-slide **presentation.**
- A **Jupyter notebook.**

The **presentation** is intended for InsulinCo's Chief Technology Officer. It needs to be compelling, concise, graphically pleasant, and professional. It cannot be overly technical, but it must have a convincing logical progression and be scientifically sound.

Each slide serves a specific purpose:

1. **Current state**: Show how the current controller performs in the standard operating condition that is already implemented in the simulator. Briefly comment on the behavior. *[1 point]*
2. **Failure mode**: Show how under certain conditions their controller can fail the task. In this slide, you want to motivate the need for a better controller. It is your job to find a compelling failure scenario, that is, one that is plausible but that their controller cannot handle well. *[2 points]*
3. **Your model-based recommendation + Demonstration**: Explain what type of model-based controller you would recommend (among those seen in class), providing the three most important reasons that support your choice. *[4 points]*
4. **Your data-driven recommendation + Demonstration**: Explain what type of data-driven controller you would recommend, given the data set that they have provided, providing the three most important reasons that motivate your data-driven controller. *[4 points]*
5. **A plan for deployment:** Briefly describe what would be the necessary technical steps needed in order to deploy the two controllers that you proposed, and what the most important requirements and trade-offs are. *[4 points]*
6. **(Extra slide) Bonus:** ReplayBgCo, the startup with the IP for the world-leading ReplayBg glucose mechanism simulator, claims that their simulator is accurate enough to be trusted for the design of new AP controllers. InsulinCo is considering partnering with ReplayBgCo to get a full commercial license for their simulator. **Task**: using the ReplayBg simulator, or data from the simulator, either improve upon one of the two AP controllers you proposed in a significant manner, or demonstrate a different type of controller that requires an accurate simulator or more data (this new controller does not need to outperform the other controllers you have presented, but should be a sound implementation). If you do the bonus, present the requirements, merits, and tradeoffs of your bonus AP control design in an extra (sixth) slide. *[2 bonus points]*

The **Jupyter notebook** you submit is intended as support material for your presentation. Assume that InsulinCo's engineers will read your Jupyter notebook to understand what you are proposing. It needs to work flawlessly: any glitch will make you look unprofessional!

When executed, the notebook must produce all the material that you used in your presentation. *[5 points] [+2 points for successful demonstration of the bonus]*

Clear code implementation with clear comments when necessary (defining all variables, explaining functions you wrote, etc.). *[5 points]*

A ReadMe cell at the start of the notebook that addresses the following points in a clear and concise manner: *[5 points] [+1 point for a clear explanation of the bonus]*

- How the failure scenario has been modeled in the simulation.
- What parameters are used to demonstrate the failure scenario.
- How the proposed model-based controller is implemented.
- What parameters need to be tuned for the model-based controller.
- How you tuned the parameters for the model-based controller and how you would recommend tuning them.
- How the proposed data-driven controller is implemented.
- What parameters need to be tuned for the data-driven controller.
- How you tuned the parameters for the data-driven controller and how you would recommend tuning them.
- If you include an extra slide, a clear explanation of the implementation considerations of your bonus AP controller.

Grading

As detailed above, the **presentation** and the **Jupyter notebook** are worth 15 points each, for a total of 30 points. These 30 points count towards the course's total of 100 points (70 points are assigned based on the final exam). The bonus allows for up to 5 additional points towards the final count for the course.

Deadline

13 June at 23:59. Submit the project on Moodle.

Rules

- **Every student submits their own work**.
- You may discuss with other students but **all written material and all code must be written by you alone** and reflect your own understanding.
- **You may not use any external packages** other than the ones we provide. This includes Reinforcement Learning packages. If you feel that a package should be included, please reach out to Keith via email at kmoffat@ethz.ch.