Intelligent systems for control
TI0090

# Homework II: Control of a dynamic system

The objective of this homework is to control the dynamical system you modelled and simulated in the first homework. It was given a choice between three dynamic systems:

S1: Three-tank system.

S2: Inverted pendulum.

S3: Hot and cold water mixing tank.

S4: Continuous bioreactor.

S5: The system of your choice.

The model you developed in HW1 will be now used as virtual plant for the implementation of different control tuning. Regardless of your system choice, you must complete the following tasks:

1. Design of the control structure:
   - Define the control objectives and the performances criteria that your controller should satisfy. Determine the model degrees of freedom and the control degrees of freedom. Justifying your choices, selected the manipulated and the controlled variables, the corresponding set-points and possible process disturbances. Describe your system as SISO, SIMO, MISO or MIMO. If needed, recommend a pairing of controlled-manipulated variables and a decoupling control for reducing control-loop interactions. Justify your recommendation. Briefly describe how the control system should operate, and sketch a block diagram. Identify whether a P, PI or PID is preferred for your system.
2. Tuning of the controller with classical methods:
   - Design the controller based on the IMC tuning relations and a reasonable choice for $\tau_c$. Design the controller based on online controller tuning methods. Simulate each controller for a change in an unmeasured disturbance and in the set-point. Which one is superior? Justify your answer. Verify the closed loop stability and attempt to obtain improved control system performance by fine-tuning your best controller.
3. Tuning of the controller with genetic algorithm:
   - Design a genetic algorithm for tuning the controller. Generate random population of chromosomes to represent the controller parameters. Define the fitness function and a stopping condition. Create a new population by repeating the selection, crossover and mutation steps until the performance met the requirements set and the stopping condition is satisfied.

4. Design a cascade controller:
   - Define and label the block diagram that includes the inner and outer control loops. Define a set-point for the outer variable and properly tune the controllers.
5. Design a fuzzy controller:
   - Define the linguistic variables and values to describe the inputs and output of your controller. Specify a set of rules to capture your knowledge about how to control the system. If possible, list all possible rules in a tabular representation. Define the membership functions. Implement the fuzzy controller using, first, Mamdani's rule for the implications and the centroid defuzzification. Modify them if necessary. Justify and comment your choices.
6. Compare the controller performances.
   - Test your controllers and compare the performance with your best "conventional" controller developed in Task 2.

## Guidelines

Regardless of your choice of dynamical system, you must generate the following:

- Report/Presentation: You must provide a clear and exhaustive description of the models and their derivation, the associated plot/tables of the simulation results and your comments. In particular, the report should include at least the following sections:
  - Introduction: Here, you provide some context and background. Briefly, explore the literature in order to understand how your chosen system has been controlled. Discuss some application examples (if any) and provide the references.
  - Theoretical background: Here, you describe the general theory needed for setting up your controller. You must provide details on the classical control strategies (defining and explaining the algorithms and tuning rules) and on the fuzzy controller. Also, you must discuss the pros and cons of the different control approaches.
  - Control system design: Here, you focus on your specific system and on the associated control structure. In particular, you must provide the details on the control objectives, on your choice of manipulated and controlled variables and on the control structure as in Task 1. You must provide a detailed description of the controllers tuned in Task 2 and in Task 3. You must provide a detailed description of the configurations and choices for designing the controllers in Task 4 and in Task 5.
  - Controlled system comparison: Here, you compare the different controller tuning strategies and discuss the results achieved in Task 6. In particular, you compare the controllers in terms of their performance for set-point tracking and disturbance rejection. You must critically discuss your results.
  - References: Here, you provide bibliographic references. Report the books and/or articles that you used for defining and analysing the system. Each reference reported in this section must be cited in the main text.

- Code listing: You must provide the executable/functioning code produced to model, simulate and perform the analysis on the system. The code can be packaged together with the report and sent trough SIGAA as a zip file.

The work will be evaluated based on: adherence to the instructions, clear and critical argumentation, formatting and orthography.

The work can be done individually or in pair. You can write your report/present either in English or Portuguese. You can base your work on the resources you might find on the web but you must adequately reference to them. The presentation of the second homework and deadline for submission of the report/presentation is set on June 6, 2024.