HAN_UNIVERSITY OF APPLIED SCIENCES

Applied System Identification

Home Taken Assignment

May 2024

Instructions:

Please read the following instructions before attempting the assignment:

- This assignment consists of 1 problem with 4 sections.
- This assignment should be solved **individually**.
- I trust that all participants want to enjoy solving the given assignment. However, failing to hand in original work will result not only in a <u>Zero</u> grade, but also a discipline from the exam board, as **MES maintains a zero-tolerance policy towards plagiarism.**
- Please consult the instructor "Hatim Mala" if you encounter any problem.
- You can use MATLAB 2020b or a more recent versions.
- The assignment is aimed to test your ability to apply system identification techniques to obtain a satisfactory model for a given case. You will be judged not only by the quality of the models you recommend, but more importantly by the reasoning that led you to those models. Therefore**<u>, at each step, always motivate your choices and show your reasoning.</u>**
- Deliverables: One zipped (*.zip) file containing:
  - 1 MATLAB live script (* .mlx). The live script must contain your code, alongside your analysis and motivations.
  - Datasets in (*. Mat) format.
- **The delivered code should run without errors**, and the order should reflect the order of the questions.
- Please keep in mind that grading these assignments is time-consuming. I don't have time on top of that to debug a faulty code. Make sure everything is readable and clear.
- The deadline for handing the assignment is **June 24th, 2023 @ 23:59**.
- Submit the deliverables via the Hand-in app, under code MBDDC_HTE2

Success!
Hatim Mala

Problem: Identification of a Multivariable Process

Model predictive control (MPC) is an industry accepted technology for advanced control of many processes. In fact, MPC is often considered a standard required solution for many applications. But as you know, an MPC requires a dynamic model in order to calculate the optimal control moves. In this assignment, we shall investigate the identification of an ubiquitous industrial process, the evaporator.

Evaporators are used to reduce the water content of a product, for example, milk. For such an energy-intensive process, the controller is not only tasked with following the set-point, but to do so in an optimal manner. The evaporator process can be modelled as a 3-input and 3-output process with disturbances.

- Input 1: Flow of feed product.
- Input 2: Flow of vapor.
- Input 3: Flow of cooling water.
- Output 1: Dry matter content of the product.
- Output 2: Flow of the outcoming product.
- Output 3: Temperature of the outcoming product.

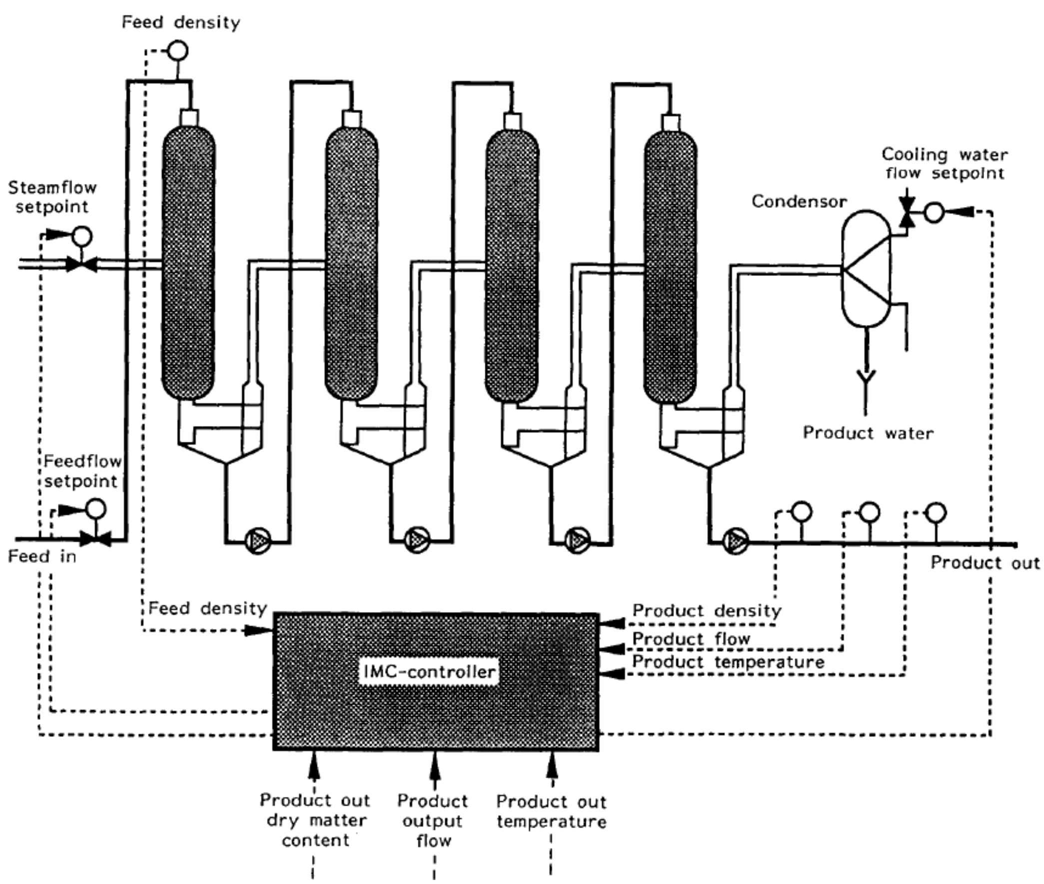

Figure 1: Model Predictive control of Evaporator process [1]

[1] Figure and dataset are courtesy of the Dutch Institute for Dairy Research (NIZO).

1) The dataset is provided with this assignment. The dataset consists of 6 columns. The first 3 are the inputs, and the last 3 are the outputs. The columns are in the order described in the previous section. The dataset is pre-processed (i.e means removed, detrended and normalized).
    a. Import the dataset to MATLAB.
    b. Create an identification data object.
    c. Label the input names and output names.
    d. Plot the dataset.
    e. Split the dataset equally into identification and validation subsets.

2) Impulse response models are usually a good starting point. Although they are useless from a control perspective, they are extremely useful as a first exploration of the dataset, because of what they reveal about the individual input-output relationships.
    a. Estimate an impulse response model.
    b. Plot the step response of the impulse model.
    c. Comment on the 6 plots you obtained in (b). Do they make sense from a physical point of view? This is usually a good verification step on the data before proceeding with identification.

3) Attention! By default, the functions “ssest” and “N4SID” force the feedthrough matrix (Matrix D in the linear state space formulation) to zero. Although this is logical for most processes, we suspect that for this process there may be a presence of feedthrough.
    a. Provide a justification, from the physical description of inputs and outputs, for why we suspect the matrix D in this process can be nonzero.
    b. Confirm this suspicion by identifying 2 continuous-time time state-space models of the same order (One with feedthrough, and one without), and compare the performance of both models in terms of validation data and residuals. What do you conclude?
    (Hint: To force ssest and n4sid functions to include a nonzero D matrix, add the argument:

```
'Feedthrough',1
```

4) Now, the task is to obtain a discrete-time state space model. This model will be implemented as an internal model in an MPC for the evaporator. We start with 3 model “candidates”.
    a. Select 3 model orders as possible candidates. Justify your selections for the orders.
    b. For the 3 model orders you chose in (a). Identify 3 discrete-time state space models.
    c. Validate the models you identified in (b) in terms of 5-step ahead prediction of validation data and residual analysis.
    d. Based on your analysis in (c), which model do you finally select for controller design and implementation? And Why?

End