CL 625 Process Modeling and Identification

Course Project

September 06, 2019

This course project is an important component of the course, wherein you can try out the various concepts and techniques learned in the classroom. You are free to choose the dynamic system which you would like to model or analyze using data-driven techniques. The aim of this note is to help you (1) finalize the process, (2a) discuss the model equations, which will be source of the data OR (2b) gather data directly from an experimental setup or some source so that you are ready to execute this project.

Note that the deadline for uploading the report which explains the process, documents the equations or the data on Moodle is November 03 (Sunday), 2019. The report should consist of the same following:

1. **System:** Provide a description of your system. The plant equations should correspond to a first principles, nonlinear dynamic model of a physical system. The number of inputs and outputs should be at least two and should be guided by the physics of the system and practical aspects (for example one cannot assume measurements of concentration on all plates of a distillation column). Bottom line is system identification is a practitioner's topic and so your plant should realistic.

2. **Simulation:** Use the Matlab command idinput to generate a pseudorandom binary sequence (PRBS) and simulate the continuous time nonlinear model and generate a data-set to be used further for analysis. Make sure that you start your simulations from a steady state.

3. What sampling time would you use? Show analysis of the system to justify your choice.

4. Using “linmod”, generate the continuous and discrete time linearized models. Validate the linearized model using the nonlinear model. Convert the linearized state-space equations thus obtained to transfer function form using the ss2tf command in Matlab. Verify if the transfer function in obtained using Matlab match with the analytical form. Use commands sim, and lsim to obtain the outputs of state space and transfer function models. Also, see commands, c2d, c2dt, d2c

2-4: If you are using data directly, find out methods of data visualization and present these **(visual analytics?)**

5. **Impulse Response:** Find the impulse response and step response coefficients as a solution to the least squares problem. Validate the impulse response and step response models so obtained with the nonlinear plant response.

6. Inject white noise in the output of the process. Use a noise to signal ratio of 1% and 10%. Using these three different datasets identify the impulse response coefficients again and comment on the effect of noise to signal ratio on the point estimates.

7. Inject coloured noise in the output of the process modeled as

$$v(t)=\frac{1}{\left(1-0.95q^{-1}\right)}e(t)$$

With this noise, repeat problem 6. What was the effect of using coloured noise on the point estimates.

8. **Using correlation analysis,** determine the impulse response coefficients for the white noise case with signal to noise ratio of 1% and 5%

9. Repeat Problem 8 for the coloured noise case (see Problem 7) with signal to noise ratio of 1% and 5%

10. **ETFE:** Using the data obtained for the white noise case obtain a ETFE for the system. Repeat for the coloured noise case.

11. Using the data obtained for the white noise case, plot the power spectrum of the input and outputs. Repeat for the coloured noise case.

12. Find a parametric model for an estimation data corrupted with 5% coloured noise, and validate using an independent validation set. Make sure you explore over different model sets, and determine a good model order for the selected model type.

13. **Data:** Generate data by using a PRBS appropriately. Make sure that you have integrated noise in the system (after each Ts, add random noise to the IC) and split data into identification set and validation set. Use a 10% noise to signal ratio.

14. **Batch PEM:** Use the id set to identify an appropriate parametric model. You should be able to show how you finalized the order of the model (AIC, FPE, etc). Also, show residual analysis as well as the frequency response of the candidate structures. Your choice of model structure should follow principal of parsimony and validation on the validation set. Obtain the best "order" of model within the following model structures
(a) ARX; (b) ARMAX; (c) OE; (d) BJ

15. **Batch PEM with filtered Data:** Using an appropriately designed filter, repeat step 3 using the filtered data. Demonstrate the effect of the filter on the models identified.

16. **Parameter Distributions:** Assuming asymptotic conditions, write down the distribution of the parameters estimated and show that the sample variance is greater than the asymptotic variance for each of the four models obtained above. Double the size of the data set and comment on the effect of the number of data points on the distribution.

17. **Recursive Estimation -I:** Assuming the best ARX model structure, use recursive LS to identify model parameters. Show trajectory of estimation of at least two parameters. Compare the RLS value with corresponding batch data value (increasing window) and comment on the difference between batch and recursive estimation.

18. **Recursive Estimation -II:** Assuming the best ARMAX model structure, use recursive MLE to identify model parameters. Show trajectory of estimation of at least two parameters. Compare the RLS value with corresponding batch data value (increasing window) and comment on the difference between batch and recursive estimation.

19. **Instrumental Variable Method:** Repeat step 3 with the IVM. Analyze the results and contrast between IVM and the method used in step 3)

20. **Nonlinear System Identification:** Use any nonlinear model to model the data. Compare the nonlinear model performance with the best linear model.

21. **Identification using closed loop data:** Design a controller and repeat step 3 using closed loop data. Contrast the effect of closed loop data on the identified models relative to open loop data based models obtained in Step 3.

Outline of Project Report:

Section 1: Introduction to the dynamic system. Discuss domain-specific aspects.

Section 2. Objective of the work.

Section 3. Each item in the previous section should be a subsection here, which gives details on how it was implemented, the graphs, equations, etc. giving the results and a discussion on each result. Figures and equations not discussed in the text should not be presented. All figures should be labeled, including their axis and must have a legend, where necessary.

Section 4: Conclusions drawn from the results.