Assignment 3: Identification

Deadline: Tuesday November 18th, 2014 23:59h

Subjects:

Closed loop and multivariable systems	Lect. 6
Identification with periodic input signals	Lect. 7
Detecting Nonlinearities	Lect. 8

Important notes

- Reports handed in after the deadline will not be marked, resulting in a zero.
- Working in teams of (not more than) two students is strongly encouraged.

How to get help

- Always check the *Assignment Guide* on Blackboard for support.
- The command functions *HELP* or *DOC <FUNCTIONNAME>* can be used for instant support to MATLAB functions.
- Assistance hours (see schedule).
- Help each other using the *Discussion Board* on Blackboard.

Report requirements

- Reports should be written in English.
- Each student hands in a report using blackboard. Always provide the name of the partner at the report.
- Always provide explanations in your answers and be precise and concise (providing irrelevant information can negatively influence your mark). Formulate your answer in such a way that you show you understood the question.
- Use figures to illustrate your findings. If possible use the same figure for the results of multiple sub-questions; this allows for easy comparison. When plotting more than one curve in a figure, use legends. Do not forget a caption and the units on the axes. Choose proper axes scales. Unclear Figures and Tables will be excluded from judgment.
- Do not submit MATLAB coding, unless it is clearly stated that you should.
- Put your name (and that of your colleague if applicable), page number, and the assignment number on each page of your report.

Goal

The goal of this assignment is to use the time domain models in the closed loop case, to analyse the contribution of perturbation signals for identification and to get familiar with nonlinearities

Accessories:

ASS3.M
WELCHSPECTRUM.M
MSINPREP.M
MSINCLIP.M
ASS3_SISOOPEN.MDL
ASS3_SISOCLOSED.MDL
ASS3_SISOOPEN_NL.MDL
FAST_NL_ANAL.M
HARMONICCONTENT.M
RSIGNALS.MAT

Question 1: Time domain models in closed loop

Use the closed loop model *ASS3_SISOCLOSED.MDL*. Use white noise (with a variance of 1) as reference signal r(t) to generate output y(t) by running the model for 50 s at 100 Hz. Closed loop time domain model estimation can be done with two different methods:

Two stage method: Estimate the time domain model from r(t) to u(t). Simulate u'(t) using the model, resulting in a 'noiseless' u(t). Estimate the time domain model form u'(t) to y(t) resulting in H_2.

Coprime method: Estimate the time domain models from r(t) to y(t) and from r(t) to u(t) and divide them to estimate H_2.

a) Derive the correct model structure (OE, ARMAX, BJ, etc) for each step of the two stage and coprime method. Hint: $H = \frac{\text{numerator}_H}{\text{denominator}_H} = \frac{N_H}{D_H}$ and $G = \frac{N_G}{D_G}$.

Perform both methods for *ASS3_SISOCLOSED.MDL* (use order 4).

b) Compare the FRF estimated using the two stage and coprime method to the spectral estimator and the true system response by making a Bode diagram. Comment on the results.
c) Give a disadvantage for the two stage method and for the coprime method.

Question 2: Perturbation Signal Design

Virtually any identification problem suffers from noise. This assignment covers some of the strategies on optimizing the input signal to minimize the effect of noise. This is particularly important when there are limitations to the maximum input (or output) amplitude that the system to be identified can handle (e.g. due to safety reasons or range of motion of the perturbed joint). The goal is to design an input signal with the highest possible power, given this limitations. The task is to design three signals and compare these.

All signals:

Sample frequency:	200 Hz
Limitation:	**±1.5** (maximum input amplitude)

Signal A: Colored noise

Filter a Gaussian white noise signal of T=200 seconds with a second order low pass Butterworth filter with a cut-off frequency of 40 Hz.

Signal B: Multisine signal

Generate a multi-sine signal of T=20 seconds with equal power on *all* frequencies in the range [1/T : 40] Hz with random phase using *MSINPREP* (see the Assignment Guide). Use the *repmat* function to create a 200 second signal consisting of 10 periods of the multisine.

Signal C: Crested multisine signal

Generate a signal which is a crested version of signal B (T=20s), use *MSINCLIP* (see the Assignment Guide). Use *repmat* again to create a 200 second signal.

Generate the three signals.

a) Plot the auto-spectral densities of the three signals. Include a table in your report stating for each signal: the maximum amplitude, the standard deviation, the crest factor and the lowest excited frequency. Comment on the differences between the three signals.

Simulate the system *(ASS3_SISOOPEN.MDL)* with each signal. Average the input and output signals using *WELCHSPECTRUM.M* over 10 segments.

b) Plot the auto-spectral density of the three output signals in one figure. Comment on the results of the simulation.
c) Explain why we average over (exactly) 10 segments and how it affects the frequency content.

Estimate the FRF and coherence three times using the three input signals.

d) Show the three estimated FRF's together with the response of the true system in one Bode diagram. Also plot the coherence. Which signal provides the best estimate? Motivate and explain.

Question 3: Detecting Nonlinear Distortions

Almost all systems are nonlinear to some extent. To be able to make a confident (linear) estimation of a system, it is important to investigate the presence of nonlinear distortions.

Open *Ass3_SISOopen_NL.MDL*

a) Why is the dead zone (in the Simulink model) a nonlinear operator?

Set the output noise variance to 0. Load *rSignals.mat*. Simulate the system with the colored noise (*rColNoise*) and the multisine (*rMultiSin*). Average the input and output signals using *WELCHSPECTRUM.M* over 10 segments. Estimate the FRF's and coherences.

b) Plot the Bode diagrams and the coherences in one figure. Describe the effect of the nonlinearity on your estimates for both input signals

Change the noise variance back to default (0.1) and simulate, average and estimate again for the two input signals.

c) Add your estimates to the previous figure. What information can we derive from the coherence? Elaborate on the differences in coherence between the two input signals. Also incorporate the results from the linear system In *Question 2c* in your reasoning.
d) Analyse signal *rFastMethod* in the frequency domain and comment on the characteristics of the frequency content.

Use Ass3.m to detect the nonlinear distortions using the *Fast method*. Vary the size of the dead zone.

e) Describe how to assess the quality of your (linear) estimate.
f) Why can the total standard deviation only be estimated from 0.15 Hz and up?