Assignment 2
Open & Closed Loop Identification

Deadline: Tuesday October 21st, 2014, 23:59h

Subjects:

Sampling and discretization	Lect. 4
Identification of linear systems	Lect. 5
Closed loop and multivariable systems	Lect. 6

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.
- Two hours of assistance by PhD-students (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 understand concepts of frequency response function, coherence, open & closed loop estimation.

Accessories:
ASS2.M
ASS2_SYSTEM_OPEN.MDL
ASS2_SYSTEM_CLOSED.MDL
WELCHSPECTRUM.M

Question 1: Fourier transformation of signals (cont'd)

As in the previous assignment, generate a signal *u(t)* that is the summation of a 3 Hz sine with amplitude 2 and a random signal (RANDN) with zero mean and variance of 1. The signal lasts for 10 seconds with a sample frequency f_s = 1000 Hz. Apply a third order Butterworth filter (BUTTER & FILTER) to *u(t)* with a cutoff frequency of 25 Hz and call the resulting signal $y_{1000}(t)$. Generate $y_{500}(t)$, $y_{250}(t)$ and $y_{100}(t)$ by taking each second, fourth and tenth sample of $y_{1000}(k)$ respectively. This results in sample frequencies of respectively 500Hz, 250 Hz and 100 Hz.

a) Perform a discrete Fourier transformation (DFT) using *FFT* to transform $y_{500}(k)$ into $Y_{1000}(n)$. Present the DFT as magnitudes and phases. Look up the word aliasing with respect to signal analysis and use this to discuss the symmetric and anti-symmetric properties of the Fourier coefficients.
b) Plot the magnitude of $Y_{1000}(n)$, $Y_{500}(n)$, $Y_{250}(n)$ and $Y_{100}(n)$ in one figure. Explain the effect of sample frequency f_s.
c) Take the DFT of the first 5 seconds of $y_{1000}(k)$ and compare the magnitude with the magnitude of full length $Y_{1000}(n)$ in one figure. Explain the effect of observation time *T*.

Question 2: Open Loop Identification

Open the MATLAB-script ASS2.M and run the Simulink model ASS2_SYSTEM_OPEN.MDL to generate the signals *u(t)* (input) and *y(t)* (output). Take a look into the model to see the structure and the additional output noise *n(t)*. Note that this system is the same as used in assignment 1.

a) Given the input signal *u(t)* is white noise, what would the input spectrum $U(\omega)$ and the output spectrum $Y(\omega)$ theoretically look like?
b) How should we estimate SYSTEM *H*, if this system is supposed to be unknown? Prove this starting with $Y(\omega) = H(\omega)U(\omega)+N(\omega)$.
c) Estimate SYSTEM *H* (magnitude, phase & coherence) and compare this with the true system (gain & phase). Use correct frequency axes. Explain what you see.
d) Apply welch averaging at the estimate (question c) using the function WELCHSPECTRUM.M. Try several numbers of segments (vary NSEGMENT). Compare the results with the non-averaged estimate and the true system. What are the effects of averaging for the estimate?
e) Why should you apply averaging methods?

For the next two question only hand in 1 plot containing gain, phase and coherence for the normal (averaged) situation and the situations of questions *f* and *g*.

f) Change the variance of the input signal *u(t) to a high value*. Explain the effect on your estimates for the transfer function and coherence? What would be the theoretically ideal input power (in this case variance of input u) and why is it in most system identification experiments not achievable?
g) Change the input variance back to 0.5. Now change the variance of the noisesignal *n(t)* within SYSTEM *H*. Explain the effect on your estimates for the transfer function and coherence.

Question 3: Closed Loop

Run the Simulink model *ASS2_SYSTEM_CLOSED.MDL* to generate the signals r*(t)* (reference signal), *u(t)* (internal signal) and *y(t)* (output signal). Take a look into the model to see the structure and the additional system output noise *n(t)*. Note that *SYSTEM H* is the same as seen before. For this part of the assignment we use welch averaging with *NSEGMENT* = 30. Set the simulation time *T* to 500s.

a) Simulate the model (variance *r(t)*=1, variance *n(t)*=0.1). Estimate *SYSTEM H* (magnitude, phase & coherence) and plot this together with the true system (gain & phase). Use system input *u(t)* & system output *y(t)* (which is similar to what was done in question 1). Is this open loop estimator a good estimator?
b) Increase the noise variance *n(t).* Check the behavior of the open loop estimator. Which system are you estimating? Generate a clear plot with all necessary lines.
c) What will be the correct spectral estimator for *SYSTEM H* in this closed loop system? Prove.
d) Verify the performance of the closed loop estimator by adding it to the plot of question 3b. Use a noise variance of 2. Explain the differences and similarities between the closed and open loop estimator.