Examination System Identification and Parameter Estimation WB2301

Wednesday June 29, 2005
14.00 - 17.00 hours

Instructions:
The answers to the questions should be written on separate sheets. Write your name and student number on each sheet. You can use all the lecture material that has been handed out during the course. Please answer the questions shortly and precise. The questions can be answered in English or Dutch.

Question 1

a) How can you increase the frequency resolution of a frequency response function (FRF)?
b) What are important issues in choosing a sampling frequency?
c) The same experiment is repeated with an increased sampling frequency of the data acquisition. How does the autospectrum of a signal changes? Show by drawing.
d) What problem might arise using time domain models (ARX, etc) when the sampling frequency is increased.

Question 2

Given a critically damped second order system with an eigenfrequency of 1 rad/s:

$$H = \frac{1}{s^2 + s\sqrt{2} + 1}$$

a) Draw the Bode diagram of this system

The system is excited with a sinusoidal input of 1 rad/s and amplitude of 1.
b) Draw the input and output signals in time in one figure and give values along the axes
c) Draw the real and imaginary part of the Fourier transform of the input signal.
d) Draw the real and imaginary part of the Fourier transform of the output signal.

Question 3

a) Draw a block scheme of an open loop system, H, with input U, output Y, and output noise N. Give the estimator for the FRF of this system.
b) Give two causes of bias of the estimator. How can bias be minimized and what are the implications of the solution?
c) What is the cause of variance of the estimator? How can variance be minimized and what is the implication of the solution?
d) Give the estimator for the coherence function. What causes bias in this expression? What does the coherence function mean?
e) The coherence function and the VAF (Variance-Accounted-For) give both information about the relationship of input and output signals. What is the relation between the coherence and the VAF?
f) Which of the following factors have an effect on either the coherence, on the VAF or on both: i) measurement noise, ii) time-variant system behavior, iii) model errors and iv) system nonlinearities.

Question 4

Given the model described in Figure 1.

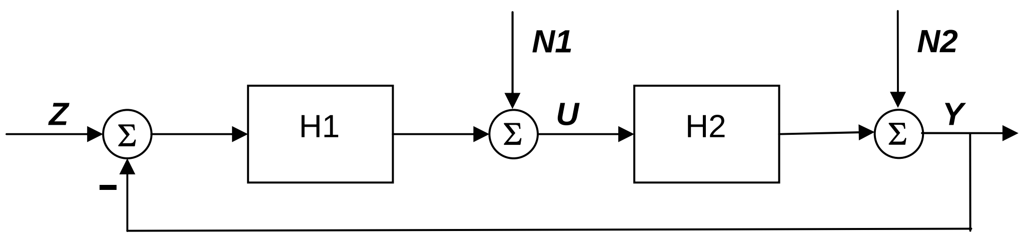

Figure 1: Closed loop configuration of two linear systems H1 and H2. ***Z***: external input; ***U***: measured output of H1, ***Y***: measured output of H2, ***N1***: output noise H1, ***N2***: output noise H2.

a) How can you estimate H2 correctly?
b) Now assume that the external input signal Z is not available from measurements. Can you still use the estimator of a)? How would you estimate H2 and what are the emerging problems?
c) What is the influence of both noise amplitudes on the chosen estimator of b)
d) Under what conditions are the estimators of a) and b) unbiased given that the observation time goes to infinite?
e) Give the closed loop spectral estimator for H1.

<u>Question 5</u>

In Figure 2 a general scheme is shown of the neuromuscular controller of the human limb. This scheme is often used for analyzing the control properties of the central nervous system during human posture tasks. All subsystems are assumed to be linear.

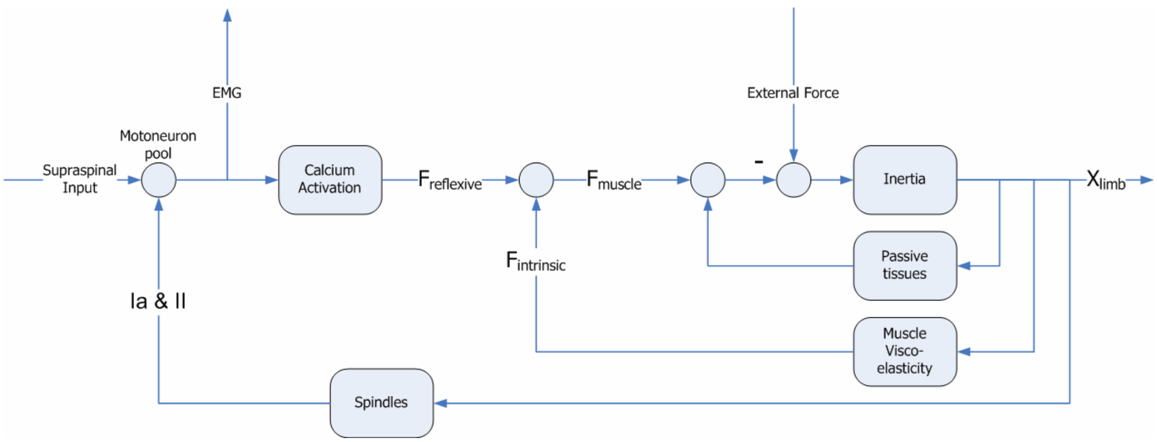

Figure 2: Control scheme of the human arm in conjunction with an environment. See text for explanation of subsystems and symbols.

The external supraspinal input is a control command from higher brain centres and can be assumed as constant. The model consists of two functionally different parts: i) the intrinsic musculoskeletal properties comprising limb inertia, passive joint tissues and muscle visco-elasticity, and ii) the reflexive feedback from muscle spindles projecting onto the motor neurons (Ia and II afferents) in the spinal cord (thus only the spindles block).

The motor neurons are represented by a simple summation. The muscle force results from the muscle visco-elasticity ($F_{intrinsic}$) and additional reflexive contribution ($F_{reflexive}$) via activation dynamics. Both contributions are important for posture maintenance and act together. By experiment and subsequent analysis both parts are to be separated.

a) Can the FRF of the intrinsic part be estimated if only the **external force** and the limb position ($\mathbf{X_{limb}}$) are available from measurements? Explain.

b) Can the FRF of the reflexive part be estimated when **EMG** is also available? Explain.

c) Give the expressions for the estimators of the FRFs for the reflexive part and for the total limb admittance (from **external force** to $\mathbf{X_{limb}}$).

d) Now assume that there is noise entering the system due to voluntary supraspinal steering that is uncorrelated with the external force. What discrete time domain model (ARX, etc.) is best suited to describe the spindle dynamics under this noise condition?

Question 6

a) How would you estimate *all* model parameters of the model given in Question 5 from estimated FRFs? Describe and motivate the chosen method and give the criterion function(s).

b) Which quantitative measures can be used to determine the quality of the parameter fit?

Question 7

The time varying (TV) properties of the human elbow are to be estimated during a cyclic movement, let say during voluntary tracking of a sinusoidal reference trajectory of 0.25 Hz. Give the procedure to quantify the TV mass-damper-stiffness properties of the elbow. You may ignore any nonlinear behavior. Describe the main steps of your strategy concisely including perturbation type, models, basis functions and physical parameter estimation.

Question 8

a) Give two advantages for using discrete time domain models (ARX, etc) instead of spectral models (FRFs)

b) Give two disadvantages

c) Why is OE much slower in finding a solution compared to ARX? Explain using equations.

Question 9

In the first stage of an identification procedure, the following FRFs were obtained for four different systems. What can you say about the properties of these systems? Which one(s) is (are) anticausal?