FRTN15 Predictive Control—Home Work 2
Model Reference Adaptive Systems

An Adaptive Regulator

In this homework exercise we consider position control of a DC-servo using an indirect self tuning regulator. We use Simulink to simulate and investigate the behavior of the adaptive control system. The process considered is the same as in Laboratory Exercise 1. It is therefore advisable to use this exercise as part of the preparation for the first laboratory exercise. You can solve the problems independently or in groups of two. The exercise consists of two parts. In the first part, you shall design an indirect self-tuning regulator, and in the second part, you shall examine the behavior of the regulator using Simulink. Recommended reading is Ch. 9 in *Predictive and Adaptive Control* by R. Johansson and Ch. 3 in *Adaptive Control, Second Edition* by K. J. Åström and B. Wittenmark.

A detailed description of the design, as well as documentation of the simulations should be handed in as part of the examination.

Theoretical Exercises: Design an indirect, discrete time self-tuning regulator for the process

$$G(s) = \frac{b}{s(s+a)} \tag{1}$$

where the parameters a and b are considered as unknown. Use the values $a = 0.12$ and $b = 11.2$ in the simulations. For the estimator design we assume that only the order of the numerator polynomial and denominator polynomial of $G(s)$ are known, and not the specific structure. The desired closed-loop response is given by

$$G_m(s) = \frac{\omega_m^2}{s^2 + 2\zeta\omega_m s + \omega_m^2} \tag{2}$$

with $\omega_m = 1$ and $\zeta_m = 0.7$.

It is not possible to meet the specification without cancelling a poorly damped zero in the sampled process, why? Modify the sampled equivalent of $G_m(s)$ to avoid zero-cancellation.

Make the controller design without integral action, and with the observer polynomial chosen as

$$A^o(s) = (s + a_1^o)^\gamma \tag{3}$$

where $a_1^o = 3$. Pick the integer γ as low as possible. You should also determine an appropriate sampling period h.

Get started with Simulink

- Start an xterm window;
- Change the directory to the directory you will work in;
- Download the file homework2.zip from
  - http://www.control.lth.se/course/FRTN15/HomeWork/HW2.zip

using your internet browser to the directory you will work in, and unzip it (unzip HW2.zip);

- Start Matlab and execute oldboxes.

The downloaded file contains a Simulink library for simulation of adaptive controllers and an example of a simulation model for a control loop. The example contains some useful blocks that you will need to simulate your adaptive controller.

Write example at the Matlab prompt to open the example, study the example and make sure you understand what the different blocks do before you continue. The parameters of each block is set by double clicking on the block and then entering the desired values in the dialog.

A simulation is started by choosing *Simulation*/*Start* in the menu or by pressing Control+t. The simulation time and other parameters are set by choosing Simulation/Parameters in the menu. If the simulation is paused select Simulation/Continue to continue the simulation, when the simulation is paused it is possible to change parameters in the model. The adaptive control library is opened by writing adaptlib at the Matlab prompt.

To build your own simulation model first write simulink at the Matlab prompt to open the Simulink model library, the select *File*/*New*/*Model* in the menu to open a empty model if you don't have one. The different model groups in Simulink are opened by double clicking on their block. Now you can drag blocks from the libraries to your model. Connections are made by clicking and holding the button down on the input you want to connect and move the pointer to the output or connection you want to connect it to and release the button.

Simulation model: Build a Simulation model to simulate your adaptive controller using the adaptive control library adaptlib. Build it in the same way as the example with disturbances acting on the input and output.

Initial conditions: Simulate the model without noise or load disturbances and with a square wave reference signal with frequency 0.1 Hz. Investigate the influence of the initial conditions of the parameters and covariance matrix.

Process variations: Simulate the model as before but pause the simulation using the pause block and change the process parameters and continue the simulation. Does the self tuner adapt to the new process? Investigate the influence of different values of the forgetting factor.

Noise: Simulate the model with noise. How does the forgetting factor affect the estimated parameters? What kind of filter is suitable to minimize the effect of the noise without affecting the convergence of the parameters? Try different filters.

Load disturbances: Add a load disturbance at the process input. Simulate the model and try to explain the behavior. Can any filter be used to minimize the influence on the estimator? Modify the control design to achieve better performance.