Predictive Control - Homework 2

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In this homework we consider position control of a DC-servo using an indirect self tuning regulator. We use Simulink to simulate and investigate the behaviour of the adaptive control system. The process considered is the same as in Laboratory Exercise 2. 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 will examine the behaviour 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.

To pass the homework exercise, you must hand in a detailed description of the design, as well as documentation of the simulations. The report should be no more than 5 pages, and must be sent by mail to `marcus.greiff@control.lth.se`

1. In this exercise, we will work on the design of an STR for the process

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

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 $G_p(s)$ are known, and not the specific structure.

a. 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 $\zeta_m = 0.7$, but in order to implement the self-tuning regulator, we need to discretise the transfer functions. To this end, determine an appropriate sampling period h and discretise the reference model $G_m(s)$.

b. Consider a design without integral action, and an observer polynomial as

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

where $a_1^o = 3$. Pick the integer γ as low as possible. Which degrees should we have in the $R(z)$, $S(z)$ and $T(z)$ polynomials with a minimal-degree design?

c. For the considered regulator, what should the linear regression model be in the RLS estimator? How should we compute the coefficients for the $R(z)$, $S(z)$ and $T(z)$ polynomials?

2. Download the files for Homework 2 from the course homepage. This zipped directory includes an `adaptlib` library with various controllers and parameter estimators. To build your own simulation model, create a new Simulink model and drag the different blocks from the `adaptlib` library to your model. To implement both load disturbances and noise acting on the process output, the signal routing block used in Computer Exercise 1 may potentially be of use.

a. *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.

b. *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.

c. *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.

d. *Load disturbances:* Add a load disturbance at the process input. Simulate the model and try to explain the behaviour. Modify the control design to achieve integral action and comment on the resulting performance.