CA1 mini-project for EE6104 Adaptive Control course

It is desired to design a control system for a continuous-time system (the plant) which is known to have the following structure:

$$\frac{Y(s)}{U(s)} = \frac{b_0 s + b_1}{(s^2 + a_1 s + a_2)} \tag{1}$$

where $Y(s)$ and $U(s)$ are the Laplace transforms of the time domain signals $y(t)$ (the plant output) and $u(t)$ (the input to the plant). In the physical setup, only $y(t)$ and $u(t)$ are measurable. The exact values of the transfer function coefficients are not known; it is only known that b_0 is a negative number, and that the plant has no zeros in the right-half of the s-plane.

(**Note:** In the simulation experiments required later, the plant is to be simulated as

$$\frac{Y(s)}{U(s)} = \frac{-0.5s - 1}{(s^2 + 0.22s + 6.1)} \tag{2}$$

This information is to be used for simulation of the plant only; the design of the controller may not explicitly use this knowledge.)

(a) Write down the continuous-time algorithm for an adaptive controller for the given plant which meets the following specifications:

- the asymptotic closed loop attained should be reasonably fast and have no steady-state offset for step changes in setpoint command signals;
- the design should be one that ensures boundedness of $y(t)$ and $u(t)$ in the adaptation process.

You are told that simple tests conducted on the open loop plant have indicated that the plant is stable, very lightly damped, and has natural frequency of approximately 2 rad/s.

(b) Using *any* programming language, run simulations to show the performance of your adaptive controller when the reference signal $r(t)$ is a square wave of an *appropriately chosen* period. Show plots of the output of the plant $y(t)$ and the output of the reference model $y_m(t)$. Show also some representative plots of the adapted controller gains, comparing these with the exact controller gains. (Note that as this is a simulation project with a simulated plant, the necessary exact controller gains can be calculated for the comparison.)

Discuss your choice of the observer polynomial (denoted as $T(p)$ in the class notes). Discuss *carefully* the simulation results that you observe.

(c) Investigate the effects of different choices of the observer polynomial (denoted as $T(p)$ in the class notes).

(d) For a particular choice of $T(p)$ which you consider *best* in some sense, investigate the specific case where the reference signal is the single sinusoid:

$$r(t) = 10\sin(0.5t)$$

Discuss the simulation results you observe for this specific case, noting especially the output tracking error and the adapted controller gains.

Compare this case of the single sinusoid reference signal with the cases where: (i) the reference signal is a square wave of comparable period and amplitude; and (ii) the reference signal is a sum of *five* or more sinusoidal signals of different but comparable periods, with a comparable overall amplitude. Discuss your observations.

(e) Run additional simulations to investigate the performance of your adaptive controller when the plant is initially given by (2), but for $t \geq 100$, the plant parameters change so that the plant is then given by

$$\frac{Y(s)}{U(s)} = \frac{-2s-5}{(s^2+20.4s+6.4)} \tag{3}$$

Include all suitable plots in your report, and discuss your observations.

(f) Include all your program code, which should be properly commented, in your report.