UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2004/2005

October 2004

EEE 550 – ADVANCED CONTROL SYSTEM

Time : 3 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **SEVEN (7)** printed pages including Appendices (1 page) and **SIX (6)** questions before answering.

Answer **FIVE (5)** questions.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

1. A plant for a control system is modeled by:

$$y(k) = -a\,y(k-1) + b\,u(k-1) + c\xi(k-1) + \xi(k)$$

where $u(k)$ and $y(k)$ are the input and output of the plant respectively. $\xi(t)$ is a white noise sequence. Using the data in Table 1 estimate:

(a) a and b using LS algorithm. (30%)

(b) a, b and c using extended exponentially weighted recursive least squares algorithm. Set the initial values of $\mathbf{P} = 100\mathbf{I}$, $\lambda = 0.95$ and others to 0. (70%)

Table 1

k	1	2	3	4
u(*k*)	-1.67	0.13	0.29	-1.15
y(*k*)	-0.44	-1.97	-1.25	-0.55

2. Pulse transfer function for sampling time of 0.2s of a continuous plant is given as:

$$G(z) = \frac{0.1z \ +0.03}{z^2 - 1.2z \ +0.25}$$

The controller structure is selected to be as follows,

$$\mathrm{r_0 u(k) + r_1 u(k-1) = t_0 u_c(k) - s_0 y(k) - s_1 y(k-1)}$$

where u, u_c and y are the control signal, command signal and output signal respectively. If the model is selected such that $A_m = z^2 - 1.0z + 0.15$ and B_m to give unity steady-state output for unit step input, design a controller based on the above structure using direct STR algorithm where all r's and s's parameters are estimated and t is calculated. Show your calculation for one sample only and take u as unit step. Show all your design steps and state all your assumptions. Set the initial values as follows, $d_0 = 1$, $r_0 = 0.1$; $r_1 = 0.01$; $s_0 = 0.1$; $s_1 = -0.1$; and the rest refer to Table 2.

Table 2

k	1	2
$u_c(k)$	1	1
$u(k)$	1.27	1.04
$y(k)$	0.13	0.32
$y_m(k)$	0.15	0.3

(100%)

3. A Model Reference Adaptive System (MRAS) is selected to have the following structure:

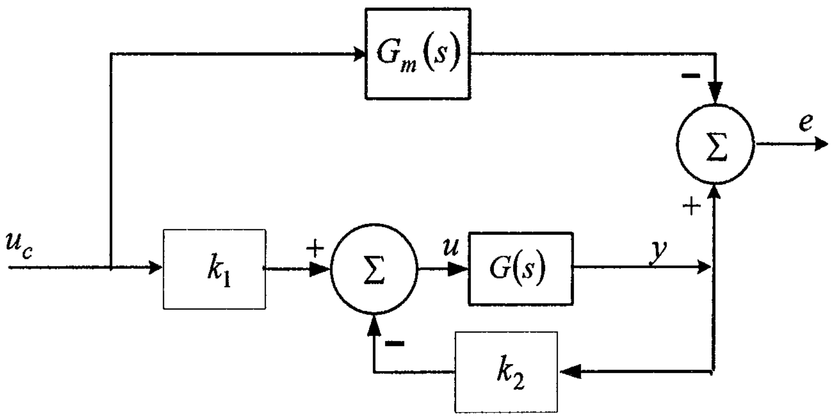

Figure 1

It is desired to adjust k_1 and k_2 such that the output of the plant $G(s)$ will follow the output of the model $G_m(s)$. If the transfer functions of the plant and model are given as:

$$G(s)=\frac{0.5}{s+1} \text{ and } G_m(s)=\frac{2}{s+2},$$

(a) Calculate the exact model following values of k_1 and k_2. (25%)

(b) Design a MRAS controller to update k_1 and k_2 based on Lyapunov approach by assigning $\gamma=1$. Show all your design steps and state all your assumptions. (50%)

(c) Draw the complete block diagram of the MRAS based on your design in (b).

(25%)

4. (a) Discuss the two distinct views of auto-tuning controllers. (20%)

(b) By using a suitable diagram, discuss the principle of model-based explicit auto-tuning controllers.

(20%)

(c) Consider a proportional controller of gain K with a plant as shown in Figure 4(a).

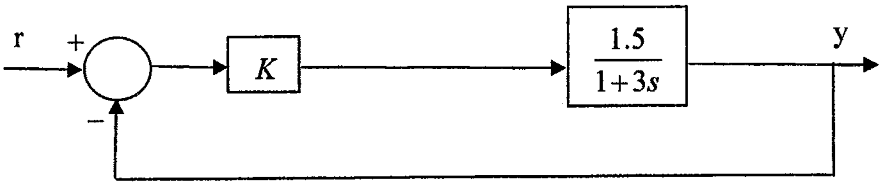

Figure 4(a)

Determine the required controller gain K if the closed-loop response is to be a first-order lag with time constant 1 second.

(20%)

(d) Consider the system shown in Figure 4(b).

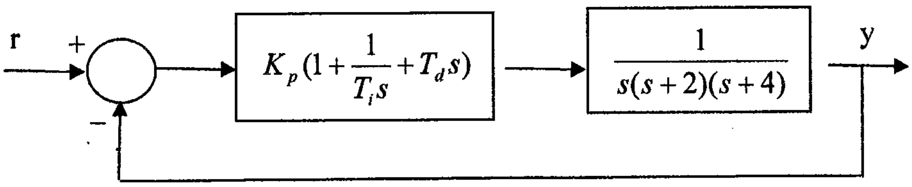

Figure 4(b)

Using a suitable Ziegler-Nichols tuning rule, determine

(i) the values of K_p, T_i, and T_d (20%)

(ii) the location of the double zeros of the controller (10%)

(iii) the closed-loop transfer function of the overall system (10%)

5. (a) (i) Discuss the idea of gain scheduling in relation to adaptive control.
(10%)

(ii) By using a suitable diagram, explain the principle of gain scheduling.
(15%)

(iii) What are the advantages and problems associated with gain scheduling in adaptive control
(15%)

(b) Assume that the ship steering dynamics can be approximated by the Nomoto model and that a PD controller is used, as shown in Figure 5(a).

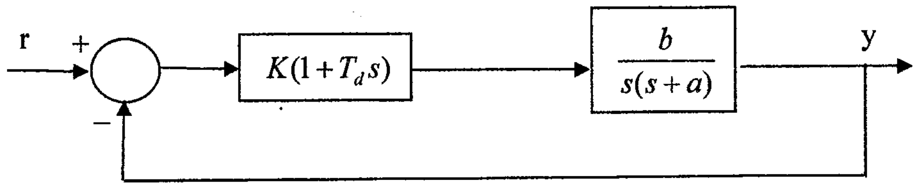

Figure 5(a)

Assume that the Nomoto model has the values a_{nom} and b_{nom} at the nominal speed u_{nom}, and $a = a_{nom}\frac{u}{u_{nom}}$ and $b = b_{nom}\left(\frac{u}{u_{nom}}\right)^2$, where u is the actual constant velocity of the ship.

(i) obtain the characteristic equation of the closed-loop system

(15%)

(ii) determine ω_n (natural frequency) and ζ (damping ratio) in terms of K, T_d, a_{nom}, and b_{nom}

(30%)

(iii) discuss how gain scheduling could be applied in the above system

(15%)

6. (a) By using an example, discuss how linearization of nonlinear actuators could be applied to design a gain scheduling controller.

(20%)

(b) Explain the difference between fuzzy logic control and conventional control methods. Give an example.

(20%)

(c) Figure 6(a) depicts a simple fuzzy logic-based temperature control system. The output of the fuzzy inference engine is HEAT, COOL, or NO CHANGE.