UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2007/2008

October/November 2007

EEE 550 – ADVANCED CONTROL SYSTEMS

Duration: 3 hours

Please check that this examination paper consists of SEVEN pages of printed material before you begin the examination.

This paper contains SIX questions.

Instructions: Answer **FIVE (5)** questions.

Answer to any question must start on a new page.

Distribution of marks for each question is given accordingly

All questions must be answered in English.

1. (a) What is a Model Reference Adaptive System (MRAS) or Model Reference Adaptive Control (MRAC)? Use relevant diagram to illustrate this control approach. Describe the use of MIT rule in MRAC system.

(20 marks)

(b) Consider a system given by:

$$G(s) = \frac{k}{s(s-a)}$$

where a and k are unknown parameters. The desired performance is given in the form of a model:

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

To achieve this an RST controller will be used. This controller has the form:

$$(s + r_1)U(s) = (t_0 s + t_1)U_c(s) - (s_0 s + s_1)Y(s)$$

(i) Since the process parameters are unknown we will use a model reference adaptive system (MRAS) designed with the MIT rule. Draw a block diagram of this system, and write down the MIT rule when the cost function to be minimised is:

$$J = \frac{1}{2}e^2$$

(40 marks)

(ii) Use the MIT rule to derive update laws for the controller parameters.

(40 marks)

2. Consider the stable process

$$y_{k+2} + a y_{k+1} = b u_k + e_{k+2}$$

where a and b are unknown parameters, $|a| < 1$, and $\{e_k\}$ is a sequence of independent white noise. Design an indirect minimum variance controller (MVC) for this process

(100 marks)

3. (a) Consider the nonlinear model:

$$y(t) + a_1 y(t-1) = b_1 u(t-1) + b_2 u(t-1) y(t-1)$$

Find a linear regression model for estimation of the parameters a_1, b_1 and b_2.

(20 marks)

(b) It is desired to use this regression model to perform online identification of the parameters. In addition, it is known that the parameters may be slowly time-varying.

Write down an appropriate algorithm for this estimation task, and explain its operation.

(30 marks)

(c) An indirect adaptive controller is to be constructed, using the estimation method from above. Design a control law, incorporating the reference signal $u_c(t)$, such that the closed loop system has the transfer function:

$$Y(z) = \frac{b_0}{z + a_0} U_c(z)$$

where $1 > a_0 > -1$. The controller may be nonlinear.

(50 marks)

4. (a) (i) Discuss the two different views on using auto-tuning controllers.

(20%)

(ii) Discuss the principle of model-based explicit auto-tuning controllers.

(20%)

(b) (i) Assume that a system involves neither integrator(s) nor dominant complex-conjugate poles. Explain the detailed procedure for tuning the PID controller using the Ziegler and Nichols method. Give suitable graphs and an example to clarify your question.

(20%)

(ii) Figure Q4 shows the block diagram of a plant with a PID controller. The Ziegler and Nichols method is to be used for tuning the PID controller.

(i) Determine the value of K_p so that the system will exhibit sustained ocsillation. (10%)

(ii) What is the frequency of the sustained ocsillation. (10%)

(iii) What is the period of a sustained ocsillation. (10%)

(iv) Suggest the suitable K_p, T_i, and T_d. (10%)

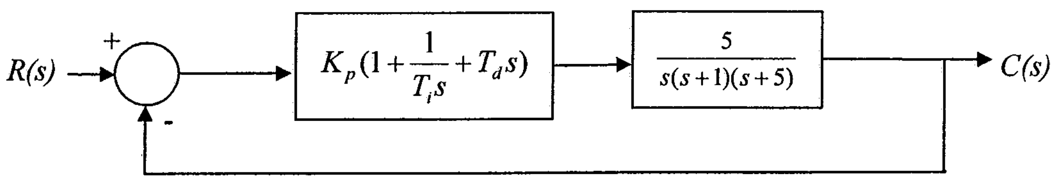

Figure Q4

5. (a) (i) Explain a modification to the PID controller that is cater for practical implementation.

(15%)

(ii) Explain the controller wind-up problem in a PID control system.

(15%)

(b) (i) Explain the principle of gain scheduling in the area of adaptive control.

(15%)

(ii) Give an example of using a gain-scheduling controller to tackle the problem of sheep steering. State what is the auxilliary variable used, and how to design the gain-scheduling controller.

(15%)

(c) Assume that a PI controller is used to control a water tank system, as shown in Figure Q5. The cross section of the tank is *A*, which varies with height *h*. Assume that flow q_{in} is the input and h is the output of the system. The linearised model at an operating point, q_{in}^o and h^o, is given by the transfer function.

$$G(s) = \frac{\beta}{s+\alpha}, \text{ where } \beta = \frac{1}{A(h^o)} \text{ and } \alpha = \frac{q_{in}^o}{2A(h^o)h^o} = \frac{a\sqrt{2gh^o}}{2A(h^o)h^o}$$

where *a* is the cross section of the outlet pipe and *g* the gravitational force.

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

(10%)

(ii) determine K and T_i in terms of ω_n (natural frequency), ζ (damping ratio), α, and β.

(10%)

(iii) discuss how gain scheduling can be applied in the system.

(10%)

(iv) suggest an assumption to simplify the gain schedule, and determine the simplified the gain schedule and discuss the implication.

(10%)

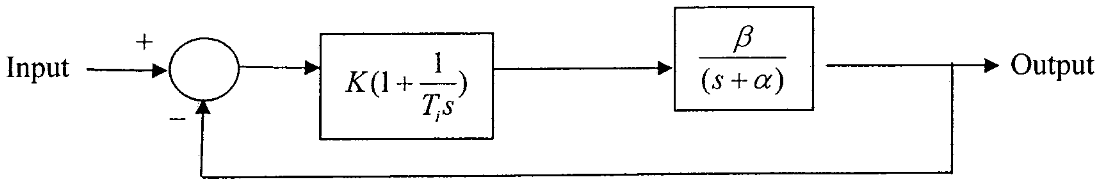

Figure Q5

6. (a) By using suitable diagrams, explain the phenomenon of computational delay in a digital control system.

(15%)

(b) Explain how to minimise the effects of computational delay when designing a digital controller.

(15%)

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

(20%)

(d) Figure Q6 depicts a simple fuzzy logic-based temperature control system. The output of the fuzzy inference engine is HEAT, COOL, or NO CHANGE.

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