
UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2007/2008

October/November 2007

EEE 550 – ADVANCED CONTROL SYSTEMS

Time : 3 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **SEVEN (7)** printed pages 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) 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:

$$(s + r_1)U(s) = (t_0s + t_1)U_c(s) - (s_0s + s_1)Y(s)$$

- (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

$$y_{k+2} + ay_{k+1} = bu_k + e_{k+2}$$

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:

$$y(t) + a_1y(t-1) = b_1u(t-1) + b_2u(t-1)y(t-1)$$

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)

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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 oscillation. (10%)
- (ii) What is the frequency of the sustained oscillation. (10%)
- (iii) What is the period of a sustained oscillation. (10%)
- (iv) Suggest the suitable K_p , T_i , and T_d . (10%)

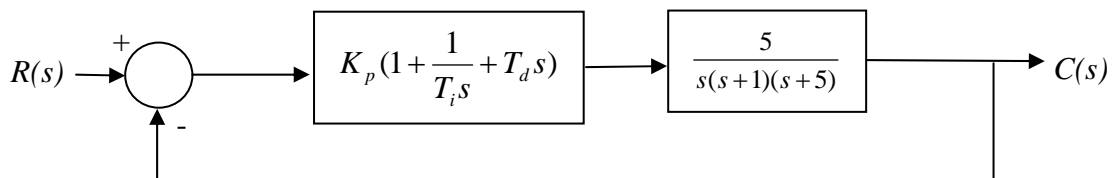


Figure Q4

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%)

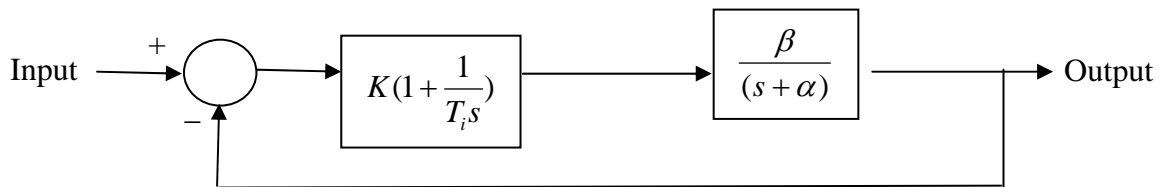


Figure Q5

- 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.

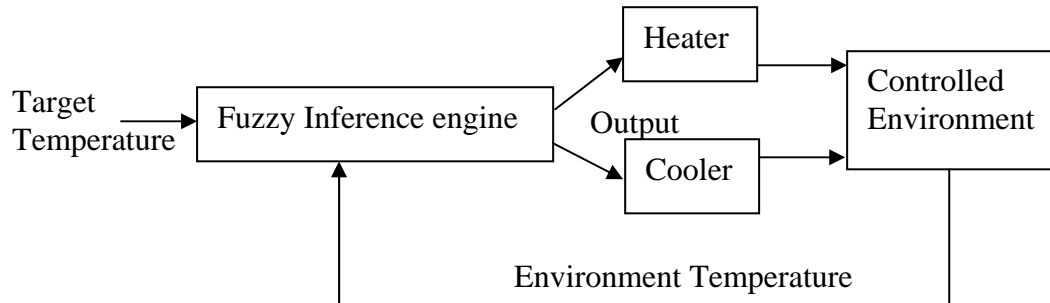


Figure Q6

- (i) Suggest two input parameters to the fuzzy inference engine, and justify your choice. (10%)

- (ii) Design a 3x3 rule matrix and propose a set of rules for the fuzzy inference engine. (20%)

- (iii) Based on (i) and (ii), explain how the fuzzy logic-based controller works. (20%)