UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2005/2006

November 2005

EEE 550 – ADVANCED CONTROL SYSTEMS

Time : 3 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **TEN (10)** 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.

...2/-

1. (a) Consider a system of the form $y = f(u)$ between three points whose cartesian (u, y) coordinates are $(5,3.5)$, $(7,4.7)$, and $(9,5.8)$, and assume that these coordinates correspond to measurements at times $t = 1,2,3$ respectively.

(i) Use the least squares algorithm and a linear model to fit the data.

(i) Calculate the estimated coefficient of the model
(ii) Calculate the modelling error
(iii) Calculate the sum-of-squares error of the residuals

(30%)

(ii) Repeat the questions in (i) with the use of a quadratic model.

(30%)

(iii) Based on the sum-of-squares errors from (i) and (ii), comment on the suitability of the models used.

(10%)

(b) To be useful in self-tuning control systems, the parameter estimation scheme should be iterative, allowing the estimated model of the system to be updated at each sample interval as new data become available.

By using a suitable diagram, explain how recursive estimation as an *iterative* process can be implemented in a control system.

(30%)

2. (a) (i) By using a suitable diagram, explain the important components in a self-tuning pole assignment system

(20%)

...3/-

(ii) The main requirements in a self-tuning pole assignment system comprise the performance requirements and configuration requirements. Explain two criteria each in the performance requirements and configuration requirements.

(20%)

(b) With reference to Figure Q2, consider a process with a discrete time model given by

$$y(t)=\frac{z^{-1}b}{1-az^{-1}}u(t)$$

and the controller structure given by

$$u(t)=-gy(t)+hr(t)$$

(i) Obtain the transfer function in terms of $y(t)$ and $r(t-1)$ of the overall system

(10%)

(ii) Suppose that a single closed loop pole at $z=t_1$ is required. From (i), what is the controller gain, *g*, in terms of *a*, *b*, and t_1?

(20%)

(iii) Following (ii), suppose that another control objective is to ensure that the output $y(t)$ equals the reference input $r(t)$ at steady state. What should be the setting of the controller parameter, *h*, in terms of *b* and t_1?

(30%)

...4/-

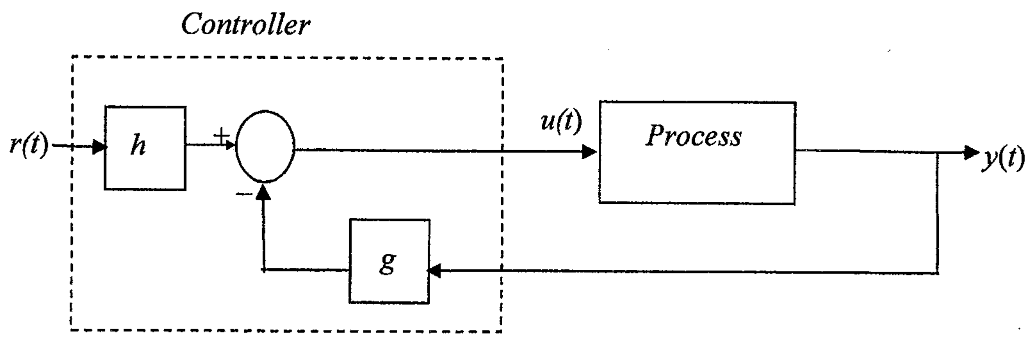

Figure Q2

3. (a) With reference to control systems, explain what is

(i) a regulator problem

(ii) a servo problem

(20%)

(b) What is the MIT rule in relation to Model Reference Adaptive System (MRAS)? Use an example to clarify the MIT rule.

(30%)

(c) With reference to Figure Q3, it is assumed that the process is linear with the transfer function $kG(s)$, where $G(s)$ is known and k is an unknown parameter. It is required to find a feedforward gain controller that gives a system with the transfer function $k_0G(s)$, where k_0 is a given constant.

...5/-

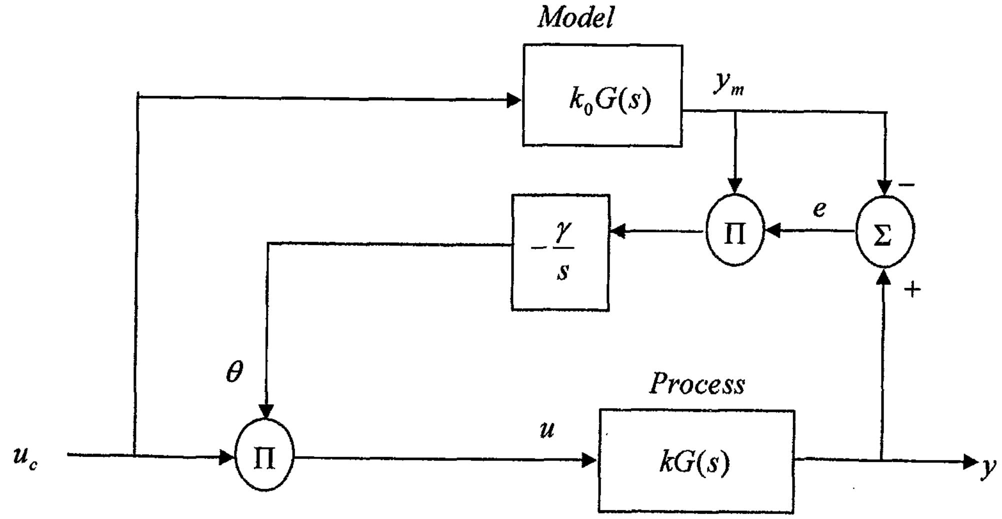

Figure Q3

By applying the MIT rule,

(i) find the error signal, e, and the sensitivity derivative, $\frac{\partial e}{\partial \theta}$ (25%)

(ii) find the adaptation law, $\frac{d\theta}{dt}$ (25%)

4. (a) One of the methods for tuning the PID (Proportional-Integral-Derivative) controllers suggested by Ziegler and Nichols is based on the closed-loop approach with sustained oscillation. Explain how to apply the method for tuning the three terms of the PID controller. Give suitable graphs and an example to clarify your question.

What are the transfer function and the locations of pole and zero of the PID controller tuned using the above method? What is the constraint of the method?

(40%)

...6/-

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

(i) Determine the value of K_p so that the system will exhibit sustained oscillation?

(20%)

(ii) What are the frequency and period of the sustained oscillation?

(20%)

(iii) Suggest the suitable values for K_p, T_i, and T_d. (20%)

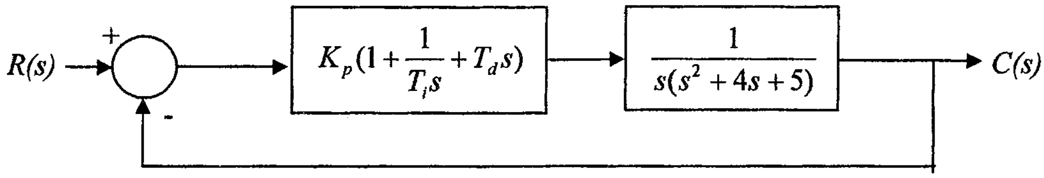

Figure Q4

5. (a) (i) By using a suitable diagram, explain the principle of gain scheduling in adaptive control.

(15%)

(ii) Give an example to illustrate how static nonlinearities can be compensated in a system, and discuss the implication in relation to gain scheduling control.

(25%)

...7/-

(b) Consider a tank in which the cross section A varies with height h. Let the flow q_{in} be the input and h be the output of the system.

The linearized 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 acceleration.

Assume that a PI controller is used to control the system, as shown in Figure Q5.

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

(15%)

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

(15%)

(iii) Discuss how gain scheduling can be applied to the system.

(15%)

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

(15%)

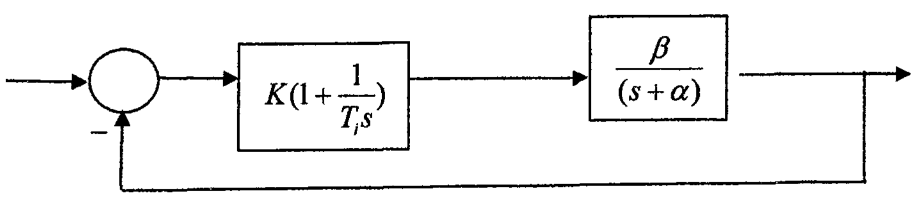

Figure Q5

...8/-

6. (a) Discuss three features of fuzzy logic that make it a particularly good choice for many control problems.

(15%)

(b) Explain the general procedures/steps involved in using fuzzy logic for controlling a system.

(25%)

(c) A fuzzy controller is to be designed to perform the task of parking a car at a designated parking lot. Figure Q6 shows a simulated car and the parking lot. The three state variables ϕ, x, and y determines the car position. Variable ϕ specifies the angle of the car with the horizontal line. The coordinate pair (x, y) specifies the position of the rear centre of the car in the plane.

The goal is to make the car arrive at the parking lot at a right angle ϕ_f, and to align the position (x, y) of the car with the desired parking lot (x_f, y_f).

The parking zone corresponds to the plane [0, 100]x[0,100], and (x_f, y_f) equals (50, 100)

The output variable is the steering-angle signal, θ.

...9/-

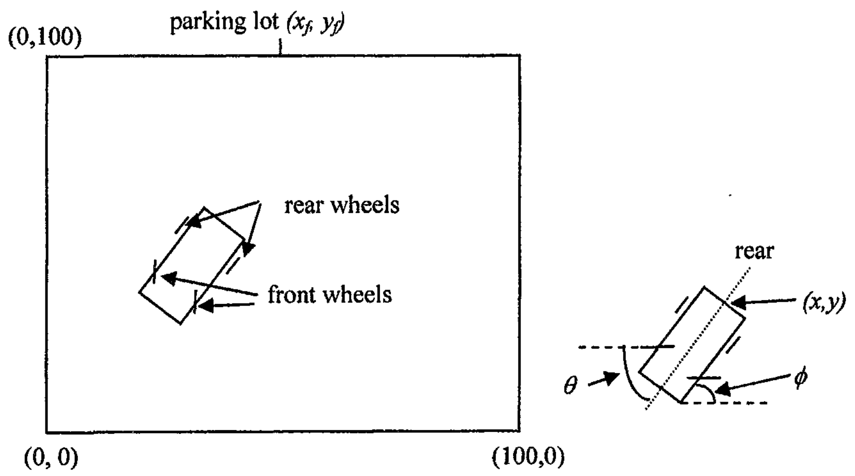

Figure Q6

Assume that enough space clearance between the car and the parking lot so that the *y*-position coordinate can be ignored, resulting in a two-input one-output system. The variable ranges are as follows.

Position *x* (Input 1):	$0 \le x \le 100$
Angle ϕ (Input 2):	$-90 \le \phi \le 270$
Steering-angle θ (Output):	$-30 \le \theta \le 30$

The fuzzy membership functions of the inputs are:
position-*x*: LE: Left, LC: Left Centre, CE: Centre, RC:Right Centre, and RI: Right;
angle ϕ: RB: Right Below, RU: Right Upper, RV: Right Verticle, VE: Verticle, LV: Left Vertical, LU: Left Upper, and LB: Left Below.

The fuzzy membership functions for the output are:
steering-angle θ: NB: Negative Big, NM: Negative Medium, NS: Negative Small, ZE: Zero, PS: Positive Small, PM: Positive Medium, and PB: Positive Big.

...10/-