UNIVERSITI SAINS MALAYSIA

Semester I Examination

Academic Session 2008/2009

November 2008

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) Define what is an adaptive control technique? Provide your answers with suitable diagrams.

(10%)

(b) Explain the Model Reference Adaptive Control (MRAC) approach and the MIT Rule in deriving a suitable control law.

(30%)

(c) Find the control law for the following control problem:

We consider a linear process with the transfer function kG(s), where G(s) is known and k is an unknown parameter. Find a feedforward controller that gives a system with the transfer function $G_m(s) = k_0G(s)$ where k_0 is a given constant. Use the controller structure

$$u = \theta u_c$$

where u is the control signal and u_c the command signal. Use the MIT rule to update the parameter q , and draw a block diagram of the resulting adaptive system.

(60%)

2. (a) Explain what are the Recursive Least Square (RLS) Technique and the purpose of using this RLS technique in an estimation problem.

(20%)

(b) Consider the FIR model

$$y(t) = b_0u(t) + b_1u(t-1) + e(t) \qquad t = 1, 2, ...$$

where $\{e(t)\}$ is a sequence of independent normal random variables with zero mean and standard deviation σ. Determine the regressor vector and parameter vector of the linear regression model.

(20%)

(c) Consider data generated by the discrete-time system:

$$y(t) = b_0 u(t-1) + b_1 u(t-2) + e(t)$$

where { $e(t)$ } is a sequence of independent, zero mean random variables with variance 1 (= $E\,e(t)^2$). Assume that the parameter $\hat{b}$ of the model

$$y(t) = \hat{b} u(t-1) + \varepsilon(t)$$

is determined by least squares.

Determine the estimated parameter $\hat{b}$ obtained for large observation sets when the input u is white noise with zero mean and variance, σ^2.

(60%)

3. (a) Define what is a Self-Tuning Control (STC) technique in an adaptive control application? Please also give the definition of a direct and indirect STC techniques.

(30%)

(b) In sampling a continuous-time process model with $h=1$, the following pulse transfer function is obtained:

$$H(z) = (z + 1.2) / (z^2 - z + 0.25)$$

The design specification states that the discrete-time closed-loop poles should correspond to the continuous-time characteristic polynomial

$$s^2 + 2s + 1$$

Design a minimal-order discrete-time indirect self-tuning regulator. The controller should have integral action and give a closed-loop system having unit gain in stationary. Determine the Diophantine equation that solves the problem.

(70%)

4. A car cruise control system is shown in Figure 4, in which the car dynamics is given by

$$\frac{y(t)}{u(t-1)} = \frac{B(q^{-1})}{A(q^{-1})} = \frac{1+q^{-1}}{1-0.96q^{-1}}$$

where $u(t)$ is the engine throttle, $y(t)$ is the speed of the car.

(a) Find the pole assignment controller, including $F(q^{-1})$, $G(q^{-1})$, constant H , such that $y(t)$ follows the desired speed command $r(t)$ with steady state gain of 1, and the closed loop denominator of $T(q^{-1}) = 1 - 0.5q^{-1}$.

(40%)

(b) If the sampling time is 0.2 seconds, and the required speed changes from 0 to 10 m/s. How long does it take the car to reach speed 8.125m/s?

(40%)

(c) What is the steady state gain of $u(t)/ r(t)$? (20%)

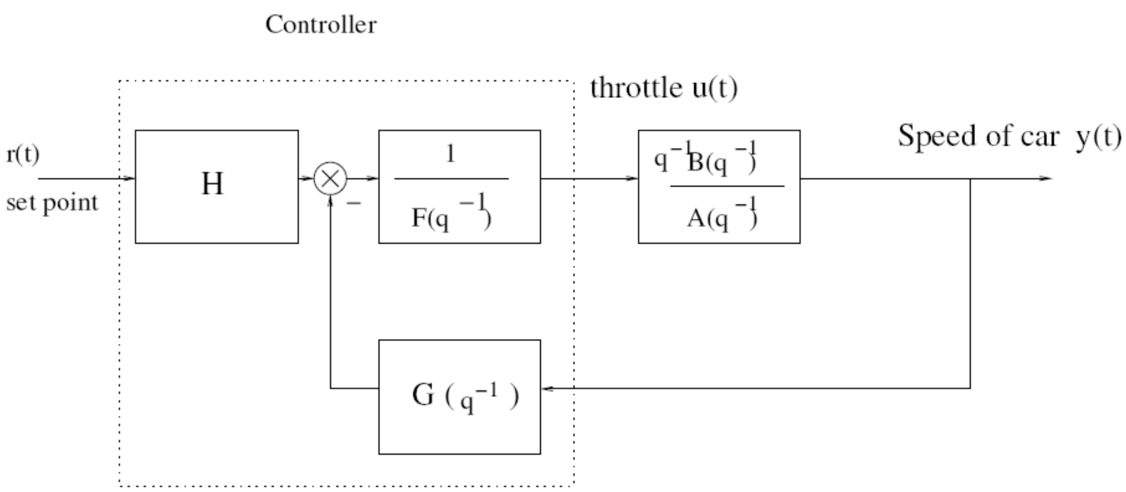

Figure 4.

5. (a) There are two methods suggested by Ziegler & Nichols for tuning PID (Proportional-Integral-Derivative) controllers. One of the methods is applicable for an open-loop system. By using suitable time-response diagram, analyse this method. Identify three controller parameters and explain how to determine those parameters.

Tabulate the tuning rule of K_p (proportional gain), T_i (integral time) and T_d (derivative time) for all three (P, PI & PID) controllers.

For the PID controller, state the transfer function and explain the pole and zero positions of the resulting controller.

(40%)

(b) Consider a closed-loop system shown in Figure 5(a)

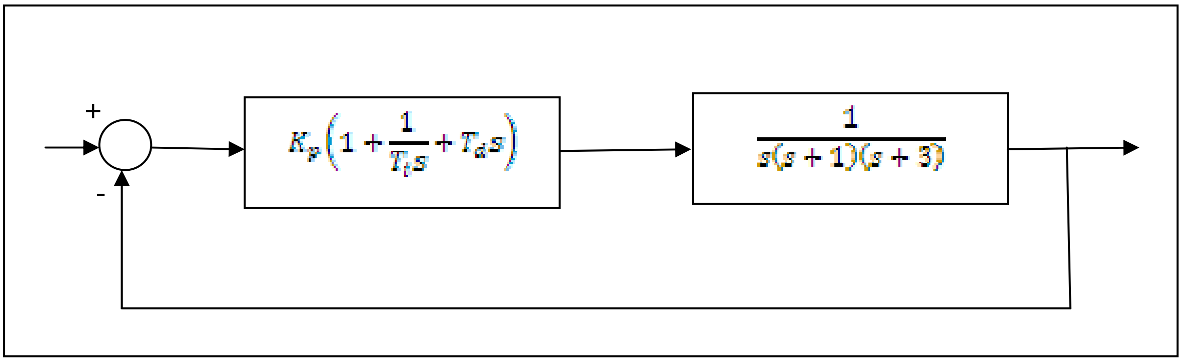

Figure 5(a)

Using a suitable Zieglar-Nichols tuning rule, determine

(i) The initial setup of the controller in order to obtain proportional control action.

(4%)

(ii) The value of K_p so that the system will exhibit sustained oscillation.

(10%)

(iii) The frequency and period of the sustained oscillation.

(20%)

(iv) The suitable values for K_p, T_i and T_d.

(6%)

(v) The pole and zero location of the PID controller.

(10%)

(vi) The closed-loop transfer functions of the overall system if the input is a unit step.

(10%)

6. (a) By using a suitable diagram, explain the principle of gain scheduling in adaptive control. Discuss two advantages and two disadvantages of gain scheduling controller.

(20%)

(b) Assume that a PD controller is used in ship steering control, in which its dynamics can be approximated by the Nomoto model given as

$$G(s) = \frac{b}{s(s+a)}; \quad \text{where } a = a_{nom}\frac{u}{u_{nom}} \quad \text{and} \quad b = b_{nom}\left(\frac{u}{u_{nom}}\right)^2$$

(i) Obtain a closed-loop transfer function and identify the characteristic equation.

(20%)

(ii) Determine the damping ratio, ζ and the natural frequency, ω_n in terms of *u* (velocity) and its nominal notation.

(20%)

(iii) Using the same model, consider an unstable tanker with

$a_{nom} = -0.3$; $b_{nom} = 0.8$; $K = 2.5$ and $T_d = 0.86$

Justify the value of ζ and ω. What are the values of these two terms at the nominal velocity?

(20%)

(iv) Discuss how gain scheduling can be applied in the system. Identify two relations between gains and the auxiliary variables.

(20%)

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