UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2010/2011

November 2010

EEE 550 – ADVANCED CONTROL SYSTEMS

Time: 3 Hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **EIGHT** printed pages and **SIX** questions before answering.

Answer **FIVE** questions.

Distribution of marks for each question is stated accordingly.

All questions must be answered in English.

1. (a) (i) What is Model Reference Adaptive System (MRAS) or Model Reference Adaptive Control (MRAC)?

(7 marks)

(ii) Use relevant diagram to illustrate this control approach.

(7 marks)

(iii) Describe the use of MIT rule in MRAC system.

(6 marks)

(b) (i) Consider a system given by:

G(s)

where *a* is an unknown parameter.

(10 marks)

(ii) Determine a controller that can give the closed loop system

$G_m(s)$

(Assume for this point that *a* is known)

(20 marks)

(iii) Determine a model-reference adaptive controller based on the MIT rule.

(20 marks)

(c) Let us consider a linear process with the transfer function $kG(s)$, where $G(s)$ is known and k is an unknown parameter. Find a feed-forward controller that gives a system with the transfer function $G_m(s) = k_o\, G(s)$, where k_o is a given constant. Use controller structure

$$u = \theta u_c$$

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

(30 marks)

2. (a) Describe what is a Self Tuning Regulator (STR) in relation to its use in adaptive control application.

(20 marks)

(b) Consider the system

$$G(s) = G_1(s)G_2(s)$$

Where

$$G_1(s) = \frac{\quad}{\quad}$$

$$G_2(s) = \frac{\quad}{\quad}$$

Here *a* and *b* are unknown parameters, *c* and *d* are known. This could for example represent a system where the plant is known, but where certain sensor dynamics are unknown. The system is to be controlled in such a way that the closed loop system is given by:

$G_m(s) =$

(i) Construct a discrete time indirect self tuning regulators without zero cancellation.

(20 marks)

(ii) Construct a discrete time direct self tuning regulators without zero cancellation.

(20 marks)

(c) Consider the second order system:

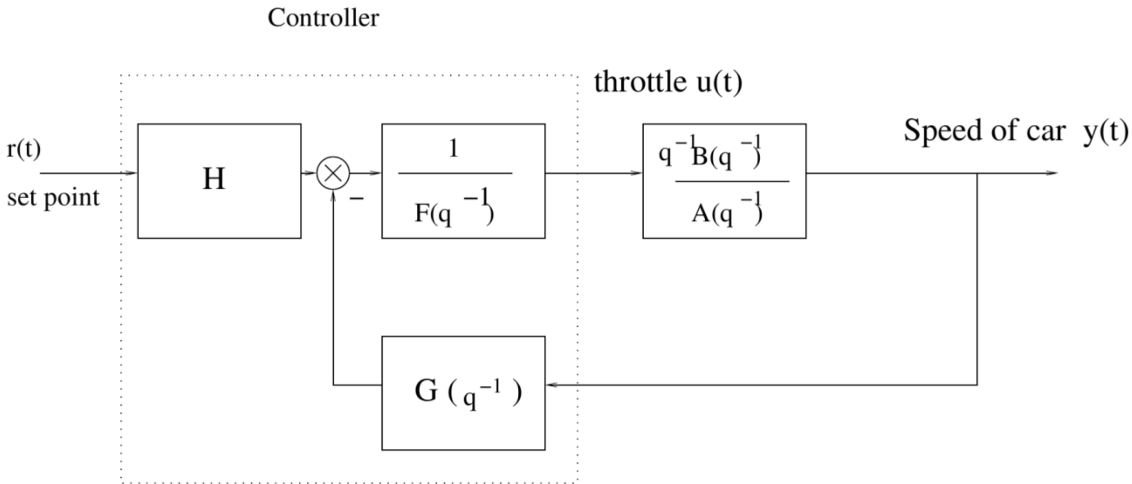
$= -x_2 + \theta$

$= u$

Assume that the parameter θ is known. Design a controller that stabilises the system using the backstepping method.

(40 marks)

3.



A car cruise control system is shown in above diagram, in which the car dynamics is given by

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 marks)

(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?

(30 marks)

(c) What is the steady state gain of

(30 marks)

4. (a) Discuss the dynamic characteristics of

   (i) The PI controller;

   (ii) The PD controller;

   (iii) The PID controller

(60 marks)

(b) Figure 4(a) shows a PID-controlled system. Determine whether the system in Figure 4(b) is equivalent to that in Figure 4(a).

What is the control scheme shown in Figure 4(b)? Explain the advantage of this control scheme in the case when *R(s)* is a step function.

(40 marks)

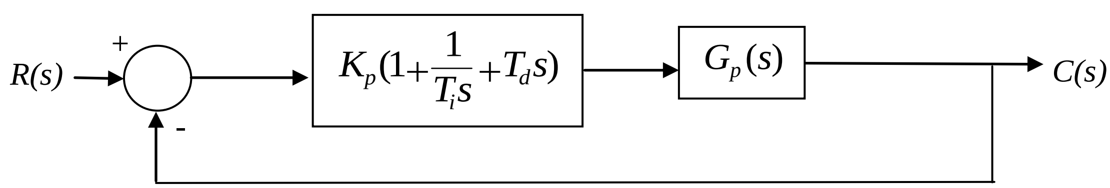


Figure 4(a)

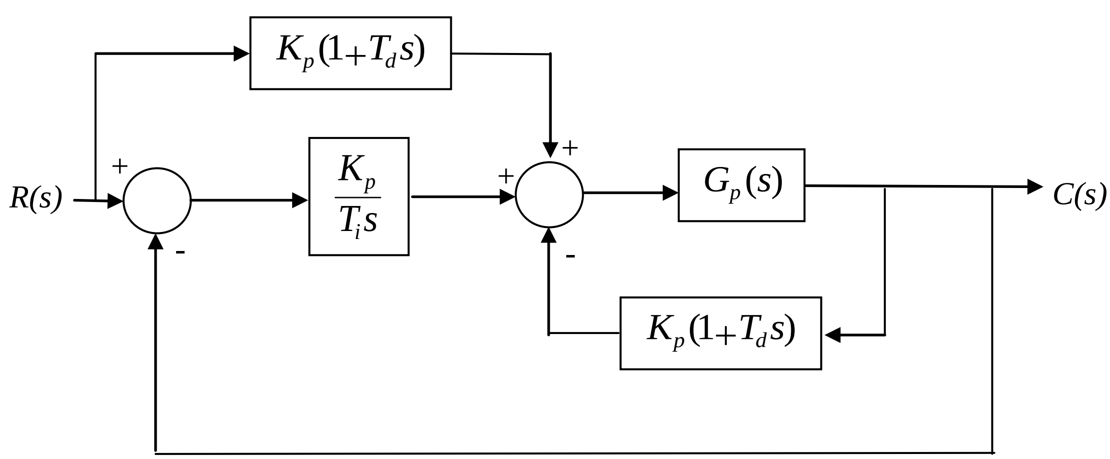


Figure 4(b)

5. (a) Suppose that the output of a system exhibits a sustained oscillation at a particular gain value. Explain how the Ziegler-Nichol method can be used to tune a PID controller that is used to control the system.

Tabulate the tuning rule of K_p (proportional gain), T_i (integral time), and T_d (derivative time) for the PID controller.

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

(30 marks)

(b) By using a diagram, explain what computational delay is. Suggest how computational delay can be made as small as possible in a control system.

(30 marks)

(c) For the system shown in Figure 5, G_{c1} and G_{c2} are the controllers, while G_p is the plant. Determine the degree-of-freedom of the system.

(40 marks)

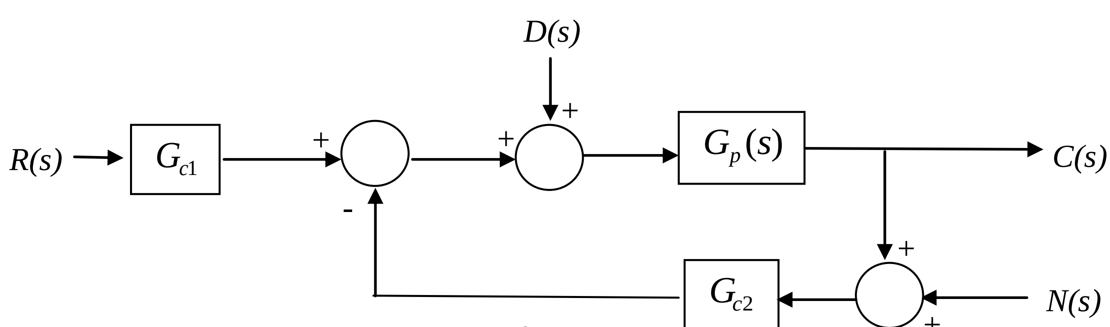


Figure 5

6. (a) Explain two different methods that can be used to tackle methods that can be used to tackle system modelling problem.

(20 marks)

(b) Discuss three features of fuzzy logic that make it a good method for undertaking control problems.

(30 marks)

(c) Figure 6 shows an inverted pendulum control problem. A fuzzy controller is used to control the pole in the upright position by moving the cart. The inputs to the fuzzy controller are the angle (as shown in Figure 6) and the angular velocity, while the output is the velocity of the cart. Assume the pole angle is between -20 and 20 degrees, and the cart velocity is between -2.0 and 2.0 m/s.

(i) By choosing a type of fuzzy membership function for the inputs and output of the fuzzy controller, design the corresponding rule matrix of the controller

(ii) Suppose the angle value is 5 degree and the angular velocity is -2 degree/second, determine the cart velocity using the MIN-MAX inference approach and the centre-of-gravity defuzzification method.

(50 marks)

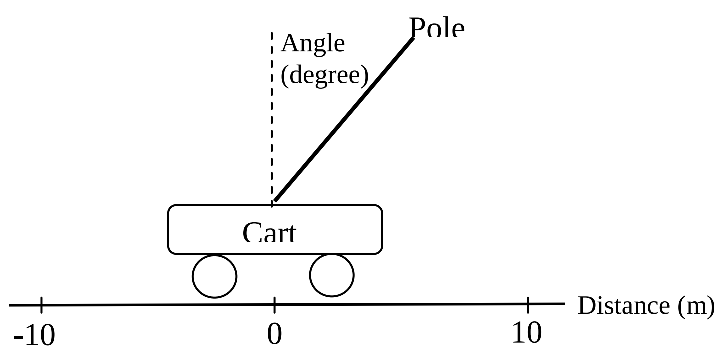


Figure 6

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