UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 2005/2006

November 2005

EEE 453 – REKABENTUK SISTEM KAWALAN

Masa : 3 jam

ARAHAN KEPADA CALON:

Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEBELAS (11)** muka surat beserta **Lampiran (3 mukasurat)** bercetak dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan.

Agihan markah bagi soalan diberikan disudut sebelah kanan soalan berkenaan.

Jawab semua soalan di dalam Bahasa Malaysia.

...2/-

1. (a) Sesuatu sistem kawalan mempunyai matrik A dan B seperti berikut:
A control system has matrices A and B, given by the following:

$$A = \begin{bmatrix} 2 & 0 \\ 0 & -2 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

(i) Tentukan matrik peralihan keadaaan, $\phi(t)$.
Determine the state transition matrix, $\phi(t)$ (20%)

(ii) Tentukan persamaan peralihan keadaaan untuk $x(t)$ bagi t>= 0. Anggapkan input adalah fungsi unit step di mana

Determine the state transition equation, for t>=0. Assume that the input is a unit step function, and that the initial state vector is represented by x(0) where

$$x(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

(40%)

...3/-

(b) Keadaan dan persamaan output untuk satu sistem tertib kedua adalah diberi seperti berikut:

The state and output equations of a second order system are given by the following:

$$\frac{dx_1(t)}{dt} = -3x_1 + 4u(t)$$
$$\frac{dx_2(t)}{dt} = -x_2(t) + u(t)$$
$$y(t) = x_1(t)$$

di mana x_1(t) dan x_2(t) adalah keadaan sistem, *y*(t) ialah output sistem dan *u*(t) adalah input.

where $x_1(t)$ and $x_2(t)$ represent the system states, y(t) is the system output and u(t) represents its input.

(i) Tentukan sama ada sistem tersebut bolehkawal
Determine whether the system is controllable.

(ii) Tentukan sama ada sistem tersebut bolehcerap
Determine whether the system is observable.

(40%)

...4/-

2. (a) Fungsi pindah suatu sistem kawalan diberikan seperti berikut:
The transfer function of a control system is given as follows:

$$G(s) = \frac{s+3}{s^3 + 9s^2 + 24s + 20}$$

Nyatakan persamaan dinamik keadaan sistem tersebut dalam bentuk:
Express the state dynamical equation of the system in the following form:

(i) CCF
(ii) OCF
(iii) JCF

(45%)

(b) Pertimbangkan sesuatu sistem yang diwakili oleh:
Consider a system that is represented by:

$$A = \begin{bmatrix} -7 & -12 \\ 1 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 2 \end{bmatrix} \qquad D = 0$$

(i) Tentukan matrik penjelmaan untuk menjelmakan persamaan matrik keadaan ke bentuk DCF.
Determine the transformation matrix which transforms the above state equations matrix into DCF

(40%)

...5/-

(ii) Cari fungsi pindah untuk sistem tersebut.
Find the transfer function for the system.

(15%)

3. (a) Pertimbangkan sesuatu sistem yang diwakili oleh:
Consider a system that is represented by:

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 1 \\ 0 & 0 & -5 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 0 \\ 5 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \qquad D = 0$$

Rekabentuk pengawal suapbalik keadaan dengan menggunakan formula Ackermann. Lokasi untuk kutub gelung tertutup adalah pada $-1 \pm 2j$ dan -10.

Design a state feedback controller using Ackermann's method. The desired closed-loop poles are to be at $-1 \pm 2j$ and -10.

(45%)

(b) Pertimbangkan sesuatu sistem yang diwakili oleh:
Consider a system that is represented by:

$$\dot{x} = Ax$$
$$y = Cx$$

$$A = \begin{bmatrix} -1 & 1 \\ 1 & -2 \end{bmatrix} \qquad C = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

...6/-

(i) Keadaan yang mana perlu diperiksa sebelum merekabentuk sistem pemerhati keadaan tertib penuh?

What condition that needs to be checked prior to designing a full order observer controller?

(ii) Rekabentuk pemerhati keadaan tertib penuh dengan kutub permerhati keadaan pada s=-5 dan s=-5.

Design a full-order observer for with the desired observer poles are at s=-5 and s=-5.

(55%)

4. (a) (i) Masalah identifikasi sistem boleh dibahagikan secara amnya kepada dua kategori. Terangkan kedua-dua kategori tersebut.

The system identification problem can be generally classified into two categories. Explain the two categories.

(10%)

(ii) Lakarkan suatu gambarajah blok untuk mewakili masalah identifikasi sistem. Terangkan komponen dalam gambarajah tersebut.

Draw a block diagram to represent the system identification problem. Explain the components in the diagram

(20%)

...7/-

(iii) Terangkan dengan jelasnya langkah-langkah yang terlibat dalam menjalankan identifikasi sistem.

Explain in detail the steps involved in carrying out system identification.

(30%)

(b) Diberi model suatu proses adalah dalam bentuk $y(k) = \frac{bz^{-1}}{1+az^{-1}}u(k)$, dan data input/output adalah seperti berikut:

Given that the process model is of the form $y(k) = \frac{bz^{-1}}{1+az^{-1}}u(k)$ *with the following input/output data.*

k	1	2	3	4
u(*k*)	1	-1	-1	1
y(*k*)	12	4	-12	-4

Anggarkan parameter *a* and *b* dengan menggunakan algorithm "least squares".

Estimate parameters a and b using the least squares algorithm.

(40%)

...8/-

5. (a) Terangkan dengan jelasnya langkah-langkah yang terlibat dalam menggunakan kaedah analitik pengoptimuman parameter dalam kawalan optimal.

Explain in detail steps involved in employing the analytical approach of parameter optimization in optimal control.

(40%)

(b) Merujuk kepada Rajah Q5, diberi $G(s)=\dfrac{100}{s^2}$ dan $R(s)=\dfrac{1}{s}$.

With reference to Figure Q5, given that $G(s)=\dfrac{100}{s^2}$ *and* $R(s)=\dfrac{1}{s}$.

(i) Tentukan nilai-nilai optimal bagi parameter K_1 dan K_2 agar

$$J=\int_0^{\infty}[e^2(t)+0.25u^2(t)]dt$$ adalah minimal.

Determine the optimal values of parameters K_1 *and* K_2 *such that*

$$J=\int_0^{\infty}[e^2(t)+0.25u^2(t)]dt$$ *is minimized*

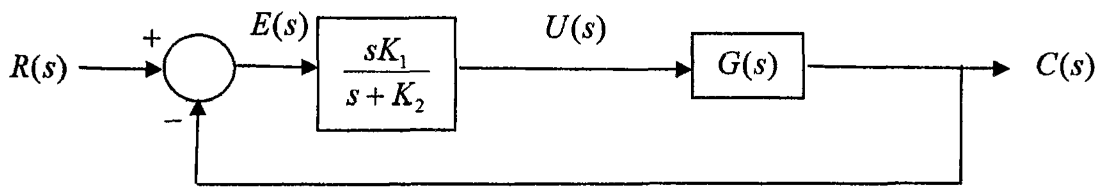
(40%)

...9/-

(ii) Cari matrik Hessian dan komen terhadap pengoptimuman sistem tersebut.

Find the Hessian matrix and comment on the optimality of the system

(20%)



Rajah Q5
Figure Q5

6. (a) Apa itu set kabur and bagaimana ianya berbeza dengan set krisp tradisional? Berikan suatu contoh dalam masalah kawalan untuk menjelaskan jawapan anda.

What is a fuzzy set and how does it differ from the tranditional crisp set? Give an example in relation to control problems to clarify your answer.

(20%)

(b) Dua langkah utama dalam kawalan logik kabur adalah fuzifikasi dan defuzifikasi. Terangkan langkah-langkah yang terlibat and berikan contoh-contoh yang sesuai untuk menjelaskan jawapan anda.

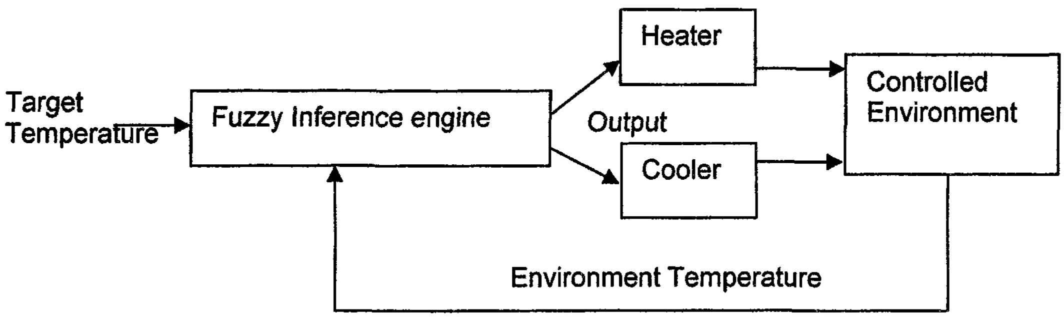
Two main steps in fuzzy logic control is fuzzification and defuzzification. Explain the steps and give suitable examples to clarify your answer.

(20%)

...10/-

(c) Rajah Q6 menunjukkan suatu sistem kawalan suhu berdasarkan logik kabur. Output utama daripada engin inferens logik kabur adalah HEAT, COOL, atau NO CHANGE.

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



Rajah Q6
Figure Q6

(i) Cadangkan dua parameter input kepada engin inferens logik kabur tersebut, dan berikan justifikasi bagi cadangan anda.

Suggest two input parameters to the fuzzy inference engine, and give justification for your choices.

(10%)

(ii) Rekabentuk suatu matrik peraturan 3 x 3 dan cadangkan satu set peraturan bagi engin inferens logik kabur tersebut.

Design a 3 x 3 rule matrix and suggest a set of rules for the fuzzy inference engine.

(20%)

...11/-

Laplace Transform Table

1	Unit-impulse function $\delta(t)$
$\frac{1}{s}$	Unit-step function $u_s(t)$
$\frac{1}{s^2}$	Unit-ramp function t
$\frac{n!}{s^{n+1}}$	t^n (n = positive integer)
$\frac{1}{s+\alpha}$	$e^{-\alpha t}$
$\frac{1}{(s+\alpha)^2}$	$te^{-\alpha t}$
$\frac{n!}{(s+\alpha)^{n+1}}$	$t^n e^{-\alpha t}$ (n = positive integer)
$\frac{1}{(s+\alpha)(s+\beta)}$	$\frac{1}{\beta-\alpha}(e^{-\alpha t}-e^{-\beta t})$ $(\alpha \neq \beta)$
$\frac{s}{(s+\alpha)(s+\beta)}$	$\frac{1}{\beta-\alpha}(\beta e^{-\beta t}-\alpha e^{-\alpha t})$ $(\alpha \neq \beta)$
$\frac{1}{s(s+\alpha)}$	$\frac{1}{\alpha}(1-e^{-\alpha t})$
$\frac{1}{s(s+\alpha)^2}$	$\frac{1}{\alpha^2}(1-e^{-\alpha t}-\alpha te^{-\alpha t})$
$\frac{1}{s^2(s+\alpha)}$	$\frac{1}{\alpha^2}(\alpha t-1+e^{-\alpha t})$
$\frac{1}{s^2(s+\alpha)^2}$	$\frac{1}{\alpha^2}\left[t-\frac{1}{\alpha}+\left(t+\frac{2}{\alpha}\right)e^{-\alpha t}\right]$

Laplace Transform Table (continued)

$\dfrac{s}{(s+\alpha)^2}$	$(1-\alpha t)e^{-\alpha t}$
$\dfrac{\omega_n^2}{s^2+\omega_n^2}$	$\sin \omega_n t$
$\dfrac{s}{s^2+\omega_n^2}$	$\cos \omega_n t$
$\dfrac{\omega_n^2}{s(s^2+\omega_n^2)}$	$1-\cos \omega_n t$
$\dfrac{\omega_n^2(s+\alpha)}{s^2+\omega_n^2}$	$\omega_n\sqrt{\alpha^2+\omega_n^2}\sin(\omega_n t+\theta)$ where $\theta=\tan^{-1}(\omega_n/\alpha)$
$\dfrac{\omega_n}{(s+\alpha)(s^2+\omega_n^2)}$	$\dfrac{\omega_n}{\alpha^2+\omega_n^2}e^{-\alpha t}+\dfrac{1}{\sqrt{\alpha^2+\omega_n^2}}\sin(\omega_n t-\theta)$ where $\theta=\tan^{-1}(\omega_n/\alpha)$
$\dfrac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\dfrac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin \omega_n\sqrt{1-\zeta^2}\,t \quad (\zeta<1)$
$\dfrac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$	$1-\dfrac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\theta)$ where $\theta=\cos^{-1}\zeta \quad (\zeta<1)$
$\dfrac{s\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\dfrac{-\omega_n^2}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t-\theta)$ where $\theta=\cos^{-1}\zeta \quad (\zeta<1)$
$\dfrac{\omega_n^2(s+\alpha)}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\omega_n\sqrt{\dfrac{\alpha^2-2\alpha\zeta\omega_n+\omega_n^2}{1-\zeta^2}}\,e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\theta)$ where $\theta=\tan^{-1}\dfrac{\omega_n\sqrt{1-\zeta^2}}{\alpha-\zeta\omega_n} \quad (\zeta<1)$
$\dfrac{\omega_n^2}{s^2(s^2+2\zeta\omega_n s+\omega_n^2)}$	$t-\dfrac{2\zeta}{\omega_n}+\dfrac{1}{\omega_n^2\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\theta)$ where $\theta=\cos^{-1}(2\zeta^2-1) \quad (\zeta<1)$

TABULATION OF DEFINITE INTEGRAL FOR CONTINUOUS-TIME SYSTEMS

$$J_n = \frac{1}{2\pi j}\int_{-j\infty}^{j\infty} \frac{B(s)B(-s)}{A(s)A(-s)}\,ds$$

$$B(s) = \sum_{k=0}^{n-1} b_k s^k$$

$A(s) = \sum_{k=0}^{n} a_k s^k$; $A(s)$ has zeros in left half plane only.

$$J_1 = \frac{b_0^2}{2a_0a_1}$$

$$J_2 = \frac{b_1^2a_0 + b_0^2a_2}{2a_0a_1a_2}$$

$$J_3 = \frac{b_2^2a_0a_1 + (b_1^2 - 2b_0b_2)a_0a_3 + b_0^2a_2a_3}{2a_0a_3(-a_0a_3 + a_1a_2)}$$

$$J_4 = \frac{b_3^2(-a_0^2a_3 + a_0a_1a_2) + (b_2^2 - 2b_1b_3)a_0a_1a_4 + (b_1^2 - 2b_0b_2)a_0a_3a_4 + b_0^2(-a_1a_4^2 + a_2a_3a_4)}{2a_0a_4(-a_0a_3^2 - a_1^2a_4 + a_1a_2a_3)}$$