Faculty of Environment and Technology
Academic Year: 2020/2021
Assessment Period or Date: May 2021

Module Leader: Quan Zhu
Module Code UFME7F-15-M
Module Title: Advanced Control & Dynamics
Examination Duration: online exam with 24 hours window submission

ONLINE EXAM

Instructions to Students:

Outline the format and process of the assessment this may include:

- Answer ONLY FOUR questions from SIX. All questions carry EQUAL marks
- This is an individual assessment: do not copy and paste work from any other source or work with any other person during this exam.

Formatting

Please use the following file format(s) (word, pdf, jpg for copies of hand writings on blank or lined white papers). We cannot ensure that other formats are compatible with markers' software and cannot guarantee to mark incorrect formats.

Please include the module name and number and your student number (not your name).
Please indicate clearly which questions you are answering.

Instructions for submission

You must submit your assignment *before* the stated deadline by electronic submission through Blackboard.

- Multiple submissions can be made to the portal, but only the final one will be accepted. Please save your work frequently.
- **It is your responsibility to submit exam in a format stipulated above**
  Your marks may be affected if markers cannot open or properly view your submission.
- **Do not leave submission to the very last minute**. Always allow time in case of technical issues.
- The date and time of your submission is taken from the Blackboard server and is recorded when your submission is complete, not when you click Submit.
- **It is essential that you check that you have submitted the correct file(s),** and that each complete file was received. Submission receipts are accessed from the Coursework tab.

There is no late submission permitted on this timed assessment.

Please find the exam questions from the next page

START OF QUESTION PAPER

1. Question – state feedback control (25 marks)

A mathematical model of an aircraft landing gear is shown as follows

$$\frac{Y(s)}{U(s)} = \frac{1}{s(s+2)}$$

a) Design a block diagram of the closed loop control system, which is structred with the full state feedback and feedforward controls. Variable names labelled must be illustrated.

[4 marks]

b) Specify a desired oscillatory output response of the stable 2nd order linear control system by selecting a damping ratio of your own choice, fast response using undamped natural frequency $\omega_n = 3$ and no steady state error to a unit step reference command.

[8 marks]

c) Explain the role of the state feedback controller (less than 60 words) and then design the controller.

[7 marks]

d) Describe the role of the feedforward controller (less than 30 words) and then design the controller.

[3 marks]

e) Present a brief report on the designed system operation. (less than 40 words)

[3 marks]

2. Question – modelling and analysis (25 marks)

Consider a simple dynamic system model of $A = \begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix}$ $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ $C = \begin{bmatrix} 2 & 1 \end{bmatrix}$ $D = 0$

a) Determine its state equation and output equation, dynamic order, numbers of input and outputs.

[6 marks]

b) Draw a block diagram for simulation demonstrations.

[3 marks]

c) Check its controllability and observability to comment briefly on the effects to control system design.

[9 marks]

d) Convert it into transfer function model and give a brief comment on the model properties.

[7 marks]

3. Question - observers (25 marks)

The following questions are related with observers

a) Explain how the observability/observer is used in conjuntion with control system design. (less than 120 words)

[5 marks]

b) Work out the linear full order observer from problem definition and criterion to formulation.

[7 marks]

c) Design an observer for $\frac{Y(s)}{U(s)} = \frac{1}{3s^2 + 3s + 2}$ with the specified poles $s_1 = -3 \quad s_2 = -4$.

[11 marks]

d) Briefly explain how to assign the observer's poles. (less than 30 words)

[2 marks]

4. Question – continuout time/discrete time analysis (25 marks)

The continuous time dynamics of a simplied robot manipulator has been modelled with

$$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & 0 \end{bmatrix} \quad D = 0$$

For digital control, you are required to carry out the following actions.

a) Determine its discrete time transfer function $\frac{Y(z)}{U(z)} = G(z)$ with sampling period 0.5 sec.

[7 marks]

b) Determine the transfer function $G(z)$ poles and zeros and then position them on the Z plane. Determine the system stability.

[6 marks]

c) Convert $\frac{Y(z)}{U(z)} = G(z)$ into the corresponding difference equation.

[7 marks]

d) Based on the difference equation, determine the numerical solutions of the output $y(n)$ from $n = 3$ to 5 by recursive computation with $u(n) = \begin{cases} 0 & n \le 0 \\ 1 & n \succ 0 \end{cases}$ and $y(n) = 0 \quad for \;\; n \prec 3$.

[5 marks]

5. Question – interpretation of the study (25 marks)

Summarise the module study that you have carried out within the two sections (five chapters each section) over the term in the following order.

a) What and how does the study contribute to dynamic modelling and analysis? (less than 70 words)

[5 marks]

b) What and how does the study contribute to control system design? (less than 70 words)

[5 marks]

c) What and how does the study integrate math with control subjects? (less than 70 words)

[5 marks]

d) How does Matlab/Simulink support the study? (less than 70 words)

[5 marks]

e) Expain the procedure to check Z transfer function based stability. (less than 70 words)

[5 marks]

6. Question – digital control (25 marks)

Consider a digital control system as shown in Figure Q6.

$Y(z)$ is the Z transform of the system output
$R(z)$ is the Z transform of the system reference input
$D(z)$ is the Z transform of the controller
$G(z)$ is the Z transform of the dynamic plant

a) Derive the closed loop output transfer function (defined as $Y(z)/R(z)$), the controller transfer function (defined as $U(z)/R(z)$), and the error transfer function (defined as $E(z)/R(z)$).

[9 marks]

b) A desired closed loop transfer function is assigned as $C(z)=\dfrac{b_1 z^{-1}}{1-1.3205z^{-1}+0.4966z^{-2}}$. For achieving zero steady state error in terms of $C(z)\big|_{z^{-1}=1} = Y(z)/R(z)\big|_{z^{-1}=1} = 1$, determin the parameter b_1 .

[3 marks]

c) let $G(z) = 1$, determine the controller $D(z)$ from the specified $C(z)$.

[4 marks]

d) With reference to Figure Q6, present an example to show the following conditions.
Stability is requested on the specified closed loop transfer function $C(z)$ with regard to the plant transfer function $G(z)$: 1- $C(z)$ must contain as zeros all the poles of $G(z)$ that are outside the unit circle and $C(z)$ must contain as zeros all the zeros of $G(z)$ that are outside the unit circle.

[9 marks]

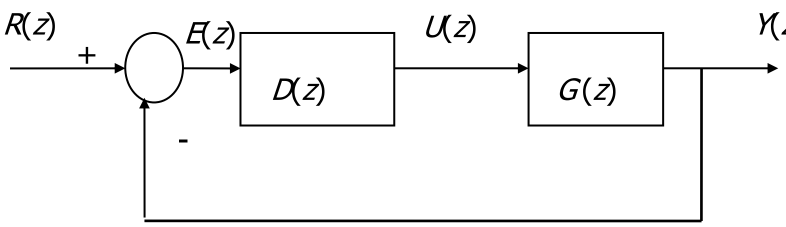

Figure Q6

END OF QUESTION PAPER