SIRE, IIT Delhi
3H (Three hours) Written Comprehensive Examination of Mr. Udayan Banerjee (2019SRZ8482)
April 09, 2021 (3-6pm) [Open Book Online with Camera On]

Instructions: Answer Sections A and B separately and upload two different .pdf files

Part A (Prof. I.N. Kar, EE Dept.): Max. marks: 50 (Write clearly each step of your calculation)

Q1. Consider the following nonlinear system (10)

$\dot{x}_1 = x_2$

$\dot{x}_2 = -x_2 - x_1^3$

and the Lyapunov function V(x) = α x_1^4 + x_2^2. Using a suitable value of α, verify the global asymptotic stability of the system.

Q2. Consider a system described by following equations where u is the control input and θ_l is the output: (15)

$\ddot{\theta}_l + \dot{\theta}_l + k(\theta_l - \theta_m) = 0$

$\ddot{\theta}_m + \dot{\theta}_m - k(\theta_l - \theta_m) = u$

(a) Derive state variable model for this system.
(b) Determine the value of k such that system will be controllable.
(c) Design a full order observer for this system and how the unknown parameters can be selected?

Q3. Consider a system (10)

$\dot{x} =$ f(x)+g(x)u

(a) State a condition such that the above system will be feedback linearizable.
(b) Suppose

$\dot{x}_1 = x_2$

$\dot{x}_2 =$ -a[$\sin(x_1 + \delta) - \sin \delta$] - b$x_2$ - cu

where a, b, and c are constants. Find a feedback linearizing control law.

Q4. A controllable system (A,B,C) and a performance function (15)

$J = (1/2)\int_0^\infty (x^T x + u^T u)dt$.

(a) Suppose $A = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, C = [1 \;\; 1]$. Find a state feedback controller gain to minimize J?
(b) What will be the minimum value of J and controller gain K if the initial condition x(0) of the system is doubled?

Part B (Prof. S.K. Saha, ME): Max. marks: 50

Q1. Answer the following: (3×5=15)

(a) What is LU decomposition?
(b) What are Euler parameters to represent a rotation matrix?
(c) What is Adams-Bashforth method?

Q2. Using SVD decomposition of the following matrix: (10)

$$\mathbf{A} = \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$$

Q3. Derive the Jacobian matrix of a 3-link spatial articulated arm with all revolute joints [Hint: Write the DH parameters first] (15)

11.1Find the selector switch matrices for the force interaction against a wall, as shown in Fig. 1. [Hint: Find the natural and artificial constraints first!] (10)

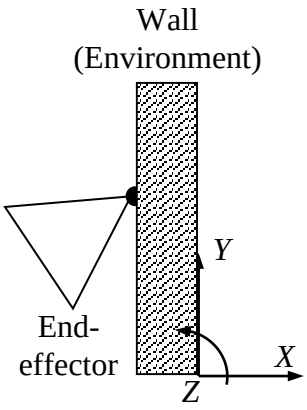

Fig. 1 Robot end-effector against a wall

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3D (Three days) Written Comprehensive Examination of Mr. Udayan Banerjee (2019SRZ8482)
Submission: April 12, 2021, 3pm

Prof. S.K. Saha, ME Dept.: Max. marks: 100

For Question Q3 of your written comprehensive, do the following:

1. Write a MATLAB program to evaluate the Jacobian matrix for some numerical values of the DH parameters.

2. Find its inverse dynamics results for some input trajectory using any existing algorithm (like RoboAnalyzer or ReDySim).

3. Verify the results of item 2 above using any software of your choice.

Submit a hand-written report in .pdf format only with the relevant printout of the plots.