

**Written Comprehensive (Open-book) Examination**  
Mr. Adnan Jawed (2018MEZ8581)  
December 28, 2020 (Monday), 3-6pm  
[Questions for open book/open source/open Internet exam]

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

Duration: 3 hours

Marks: 100

**Section A (Prof. S.K. Saha): 80 marks**

1. Answer the following:

- (a) Does a singular matrix have eigen values and eigen vectors?
- (b) Define Euler-angles to represent a rotation matrix. State at least two drawbacks of rotation representation using Euler-angles.
- (c) What is Newton-Raphson method? Where is it used?
- (d) Draw S-N diagram for steel in fatigue loading. How is it different from stress-strain diagram in static loading?

(4×5=20)

2. Decide whether the vectors in each sub-set of  $\mathbb{R}^3$  are linearly dependent or independent. Justify answers.

(a)  $\begin{bmatrix} 1 \\ -3 \\ 5 \end{bmatrix}, \begin{bmatrix} 2 \\ 2 \\ 4 \end{bmatrix}, \begin{bmatrix} 4 \\ -4 \\ 14 \end{bmatrix};$  (b)  $\begin{bmatrix} 9 \\ 9 \\ 0 \end{bmatrix}, \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix}, \begin{bmatrix} 3 \\ 5 \\ -4 \end{bmatrix}, \begin{bmatrix} 12 \\ 12 \\ 1 \end{bmatrix}$  (2×5=10)

3. Using SVD decomposition of the following matrix, find its pseudo-inverse:

$$\mathbf{A} = \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \quad (15)$$

4. (a) Using sketches, define holonomic and non-holonomic constraints of a mechanical system.
- (b) Using DH parameters find out the final Homogeneous Transformation Matrix (HTM) of the end-effector for the revolute-prismatic manipulator. Find out its equations of motion using the DeNOC matrices.
- (c) Derive the Jacobian matrix of a UAV with six rotors (Hexa-Copter). How can you solve inverse kinematics in velocity level?

(5+10+5=20)

5. (a) What are the major differences between Stiffness control, Impedance control, Admittance control, and hybrid control.

(b) Suppose the unforced equations of motion of a system in state space is given by

$$\dot{\mathbf{x}} = \begin{bmatrix} 0 & 0 & -2 \\ 0 & 1 & 0 \\ 1 & 0 & 3 \end{bmatrix} \mathbf{x}$$

Find out the State Transition Matrix and find the response if the initial value (at time  $t = 0$ ) is given

by  $\mathbf{x}_0 = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$ . (5+10=15)

**Section B (Prof. Sumantra Dutta Roy): 20 marks**

*(This is a test of mathematical and concept understanding. Please use consistent notation across questions, and state what practical assumptions are used, and where. The test seeks to check the depth of one's understanding, not how well one can search for a topic in Google, or otherwise).*

1. Give a proper mathematical formulation of bundle adjustment in terms of the inputs, outputs and the basic mathematics involved.

2. Give a mathematical formulation of 3-D projective structure, and how one can upgrade projective structure to Euclidean.
3. Read up about 'Building Rome in a Day', and SLAM. How are the two different in terms of the problems, the mathematical descriptions, the algorithmic principles, and the solutions?
4. How can one get correspondence across images: what are common practical assumptions, in practically important scenarios? Consider the practical scenarios from 'Building Rome in a Day' and getting structure from motion.

(4×5=20)

**Take Home Comprehensive Examination for Mr. Adnan Jawed  
December 28, 2020**

*[Open book/open source/open Internet exam]*

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

Duration: 48 hours (Submission: December 30, 9pm)

Marks: 100

**Section A (Prof. S.K. Saha): 70 marks**

1. Write MATLAB programs to solve HTM, inverse and forward dynamics of Question 4 (b) of Section A numerically. (10+20+20=50)
2. For the Hexa-Copter, solve the problem of Question 4(c) of Section A. (20)

Submit a handwritten report in .pdf file describing the methodologies followed and the results obtained. Add the plots saved in .pdf as a part of the report.

**Section B (Prof. Sumantra Dutta Roy): 30 marks**

1. Survey the state-of-the-art in terms of the concepts behind 'Building Rome in a Day', and write the entire engineering effort needed in terms of the basic input and output, in your own words.
2. Survey the state-of-the-art in terms of SLAM with a single moving camera, and write the entire engineering effort needed in terms of the basic input and output, in your own words.
3. Read up about Monocular SLAM from <http://www.cse.iitd.ac.in/~chetan> and summarize the basic math and engineering needed to build a system from scratch. The camera is on a person. One needs to find the 3-D structure of the world around, from the views of the camera.

(3×10=30)