ID NO. _____ NAME _____

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
SCOND SEMESTER 2022-2023
BITS F441 ROBOTICS

COMPREHENSIVE EXAM **May 16, 2023**

Part A – CLOSE BOOK

60 Minutes **20 marks**

…..**[0.5M each]**

Q1. (a) The approximating function for quntic trajectory has a …….polynomial order

(b) Expand PUMA…….

(c) If a robot arm has 3-DOF (degrees of freedom), wrist has 2-DOF and end-effector has 3-DOF, then the manipulator has _____DOF

(d) Manipulator is the combination of arm and wrist. Arm is meant for _____of object and wrist is meant for _____of object.

(e) A mobile robot has _____ (how many?) degrees of freedom.

(f) The symbolic representation of dynamic equation of a manipulator is …..

$\tau(t) = M(q)\ddot{q}(t) + ... + ... + ...$ where $M(q) =$

(g) What are the different types of forces of friction, considered in manipulator joint?

(i) _____and (ii) _____

(h) ABB -1410 has a fly by operation discuss its utility

(i) Discuss importance of Move L and Move J command used for ABB -1410

(k) Discuss special feature of teach pendant in ABB 1410

ID NO _____ NAME _____

(l) List down different types of basic joints used in a manipulator and provide standard symbols for those

(m) If a manipulator has an open loop structure and for kinematic model DH algorithms is used. The number of frames assigned are 6. Then the DOF of this manipulator is _____.

(n) Write the inverse of ${}^{1}T_{2}$, the homogenous transformation matrix

(o) Specify the symbolic equation used for mapping of forces and moments acting at end-effector of a manipulator into equivalent joint torques.

(p) What is the control law used for PD control system?

(q) Provide the relation between ${}^{1}\dot{R}_{2}$, and associated terms

(r) Discuss how Jacobian matrix can be used for inverse kinematics

(s) If you fail to get the closed form solution for Inverse kinematics then what should be method used mostly

(t) List down the sensors used in ABB -1410 (present setup in Lab)

Q2. (a) How do you define spatial resolution of a manipulator? (Explain with figure). Explain, the difficulty faced to the compute control resolution of multi degrees of freedom manipulator? [1]

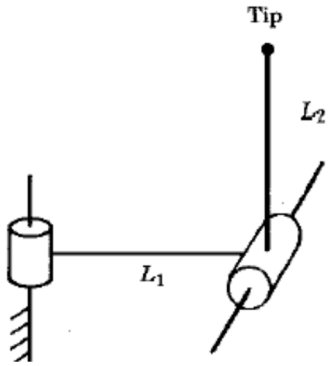
(b) In a robot rotary joint mechanism of total angle 140^0. The robot has control memory 8 bit capacity. The mechanical accuracy associated with the moving arm is a random variable with a standard deviation 0.1^0. Determine the control resolution, spatial resolution, accuracy and repeatability. [1]

(c) Discuss pros and cons of Cartesian space and joint space trajectory planning. [1]

(d) What do you understand by the interior singularity of a manipulator? Under what circumstances interior singularity is observed. [1]

(e) Mention the formula used for Jacobian computation [1]

(f) Assign frame and get the link and joint parameters for the manipulator shown in the Figure. Assume the manipulator at zero position before frame assignment. The length of the first link and second link are L_1 and L_2 respectively. [2]



(f) Given the following 3 × 3 matrix: (a) Prove that matrix is a rotation matrix. (b) Determine the unit vector that defines the axis of rotation . [2]

$$\begin{bmatrix} 1/\sqrt{2} & 0 & 1/\sqrt{2} \\ -1/2 & 1/\sqrt{2} & 1/2 \\ -1/2 & -1/\sqrt{2} & 1/2 \end{bmatrix}$$

(h)A frame {B} is initially coincident with a frame {A}. We rotate {B} about Y_B by Φ. Next, we rotate the resulting frame {B} about X_B by θ degrees. (a) Give the rotation matrix, ${}^{A}R_B$ which will change the description of a vector P in frame {B}, ${}^{B}P$, to frame {A}, ${}^{A}P$. (b) What is the result if $\Phi = 60^0$ and $\theta = 30^0$? [2]

****

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
SCOND SEMESTER 2022-2023
BITS F441 ROBOTICS

COMPREHENSIVE EXAM **May 16, 2023**

Part B – OPEN BOOK

120 Minutes **25 marks**

Q1. A 2-DOF Cartesian manipulator loaded with a Payload W acting at the end, shown in Fig. 1. Assume both links are slender with length L_1 and L_2 respectively. The masses of first and second links are m_1 and m_2 respectively, and center of mass is located at the midpoint of each link. Provide the answer of the following

(i) Derive Forward Kinematic Model [2M]
(ii) Derive Inverse Kinematic Model [2M]
(iii) Determine the Jacobian matrix. [2M]
(iv) Determine Inertia coefficients M_{ij} [5M]
(v) Determine Gravity G_i and Centrifugal and Coriolis coefficients h_{ijk} [5M]

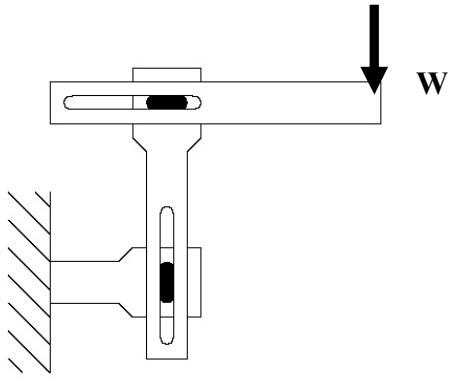


Fig. 1

Q2. Determine the two segment continuous acceleration spline. For a joint where $\theta_0 = 4^0$, $\theta_v = 10^0$ $\theta_g = 20^0$ and each segment lasts 2 second. [3M]

Q3. Discuss the implications of highly geared over direct drive motors for high speed application of manipulators. Explain how the electromechanical system get impacted by highly geared system [3M]

Q4. Prove that the proportional controller for the single joint robot is a second order system which is always stable, if all the system parameters are positive. What is required to increase the system response time and reduce the steady state error? [4M]

****