Question Paper

Exam Date & Time: 10-Jun-2019 (09:30 AM - 12:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

INTERNATIONAL CENTRE FOR APPLIED SCIENCES
IV SEMESTER B.Sc (Applied Sciences) IN ENGINEERING
END SEMESTER THEORY EXAMINATION APRIL / MAY 2019
INDUSTRIAL ROBOTS [IMET 244 - S2]

Marks: 100 **Duration: 180 mins.**

Answer 5 out of 8 questions.

Missing data, if any, may be suitably assumed.

1) A) Define a manipulator and explain serial link, parallel link and hybrid link manipulator with a relevant example. (6)

B) Write a short note on the advantages and disadvantages of robots. (8)

C) Discuss on commonly used manipulators configuration with a neat and suitable diagram. (6)

2) A) Explain the following with a suitable example: (8)
a. Vision Inspection System
b. Robot-manipulated Inspection

B) A leading automobile company has decided to automate their welding operation with manipulators. Discuss the features it should possess. (6)

C) A cola making company ABC has decided to automate their firm. Discuss on the various possible assembly system configurations. (6)

3) A) Figure 1 shows a scissor jack configuration. As you turn the screw, the jack goes up and down. The mechanical advantage provided by the mechanism allows a single person to jack up a car to change a tire. Think about what rigid bodies and joints must be present in the scissor jack as you may not be able to see all of them in the image. Using Grubler's formula, calculate the number of degrees of freedom (6)

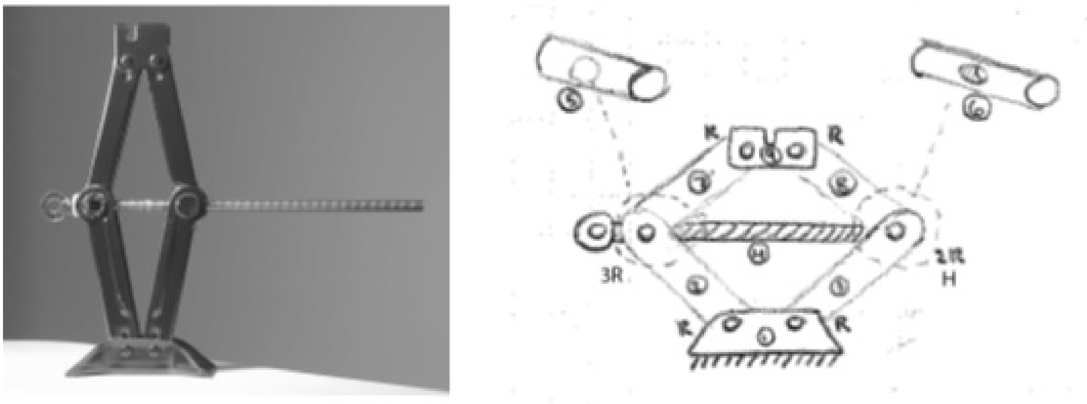

Figure 1

B) Consider the satellite and Earth shown in Figure 2. Let ω_b = (0; 1; 1) be the angular velocity of the satellite expressed in the satellite body frame {b}. Assuming a fixed Earth frame {e} (a geocentric view of the universe like the ancient Greeks had). (8)

a. Solve for the coordinate axis velocities of {b} ($\dot{x}_b$, $\dot{y}_b$ and $\dot{z}_b$) represented in the {b} frame. Sketch the velocity vectors on the figure below to confirm that the solution make sense.
b. The orientation of the {b} frame is equivalent to the {e} frame after it has been rotated -90 degrees about its z_e-axis. Solve for ω_e, the satellite angular velocity represented in {e}. Sketch the velocity vectors on the figure below to confirm that the solution makes sense.
c. Solve for R_{eb} dot, the time derivative of the body orientation expressed in {e}
d. Give the SO(3) representation of the angular velocity in both the Earth and the body frame.

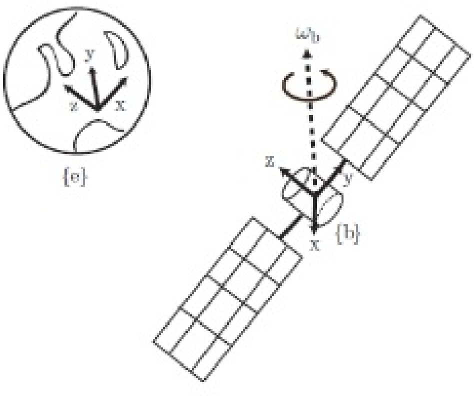

Figure 2

C) Find the Z-Y-Z fixed angle and substitute α = 60,β=30,γ=90. (6)

4) Consider the scene in Figure 3 of a once peaceful park overrun by robots. Frames are shown attached to the tree {t}, robot chassis {c}, manipulator (8)

A) {m}, and quadcopter {q}. The distances shown in the figure are $d_1 = 4$ m, $d_2 = 3$ m, $d_3 = 6$ m, $d_4 = 5$ m, $d_5 = 3$ m. The manipulator is at a position $P_{cm} = (0, 2, 1)$ m relative to the chassis frame {c}, and {m} is rotated from {c} by 45 degrees about the x_c-axis.

a. Give the transformation matrices representing the quadcopter frame {q}, chassis frame {c}, and manipulator frame{m} in the tree frame {t}.
b. Assume that the position controller for the manipulator on the mobile robot is referenced to the chassis frame {c}. What position should you command the gripper to go to if you would like to snatch the quadcopter out of the sky?
c. You are tasked to move the mobile robot so that the chassis origin is directly underneath the quadcopter and its frame is aligned with the tree frame. Assuming the mobile robot chassis controller takes transformation matrices in the chassis frame as inputs, what transformation should you command the robot to follow?

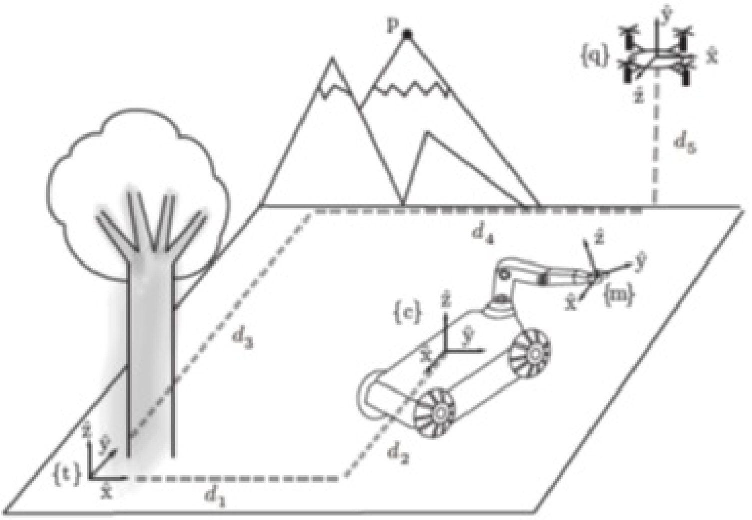

Figure 3

B) Sketch a 3R planar serial link manipulator and find the D-H parameters. (6)

C) Identify the transformation matrix of PRR robot shown in Figure 4. Here first joint translates around its y axis, joint 2 and 3 rotates about its z axis to follow the desired trajectory. (6)

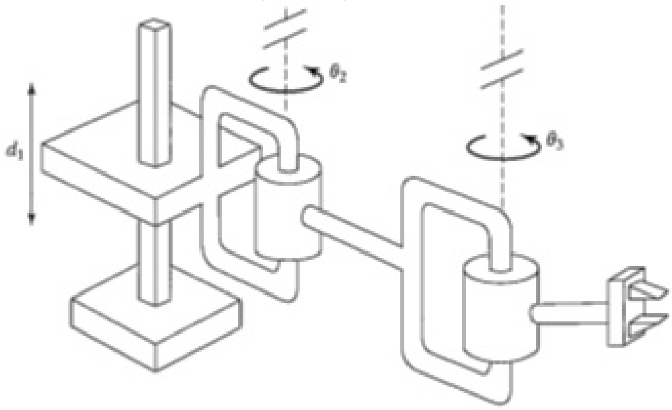

Figure 4

5) Figure 5 shows the KUKA LBR iiwa (German for lightweight robot) 7R robot (6)

A) arm. The figure defines an {s} frame at the base with the y_s-axis pointing out of the page and a {b} frame aligned with {s} at the end-effector. The robot is at its home configuration The screw axes for the seven joints are illustrated (positive rotation about these axes is by the right hand rule). The axes for joints 2, 4, and 6 are aligned, and the axes for joints 1, 3, 5, and 7 are identical at the home configuration. Write M (T_{sb} when the robot is at its home configuration), the screw axes S1; : : : ; S7 in {s}, and the screw axes B1; : : : ; B7 in {b}.

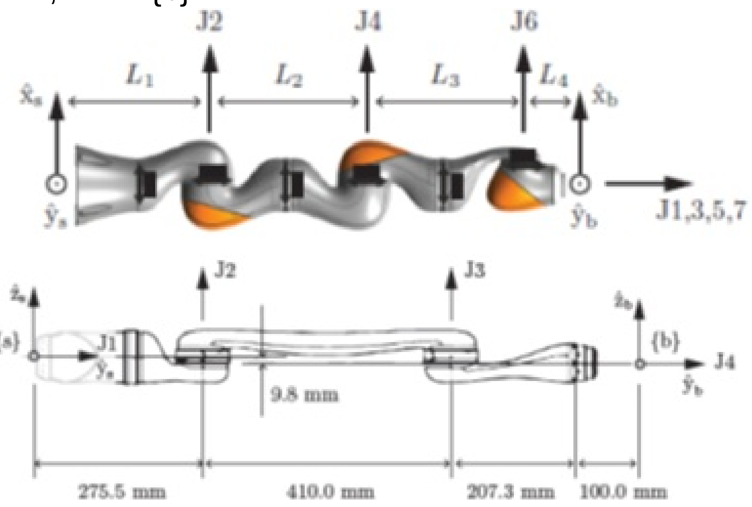

Figure5

B) (8)

Figure 6 shows a Da Vinci Xi, used in several types of robot-assisted surgery. Though it is mechanically constrained to have only 3 degrees of freedom per arm, for the sake of this exercise assume each arm as a simple serial chain with 6 degrees of freedom.

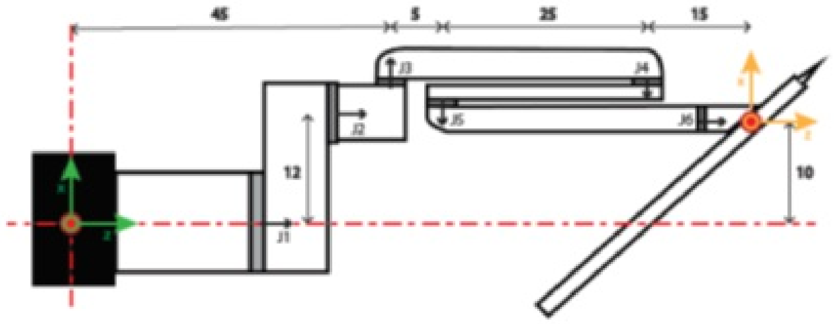

Figure 6

a. Write the M matrix for the arm if its home configuration is shown in Figure 6
b. Find the space frame screw axes for this system.
c. Determine the position of the end-effector if the joints are at (0,π/4,0, π/4, 3π/4,π/2).

C) Use Newton Raphson iterative root finding to perform two steps of finding the root of (6)

$$f(x,y) = \begin{bmatrix} x^2 - 9 \\ y^2 - 4 \end{bmatrix}$$

When your initial guess is $(x^0,y^0) = (1,1)$ give results after two iterations.

6) A) Define dynamics and explain Newton Euler method to find the manipulator torque equation (6)

B) Compare and contrast Lagrangian method and Newton Euler method to find the force/ torque of a manipulator. (6)

C) Derive the state space representation of a 2R serial link manipulator using Newton Euler equations. (8)

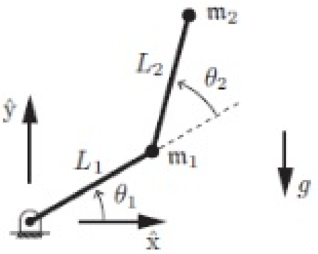

Figure 7

7) A) Identify the torque equation of a two link serial manipulator shown in Figure 7 using Euler Lagragian method. (6)

B) The equations of motion for a particular 2R robot arm can be written The Lagrangian for the robot can be written in components as (8)

$$\mathcal{L}(\theta,\dot{\theta}) = \mathcal{L}^1(\theta,\dot{\theta}) + \mathcal{L}^2(\theta,\dot{\theta}) + \mathcal{L}^3(\theta,\dot{\theta}) + \dots$$

$$\mathcal{L}^1 = \mathrm{m}\dot{\theta}_1\dot{\theta}_2\cos\theta_2.$$

One of these components is

a. Find the joint torques τ_1 and τ_2 corresponding to the component L1.Write the 2x2

b. mass matrix M(θ) the velocity product vector and the gravity vector g(θ) corresponding to L

C) Explain how do you identify the twist and wrench of a system assuming that the force and moment of the system is known. (6)

8) A) A single-link robot with a rotary joint is motionless at θ = 20 degrees. It is desired to move the joint in a smooth manner to θ = 90 degrees in 3 s. Find the coefficients of a cubic that accomplishes this motion and brings the manipulator to rest at the goal. Plot the position, velocity, and acceleration of the joint as a function of time (rough sketch). (6)

B) Explain the following with a suitable example (6)
1. Trajectory.
2. Straight line motion.
3. Polynomial Via point Trajectory.

C) Two link manipulator has to follow a cuboidal trajectory to perform pick and place operation. Discuss on the equation related to follow the given trajectory and identify the constraints related to that equation (8)

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