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ME 639: Assignment-1

Q2.
Ans:

1) **PUMA Robot**

    - RRR (3 revolute joints)
    - 3 DOF which are three degrees of rotation.
    - First Revolute joint has vertical axis of rotation while other two revolute joint has same axis of rotation.

    PUMA robot welding
    PUMA robot Drawing

2) **SCARA Robot**

    - RRP (2 revolute joints + 1 prismatic joint)
    - First two joints are revolute and their axis of rotation is parallel. The third joint is prismatic which can only move up and down direction.

    YASKAWA robot
    YK500TW

3) **Stanford Type Robot**

    - RRP (2 revolute joints + 1 prismatic joint)
    - First two joints are revolute joints but the axis of rotation of both joints are normal to each other.
    - Third joint is prismatic joint.
    - 3 DOF

    Manipulator
    Puzzle solving

4) **Exoskeleton Robot**

- a wearable device that is designed to enhance or augment the physical capabilities of a human user.
- consist of a wearable frame that houses mechanical components, sensors, and often actuators to provide assistance, support, or enhanced mobility to the wearer.

MARCH
SARCOS GUARDIAN

5) **Aerial Robot**

- An aerial robot, often referred to as a drone or unmanned aerial vehicle (UAV), is a type of robotic system designed to fly and operate in the air without a human pilot on board.

Quadrotor
Swarms

6) **Mobile Robot**

- Mobile robots are robotic systems that are designed to move and operate autonomously in various environments. Unlike fixed robots that are confined to a single location, mobile robots have the ability to navigate and explore their surroundings, making them suitable for a wide range of applications.

YASKAWA
OMRON

7) **Underwater Robot**

- Underwater robots, also known as underwater autonomous vehicles (AUVs) or remotely operated vehicles (ROVs), are robotic systems designed to operate in underwater environments.

Underwater robots
Underwater robots1

Q3.

Ans: Types of motors:

1) **AC motors:**

    a) **Synchronous motors:**

    This motor is called "synchronous" because the rotational speed of the motor is synchronized with the frequency of the AC power source. It contains electromagnets and also have coil wounded around circular disk. This motor operates at a constant speed determined by the frequency of the alternating current (AC) power supply and the number of magnetic poles in the motor.

    b) **Asynchronous motors (Induction Motors):**

    This is a type of electric motor that operates at a speed that is not synchronized with the frequency of the AC power supply. In these motors, torque is produced by the interaction between stator and rotor which is result of electromagnetic induction. Unlike synchronous motors, Asynchronous or induction motors do not operate at a constant speed; their speed varies depending on the load applied to the motor.

2) **DC motors:**

    a) **Brushed DC motors:**

    This motor uses DC voltage to operate. This motor contains armature which is rotating part of the motor, consisting of coils wound around a central code. Commutator is a split ring made of segments that connected to armature coils. Commutator is responsible for reversing direction of current flow in coils. The brushes used in motor are made up of carbon. They maintain contact with commutator and provide current to armature coils. The two magnets of opposite poles are fixed in motor which interacts with magnetic field generated by changing direction of current and produced a torque that causes the armature to rotate.

b) **Brushless DC motors:**

- ❖ **BLDC motors:**

  It is type of motor that operates using DC current and do not use brushes and commutator for rotation. BLDC motor contains more than 2 stators. The BLDC motor is controlled by an electronic controller, which provides the necessary signals to switch the current in the stator windings in a specific sequence. These motors used where higher rpm is required such as drones, cooling fans, etc.

- ❖ **Stepper motors:**

  A stepper motor is a type of electric motor that divides a full rotation into a number of equal steps. It's designed to move or rotate in discrete increments, allowing for precise control of position and speed. Stepper motors are commonly used in applications where accurate positioning, control, and repeatability are crucial. This type of motors used in 3D printers, robots,etc.

3) **Servo motors:**

A servo motor is a type of electric motor that is designed for precise control of position, speed, and torque. This type of motor can only rotate for some angle. Servo motors are widely used in various applications where accurate and controlled movement is required. They offer a closed-loop control system that continuously adjusts the motor's position to match a desired target, providing high accuracy and stability. This motor actually provides information about position of motors in terms of angle.

Q6.
Ans:

6] Rotation matrix given as

$$R_0^1 = \begin{bmatrix} \hat{i}_1\cdot\hat{i}_0 & \hat{j}_1\hat{i}_0 & \hat{k}_1\hat{i}_0 \\ \hat{i}_1\hat{j}_0 & \hat{j}_1\hat{j}_0 & \hat{k}_1\hat{j}_0 \\ \hat{i}_1\hat{k}_0 & \hat{j}_1\hat{k}_0 & \hat{k}_1\hat{k}_0 \end{bmatrix}$$

let the columns are, $C_1 = \begin{bmatrix} \hat{i}_1\hat{i}_0 \\ \hat{i}_1\hat{j}_0 \\ \hat{i}_1\hat{k}_0 \end{bmatrix}$ $C_2 = \begin{bmatrix} \hat{j}_1\hat{i}_0 \\ \hat{j}_1\hat{j}_0 \\ \hat{j}_1\hat{k}_0 \end{bmatrix}$ $C_3 = \begin{bmatrix} \hat{k}_1\hat{i}_0 \\ \hat{k}_1\hat{j}_0 \\ \hat{k}_1\hat{k}_0 \end{bmatrix}$

The columns will be orthogonal if their dot product is 0.

$$\begin{aligned} C_1\cdot C_2 &= (\hat{i}_1\hat{i}_0)\cdot(\hat{j}_1\hat{i}_0) + (\hat{i}_1\hat{j}_0)\cdot(\hat{j}_1\hat{j}_0) + (\hat{i}_1\hat{k}_0)\cdot(\hat{j}_1\cdot\hat{k}_0) \\ &= (\hat{i}_1\cdot\hat{j}_1)(\hat{i}_0\hat{i}_0)^2 + (\hat{i}_1\cdot\hat{j}_1)(\hat{j}_0\cdot\hat{j}_0) + (\hat{i}_1\cdot\hat{j}_1)(\hat{k}_0\cdot\hat{k}_0) \\ &= (0)\cdot(1) + (0)\cdot(1) + (0)\cdot(1) \quad \text{--- (as } \hat{i}\cdot\hat{j} = 0) \\ &= 0 \end{aligned}$$

similarly,

$$\begin{aligned} C_2\cdot C_3 &= (\hat{j}_1\cdot\hat{i}_0)(\hat{k}_1\cdot\hat{i}_0) + (\hat{j}_1\hat{j}_0)\cdot(\hat{k}_1\hat{j}_0) + (\hat{j}_1\hat{k}_0)(\hat{k}_1\hat{k}_0) \\ &= (\hat{j}_1\cdot\hat{k}_1)(\hat{i}_0\cdot\hat{i}_0) + (\hat{j}_1\hat{k}_1)(\hat{j}_0\cdot\hat{j}_0) + (\hat{j}_1\cdot\hat{k}_1)(\hat{k}_0\cdot\hat{k}_0) \\ &= (0)\cdot(1) + (0)\cdot(1) + (0)\cdot(1) \\ &= 0 \end{aligned}$$

$$\begin{aligned} C_3\cdot C_1 &= (\hat{k}_1\cdot\hat{i}_0)(\hat{i}_1\cdot\hat{i}_0) + (\hat{k}_1\hat{j}_0)(\hat{i}_1\cdot\hat{j}_0) + (\hat{k}_1\cdot\hat{k}_0)(\hat{i}_1\hat{k}_0) \\ &= (\hat{k}_1\cdot\hat{i}_1)(\hat{i}_0\cdot\hat{i}_0) + (\hat{k}_1\cdot\hat{i}_1)(\hat{j}_0\cdot\hat{j}_0) + (\hat{k}_1\cdot\hat{i}_1)(\hat{k}_0\cdot\hat{k}_0) \\ &= (0)(1) + (0)\cdot(1) + (0)(1) \\ &= 0 \end{aligned}$$

all dot products of columns are zero
hence colums of rotation matrix are orthogonal

Q7.
Ans:

7]
$$R_0^1 = \begin{bmatrix} \hat{i}_1\hat{i}_0 & \hat{j}_1\hat{i}_0 & \hat{k}_1\hat{i}_0 \\ \hat{i}_1\hat{j}_0 & \hat{j}_1\hat{j}_0 & \hat{k}_1\hat{j}_0 \\ \hat{i}_1\hat{k}_0 & \hat{j}_1\hat{k}_0 & \hat{k}_1\hat{k}_0 \end{bmatrix} \qquad (R_0^1)^T = \begin{bmatrix} \hat{i}_1\hat{i}_0 & \hat{i}_1\hat{j}_0 & \hat{i}_1\hat{k}_0 \\ \hat{j}_1\hat{i}_0 & \hat{j}_1\hat{j}_0 & \hat{j}_1\hat{k}_0 \\ \hat{k}_1\hat{i}_0 & \hat{k}_1\hat{j}_0 & \hat{k}_1\hat{k}_0 \end{bmatrix}$$

$$(R_0^1)(R_0^{1\,T}) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = I$$

hence, R_0^1 is a orthogonal matrix.

$$(R_0^1)\cdot(R_0^1)^T = I$$

$$\det[R_0^1]\cdot\det[(R_0^1)^T] = 1 \quad \text{——} \ (1)$$

but $\det[R_0^1] = \det[(R_0^1)^T]$

$\therefore$ eq^n (1) becomes

$$[\det(R_0^1)]^2 = 1$$

$$\therefore \det(R_0^1) = 1$$