Assignment 1

Q2) Classification of Robots:

1. Robotic Manipulator: An arm-like manipulator that can autonomously move elements within a certain range of degrees of freedom is created by joining together a variety of sliding or jointed segments.
   Video 1- These robotic manipulators can be programmed to do almost any task a human arm can do, something as interesting as playing music and acting as a band member.

2. Ground mobile robots: These robots can have the freedom to move in their surroundings and perform certain tasks preassigned to them like surveillance, damning, inspection, rescue, exploratory missions, etc.
   Ground robots can be employed in any kind of environment where humans can or cannot enter and perform certain tasks like Hospital Robot, etc.

3. Aerial Robots: Aerial robots, also known as unmanned aerial vehicles (UAVs) or drones, fly through the air. They can cover distances at a higher speed in comparison to the other robots. It can be programmed to perform many operations like Autonomous exploration and mapping, precision farming, surveillance, emergency disaster control management etc.

4. Underwater Robots: Marine research requires the use of underwater robots, such as remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). These robotic systems can travel to parts of the ocean that are too unsafe or challenging for people. Undersea robots can be configured with a broad range of sensors and equipment to gather vast amounts of data from deep-sea environments. They are available in a variety of sizes and configurations..[ref]

5. Soft Robots: Robots inspired by flexible creatures such as octopuses, caterpillars or fish. Soft robots made mostly of flexible or elastic materials may simply adapt to their environment without the need for complex computations. Although some of these devices simulate muscles and tendons with wires or springs, soft robots as a whole have effectively dealt with the skeletons that characterised earlier robot generations. These machines can stretch, twist, scrunch, and squish in entirely new ways since they lack any bones or joints. More safely than ever before, they can change size or shape, wrap around things, and sometimes even touch humans..[ref]

6. Microrobots: A microrobot is a very small robot built to do specific tasks. In general, a microrobot is just a bit larger than a nanorobot, which is created on the nanoscale. Microrobots are usually visible, whereas some nanobots are not immediately visible to the human eye.

7. Humanoid Robot: Professional service robots called humanoids are made to move and interact resembling people. They add value by automating processes in a way that increases productivity and reduces costs, similar to what all service robots do. Humanoids are rather a newer form of service robots. They can be used to effectively increase the tedious work of humans.[ref]

Q3) Some common used electric motors:

1. AC motor: The AC motors are driven by AC current and they are some of the most popular motors in motion control. They use induction of a rotating magnetic field, generated in a stator, to turn the stator and rotor at a synchronous rate. They are typically utilised in demanding situations requiring high torque (high load carrying or load bearing capacity). Because of this, these motors are employed in robotic assembly lines that are installed in manufacturing facilities.

2. Brushed DC motor: The contacts in brushed DC motors are used to carry current from the source to the armature. The brushed DC motor comes in a variety of forms, but permanent magnet DC motors are primarily employed in robots. The high torque to inertia ratio of these motors is well recognised. Three to four times more torque than their rated torque can be produced by brush DC motors. Six separate parts make up a Brush DC motor: an axle, a commutator, an armature, a stator, magnets, and brushes.

3. Brushless DC motors: In terms of construction, brushless DC motors are comparable to brushed DC motors, but they use closed-loop controllers and need inverters or SMPS for power. These motors rotate a fixed armature using permanent magnets. They don't have a commutator assembly like Brush DC motors do; instead, they have a closed-loop electronic controller. In industrial robotics, where precise control over motion and positioning is necessary, these motors are typically employed. However, the electronics and intricate design of these motors make them rather pricey.

4. Geared DC motor: In comparison to brush DC motors, geared DC motors are a more precise application. The motor is coupled with a gear arrangement. Rotation Per Minute is a unit used to express motor speed (RPM). The use of a gear assembly allows for a reduction in motor speed and an increase in torque. A DC motor's speed can be decreased while its torque is increased by utilising the right gearing. The motor can be halted or its speed modified carefully thanks to the stability this provides in its rotation.

5. Servo motor: The angular position can be precisely controlled by a servo motor, which is a rotary actuator. Where an exact rotational motion is needed, servo motors are typically employed. To precisely control the motor's rotating position, the drive makes use of the feedback sensor. They are frequently employed in applications requiring angle control and robotic arms.

6. Stepper motor: A stepper motor divides the rotation into multiple steps. Like the servo motor rotates by a specific angle, a stepper motor rotates by a specific number of angular steps. As long as the motor is appropriately scaled for the application in terms of torque and speed, the position of the motor can be instructed to move and hold at one of these steps without the use of a position sensor for feedback (an open-loop controller).

Q6

Show that columns of R_0^1 are Orthogonal.

Let us take the case of $R_{z,0}$ transformation, We know that $R_{z,0} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

We know that matrix is said to be Orthogonal when

$$Q^T = Q^{-1}.$$

So, here

$$R_0^{1\,T} = R_0^{1\,-1}$$

$$\therefore R_0^{1\,T} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \text{———} \quad \text{A}$$

For, $R_0^{1\,-1}$, we will first determine $\mathrm{Det}(R_0^1)$

$$\mathrm{Det}(R_0^1) = \begin{vmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{vmatrix} = +1[(\cos\theta)(\cos\theta) - (\sin\theta)(-\sin\theta)]$$

$$= \cos^2\theta + \sin^2\theta$$

$$= 1. \neq 0$$

Thus, we can say that the inverse of Matrix R_0^1 is possible.

Now, determining the Adjoint of matrix R_0^1

$$\mathrm{Adj}(R_0^1) = \begin{bmatrix} \begin{bmatrix} \cos\theta & 0 \\ 0 & 1 \end{bmatrix} & \begin{bmatrix} -\sin\theta & 0 \\ 0 & 1 \end{bmatrix} & \begin{bmatrix} -\sin\theta & \cos\theta \\ 0 & 0 \end{bmatrix} \\ \begin{bmatrix} \sin\theta & 0 \\ 0 & 1 \end{bmatrix} & \begin{bmatrix} \cos\theta & 0 \\ 0 & 1 \end{bmatrix} & \begin{bmatrix} \cos\theta & \sin\theta \\ 0 & 0 \end{bmatrix} \\ \begin{bmatrix} \sin\theta & 0 \\ \cos\theta & 0 \end{bmatrix} & \begin{bmatrix} \cos\theta & 0 \\ -\sin\theta & 0 \end{bmatrix} & \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \end{bmatrix} = \begin{bmatrix} +(\cos\theta \times 1) & -(-\sin\theta \times 1) & +(0) \\ -(\sin\theta) & +(\cos\theta) & -(0) \\ +(0) & -(0) & +(\cos\theta \times \cos\theta - (-\sin\theta) \times (\sin\theta)) \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta & +\sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (\because \cos^2\theta + \sin^2\theta = 1)$$

Now, $R_0^{1\,-1} = \dfrac{1}{\mathrm{Det}(R_0^1)} \times \mathrm{Adj}(R_0^1)$

$$= \frac{1}{(1)} \times \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \text{———} \quad \text{B}$$

Comparing A and B, we get

$$R_0^{1\,T} = R_0^{1\,-1}.$$

Thus, we can say that the columns of Matrix R_0^1 are Orthogonal.

Q7

Show that $Det(R_0^1) = 1$.

We know that, $R_{z,0} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$\therefore Det(R_0^1) = \begin{vmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{vmatrix}$

$= +1(\cos\theta \cdot \cos\theta - (-\sin\theta) \cdot \sin\theta)$

$= 1(\cos^2\theta + \sin^2\theta)$

$= 1. \qquad (\because \cos^2\theta + \sin^2\theta = 1)$

Simillarly, other rotation matrix $R_{x,0}$ and $R_{y,0}$ can be expressed likewise.

$R_{x,0} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$

$Det(R_0^1) = \begin{vmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{vmatrix} = +1(\cos\theta \cdot \cos\theta - (-\sin\theta) \cdot \sin\theta)$

$= \cos^2\theta + \sin^2\theta$

$= 1.$

and,

$R_{y,0} = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$

$Det(R_0^1) = \begin{vmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{vmatrix} = +1(\cos\theta \cdot \cos\theta - (\sin\theta)(-\sin\theta))$

$= \cos^2\theta + \sin^2\theta$

$= \underline{\underline{1.}}$

Thus, we can say that $Det(R_0^1) = 1$