Assignment - 1

ME 639 - Introduction to Robotics.

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Q. 6] let us assume rotation matrix $R_0^1 = R_{z,\theta}$

$$\Rightarrow \quad R_0^1 = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$ It is a 3×3 matrix.

$$\therefore \quad R_0^1\Big|_{c=1} = \begin{bmatrix} \cos\theta \\ \sin\theta \\ 0 \end{bmatrix} ; \quad R_0^1\Big|_{c=2} = \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix} ; \quad R_0^1\Big|_{c=3} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Now, to show that the column matrices are orthogonal, we need to verify the condition,

$$\boxed{R_0^1 \cdot R_1^{1\,T} = I}$$

Now, for $c = 1$, i.e. first column,

$$R_0^1\Big|_{c=1} \cdot R_0^1\Big|_{c=1}^{T} = \begin{bmatrix} \cos\theta \\ \sin\theta \\ 0 \end{bmatrix} \begin{bmatrix} \cos\theta & \sin\theta & 0 \end{bmatrix} = \begin{bmatrix} \cos^2\theta + \sin^2\theta + 0 \end{bmatrix}$$

$$= [1]$$

$$= I$$

Now, for $c = 2$, i.e. second column,

$$R_0^1\Big|_{c=2} \cdot R_0^1\Big|_{c=2}^{T} = \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix} \begin{bmatrix} -\sin\theta & \cos\theta & 0 \end{bmatrix} = \begin{bmatrix} \sin^2\theta + \cos^2\theta + 0 \end{bmatrix}$$

$$= [1]$$

$$= I$$

Now, for $c=3$, i.e. 3rd column.

$$R_0'|_{c=3} \cdot R_0'|_{c=3}^T = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} [0\ 0\ 1] = [0+0+1]$$

$$= [1]$$

$$= I.$$

Thus, above calculation shows that,

$$R_0'|_c \cdot R_0'|_c^T = I \quad \text{for } c=1,2,3$$

$\Rightarrow$ The columns of the rotation matrix R_0' are orthogonal

3.7] Let us assume, $R_0' = R_{z,\theta}$ for calculation,

Now, $$R_0' = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\therefore \det(R_0') = \begin{vmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{vmatrix} = \cos\theta(\cos\theta - 0) - (-\sin\theta)(\sin\theta - 0) + 0(0+0)$$

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

$$\boxed{\det(R_0') = 1}$$

Similarly we can proove this for $R_0' = R_{y,\theta}$ and $R_{x,\theta}$.

Question 2:

1. SCARA Robot
   This robot has an RRP configuration. One specific property of SCARA robots id that all the revolute joint's axis of rotation is parallel. The below links show prominent examples of these types of robots.
   a. https://www.youtube.com/watch?v=u1WJJyZP2IM&ab_channel=FUMRoboticsLab
   b. https://www.youtube.com/watch?v=-m1oKuFkSTE&pp=ygULc2NhcmEgcm9ib3Q%3D
2. PUMA Robot
   This robot has an RRR configuration. The below links show prominent examples of these types of robots.
   a. https://www.youtube.com/watch?v=tjOhGqOHfhg&pp=ygUKUHVtYSByb2JvdA%3D%3D
3. Stanford Robot
   This robot has an RRP configuration. The below links show prominent examples of these types of robots.
   a. https://www.youtube.com/watch?v=r4aNOM3IK7A&ab_channel=EmmanuelAyala
4. UAV Robots
   As the name suggests, these vehicles can be controlled by the person outside them. These types of robots have proven to be very useful in various sectors, including the defense and health sectors. One of the most common examples of a UAV is a drone or a quadcopter.
   a. https://www.youtube.com/watch?v=IgMKiIEbfN8&pp=ygUJVUFWIHJvYm90
5. AUV Robot
   AUV stands for autonomous underwater vehicles. These robots are similar to UAVs but can be deployed underwater.
   a. https://www.youtube.com/watch?v=rril44oN63s&ab_channel=KawasakiGroupChannel
6. Humanoid Robot
   These types of robots are fundamentally built to perform the actions of a human, like walking, jumping, dancing, and reacting to their surroundings on their own.
   a. https://www.youtube.com/watch?v=uhND7Mvp3f4&pp=ygUOSHVtYW5vaWQgcm9ib3Q%3D
7. Hybrid robots
   These types of robots are designed for multitasking. The example in the youtube video below is of a vehicle that can propel both in the air and on land.
   a. https://www.youtube.com/watch?v=S4eQXXxUnNE&pp=ygUMSHlicmlkIHJvYm90

Question 3:

The very first differentiation of motors is AC motors and DC motors.
Types of AC motors:

1. Synchronous - The rotor rotates at the same speed as the revolving speed of the stator. It also applies the principle of magnetic field generation due to current passing through a conductor. A 3-phase ac circuit is used.
2. Asynchronous - The rotor speed is not equal to the speed of the stator.

Types of DC motors:

1. Brushed motor - It works on the principle of the current-carrying conductor. When a conductor is energized by passing a current through it, a magnetic field is generated around the conductor, which then reacts with the magnetic field of the permanent magnets inside the motor to cause rotation. It has a brush for completing the electric circuit, so Brushed motor. The brushes have a limited life.
2. Brushless motor -
    a. Normal BLDC - In this type of motor, the windings are done within the permanent magnets. When the current passes through the coil, it produces a magnetic field that reacts with the permanent magnet and results in rotation.
    b. Stepper motor - The principle of working is similar to the typical BLDC motor, but the rotation of the stepper motor is performed in steps. Because of its internal structure, the motor rotates by a fixed amount of angle in a step. Thus the rotation of the motor can be easily calculated by counting the steps.
3. Servo Motor - This motor gives high-precision output. It has a control circuit that provides feedback on the current position of the shaft. This feedback allows the motor to rotate with great precision.