ME 639
Introduction to Robotics

Assignment 1

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2. Examples of Robots

1. Manipulators

    a. SCARA: https://www.youtube.com/watch?v=Te5AfPQFz8U

    This is a RRP manipulator by KUKA robots. It is designed for industrial assembly line operations.

    b. Stanford: https://www.youtube.com/watch?v=r4aNOM3IK7A

    (Only example of Stanford type robot available)

    c. PUMA: https://www.youtube.com/watch?v=k8YllznjkSo

    This is a RRR manipulator.

2. Mobile Robots: https://www.youtube.com/watch?v=3TRjOVSQac8

   Mobile robots are becoming common in automating large warehouses.

3. Aerial Robots: https://www.youtube.com/watch?v=fjjbeltn4Fo

   Zipline has started blood delivery operations via autonomous miniature airplanes in Rwanda where navigating the ground terrain is extremely difficult.

4. Exoskeleton: https://www.youtube.com/watch?v=TFTNlO2Ov7U

   Finger exoskeleton designed for rehabilitation of finger muscles post operations.

5. Underwater Robots: https://www.youtube.com/watch?v=Hsy_ch2uEvE

   This robot has extremely flexible maneuverability making it especially useful to navigate through debris underwater.

6. Soft Robots: https://www.youtube.com/watch?v=qevIIQHrJZg

   This inflatable robot can navigate through tight spaces.

7. Microrobots: https://www.youtube.com/watch?v=N7lXymxsdhw

   This millimeter scale robot can be manipulated using magnetic fields.

3. Different kinds of motors

1. DC Motor: A DC motor has copper coils wound on a soft iron core placed inside a magnetic field of some permanent magnets. The coil is connected to the DC power supply via commutators that ensures correct direction of current through the coil for it to rotate in the same direction. In general, the current through the coil is directly proportional to the torque provided by the motor.
2. Servo Motor: Servo motor generally have a DC motor with additional circuitry to control the position of the shaft of the motor. One can control the position of the servo motor using PWM signals to communicate with the circuitry.

3. Stepper Motor: Stepper motors are used for very high precision shaft positioning. The motor rotates in steps. A stepper driver sends appropriate signals to the motor to take a step (or half a step).
4. BLDC Motors: These motors do not require commutators since the coils are stationary while the permanent magnet rotates to power the shaft. These motors are commonly used for quadcopters and other high speed, low weight applications.
5. AC Motors: These motors are designed to operate directly with AC power.

6. Orthogonal Column Vectors in Rotation Matrix

Let the rotation matrix R_0^1 translate the vector p from the axes (x_1, y_1, z_1) to axes (x_0, y_0, z_0).

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

Similarly, the rotation matrix R_1^0 is given by

$$R_1^0 = \begin{bmatrix} \hat{\imath}_0 \cdot \hat{\imath}_1 & \hat{\jmath}_0 \cdot \hat{\imath}_1 & \hat{k}_0 \cdot \hat{\imath}_1 \\ \hat{\imath}_0 \cdot \hat{\jmath}_1 & \hat{\jmath}_0 \cdot \hat{\jmath}_1 & \hat{k}_0 \cdot \hat{\jmath}_1 \\ \hat{\imath}_0 \cdot \hat{k}_1 & \hat{\jmath}_0 \cdot \hat{k}_1 & \hat{k}_0 \cdot \hat{k}_1 \end{bmatrix}$$

Clearly, $(R_0^1)^T = R_1^0$.

Thus, $p_0 = R_0^1 \cdot p_1$ and $p_1 = R_1^0 \cdot p_0$. But substituting p_0 from the former equation into the latter gives,

$$p_1 = R_1^0 \cdot (R_0^1 \cdot p_1)$$

$$\Rightarrow I \cdot p_1 = (R_1^0 \cdot R_0^1) \cdot p_1$$

$$\Rightarrow R_1^0 \cdot R_0^1 = I$$

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

Let r_{ij} denote the element in ith row and jth column of R_0^1. Thus, from the last equation,

$$\sum_{k=1,2,3} r_{ki} r_{kj} = \delta_{ij}$$

This implies the column vectors have the magnitude 1 and are orthogonal to each other. Hence proved, they are orthonormal.

7. Determinant of Rotation Matrix

From the previous proof,

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

Taking determinant both sides and using the fact that $\det(A^T) = \det(A)$,

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

$$\Rightarrow (\det(R_0^1))^2 = 1$$

$$\Rightarrow \det(R_0^1) = \pm 1$$