ME 639: Introduction to Robotics

Midsem

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Midsem Questions and Answers (Q.5 to Q.9):

5. In the DH convention are all joint axes always aligned with respective z axis?

   Solution: Yes; irrespective of the type of joint, this would be true.

6. In the DH convention, are the origins of all the coordinate frames always at the centres of the joints?

   Solution: No, this is not necessary, the origins of the coordinate frames are at the intersection of the common normal with the previous z-axis.

7. Is it true that a homogeneous transformation consists of both a rotation and a translation?

   Solution: Yes.

8. For a sequence of rotations performed one after the other, can the rotation matrices for each individual rotation be multiplied together to form the overall rotation matrix (capturing the sequence of rotations)?

   Solution: Yes, however, the order of multiplication of matrices should be consistent with the order (sequence) of rotations.

9. Is a composite rotation matrix consisting of a sequence of several rotations still an orthogonal matrix with determinant equal to 1?

   Solution: Yes.

$$Given: \; R_1^T R_1 = R_2^T R_2 = \ldots = R_n^T R_n = I \quad \& \quad \det(R_1) = \det(R_2) = \ldots. = \det(R_n) = 1$$

$$Let \; R = R_1 R_2 \ldots R_n \implies \det R = det(R_1 R_2 \ldots R_n) = \det(R_1)\det(R_2)\ldots\det(R_n) = 1$$

$$Also, \; R^T = (R_1 R_2 \ldots R_n)^T = R_n^T R_{n-1}^T \ldots R_1^T$$

$$\therefore R^T R = (R_n^T \ldots R_2^T R_1^T) \cdot (R_1 R_2 \ldots R_n) = (R_n^T \ldots R_2) R_1^T R_1 (R_2 \ldots R_n) = I$$

Answer to Question 2:

Part (a): A soft gripper is more suitable for pill-picking purpose. There are two main reasons for this:

1. A hard gripper cannot handle fragile objects like pills, glass items, etc. and they would crush the object, whereas a soft gripper can handle it without damaging it.
2. A soft gripper matches the object regardless of its shape (due its compliant nature), that is, it can fit different objects between its grip and hence they are faster than hard grippers. Also, these grippers can be used for a variety of pills rather than just one pill due to this feature.

Part (b): Flexible mechanisms, soft robotic grippers, universal grippers, origami robots and paper grippers are all relevant ideas for the application of pill-picking.

Flexible mechanisms allow lesser parts to be used in the robot or the machine setup, reduce friction and wear, and therefore allow longer life of the robot as well as reduce the costs.

Soft robotic grippers and universal grippers allow a variety of objects to be picked up by the gripper. Apart from the advantages of the soft grippers mentioned in 'Part (a)', the universal gripper also works on the same principle (compliance) or works on vacuum in order to be able to suck objects of various shapes.

Origami robots are also relevant due to their ability to fold on the spot into the desired shape as per the requirement of the task. Thus, again the need for a gripper that can pick objects of different shapes and build is satisfied by origami robots.

Paper grippers are connected to origami robots as they are exploiting the origami technique to make paper-based soft robots that give the advantages of easy fabrication, lightweight, low-cost and even variable stiffness[5].

References:

1. Website For Soft Grippers
2. Video on Flexible Mechanisms
3. Video on Origami Robot by MIT
4. Video on Universal Gripper
5. Research Paper on Paper-made Grippers

Answer to Question 3:

Part (a): I measured my own hip-to-knee and knee-to-ankle distances and they came out to be $40.5\ cm$ & $39.1\ cm$ respectively. Therefore:

$$Link\ length\ 1 : l_1 = 0.405\ m$$

$$Link\ length\ 2 :\ l_2 = 0.391\ m$$

Gait Trajectory: In gait analysis, the patient's lower body is marked with sensors at specific points (reference points) and the patient is asked to walk on a treadmill. The trajectory recorded by these sensors during this time is called the gait trajectory. In other words, it is the movement of lower limb segments and joints recorded by sensors placed on the lower body.

Step Height: It is the clearance from the floor that the foot achieves while lifting the leg during walking.

Step Length: It is the distance covered in one step (of either foot) starting from a position where both right and left foot are together.

Answer to Question 4:

Part (a): D-H Parameters for a robot (shown in figure) with a single link and a single revolute joint is given as follows:

Link 1	a_i	α_i	d_i	θ_i
1	a_1	$0°$	0	θ

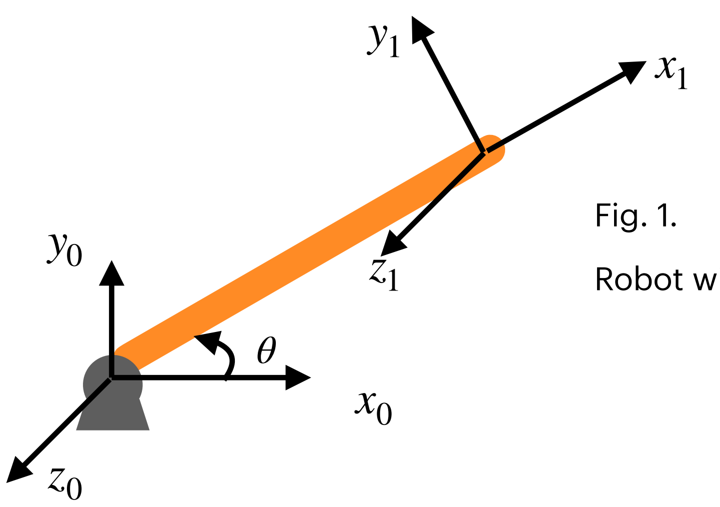

Fig. 1.

Robot with single link and single revolute joint

Part(b): If the joint behaves as a torsional spring (of coefficient K), then it exerts a potential energy equal to:

$$V_{torsional} = \frac{1}{2}K\theta^2$$

Since gravity is not considered, the total potential energy is equal to:

$$V = V_{torsional} = \frac{1}{2}K\theta^2$$

The kinetic energy can be written as:

$$T = \frac{1}{2}I\dot{\theta}^2$$

Therefore, $L = T - V = \frac{1}{2}I\dot{\theta}^2 - \frac{1}{2}K\theta^2 \;=\; \frac{ml^2}{6}\dot{\theta}^2 - \frac{1}{2}K\theta^2$

$\therefore \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) - \frac{\partial L}{\partial \theta} = \tau \implies \frac{ml^2}{6}\ddot{\theta} + K\theta = \tau$ (Equation of Motion for this system)

1(d)

$$\underset{(p_x, p_y, p_z)}{A} \longrightarrow \underset{(p_x', p_y', p_z')}{B} \longrightarrow C$$

(p_x', p_y', p_z') ↳ similar procedure

(p_x, p_y, p_z)

↓ Inverse Kinematics

Joint variables

↓ D-H parameters & orientation

Jacobian

↳ xdot ≡ given

$$\dot{x} = J(q)\,\dot{q}$$

↳ $\dot{q} = J(q)^{-1}\dot{x}$

↳ changing points with 1 cm interval, keeping velocity same

↳ joint variables & joint velocities at that point