Assignments 3 & 4
ME 639 - Introduction to Robotics
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Q1
The configurations where a parallel robot loses its rigidity in which
the end-effector degree of freedom becomes uncontrollable. One good
example of a singular configuration is q1 and q2 (taken concerning
the base frame), which are zero for a 2R planar manipulator. Also,
the points that do not belong to the manipulator's workspace can be
the points of singular configuration.
Yes, at the singular configurations, the Jacobian matrix of the
manipulator loses its rank. So, by calculating the rank of the
Jacobian, we can determine whether the configurations are singular or
not.

Q4
I have taken a simple RRP SCARA configuration. In this, most simple
DH parameters are taken.

	a_i	α_i	d_i	θ_i
1	a_1	0	0	θ_1^*
2	a_2	180°	0	θ_2^*
3	0	0	d_3^*	0

Schematics of SCARA Robot   DH Parameters

I have taken a1 = a2 = 0, d3* = 1, θ1* = 0, and θ2* = 0.

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Your DH Matrix is as below:
0 0 0 0
0 0 0 180
1 0 0 0
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The end effector position is [0.] i + [0.80115264] j + [−0.59846007] k

Q7
Direct-Drive Configuration:
In a direct drive 2R manipulator, each joint is directly connected to the actuator. This means that the motor is directly connected to the joint shaft of the link.
<u>Advantages:</u>
- It has a simple design
- It provides high torque and precision.
- It reduces backlash.

<u>Disadvantages:</u>
- It provides a limited range of motion.
- It cannot provide high speed.

Remotely-Driven Configuration:
In a remotely driven 2R manipulator, each joint is not directly connected to the actuator but instead located remotely and drives the joint through some form of linkage or mechanism.
<u>Advantages:</u>
- Increased range of motion.
- The robot arm can be smaller, making it suitable for compact spaces.
- The remote linkage allows for control over the trade-off between speed and torque.

<u>Disadvantages:</u>
- This configuration contains an additional mechanism that increases the complexity.
- The additional linkage can reduce precision.

5-Bar Parallelogram Arrangement:
In this design, the 2R manipulator is designed in a parallelogram shape where both joints are connected in a way that forms a closed-loop parallelogram.
<u>Advantages:</u>
- It maintains the original orientation throughout the task.
- It reduces the chances of attaining singularity.
- It enhances the stability of the structure.

<u>Disadvantages:</u>
- It has a limited range of motion.
- It also reduces the flexibility of the structure.

Q10.
- First, we find the kinetic energy using D(q).
- Now L = K - V, put the value of K(kinetic energy calculated in the first ste $\frac{\partial L}{\partial \dot{q}_k}$ a $\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_k}$ '(q). $\frac{\partial L}{\partial q_k}$
- Find the valu $\frac{\partial L}{\partial \dot{q}_k}$ f $\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_k}$, and

- Apply the Euler-Lagrange equations to derive the equations of motion:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = \tau_i$$

- By interchanging the order of summation and using symmetry, we get the Euler-Lagrange equation in the form:

$$\sum_{i,j}\left\{\frac{\partial d_{kj}}{\partial q_i} - \frac{1}{2}\frac{\partial d_{ij}}{\partial q_k}\right\}\dot{q}_i\dot{q}_j = \sum_{i,j}\frac{1}{2}\left\{\frac{\partial d_{kj}}{\partial q_i} + \frac{\partial d_{ki}}{\partial q_j} - \frac{\partial d_{ij}}{\partial q_k}\right\}\dot{q}_i\dot{q}_j$$

- Here comes a notation that reduces our efforts of involving the symbols in computing: the Christoffel symbol(c_{ijk}).

$$c_{ijk} \qquad \frac{1}{2}\left\{\frac{\partial d_{kj}}{\partial q_i} + \frac{\partial d_{ki}}{\partial q_j} - \frac{\partial d_{ij}}{\partial q_k}\right\}$$

- In the end, we determine a function Φ_k as:

$$\phi_k = \frac{\partial P}{\partial q_k}$$

- Now we get the Equation of motion:

$$\sum_i d_{kj}(q)\ddot{q}_j + \sum_{i,j} c_{ijk}(q)\dot{q}_i\dot{q}_j + \phi_k(q) = \tau_k, \qquad k = 1,\ldots,n$$