Simulation of Robotic Systems 2025

Laboratory Works Assignment

Task 4: Actuation and PD Control of the OPTIMUS Mechanism.

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1. Objective

The goal of Task 4 is to extend the passive OPTIMUS mechanism (from Task 3) by:

- Adding one actuator to joint (q1**).**
- Adding sensors for joint position and velocity
- Defining a sinusoidal reference using the assigned parameters (AMP, FREQ, BIAS)
- Implementing a PD controller to track the reference
- Ensuring the motion stays inside the workspace

2. Assigned Control Parameters

(Tab.1: Geometric Parameters Assigned for Mechanism Control)

Joint	AMP (deg)	FREQ (Hz)	BIAS (deg)
q1	**33.61°**	**2.7 Hz**	**26.8°**

Converted to radians:

- AMP = 0.5866 rad
- FREQ = 16.9646 rad/s
- BIAS = 0.4670 rad

Reference trajectory:

$$q_{\text{des}}(t) = 0.5866 \sin(16.9646\, t) + 0.4670$$

3. XML Modifications

The actuator and sensors were added to the MuJoCo model as required:

```
<actuator>
   <motor name="A_motor" joint="A" ctrlrange="-5 5" gear="1"/>
</actuator>
<sensors>
   <jointpos name="q1_pos" joint="A"/>
   <jointvel name="q1_vel" joint="A"/>
   <framepos name="P_pos" objtype="site" objname="sP"/>
</sensor>
```

This gives control authority over joint A (q1) and allows measurement of position, velocity, and endpoint P.

4. PD Control Law

The PD controller used is:

$$\tau = K_p(q_{\text{des}} - q) + K_d(\dot{q}_{\text{des}} - \dot{q})$$

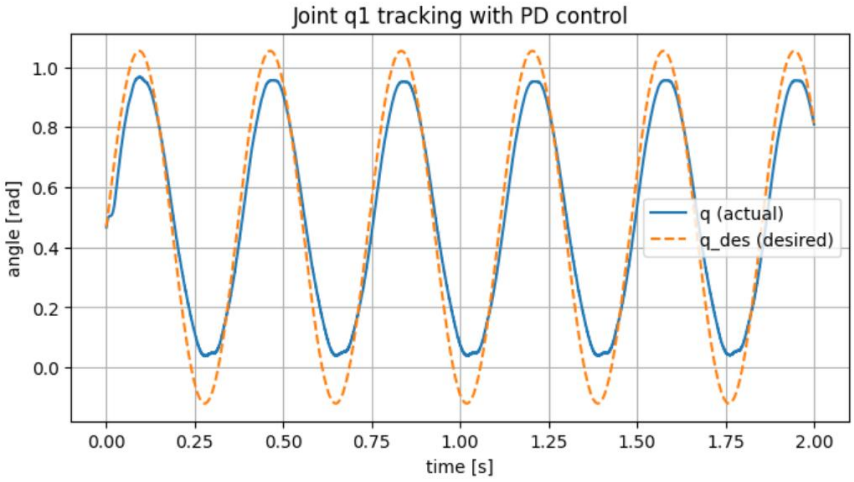
Gains used: Kp = 80 and Kd = 5

Python implementation:

```
q_des  = AMP * np.sin(FREQ * t) + BIAS

qd_des = AMP * FREQ * np.cos(FREQ * t)

tau = Kp*(q_des - q) + Kd*(qd_des - qd)

data.ctrl[0] = tau
```

5. Results

The PD controller successfully drove joint q1 to follow the sinusoidal reference. The mechanism remained stable, and the loop-closure constraint was preserved. Motion stayed inside the workspace without requiring amplitude reduction.



(Fig.3:Real Tracking Plot q vs q_des)

7. Conclusions.

Task 4 was successfully completed.
The actuator and sensors were implemented in the XML file, the PD controller was developed, and the mechanism tracked the desired sinusoidal reference accurately.
Simulation results confirm stable motion and correct closed-chain behavior.