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Humanoid Robotics

Assignment 7

Due **Tuesday, June 17th**, before lecture.

Object Manipulation and Trajectory Generation:

1. Uncommon Gripper Type from Literature (Total: 3 points)

In the lecture we discussed different types of grippers. Identify one gripper (or end - effector) from the robotics literature that is not a standard 2 - finger parallel - jaw gripper, multi - finger (e.g. 5-finger) hand, or vacuum - based suction cup. (Tip: look for recent conference papers—examples include underactuated “soft” grippers, gecko-adhesive pads, or the ROSE-Gripper as discussed in the lecture):

Please provide:

a. **Name & Reference:** Full name of the gripper, authors, publication venue, and year.

b. **Working Principle:** How does it grasp? Describe its actuation method (e.g., rotation-based squeezing, adhesion, compliance, etc.) and key mechanical/fabrication elements.

c. **What Makes It Uncommon:** Explain why this gripper is “uncommon” compared to typical parallel-jaw or multi-finger hands. Is it the geometry, the materials, the actuation strategy, the contact model, or something else?

d. **Advantages & Limitations:**

- List at least two advantages (e.g., gentle compliance, ability to handle highly irregular shapes, reduced hardware complexity).
- List at least two limitations or challenges (e.g., limited force, sensitivity to surface conditions, speed constraints).

e. **Application Scenario:** Give one concrete scenario (pick a specific object type or manipulation task) where this gripper would outperform a standard parallel-jaw gripper, and explain why.

2. Friction Cone & Maximum Liftable Load (Total: 4 points)

Consider a simple planar (2D) parallel-jaw gripper grasping a block of mass m by pinching it on two opposite faces. Each finger applies a normal force F perpendicular to the contact surface. The contact between each finger and the block is modeled as a **hard-finger** model. Assume static friction coefficient μ between the finger pads and the block.

Consider a block of unknown mass m, gripped by a parallel-jaw gripper with each finger capable of applying F=80N. The fingertip material and the block surface together give μ=0.3. Use g=9.81m/s2.

a. Compute the half-angle θ of the friction cone in degrees.

b. Find the maximum frictional force ft,max at each finger.

c. Determine the maximum mass m_max that the gripper can lift without slipping.

d. Suppose the block's actual mass is m=2.0kg. Verify whether this gripper can lift it. If not, compute the **minimum** normal force Fmin each finger must apply (for the same μ=0.3) to just barely lift a 2.0kg block.

You can decide if you want to do this exercise in python or pen-and-paper. If you decide for the latter, please upload it as pdf to your solutions.

3. Trajectory Interpolation **(Total: 8 points)**

In this task, you will implement various trajectory-parameterization schemes for a single- and multi-degree-of-freedom manipulator using the concepts introduced in the Trajectory Generation section of hr06_manipulation_2.pdf. Clearly define your functions, document inputs/outputs, and include brief comments explaining your approach. You may use Python and NumPy; plotting libraries (e.g., Matplotlib) are permitted for visualization. Ensure your solutions work for arbitrary number of multiple joints for c and d.

a. Implement a **constant velocity trajectory interpolator** for a single joint that has a maximum joint speed of **90** degrees/s. At t=0, the joint position is π radians. The goal joint position is **-2.5** radians. At what time will it reach the desired the goal state? Use a cycle time of **0.01** seconds for interpolation. Plot joint position and velocity curves. **(1 point)**

b. Implement a **trapezoidal velocity interpolator** for a joint that has a maximum joint speed of **90** degrees/s and a maximum acceleration of **180** degree/s2. It should ensure that when motion duration is too low, it skips the constant velocity phase. Plot the joint position, velocity and acceleration curves for the following two cases. Use a cycle time of **0.01** seconds for interpolation. **(3 points)**

- Initial position = **0** radians, Final position = π radians
- Initial position = **0.1** radians, Final position = $\pi/4$ radians

c. Extend the **trapezoidal velocity interpolator** for **multiple joints in vectorized fashion**. Calculate the time required and attained peak velocity for each joint to reach its goal. Plot the position, velocity and acceleration curves. Use a cycle time of **0.01** seconds for interpolation. **(2 points)**

Joint	Initial (radians)	Final (radians)	Maximum Speed (degree/s)	Maximum Acceleration (degree/s2)
1	0.5	2.0	45	90
2	-0.2	0.4	90	90
3	1.0	0.5	30	90

d. Now implement **synchronized multi-joint trapezoidal velocity interpolator** so that all joints reach the final position at the same time. Plot the position, velocity and acceleration curves. Use a cycle time of **0.01** seconds for interpolation for the example given in c. Compare and contrast c vs d using the plotted curves and explain which one is preferred and why. **(3 points)**