ECE 383/MEMS 442/ECE 590 Lab 4: Feedback Control and Trajectory Control

Due date: 11/13/2016 at 5pm

Instructions: This assignment is to be completed *individually*. You are allowed to discuss the problems with your classmates, but all work must be your own. You are not permitted to copy code, take written notes, or look up online solutions.

All coding will be done on the Klamp't Docker container on http://vm-manage.oit.duke.edu/. You may wish to revisit the Klamp't robot documentation at

http://motion.pratt.duke.edu/klampt/pyklampt_docs/classklampt_1_1robotsim_1_1RobotModel.html

and the IK documentation at

http://motion.pratt.duke.edu/klampt/pyklampt_docs/namespaceklampt_1_1model_1_1ik.html

To submit, copy your code from the browser to a file lab4.py, and submit it on Sakai.

A. PID control

Throughout this assignment you will be considering a SCARA robot, which is a serial 3RP mechanism. It has two revolute joints in line with the Z axis, a third in line with the X axis, and then a prismatic joint pointing along the Z axis. You will be controlling it via torque control.

1. An incomplete PID controller is provided for you. Right now, it only computes the P term. Complete this function by computing the I and D terms. Also, use the provided quantities to update the integral term.
2. The provided constants for the PID controller work quite poorly for this problem. Tune the constants to provide improved behavior. Explain in the comments section why you chose these constants.
3. Gravity acting on the weight of the end effector applies a constant force in the Z direction which should be resisted by a force on the prismatic joint. Implement a feedforward gravity compensation controller. In the comment section in the bottom of the file, describe how this term helps with more accurate control in the Z direction.

B. Trajectory control

The robot's job is to move the tool tip along a given set of strokes on the plane. For this problem you will develop a controller to do so. You are free to solve this problem however you wish, according to the following guidelines:

- The tool tip's Z coordinate should lie within the range [-0.005,0] as it draws the strokes. It should be brought above 0.005 while the tool is in transit to the beginning of the next stroke.
- The tool should be held approximately vertical while drawing (q_3=0).

- The torques applied to each joint should not exceed their limits.
- The velocity of each joint should not exceed 2 radians / s.
- The strokes drawn by the robot should not exceed 0.005m deviation from the input strokes.

A recommended method is the following:

- Develop an IK solver that takes as input a 3D target position and outputs a configuration. Make sure the configuration has a consistent elbow bend.
- Develop a state machine that gradually moves the target position along the strokes of the letter.
- Limit the target position's velocity to stay within the joint velocity bounds. (The determinant of the Jacobian may be helpful here to determine an appropriate limit.)
- [Note: for even smoother motion, you might also decide to gradually speed up / slow down the trajectory at the beginning / end of each stroke.]

Right now, a sequence of strokes spelling out the initials KH are provided for you. As the tool tip Z coordinate moves below zero, its stroke will be drawn in the visualization.

Explain the rationale behind your method in the comments section. Also, to demonstrate that your controller works in more general cases, change the "KH" to your own initials.