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ME 449 Assignment 3

Introduction:

Please see details for each test case and answers to all questions below. The code can be run by executing the file “run.py”.

Part 1:

a. Case 1a: dt = 0.005 s, t = 4 s, stiffness = 0 N/m, damping = 0 Nms/rad
b. Case 1b: dt = 0.1 s, t = 5 s, stiffness = 0 N/m, damping = 0 Nms/rad
c. To calculate the total energy, you would need to first calculate the kinetic and potential energy for each link. Kinetic energy for the links can be calculated using the equation KE = ½ mv^2, where m is the mass of the link and v is the magnitude of the velocity of the link. Potential energy is calculated using the equation PE = ½ mgh, where m is the mass of the link, g is the gravitational constant, and h is the height of the center of mass of the link, relative to a fixed referenceus point. In this case, it would be reasonable to use the origin of the space frame as the reference point, meaning the heigh of each link is equivalent to the z coordinate in the space frame. Once PE and KE are calculated for each link, they should all be summed together to calculate the total energy. This value should stay constant if friction is ignored and there is no input from the robot joints.

Part 2:

a. Case 2a: dt = 0.01 s, t = 5 s, stiffness = 0 N/m, damping = 2 Nms/rad
b. Case 2b: dt = 0.01 s, t = 5 s, stiffness = 0 N/m, damping = -0.025 Nms/rad
c. If an excessively large damping value is used, the simulation runs for a short period of time and then stops (the larger the damping value, the quicker the simulation stops). I suspect this is a result of the large damping force causing the robot to not only slowdown, which is expected behavior for a damper, but actually reverse direction. This would happen if a joint experiences a high damping force for a long time interval, dt. In reality, as the joint slows, the damping force is reduced. However, in simulation, if dt is too long, it has the effect of a joint with a constant torque, rather than a torque than varies with speed. By decreasing the time step, dt, the joint toque is updated more frequently, and therefore the joint never outputs a single torque for excessively long. Therefore, the joint direction is never reversed by the simulated damping toque, and the simulation runs smoothly.

Part 3:

a. Case 3a: dt = 0.01 s, t = 10 s, stiffness = 10 N/m, damping = 0.5 Nms/rad
b. Case 3b: dt = 0.01 s, t = 10 s, stiffness = 50 N/m, damping = 3.0 Nms/rad
c. In both cases, the motion of the robot does make sense. With only a spring in the system, the robot would oscillate indefinitely, as the spring would not remove any energy from the system.

The kinetic energy of the robot is converted to potential energy in the spring and vice versa as the robot oscillates. With a damping force applied, the energy should decrease, as the damping force acts to remove energy from the system. This is what can be seen in the video for case A. The robot oscillates several times, but each time, it travels a shorter distance as the damper slows the joints and removes energy. In the video for case B, with the higher damping and stiffness, the robot is pulled directly toward the pinned end of the spring by the spring force. The higher damping causes the robot to slow more quickly. As a result, the robot is nearly stationary and pointing directly at the spring pinned point by the end of the video. If a very large spring stiffness is used (>>100), the robot appears to essentially go crazy and flails all over the environment. This is because the spring is causing the robot to oscillate with such force that it begins to spin and lose control. This can be mitigated with a higher damping force to stop the robot from gaining too much speed when it experiences a high spring force.