Advanced Dynamics Project (Spring 2019)

Final Project: 3-DOFs Scalar Robot Manipular Dynamics and Control
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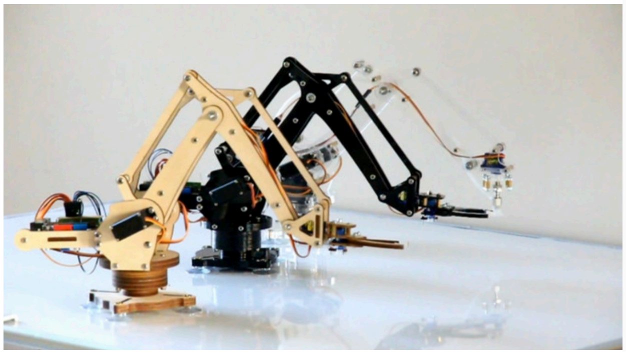
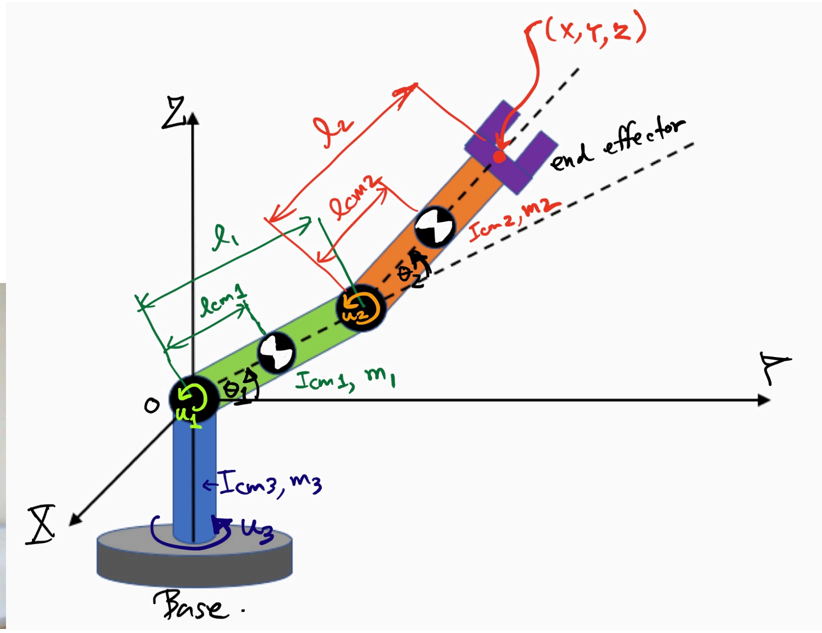
In this project, we will explore the dynamics and control of 3-DOFs Scalar Robot Manipulator which is commonly used in many industrial applications. The robot in figure below describes how a scalar robot operates in workspace given the reference coordinate frame XYZ. The robot has 3-DOFs including rotation at joint 1 (along X axis), rotation at joint 2 (along X axis) and rotation at joint 3 (along Z axis). The end effector position is described by (x,y,z).





a) uARM robot manipulator (left) b) diagram and related parameters (right)

Parameters:

l1:	Length of link 1 (Green) [1 m]
l2:	Length of link 2 (Orange) [1 m]
lcm1:	Center of mass position of link 1 with respect to joint 1 (@u1) [0.5 m]
lcm2:	Center of mass position of link 2 with respect to joint 2 (@u2) [0.5 m]
theta1, theta2, theta3:	Angle of joint 1,2 and 3 respectively [rad, deg]
m1, m2, m3:	Mass of joint 1,2 and 3 respectively [50, 50, 50 Kg]
Icm1, Icm2, Icm3:	Moment of inertia @ CM [10, 10, 10 Kg.m^2]
(x,y,z):	End effector position [m]
XYZ:	Global coordinate system as world reference
u1, u2, u3:	Control inputs = Motor torque [N.m]
kr1, kr2, kr3:	Gear ratio of motor at joint 1,2,3 [kri = 100/1]
Imotor1, Imotor2, Imotor3:	Moment of inertia of motor at joint 1,2,3 [0.01, 0.01. 0.01 Kg.m^2]
g:	Gravity (9.81 m/s^2)

Q1: Derive forward kinematics relationship, given all joint angles theta1,2,3, what's the end effector position (x,y,z) as a function of joint angles and the robot parameters.

Q2: Derive inverse kinematics relationship, given the end effector position (x,y,z), what're the joint angles (theta1, theta2, theta3) as a function of (x,y,z) and the robot parameters?

[50 Points] Must include a plot to verify whether the forward and inverse kinematics mappings are correct. For example, you may create desired trajectory of the end effector (x,y,z), then calculate the joint angles, then cross check again whether the calculated joint angles give the same end effector (x,y,z) or not.

Q3 [50 Points]: Derive the equations of motions (EOMs) of this 3-DOFs Scalar Robot Manipulator. Let define the state as X=[theta1, theta2, theta3]'; X_dot = f(X, u, t, robot parameters) = ? Note that Xdot dimension is 6x1. Simulate open loop response by

- Let initial posture is theta1 = 90 deg, theta2 = 0 deg, theta3 = 0 deg.
- All control inputs are inactive (ui = 0)
- Don't forget about the gravity.
- Create a Simmechanics model to demonstrate this motion in 3D, summit Simmechanics model, Plots of all states, and recorded robot motion video.

Q4 [Extra Credit 30 Points]: Create the controller for trajectory tracking. You may create the desired trajectory of the end effector. You should adapt the control law derivation from the case of 2-DOFs Scalar robot manipulator. First thing to check is that the simulation result should be the same if there's no rotation at joint 3 (theta3 is fixed). If your model is valid from this point, then let explore the controller performance when operating in 3D space. A well-designed controller should be robustly stable and achieve the tracking performance (small tracking error). Note that tracking error = desired goal – actual response (i.e. error of theta1 = desired theta1 – actual theta1).

- Show your work on the control law derivation! Stability Check?
- Given the desired trajectory (x,y,z) → derived the desired joint angles (theta1d, theta2d, theta3d)
- Given the states are all zeros, simulate the closed loop response. Summit Matlab, Simmechanics models, comparison plots between desired (x,y,z) vs actual (x,y,z), comparision plots between desired joint angles vs actual joint angles. Error plots are optional. Also summit the recored robot motion video)