HW#2, 9/27/17

Robot Dynamics

Due: Sunday, 10/8/2017 @11:59 PM

Assignment Objective

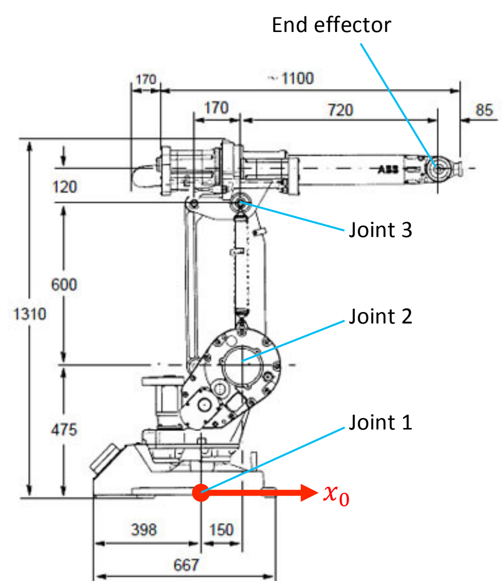
This homework covers topics from Lectures 4-5 of RBE501 and is designed in direction of the course outcomes – objectives #1-3, 5-6, and 8 as in the syllabus – to assess your ability of kinematic modeling and analysis, deriving workspace, solving for inverse position and velocity kinematics and singularity, and developing simulation of serial manipulators.

Problem#1

Consider the ABB IRB1400 articulated arm in its home position with the dimensions shown below in millimeters.

Important: Consider the ABB robot with 3-DOF exactly the same as the Elbow Manipulator! In other words, assume that the robot has ONLY three joints with the configuration/geometry shown below. So, disregard any additional joints you see at the wrist.

The ABB IRB1400 Robot



The robot in its home position

a) Represent the workspace of the robot both **mathematically** and **visually**. For visualization, you can use any software that you know and feel comfortable with. It could be CAD software, MATLAB, etc. Note: Representing the workspace mathematically means that you need to come up with the equations of boundary of the workspace from the Side view (2D). Since the joint rotation limitations affect the final shape of the workspace, from the home position, consider

± 90, ± 60, and ± 60 degrees for Joint1, Joint 2, and Joint 3 respectively. For Joint 2 and Joint 3, consider z+ coming out of the plane.

b) Attach a spherical wrist to the end-effector of the robot while in its home position. Then, write the complete inverse kinematics solution (Position and Orientation) for this 6-DOF robot. Remember, spherical wrist theoretically acts as a point and therefore has no dimensions. Note: Adding a spherical joint to the robot's end-effector will add 3 DOF which makes the robot to have total of 6-DOF (Elbow manipulator + Spherical wrist). The homework is designed to be similar to the example solved in Chapter 3 of the book, so it should be easy for you to solve for the inverse kinematics of the robot.

c) Using the solution for Part b, calculate the six joint angles of the robot for the following given/desired homogenous transformation matrix of the robot:

$$H = \begin{bmatrix} 1 & 0 & 0 & 500 \\ 0 & 1 & 0 & 100 \\ 0 & 0 & 1 & 1500 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

d) Derive the $6\times n$ Jacobian matrix of the robot without the spherical wrist. (The geometric Jacobian)

e) Calculate the joint velocities of the robot leading to the end-effector velocity of $\dot{\vec{x}} = [5 \quad 5 \quad 10 \quad 0 \quad 0 \quad 0]^{T}$. Consider the robot in the position given in Part c (last column of H) and without the spherical wrist.

f) With mathematical proof, derive and discuss singularities (singular configurations) of the robot without spherical wrist. Show your work and illustrate examples of singular configurations for clarity.

<u>Extra Credit:</u> Provide a MATLAB code, which simulates the robot (without the spherical wrist) showing that the end-effector of the robot goes to any arbitrary given/input position in its workspace. This is simply the inverse position kinematic problem.

<u>Note: When solving the problems, if you think something is missing or not give, just make your own assumptions. Your assumptions should be clear.</u>

Good Luck!