University of British Columbia
Department of Electrical & Computer Engineering
EECE 487 (Winter 2012-2013): Introduction to Robotics
Assignment #4, due Tuesday March 26

This is a group assignment. Please form groups, preferably of 5 students each, and of no more than 6 students.

- All necessary Matlab files and supporting documentation must be e-mailed to the teaching assistant Mr. Omid Mohareri (*omidm@ece.ubc.ca)* by 2 pm Tuesday March 26th.
- You will demonstrate your work to Ms. Mahdavi in a 30 minute meeting on Thursday March 28 or Friday March 29th. Instructions on how to set up the times will be found at *http://www.ece.ubc.ca/˜omidm/eece487.htm*

  In this meeting, which will take place in MCLD 306, you will demonstrate your results and code. All group members must be present to answer the TAs questions.
- The marking scheme is 40% for the approach/code (group), 25% for questions (individual questions answered during the interview with the TA) and 35% for the report (group).

Exercise #1. Kinematics of SCARA robot with spherical wrist.

(a) Solve the manipulator direct kinematics.
(b) Determine the manipulator Jacobian symbolically and discuss when singularities occur.
(c) Solve the manipulator inverse kinematics.

Exercise #2. Teleoperation system.

You will set up a teleoperation system in which you will use the Novint haptic device to control the robot gripper.
(i) Examine the instructions on how to link the Novint to Matlab so that the Novint is controlled in real time. Interface the Novint Falcon haptic interface to Simulink and set it up in PD control mode with relatively low gains, comfortable to the hand.
(ii) Set up a model of the SCARA robot that can be displayed on the screen in real time as a function of the joint angles.

(iii) Use the Novint to control the SCARA gripper motion. Because the Novint has three degrees of freedom, while the robot gripper has six, you will control three degrees of freedom at a time - the gripper translation (with fixed orientation), and the gripper orientation (with fixed translation).
When the gripper orientation is fixed, the Novint will control gripper translation. That is, $\underset{\sim}{o}_6$ follows the vector direction of the Novint deflection from its nominal center, i.e., when you lift the Novint handle, $\underset{\sim}{o}_6$ should move up (positive $\underline{k}_0$ direction), when you move the Novint handle to the right, the robot should move to the right (positive $\underline{i}_0$ direction), when you move forward, the robot should move forward (positive $\underline{j}_0$ direction). In order to do this, if (in the same coordinate system, e.g. $\{\underset{\sim}{o}_0, \underline{C}_0\}$) the Novint deflection is $x_m = [a_m \ b_m \ c_m]^T$, set $v = [x_m^T \ 0 \ 0 \ 0]^T = [a_m \ b_m \ c_m \ 0 \ 0 \ 0]^T$, solve for $\dot{q} = [\dot{\theta}_1 \ \dot{\theta}_2 \ \dot{d}_3 \ \dot{\theta}_4 \ \dot{\theta}_5 \ \dot{\theta}_6]^T$ from $v = J(q)\dot{q}$, where $J(q)$ is the coordinate representation of the robot arm Jacobian, then integrate joint rates to obtain q from v and $J(q)$ from q. The wrist angles will be left unchanged, since the angular velocity entries are zero.
When the gripper translation is fixed, the Novint will control the gripper orientation. Set $v = [0 \ 0 \ 0 \ x_m^T]^T$, (wrist angular velocity is equal to the Novint deflection), then follow the same approach.
Try to move the robot to a singular configuration. What happens? Why? Demonstrate your system to the Teaching Assistant.
Note that you may need to use a dead-band to have the robot stop when the joystick is released or held softly, and that you will have to adjust the scaling to have reasonable robot velocities that you can see on the screen.

Exercise #3. Inverse kinematics-based Resolved Motion Control

Repeat **Exercise #3** (iii) by using an inverse kinematics approach. Discuss the relative advantages of the two methods.

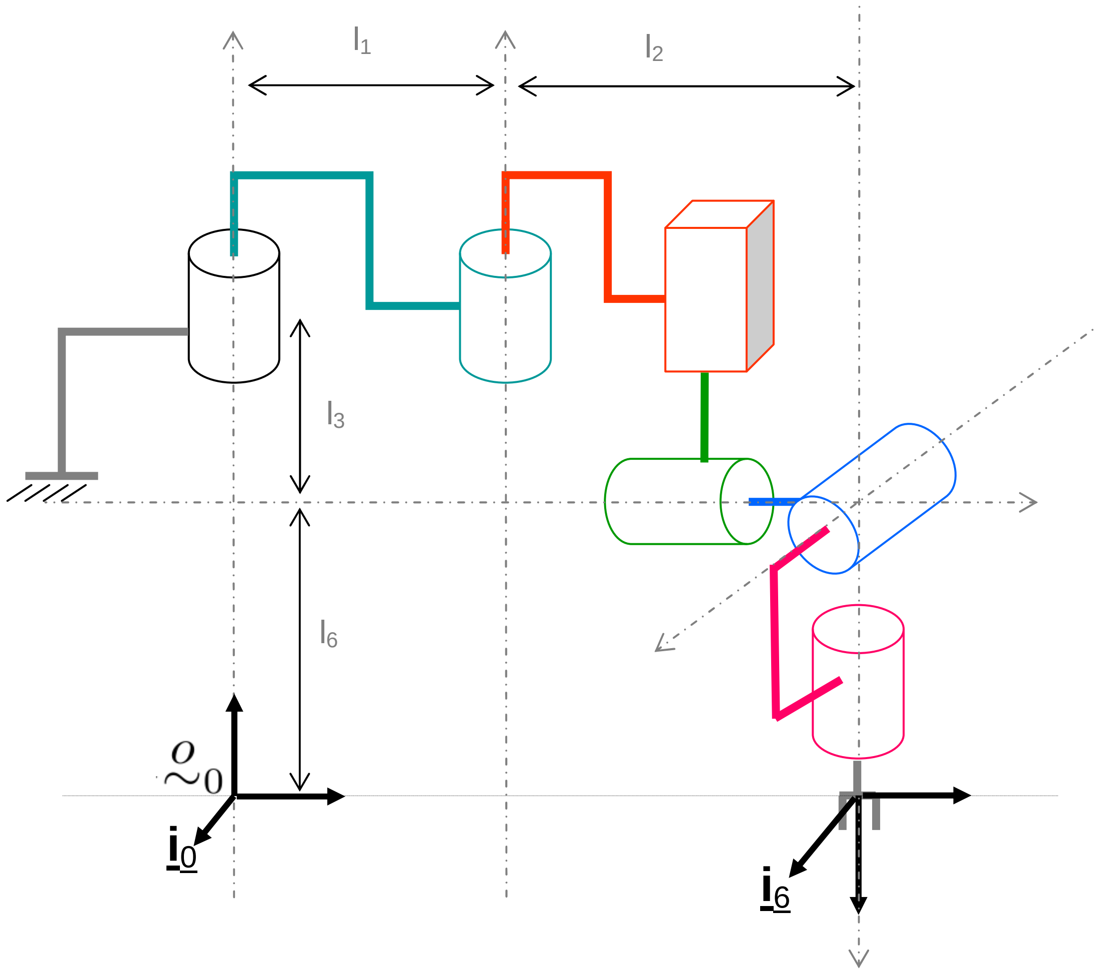

Figure 1. SCARA arm with spherical wrist. Take $l_1=1$m, $l_2=1$m, $l_3=0.5$m $l_6=0.2$m.