ME7752: Mechanics and Control of Robots.
Homework 1

Due Sept 9, 2015
Instructor: Professor Manoj Srinivasan

Guidelines. Please upload a MATLAB program into the homework dropbox on Carmen if such submission is explicitly asked for – or if you wrote one even if not. Please also submit **human readable and well-commented** MATLAB program print-outs. You must use meaningful variable names, not meaningless names such as a, b, c, p, q, r, etc. Google 'style guide for MATLAB programming'. We need SEPARATE programs for each sub-question. Do not combine Q1b and Q1c, etc. This makes it impossible to grade.

For Carmen Dropbox submissions, please follow guidelines in the Course Guidelines handout, especially the naming conventions, recalled below. a) You submission should be a single zip file of a folder containing all your code. b) Name the folder Lastname_Firstname_HWnumber. Thus when you compress this folder, the compressed file will have the file name Lastname_Firstname_HWnumber.zip. (that is, do not name the folder HW1, then compress it and then change its name!) c) If the homework has multiple questions that require code submission, please separate the code into separate folders inside your submission folder (appropriately named question1, question2a, question2b, etc.) d) This system helps me keep your submissions organized, test them easily, and eventually give you better feedback. Submissions not in this format will not be graded.

Q1. Three link planar robot manipulator [16 points]

Consider the three link manipulator shown in Figure 1. The lengths of the links are: OA = ℓ_1, AB = ℓ_2, and BC = ℓ_3. When numbers are needed, use $\ell_1 = 1$, $\ell_2 = 0.8$, and $\ell_3 = 0.3$.

a) Derive an expression for the end point position (x_C, y_C) as a function of the **relative** joint angles θ_1, θ_2, and θ_3, and the link lengths. [3pts]

b) Write a MATLAB program to compute position (x_C, y_C) of the end point C, when given the values of the joint angles θ_1, θ_2, θ_3. What is the end point position when $\theta_1 = \pi/23$, $\theta_2 = \pi/21$, and $\theta_3 = \pi/7$? Angles always in radians, unless otherwise specified. [3 pts]

c) Write a MATLAB program to draw, approximately, the **reachable workspace** of the end point C of the three-link manipulator given the following **joint ranges of motion**: θ_1 can range between 0 to $\pi/6$, θ_2 can range between 0 and $\pi/2$, and θ_3 can range between 0 and $\pi/7$. Show a well-labeled printout of the plot, in addition to uploading code. [6pts]

d) Write a MATLAB program to **draw** the three-link manipulator given values for θ_1, θ_2, and θ_3. Show the output of your program for $\theta_1 = \pi/3$, $\theta_2 = \pi/4$, $\theta_3 = \pi/6$. Drawing the manipulator = drawing the three line segments OA, AB, and BC. Be sure to label your drawing and use "`axis equal`." [4pts]

e) Write a MATLAB program to show an **animation** of the three link manipulator, when the joint angles are given by the following functions of time t:

$$\theta_1(t) = \sin(t) \tag{1}$$
$$\theta_2(t) = 0.8 \cdot \sin(0.7t) \tag{2}$$
$$\theta_3(t) = 2 \cdot \sin(1.2t) \tag{3}$$

for time $t = 0$ to $t = 10$. Make sure the animation is slow enough for the human eye to be able to see it, on your computer. [10pts]

Be sure to use “`axis equal`” for the plot, otherwise the scales on the plot will not be equal. For Q1, please upload the MATLAB code for (c,d,e) through Carmen. Make sure that when we run the code, we see the animation or other expected output, with nothing else to be done by the user.

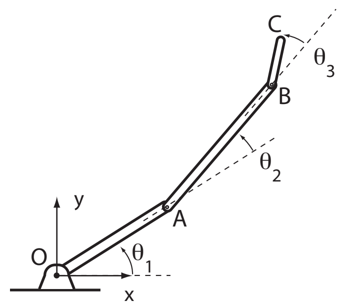

Figure 1: A planar three link manipulator. C is the end point of the third segment. The point O is the origin $(0, 0)$

Q2. Using fsolve. [12 pts]

a) Using `fsolve`, solve the equations $x^2 - y = 0$ and $x = 2y$. Upload program.

b) Consider the 3 link manipulator in Q1. For a given point (x_C, y_C) inside the reachable workspace (not on the boundary), how many solutions for θ_1, θ_2, and θ_3 do you think there might be? Explain.

c) Write a MATLAB program for inverse kinematics, to compute angles θ_1, θ_2, and θ_3 using fsolve. Pick some point (x_C, y_C) inside the reachable workspace (not on the boundary). Try different initial seeds to see what answers you get. Do you get the same answer for $(\theta_1, \theta_2, \theta_3)$?

Q3. Using inverse kinematics ... [6 pts]

Consider the two-link manipulator that we discussed in class, with link lengths $\ell_1 = \ell_2 = 1$. Now, lets say you want to make an animation of the two-link manipulator as the end-point P_2 goes from $(1, 0)$ to $(0, 0)$ at some “constant speed” (say). How would you do it?

First explain in words and then submit MATLAB code that achieves such an animation. Hint: inverse kinematics, but there are lots of ways to achieve this goal.

Q4. Splines and polynomial approximations [6 points]

Consider the function $f(t) = \sin(t)$ from $0 \le t \le 2\pi$. Evaluate this function at N equidistant points. Using `interp1`, use a cubic spline to interpolate at a number of points between these N points. How big is the error between the spline interpolant and the original sine curve? Try different N. Does the error go down with N as expected?