# ASE-9406 ROBOT MODELLING, CONTROL AND PROGRAMING

## Assignment 2: Jacobians, Trajectory Planning and Robot Programming

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| Due Date | 13 December 2016 @ 11:55PM |

Submit assignment on Moodle in a ZIP file, include a PDF of the report and the Matlab code properly commented/documented. Work in groups of 3 persons.

### JACOBIANS

1) With the Jacobian of a manipulator we can compute speeds in the Cartesian speeds out of speeds in the joint space. Explain what is the difference between ${}^{0}J$ and ${}^{n}J$ of a manipulator, when they are used to compute the Cartesian speeds out of the joints speeds

2) How do you convert ${}^{n}J$ to ${}^{0}J$. Why is it important to make computations respect to frame {0}?

### TRAJECTORY PLANNING

Your task is to plan a welding profile done by a robot. The robot that performs this operation has a welding torch attached to its last link as shown in figure 1.

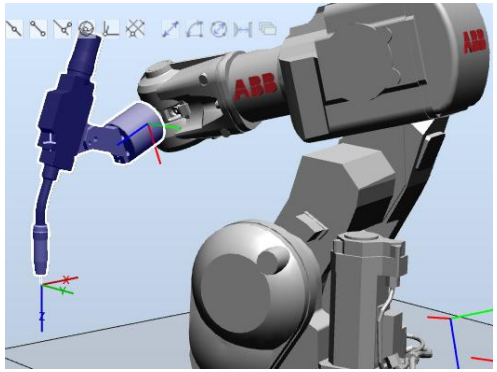


Figure 1. Robot and welding torch

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The welding profile is shown in figure 2. It consists of two shapes: “L” and “C”. Here you have some requirements:

- “L” shape is done out of linear segments.
- “C” shape is done out of linear and circular segments.
- Before starting the welding operation, the robot tool has to be positioned 5 cm on top of the arrival point, then it has to land into the work piece with a vertical movement
- The welding torch has to leave the workpiece by moving vertically 5 cm on top of the departure point.
- The velocities are: welding 400 mm/s, landing and departure: 200 mm/s, free movement: 700 mm/s
- The left corner of the “L” shape is located at: x=4, y=4 and z=0 of the work piece frame
- All the units are in cm

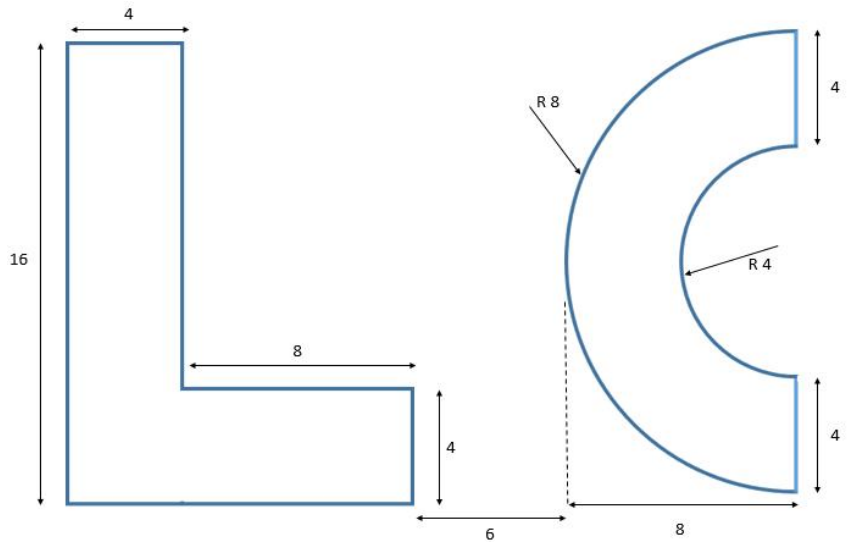


Figure 2. Welding profile

3) Using the scenario and points described in the welding profile (do not consider velocities in this question), describe in detail, the sequence of movements to accomplish the required profile. State which portions are Joint space and which are Cartesian space trajectories.

4) What is the shape that is generated during the Joint Space segment? Is it a circular segment? Argument your answer.

5) Suppose we need to plan the trajectory of one of the robot joints that goes from $\theta 1$ to $\theta$ 2, by following a cubic interpolation. Using Matlab and symbolic toolbox provide: the code that will solve the cubic polynomials, also provide the obtained equations for the coefficients:

a0,a1, a2 and a3

The input variables that your algorithm uses are: $\theta 1$, $\theta 2$, $\dot{\theta}_0$, $\dot{\theta}_{tf}$ and $t_f$

Hint: Use symbolic toolbox and *solve* command for this

6) With the expressions generated in the previous algorithm obtain the polynomial coefficients when: $\theta 1$=25, $\theta 2$=90, $\dot{\theta}_0 = 0$, $\dot{\theta}_{tf}$=0 and $t_f$=4s

Plot $\theta(t)$, $\dot{\theta}(t)$ and $\ddot{\theta}(t)$ in the range of 0 to 4s

Interpret the plots, What are the advantages of using this kind of interpolation? What are the drawbacks?

Hint: use *subs* from symbolic toolbox to obtain actual values for: a0, a1, a2 and a3

## ROBOT PROGRAMMING

7) Provide the code in ABB Rapid programming language to generate the profile of figure 2. Use the next commands: *moveL, moveJ, moveC and offs*. Pay special attention to the velocity and the zone parameters of the move commands so that they fulfill the specifications of the welding profile given in the previous section. Use as template the code shown in Figure 3. Please notice the next:

- wobj1 frame is assumed to be in the left lower corner of the work piece
- The robot targets, for this assignment purposes, are defined just with x, y and z positions. The other parameters such as orientation and robot configuration are out of the scope of this assignment.
- tTorch is assumed to have the welding torch homogenous transformation respect to the manipulator end plate. So you do not need to define it.

8) Suppose that every time a workpiece has been finished, a new sheet of metal is placed exactly on top of the previous one. Then the welding profile is done again on top of the new one. Each sheet of metal has a thickness of 6mm. Which approach would you follow, so that you modify as little as possible your code (done in the previous step), but still can handle properly the welding profile on the incoming sheets of metal.

9) Explain how the theoretical concepts learnt during the lecture are applied/involved in practice when the robot is moved by using the *moveL* or *moveJ* commands. Brainstorm, organize and describe clearly your answer. You can use flowcharts to support your answer.

```
CONST robtarget p10 := [ [600, -100, 800]];
PROC main()
        MoveJ p10, v200, z50, tTorch, \WObj:=wobj1;
        .
        .
        .
        .
ENDPROC
```

Figure 3. Rapid code template