INNOPOLIS UNIVERSITY

“Project Task3”

DYNAMICS OF NON-LINEAR ROBOTIC SYSTEMS

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Date

26-sep-2021

Home Task 3

This report show the result of code implementation for Home Task 3. There are some code files attached with this report that contain the following:

- Trajectory Planning: contains the solution for task 1,2,3,4 respectively
- Plan_trajectory: function that calculates the trajectory for q, velocity, and acceleration
- Trajectory_time: function that calculates time parameters needed for trajectory planning
- FK: forward kinematics function needed in task 4
- Task6: This file performs junction solution (task 6)

Results

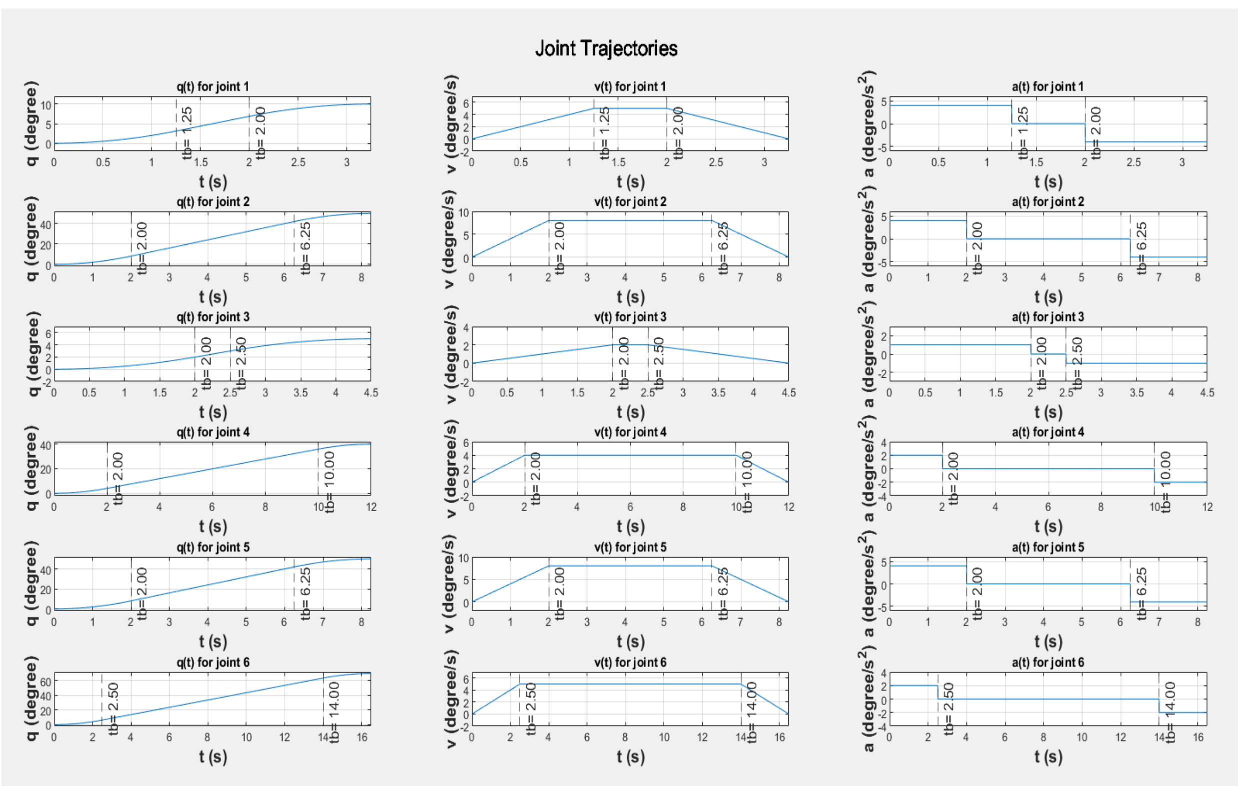
1) Trajectory Planning

The graphs for arbitrary trajectories were obtained for the whole robot motion. All joints are revolute except for the third one (prismatic).

The input values were as follows:

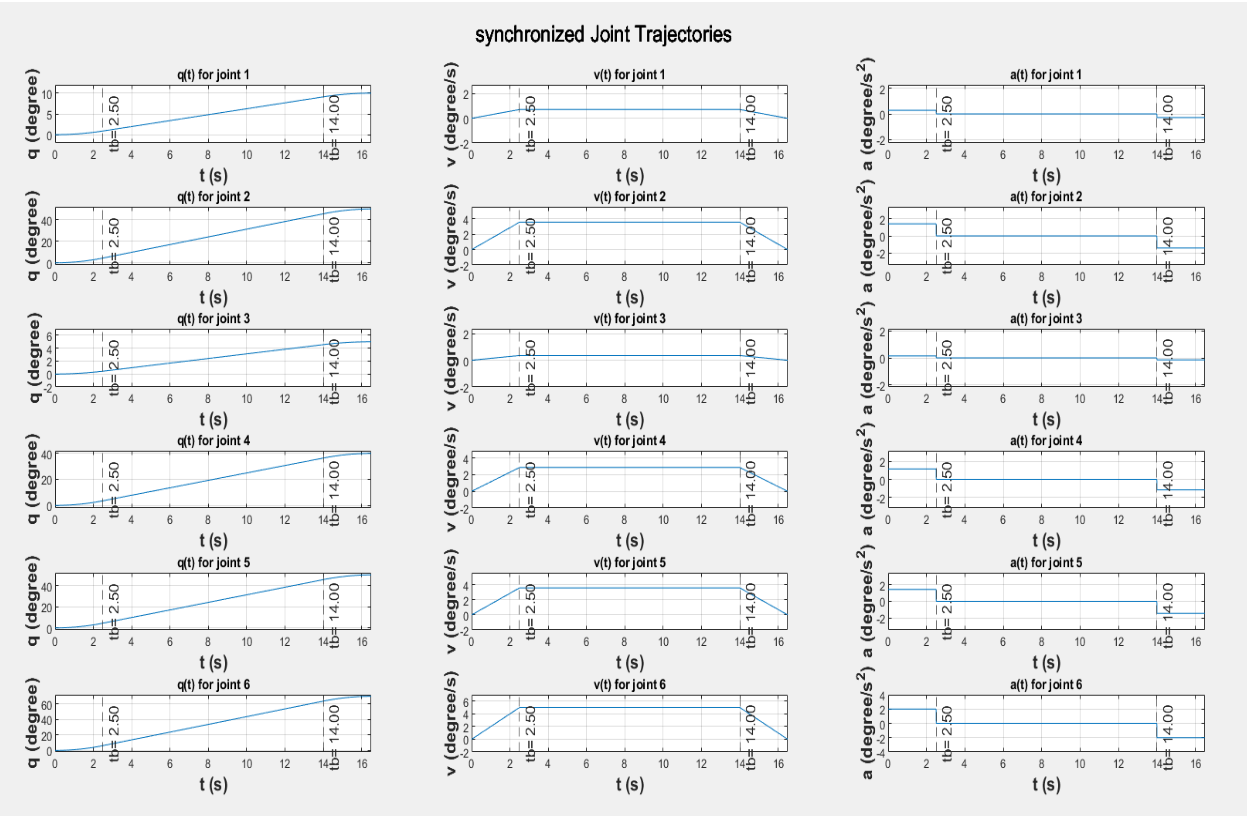
```
j1 =[0,10,5,4];
j2=[0,50,8,4];
j3 =[0,5,2,1]; %prismatic joint
j4=[0,40,4,2];
j5 =[0,50,8,4];
j6=[0,70,5,2];
```

The trajectories were as follo



2) Synchronization

All joint have to be synchronized (to start and end at the same time) in order to achieve the desired motion. Calculating new t0, tb, T, tf as the maximum of time parameters of all joints, the following trajectories were obtained:



Remark: All joints have now a maximum velocity and acceleration less than before due to the prolongation of execution time.

3) Synchronization with numerical control:

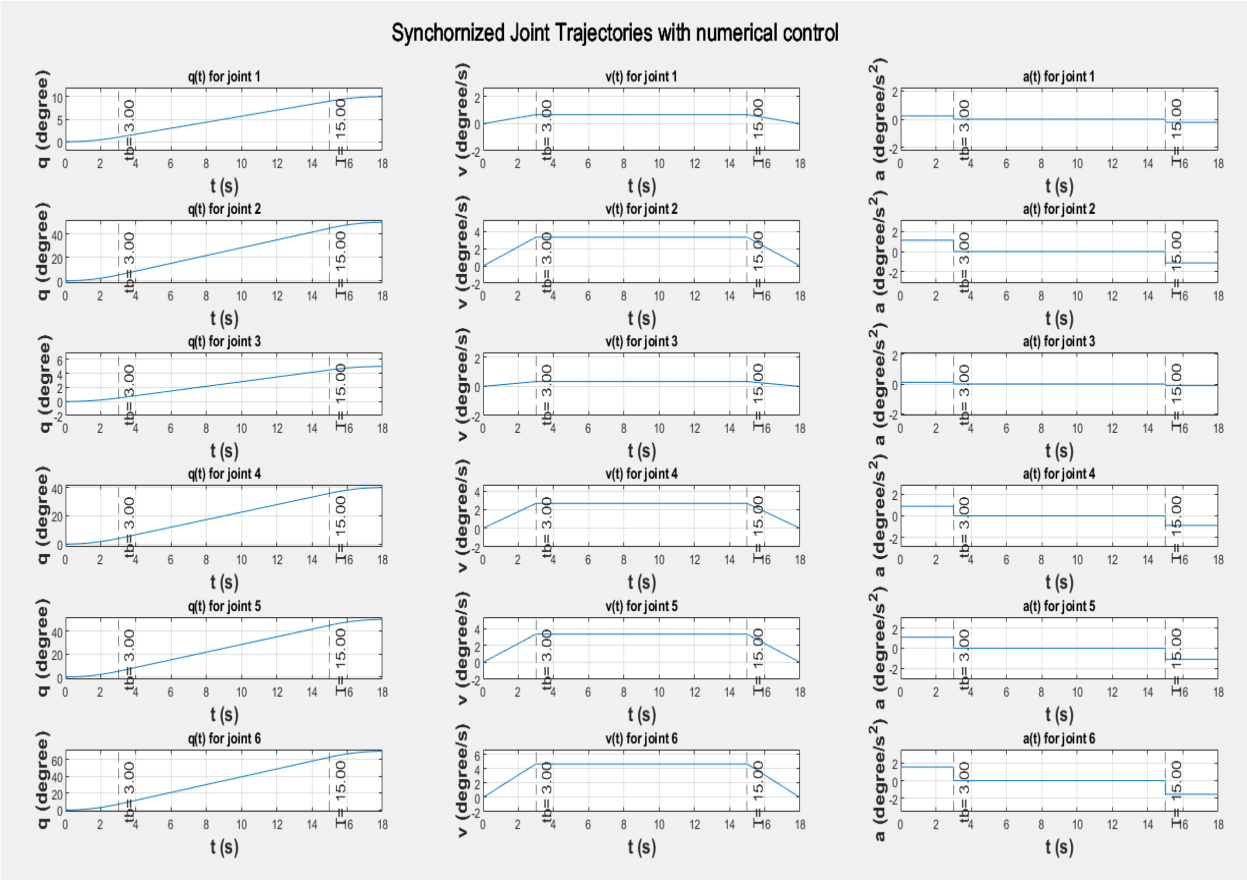
Numerical control needed because the robot controller acts at certain frequency. Thus, controller change the joint parameters at certain time. The new numerical time parameters can be calculated as follows:

$$t_b = \left(\frac{t_b}{\Delta t} + 1\right)\Delta t$$

The same goes for T.

Remark: the output of the above equation have to be integer not float. We round it up to the nearest higher decimal if float.

The new trajectories are:



4) Propagated error:

The code implemented for error calculation is :

```
%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Task 3.4 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Calculate FK before and after numerical control
Actual_FK= FK( q_1(length(q_1)) , q_2(length(q_2)),q_3(length(q_3)),q_4(length(q_4)),q_5(length(q_5)),q_6(length(q_6)));
Numerical_FK=FK(q_sn1(length(q_sn1)),q_sn2(length(q_sn2)),q_sn3(length(q_sn3)),q_sn4(length(q_sn4)),q_sn5(length(q_sn5)),q_sn6(length(q_sn6)));

%Calculate the difference between x,y,z postion
x_error=Actual_FK(1:4)-Numerical_FK(1:4);
y_error=Actual_FK(2:4)-Numerical_FK(2:4);
z_error=Actual_FK(3:4)-Numerical_FK(3:4);

fprintf("\nError for end effector position is : %.2f in x and %.2f in y and %.2f in z\n",x_error,y_error,z_error)
```

It uses the joint parameters obtained before and after numerical control, calculates forward kinematics, and then compare the difference between the end effector position in both cases in terms of x,y,z position. In the arbitrary values provided, the error is 0

5) Polynomial solution:

Given three points, polynomial equation with third degree (four conditions -1) describe the motion between each two consecutive points. The manual solution is show below.

Task 5

Three points are $q(0)=0$, $q(1.625)=5$, $q(3.25)=10$

where $\dot{q}(0)=0$ $\dot{q}(1.625)=5$, $\dot{q}(3.25)=0$

- The motion will be segmented into two polynomial equations. with 3^{rd} degree $\rightarrow N-1$

First segment: $q_0=0$ $q_f=5$ $t_0=0$

$\dot{q}_0=0$ $\dot{q}_f=5$ $t_f=1.625$ $\boxed{N=4}$

$$q_1(t) = a_{13}t^3 + a_{12}t^2 + a_{11}t + a_{10}$$

$$\dot{q}(t) = 3a_{13}t^2 + 2a_{12}t + a_{11}$$

★ $q(0)=0 \longrightarrow \boxed{a_{10}=0}$

★ $\dot{q}(0)=0 \longrightarrow \boxed{a_{11}=0}$

★ $q(1.625)=5 \longrightarrow 4.29a_{13} + 2.64a_{12} = 5 \longrightarrow ①$

★ $\dot{q}(1.625)=5 \longrightarrow 7.92a_{13} + 3.25a_{12} = 5 \longrightarrow ②$

From 1,2 $\longrightarrow \boxed{a_{13}=-0.44 \ , \ a_{12}=2.61}$

$$\therefore \left.\begin{aligned} q_1(t) &= -0.44t^3 + 2.61t^2 \\ \dot{q}_1(t) &= -1.32t^2 + 5.22t \end{aligned}\right\}$$

segment 2

$q_0 = 5$, $q_f = 10$ $\qquad t_0 = 1.625$

$\dot{q}_0 = 5$, $\dot{q}_f = 0$ $\qquad t_f = 3.25$

☆ $q_0 = 5 \longrightarrow 4.29 a_{23} + 2.64 a_{22} + 1.62 a_{21} + a_{20} = 5 \longrightarrow (1)$

☆ $\dot{q}_0 = 5 \longrightarrow 7.92 a_{23} + 3.25 a_{22} + a_{21} = 5 \longrightarrow (2)$

☆ $q_f = 10 \longrightarrow 34.33 a_{23} + 10.5625 a_{22} + 3.25 a_{21} + a_{20} = 10 \rightarrow (3)$

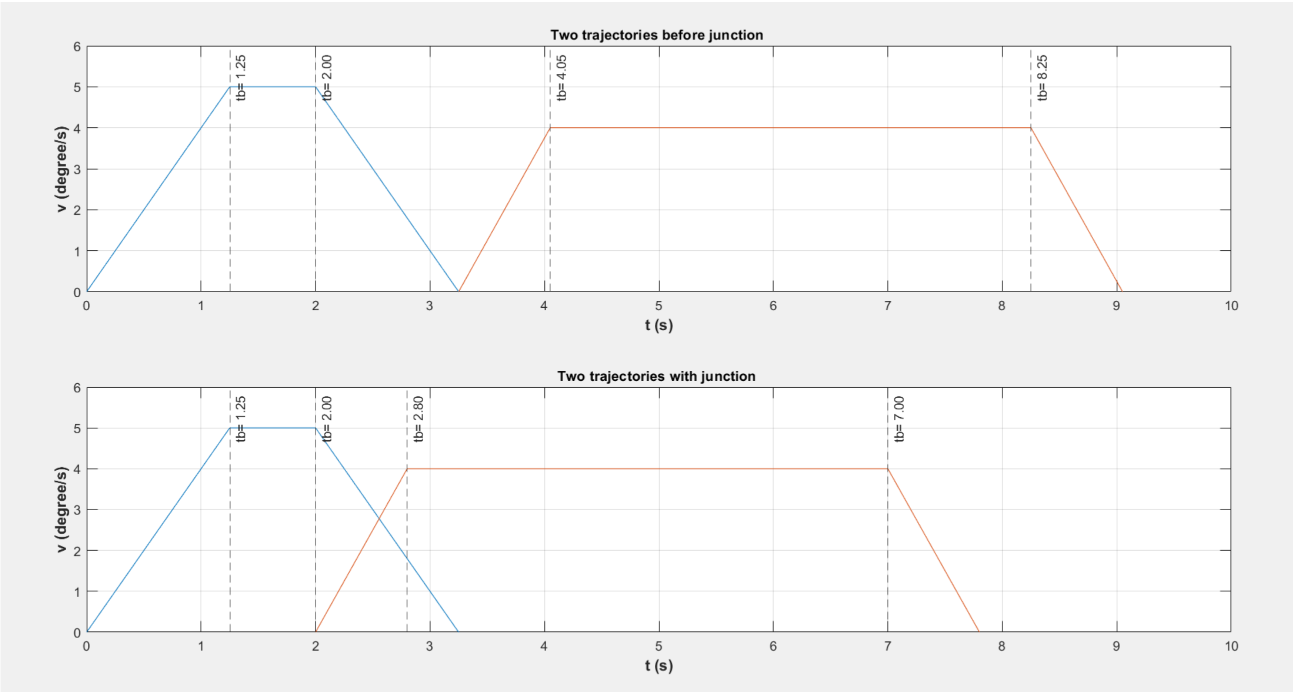
☆ $\dot{q}_f = 0 \longrightarrow 31.68 a_{23} + 6.5 a_{22} + a_{21} = 0 \longrightarrow (4)$

From 1, 2, 3, 4:

$$\boxed{\begin{aligned} q_2(t) &= 0.09 t^3 - 2.6 t^2 + 14.16 t - 11.5 \\ \dot{q}_2(t) &= 0.27 t^2 - 5.2 t + 14.16 \end{aligned}}$$

6) Junction:

To avoid motor malfunction, it is recommended to use smooth motion trajectory in which the joint does not change direction suddenly. The junction is utilized here for this purpose. Below is the graphs before and after the junction:



The two trajectories is combined (especially in the intersection region) to perform the task.