

July 2021

## 01211433 Homework # 1

Using RTSX toolbox, below is Scilab script to plot 3-segment quintic polynomial trajectory in Figure 1

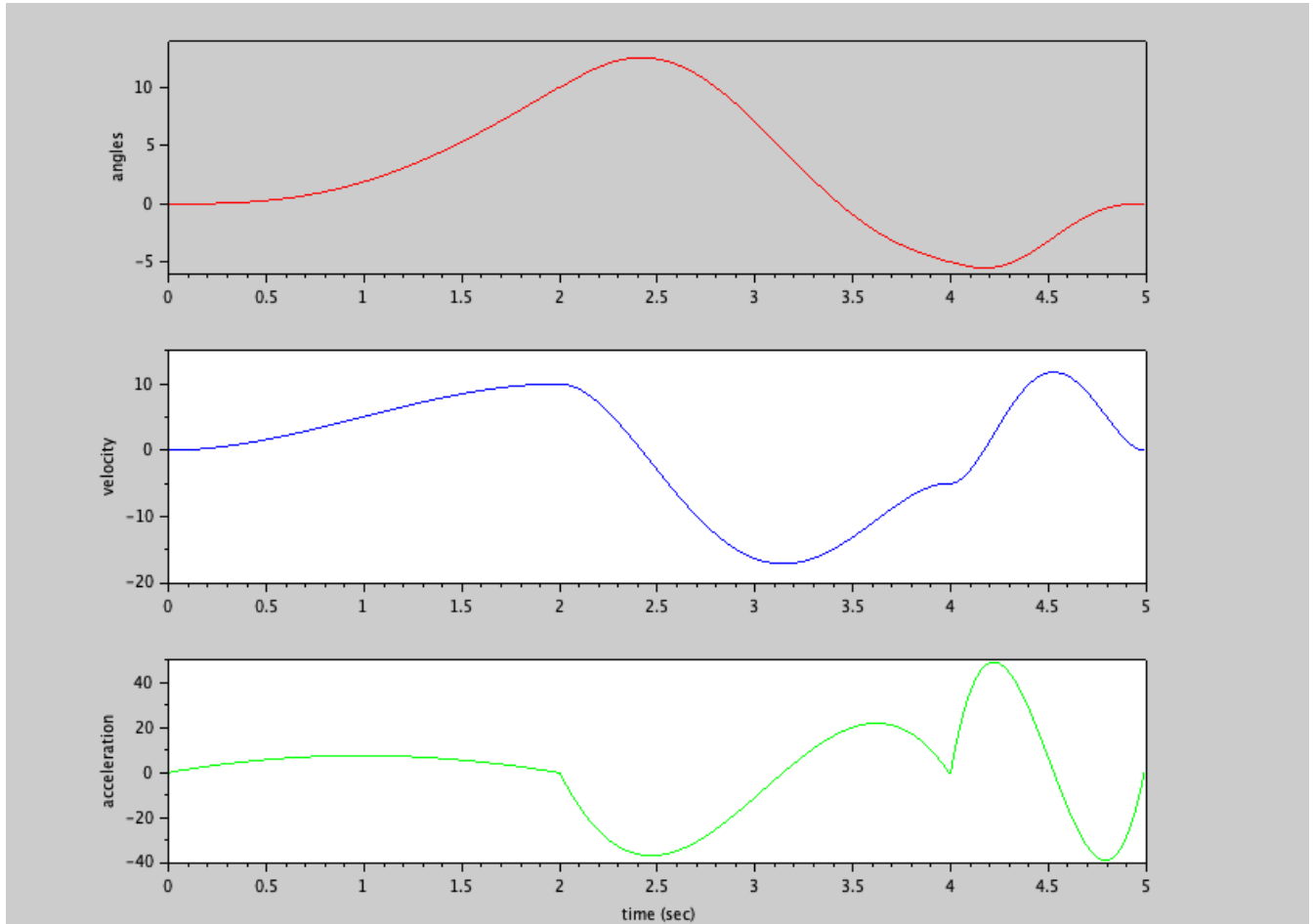


Figure 1 3-segment quintic polynomial trajectory

```
// #Scilab script example. Do not run this cell in notebook.  
// #command trajectory generation
```

```
t1=0:0.01:1.99;  
t2 = 0:0.01:0.99;
```

```
// joint 1 trajectory  
[q11,qd11,qdd11]=qpoly(0,10,t1,0,10); // segment 1  
[q12,qd12,qdd12]=qpoly(10,-5,t1,10,-5); // segment 2  
[q13,qd13,qdd13]=qpoly(-5,0,t2,-5,0); // segment 3
```

```
q1 = [q11;q12;q13]; // position (angles)  
qd1 = [qd11;qd12;qd13]; // velocity  
qdd1 = [qdd11;qdd12;qdd13]; // acceleration
```

```
t=0:0.01:4.99;  
t=t';
```

```
figure(1);  
subplot(311), plot(t, q1, 'r-')  
//xlabel('time (sec)')  
ylabel('angles')
```

```
subplot(312), plot(t, qd1, 'b-')  
//xlabel('time (sec)')  
ylabel('velocity')
```

```
subplot(313), plot(t, qdd1, 'g-')  
xlabel('time (sec)')  
ylabel('acceleration')
```

Here is Scilab script for qpoly function

```
// #Scilab script. Do not run this cell in notebook.
function [s,sd,sdd] = qpoly(q0, qf, t, qd0, qdf)

    t0 = t;
    nargin=argn(2);
    nargout = argn(1);
    if isscalar(t)
        t = (0:t-1)';
    else
        t = t(:);
    end
    if nargin < 4
        qd0 = 0;
    end
    if nargin < 5
        qdf = 0;
    end

    tf = max(t);

    // solve for the polynomial coefficients using least squares
    X = [
        0          0          0          0          0      1
        tf^5       tf^4       tf^3       tf^2       tf      1
        0          0          0          0          1      0
        5*tf^4     4*tf^3     3*tf^2     2*tf        1      0
        0          0          0          2          0      0
        20*tf^3    12*tf^2    6*tf        2          0      0
    ];
    b = [q0 qf qd0 qdf 0 0]';
    coeffs = (inv(X)*b)';
    // coefficients of derivatives
    coeffs_d = coeffs(1:5) .* (5:-1:1);
    coeffs_dd = coeffs_d(1:4) .* (4:-1:1);

    // evaluate the polynomials
    p = polyval(coeffs, t);
    pd = polyval(coeffs_d, t);
    pdd = polyval(coeffs_dd, t);

    select nargout
        case 1
            s = p;
        case 2
            s = p;
            sd = pd;
        case 3
            s = p;
            sd = pd;
            sdd = pdd;
    end

endfunction
```

Use Julia to generate the same trajectory. The position, velocity, and acceleration plot should resemble Figure 1. For simplicity, assume that  $t$  argument is always a vector in `qpoly()` function

## Solution

```

• #import Pkg
• #Pkg.add("Plots")
• using Plots

```

qpoly (generic function with 3 methods)

```

• function qpoly(q0,qf,t,qd0=0,qdf=0)
•     tf = t[end]
•     T = [0 0 0 0 0 1;tf^5 tf^4 tf^3 tf^2 tf 1; 0 0 0 0 1 0; 5tf^4 4tf^3 3tf^2 2tf 1
0;0 0 0 2 0 0; 20tf^3 12tf^2 6tf 2 0 0]
•     b = [q0 qf qd0 qdf 0 0]'
•     coeffs = inv(T)*b
•     coeffs_d = coeffs[1:5].*reverse(collect(1:5))
•     coeffs_dd = coeffs_d[1:4].*reverse(collect(1:4))
•
•     q = polyval(coeffs, t)
•     q_d = polyval(coeffs_d,t)
•     q_dd = polyval(coeffs_dd, t)
•     return q, q_d, q_dd
• end

```

polyval (generic function with 1 method)

```

• function polyval(P,X)
•     Y = zeros(size(X))
•     n = size(P,1)
•     for i=1:n
•         Y = Y + P[i]*X.^(n-i)
•     end
•     return Y
• end

```

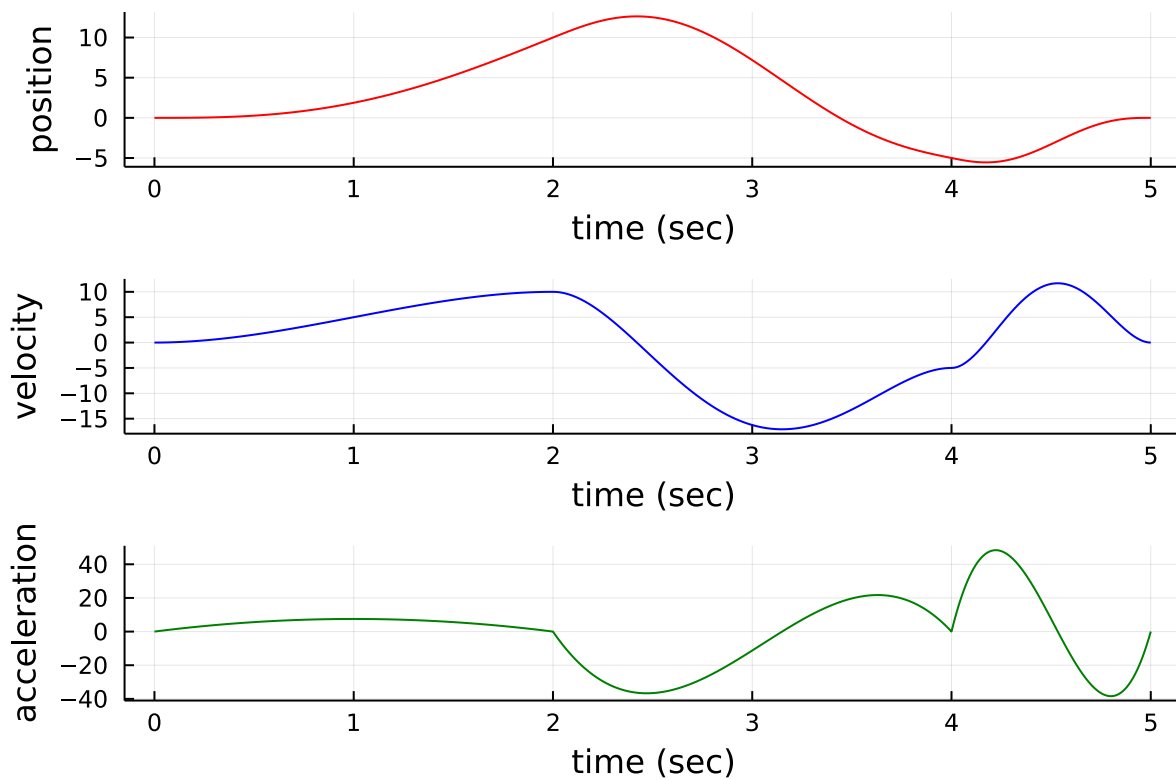
[0.0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19, 0.2]

```

• begin
•     t1 = collect(0:0.01:2);
•     t2 = collect(0:0.01:1);
• end

```

([-5.0, -5.04992, -5.09938, -5.14793, -5.19517, -5.2407, -5.28418, -5.32525, -5.3636, -5.4017, -5.4394, -5.4767, -5.5136, -5.5501, -5.5862, -5.6219, -5.6572, -5.6921, -5.7266, -5.7607, -5.7944, -5.8277, -5.8606, -5.8931, -5.9252, -5.9569, -5.9882, -6.0191, -6.0496, -6.0797, -6.1094, -6.1387, -6.1676, -6.1961, -6.2242, -6.2519, -6.2792, -6.3061, -6.3326, -6.3587, -6.3844, -6.4097, -6.4346, -6.4591, -6.4832, -6.5069, -6.5302, -6.5531, -6.5756, -6.5977, -6.6194, -6.6407, -6.6616, -6.6821, -6.7022, -6.7219, -6.7412, -6.7601, -6.7786, -6.7967, -6.8144, -6.8317, -6.8486, -6.8651, -6.8812, -6.8969, -6.9122, -6.9271, -6.9416, -6.9557, -6.9694, -6.9827, -6.9956, -7.0081, -7.0202, -7.0319, -7.0432, -7.0541, -7.0646, -7.0747, -7.0844, -7.0937, -7.1026, -7.1111, -7.1192, -7.1269, -7.1342, -7.1411, -7.1476, -7.1537, -7.1594, -7.1647, -7.1696, -7.1741, -7.1782, -7.1819, -7.1852, -7.1881, -7.1906, -7.1927, -7.1944, -7.1957, -7.1966, -7.1971, -7.1973, -7.1972, -7.1968, -7.1961, -7.1951, -7.1938, -7.1922, -7.1903, -7.1881, -7.1856, -7.1828, -7.1797, -7.1763, -7.1726, -7.1686, -7.1643, -7.1597, -7.1548, -7.1496, -7.1441, -7.1383, -7.1322, -7.1258, -7.1191, -7.1121, -7.1048, -7.0972, -7.0893, -7.0811, -7.0726, -7.0638, -7.0547, -7.0453, -7.0356, -7.0256, -7.0153, -7.0047, -6.9938, -6.9826, -6.9711, -6.9593, -6.9472, -6.9348, -6.9221, -6.9091, -6.8958, -6.8822, -6.8683, -6.8541, -6.8396, -6.8248, -6.8097, -6.7943, -6.7786, -6.7626, -6.7463, -6.7297, -6.7128, -6.6956, -6.6781, -6.6603, -6.6422, -6.6239, -6.6053, -6.5864, -6.5672, -6.5477, -6.5279, -6.5078, -6.4874, -6.4667, -6.4457, -6.4244, -6.4028, -6.3809, -6.3587, -6.3362, -6.3134, -6.2903, -6.2669, -6.2432, -6.2192, -6.1949, -6.1703, -6.1454, -6.1202, -6.0947, -6.0689, -6.0428, -6.0164, -5.9897, -5.9627, -5.9354, -5.9078, -5.8799, -5.8517, -5.8232, -5.7944, -5.7653, -5.7359, -5.7062, -5.6762, -5.6459, -5.6153, -5.5844, -5.5532, -5.5217, -5.49, -5.4579, -5.4255, -5.3928, -5.3598, -5.3265, -5.2929, -5.259, -5.2248, -5.1903, -5.1555, -5.1204, -5.085, -5.0493, -5.0133, -4.977, -4.9404, -4.9035, -4.8663, -4.8288, -4.791, -4.7529, -4.7145, -4.6758, -4.6368, -4.5975, -4.5579, -4.518, -4.4778, -4.4373, -4.3965, -4.3554, -4.314, -4.2723, -4.2303, -4.188, -4.1454, -4.1025, -4.0593, -4.0158, -3.972, -3.9279, -3.8835, -3.8388, -3.7938, -3.7485, -3.7029, -3.657, -3.6108, -3.5643, -3.5175, -3.4704, -3.423, -3.3753, -3.3273, -3.279, -3.2304, -3.1815, -3.1323, -3.0828, -3.033, -2.9829, -2.9325, -2.8818, -2.8308, -2.7795, -2.7279, -2.676, -2.6238, -2.5713, -2.5185, -2.4654, -2.412, -2.3583, -2.3043, -2.25, -2.1953, -2.1403, -2.085, -2.0294, -1.9735, -1.9173, -1.8608, -1.804, -1.7469, -1.6895, -1.6318, -1.5738, -1.5155, -1.4569, -1.398, -1.3388, -1.2793, -1.2195, -1.1594, -1.099, -1.0383, -97.73, -91.47, -85.16, -78.8, -72.39, -65.93, -59.42, -52.86, -46.25, -39.59, -32.88, -26.12, -19.31, -12.45, -5.54, 1.41, 8.3, 15.03, 21.6, 28.01, 34.26, 40.35, 46.28, 52.05, 57.66, 63.11, 68.4, 73.53, 78.5, 83.31, 87.96, 92.45, 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178.06, 177.96, 177.76, 177.46, 177.06, 176.56, 175.96, 175.26, 174.46, 173.56, 172.56, 171.46, 170.26, 168.96, 167.56, 166.06, 164.46, 162.76, 160.96, 159.06, 157.06, 154.96, 152.76, 150.46, 148.06, 145.56, 142.96, 140.26, 137.46, 134.56, 131.56, 128.46, 125.26, 121.96, 118.56, 115.06, 111.46, 107.76, 103.96, 99.41, 95.31, 91.06, 86.66, 82.11, 77.41, 72.56, 67.56, 62.41, 57.11, 51.66, 46.06, 40.31, 34.41, 28.36, 22.16, 15.81, 9.31, 2.66, -4.11, -10.71, -17.16, -23.46, -29.61, -35.61, -41.46, -47.16, -52.71, -58.11, -63.36, -68.46, -73.41, -78.21, -82.86, -87.36, -91.71, -95.91, -100.0, -103.96, -107.76, -111.46, -115.06, -118.56, -121.96, -125.26, -128.46, -131.56, -134.56, -137.46, -140.26, -142.96, -145.56, -148.06, -150.46, -152.76, -154.96, -157.06, -159.06, -160.96, -162.76, -164.46, -166.06, -167.56, -168.96, -170.26, -171.46, -172.56, -173.56, -174.46, -175.26, -175.96, -176.56, -177.06, -177.46, -177.76, -177.96, -178.06, -178.06, -177.96, -177.76, -177.46, -177.06, -176.56, -175.96, -175.26, -174.46, -173.56, -172.56, -171.46, -170.26, -168.96, -167.56, -166.06, -164.46, -162.76, -160.96, -159.06, -157.06, -154.96, -152.76, -150.46, -148.06, -145.56, -142.96, -140.26, -137.46, -134.56, -131.56, -128.46, -125.26, -121.96, -118.56, -115.06, -111.46, -107.76, -103.96, -99.41, -95.31, -91.06, -86.66, -82.11, -77.41, -72.56, -67.56, -62.41, -57.11, -51.66, -46.06, -40.31, -34.41, -28.36, -22.16, -15.81, -9.31, -2.66, 4.11, 10.71, 17.16, 23.46, 29.61, 35.61, 41.46, 47.16, 52.71, 58.11, 63.36, 68.46, 73.41, 78.21, 82.86, 87.36, 91.71, 95.91, 100.0, 103.96, 107.76, 111.46, 115.06, 118.56, 121.96, 125.26, 128.46, 131.56, 134.56, 137.46, 140.26, 142.96, 145.56, 148.06, 150.46, 152.76, 154.96, 157.06, 159.06, 160.96, 162.76, 164.46, 166.06, 167.56, 168.96, 170.26, 171.46, 172.56, 173.56, 174.46, 175.26, 175.96, 176.56, 177.06, 177.46, 177.76, 177.96, 178.06, 178.06, 177.96, 177.76, 177.46, 177.06, 176.56, 175.96, 175.26, 174.46, 173.56, 172.56, 171.46, 170.26, 168.96, 167.56, 166.06, 164.46, 162.76, 160.96, 159.06, 157.06, 154.96, 152.76, 150.46, 148.06, 145.56, 142.96, 140.26, 137.46, 134.56, 131.56, 128.46, 125.26, 121.96, 118.56, 115.06, 111.46, 107.76, 103.96, 99.41, 95.31, 91.06, 86.66, 82.11, 77.41, 72.56, 67.56, 62.41, 57.11, 51.66, 46.06, 40.31, 34.41, 28.36, 22.16, 15.81, 9.31, 2.66, -4.11, -10.71, -17.16, -23.46, -29.61, -35.61, -41.46, -47.16, -52.71, -58.11, -63.36, -68.46, -73.41, -78.21, -82.86, -87.36, -91.71, -95.91, -100.0, -103.96, -107.76, -111.46, -115.06, -118.56, -121.96, -125.26, -128.46, -131.56, -134.56, -137.46, -140.26, -142.96, -145.56, -148.06, -150.46, -152.76, -154.96, -157.06, -159.06, -160.96, -162.76, -164.46, -166.06, -167.56, -168.96, -170.26, -171.46, -172.56, -173.56, -174.46, -175.26, -175.96, -176.56, -177.06, -177.46, -177.76, -177.96, -178.06, -178.06, -177.96, -177.76, -177.46, -177.06, -176.56, -175.96, -175.26, -174.46, -173.56, -172.56, -171.46, -170.26, -168.96, -167.56, -166.06, -164.46, -162.76, -160.96, -159.06, -157.06, -154.96, -152.76, -150.46, -148.06, -145.56, -142.96, -140.26, -137.46, -134.56, -131.56, -128.46, -125.26, -121.96, -118.56, -115.06, -111.46, -107.76, -103.96, -99.41, -95.31, -91.06, -86.66, -82.11, -77.41, -72.56, -67.56, -62.41, -57.11, -51.66, -46.06, -40.31, -34.41, -28.36, -22.16, -15.81, -9.31, -2.66, 4.11, 10.71, 17.16, 23.46, 29.61, 35.61, 41.46, 47.16, 52.71, 58.11, 63.36, 68.46, 73.41, 78.21, 82.86, 87.36, 91.71, 95.91, 100.0, 103.96, 107.76, 111.46, 115.06, 118.56, 121.96, 125.26, 128.46, 131.56, 134.56, 137.46, 140.26, 142.96, 145.56, 148.06, 150.46, 152.76, 154.96, 157.06, 159.06, 160.96, 162.76, 164.46, 166.06, 167.56, 168.96, 170.26, 171.46, 172.56, 173.56, 174.46, 175.26, 175.96, 176.56, 177.06, 177.46, 177.76, 177.96, 178.06, 178.06, 177.96, 177.76, 177.46, 177.06, 176.56, 175.96, 175.26, 174.46, 173.56, 172.56, 171.46, 170.26, 168.96, 167.56, 166.06, 164.46, 162.76, 160.96, 159.06, 157.06, 154.96, 152.76, 150.46, 148.06, 145.56, 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```
• begin
•   plot_q = plot(tvec, q, ylabel="position",color="red")
•   plot_qd = plot(tvec, qd, ylabel="velocity",color="blue")
•   plot_qdd = plot(tvec, qdd, ylabel="acceleration",color="green")
•   plotall = plot(plot_q, plot_qd, plot_qdd,layout=(3,1),legend=false)
•   xlabel!("time (sec)")
• end
```