

10/1/18

ME535 ASSIGNMENT #3

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4.1

(a)

$$N_{i,p} = \frac{u - u_i}{u_{i+p} - u_i} N_{i,p-1} + \frac{u_{i+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}$$

$$u = \{0, 1, 2, 3, 3, 4, 5, 6\}.$$

$$u_0 u_1 u_2 u_3 u_4 u_5 u_6 u_7.$$

$$p = 2$$

Solution: ( $p=0$ )

$$\begin{aligned} i=0 \quad N_{0,0} &= \begin{cases} 1 & u \in [u_0, u_1] \\ 0 & \text{otherwise} \end{cases} \end{aligned}$$

$$i=1 \quad N_{1,0} = \begin{cases} 1 & u \in [1, 2) \\ 0 & \text{otherwise} \end{cases}$$

$$i=2 \quad N_{2,0} = \begin{cases} 1 & u \in [2, 3) \\ 0 & \text{otherwise} \end{cases}$$

$$i=3 \quad N_{3,0} = \begin{cases} 1 & u \in [3, 3) \\ 0 & \text{otherwise} \end{cases}$$

$$i=4 \quad N_{4,0} = \begin{cases} 1 & u \in [3, 4) \\ 0 & \text{otherwise} \end{cases}$$

$$i=5 \quad N_{5,0} = \begin{cases} 1 & u \in [4, 5) \\ 0 & \text{otherwise} \end{cases}$$

$$i=6 \quad N_{6,0} = \begin{cases} 1 & u \in [5, 6) \\ 0 & \text{otherwise} \end{cases}$$

( $p=1$ )

$$\begin{aligned} i=0 \quad N_{0,1} &= \frac{u - 0}{u_1 - u_0} N_{0,0}(u) + \frac{u_2 - u}{u_2 - u_1} N_{1,0}(u) \\ &= \frac{u}{1-0} N_{0,0}(u) + \frac{2-u}{2-1} N_{1,0}(u) \\ &= u N_{0,0}(u) + (2-u) N_{1,0}(u) \end{aligned}$$

$$\begin{aligned} i=1 \quad N_{1,1} &= \frac{u - u_1}{u_2 - u_1} N_{1,0}(u) + \frac{u_3 - u}{u_3 - u_2} N_{2,0}(u) \\ &= \frac{u-1}{2-1} N_{1,0}(u) + \frac{3-u}{3-2} N_{2,0}(u) \\ &= (u-1) N_{1,0}(u) + (3-u) N_{2,0}(u) \end{aligned}$$

$$\begin{aligned} i=2 \quad N_{2,1} &= \frac{u - u_2}{u_3 - u_2} N_{2,0}(u) + \frac{u_4 - u}{u_4 - u_3} N_{3,0}(u) \\ &= \frac{u-2}{3-2} N_{2,0}(u) \\ &= (u-2) N_{2,0}(u). \end{aligned}$$

$$i=3 \quad N_{3,1} = \frac{u - u_3}{u_4 - u_3} N_{3,0}(u) + \frac{u_5 - u}{u_5 - u_4} N_{4,0}(u)$$

$$= (4-u) N_{4,0}(u).$$

$$i=4 \quad N_{4,1} = \frac{u - u_4}{u_5 - u_4} N_{4,0}(u) + \frac{u_6 - u}{u_6 - u_5} N_{5,0}(u)$$

$$= \frac{u - 3}{4 - 3} N_{4,0}(u) + \frac{5 - u}{5 - 4} N_{5,0}(u)$$

$$= (u-3) N_{4,0}(u) + (5-u) N_{5,0}(u).$$

$$i=5 \quad N_{5,1} = \frac{u - u_5}{u_6 - u_5} N_{5,0}(u) + \frac{u_7 - u}{u_7 - u_6} N_{6,0}(u)$$

$$= \frac{u - 4}{5 - 4} N_{5,0}(u) + \frac{6 - u}{6 - 5} N_{6,0}(u)$$

$$= (u-4) N_{5,0}(u) + (6-u) N_{6,0}(u).$$

b=2

$$i=0 \quad N_{0,2} = \frac{u - u_0}{u_2 - u_0} N_{0,1}(u) + \frac{u_3 - u}{u_3 - u_1} N_{1,1}(u)$$

$$= \frac{u - 0}{2 - 1} \left( u N_{0,0}(u) + (2-u) N_{1,0}(u) \right) + \frac{3-u}{3-1} \left( (u-1) N_{1,0}(u) + (3-u) N_{2,0}(u) \right)$$

$$= \frac{u}{2} (u N_{0,0}(u) + (2-u) N_{1,0}(u)) + \frac{3-u}{2} ((u-1) N_{1,0}(u) + (3-u) N_{2,0}(u))$$

$$= \underbrace{\frac{u^2}{2} N_{0,0}(u)}_{(0,1)} + \underbrace{\frac{u}{2} (2-u) N_{1,0}(u)}_{(1,2)} + \underbrace{\frac{(3-u)(u-1)}{2} N_{1,0}(u)}_{(1,2)} + \underbrace{\frac{(3-u)^2}{2} N_{2,0}(u)}_{(2,3)}.$$

$i=1$ 

$$\begin{aligned}
 N_{1,2} &= \frac{u - u_1}{u_3 - u_1} N_{1,1}(u) + \frac{u_4 - u}{u_4 - u_2} N_{2,1}(u). \\
 &= \frac{u - 1}{3 - 1} ((u-1)N_{1,0}(u) + (3-u)N_{2,0}(u)) + \frac{3-u}{3-2} ((u-2)N_{2,0}(u)) \\
 &= \left( \frac{u-1}{2} \right) ((u-1)N_{1,0}(u) + (3-u)N_{2,0}(u)) + (3-u)(u-2) N_{2,0}(u). \\
 &= \underbrace{\frac{(u-1)^2}{2} N_{1,0}(u)}_{[1,2]} + \underbrace{\frac{(3-u)(u-1)}{2} N_{2,0}(u)}_{[2,3]} + (3-u)(u-2) N_{2,0}(u).
 \end{aligned}$$

 $i=2$ 

$$\begin{aligned}
 N_{2,2} &= \frac{u - u_2}{u_4 - u_2} N_{2,1}(u) + \frac{u_5 - u}{u_5 - u_3} N_{3,1}(u). \\
 &= \frac{u - 2}{3 - 2} N_{2,1}(u) + \frac{4 - u}{4 - 3} N_{3,1}(u). \\
 &= \frac{u - 2}{3 - 2} ((u-2)N_{2,0}(u)) + \frac{4-u}{4-3} ((4-u)N_{1,0}(u)) \\
 &= \underbrace{(u-2)^2 N_{2,0}(u)}_{[2,3]} + \underbrace{(4-u)^2 N_{1,0}(u)}_{[4,5]}.
 \end{aligned}$$

 $i=3$ 

$$\begin{aligned}
 N_{3,2} &= \frac{u - u_3}{u_5 - u_3} N_{3,1}(u) + \frac{u_6 - u}{u_6 - u_4} N_{4,1}(u) \\
 &= \frac{u - 3}{4 - 3} N_{3,1}(u) + \frac{5 - u}{5 - 3} N_{4,1}(u) \\
 &= (u-3)((4-u)N_{1,0}(u)) + \frac{5-u}{2} ((u-3)N_{1,0}(u) + (5-u)N_{5,0}(u)) \\
 &= \underbrace{((u-3)(4-u) + \frac{(5-u)(u-3)}{2})}_{[4,5]} N_{4,0}(u) + \underbrace{\frac{(5-u)^2}{2} N_{5,0}(u)}_{[5,6]}.
 \end{aligned}$$

$$\begin{aligned}
 N_{4,2} &= \frac{u-u_4}{u_6-u_4} N_{4,1}(u) + \frac{u_7-u}{u_7-u_5} N_{5,1}(u). \\
 &= \frac{u-3}{5-3} \left( (u-3) N_{4,0}(u) + (5-u) N_{5,0}(u) \right) + \frac{6-u}{6-4} \\
 &\quad \left( (u-1) N_{5,0}(u) + (6-u) N_{6,0}(u) \right) \\
 &= \frac{(u-3)^2}{2} N_{4,0}(u) + \frac{(u-3)(5-u)}{2} N_{5,0}(u) + \frac{(6-u)(u-1)}{2} N_{5,0}(u) + \frac{(6-u)^2}{2} N_{6,0}(u) \\
 &= \underbrace{\frac{(u-3)^2}{2} N_{4,0}(u)}_{[4,5]} + \underbrace{\frac{(u-3)(5-u)+(6-u)(u-1)}{2} N_{5,0}(u)}_{[5,6]} + \underbrace{\frac{(6-u)^2}{2} N_{6,0}(u)}_{[6,7]}.
 \end{aligned}$$

4.1.b

Values at  $u = 2.5$ :

Since the region of influence lies in  $[2, 3]$  we consider specific contributions:

$$\text{from } N_{0,2} = \frac{(3-u)^2}{2} N_{2,0}(u)$$

$$\text{from } N_{1,2} = \frac{(3-u)(u-1)}{2} N_{2,0}(u) + (3-u)(u-2) N_{2,0}(u)$$

$$\text{from } N_{2,2} = (u-2)^2 N_{2,0}(u).$$

Summing them:  $N_{0,2} + N_{1,2} + N_{2,2}$  within  $[2, 3]$

$$\begin{aligned}
 &= \frac{(3-2.5)^2}{2} + (3-u) \left( \frac{u-1}{2} + u-2 \right) + (2.5-2)^2 \\
 &= (0.5)^2 \frac{3}{2} + (0.5) \left( \frac{7.5-5}{2} \right) = 0.5 \left( \frac{1.5}{2} + \frac{2.5}{2} \right) = 1
 \end{aligned}$$

Satisfying the "partition of unity" condition.

4.1. d

$$\begin{aligned}
 C(u) &= \sum_{i=0}^M b_i N_{i,p}(u) . \quad \left[ \begin{array}{l} b_0 = \begin{cases} 0 \\ 1 \end{cases} \quad b_1 = \begin{cases} 1.5 \\ 0.7 \end{cases} \quad b_2 = \begin{cases} 3 \\ 0.85 \end{cases} \quad b_3 = \begin{cases} 3.5 \\ 1.2 \end{cases} \\ b_4 = \begin{cases} 5 \\ 1.1 \end{cases} \end{array} \right] \\
 &= \left( \frac{u^2}{2} N_{0,0}(u) + \frac{u}{2} (2-u) N_{1,0}(u) + \frac{(3-u)(u-1)}{2} N_{2,0}(u) + \frac{(3-u)^2}{2} N_{3,0}(u) \right) b_0 \\
 &\quad + \left( \frac{(u-1)^2}{2} N_{1,0}(u) + \left[ \frac{(3-u)(u-1)}{2} + (3-u)(u-2) \right] N_{2,0}(u) \right) b_1 \\
 &\quad + \left( (u-2)^2 N_{2,0}(u) + (4-u)^2 N_{3,0}(u) \right) b_2 \\
 &\quad + \left( (u-3)(1-u) + \frac{(5-u)(u-3)}{2} \right] N_{4,0}(u) + \frac{(5-u)^2}{2} N_{5,0}(u) \right) b_3 \\
 &\quad + \left( \frac{(u-3)^2}{2} N_{4,0}(u) + \frac{(u-3)(5-u)}{2} + (6-u)(u-4) \right] N_{5,0}(u) + \frac{(6-u)^2}{2} N_{6,0}(u) \right) b_4
 \end{aligned}$$

FOR  $u = 2.5$ Domain :  $[2, 3]$ 

$$\begin{aligned}
 C(2.5) &= \frac{(3-u)^2}{2} b_0 + \left[ \frac{(3-u)(u-1)}{2} + (3-u)(u-2) \right] b_1 + (u-2)^2 b_2 \\
 &= \frac{(3-2.5)^2}{2} \begin{cases} 0 \\ 1 \end{cases} + (0.5) \left( \frac{2.5}{2} \right) \begin{cases} 1.5 \\ 0.7 \end{cases} + (2.5-2)^2 \begin{cases} 3 \\ 0.85 \end{cases} \\
 &= \frac{(0.5)^2}{2} \begin{cases} 0 \\ 1 \end{cases} + \left( \frac{1.25}{2} \right) \begin{cases} 1.5 \\ 0.7 \end{cases} + (0.5)^2 \begin{cases} 3 \\ 0.85 \end{cases} = \begin{cases} 1.6875 \\ 0.775 \end{cases} \rightarrow ①
 \end{aligned}$$

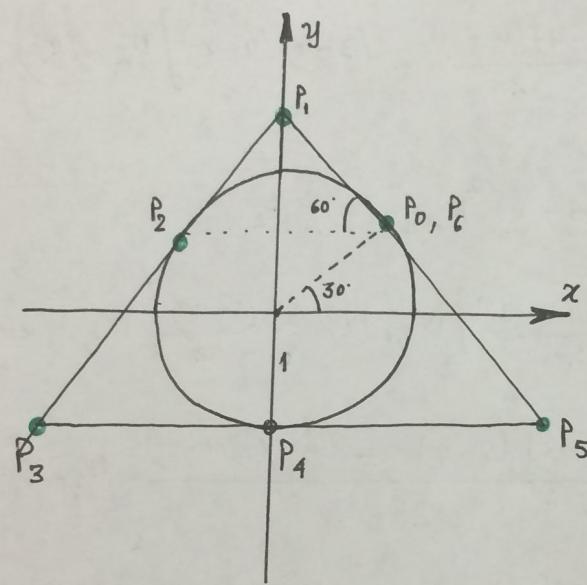
FOR  $u = 3.5$ Domain :  $[3, 4]$ 

$$\begin{aligned}
 C(3.5) &= (4-u)^2 b_2 + \left[ (u-3)(1-u) + \frac{(5-u)(u-3)}{2} \right] b_3 + \frac{(u-3)^2}{2} b_4 \\
 &= (0.5)^2 \begin{cases} 3 \\ 0.85 \end{cases} + \left( \frac{1.25}{2} \right) \begin{cases} 3.5 \\ 1.2 \end{cases} + \frac{(0.5)^2}{2} \begin{cases} 5 \\ 1.1 \end{cases} = \begin{cases} 3.5825 \\ 1.1 \end{cases} \rightarrow ②
 \end{aligned}$$

$$C(2.5) = \begin{pmatrix} 1.6875 \\ 0.775 \end{pmatrix}$$

$$C(3.5) = \begin{pmatrix} 3.5625 \\ 1.1 \end{pmatrix}$$

4.2



Given:

- Radius of circle : 1
- Equilateral triangle

a. Co-ordinates of control points:

$$P_0 : (1 \cos 30, 1 \sin 30) = \left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right)$$

$$P_1 : (0, 1 \csc 30) = (0, 2)$$

$$P_2 : (-1 \cos 30, 1 \sin 30) = \left(-\frac{\sqrt{3}}{2}, \frac{1}{2}\right)$$

$$P_3 : (-3 \cot 60, -1) = (-\sqrt{3}, -1)$$

$$P_4 : (0, -1)$$

$$P_5 : (3 \cot 60, -1) = (\sqrt{3}, -1)$$

$$P_6 : (1 \cos 30, 1 \sin 30) = \left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right)$$

b. Weights

$$w_0 : 1$$

$$w_1 : \cos 60 = \frac{1}{2}$$

$$w_2 : 1$$

$$w_3 : \frac{1}{2}$$

$$w_4 : 1$$

$$w_5 : \frac{1}{2}$$

$$w_6 : 1$$

4.2 (c):

$$u = \{0, 0, 0, 1, 1, 2, 2, 3, 3, 3\}.$$

$$N_{i,p} = \frac{u - u_i}{u_{i+p} - u_i} N_{i,p-1}(u) + \frac{u_{i+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}(u).$$

p=0

$$N_{0,0} = 0$$

$$N_{1,0} = 0$$

$$N_{2,0} = 1 \quad u \in [u_2, u_3]$$

$$N_{3,0} = 0$$

$$N_{4,0} = 1 \quad u \in [u_4, u_5]$$

$$N_{5,0} = 0$$

$$N_{6,0} = 1 \quad u \in [u_6, u_7]$$

$$N_{7,0} = 0 \quad u \in [u_7, u_8]$$

$$N_{8,0} = 0 \quad u \in [u_8, u_9]$$

p=1

$$N_{0,1} = 0$$

$$N_{1,1} = \frac{u_3 - u}{u_3 - u_2} N_{2,0} = (1-u) N_{2,0}$$

$$N_{2,1} = \frac{u}{1} N_{2,0} + \frac{u_4 - u}{u_4 - u_3} N_{3,0} = u N_{2,0}$$

$$N_{3,1} = \frac{u_5 - u}{u_5 - u_4} N_{4,0} = \frac{2-u}{2-1} N_{4,0} \\ = (2-u) N_{4,0}$$

$$N_{4,1} = \frac{u - u_4}{u_5 - u_4} N_{4,0} = (u-1) N_{4,0}$$

$$N_{5,1} = \frac{u_7 - u}{u_7 - u_6} N_{6,0} = (3-u) N_{6,0}$$

$$N_{6,1} = \frac{u - u_6}{u_7 - u_6} N_{6,0} + \frac{u_8 - u}{u_8 - u_7} N_{7,0} = (u-2) N_{6,0}$$

$$N_{7,1} = 0$$

p=2

$$N_{0,2} = (1-u)(1-u) N_{2,0} = (1-u)^2 N_{2,0}$$

$$N_{1,2} = u(1-u) N_{2,0} + (1-u)u N_{2,0} = 2u(1-u) N_{2,0}$$

$$N_{2,2} = u(u N_{2,0}) + (2-u)((2-u)) N_{4,0} = u^2 N_{2,0} + (2-u)^2 N_{4,0}$$

$$N_{3,2} = (u-1)((2-u) N_{4,0}) + (2-u)(u-1) N_{4,0} = 2(u-1)(2-u) N_{4,0}$$

$$N_{4,2} = (u-1)^2 N_{4,0} + (3-u)^2 N_{6,0}$$

$$N_{5,2} = 2(u-2)(3-u) N_{6,0} ; N_{6,2} = (u-2)^2 N_{6,0}$$

Computing curve points at  $u = 0.25$ ;  $u = 0.5$ ;  $u = 0.75$

It has a common domain  $u \in [0, 1]$

$$C(u) = \frac{(1-u)^2 N_{2,0} \begin{Bmatrix} \sqrt{3}/2 \\ 1/2 \end{Bmatrix} + 2u(1-u) N_{2,0} \begin{Bmatrix} 0 \\ 2 \end{Bmatrix} \frac{1}{2} + u^2 N_{2,0} \begin{Bmatrix} -\frac{\sqrt{3}}{2} \\ 1/2 \end{Bmatrix} \cdot 1}{(1-u)^2 N_{2,0} + 2u(1-u) N_{2,0} + u^2 N_{2,0}}$$

$$\text{For } u = 0.25 : \frac{\begin{pmatrix} 0.433 \\ 0.6875 \end{pmatrix}}{(0.8125)} = \begin{pmatrix} 0.5329 \\ 0.8461 \end{pmatrix}$$

$$\text{For } u = 0.5 \quad \frac{1}{0.8125} \begin{pmatrix} 0 \\ 0.8125 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$\text{For } u = 0.75 \quad \frac{1}{0.8125} \begin{pmatrix} -0.433 \\ 0.6875 \end{pmatrix} = \begin{pmatrix} -0.5329 \\ 0.8461 \end{pmatrix}$$

$$\text{Curve points: } C(0.25) = (0.5329, 0.8461)$$

$$C(0.50) = (0, 1)$$

$$C(0.75) = (-0.5329, 0.8461)$$

**Question 4.1: c**

**Plot the basis functions with a computer program.**

```
clear all;close all;

%define order
order = 3;
%define knot vector
%knots = [0 0 0 0 0.5 1 1 1 1];
%knots = [-2 -1 0 1 2 3 4 5 6]
%knots = [ 0 0 0 1 1 1];
% knots=[0 0 0 1 2 3 4 4 4];
knots = [0, 1, 2, 3, 3, 4, 5, 6];
%knots = [1 2 3 4 5 6 7 8 9 10 11 12];
%knots = [-10 -8 -6 -4 -2 0 2 4 6];

figure(1);

hold on;

% Plot all basis functions
for span=order-2: length(knots)-order
    u=linspace(knots(span+1),knots(span+2),20);
    f = zeros(order,length(u));

    for i=1:length(u)
        f(:,i)=Basisfun(u(i), knots, span, order);
    end

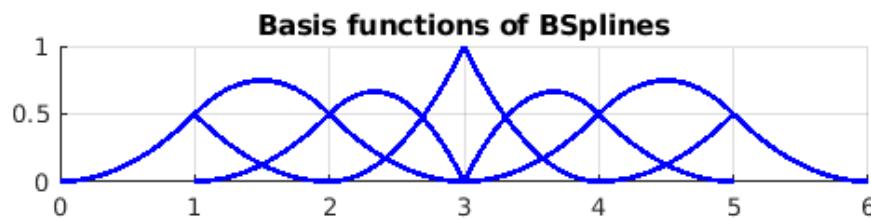
    % figure;
    % xlim([0 6])
    % ylim([0 1])

    plot(u,f,'b-', 'LineWidth',2);%, 'MarkerFaceColor', 'w', 'MarkerSize',4);
    % xlim([0 6])
    % ylim([-0.1 1.1])

    grid on;
    axis equal
end
xlim([0 6])
ylim([0 1])

u=linspace(knots(1),knots(2),20);
y= (u.^2)/2;
plot(u,y,'b-', 'LineWidth',2);
u=linspace(knots(7),knots(8),20);
y= 0.5* ((6-u).^2);
plot(u,y,'b-', 'LineWidth',2);
% set(gca, 'FontSize',20)
% xlabel('x','FontSize',20);
% ylabel('y','FontSize',20);
```

```
title("Basis functions of BSplines")
```



## ME 535 Assignment 3, Fall 2018

### Debabrata Auddya

#### Question 4.3:

##### c. Read the IGES file into Matlab

Name of igs file: Fish.igs

```
% read the igs file to matlab
clear;clf;
file_name = input('Please input the file name: ','s');
fp = fopen(file_name, 'r');
s = fscanf(fp, '%c',[82 inf]);s=s';
fclose(fp);

n=size(s);
j=0;
for i=1:n(1)-1
    temp = s(i,:);
    t = str2double(temp(6:8));
    % If t=126 indicate this line recorded a BS_curve
    if t == 126
        j = j+1;
        % find the bs_curve parameter segment number
        l = temp(13:16);
        % the following find BS_curve parameter segment
        for ii = i:n(1)-1
            temp1 = s(ii,:);
            % find BSCURVE parameter segment
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t
                % parameter segment sign, in our example is '21P'
                temp2 = temp1(70:73);
                row1 = ii;
                for i2 = ii:n(1)-1
                    temp3 = s(i2,:);
                    % find all parameter lines in the same BSCURVE
                    if strcmp(temp3(70:73),temp2)
                        % record the last BS_curve parameter line
                        k = i2;
                    end
                end
                for i3=1:k-row1+1
                    bs(i3,:)=s(row1+i3-1,:);
                end
                %call bspline processing function
                hold on;
                bsp_curve(bs);
                clear bs
            end
        end
    elseif t==128 % BS_surface
        j=j+1;
        l = temp(13:16);%bs_surface eparameter segment
        % find bs_surface parameter
        for ii=i:n(1)-1
            temp1=s(ii,:);
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t% find BSCURVE parameter segment
                % parameter segment example: 25p
                temp2 = temp1(70:73);
                row1=ii;
                for i2=ii:n(1)-1
                    temp3=s(i2,:);
                    % find all parameter lines in the same BSCURVE

```

```

        if strcmp(temp3(70:73),temp2)
            k=i2; %record the last BS_cruve parameter line
        end
    end
    for i3=1:k-row1+1
        bs(i3,:)=s(row1+i3-1,:);
    end
    %call bs drawing function
    hold on;
    bsp_surface(bs);
    view(-8,-42);
    clear bs
end
end
end

```

degree 3

weights

Columns 1 through 23

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Columns 24 through 42

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

control points...

0.0600	9.0265	0
2.7841	7.1406	0
3.0355	4.7518	0
3.2451	2.1115	0
3.2870	1.1057	0
3.4127	0.3094	0
3.9575	0.0580	0
4.4604	-0.6545	0
4.9214	-1.5346	0
5.3405	-2.6661	0
5.4662	-3.7138	0
5.4662	-4.5520	0
5.5919	-5.1387	0
5.0890	-4.8873	0
4.8795	-4.6358	0
4.6700	-4.1748	0
4.3347	-3.3785	0
4.2090	-3.0433	0
4.1670	-3.0433	0
3.9994	-3.1690	0
4.1251	-3.7557	0
4.2928	-4.2586	0
3.4546	-3.6719	0
3.1193	-2.6661	0
2.8679	-2.5404	0
3.0355	-3.8395	0
3.1193	-6.0607	0
2.4488	-7.5275	0
1.7782	-8.2819	0
1.0671	-9.2445	0
1.0671	-9.4482	0
1.3726	-11.1455	0
2.5267	-12.6730	0
3.5112	-13.6235	0
4.1561	-14.1667	0
4.7332	-14.6759	0
4.9709	-14.9474	0
3.3075	-14.3364	0
2.3570	-13.8612	0
1.4065	-13.3520	0

0.7276	-12.9107	0
0.0147	-12.5033	0

## knotvector

Columns 1 through 14

0	0	0	0	1.0971	2.1942	3.2913	4.3884	5.4855	6.5826	7.6797	8.
---	---	---	---	--------	--------	--------	--------	--------	--------	--------	----

Columns 15 through 28

12.0680	13.1651	14.2622	15.3593	16.4564	17.5535	18.6506	19.7477	20.8448	21.9419	23.0390	24.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 29 through 42

27.4274	28.5245	29.6216	30.7187	31.8157	32.9128	34.0099	35.1070	36.2041	37.3012	38.3983	39.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 43 through 46

42.7867	42.7867	42.7867	42.7867
---------	---------	---------	---------

## degree 3

## weights

Columns 1 through 23

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Columns 24 through 42

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

## control points...

-0.0600	9.0265	0
-2.7841	7.1406	0
-3.0355	4.7518	0
-3.2451	2.1115	0
-3.2870	1.1057	0
-3.4127	0.3094	0
-3.9575	0.0580	0
-4.4604	-0.6545	0
-4.9214	-1.5346	0
-5.3405	-2.6661	0
-5.4662	-3.7138	0
-5.4662	-4.5520	0
-5.5919	-5.1387	0
-5.0890	-4.8873	0
-4.8795	-4.6358	0
-4.6700	-4.1748	0
-4.3347	-3.3785	0
-4.2090	-3.0433	0
-4.1670	-3.0433	0
-3.9994	-3.1690	0
-4.1251	-3.7557	0
-4.2928	-4.2586	0
-3.4546	-3.6719	0
-3.1193	-2.6661	0
-2.8679	-2.5404	0
-3.0355	-3.8395	0
-3.1193	-6.0607	0
-2.4488	-7.5275	0
-1.7782	-8.2819	0
-1.0671	-9.2445	0
-1.0671	-9.4482	0
-1.3726	-11.1455	0
-2.5267	-12.6730	0
-3.5112	-13.6235	0
-4.1561	-14.1667	0
-4.7332	-14.6759	0
-4.9709	-14.9474	0
-3.3075	-14.3364	0
-2.3570	-13.8612	0

-1.4065	-13.3520	0
-0.7276	-12.9107	0
-0.0147	-12.5033	0

knotvector

Columns 1 through 14

0	0	0	0	1.0971	2.1942	3.2913	4.3884	5.4855	6.5826	7.6797	8.
---	---	---	---	--------	--------	--------	--------	--------	--------	--------	----

Columns 15 through 28

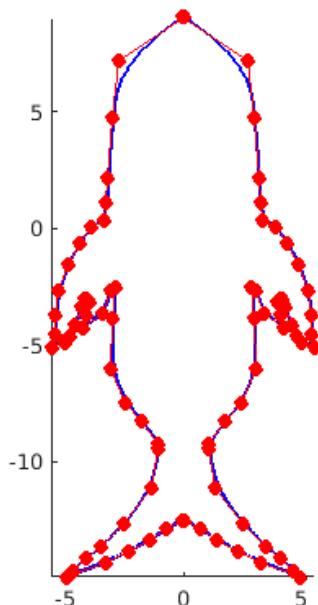
12.0680	13.1651	14.2622	15.3593	16.4564	17.5535	18.6506	19.7477	20.8448	21.9419	23.0390	24.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 29 through 42

27.4274	28.5245	29.6216	30.7187	31.8157	32.9128	34.0099	35.1070	36.2041	37.3012	38.3983	39.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 43 through 46

42.7867	42.7867	42.7867	42.7867
---------	---------	---------	---------



d. Demonstrate the geometric effect of changing control points:

**Changing control points.****File name:** fishControl.igs**Control points changed from :**

(2.7841,7.1406) --&gt; (2.98,6.000)

(3.0355,4.7517) --&gt; (3.1355,4.2517)

(3.245,2.115) --&gt; (3.255,1.915)

(3.287,1.1057) --&gt; (3.3569, 0.8057)

```
% read the igs file to matlab
clear;clf;
file_name = input('Please input the file name: ','s');
fp = fopen(file_name, 'r');
s = fscanf(fp,'%c',[82 inf]);s=s';
fclose(fp);

n=size(s);
j=0;
for i=1:n(1)-1
    temp = s(i,:);
    t = str2double(temp(6:8));
    % If t=126 indicate this line recorded a BS_curve
    if t == 126
        j = j+1;
        % find the bs_curve parameter segment number
        l = temp(13:16);
        % the following find BS_curve parameter segment
        for ii = i:n(1)-1
            temp1 = s(ii,:);
            % find BSCURVE parameter segment
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t
                % parameter segment sign, in our example is '21P'
                temp2 = temp1(70:73);
                row1 = ii;
                for i2 = ii:n(1)-1
                    temp3 = s(i2,:);
                    % find all parameter lines in the same BSCURVE
                    if strcmp(temp3(70:73),temp2)
                        % record the last BS_curve parameter line
                        k = i2;
                    end
                end
                for i3=1:k-row1+1
                    bs(i3,:)=s(row1+i3-1,:);
                end
                %call bspline processing function
                hold on;
                bsp_curve(bs);
                clear bs
            end
        end
    elseif t==128 % BS_surface
        j=j+1;
        l = temp(13:16);%bs_surface eparameter segment
        % find bs_surface parameter
        for ii=i:n(1)-1
            temp1=s(ii,:);
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t% find BSCURVE parameter segment
                % parameter segment example: 25P
                temp2 = temp1(70:73);
                row1=ii;
                for i2=ii:n(1)-1

```

```

        temp3=s(i2,:);
        % find all parameter lines in the same BSCURVE
        if strcmp(temp3(70:73),temp2)
            k=i2; %record the last BS_cruve parameter line
        end
    end
    for i3=1:k-row1+1
        bs(i3,:)=s(row1+i3-1,:);
    end
    %call bs drawing function
    hold on;
    bsp_surface(bs);
    view(-8, -42);
    clear bs
end
end
end

```

degree 3

weights

Columns 1 through 23

1 1

Columns 24 through 42

1 1

control points...

0.0600	9.0265	0
2.9821	6.0006	0
3.1355	4.2518	0
3.2551	1.9115	0
3.3570	0.8057	0
3.4127	0.3094	0
3.9575	0.0580	0
4.4604	-0.6545	0
4.9214	-1.5346	0
5.3405	-2.6661	0
5.4662	-3.7138	0
5.4662	-4.5520	0
5.5919	-5.1387	0
5.0890	-4.8873	0
4.8795	-4.6358	0
4.6700	-4.1748	0
4.3347	-3.3785	0
4.2090	-3.0433	0
4.1670	-3.0433	0
3.9994	-3.1690	0
4.1251	-3.7557	0
4.2928	-4.2586	0
3.4546	-3.6719	0
3.1193	-2.6661	0
2.8679	-2.5404	0
3.0355	-3.8395	0
3.1193	-6.0607	0
2.4488	-7.5275	0
1.7782	-8.2819	0
1.0671	-9.2445	0
1.0671	-9.4482	0
1.3726	-11.1455	0
2.5267	-12.6730	0
3.5112	-13.6235	0
4.1561	-14.1667	0
4.7332	-14.6759	0
4.9709	-14.9474	0
3.3075	-14.3364	0

2.3570	-13.8612	0
1.4065	-13.3520	0
0.7276	-12.9107	0
0.0147	-12.5033	0

## knotvector

Columns 1 through 14

0	0	0	0	1.0971	2.1942	3.2913	4.3884	5.4855	6.5826	7.6797	8.
---	---	---	---	--------	--------	--------	--------	--------	--------	--------	----

Columns 15 through 28

12.0680	13.1651	14.2622	15.3593	16.4564	17.5535	18.6506	19.7477	20.8448	21.9419	23.0390	24.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 29 through 42

27.4274	28.5245	29.6216	30.7187	31.8157	32.9128	34.0099	35.1070	36.2041	37.3012	38.3983	39.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 43 through 46

42.7867	42.7867	42.7867	42.7867
---------	---------	---------	---------

## degree 3

## weights

Columns 1 through 23

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Columns 24 through 42

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

## control points...

-0.0600	9.0265	0
-2.7841	7.1406	0
-3.0355	4.7518	0
-3.2451	2.1115	0
-3.2870	1.1057	0
-3.4127	0.3094	0
-3.9575	0.0580	0
-4.4604	-0.6545	0
-4.9214	-1.5346	0
-5.3405	-2.6661	0
-5.4662	-3.7138	0
-5.4662	-4.5520	0
-5.5919	-5.1387	0
-5.0890	-4.8873	0
-4.8795	-4.6358	0
-4.6700	-4.1748	0
-4.3347	-3.3785	0
-4.2090	-3.0433	0
-4.1670	-3.0433	0
-3.9994	-3.1690	0
-4.1251	-3.7557	0
-4.2928	-4.2586	0
-3.4546	-3.6719	0
-3.1193	-2.6661	0
-2.8679	-2.5404	0
-3.0355	-3.8395	0
-3.1193	-6.0607	0
-2.4488	-7.5275	0
-1.7782	-8.2819	0
-1.0671	-9.2445	0
-1.0671	-9.4482	0
-1.3726	-11.1455	0
-2.5267	-12.6730	0
-3.5112	-13.6235	0
-4.1561	-14.1667	0
-4.7332	-14.6759	0
-4.9709	-14.9474	0

-3.3075	-14.3364	0
-2.3570	-13.8612	0
-1.4065	-13.3520	0
-0.7276	-12.9107	0
-0.0147	-12.5033	0

## knotvector

Columns 1 through 14

0	0	0	0	1.0971	2.1942	3.2913	4.3884	5.4855	6.5826	7.6797	8.
---	---	---	---	--------	--------	--------	--------	--------	--------	--------	----

Columns 15 through 28

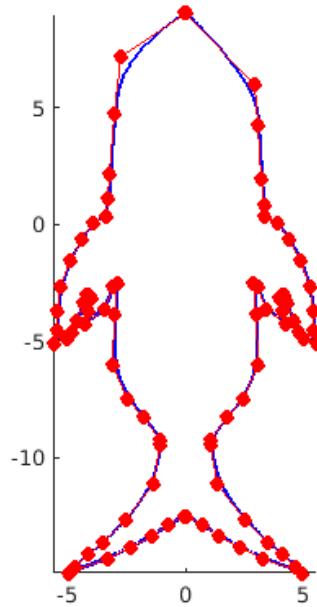
12.0680	13.1651	14.2622	15.3593	16.4564	17.5535	18.6506	19.7477	20.8448	21.9419	23.0390	24.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 29 through 42

27.4274	28.5245	29.6216	30.7187	31.8157	32.9128	34.0099	35.1070	36.2041	37.3012	38.3983	39.
---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	-----

Columns 43 through 46

42.7867	42.7867	42.7867	42.7867
---------	---------	---------	---------



Demonstrate the effect of changing knot vector

```
% read the igs file to matlab
clear;clf;
file_name = input('Please input the file name: ','s');
fp = fopen(file_name, 'r');
s = fscanf(fp, '%c',[82 inf]);s=s';
fclose(fp);

n=size(s);
j=0;
for i=1:n(1)-1
    temp = s(i,:);
    t = str2double(temp(6:8));
    % If t=126 indicate this line recorded a BS_curve
    if t == 126
        j = j+1;
        % find the bs_curve parameter segment number
        l = temp(13:16);
        % the following find BS_curve parameter segment
        for ii = i:n(1)-1
            temp1 = s(ii,:);
            % find BSCURVE parameter segment
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t
                % parameter segment sign, in our example is '21P'
                temp2 = temp1(70:73);
                row1 = ii;
                for i2 = ii:n(1)-1
                    temp3 = s(i2,:);
                    % find all parameter lines in the same BSCURVE
                    if strcmp(temp3(70:73),temp2)
                        % record the last BS_curve parameter line
                        k = i2;
                    end
                end
                for i3=1:k-row1+1
                    bs(i3,:)=s(row1+i3-1,:);
                end
                %call bspline processing function
                hold on;
                bsp_curve(bs);
                clear bs
            end
        end
    elseif t==128 % BS_surface
        j=j+1;
        l = temp(13:16);%bs_surface eparameter segment
        % find bs_surface parameter
        for ii=i:n(1)-1
            temp1=s(ii,:);
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t% find BSCURVE parameter segment
                % parameter segment example: 25p
                temp2 = temp1(70:73);
                row1=ii;
                for i2=ii:n(1)-1
                    temp3=s(i2,:);
                    % find all parameter lines in the same BSCURVE
                    if strcmp(temp3(70:73),temp2)
                        k=i2; %record the last BS_cruve parameter line
                    end
                end
                for i3=1:k-row1+1
                    bs(i3,:)=s(row1+i3-1,:);
                end
                %call bs drawing function
            end
        end
    end
end
```

```

        hold on;
        bsp_surface(bs);
        view(-8, -42);
        clear bs
    end
end
end

degree 3
weights
Columns 1 through 24

1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1

Columns 25 through 42

1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1

control points...
0.0600    9.0265    0
2.7841    7.1406    0
3.0355    4.7518    0
3.2451    2.1115    0
3.2870    1.1057    0
3.4127    0.3094    0
3.9575    0.0580    0
4.4604   -0.6545    0
4.9214   -1.5346    0
5.3405   -2.6661    0
5.4662   -3.7138    0
5.4662   -4.5520    0
5.5919   -5.1387    0
5.0890   -4.8873    0
4.8795   -4.6358    0
4.6700   -4.1748    0
4.3347   -3.3785    0
4.2090   -3.0433    0
4.1670   -3.0433    0
3.9994   -3.1690    0
4.1251   -3.7557    0
4.2928   -4.2586    0
3.4546   -3.6719    0
3.1193   -2.6661    0
2.8679   -2.5404    0
3.0355   -3.8395    0
3.1193   -6.0607    0
2.4488   -7.5275    0
1.7782   -8.2819    0
1.0671   -9.2445    0
1.0671   -9.4482    0
1.3726  -11.1455    0
2.5267  -12.6730    0
3.5112  -13.6235    0
4.1561  -14.1667    0
4.7332  -14.6759    0
4.9709  -14.9474    0
3.3075  -14.3364    0
2.3570  -13.8612    0
1.4065  -13.3520    0
0.7276  -12.9107    0
0.0147  -12.5033    0

knotvector
Columns 1 through 14

0         0         0         0      1.0971      2.1942      3.2913      4.3884      5.4855      5.5826      5.6797      5.

Columns 15 through 28

```

12.0680 18.1651 18.2622 18.3593 18.4564 18.5535 18.6506 19.7477 20.8448 21.9419 23.0390 24.

Columns 29 through 42

27.4274 29.5245 29.6216 30.7187 31.8157 33.9128 34.0099 35.1070 36.2041 37.3012 39.3983 39.

Columns 43 through 46

48.7867 48.7867 48.7867 48.7867

degree 3

weights

Columns 1 through 24

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Columns 25 through 42

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

control points...

-0.0600	9.0265	0
-2.7841	7.1406	0
-3.0355	4.7518	0
-3.2451	2.1115	0
-3.2870	1.1057	0
-3.4127	0.3094	0
-3.9575	0.0580	0
-4.4604	-0.6545	0
-4.9214	-1.5346	0
-5.3405	-2.6661	0
-5.4662	-3.7138	0
-5.4662	-4.5520	0
-5.5919	-5.1387	0
-5.0890	-4.8873	0
-4.8795	-4.6358	0
-4.6700	-4.1748	0
-4.3347	-3.3785	0
-4.2090	-3.0433	0
-4.1670	-3.0433	0
-3.9994	-3.1690	0
-4.1251	-3.7557	0
-4.2928	-4.2586	0
-3.4546	-3.6719	0
-3.1193	-2.6661	0
-2.8679	-2.5404	0
-3.0355	-3.8395	0
-3.1193	-6.0607	0
-2.4488	-7.5275	0
-1.7782	-8.2819	0
-1.0671	-9.2445	0
-1.0671	-9.4482	0
-1.3726	-11.1455	0
-2.5267	-12.6730	0
-3.5112	-13.6235	0
-4.1561	-14.1667	0
-4.7332	-14.6759	0
-4.9709	-14.9474	0
-3.3075	-14.3364	0
-2.3570	-13.8612	0
-1.4065	-13.3520	0
-0.7276	-12.9107	0
-0.0147	-12.5033	0

knotvector

Columns 1 through 14

0	0	0	0	0.5551	1.9942	3.2913	4.3884	5.4855	6.5826	7.6797	8.
---	---	---	---	--------	--------	--------	--------	--------	--------	--------	----

Columns 15 through 28

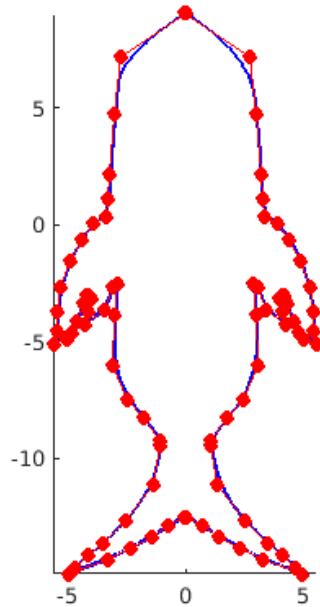
12.0680 13.1651 14.2622 15.3593 16.4564 17.5535 18.6506 19.7477 20.8448 21.9419 23.0390 24.

Columns 29 through 42

27.4274 28.5245 29.6216 30.7187 31.8157 32.9128 34.0099 35.1070 36.2041 37.3012 38.3983 39.

Columns 43 through 46

42.7867 42.7867 42.7867 42.7867



### Demonstrate the effect of changing degree

#### Degree of the problem changed from 3 to 2

```
% read the igs file to matlab
clear;clf;
file_name = input('Please input the file name: ','s');
fp = fopen(file_name, 'r');
s = fscanf(fp, '%c',[82 inf]);s=s';
fclose(fp);

n=size(s);
j=0;
for i=1:n(1)-1
    temp = s(i,:);
    t = str2double(temp(6:8));
    % If t=126 indicate this line recorded a BS_curve
    if t == 126
        j = j+1;
        % find the bs_curve parameter segment number
        l = temp(13:16);
        % the following find BS_curve parameter segment
        for ii = i:n(1)-1
            temp1 = s(ii,:);
            % find BSCURVE parameter segment
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t
                % parameter segment sign, in our example is '21P'
                temp2 = temp1(70:73);
                row1 = ii;
                for i2 = ii:n(1)-1
                    temp3 = s(i2,:);
                    % find all parameter lines in the same BSCURVE
                    if strcmp(temp3(70:73),temp2)
                        % record the last BS_curve parameter line
                        k = i2;
                    end
                end
                for i3=1:k-row1+1
                    bs(i3,:)=s(row1+i3-1,:);
                end
                %call bspline processing function
                hold on;
                bsp_curve(bs);
                clear bs
            end
        end
    elseif t==128 % BS_surface
        j=j+1;
        l = temp(13:16);%bs_surface eparameter segment
        % find bs_surface parameter
        for ii=i:n(1)-1
            temp1=s(ii,:);
            if strcmp(temp1(77:80),l) & str2double(temp1(1:3)) == t% find BSCURVE parameter segment
                % parameter segment example: 25p
                temp2 = temp1(70:73);
                row1=ii;
                for i2=ii:n(1)-1
                    temp3=s(i2,:);
                    % find all parameter lines in the same BSCURVE
                    if strcmp(temp3(70:73),temp2)
                        k=i2; %record the last BS_cruve parameter line
                    end
                end
                for i3=1:k-row1+1
                    bs(i3,:)=s(row1+i3-1,:);
                end
            end
        end
    end
end
```

```

        end
    %call bs drawing function
    hold on;
    bsp_surface(bs);
    view(-8, -42);
    clear bs
    end
end
end

```

degree 2  
weights  
Columns 1 through 23

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Columns 24 through 42

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

control points...

1.0000	0.0600	9.0265
0	2.7841	7.1406
0	3.0355	4.7518
0	3.2451	2.1115
0	3.2870	1.1057
0	3.4127	0.3094
0	3.9575	0.0580
0	4.4604	-0.6545
0	4.9214	-1.5346
0	5.3405	-2.6661
0	5.4662	-3.7138
0	5.4662	-4.5520
0	5.5919	-5.1387
0	5.0890	-4.8873
0	4.8795	-4.6358
0	4.6700	-4.1748
0	4.3347	-3.3785
0	4.2090	-3.0433
0	4.1670	-3.0433
0	3.9994	-3.1690
0	4.1251	-3.7557
0	4.2928	-4.2586
0	3.4546	-3.6719
0	3.1193	-2.6661
0	2.8679	-2.5404
0	3.0355	-3.8395
0	3.1193	-6.0607
0	2.4488	-7.5275
0	1.7782	-8.2819
0	1.0671	-9.2445
0	1.0671	-9.4482
0	1.3726	-11.1455
0	2.5267	-12.6730
0	3.5112	-13.6235
0	4.1561	-14.1667
0	4.7332	-14.6759
0	4.9709	-14.9474
0	3.3075	-14.3364
0	2.3570	-13.8612
0	1.4065	-13.3520
0	0.7276	-12.9107
0	0.0147	-12.5033

knotvector

Columns 1 through 14

10/1/2018

Untitled

0 0 0 0 1.0971 2.1942 3.2913 4.3884 5.4855 6.5826 7.6797 8.

Columns 15 through 28

12.0680 13.1651 14.2622 15.3593 16.4564 17.5535 18.6506 19.7477 20.8448 21.9419 23.0390 24.

Columns 29 through 42

27.4274 28.5245 29.6216 30.7187 31.8157 32.9128 34.0099 35.1070 36.2041 37.3012 38.3983 39.

Columns 43 through 45

42.7867 42.7867 42.7867

degree 3

weights

Columns 1 through 23

1 1

Columns 24 through 42

1 1

control points...

-0.0600	9.0265	0
-2.7841	7.1406	0
-3.0355	4.7518	0
-3.2451	2.1115	0
-3.2870	1.1057	0
-3.4127	0.3094	0
-3.9575	0.0580	0
-4.4604	-0.6545	0
-4.9214	-1.5346	0
-5.3405	-2.6661	0
-5.4662	-3.7138	0
-5.4662	-4.5520	0
-5.5919	-5.1387	0
-5.0890	-4.8873	0
-4.8795	-4.6358	0
-4.6700	-4.1748	0
-4.3347	-3.3785	0
-4.2090	-3.0433	0
-4.1670	-3.0433	0
-3.9994	-3.1690	0
-4.1251	-3.7557	0
-4.2928	-4.2586	0
-3.4546	-3.6719	0
-3.1193	-2.6661	0
-2.8679	-2.5404	0
-3.0355	-3.8395	0
-3.1193	-6.0607	0
-2.4488	-7.5275	0
-1.7782	-8.2819	0
-1.0671	-9.2445	0
-1.0671	-9.4482	0
-1.3726	-11.1455	0
-2.5267	-12.6730	0
-3.5112	-13.6235	0
-4.1561	-14.1667	0
-4.7332	-14.6759	0
-4.9709	-14.9474	0
-3.3075	-14.3364	0
-2.3570	-13.8612	0
-1.4065	-13.3520	0
-0.7276	-12.9107	0
-0.0147	-12.5033	0

knotvector

Columns 1 through 14

0	0	0	0	1.0971	2.1942	3.2913	4.3884	5.4855	6.5826	7.6797	8.
Columns 15 through 28											
12.0680	13.1651	14.2622	15.3593	16.4564	17.5535	18.6506	19.7477	20.8448	21.9419	23.0390	24.
Columns 29 through 42											
27.4274	28.5245	29.6216	30.7187	31.8157	32.9128	34.0099	35.1070	36.2041	37.3012	38.3983	39.
Columns 43 through 46											
42.7867	42.7867	42.7867	42.7867								

