10/1/18

ME535 ASSIGNMENT #3

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: $(p=0)$

$i=0$ $N_{0,0} = \begin{cases} 1 & u \in [u_0, u_1) \\ 0 \end{cases}$

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

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

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

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

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

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

$(p=1)$

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

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

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

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

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

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

$i=2$ $N_{2,1} = \frac{u - u_2}{u_3 - u_2} N_{2,0}(u) + \frac{u_4 - u}{u_4 - u_3} N_{3,0}(u)$

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

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

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

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

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

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

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

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

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

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

$\underline{p=2}$

$i=0$

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

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

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

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

$i = 1$

$$N_{1,2} = \frac{u - u_1}{u_3 - u_1} N_{1,1}(u) + \frac{u_4 - u}{u_4 - u_2} N_{2,1}(u).$$

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

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

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

$i = 2$

$$N_{2,2} = \frac{u - u_2}{u_4 - u_2} N_{2,1}(u) + \frac{u_5 - u}{u_5 - u_3} N_{3,1}(u).$$

$$= \frac{u-2}{3-2} N_{2,1}(u) + \frac{4-u}{4-3} N_{3,1}(u).$$

$$= \frac{u-2}{3-2}\left((u-2)N_{2,0}(u)\right) + \frac{4-u}{4-3}\left((4-u)N_{4,0}(u)\right)$$

$$= \underbrace{(u-2)^2 N_{2,0}(u)}_{[2,3)} + \underbrace{(4-u)^2 N_{4,0}(u)}_{[4,5)}.$$

$i = 3$

$$N_{3,2} = \frac{u - u_3}{u_5 - u_3} N_{3,1}(u) + \frac{u_6 - u}{u_6 - u_4} N_{4,1}(u)$$

$$= \frac{u-3}{4-3} N_{3,1}(u) + \frac{5-u}{5-3} N_{4,1}(u)$$

$$= (u-3)\left((4-u)N_{4,0}(u)\right) + \frac{5-u}{2}\left((u-3)N_{4,0}(u) + (5-u)N_{5,0}(u)\right)$$

$$= \underbrace{\left((u-3)(4-u) + \frac{(5-u)(u-3)}{2}\right) N_{4,0}(u)}_{[4,5)} + \underbrace{\frac{(5-u)^2}{2} N_{5,0}(u)}_{[5,6)}.$$

$i=4$

$$N_{4,2} = \frac{u-u_4}{u_6-u_4} N_{4,1}(u) + \frac{u_7-u}{u_7-u_5} N_{5,1}(u).$$

$$= \frac{u-3}{5-3}\left((u-3)N_{4,0}(u) + (5-u)N_{5,0}(u)\right) + \frac{6-u}{6-4}\left((u-4)N_{5,0}(u) + (6-u)N_{6,0}(u)\right)$$

$$= \frac{(u-3)^2}{2} N_{4,0}(u) + \frac{(u-3)(5-u)}{2} N_{5,0}(u) + \frac{(6-u)(u-4)}{2} N_{5,0}(u) + \frac{(6-u)^2}{2} N_{6,0}(u)$$

$$= \underbrace{\frac{(u-3)^2}{2} N_{4,0}(u)}_{[4,5)} + \underbrace{\left(\frac{(u-3)(5-u)+(6-u)(u-4)}{2}\right) N_{5,0}(u)}_{[5,6)} + \underbrace{\frac{(6-u)^2}{2} N_{6,0}(u)}_{[6,7)}$$

4.1.b

Values at $u = 2.5$:

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

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

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

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

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

$$= \frac{(3-2.5)^2}{2} + (3-u)\left(\frac{u-1}{2} + u - 2\right) + (2.5-2)^2$$

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

Satisfying the "partition of unity" condition.

4.1.d

$$C(u) = \sum_{i=0}^{M} P_i N_{i,p}(u) \qquad \left[P_0 = \begin{Bmatrix} 0 \\ 1 \end{Bmatrix} \quad P_1 = \begin{Bmatrix} 1.5 \\ 0.7 \end{Bmatrix} \quad P_2 = \begin{Bmatrix} 3 \\ 0.85 \end{Bmatrix} \quad P_3 = \begin{Bmatrix} 3.5 \\ 1.2 \end{Bmatrix} \quad P_4 = \begin{Bmatrix} 5 \\ 1.1 \end{Bmatrix} \right]$$

$$= \left(\frac{u^2}{2} N_{0,0}(u) + \frac{u}{2}(2-u) N_{1,0}(u) + \frac{(3-u)(u-1)}{2} N_{1,0}(u) + \frac{(3-u)^2}{2} N_{2,0}(u) \right) P_0$$

$$+ \left(\frac{(u-1)^2}{2} N_{1,0}(u) + \left[\frac{(3-u)(u-1)}{2} + (3-u)(u-2) \right] N_{2,0}(u) \right) P_1$$

$$+ \left((u-2)^2 N_{2,0}(u) + (4-u)^2 N_{4,0}(u) \right) P_2$$

$$+ \left(\left[(u-3)(4-u) + \frac{(5-u)(u-3)}{2} \right] N_{4,0}(u) + \frac{(5-u)^2}{2} N_{5,0}(u) \right) P_3$$

$$+ \left(\frac{(u-3)^2}{2} N_{4,0}(u) + \frac{(u-3)(5-u) + (6-u)(u-4)}{2} N_{5,0}(u) + \frac{(6-u)^2}{2} N_{6,0}(u) \right) P_4$$

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

$$C(2.5) = \frac{(3-u)^2}{2} P_0 + \left[\frac{(3-u)(u-1)}{2} + (3-u)(u-2) \right] P_1 + (u-2)^2 P_2$$

$$= \frac{(3-2.5)^2}{2} \begin{Bmatrix} 0 \\ 1 \end{Bmatrix} + (0.5)\left(\frac{2.5}{2}\right) \begin{Bmatrix} 1.5 \\ 0.7 \end{Bmatrix} + (2.5-2)^2 \begin{Bmatrix} 3 \\ 0.85 \end{Bmatrix}$$

$$= \frac{(0.5)^2}{2} \begin{Bmatrix} 0 \\ 1 \end{Bmatrix} + \left(\frac{1.25}{2}\right) \begin{Bmatrix} 1.5 \\ 0.7 \end{Bmatrix} + (0.5)^2 \begin{Bmatrix} 3 \\ 0.85 \end{Bmatrix} = \begin{Bmatrix} 1.6875 \\ 0.775 \end{Bmatrix} \rightarrow (1)$$

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

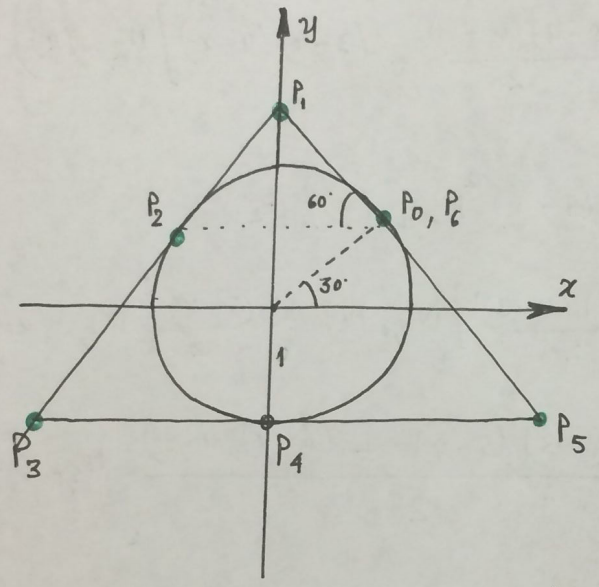
$$C(3.5) = (4-u)^2 P_2 + \left[(u-3)(4-u) + \frac{(5-u)(u-3)}{2} \right] P_3 + \frac{(u-3)^2}{2} P_4$$

$$= (0.5)^2 \begin{Bmatrix} 3 \\ 0.85 \end{Bmatrix} + \left(\frac{1.25}{2}\right) \begin{Bmatrix} 3.5 \\ 1.2 \end{Bmatrix} + \frac{(0.5)^2}{2} \begin{Bmatrix} 5 \\ 1.1 \end{Bmatrix} = \begin{Bmatrix} 3.5875 \\ 1.1 \end{Bmatrix} \rightarrow (2)$$

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

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

4.2



Given:
- Radius of circle : 1
- Equilateral triangle

a. Co-ordinates of control points:

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

$P_1 : (0,\ 1\operatorname{cosec} 30) = (0, 2)$

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

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

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

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

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

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 $u \in [0, 1)$

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

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

For $u = 0.5$ $\dfrac{1}{0.8125} \begin{pmatrix} 0 \\ 0.8125 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$

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

Curve points :

$C(0.25) = (0.5329, 0.8461)$

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

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

ME 535 Assignment 3, Fall 2018

Debabrata Auddya

Question 4.3:

c. Read the IGES file into Matlab

Name of igs file: Fish.igs

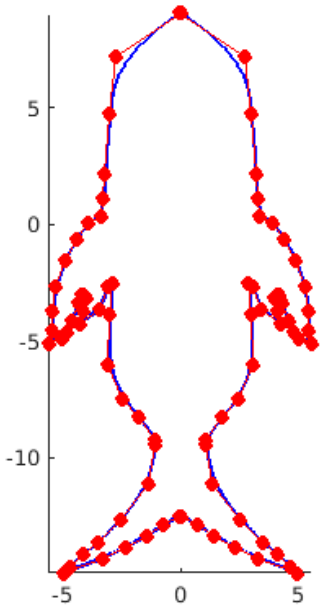
```
% read the igs file to matlab
clear;clf;
file_name = input('Pleas input the file name: ','s');
fp = fopen(file_name, 'r');
s = fscanf(fp,'%c',[82 inf]);s=s';
fclose(fp);

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

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

  Columns 24 through 42

     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

  Columns 24 through 42

     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) --> (2.98,6.000)

(3.0355,4.7517) --> (3.1355,4.2517)

(3.245,2.115) --> (3.255,1.915)

(3.287,1.1057) --> (3.3569, 0.8057)

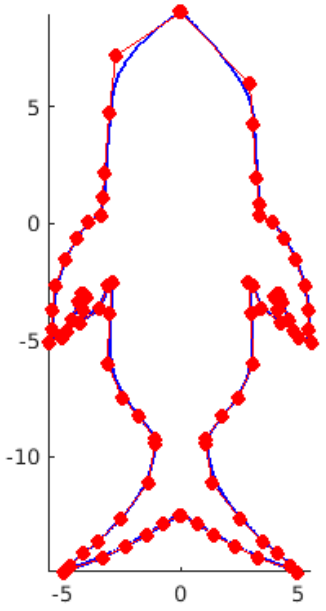
```
% read the igs file to matlab
clear;clf;
file_name = input('Pleas input the file name: ','s');
fp = fopen(file_name, 'r');
s = fscanf(fp,'%c',[82 inf]);s=s';
fclose(fp);

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

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

  Columns 24 through 42

     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
    2.9821    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

  Columns 24 through 42

     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

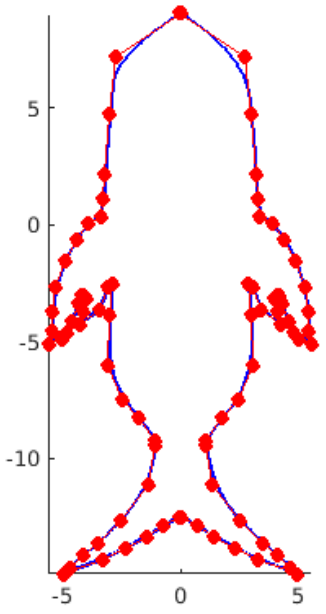
```
% read the igs file to matlab
clear;clf;
file_name = input('Pleas input the file name: ','s');
fp = fopen(file_name, 'r');
s = fscanf(fp,'%c',[82 inf]);s=s';
fclose(fp);

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

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

  Columns 25 through 42

     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

  Columns 25 through 42

     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('Pleas 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

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

  Columns 24 through 42

     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
```

```
            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     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

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
```