
Fundamentals of Computer-Aided Design
(ME 6104)

HW#4 : Parametric Surfaces

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< 1- b> Bicubic Bezier Surface

[MATLAB Program Files : cad_hw_4_1.m]

```
%% cad_hw_4_1.m
%% ME 6104 Homework #4, Spring 2002
%% Parametric Surfaces
%%
```

```
clear;
```

```
clf;
```

```
% Blending Function
```

```
% Parametric Values
```

```
u= 0 : 0.05 : 1;
```

```
for i=1:21
```

```
    U(i,1)=u(i)^3;
```

```
    U(i,2)=u(i)^2;
```

```
    U(i,3)=u(i);
```

```
    U(i,4)=1;
```

```
end
```

```
w= 0 : 0.05 : 1;
```

```
for i=1:21
```

```
    W(i,1)=w(i)^3;
```

```
    W(i,2)=w(i)^2;
```

```
    W(i,3)=w(i);
```

```
    W(i,4)=1;
```

```
end
```

```
% Cubic Bezier transformation Matrix
```

```
M=[ -1  3 -3  1;
```

```
     3 -6  3  0;
```

```
    -3  3  0  0;
```

```
     1  0  0  0;];
```

```

% Control Vertices of patch1
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
patch1 = [-5, -2, 2, 5, -4, -2.5, 2.5, 4, -8.5, -4.5, 4.5, 8.5, -7, -3, 3, 7;
          1, 3, 3, 1, 1, 2, 2, 1, -1, 0, 0, -1, 2, 4, 4, 2;
          -6, -6, -6, -6, -3, -3, -3, -3, 1, 3, 3, 1, 5, 6.5, 6.5, 5;
          1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1];

```

```

% Control Vertices of patch1
CV_X=[ patch1(1,1) patch1(1,5) patch1(1,9) patch1(1,13);
       patch1(1,2) patch1(1,6) patch1(1,10) patch1(1,14);
       patch1(1,3) patch1(1,7) patch1(1,11) patch1(1,15);
       patch1(1,4) patch1(1,8) patch1(1,12) patch1(1,16)];

```

```

CV_Y=[ patch1(2,1) patch1(2,5) patch1(2,9) patch1(2,13);
       patch1(2,2) patch1(2,6) patch1(2,10) patch1(2,14);
       patch1(2,3) patch1(2,7) patch1(2,11) patch1(2,15);
       patch1(2,4) patch1(2,8) patch1(2,12) patch1(2,16)];

```

```

CV_Z=[ patch1(3,1) patch1(3,5) patch1(3,9) patch1(3,13);
       patch1(3,2) patch1(3,6) patch1(3,10) patch1(3,14);
       patch1(3,3) patch1(3,7) patch1(3,11) patch1(3,15);
       patch1(3,4) patch1(3,8) patch1(3,12) patch1(3,16)];

```

```

% Bezier Surfaces
for i=1:21
    for j=1:21
        P_X(i,j)=U(i,:)*M*CV_X*M'*W(j,:);
        P_Y(i,j)=U(i,:)*M*CV_Y*M'*W(j,:);
        P_Z(i,j)=U(i,:)*M*CV_Z*M'*W(j,:);
    end
end

```

```

% figure lange
MIN_X=-8;

```

```

MAX_X=8;

MIN_Y=-8;

MAX_Y=8;

MIN_Z=-8;

MAX_Z=8;

%Plot Bezier Surfaces

figure(1);

axis ([MIN_X, MAX_X, MIN_Y, MAX_Y, MIN_Z, MAX_Z]);

title('4-1 : Bezier Surfaces (SCREW ANGLE)');

xlabel('X');

ylabel('Y');

zlabel('Z');

hold on;

for i=1:21

    plot3 (P_X(:,i), P_Y(:,i), P_Z(:,i), 'k');

    plot3 (P_X(i,:), P_Y(i,:), P_Z(i,:), 'k');

end

for i=1:4

    plot3 (CV_X(:,i), CV_Y(:,i), CV_Z(:,i), 'r');

    plot3 (CV_X(i,:), CV_Y(i,:), CV_Z(i,:), 'r');

end

hold off;

figure(2);

axis ([MIN_X, MAX_X, MIN_Z, MAX_Z]);

title('4-1 : Bezier Surfaces (SIDE VIEW1)');

xlabel('X');

ylabel('Z');

hold on;

for i=1:21

    plot (P_X(:,i), P_Z(:,i), 'k');

    plot (P_X(i,:), P_Z(i,:), 'k');

end

for i=1:4

    plot (CV_X(:,i), CV_Z(:,i), 'r');

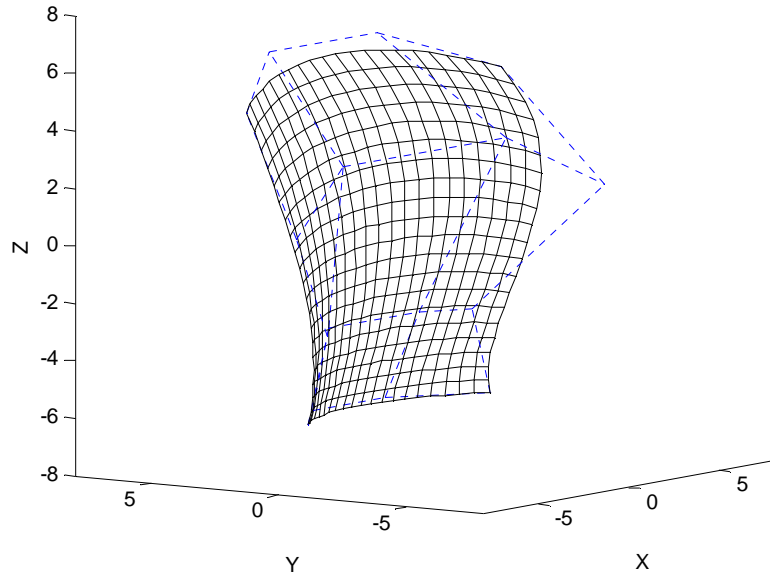
```

```
    plot (CV_X(i,:), CV_Z(i,:), 's');
end
hold off;

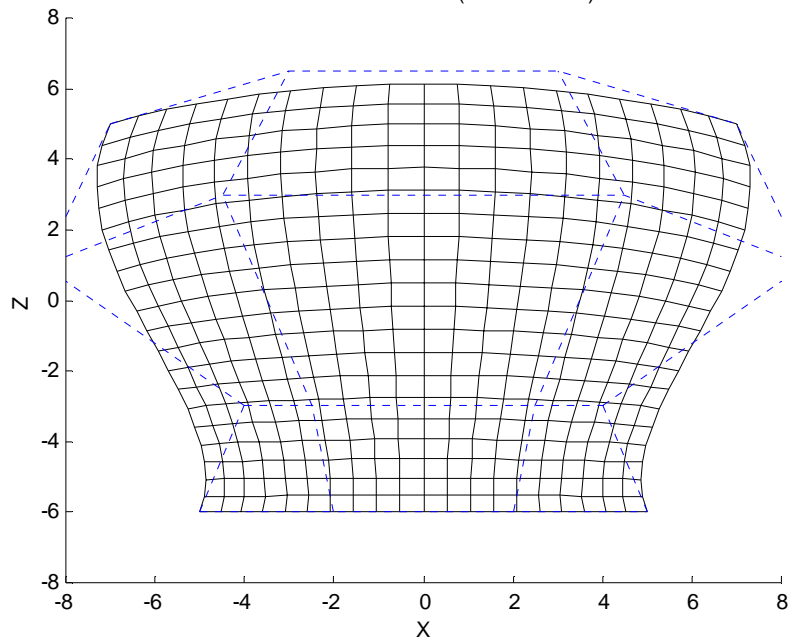
figure(3);
axis ([MIN_Y, MAX_Y, MIN_Z, MAX_Z]);
title('4-1 : Bezier Surfaces (SIDE VIEW2)');
xlabel('Y');
ylabel('Z');
hold on;
for i=1:21
    plot (P_Y(:,i), P_Z(:,i), 'k');
    plot (P_Y(i,:), P_Z(i,:), 'k');
end
for i=1:4
    plot (CV_Y(:,i), CV_Z(:,i), 's');
    plot (CV_Y(i,:), CV_Z(i,:), 's');
end
hold off;

figure(4);
axis ([MIN_X, MAX_X, MIN_Y, MAX_Y]);
title('4-1 : Bezier Surfaces (TOP VIEW)');
xlabel('X');
ylabel('Y');
hold on;
for i=1:21
    plot (P_X(:,i), P_Y(:,i), 'k');
    plot (P_X(i,:), P_Y(i,:), 'k');
end
for i=1:4
    plot (CV_X(:,i), CV_Y(:,i), 's');
    plot (CV_X(i,:), CV_Y(i,:), 's');
end
hold off;
```

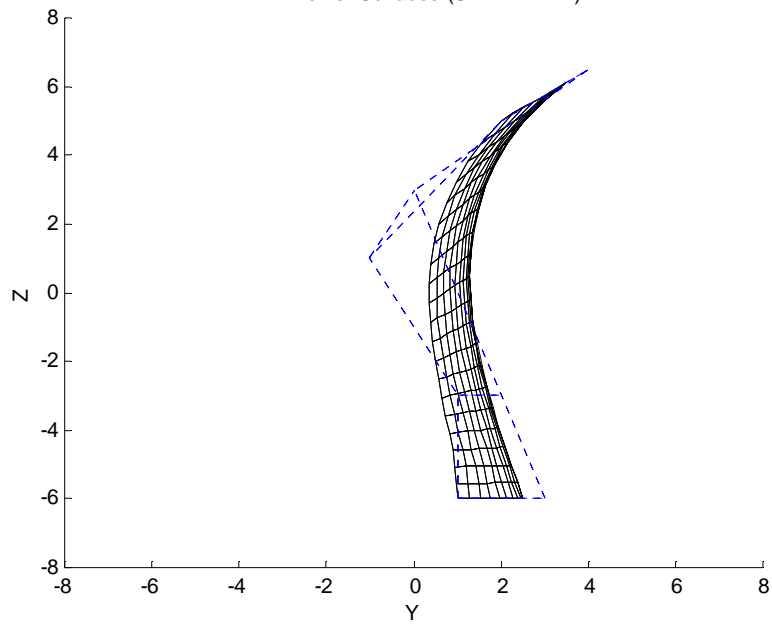
4-1 : Bezier Surfaces (SCREW ANGLE)



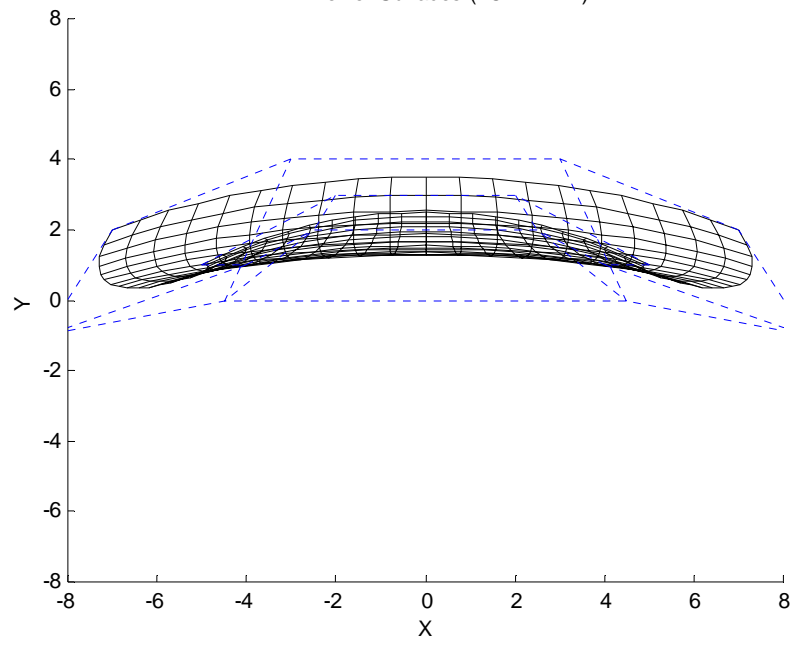
4-1 : Bezier Surfaces (SIDE VIEW1)



4-1 : Bezier Surfaces (SIDE VIEW2)



4-1 : Bezier Surfaces (TOP VIEW)



< 2- b> Composite Bicubic Bezier Surfaces 1

[MATLAB Program Files : cad_hw_4_2b.m]

```
%% cad_hw_4_2b.m
%% ME 6104 Homework #4, Spring 2002
%% Parametric Surfaces
%%
```

```
clear;
```

```
clf;
```

```
% Blending Function
```

```
% Parametric Values
```

```
u= 0 : 0.05 : 1;
```

```
for i=1:21
```

```
    U(i,1)=u(i)^3;
```

```
    U(i,2)=u(i)^2;
```

```
    U(i,3)=u(i);
```

```
    U(i,4)=1;
```

```
end
```

```
w= 0 : 0.05 : 1;
```

```
for i=1:21
```

```
    W(i,1)=w(i)^3;
```

```
    W(i,2)=w(i)^2;
```

```
    W(i,3)=w(i);
```

```
    W(i,4)=1;
```

```
end
```

```
% Cubic Bezier transformation Matrix
```

```
M=[ -1  3 -3  1;
```

```
     3 -6  3  0;
```

```
    -3  3  0  0;
```

```

    1 0 0 0;];

% Mirroring Matrix about yz plane
mirror_about_yz=scale3D(-1,1,1);

% Control Vertices of patch1
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
patch1 = [ -8, -5, -2, 0, -8, -5, -2, 0, -7.5, -4, -2, 0, -7, -4, -2, 0;
           0.5, 0.7, 1, 1, 0.7, 0.8, 1.1, 1.1, 2.1, 2.6, 3.1, 3.1, 2, 2.5, 3, 3;
           0, 0, 0, 0, 2, 2, 2, 2, 3.5, 3.5, 3.5, 3.5, 5, 5.5, 6, 6;
           1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1];

% Control Vertices of patch1
CV_X_1=[ patch1(1,1) patch1(1,5) patch1(1,9) patch1(1,13);
        patch1(1,2) patch1(1,6) patch1(1,10) patch1(1,14);
        patch1(1,3) patch1(1,7) patch1(1,11) patch1(1,15);
        patch1(1,4) patch1(1,8) patch1(1,12) patch1(1,16)];

CV_Y_1=[ patch1(2,1) patch1(2,5) patch1(2,9) patch1(2,13);
        patch1(2,2) patch1(2,6) patch1(2,10) patch1(2,14);
        patch1(2,3) patch1(2,7) patch1(2,11) patch1(2,15);
        patch1(2,4) patch1(2,8) patch1(2,12) patch1(2,16)];

CV_Z_1=[ patch1(3,1) patch1(3,5) patch1(3,9) patch1(3,13);
        patch1(3,2) patch1(3,6) patch1(3,10) patch1(3,14);
        patch1(3,3) patch1(3,7) patch1(3,11) patch1(3,15);
        patch1(3,4) patch1(3,8) patch1(3,12) patch1(3,16)];

% Control Vertices of patch2
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
patch2 = mirror_about_yz * patch1;

% Control Vertices of patch2
CV_X_2=[ patch2(1,1) patch2(1,5) patch2(1,9) patch2(1,13);
        patch2(1,2) patch2(1,6) patch2(1,10) patch2(1,14);
        patch2(1,3) patch2(1,7) patch2(1,11) patch2(1,15);
        patch2(1,4) patch2(1,8) patch2(1,12) patch2(1,16)];

```

```
CV_Y_2=[ patch2(2,1) patch2(2,5) patch2(2,9) patch2(2,13);
        patch2(2,2) patch2(2,6) patch2(2,10) patch2(2,14);
        patch2(2,3) patch2(2,7) patch2(2,11) patch2(2,15);
        patch2(2,4) patch2(2,8) patch2(2,12) patch2(2,16)];
```

```
CV_Z_2=[ patch2(3,1) patch2(3,5) patch2(3,9) patch2(3,13);
        patch2(3,2) patch2(3,6) patch2(3,10) patch2(3,14);
        patch2(3,3) patch2(3,7) patch2(3,11) patch2(3,15);
        patch2(3,4) patch2(3,8) patch2(3,12) patch2(3,16)];
```

```
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
```

```
patch3 = [-5, -3, -2, 0, -5.5, -3, -2, 0, -8, -5, -2, 0, -8, -5, -2, 0;
          1, 1.5, 2, 2, 0.5, 1.0, 1.5, 1.5, 0.3, 0.6, 0.9, 0.9, 0.5, 0.7, 1, 1;
          -6, -6, -6, -6, -4, -4, -4, -4, -2, -2, -2, -2, 0, 0, 0, 0;
          1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1];
```

```
% Control Vertices of patch3
```

```
CV_X_3=[ patch3(1,1) patch3(1,5) patch3(1,9) patch3(1,13);
        patch3(1,2) patch3(1,6) patch3(1,10) patch3(1,14);
        patch3(1,3) patch3(1,7) patch3(1,11) patch3(1,15);
        patch3(1,4) patch3(1,8) patch3(1,12) patch3(1,16)];
```

```
CV_Y_3=[ patch3(2,1) patch3(2,5) patch3(2,9) patch3(2,13);
        patch3(2,2) patch3(2,6) patch3(2,10) patch3(2,14);
        patch3(2,3) patch3(2,7) patch3(2,11) patch3(2,15);
        patch3(2,4) patch3(2,8) patch3(2,12) patch3(2,16)];
```

```
CV_Z_3=[ patch3(3,1) patch3(3,5) patch3(3,9) patch3(3,13);
        patch3(3,2) patch3(3,6) patch3(3,10) patch3(3,14);
        patch3(3,3) patch3(3,7) patch3(3,11) patch3(3,15);
        patch3(3,4) patch3(3,8) patch3(3,12) patch3(3,16)];
```

```
% Control Vertices of patch4
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
```

```
patch4 = mirror_about_yz * patch3;
```

```
% Control Vertices of patch4
```

```
CV_X_4=[ patch4(1,1) patch4(1,5) patch4(1,9) patch4(1,13);
        patch4(1,2) patch4(1,6) patch4(1,10) patch4(1,14);
        patch4(1,3) patch4(1,7) patch4(1,11) patch4(1,15);
        patch4(1,4) patch4(1,8) patch4(1,12) patch4(1,16)];
```

```
CV_Y_4=[ patch4(2,1) patch4(2,5) patch4(2,9) patch4(2,13);
        patch4(2,2) patch4(2,6) patch4(2,10) patch4(2,14);
        patch4(2,3) patch4(2,7) patch4(2,11) patch4(2,15);
        patch4(2,4) patch4(2,8) patch4(2,12) patch4(2,16)];
```

```
CV_Z_4=[ patch4(3,1) patch4(3,5) patch4(3,9) patch4(3,13);
        patch4(3,2) patch4(3,6) patch4(3,10) patch4(3,14);
        patch4(3,3) patch4(3,7) patch4(3,11) patch4(3,15);
        patch4(3,4) patch4(3,8) patch4(3,12) patch4(3,16)];
```

```
% Bezier Surfaces
```

```
for i=1:21
```

```
    for j=1:21
```

```
        P_X_1(i,j)=U(i,:)*M*CV_X_1*M*W(j,:);
```

```
        P_Y_1(i,j)=U(i,:)*M*CV_Y_1*M*W(j,:);
```

```
        P_Z_1(i,j)=U(i,:)*M*CV_Z_1*M*W(j,:);
```

```
        P_X_2(i,j)=U(i,:)*M*CV_X_2*M*W(j,:);
```

```
        P_Y_2(i,j)=U(i,:)*M*CV_Y_2*M*W(j,:);
```

```
        P_Z_2(i,j)=U(i,:)*M*CV_Z_2*M*W(j,:);
```

```
        P_X_3(i,j)=U(i,:)*M*CV_X_3*M*W(j,:);
```

```
        P_Y_3(i,j)=U(i,:)*M*CV_Y_3*M*W(j,:);
```

```
        P_Z_3(i,j)=U(i,:)*M*CV_Z_3*M*W(j,:);
```

```
        P_X_4(i,j)=U(i,:)*M*CV_X_4*M*W(j,:);
```

```
        P_Y_4(i,j)=U(i,:)*M*CV_Y_4*M*W(j,:);
```

```
        P_Z_4(i,j)=U(i,:)*M*CV_Z_4*M*W(j,:);
```

```

    end
end

% figure lange
% figure lange
MIN_X=-8;
MAX_X=8;
MIN_Y=-8;
MAX_Y=8;
MIN_Z=-8;
MAX_Z=8;

%Plot Bezier Surfaces
figure(1);
axis ([MIN_X, MAX_X, MIN_Y, MAX_Y, MIN_Z, MAX_Z]);
title('4-2b : Bezier Surfaces (SCREW ANGLE)');
xlabel('X');
ylabel('Y');
zlabel('Z');
hold on;
for i=1:21
    plot3 (P_X_1(:,i), P_Y_1(:,i), P_Z_1(:,i), 'k');
    plot3 (P_X_1(i,:), P_Y_1(i,:), P_Z_1(i,:), 'k');
    plot3 (P_X_2(:,i), P_Y_2(:,i), P_Z_2(:,i), 'k');
    plot3 (P_X_2(i,:), P_Y_2(i,:), P_Z_2(i,:), 'k');
    plot3 (P_X_3(:,i), P_Y_3(:,i), P_Z_3(:,i), 'k');
    plot3 (P_X_3(i,:), P_Y_3(i,:), P_Z_3(i,:), 'k');
    plot3 (P_X_4(:,i), P_Y_4(:,i), P_Z_4(:,i), 'k');
    plot3 (P_X_4(i,:), P_Y_4(i,:), P_Z_4(i,:), 'k');
end
for i=1:4
    plot3 (CV_X_1(:,i), CV_Y_1(:,i), CV_Z_1(:,i), 'r');
    plot3 (CV_X_1(i,:), CV_Y_1(i,:), CV_Z_1(i,:), 'r');
    plot3 (CV_X_2(:,i), CV_Y_2(:,i), CV_Z_2(:,i), 'r');
    plot3 (CV_X_2(i,:), CV_Y_2(i,:), CV_Z_2(i,:), 'r');
    plot3 (CV_X_3(:,i), CV_Y_3(:,i), CV_Z_3(:,i), 'r');

```

```

    plot3 (CV_X_3(i,:), CV_Y_3(i,:), CV_Z_3(i,:), 'r');
    plot3 (CV_X_4(i,:), CV_Y_4(i,:), CV_Z_4(i,:), 'r');
    plot3 (CV_X_4(i,:), CV_Y_4(i,:), CV_Z_4(i,:), 'r');
end
hold off;

figure(2);
axis ([MIN_X, MAX_X, MIN_Z, MAX_Z]);
title('4-2b : Bezier Surfaces (SIDE VIEW1)');
xlabel('X');
ylabel('Z');
hold on;
for i=1:21
    plot (P_X_1(:,i), P_Z_1(:,i), 'k');
    plot (P_X_1(i,:), P_Z_1(i,:), 'k');
    plot (P_X_2(:,i), P_Z_2(:,i), 'k');
    plot (P_X_2(i,:), P_Z_2(i,:), 'k');
    plot (P_X_3(:,i), P_Z_3(:,i), 'k');
    plot (P_X_3(i,:), P_Z_3(i,:), 'k');
    plot (P_X_4(:,i), P_Z_4(:,i), 'k');
    plot (P_X_4(i,:), P_Z_4(i,:), 'k');
end
for i=1:4
    plot (CV_X_1(:,i), CV_Z_1(:,i), 'r');
    plot (CV_X_1(i,:), CV_Z_1(i,:), 'r');
    plot (CV_X_2(:,i), CV_Z_2(:,i), 'r');
    plot (CV_X_2(i,:), CV_Z_2(i,:), 'r');
    plot (CV_X_3(:,i), CV_Z_3(:,i), 'r');
    plot (CV_X_3(i,:), CV_Z_3(i,:), 'r');
    plot (CV_X_4(:,i), CV_Z_4(:,i), 'r');
    plot (CV_X_4(i,:), CV_Z_4(i,:), 'r');
end
hold off;

figure(3);
axis ([MIN_Y, MAX_Y, MIN_Z, MAX_Z]);

```

```

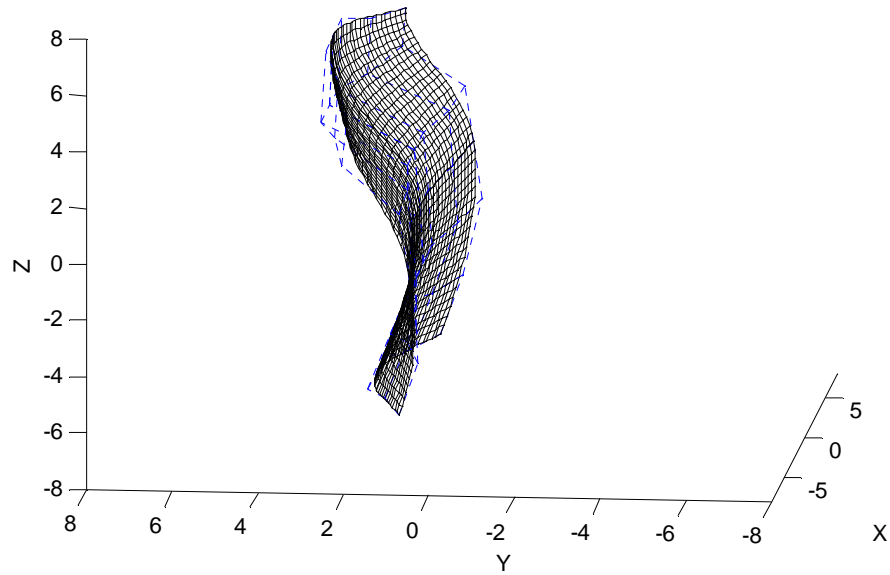
title('4-2b : Bezier Surfaces (SIDE VIEW2)');
xlabel('Y');
ylabel('Z');
hold on;
for i=1:21
    plot (P_Y_1(:,i), P_Z_1(:,i), 'k');
    plot (P_Y_1(i,:), P_Z_1(i,:), 'k');
    plot (P_Y_2(:,i), P_Z_2(:,i), 'k');
    plot (P_Y_2(i,:), P_Z_2(i,:), 'k');
    plot (P_Y_3(:,i), P_Z_3(:,i), 'k');
    plot (P_Y_3(i,:), P_Z_3(i,:), 'k');
    plot (P_Y_4(:,i), P_Z_4(:,i), 'k');
    plot (P_Y_4(i,:), P_Z_4(i,:), 'k');
end
for i=1:4
    plot (CV_Y_1(:,i), CV_Z_1(:,i), 'b');
    plot (CV_Y_1(i,:), CV_Z_1(i,:), 'b');
    plot (CV_Y_2(:,i), CV_Z_2(:,i), 'b');
    plot (CV_Y_2(i,:), CV_Z_2(i,:), 'b');
    plot (CV_Y_3(:,i), CV_Z_3(:,i), 'b');
    plot (CV_Y_3(i,:), CV_Z_3(i,:), 'b');
    plot (CV_Y_4(:,i), CV_Z_4(:,i), 'b');
    plot (CV_Y_4(i,:), CV_Z_4(i,:), 'b');
end
hold off;

figure(4);
axis ([MIN_X, MAX_X, MIN_Y, MAX_Y]);
title('4-2b : Bezier Surfaces (TOP VIEW)');
xlabel('X');
ylabel('Y');
hold on;
for i=1:21
    plot (P_X_1(:,i), P_Y_1(:,i), 'k');
    plot (P_X_1(i,:), P_Y_1(i,:), 'k');

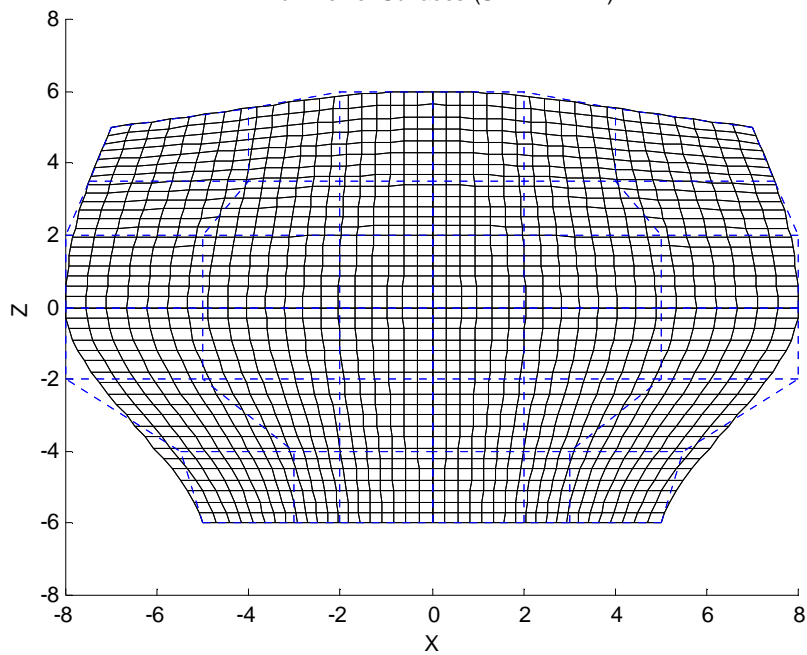
```

```
plot (P_X_2(:,i), P_Y_2(:,i), 'k');
plot (P_X_2(i,:), P_Y_2(i,:), 'k');
plot (P_X_3(:,i), P_Y_3(:,i), 'k');
plot (P_X_3(i,:), P_Y_3(i,:), 'k');
plot (P_X_4(:,i), P_Y_4(:,i), 'k');
plot (P_X_4(i,:), P_Y_4(i,:), 'k');
end
for i=1:4
    plot (CV_X_1(:,i), CV_Y_1(:,i), 'r');
    plot (CV_X_1(i,:), CV_Y_1(i,:), 'r');
    plot (CV_X_2(:,i), CV_Y_2(:,i), 'r');
    plot (CV_X_2(i,:), CV_Y_2(i,:), 'r');
    plot (CV_X_3(:,i), CV_Y_3(:,i), 'r');
    plot (CV_X_3(i,:), CV_Y_3(i,:), 'r');
    plot (CV_X_4(:,i), CV_Y_4(:,i), 'r');
    plot (CV_X_4(i,:), CV_Y_4(i,:), 'r');
end
hold off;
```

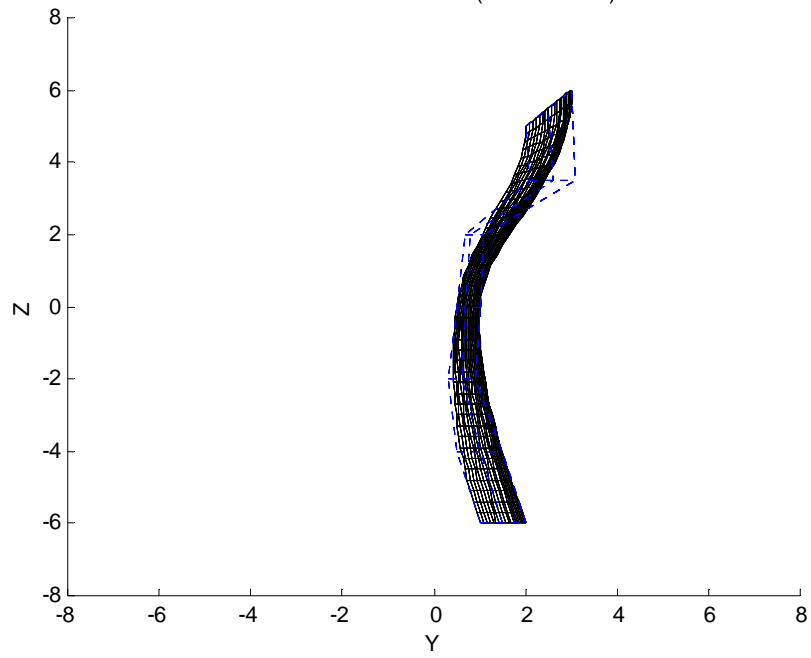
4-2b : Bezier Surfaces (SCREW ANGLE)



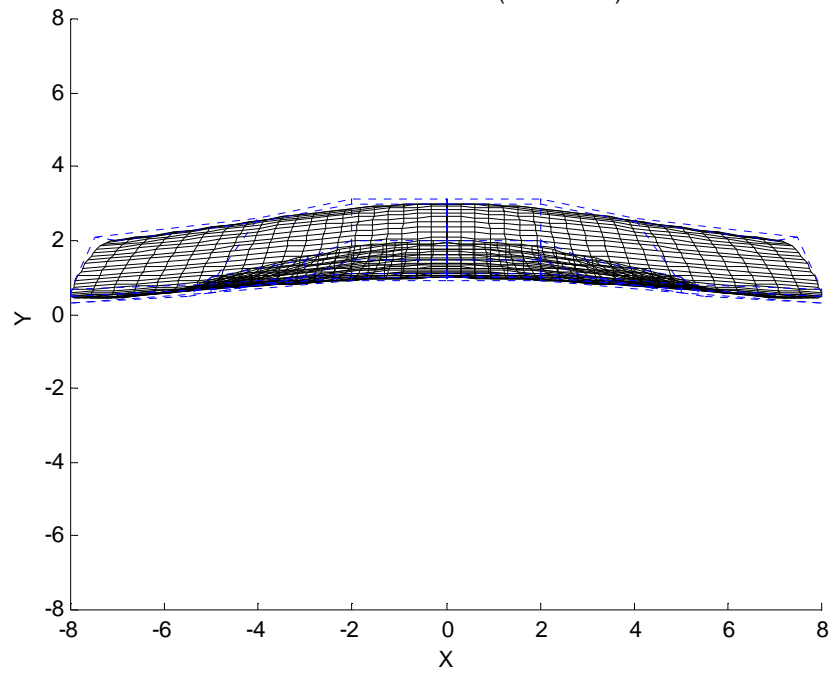
4-2b : Bezier Surfaces (SIDE VIEW1)



4-2b : Bezier Surfaces (SIDE VIEW2)



4-2b : Bezier Surfaces (TOP VIEW)



< 2- d> Composite Bicubic Bezier Surfaces 2

[MATLAB Program Files : cad_hw_4_2d.m]

```
%% cad_hw_4_2d.m
%% ME 6104 Homework #4, Spring 2002
%% Parametric Surfaces
%%
```

```
clear;
```

```
clf;
```

```
% Blending Function
```

```
% Parametric Values
```

```
u= 0 : 0.05 : 1;
```

```
for i=1:21
```

```
    U(i,1)=u(i)^3;
```

```
    U(i,2)=u(i)^2;
```

```
    U(i,3)=u(i);
```

```
    U(i,4)=1;
```

```
end
```

```
w= 0 : 0.05 : 1;
```

```
for i=1:21
```

```
    W(i,1)=w(i)^3;
```

```
    W(i,2)=w(i)^2;
```

```
    W(i,3)=w(i);
```

```
    W(i,4)=1;
```

```
end
```

```
% Cubic Bezier transformation Matrix
```

```
M=[ -1  3 -3  1;
```

```
     3 -6  3  0;
```

```
    -3  3  0  0;
```

```

1 0 0 0;];

% Mirroring Matrix about yz plane
mirror_about_yz=scale3D(-1,1,1);

% Center Point;
c_y=1;
c_z=0;

% Parametric value of patch1
ph1_p30_y=c_y;
ph1_p30_z=c_z;
ph1_p20_y=ph1_p30_y;
ph1_p20_z=ph1_p30_z;
ph1_p10_y=(c_y-0.5)*(0.2/0.5)+0.5;
ph1_p10_z=(c_z-0)/2.0+0;

ph1_p31_y=3-(3-c_y)*(19/20);
ph1_p31_z=6-(6-c_z)*(2/3);
ph1_p21_y=ph1_p31_y;
ph1_p21_z=ph1_p31_z;
ph1_p11_y=(ph1_p31_y-0.7)*(0.1/0.4)+0.7;
ph1_p11_z=(ph1_p31_z-2)/2.0+2;

ph1_p32_y=3+(3-c_y)*(1/20);
ph1_p32_z=6-(6-c_z)*(1/3);
ph1_p22_y=ph1_p32_y;
ph1_p22_z=ph1_p32_z;
ph1_p12_y=(ph1_p32_y-2.1)*(0.5/1.0)+2.1;
ph1_p12_z=(ph1_p32_z-3.5)/2.0+3.5;

% Control Vertices of patch1
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
patch1 = [ -8,      -5,      -2,      0,  -8,      -5,      -2,      0,  -7.5,      -4,
-2,      0,  -7,   -4,  -2,  0;
          0.5,  ph1_p10_y,  ph1_p20_y,  ph1_p30_y, 0.7,  ph1_p11_y, ph1_p21_y,  ph1_p31_y,  2.1,  ph1_p12_y,
ph1_p22_y,  ph1_p32_y,  2,  2.5,  3,  3;

```

```
0, ph1_p10_z, ph1_p20_z, ph1_p30_z, 2, ph1_p11_z, ph1_p21_z, ph1_p31_z, 3.5,  
ph1_p12_z, ph1_p22_z, ph1_p32_z, 5, 5.5, 6, 6;  
1, 1, 1, 1, 1, 1, 1, 1,  
1, 1, 1, 1, 1, 1, 1];
```

```
% Control Vertices of patch1
```

```
CV_X_1=[ patch1(1,1) patch1(1,5) patch1(1,9) patch1(1,13);  
patch1(1,2) patch1(1,6) patch1(1,10) patch1(1,14);  
patch1(1,3) patch1(1,7) patch1(1,11) patch1(1,15);  
patch1(1,4) patch1(1,8) patch1(1,12) patch1(1,16)];
```

```
CV_Y_1=[ patch1(2,1) patch1(2,5) patch1(2,9) patch1(2,13);  
patch1(2,2) patch1(2,6) patch1(2,10) patch1(2,14);  
patch1(2,3) patch1(2,7) patch1(2,11) patch1(2,15);  
patch1(2,4) patch1(2,8) patch1(2,12) patch1(2,16)];
```

```
CV_Z_1=[ patch1(3,1) patch1(3,5) patch1(3,9) patch1(3,13);  
patch1(3,2) patch1(3,6) patch1(3,10) patch1(3,14);  
patch1(3,3) patch1(3,7) patch1(3,11) patch1(3,15);  
patch1(3,4) patch1(3,8) patch1(3,12) patch1(3,16)];
```

```
% Control Vertices of patch2
```

```
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33  
patch2 = mirror_about_yz * patch1;
```

```
% Control Vertices of patch2
```

```
CV_X_2=[ patch2(1,1) patch2(1,5) patch2(1,9) patch2(1,13);  
patch2(1,2) patch2(1,6) patch2(1,10) patch2(1,14);  
patch2(1,3) patch2(1,7) patch2(1,11) patch2(1,15);  
patch2(1,4) patch2(1,8) patch2(1,12) patch2(1,16)];
```

```
CV_Y_2=[ patch2(2,1) patch2(2,5) patch2(2,9) patch2(2,13);  
patch2(2,2) patch2(2,6) patch2(2,10) patch2(2,14);  
patch2(2,3) patch2(2,7) patch2(2,11) patch2(2,15);  
patch2(2,4) patch2(2,8) patch2(2,12) patch2(2,16)];
```

```
CV_Z_2=[ patch2(3,1) patch2(3,5) patch2(3,9) patch2(3,13);
        patch2(3,2) patch2(3,6) patch2(3,10) patch2(3,14);
        patch2(3,3) patch2(3,7) patch2(3,11) patch2(3,15);
        patch2(3,4) patch2(3,8) patch2(3,12) patch2(3,16)];
```

```
% Parametric value of patch3
```

```
ph3_p33_x=patch1(1,4);
ph3_p33_y=patch1(2,4);
ph3_p33_z=patch1(3,4);
ph3_p23_x=patch1(1,3);
ph3_p23_y=patch1(2,3);
ph3_p23_z=patch1(3,3);
ph3_p13_x=patch1(1,2);
ph3_p13_y=patch1(2,2);
ph3_p13_z=patch1(3,2);
ph3_p03_x=patch1(1,1);
ph3_p03_y=patch1(2,1);
ph3_p03_z=patch1(3,1);
```

```
ratio=1;
```

```
ph3_p32_x=ratio*(patch1(1,4)-patch1(1,8))+ph3_p33_x;
ph3_p32_y=ratio*(patch1(2,4)-patch1(2,8))+ph3_p33_y;
ph3_p32_z=ratio*(patch1(3,4)-patch1(3,8))+ph3_p33_z;
ph3_p22_x=ratio*(patch1(1,3)-patch1(1,7))+ph3_p23_x;
ph3_p22_y=ratio*(patch1(2,3)-patch1(2,7))+ph3_p23_y;
ph3_p22_z=ratio*(patch1(3,3)-patch1(3,7))+ph3_p23_z;
ph3_p12_x=ratio*(patch1(1,2)-patch1(1,6))+ph3_p13_x;
ph3_p12_y=ratio*(patch1(2,2)-patch1(2,6))+ph3_p13_y;
ph3_p12_z=ratio*(patch1(3,2)-patch1(3,6))+ph3_p13_z;
```

```
ph3_p31_y=2-(2-c_y)*(1/2);
ph3_p31_z=-6+(c_z+6)*(1/3);
ph3_p21_y=ph3_p31_y;
ph3_p21_z=ph3_p31_z;
```

```

ph3_p11_y=(ph3_p31_y-0.5)*(1/2)+0.5;
ph3_p11_z=(ph3_p31_z+4)/2.0-4;

% Control Vertices of patch3
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
patch3 = [-5, -3, -2, 0,-5.5, -3, -2, 0, ph3_p02_x, ph3_p12_x, ph3_p22_x, ph3_p32_x,
ph3_p03_x, ph3_p13_x, ph3_p23_x, ph3_p33_x;
          1, 1.5, 2, 2, 0.5, ph3_p11_y, ph3_p21_y, ph3_p31_y, ph3_p02_y, ph3_p12_y, ph3_p22_y, ph3_p32_y,
ph3_p03_y, ph3_p13_y, ph3_p23_y, ph3_p33_y;
          -6, -6, -6, -6, -4, ph3_p11_z, ph3_p21_z, ph3_p31_z, ph3_p02_z, ph3_p12_z, ph3_p22_z, ph3_p32_z,
ph3_p03_z, ph3_p13_z, ph3_p23_z, ph3_p33_z;
          1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1];
% Control Vertices of patch3
CV_X_3=[ patch3(1,1) patch3(1,5) patch3(1,9) patch3(1,13);
        patch3(1,2) patch3(1,6) patch3(1,10) patch3(1,14);
        patch3(1,3) patch3(1,7) patch3(1,11) patch3(1,15);
        patch3(1,4) patch3(1,8) patch3(1,12) patch3(1,16)];

CV_Y_3=[ patch3(2,1) patch3(2,5) patch3(2,9) patch3(2,13);
        patch3(2,2) patch3(2,6) patch3(2,10) patch3(2,14);
        patch3(2,3) patch3(2,7) patch3(2,11) patch3(2,15);
        patch3(2,4) patch3(2,8) patch3(2,12) patch3(2,16)];

CV_Z_3=[ patch3(3,1) patch3(3,5) patch3(3,9) patch3(3,13);
        patch3(3,2) patch3(3,6) patch3(3,10) patch3(3,14);
        patch3(3,3) patch3(3,7) patch3(3,11) patch3(3,15);
        patch3(3,4) patch3(3,8) patch3(3,12) patch3(3,16)];

% Control Vertices of patch4
% P00 p10 p20 p30 p01 p11 p21 p31 p02 p12 p22 p32 p03 p13 p23 p33
patch4 = mirror_about_yz * patch3;

% Control Vertices of patch4
CV_X_4=[ patch4(1,1) patch4(1,5) patch4(1,9) patch4(1,13);

```

```

    patch4(1,2) patch4(1,6) patch4(1,10) patch4(1,14);
    patch4(1,3) patch4(1,7) patch4(1,11) patch4(1,15);
    patch4(1,4) patch4(1,8) patch4(1,12) patch4(1,16)];

CV_Y_4=[ patch4(2,1) patch4(2,5) patch4(2,9)  patch4(2,13);
        patch4(2,2) patch4(2,6) patch4(2,10) patch4(2,14);
        patch4(2,3) patch4(2,7) patch4(2,11) patch4(2,15);
        patch4(2,4) patch4(2,8) patch4(2,12) patch4(2,16)];

CV_Z_4=[ patch4(3,1) patch4(3,5) patch4(3,9)  patch4(3,13);
        patch4(3,2) patch4(3,6) patch4(3,10) patch4(3,14);
        patch4(3,3) patch4(3,7) patch4(3,11) patch4(3,15);
        patch4(3,4) patch4(3,8) patch4(3,12) patch4(3,16)];

% Bezier Surfaces
for i=1:21
    for j=1:21
        P_X_1(i,j)=U(i,:)*M*CV_X_1*M'*W(j,:);
        P_Y_1(i,j)=U(i,:)*M*CV_Y_1*M'*W(j,:);
        P_Z_1(i,j)=U(i,:)*M*CV_Z_1*M'*W(j,:);
        P_X_2(i,j)=U(i,:)*M*CV_X_2*M'*W(j,:);
        P_Y_2(i,j)=U(i,:)*M*CV_Y_2*M'*W(j,:);
        P_Z_2(i,j)=U(i,:)*M*CV_Z_2*M'*W(j,:);
        P_X_3(i,j)=U(i,:)*M*CV_X_3*M'*W(j,:);
        P_Y_3(i,j)=U(i,:)*M*CV_Y_3*M'*W(j,:);
        P_Z_3(i,j)=U(i,:)*M*CV_Z_3*M'*W(j,:);
        P_X_4(i,j)=U(i,:)*M*CV_X_4*M'*W(j,:);
        P_Y_4(i,j)=U(i,:)*M*CV_Y_4*M'*W(j,:);
        P_Z_4(i,j)=U(i,:)*M*CV_Z_4*M'*W(j,:);
    end
end

% figure lange
% figure lange
MIN_X=-8;
MAX_X=8;

```

```

MIN_Y=-8;
MAX_Y=8;
MIN_Z=-8;
MAX_Z=8;

%Plot Bezier Surfaces
figure(1);
axis ([MIN_X, MAX_X, MIN_Y, MAX_Y, MIN_Z, MAX_Z]);
title('4-2d : Bezier Surfaces (SCREW ANGLE)');
xlabel('X');
ylabel('Y');
Zlabel('Z');
hold on;
for i=1:21
    plot3 (P_X_1(:,i), P_Y_1(:,i), P_Z_1(:,i), 'k');
    plot3 (P_X_1(i,:), P_Y_1(i,:), P_Z_1(i,:), 'k');
    plot3 (P_X_2(:,i), P_Y_2(:,i), P_Z_2(:,i), 'k');
    plot3 (P_X_2(i,:), P_Y_2(i,:), P_Z_2(i,:), 'k');
    plot3 (P_X_3(:,i), P_Y_3(:,i), P_Z_3(:,i), 'k');
    plot3 (P_X_3(i,:), P_Y_3(i,:), P_Z_3(i,:), 'k');
    plot3 (P_X_4(:,i), P_Y_4(:,i), P_Z_4(:,i), 'k');
    plot3 (P_X_4(i,:), P_Y_4(i,:), P_Z_4(i,:), 'k');
end
for i=1:4
    plot3 (CV_X_1(:,i), CV_Y_1(:,i), CV_Z_1(:,i), 'r');
    plot3 (CV_X_1(i,:), CV_Y_1(i,:), CV_Z_1(i,:), 'r');
    plot3 (CV_X_2(:,i), CV_Y_2(:,i), CV_Z_2(:,i), 'r');
    plot3 (CV_X_2(i,:), CV_Y_2(i,:), CV_Z_2(i,:), 'r');
    plot3 (CV_X_3(:,i), CV_Y_3(:,i), CV_Z_3(:,i), 'r');
    plot3 (CV_X_3(i,:), CV_Y_3(i,:), CV_Z_3(i,:), 'r');
    plot3 (CV_X_4(:,i), CV_Y_4(:,i), CV_Z_4(:,i), 'r');
    plot3 (CV_X_4(i,:), CV_Y_4(i,:), CV_Z_4(i,:), 'r');
end
hold off;

figure(2);

```

```
axis ([MIN_X, MAX_X, MIN_Z, MAX_Z]);
title('4-2d : Bezier Surfaces (SIDE VIEW1)');
xlabel('X');
ylabel('Z');
hold on;
for i=1:21
    plot (P_X_1(:,i), P_Z_1(:,i), 'k');
    plot (P_X_1(i,:), P_Z_1(i,:), 'k');
    plot (P_X_2(:,i), P_Z_2(:,i), 'k');
    plot (P_X_2(i,:), P_Z_2(i,:), 'k');
    plot (P_X_3(:,i), P_Z_3(:,i), 'k');
    plot (P_X_3(i,:), P_Z_3(i,:), 'k');
    plot (P_X_4(:,i), P_Z_4(:,i), 'k');
    plot (P_X_4(i,:), P_Z_4(i,:), 'k');
end
for i=1:4
    plot (CV_X_1(:,i), CV_Z_1(:,i), 'b');
    plot (CV_X_1(i,:), CV_Z_1(i,:), 'b');
    plot (CV_X_2(:,i), CV_Z_2(:,i), 'b');
    plot (CV_X_2(i,:), CV_Z_2(i,:), 'b');
    plot (CV_X_3(:,i), CV_Z_3(:,i), 'b');
    plot (CV_X_3(i,:), CV_Z_3(i,:), 'b');
    plot (CV_X_4(:,i), CV_Z_4(:,i), 'b');
    plot (CV_X_4(i,:), CV_Z_4(i,:), 'b');
end
hold off;

figure(3);
axis ([MIN_Y, MAX_Y, MIN_Z, MAX_Z]);
title('4-2d : Bezier Surfaces (SIDE VIEW2)');
xlabel('Y');
ylabel('Z');
hold on;
for i=1:21
    plot (P_Y_1(:,i), P_Z_1(:,i), 'k');
    plot (P_Y_1(i,:), P_Z_1(i,:), 'k');
```

```

plot (P_Y_2(:,i), P_Z_2(:,i), 'k');
plot (P_Y_2(i,:), P_Z_2(i,:), 'k');
plot (P_Y_3(:,i), P_Z_3(:,i), 'k');
plot (P_Y_3(i,:), P_Z_3(i,:), 'k');
plot (P_Y_4(:,i), P_Z_4(:,i), 'k');
plot (P_Y_4(i,:), P_Z_4(i,:), 'k');
end
for i=1:4
    plot (CV_Y_1(:,i), CV_Z_1(:,i), 'b');
    plot (CV_Y_1(i,:), CV_Z_1(i,:), 'b');
    plot (CV_Y_2(:,i), CV_Z_2(:,i), 'b');
    plot (CV_Y_2(i,:), CV_Z_2(i,:), 'b');
    plot (CV_Y_3(:,i), CV_Z_3(:,i), 'b');
    plot (CV_Y_3(i,:), CV_Z_3(i,:), 'b');
    plot (CV_Y_4(:,i), CV_Z_4(:,i), 'b');
    plot (CV_Y_4(i,:), CV_Z_4(i,:), 'b');
end
hold off;

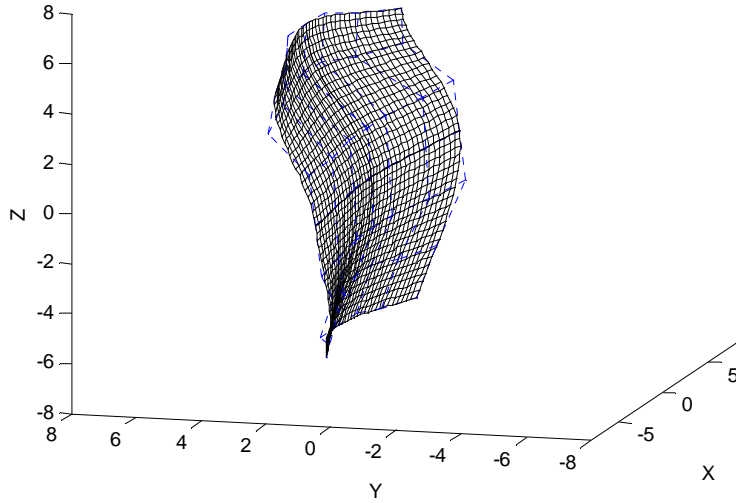
figure(4);
axis ([MIN_X, MAX_X, MIN_Y, MAX_Y]);
title('4-2d : Bezier Surfaces (TOP VIEW)');
xlabel('X');
ylabel('Y');
hold on;
for i=1:21
    plot (P_X_1(:,i), P_Y_1(:,i), 'k');
    plot (P_X_1(i,:), P_Y_1(i,:), 'k');
    plot (P_X_2(:,i), P_Y_2(:,i), 'k');
    plot (P_X_2(i,:), P_Y_2(i,:), 'k');
    plot (P_X_3(:,i), P_Y_3(:,i), 'k');
    plot (P_X_3(i,:), P_Y_3(i,:), 'k');
    plot (P_X_4(:,i), P_Y_4(:,i), 'k');
    plot (P_X_4(i,:), P_Y_4(i,:), 'k');
end

```

```
for i=1:4
    plot (CV_X_1(:,i), CV_Y_1(:,i), 'b');
    plot (CV_X_1(i,:), CV_Y_1(i,:), 'b');
    plot (CV_X_2(:,i), CV_Y_2(:,i), 'b');
    plot (CV_X_2(i,:), CV_Y_2(i,:), 'b');
    plot (CV_X_3(:,i), CV_Y_3(:,i), 'b');
    plot (CV_X_3(i,:), CV_Y_3(i,:), 'b');
    plot (CV_X_4(:,i), CV_Y_4(:,i), 'b');
    plot (CV_X_4(i,:), CV_Y_4(i,:), 'b');
end
hold off;
```

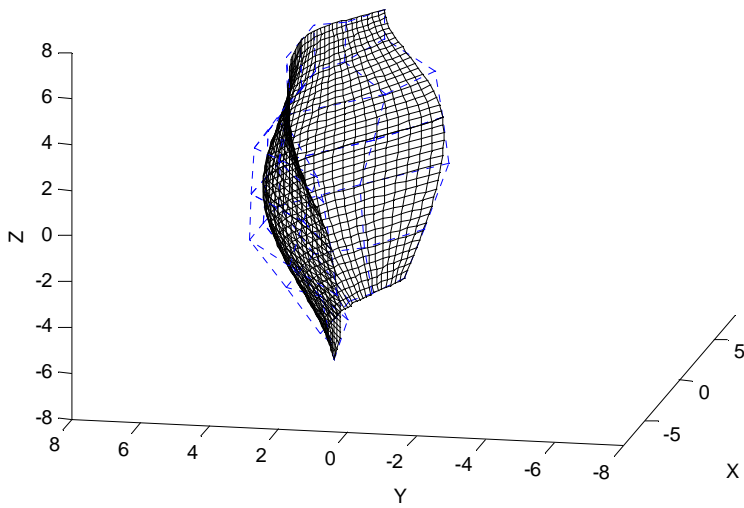
[Central Vertice (0, 1, 0)]

4-2d : Bezier Surfaces (SCREW ANGLE)



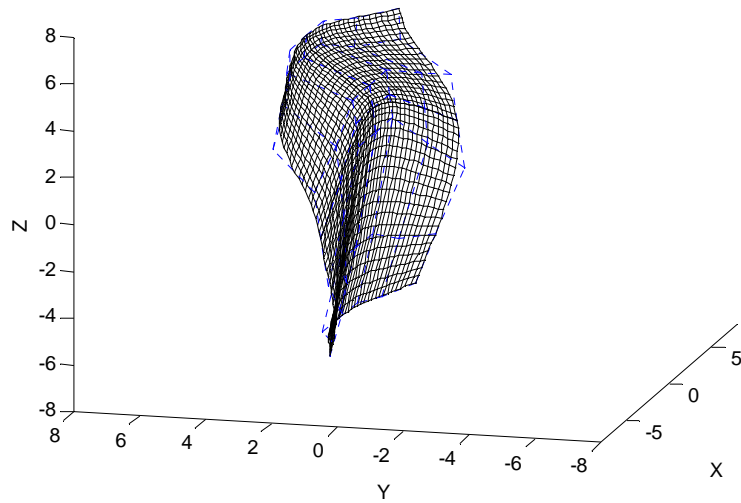
[Central Vertice (0, 4, 0)]

4-2d : Bezier Surfaces (SCREW ANGLE)



[Central Vertice (0, 1, 3)]

4-2d : Bezier Surfaces (SCREW ANGLE)



[Central Vertice (0, 2, -3)]

4-2d : Bezier Surfaces (SCREW ANGLE)

