CZ2003: Computer Graphics and Visualization

Lab Report 4:

Implicit Surfaces and Solids

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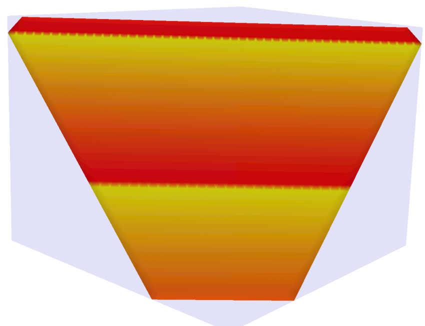
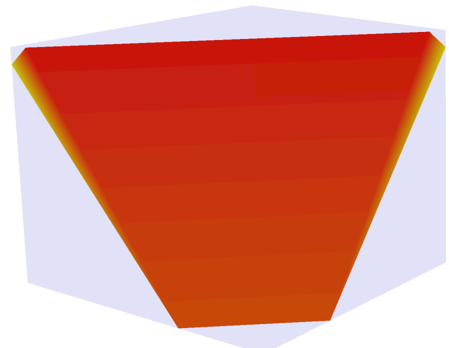
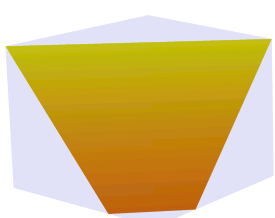
1. In 4 separate files, define by implicit functions $f(x, y, z) = 0$ and by setting a proper bounding box:
    a. A plane passing through the points with coordinates (**N**, **M**, 0), (0, **M**, **N**), (**N**, 0, **M**).

<table>
<tr>
<td>
Fig 1.0 Snapshot of "Q1A1.wrl" which defines a plane with bboxCenter 2 1.5 2, bboxSize 4.5 3.5 4.5 and resolution [50 50 50]</td>
<td>
Fig 1.1 Snapshot of "Q1A2.wrl" which defines a plane with bboxCenter 2 1.5 2, bboxSize 4.5 3.5 4.5and resolution [2 2 2]</td>
</tr>
<tr>
<td colspan="2">Fig.1s are snapshots of a plane passing through the points with coordinates (4, 3, 0), (0, 3, 4), (4, 0, 3).

<u>*Implicit Function Definition:*</u>
x/7+y/7+z/7-1

<u>*Remarks*</u>
When tested with a smaller size bounding box, the plane with become a triangle sized plane. The minimum resolution to show the surface is 2 2 2 as shown in Fig 1.1. The parameters used above will give it a tight bounding box.

To give it an even tighter bounding box, bboxCenter 2 1.5 2, bboxSize 4 3 4 can be used. The points will sit on the edges of the box on the top right, top left and bottom right.
</td>
</tr>
</table>

b. A lower half of the surface of the origin-centered sphere with radius **M**.

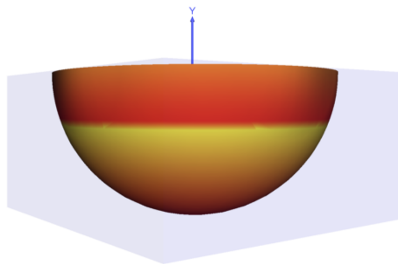


Fig 2.0 Snapshot of "Q1B1.wrl" which defines the lower half of an origin centered sphere with bboxCenter 0 −1.5 0 bboxSize 6 3 6 and resolution of [20 20 20]

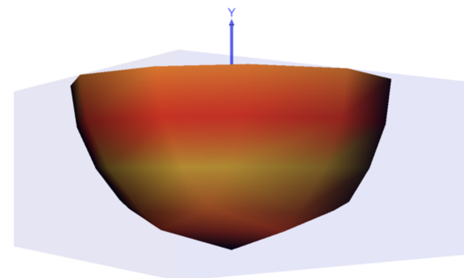


Fig 2.1 Snapshot of "Q1B2.wrl" which defines the lower half of an origin centered sphere with bboxCenter 0 −1.5 0
bboxSize 6 3 6 and resolution of [5 5 5]

Fig 2s are snapshots a lower half of the surface of the origin-centered sphere with radius 3 at different resolutions.

<u>*Implicit Function Definition:*</u>
(3)^2-(x)^2 - (y)^2 - z^2

<u>*Remarks*</u>
The bounding box center is moved to 0 −1.5 0. This is the center of the lowest point of the sphere to the origin. The minimum bounding box size is 6 3 6. The box size is 6 on the x and the z axis this is to fit the diameter of the sphere whereas the y axis is 3 because the sphere only consists of the lower half this thus y axis will be the size of the radius.

The minimum resolution to display the sphere is [20 20 20]. Using any resolution lower than this, such as resolution [5 5 5] displayed in Fig 2.1 will cause multiple jagged edges to be produced. This is because to display a curve using straight lines/polygons, there must be reasonably large number of sampling points.

c. A cylindrical surface with radius $\boldsymbol{M}$ which is aligned with axis Z, and spans from $z1 = -\boldsymbol{N}$ to $z1 = \boldsymbol{M}$.

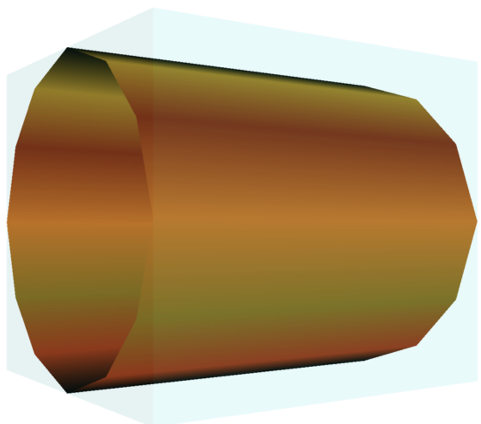


Fig 3.0 Snapshot of "1C1.wrl" defines a cylindrical surface with bboxCenter 0 0 −0.5, *bboxSize* 6 6 7 *resolution of* [5 5 5]

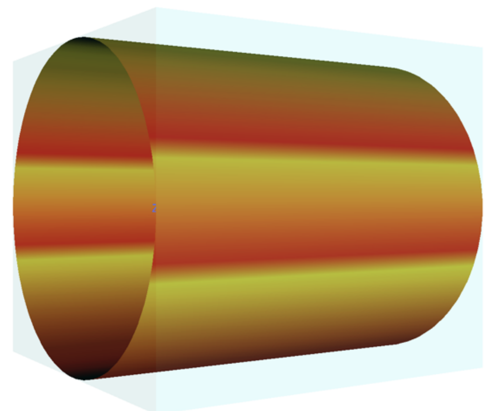


Fig 3.1 Snapshot of "1C2.wrl" defines a cylindrical surface with bboxCenter 0 0 −0.5, *bboxSize* 6 6 7 *resolution of* [20 20 20]

Fig 3 are snapshots of a cylindrical surface with radius 3 which is aligned with axis Z, and spans from $z1$ = -1 to $z1$ = 1.

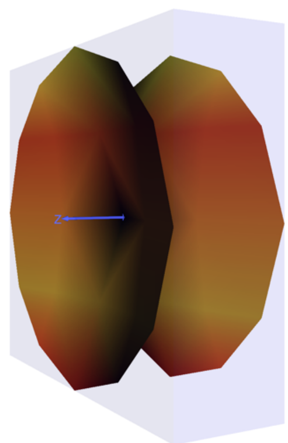
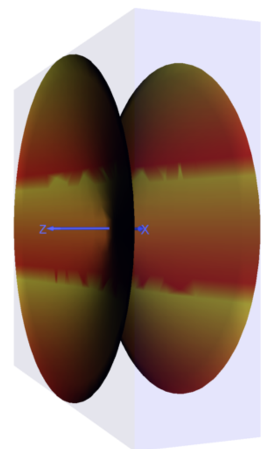
<u>*Implicit Function Definition:*</u>
(1)^2-(x/3)^2 - (y/3)^2

<u>*Remarks*</u>
The bounding box is set at 6 6 7.

6 on the x and y axis to fit the diameter of the cylinder and 7 on the z axis as the height of the cylinder spans from −4 to 3 the height of the cylinder will be 7. To ensure it spans from −4 to 3 in the z axis we need to offset the center of the box by −0.5. Thus, the final box center is 0 0 -0.5

The minimum resolution to display the cylinder is [20 20 20]. Using any resolution lower than this, such as resolution [5 5 5] displayed in Fig 3.0 will cause multiple jagged edges to be produced. This is because to display a curve using straight lines/polygons, there must be reasonably large number of sampling points.

d. A two-side conical surface with radius **M** at distance 1 from its apex. The cone is aligned with axis Z, and spans from $z1 = -1$ to $z1 = 1$ with the cone apex located at the origin

<table>
<tr>
<td>
Fig 4.0 Snapshot of "1D1.wrl" which defines two-side conical surface with bboxCenter 0 0 0, bboxSize 6 6 2 at resolution [5 5 5]</td>
<td>
Fig 4.1 Snapshot of "1D2.wrl" which defines two-side conical surface with bboxCenter 0 0 0, bboxSize 6 6 2 at resolution [20 20 20]</td>
</tr>
<tr>
<td colspan="2">Fig 4s are snapshots of a two-side conical surface with radius 3 at distance 1 from its apex. The cone is aligned with axis Z, and spans from $z1 = -1$ to $z1 = 1$ with the cone apex located at the origin

<u>Implicit Function Definition:</u>
(z/1)^2 - (x/3)^2 - (y/3)^2

<u>Remarks</u>
The bounding box center is 0 0 0 which is the center of the conical surface. The minimum bounding box size is 6 6 2.

6 on the x and y axis is the fit the diameter of the cone and 2 on the z axis so to restrict the cone such that it spans from −1 to 1 on the z axis.

The minimum resolution to display the cylinder is [20 20 20]. Using any resolution lower than this, such as resolution [5 5 5] displayed in Fig 4.0 will cause multiple jagged edges to be produced. This is because to display a curve using straight lines/polygons, there must be reasonably large number of sampling points.</td>
</tr>
</table>

2. With reference to Table 2, build one complex shape using set-theoretic operations following the design sketch number **M**. It has to be one function script created with MIN/MAX functions and functions $f(x, y, z) \geq 0$ of the participating shapes. Note that in FVRML each min/max function can take only two arguments and therefore nested functions have to be used.

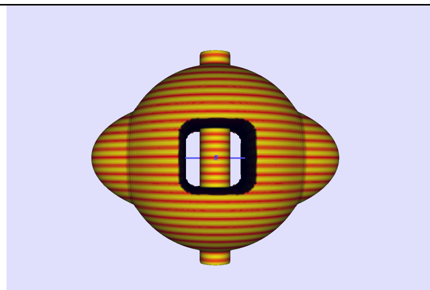


Fig 5.0 Snapshot of "2A.wrl" which defines a solid object with bboxCenter 0 0 0, bboxSize 8 7 6 at resolution of [125 125 125]

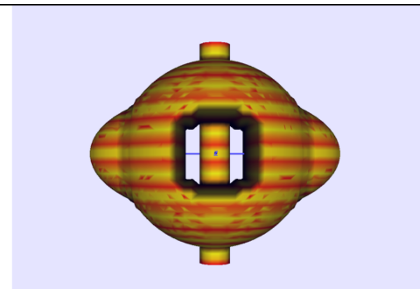


Fig 5.1 Snapshot of "2B.wrl" which defines a solid object with bboxCenter 0 0 0, bboxSize 8 7 6 at resolution of [40 40 40]

Fig 5 are snapshots for Q2 of a solid object of sketch number 3 shown in table 2.

```
definition "function frep(x,y,z,t){
        cylinder = min(min((0.5)^2-(x)^2-(z)^2,y+3.4), -(y-3.4));
        sphere = 3^2 - (x)^2 - (y)^2 - (z)^2;
        box =6^6-(6*x)^6-(6*y)^6-z^6;
        ellipsoid = 1 - ((1/4)*x)^2 - (1/2*y)^2 - (1/2*z)^2;
        final = max(cylinder, min(max(sphere, ellipsoid), -box));
        return final;
}"
```

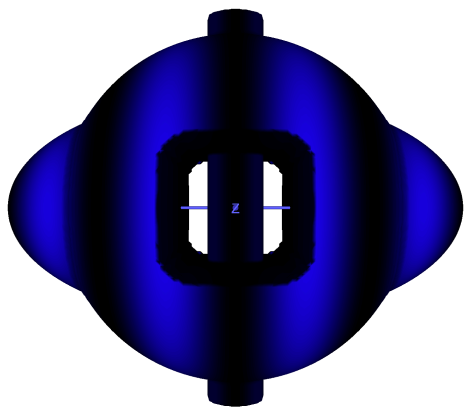
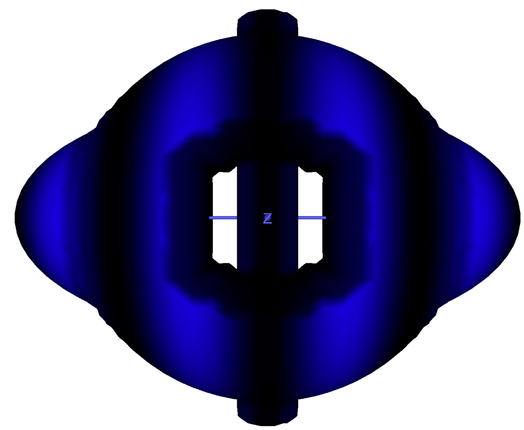
<u>*Remarks:*</u>

The bounding box center is set at 0 0 0 which is the center of the object. The minimum bounding box size for this object is 8 7 6.

8 on the x axis because the longest length along the x axis is 8 which is the length of the major axis for the ellipsoid. It is 7 on the y axis to ensure the height of the cylinder is slightly larger than the diameter of the sphere. This ensures that the cylinder has protruding ends. It is 6 for the z axis so to fit the diameter of the sphere.

The minimum resolution for this solid object is [125 125 125], a resolution lower than that such as [40 40 40] shown in Fig 5.1 which cause the object to appear "blurry".

3. **This exercise can only be done using FVRML.** Color the shape defined in exercise 2 with a variable color. To do it, define in **FMaterial** field a function-defined diffuse color for the whole shape by writing functions $r(u, v, w)$, $g(u, v, w)$, $b(u, v, w)$ where $u=x$, $v=y$,and$w=z$. Use function number **M** from Table1 as a color profile but scale it so that the color values will be located within [0,1] on the visible surfaces of the shape.

<table>
<tr>
<td>
Fig 6.0 Snapshot of “3A.wrl” which defines a solid object with bboxCenter 0 0 0, bboxSize 8 7 6 at resolution of [125 125 125]</td>
<td>
Fig 6.1 Snapshot of “3B.wrl” which defines a solid object with bboxCenter 0 0 0, bboxSize 8 7 6 at resolution of [40 40 40]</td>
</tr>
<tr>
<td colspan="2">
<u>DiffuseColor in FMaterial will set as following:</u>
diffuseColor "r=0; g=0; b=(sin(((u-4)/8)*4*pi))^2;"

The initial equation is f(u) = y = (sin(u*4*pi))^2. The domain is [0,1] and since it’s a sin^2 curve the y values range will always like in [0, 1]. Thus no translation or scaling is needed.

The domain for the figure is [-4, 4] and we want to fit the f(u) within the domain of the figure. To do that we have perform scaling followed by translation

<u>By scaling the equation becomes</u>
f(u) = (sin((u/8)*4*pi))^2
Thus the domain will be changed to [0,8]

<u>Followed by translation, the equation will become</u>
f(u) =(sin(((u-4)/8)*4*pi))^2.
Thus the domain will be changed to [-4, 4]

<u>Remarks:</u>
The minimum resolution use to form this solid object is [125 125 125]
</td>
</tr>
</table>

4. Besides the above compulsory part, you are welcome to add any other shapes of implicit surfaces and CSG solids into folder Lab4/Extras. These extra exercises may increase your total mark.

Creating a Rainbow Princess

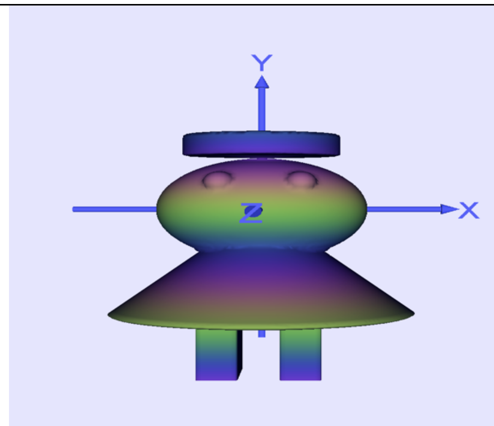


Fig 7.0 Snapshot of "Bonus_Princess.wrl"

This is a princess wearing a dress and a crown. The dress is a cone with a base. The head is an ellipsoid joined by 2 spheres as eyes and minusing another sphere as a mouth. The crown is a cylinder. The feet are cuboids that are made from intersecting lines. All these elements are merged together to form the princess

Definition:

```
definition "function frep(x,y,z,t) {
	crown1 = y - 0.7;
	crown2 = y - 0.5;
	cylinder = min(0.5^2 - x^2 - z^2, min(crown2, -crown1));

	halfspace3 = y;
	halfspace4 = y + 1;
	cone = max((x/3)^2 - ((y)/3)^2 + ((z)/3)^2, halfspace3);
	coneWithBase = min(halfspace4, -cone);
	ellipsoid = 0.3^2 - 0.2 * x^2 - 0.4 * y^2 - 0.5*z^2;
	eye1 = 0.1^2 - (x+0.25)^2 - (y-0.25)^2 -(z-0.3)^2;
	eye2 = 0.1^2 - (x-0.25)^2 - (y-0.25)^2 -(z-0.3)^2;
	mouth = 0.3^2 - x^2 - y^2 -(z-0.6)^2;
	foot1=min(min(min(min(min(x-0.125,0.9-y),-0.90-y),0.375-x),z+0.1),0.5-z);
	foot2=min(min(min(min(min(x+0.375,0.0-y),-0.90-y),-0.125-x),z+0.1),0.5-z);
	feet = max(foot1,foot2);
	final= max(max(max(max(cylinder, max(ellipsoid, coneWithBase)),eye1),eye2),feet);
	return final;
   }"
```

Rainbow Colour:

```
diffuseColor "r=0.5+0.3*sin(v*2*pi); g=0.5+0.3*cos(v*2*pi); b=0.5-0.3*cos(v*2*pi)
```