# Geometric Modeling for Computer Graphics

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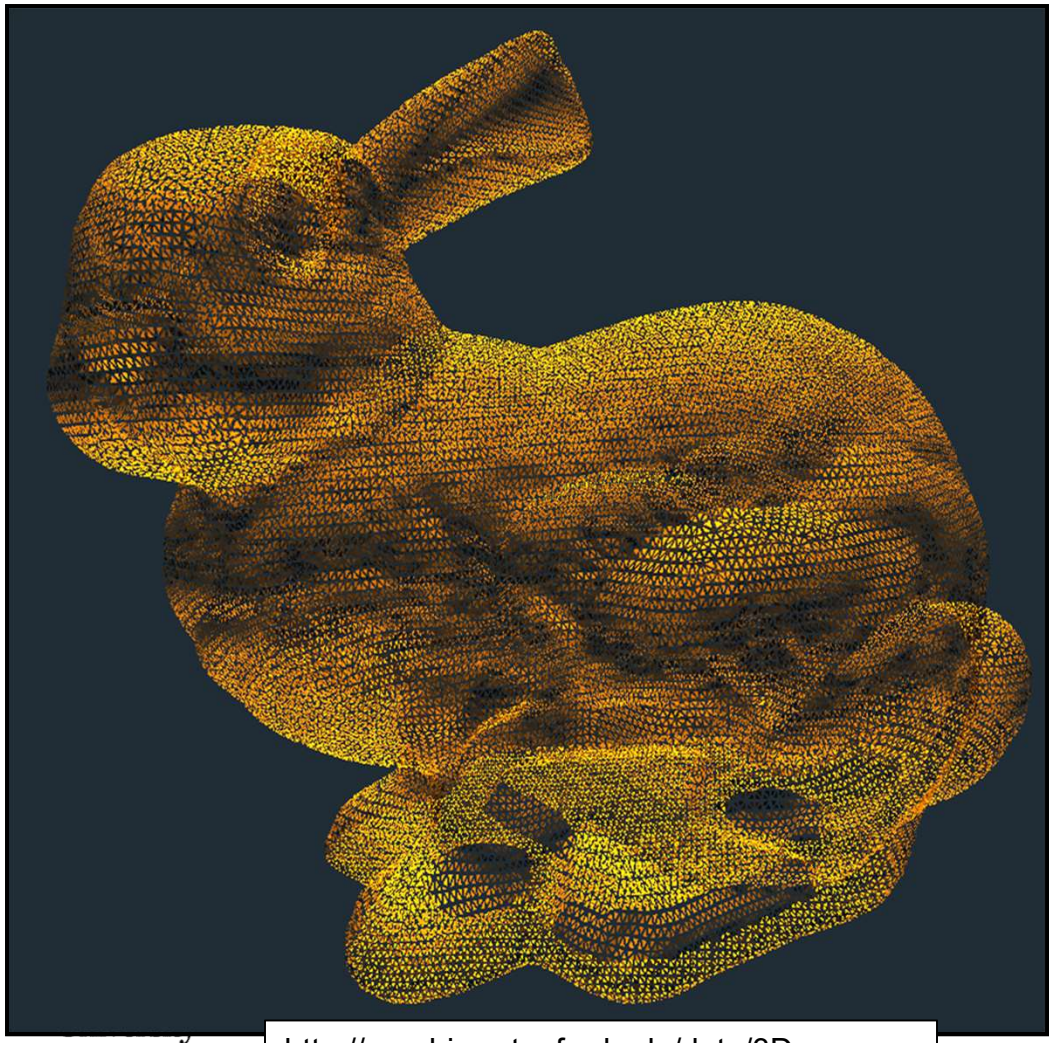
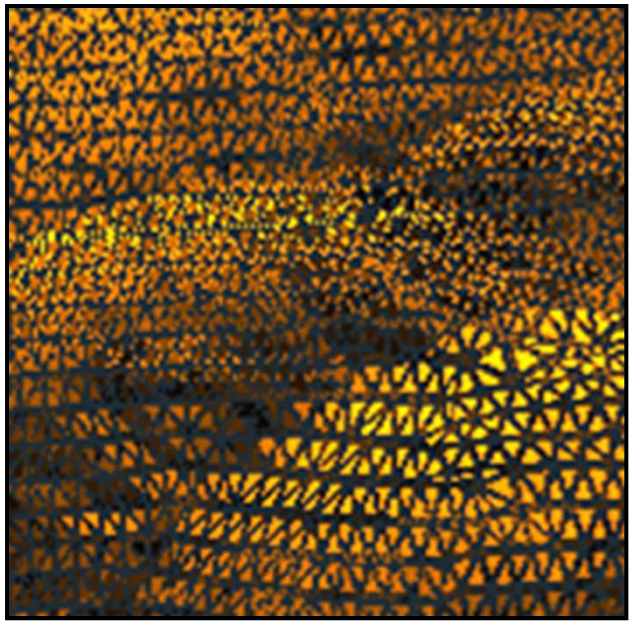
Oregon State University
Computer Graphics

# Explicitly Listing Geometry and Topology

Models can consist of thousands of vertices and faces – we need some way to list them efficiently



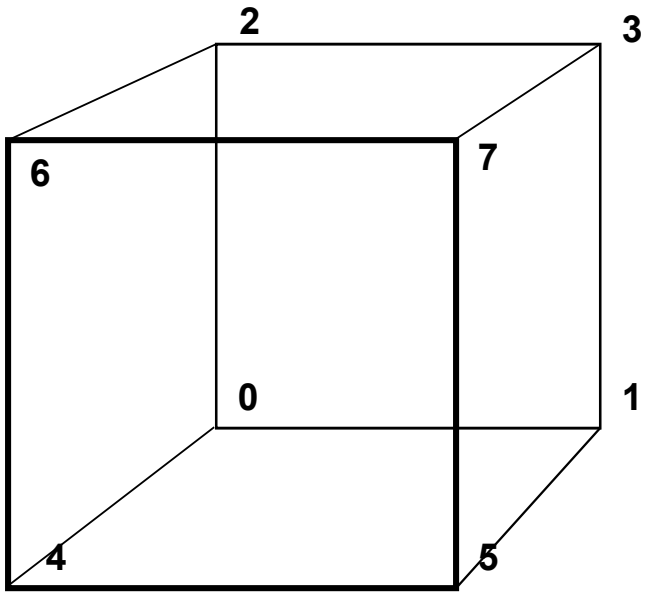


This is called a **Mesh.**



http://graphics.stanford.edu/data/3Dscanrep

# Explicitly Listing Geometry and Topology

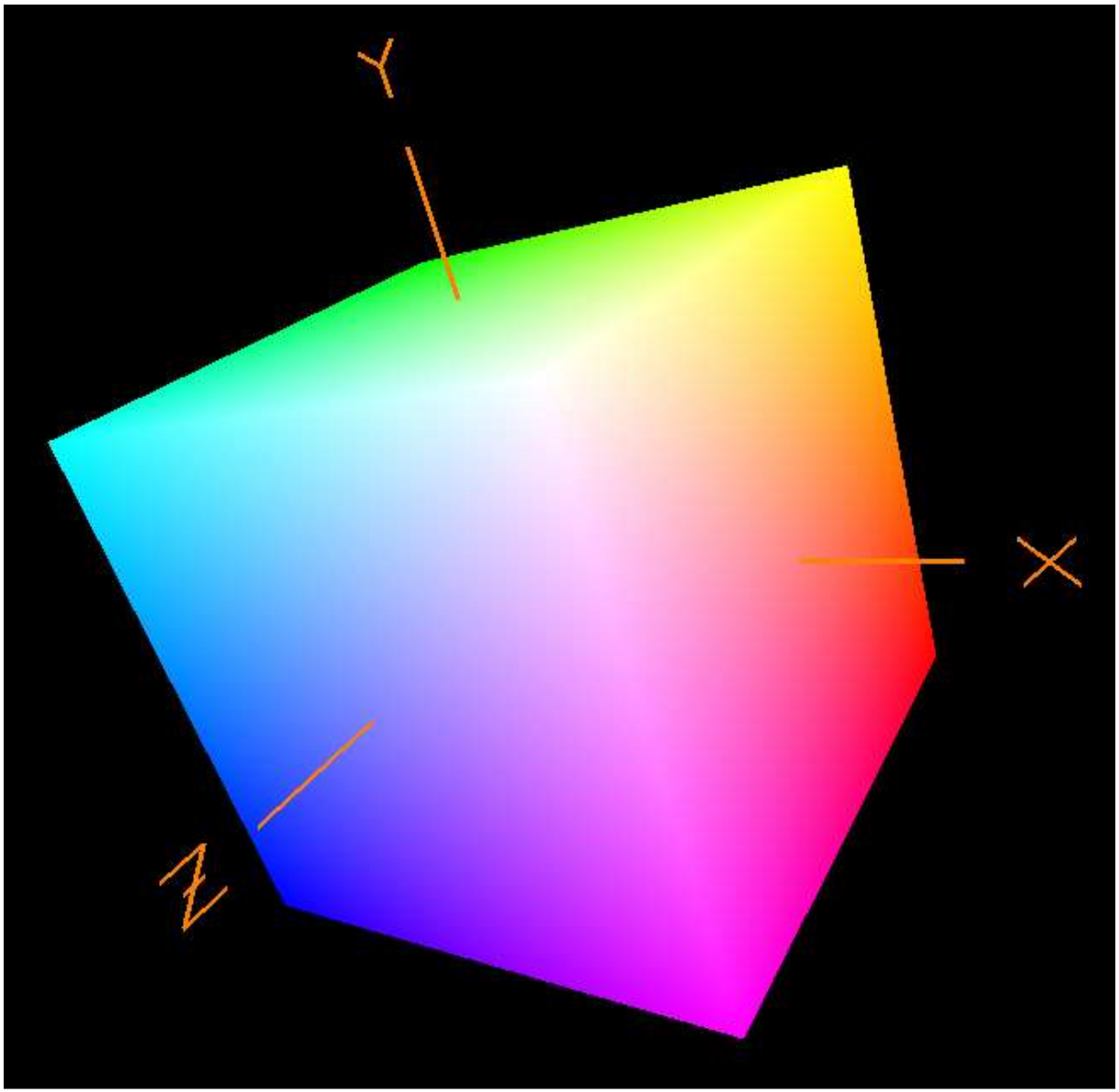



```
static GLfloat CubeVertices[ ][3] =
{
        { -1., -1., -1. },
        {  1., -1., -1. },
        { -1.,  1., -1. },
        {  1.,  1., -1. },
        { -1., -1.,  1. },
        {  1., -1.,  1. },
        { -1.,  1.,  1. },
        {  1.,  1.,  1. }
};
```

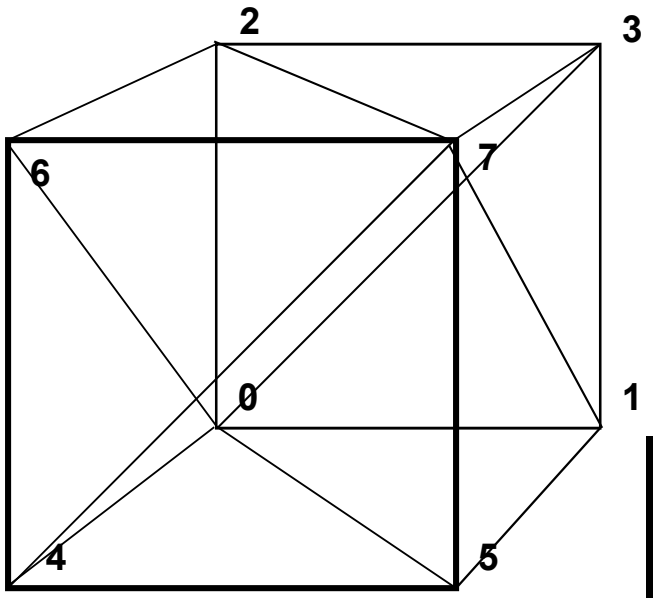
```
static GLfloat CubeColors[ ][3] =
{
        { 0., 0., 0. },
        { 1., 0., 0. },
        { 0., 1., 0. },
        { 1., 1., 0. },
        { 0., 0., 1. },
        { 1., 0., 1. },
        { 0., 1., 1. },
        { 1., 1., 1. },
};
```

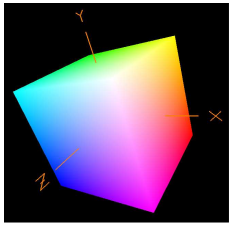
```
static GLuint CubeQuadIndices[ ][4] =
{
        { 0, 2, 3, 1 },
        { 4, 5, 7, 6 },
        { 1, 3, 7, 5 },
        { 0, 4, 6, 2 },
        { 2, 6, 7, 3 },
        { 0, 1, 5, 4 }
};
```

# Cube Example



# The Cube Can Also Be Defined with Triangles



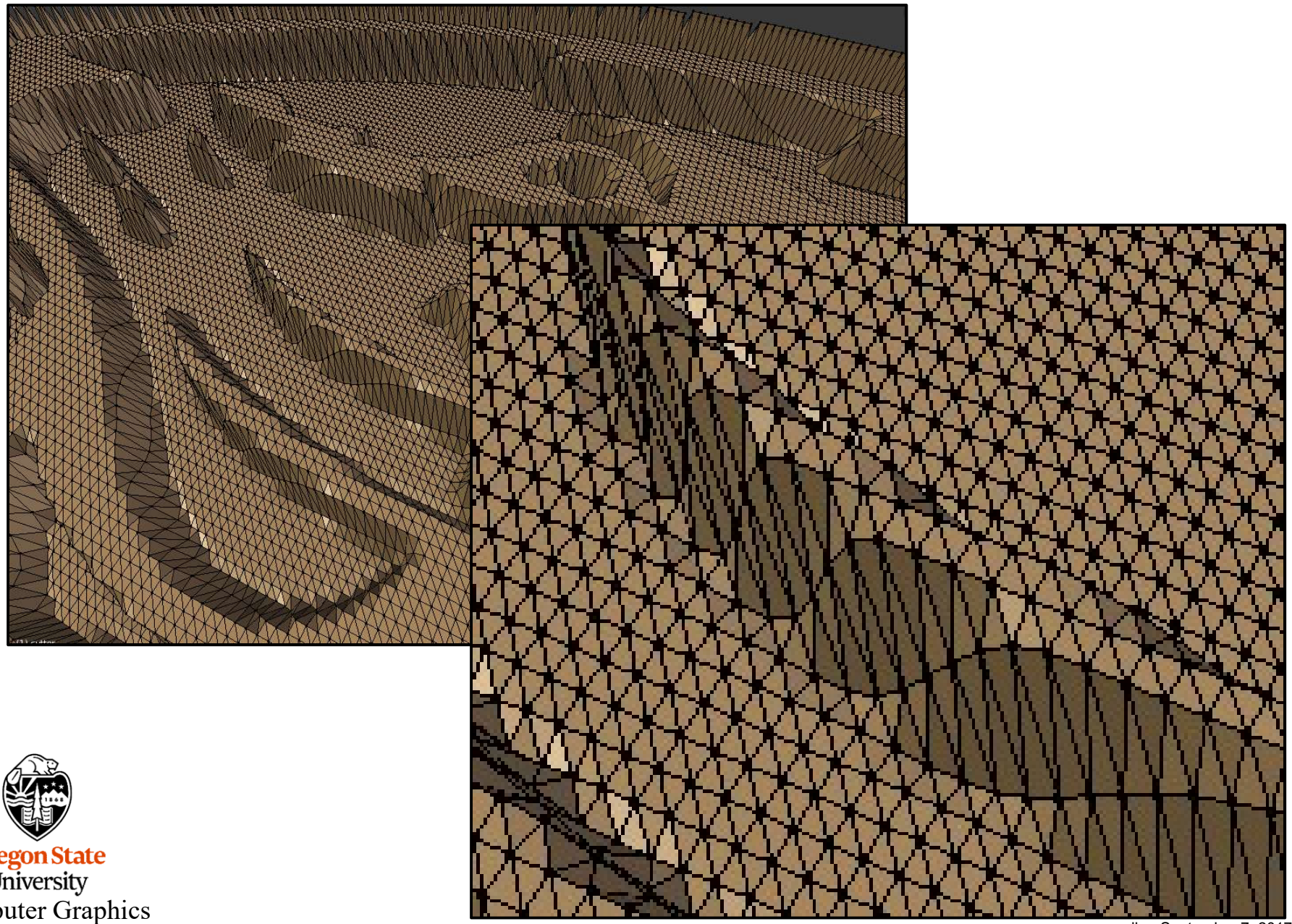



```
GLuint CubeQuadIndices[ ][4] =
{
        { 0, 2, 3, 1 },
        { 4, 5, 7, 6 },
        { 1, 3, 7, 5 },
        { 0, 4, 6, 2 },
        { 2, 6, 7, 3 },
        { 0, 1, 5, 4 }
};
```

```
GLuint CubeTriangleIndices[ ][3] =
{
        { 0, 2, 3 },
        { 0, 3, 1 },
        { 4, 5, 7 },
        { 4, 7, 6 },
        { 1, 3, 7 },
        { 1, 7, 5 },
        { 0, 4, 6 },
        { 0, 6, 2 },
        { 2, 6, 7 },
        { 2, 7, 3 },
        { 0, 1, 5 }
        { 0, 5, 4 }
};
```

# 3D Printing uses a Triangular Mesh Data Format



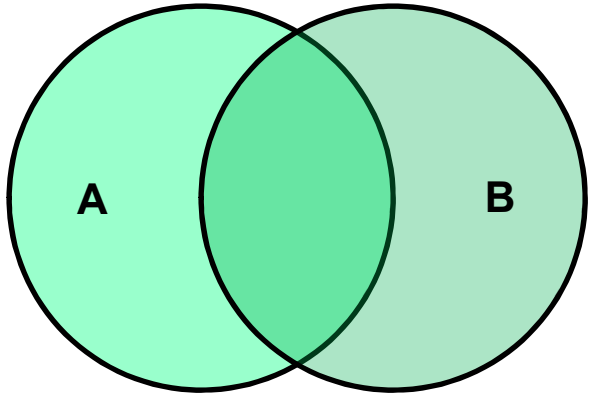


# 3D Printing uses a Triangular Mesh Data Format

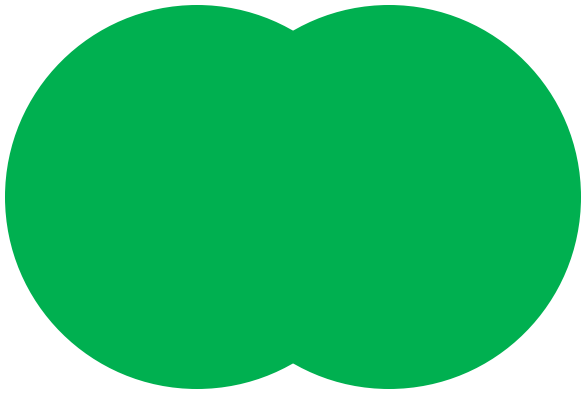
# Dessert at the House of Someone Obsessed with OSU and Computer Graphics ☺



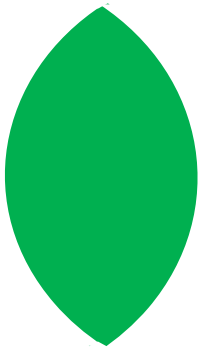
# Another way to Model:
# Remember Venn Diagrams (2D Boolean Operators) from High School?




Two Overlapping Shapes



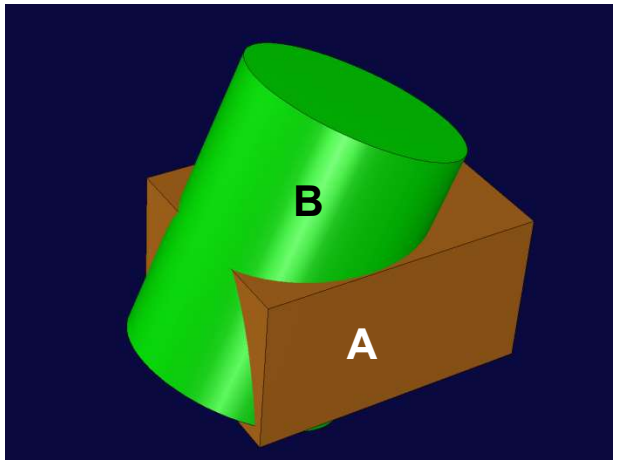
Union: A∪B



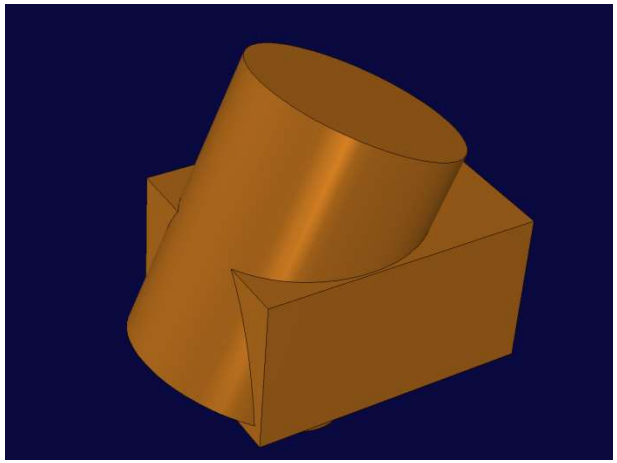
Intersection: A∩B

Difference: A-B

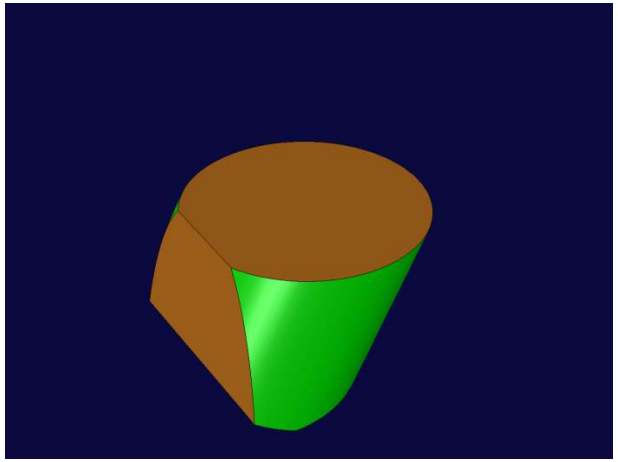
# Solid Modeling Using 3D Boolean Operators



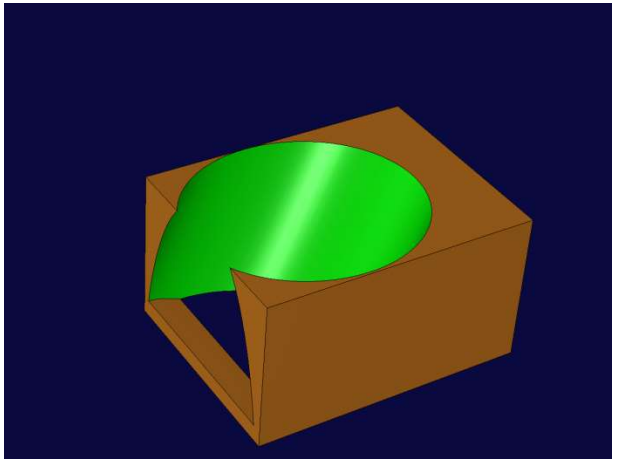

Two Overlapping Solids



Union: A∪B



Intersection: A∩B

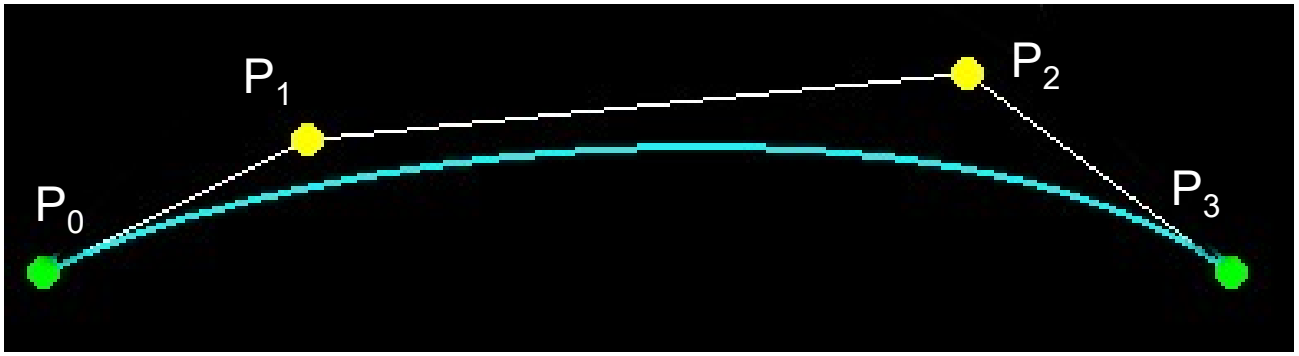


Difference: A-B



This is often called **Constructive Solid Geometry**, or CSG

# Another way to Model:
# Curve Sculpting – Bezier Curve Sculpting



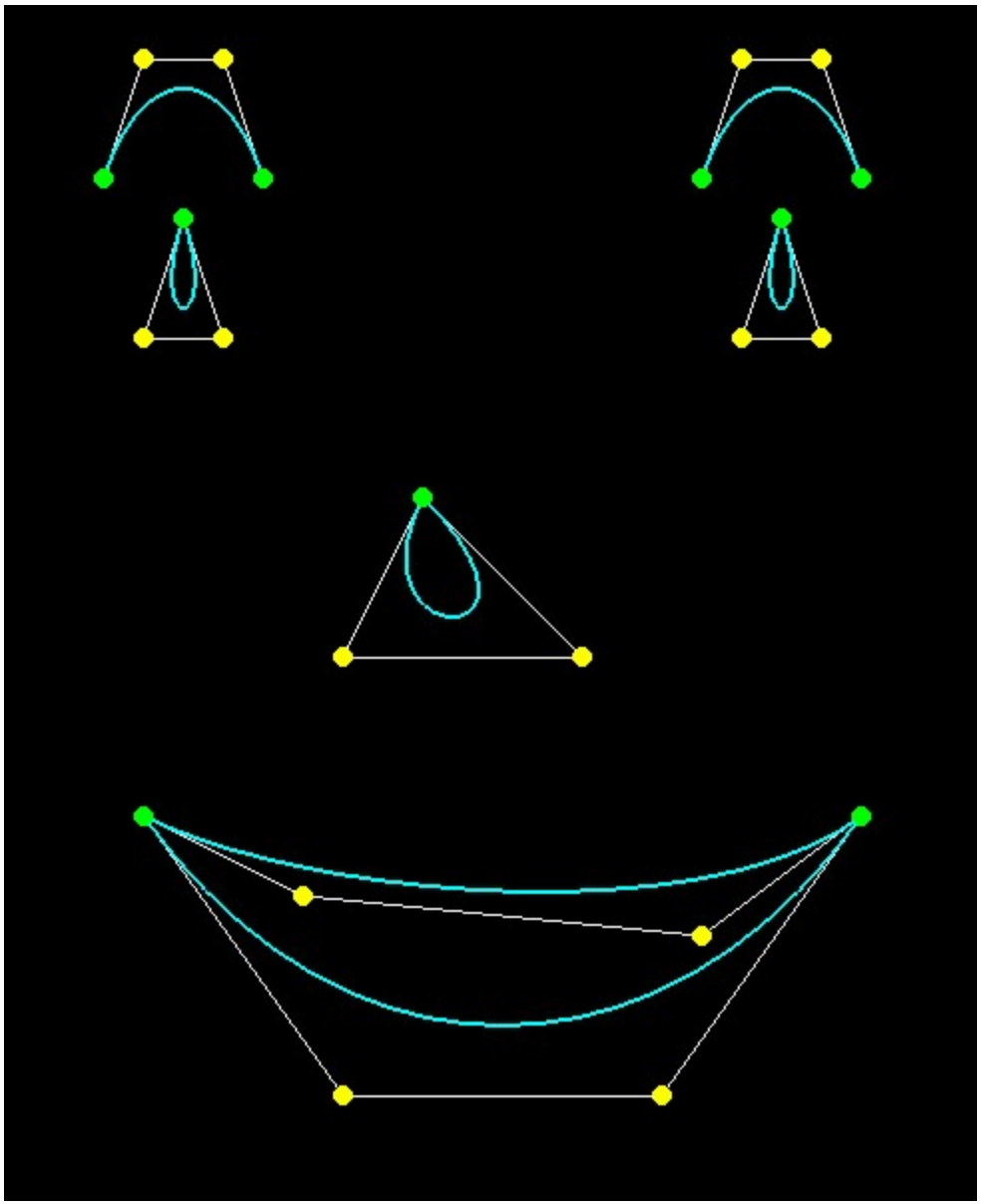

$$P(t) = (1-t)^3 P_0 + 3t(1-t)^2 P_1 + 3t^2(1-t)P_2 + t^3 P_3$$

$$0. \le t \le 1.$$

where *P* represents $\begin{Bmatrix} x \\ y \\ z \end{Bmatrix}$

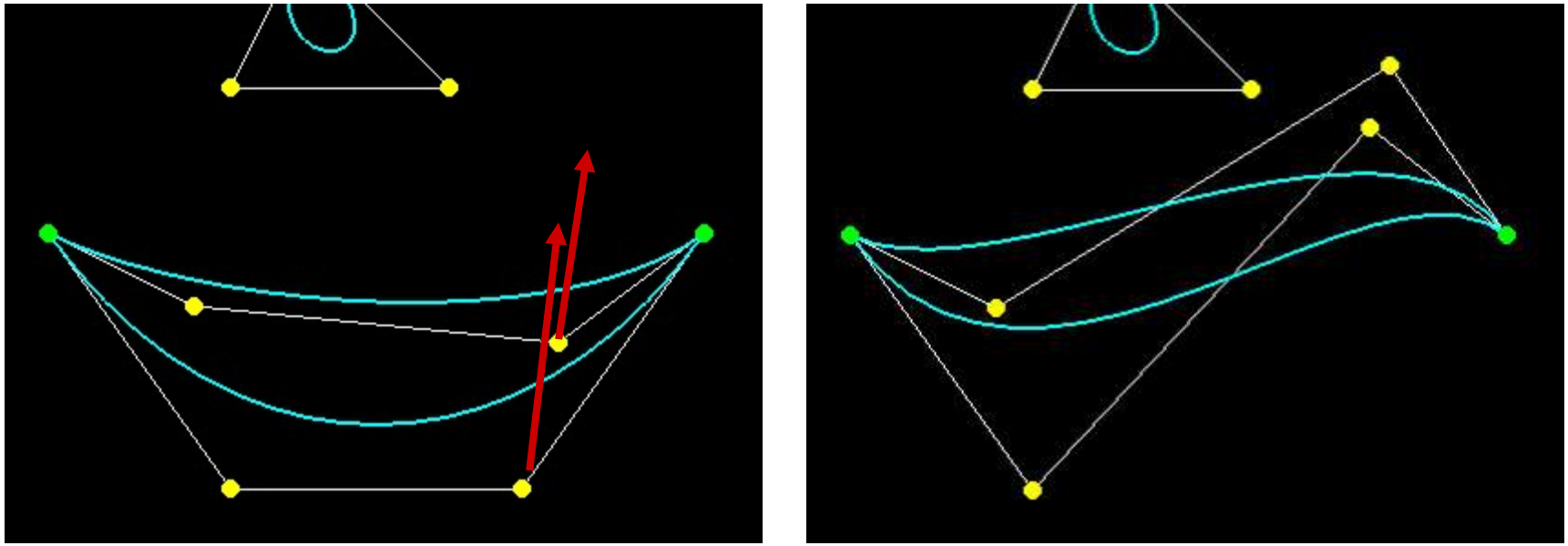
# Curve Sculpting – Bezier Curve Sculpting Example





# Curve Sculpting – Bezier Curve Sculpting Example

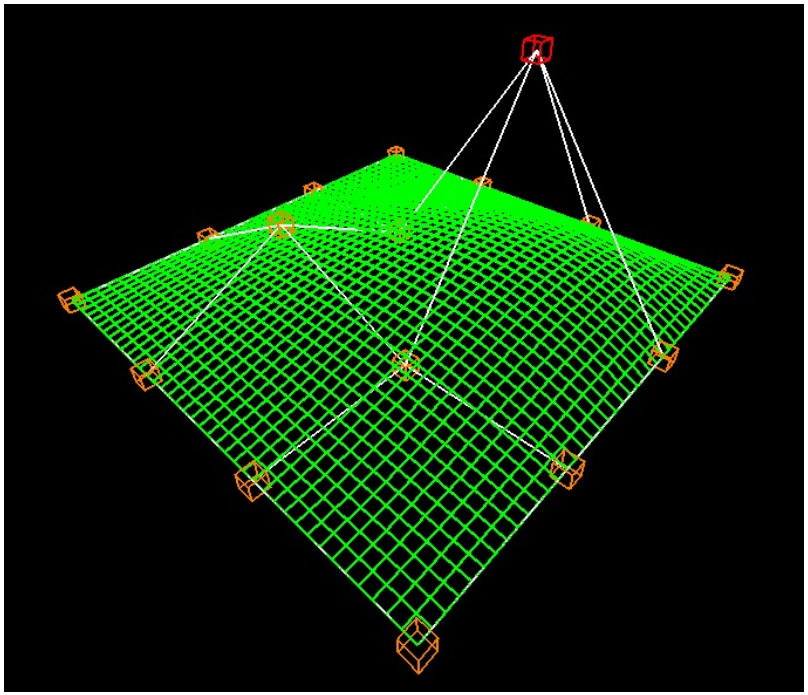




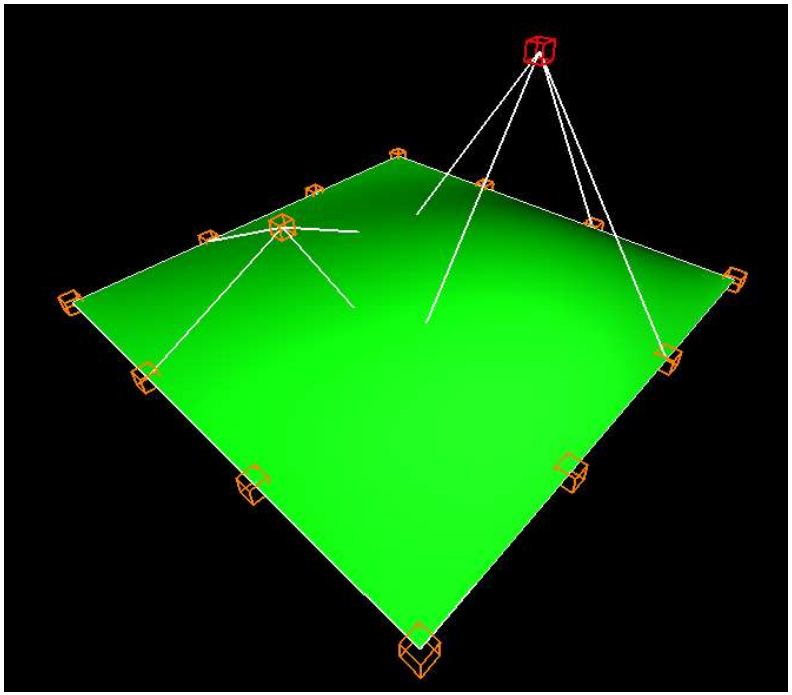
Moving a single point moves an entire curve

# Another way to Model: Surface Sculpting





Wireframe

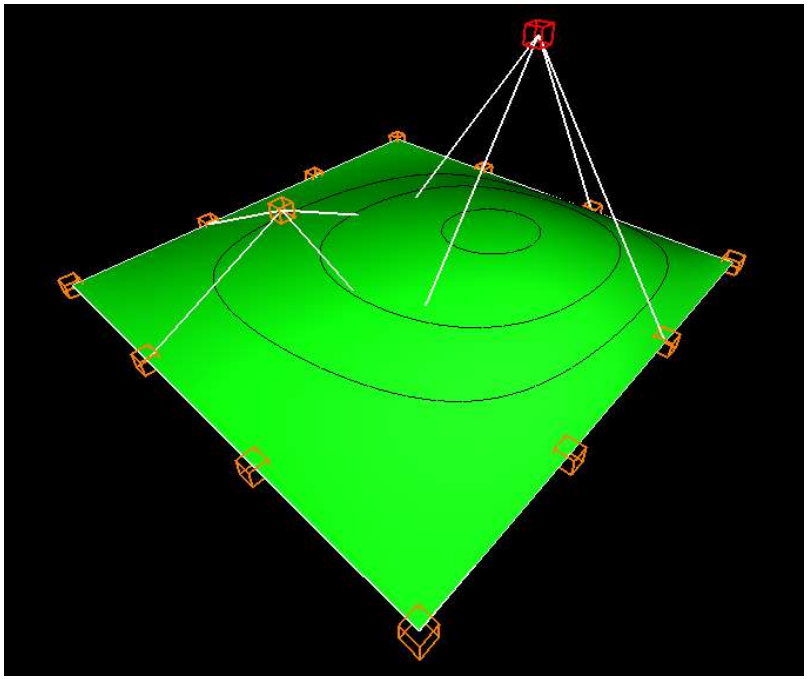


Surface

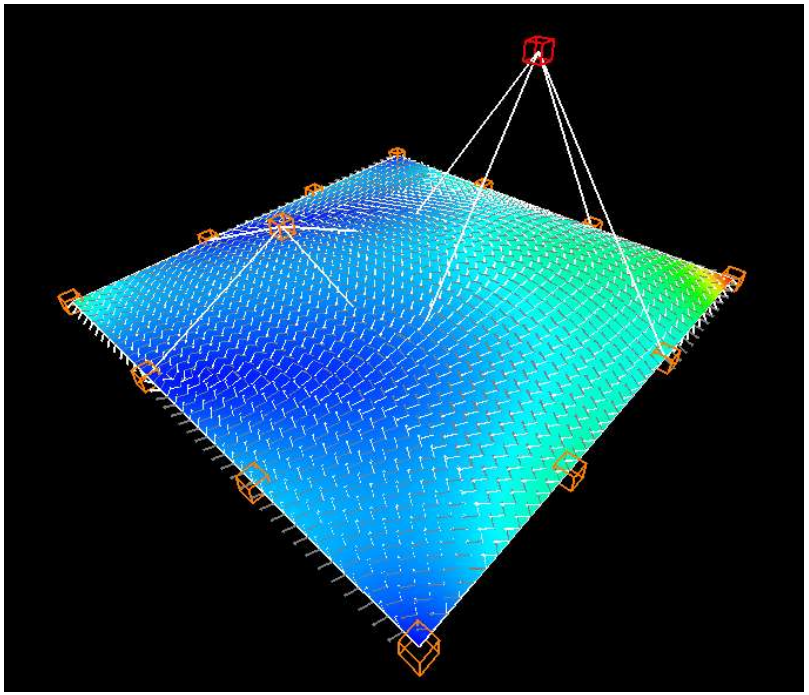
Moving a single point moves an entire surface

# Surface Equations can also be used for Analysis





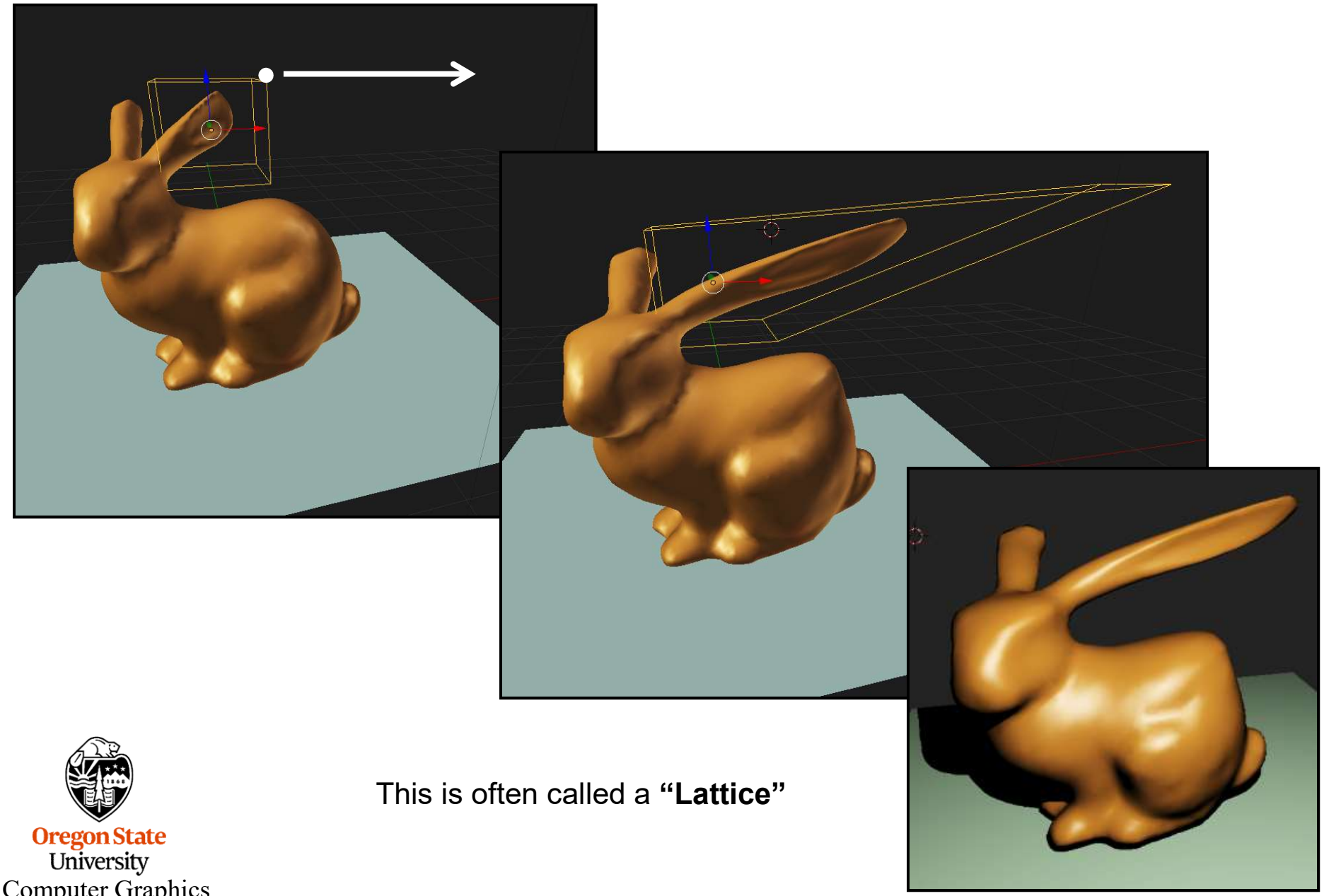
With Contour Lines



Showing Curvature

# Another way to Model: Sculpting with a Wireframe Mesh

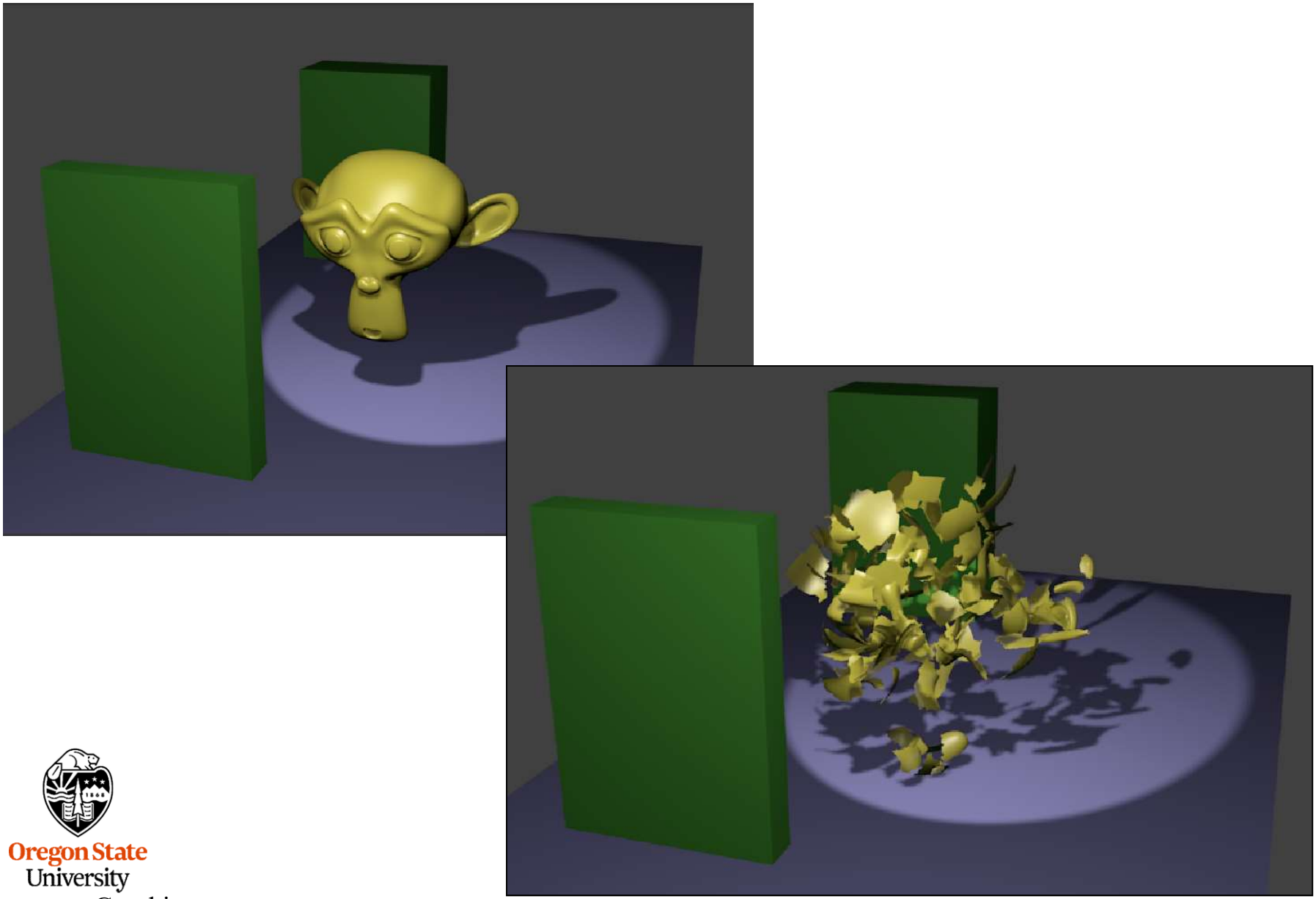




This is often called a **"Lattice"**

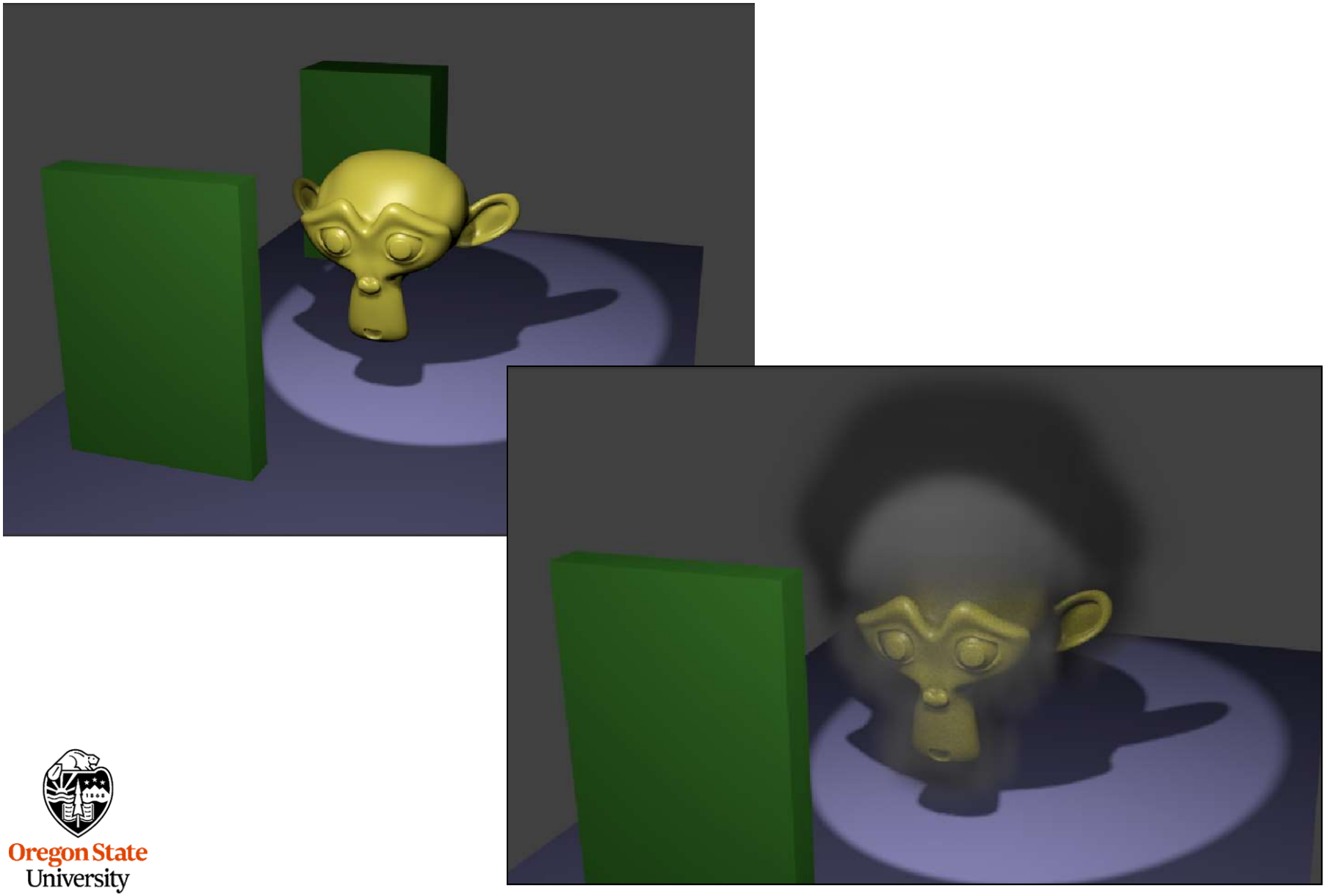
# Modeling → Simulation (Explosion)





# Modeling → Simulation (Smoke)

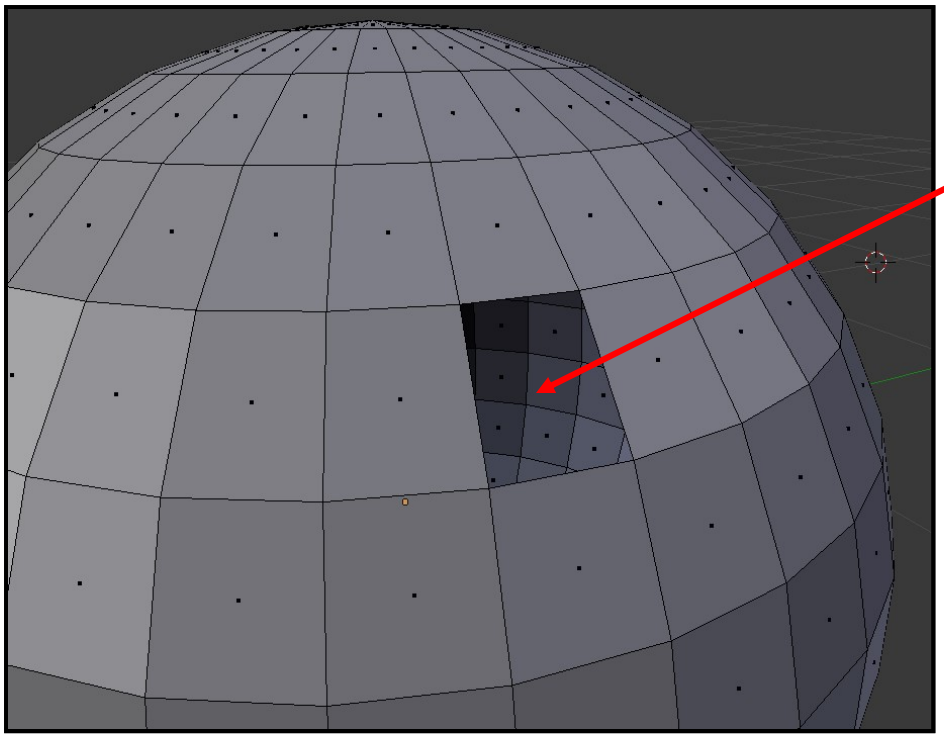




# Object Modeling Rules for 3D Printing



The object must be a legal solid. It must have a definite inside and a definite outside. It can't have any missing face pieces.

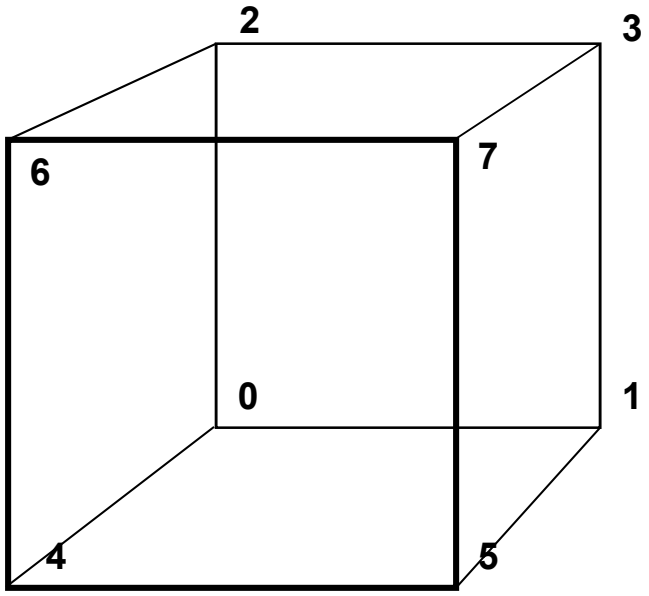



"Definite inside and outside" is sometimes called "Two-manifold" or "Watertight"

# The Simplified Euler's Formula* for Legal Solids



*sometimes called the Euler-Poincaré formula




$$F - E + V = 2$$

| | |
|---|---|
| **F** | **Faces** |
| **E** | **Edges** |
| **V** | **Vertices** |

For a cube, 6 – 12 + 8 = 2

**The full formula is:**

$$F - E + V - L = 2( B - G )$$

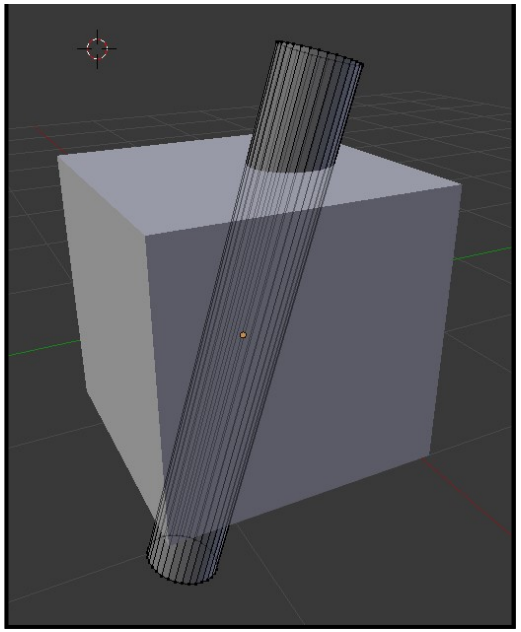
| | |
|---|---|
| **F** | **Faces** |
| **E** | **Edges** |
| **V** | **Vertices** |
| **L** | **Inner Loops (within faces)** |
| **B** | **Bodies** |
| **G** | **Genus (number of through-holes)** |

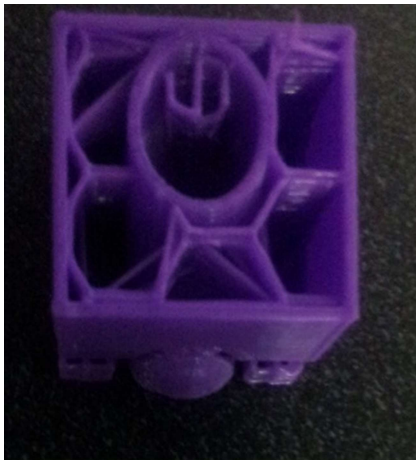
# Object Modeling Rules for 3D Printing



Objects cannot pass through other objects. If you want two shapes together, do a Boolean union on them so that they become one complete object.

**Overlapped in 3D -- bad**





**Boolean union -- good**