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.

Cube Example

static GLfloat CubeVertices[ 8 ] =
{ 
    { -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[ 8 ][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[ 12 ][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 }
};
The Cube Can Also Be Defined with Triangles

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

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

3D Printing uses a Triangular Mesh Data Format

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: \( A \cup B \)
Intersection: \( A \cap B \)
Difference: \( A - B \)

Solid Modeling Using 3D Boolean Operators

Two Overlapping Solids
Union: \( A \cup B \)
Intersection: \( A \cap B \)
Difference: \( A - B \)
This is often called Constructive Solid Geometry, or CSG

Another way to Model:
Curve Sculpting – Bezier Curve Sculpting

Curve Sculpting – Bezier Curve Sculpting Example

\[
P(t) = (1 - t)^3 P_0 + 3t(1 - t)^2 P_1 + 3t^2(1 - t)P_2 + t^3 P_3
\]
where \( P \) represents \( \begin{bmatrix} x \\ y \\ z \end{bmatrix} \)
Curve Sculpting – Bezier Curve Sculpting Example

Moving a single point moves an entire curve

Another way to Model: Surface Sculpting

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"
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, \( 6 - 12 + 8 = 2 \)
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