Building Models

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Objectives

Introduce simple data structures for building polygonal models

- Vertex lists
- Edge lists

Implementation with VBOs
Representing a Mesh

Consider a mesh

There are 6 nodes and 9 edges

- 4 interior polygons
- 3 interior (shared) edges

Each vertex has a location $v_i = (x_i, y_i, z_i)$
Simple Representation

Define each polygon by the geometric locations of its vertices
Leads to OpenGL code such as

```cpp
vertex[i] = vec3(x1, y1, z1);
vertex[i+1] = vec3(x2, y2, z2);
vertex[i+2] = vec3(x3, y3, z3);
i+=3;
vertex[i] = vec3(x2, y2, z2);
vertex[i+1] = vec3(x3, y3, v3);
vertex[i+2] = vec3(x4, y4, v4);
```

*Inefficient and unstructured*

Shared vertices are repeated
Consider moving a vertex to a new location
Geometry vs Topology

Generally it is a good idea to look for data structures that separate the geometry from the topology

Geometry: locations of the vertices
Topology: organization of the vertices and edges

Example: a polygon is an ordered list of vertices with an edge connecting successive pairs of vertices and the last to the first

Topology holds even if geometry changes
Cube: Geometry and Topology

Geometry
8 vertices

Topology
6 faces
Each face is a quad (really 2 triangles)
3 quads share each vertex

Even if the geometry changes, this topology always describes a six-sided polyhedron
Vertex Lists

Put the geometry in an array
Use pointers from the vertices into this array
Introduce a polygon list

topology

geometry

P1
P2
P3
P4
P5

v1
v7
v6

v8
v5
v6

x1 y1 z1
x2 y2 z2
x3 y3 z3
x4 y4 z4
x5 y5 z5
x6 y6 z6
x7 y7 z7
x8 y8 z8
Cube Model Example
Inward and Outward Facing Polygons

The order \{0,3,2,1\} and \{1,0,3,2\} are equivalent in that the same polygon will be rendered by OpenGL but the order \{0,1,2,3\} is different.

The first two describe *outwardly facing* polygons.

Use the *right-hand rule* = counter-clockwise encirclement of outward-pointing normal.

OpenGL can treat inward and outward facing polygons differently.
See 3D_ModelingDemo_VL
Using VBOs for Indexed Data

Option I
- Stored vertices, colors, etc.
- Stored index info
  
  *Manually turn indexed data into raw vertex data arrays*

Leads to duplicates and (somewhat) defeats the purpose of the indexing

Option II
- VBO with glDrawElements
glDraw Elements

Setup your VBO

Specify an **Index VBO** – another VBO that holds the array of face indices

Use glDrawElements instead of glDrawArrays: the Index VBO is used to index into the position VBO
Example

```cpp
c vec2 vertices[3] = {
    vec2(0.0, 0.0), vec2(1.0, 0.0), vec2(1.0, 1.0),
    vec2(0.0, 1.0)};

int indices[6] = {0, 1, 2, 0, 2, 3}; // 2 triangles

/* vao stuff left out */
Gluint buffer;
glGenBuffers(1, &buffer);
glBindBuffer(GL_ARRAY_BUFFER, buffer);
glBufferData(GL_ARRAY_BUFFER, sizeof(vertices), vertices, GL_STATIC_DRAW);

/* Generate a buffer for the indices */
Gluint elementbuffer;
glGenBuffers(1, &elementbuffer);
glBindBuffer(GL_ELEMENT_ARRAY_BUFFER, elementbuffer);
glBufferData(GL_ELEMENT_ARRAY_BUFFER, sizeof(indices), &indices[0], GL_STATIC_DRAW);
```
Example (cont...)

```cpp
myDisplay() {
    ...
    glBindBuffer(GL_ELEMENT_ARRAY_BUFFER, elementbuffer);

    // Draw the triangles!
    glDrawElements(
        GL_TRIANGLES, // kind of primitive to render
        NumIndices, // # indices to render
        GL_UNSIGNED_INT, // index type
        (void*)0 // Offset into the array buffer
    );
}
```
See 3D_ModelingDemo_IB