Building Models

Ed Angel

Professor of Computer Science, Electrical and Computer Engineering, and Media Arts

University of New Mexico

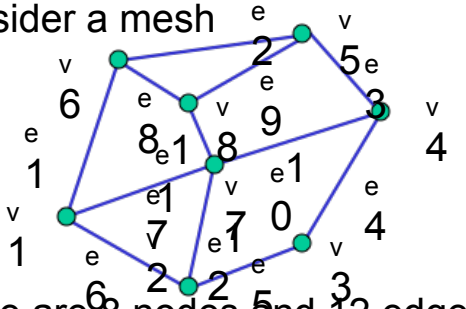
(minor modifications by lmtb@estgp.pt, Nov/2012)

Objectives

- Introduce simple data structures for building polygonal models
  - Vertex lists
  - Edge lists
- OpenGL vertex arrays

Representing a Mesh

- Consider a mesh



- There are 8 nodes and 12 edges
  - 5 interior polygons
  - 6 interior (shared) edges
- Each vertex has a location $v_i = (x_i\ y_i\ z_i)$

Simple Representation

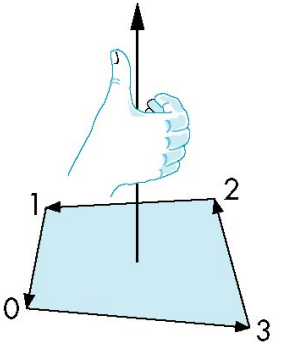
- Define each polygon by the geometric locations of its vertices
- Leads to OpenGL code such as

```
glBegin(GL_POLYGON);
   glVertex3f(x1, y1, z1);
   glVertex3f(x6, y6, z6);
   glVertex3f(x7, y7, z7);
glEnd();
```

- Inefficient and unstructured
  - Consider moving a vertex to a new location
  - Must search for all occurrences

Inward and Outward Facing Polygons

- The order {v1, v6, v7} and {v6, v7, v1} are equivalent in that the same polygon will be rendered by OpenGL but the order {v1, v7, v6} 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



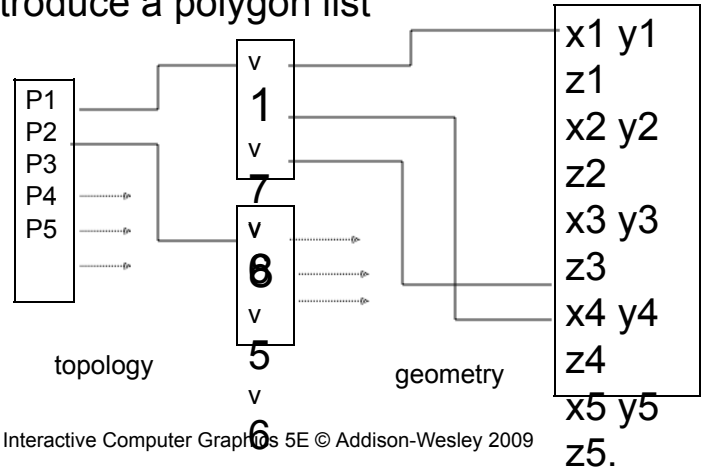

```
glEnable(GL_CULL_FACE)
```

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

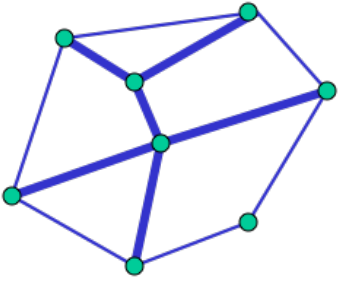
Vertex Lists

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



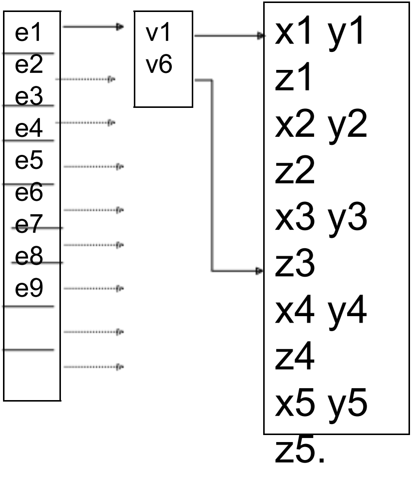
Shared Edges

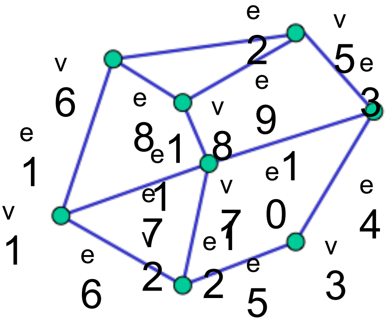
- Vertex lists will draw filled polygons correctly but if we draw the polygon by its edges, shared edges are drawn twice



- Can store mesh by *edge list*

Edge List





Note polygons are not represented

Modeling a Cube

Model a color cube for rotating cube program

Define global arrays for vertices and colors

```
GLfloat vertices[][3] = {{-1.0,-1.0,-1.0},{1.0,-1.0,-1.0},
  {1.0,1.0,-1.0}, {-1.0,1.0,-1.0}, {-1.0,-1.0,1.0},
  {1.0,-1.0,1.0}, {1.0,1.0,1.0}, {-1.0,1.0,1.0}};
```

```
GLfloat colors[][3] = {{0.0,0.0,0.0},{1.0,0.0,0.0},
  {1.0,1.0,0.0}, {0.0,1.0,0.0}, {0.0,0.0,1.0},
  {1.0,0.0,1.0}, {1.0,1.0,1.0}, {0.0,1.0,1.0}};
```

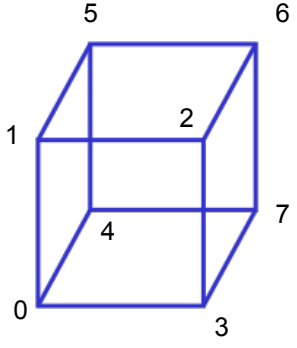
Drawing a polygon from a list of indices

Draw a quadrilateral from a list of indices into the array **vertices** and use color corresponding to first index

```
void polygon(int a, int b, int c
, int d)
{
  glBegin(GL_POLYGON);
     glColor3fv(colors[a]);
     glVertex3fv(vertices[a]);
     glVertex3fv(vertices[b]);
     glVertex3fv(vertices[c]);
     glVertex3fv(vertices[d]);
   glEnd();
}
```

Draw cube from faces

```
void colorcube( )
{
    polygon(0,3,2,1);
    polygon(2,3,7,6);
    polygon(0,4,7,3);
    polygon(1,2,6,5);
    polygon(4,5,6,7);
    polygon(0,1,5,4);
}
```



Note that vertices are ordered so that
we obtain correct outward facing normals

Efficiency

- The weakness of our approach is that we are building the model in the application and must do many function calls to draw the cube
- Drawing a cube by its faces in the most straight forward way requires
  6 **`glBegin`**, 6 **`glEnd`**
  6 **`glColor`**
  24 **`glVertex`**
  More if we use texture and lighting

Vertex Arrays

- OpenGL provides a facility called *vertex arrays* that allows us to store array data in the implementation
- Six types of arrays supported
  - Vertices
  - Colors
  - Color indices
  - Normals
  - Texture coordinates
  - Edge flags
- We will need only colors and vertices

Initialization

- Using the same color and vertex data, first we enable

```
glEnableClientState(GL_COLOR_ARRAY);
glEnableClientState(GL_VERTEX_ARRAY);
```

- Identify location of arrays

```
glVertexPointer(3, GL_FLOAT, 0, vertices);
```


```
glColorPointer(3, GL_FLOAT, 0, colors);
```

Mapping indices to faces

- Form an array of face indices

```
GLubyte cubeIndices[24] = {0,3,2,1,2,3,7,6
   0,4,7,3,1,2,6,5,4,5,6,7,0,1,5,4};
```

- Each successive four indices describe a face of the cube
- Draw through **`glDrawElements`** which replaces all **`glVertex`** and **`glColor`** calls in the display callback

Drawing the cube

- Method 1:

what to draw

number of indices

```
for(i=0; i<6; i++) glDrawElements(GL_POLYGON, 4,
     GL_UNSIGNED_BYTE, &cubeIndices[4*i]);
```

format of index data

start of index data

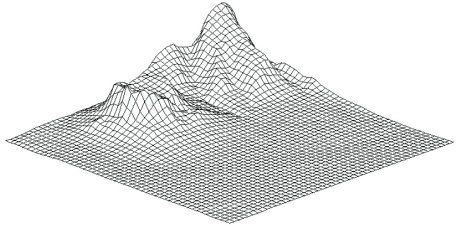
- Method 2:

```
glDrawElements(GL_QUADS, 24,
   GL_UNSIGNED_BYTE, cubeIndices);
```

Draws cube with 1 function call!!

Mesh plot of Honolulu data

- Generate surface using GL_QUADS



- Generate lines using GL_LINE_LOOP

  Avoid numerical inaccuracies - Polygon Offset, moves polygons slightly away from the viewer.

```
glPolygonOffset(scale_factor,units);
glEnable(GL_POLYGON_OFFSET_FILL)
```