CS 4731: Computer Graphics
Lecture 10: 3D Modeling: Polygonal Meshes

Emmanuel Agu

3D Modeling

- Previously
- Introduced 3D modeling
- Previously introduced GLUT models (wireframe/solid) and Scene Description Language (SDL): 3D file format
- Previously used GLUT calls
  - Cylinder: glutWireCylinder( ), glutSolidCylinder( )
  - Cone: glutWireCone( ), glutSolidCone( )
  - Sphere: glutWireSphere( ), glutSolidSphere( )
  - Cube: glutWireCube( ), glutSolidCube( )
  - Newell Teapot, torus, etc

Polygonal Meshes

- Modeling with basic shapes (cube, cylinder, sphere, etc) too primitive
- Difficult to approach realism
- Polygonal meshes:
  - Collection of polygons, or faces, that form "skin" of object
  - Offer more flexibility
  - Models complex surfaces better
  - Examples:
    - Human face
    - Animal structures
    - Furniture, etc

Polygonal Meshes

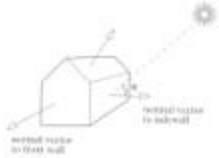
- Have become standard in CG
- OpenGL
  - Good at drawing polygon
  - Mesh = sequence of polygons
- Simple meshes exact. (e.g barn)
- Complex meshes approximate (e.g. human face)
- Later: use shading technique to smoothen

Non-solid Objects

- Examples: box, face
- Visualize as infinitely thin skin
- Meshes to approximate complex objects
- Shading used later to smoothen
- Non-trivial: creating mesh for complex objects (CAD)

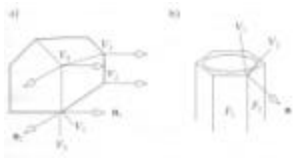
What is a Polygonal Mesh

- Polygonal mesh given by:
  - Polygon list
  - Direction of each polygon
  - Represent direction as normal vector
  - Normal vector used in shading
  - Normal vector/light vector determines shading



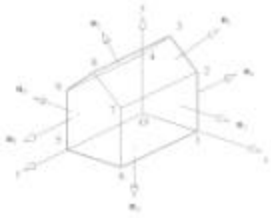
Vertex Normal

- Use vertex normal instead of face normal
- See advantages later:
  - Facilitates clipping
  - Shading of smoothly curved shapes
  - Flat surfaces: all vertices associated with same **n**
  - Smoothly curved surfaces: *V1*, *V2* with common edge share **n**



Defining Polygonal Mesh

- Use barn example below:



Defining Polygonal Mesh

- Three lists:
  - Vertex list: distinct vertices (vertex number, Vx, Vy, Vz)
  - Normal list: Normals to faces (normalized nx, ny, nz)
  - Face list: indexes into vertex and normal lists. i.e. vertices and normals associated with each face
- Face list convention:
  - Traverse vertices counter-clockwise
  - Interior on left, exterior on right

Newell Method for Normal Vectors

- Martin Newell at Utah (teapot guy)
- Normal vector:
  - calculation difficult by hand
  - Given formulae, suitable for computer
  - Compute during mesh generation
- Simple approach used previously:
  - Start with any three vertices V1, V2, V3
  - Form two vectors, say V1-V2, V3-V2
  - Normal: cross product (perp) of vectors

Newell Method for Normal Vectors

- Problems with simple approach:
  - If two vectors are almost parallel, cross product is small
  - Numerical inaccuracy may result
  - Newell method: robust
  - Formulae: Normal N = (mx, my, mz)

$$m_x = \sum_{i=0}^{N-1} (y_i - y_{next(i)})(z_i + z_{next(i)})$$

$$m_y = \sum_{i=0}^{N-1} (z_i - z_{next(i)})(x_i + x_{next(i)})$$

$$m_z = \sum_{i=0}^{N-1} (x_i - x_{next(i)})(y_i + y_{next(i)})$$

Newell Method Example

- Example: Find normal of polygon with vertices
  P0 = (6,1,4), P1=(7,0,9) and P2 = (1,1,2)
- Solution:
  Using simple cross product:
  ((7,0,9)-(6,1,4)) X ((1,1,2)-(6,1,4)) = (2,-23,-5)

  Using Newell method, plug in values result is the same:
  Normal is (2, -23, -5)

Meshes in Programs

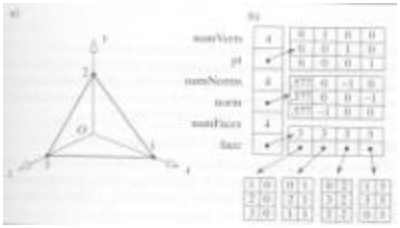
- Class *Mesh*
- Helper classes
  - VertexID
  - Face
- Mesh Object:
  - Normal list
  - Vertex list
  - Face list
- Use arrays of pt, norm, face
- Dynamic allocation at runtime
- Array lengths: numVerts, numNormals, numFaces

Meshes in Programs

- Face:
  - Vertex list
  - Normal vector associated with each face
  - Array of index pairs
- Example, vth vertex of fth face:
  - Position: pt[face[f]. vert[v]. vertIndex]
  - Normal vector: norm[face[f]. vert[v]. normIndex]
- Organized approach, permits random access

Meshes in Programs

- Tetrahedron example



Meshes in Programs

- Data structure:

```
// ################ Vertex ID ######################
class VertexID
    public:
        int vertIndex;    // index of this vertex in the vertex list
        int normIndex;   // index of this vertex's normal
}
// ################ Face ######################
class Face
    public:
        int nVerts;       // number of vertices in this face
        VertexID  *vert;    // the list of vertex and normal indices
        Face( ){ nVerts = 0; vert = NULL;}    // constructor
        ~Face( ){delete[ ] vert; nVerts = 0;  // destructor
};
```

Meshes in Programs

```
// ################ Mesh ######################
class Mesh{
    private:
        int numVerts;          // number of vertices in the mesh
        Point3 *pt;            // array of 3D vertices
        int numNormals;        // number of normal vertices for the mesh
        Vector3 *norm;         // array of normals
        int numFaces;          // number of faces in the mesh
        Face *face;            // array of face data
        //... others to be added later
    public:
        Mesh( );               // constructor
        ~Mesh( );              // destructor
        int readFile(char *fileName);    // to read in a filed mesh
        ..... other methods....
}
```

Drawing Meshes Using OpenGL

- Pseudo-code:

```
for(each face f in Mesh)
{
    glBegin(GL_POLYGON);
    for(each vertex v in face f)
    {
       glNormal3f(normal at vertex v );
       glVertex3f(position of vertex v);
    }
    glEnd( );
}
```

Drawing Meshes Using OpenGL

- Actual code:

```
Void Mesh::draw( )          // use openGL to draw this mesh
{
   for(int f = 0;f < numFaces;f++)
   {
      glBegin(GL_POLYGON);
         for(int v=0;v<face[f].nVerts;v++)        // for each one
         {
            int in = face[f].vert[v].normIndex;   // index of this normal
            int iv = face[f].vert[v].vertIndex;   // index of this vertex
            glNormal3f(norm[in].x, norm[in].y, norm[in].z);
            glVertex3f(pt[iv].x, pt[iv].y, pt[iv].z);
         }
      glEnd( );
    }
}
```

Drawing Meshes Using SDL

- Scene class reads SDL files
- Accepts keyword *Mesh*
- Example:
  - Pawn stored in mesh file pawn.3vn
  - Add line:
    - Push translate 3 5 4 scale 3 3 3 mesh pawn.3vn pop

More on Meshes

- Simple meshes easy by hand
- Complex meshes:
  - Mathematical functions
  - Algorithms
  - Digitize real objects
- Libraries of meshes available
- Mesh trends:
  - 3D scanning
  - Mesh Simplification

3D Simplification Example

Original: 424,000 triangles

60,000 triangles (14%).

1000 triangles (0.2%)

(courtesy of Michael Garland and Data courtesy of Iris Development.)

References

- Hill, 6.1-6.2