Surface Representation / Meshes

EE-148 3D Photography
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3D Representations

- Volumes (solid objects)
- Surfaces (boundaries of solids)
- What is a 3D Representation ?
  - Computer memory is finite
  - Approximation defined by finite number of parameters
  - Efficient to perform certain operations (transmit, render, etc.)
  - Data structures

Surface Modeling

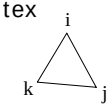
- Polygon meshes
  - Planar subdivisions
  - Set of connected polygonally bounded planar surfaces
- Parametric surfaces
  - Curved surfaces
  - Piecewise polynomial : Bezier patches / Splines
- Implicit surfaces
  - Iso-surfaces
  - How to convert to polygon mesh ?

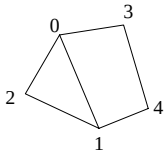
Polygon meshes

- Simplest case: triangle mesh
- Triangle defined by 3 vertices in 3D
  - Vertex specified by 3 (x,y,z) coordinates
  - 9 floats per triangle
  - No connectivity
  - STL file format
    used for rapid prototyping applications
  - Inefficient for other operations

IndexedFaceSet

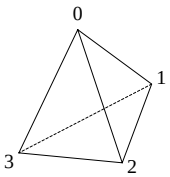
- Array of vertex coordinates
- Each 3D vertex has an associated vertex index in {0,...,V-1}
- A triangle is defined by three vertex indices (i,j,k)
- A polygonal face without holes is defined by more indices
- coordIndex [0,1,2,-1,0,3,4,1,-1]
- VRML'97 file format





Tetrahedron.wrl

```
#VRML V2.0 utf8
Shape {
  geometry IndexedFaceSet {
    coord Coordinate {
      point [
         1.633 –0.943 –0.667
         0.000  0.000  2.000
        -1.633 –0.943 –0.667
         0.000  1.886 –0.667
      ]
    }
    coordIndex [
      0 1 2 –1 3 1 0 –1 2 1 3 –1 2 3 0 -1
    ]
  }
}
```



Classification

- Connectivity
  - coordIndex (faces)
- Geometry
  - coord (vertex coordinates)
- Properties
  - color/colorIndex/colorPerVertex
  - normal/normalIndex/normalPerVertex
  - texCoord/texCoordIndex

Connectivity

- Edges
  - Boundary (1 incident face)
  - Regular (2 incident faces)
  - Singular (3 or more incident faces)
- Vertices
  - Regular / Singular
- Connected components
  - Connected Components of Dual Graph

Manifold / Non-Manifold

- Data structures to represent
- Traversal Operations
- Algorithm to generate representation from IndexedFaceSet

Curved surfaces

- Parametric curves
  - $p(t) = (x(t),y(t),z(t))$ t in [0,1]
- Parametric surfaces
  - $p(u,v) = (x(u,v),y(u,v),z(u,v))$ (u,v) in [0,1]x[0,1]
- Triangle patches
  - Affine coordinates, partition of unit
  - Bezier surfaces
- Subdivision surfaces

Interpolation

- Linear interpolation
- Triangle : Baricentric coordinates
  - Triangle
  - Tetrahedron
- Quadrilateral ?
  - Bi-linear interpolation
- Cube ?
  - Tri-linear interpolation

Subdivision surfaces

- Limit of sequence of polygonal meshes
- Representation
  - Base mesh
  - N subdivision steps
    - Connectivity refinement
    - Smoothing
- Approximation vs. Interpolation
- Proof of convergence
- Loop / Catmull-Clark
- Dual mesh / Doo-Sabin

Operations on meshes

- Construction of triangle strips
- Subdivision
- Intersection
- Rendering (rasterization/sampling)
- Conversion to Manifold
- Simplification / Decimation

Doubly-linked data structure

- Planar subdivisions
- Planar graph embedding
- Vertices / Faces / Half-Edges
- Orientation