Solid Modeling

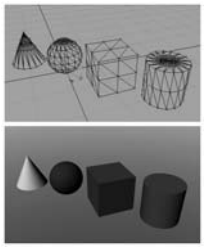
- Polygonal Objects:
  Real data
  Modeling Packages
  Extrusion, revolution
  Procedural Techniques (Fractal, L-System)
- Implicit surface
  Constructive Solid Geometry (CSG)
  Quadric Surfaces
  Metaballs/Blobby

Modeling Overview

- Polygonal Objects
  - Real data
  - Modeling Packages
  - Extrusion, revolution
  - Procedural Techniques (Fractal, L-System)
- Implicit surface
  - Constructive Solid Geometry (CSG)
  - Quadric Surfaces
  - Metaballs/Blobby

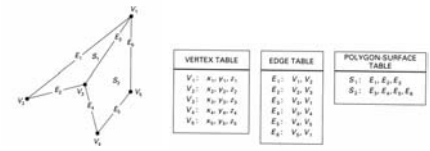
Polygon Surfaces

Set of surface polygons that enclose an object interior



Polygon Tables

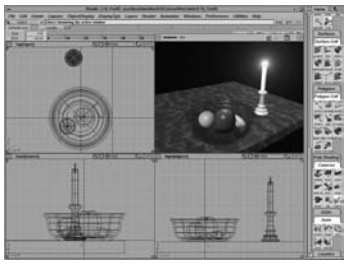
We specify a polygon surface with a set of vertex coordinates and associated attribute parameters



Polygonal Objects: Real Data

- Numerical Model of Terrains
  - Measure height on a 2D map
- 3D Scanner
- Result:
  Cloud of points or lines

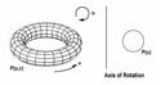
Polygonal Objects: Modeling Packages



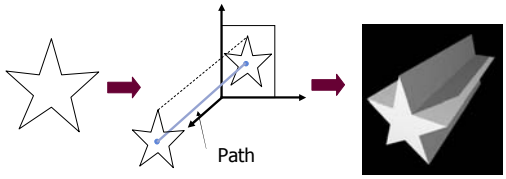
Polygonal Objects: Extrusion

- Step 1: Draw shape in 2D
- Step 2:
  - Extrusion : Translate the 2D shape, follow the path

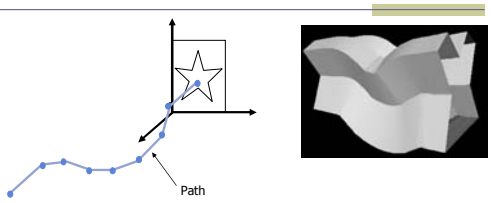
or
  - Revolution: Rotate in 3D the 2D shape (rotation axe is in the plan)
- Step 3: Join vertexes to form polygons



Polygonal Objects: Extrusion

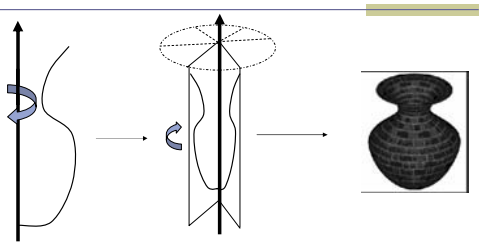


Polygonal Objects: Extrusion



Scale value and deformation can be apply on each vertex of the path

Polygonal Objects: Extrusion



Revolution: The path can be a circle to define a revolution

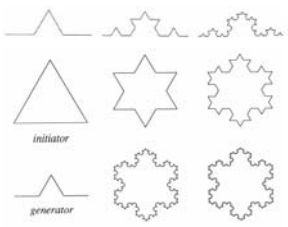
Polygonal Objects: Procedural Techniques

- Fractal
  - Recursive subdivision
  - random

- Grammar: L-System

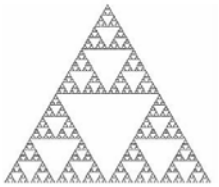
Procedural Techniques: Fractals (1)

Apply algorithmic rules to generate shapes



Procedural Techniques: Fractals (2)

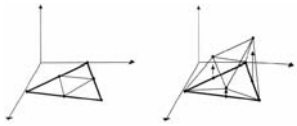
Another example: Sierpinsky gasket made by recursive subdivision of triangles(2D)/tetrahedral (3D)



Procedural Techniques: Fractals (3)

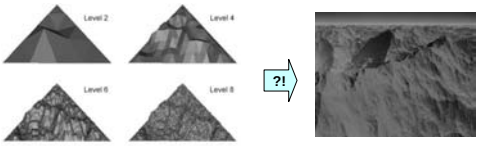
Another Method : *Random midpoint displacement*

- start with some initial figure
- split at midpoints and add random displacement
- recurse, decreasing the magnitude of displacements



Procedural Techniques: Fractals (4)

Random midpoint displacement: Example output

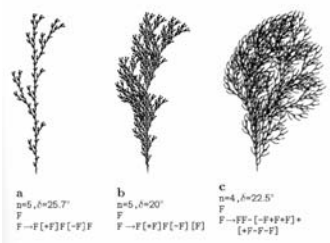


Procedural Techniques: L-System

- Grammar-based fractal-like models
- also sometimes called "graftals"
- we describe an object by a string of symbols
- and we provide a set of production rules
- can also vary objects by randomly applying rules
- common in modeling plant structures
- demo: http://www.cpsc.ucalgary.ca/Redirect/bmv/java/LSystems/LSys.html

Procedural Techniques: L-systems

Biologically-motivated approach to modeling botanical structures



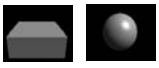
Example of a complex L-system model

Implicit surfaces

- Constructive Solid Geometry (CSG)
- Quadrics
- Metaballs / Blobby

Implicit Surface: Constructive Solid Geometry

Two primitives



CGS Operations:

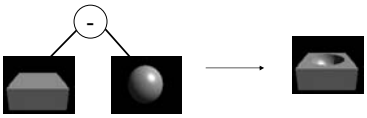
- The union of the 2 primitives

- The intersection of the 2 primitives

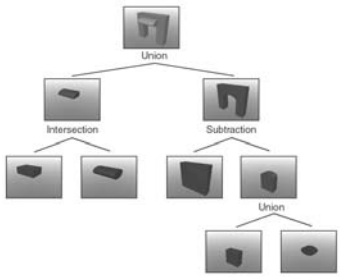
- The difference of the two primitives:
  - box minus sphere

Implicit Surface: CSG Tree

- Binary Tree
  - Each node contains an operation:
    - Union, Intersection, Difference
  - Each leaf represent a primitive (quadric solid)



Another CSG Tree Example



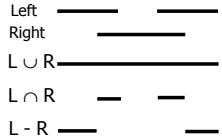
Implicit Surface: CSG Rendering

- Ray-Tracing
  - For each leaf compute the entering and the outgoing t-values of the ray (p + td)
  - Traverse recursively the tree
  - Result
    ordered sequence of t-values $t_1, t_2, \ldots, t_n$

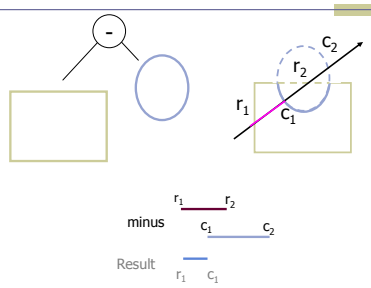
Implicit Surface: CSG Rendering

```
List RayCast(Ray r, CSGTree solid)
{
  if solid->op   // if there is a CSG operation
    left   = RayCast( r, solid->left)
    right = RayCast( r, solid->right)
    Combine( solid->op, left, right)
  else
    switch(solid->primitive)
      case Cube …
      case Sphere …
                …
}
```

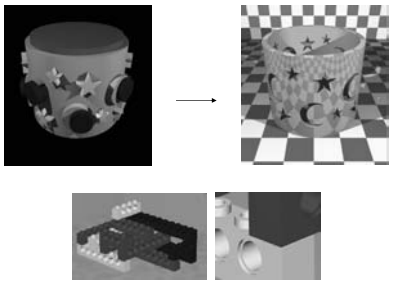
Example CSG combination



Implicit Surface: CSG Rendering



Implicit Surface: CSG Examples



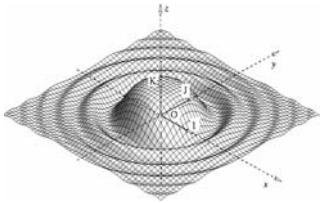
Implicit Surface

- Definition
  - Surface S(x,y,z)=0
  - Inside S(x,y,z)<0
  - Outside S(x,y,z)>0
- Normal vector = gradient vector
  (dS/dx, dS/dy, dS/dz)$_{|x0, y0, z0}$

Implicit Surface

Example

f(x,y) = a.sin(b(x2+y2)) / (x2+y2) = z



z-a.sin(b(x2+y2)) / (x2+y2) = 0

Implicit Surface: Quadric

- Quadric surfaces
  - S(x,y,z) = p Q p^T = 0
    p is the vector [x,y,z,1] and
    Q a symmetric matrix 4x4 of constants
- The quadric solid (points inside the surface)
  - S(x,y,z) = p Q $p^T \le 0$

Implicit Surface: Quadric

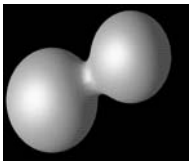
$$Q = \begin{pmatrix} a & b & c & d \\ b & e & f & g \\ c & f & h & i \\ d & g & i & j \end{pmatrix}$$

$$s(x,y,z) = ax^2 + ey^2 + hz^2 + 2bxy + 2cxz + 2fyz + 2dx + 2gy + 2iz + j = 0$$

- Easy to define
  - Plane **Ax+By+Cz-D=0** 2d=A, 2g=B, 2i=C, j=-D, others=0
  - Sphere **$x^2+y^2+z^2=r^2$** a=e=h=1, b=c=f=d=g=I=0, j=-r^2
  - Cylinder **$x^2+y^2-1=0$** a=e=1, h=b=c=f=d=g=I=0, j=-1
  - Cone **$x^2+y^2-z^2=0$** a=e=1, h=-1, others=0
  - Paraboloid, Torus, …

Implicit Surface: Metaballs/Blobby

- Particle surrounded by a density field
- Influence decreases with distance r from the particle
- Isosurface through this density field



Implicit Surface

- Good points
  - Allow modelling of complex shape that would be difficult to do with an other technique
- Limitations
  - CSG Computation very expensive
  - Need polygonal conversion