University of Palestine

Computer Graphics

ITGD3107

Assistant Professor

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ITGD3107 Computer Graphics

Chapter 9-10

Three Dimensional Concepts and Object Representations

Object Representation

- Graphics scenes can contain many different kinds of objects and material surfaces
  - Trees, flowers, clouds, rocks, water, bricks, wood paneling, rubber, paper, steel, glass, plastic and cloth
- So it may not be surprising that there is no single method that we can use to describe all the characteristics of these different shapes/materials

Object Representation

- Scene = an assembly of one or more models

- A model contains
  - Structural description: Geometry of the shape
  - Surface description: Appearance and light

3D Object Representations

- Boundary representation
  - A set of surfaces that separate the object interior from the environment
  - Eg) Polyhedra, curved boundary surfaces
- Space-partitioning
  - Partitioning the spatial region into a set of small, non overlapping, contiguous solids (usually cubes)
  - Eg) Volumetric data, trees
- Procedural methods
  - Fractals, shape grammars
- Constructive solid geometry
- Physically-based modeling

Issues in Model Selection

- Computational cost
  - Storage space
  - Model construction time
  - Display time
- Effectiveness in modeling the desired phenomena
  - Geometry
    - Looks good for image synthesis
    - Accuracy for simulation
  - Appearance
    - Looks / Accuracy

Issues in Model Selection

- Implementation complexity
  - The number of primitives
  - The complexity of each primitives
- Ease of acquiring (or creating) data
- Ease of manipulation
  - Operations on models
- Ease of animation
  - Match to simulator
  - Cost of conversion
  - Physics of motion

Polyhedra

- A polyhedron is a 3D solid which consists of a collection of polygons, usually joined at their edges
- The inside of the solid is divided by the polygons from the outside of the solid

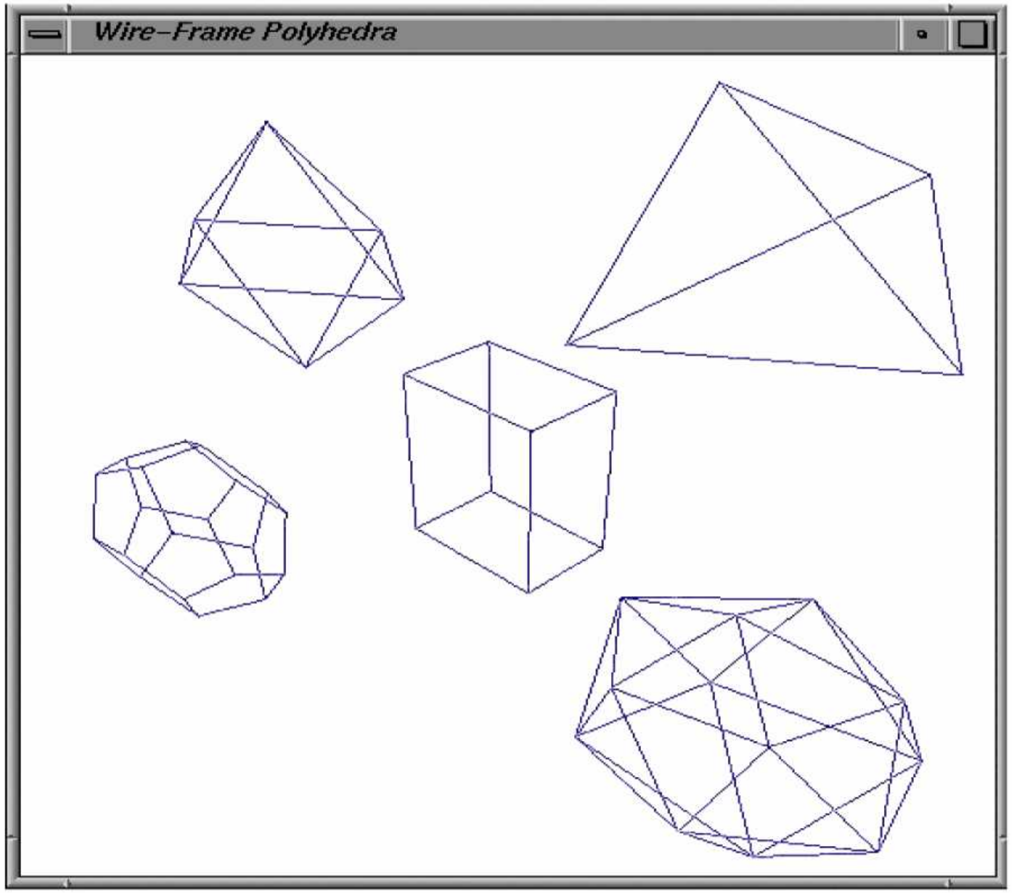


Figure 8-1

A perspective view of the five GLUT polyhedra, scaled and positioned within a display window by procedure displayWirePolyhedra.

Polyhedra

- Euler formula
  - Determines the validity of planar graphs

$$V - E + F = 2$$

  - V: The number of vertices
  - E: The number of edges
  - F: The number of faces

Polyhedra

- Euler-Poincare formula
  - Generalizes the Euler formula for arbitrary dimension and genus
  - Polyhedra in three-dimension space follows

$$V - E + F - L = 2(S - G)$$

  - L: The number of Inner loops
  - S: The number of shells
  - G: The number of holds

Functional Representation

- Explicit surfaces $z = f(x, y)$
- Implicit surfaces $f(x, y, z) = 0$
- Parametric surfaces
- Issues $\left(x(t),\ y(t),\ z(t)\right)$ for $t \in [a, b]$
  - Representation power
  - Easy to render
  - Easy to manipulate (translate, rotate, and deform)

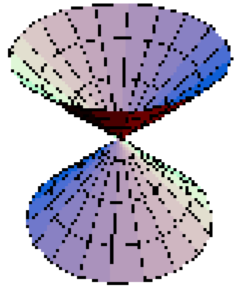
Implicit Surfaces

- Quadric surfaces
  - Implicit second-order polynomial equations
- Superquadric surfaces
  - A generalization of quadric surfaces
- Blobby objects (metaballs)
  - A collection of spherical density functions

Quadric surfaces

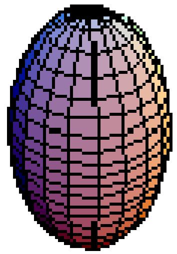
- Double cones

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}-\frac{z^2}{c^2}=0$$



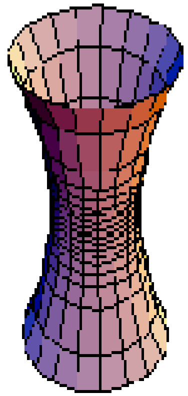
- Ellipsoids

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1$$



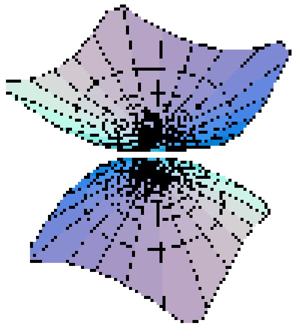
- Hyperboloids of one sh

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}-\frac{z^2}{c^2}=1$$



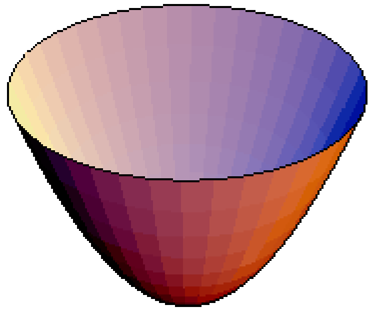
- Hyperboloids of two sheets

$$\frac{z^2}{c^2}-\frac{x^2}{a^2}-\frac{y^2}{b^2}=1$$



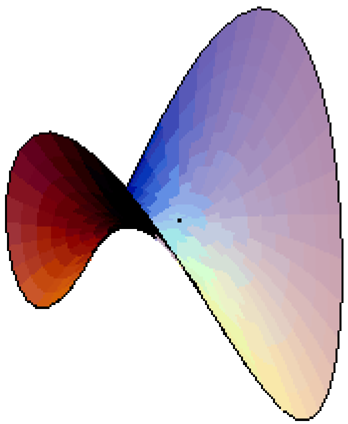
Quadric surfaces

- Elliptic parabolo $\frac{x^2}{a^2}+\frac{y^2}{b^2}=\frac{z}{c}$



- Hyperbolic paraboloids

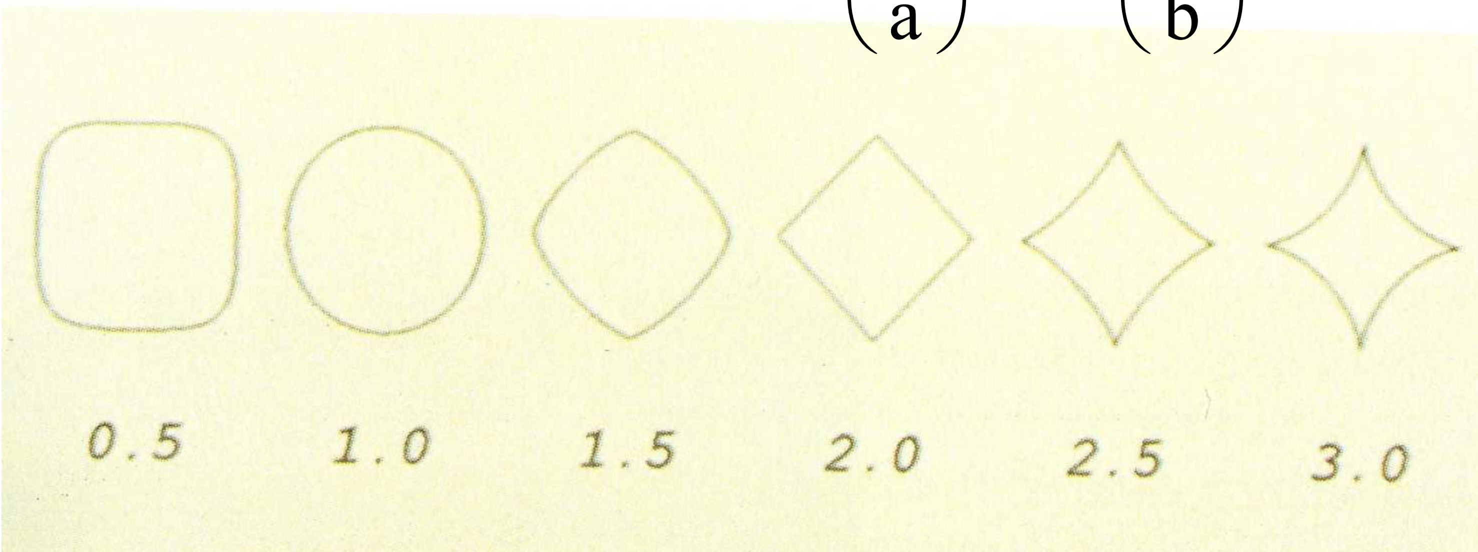
$$\frac{y^2}{b^2}-\frac{x^2}{a^2}=\frac{z}{c}$$



Superquadrics

- A generalization of quadric surfaces, formed by incorporating additional parameters into quadric equations
  - Increased flexibility for adjusting object shapes

$$\left(\frac{x}{a}\right)^{2/S} + \left(\frac{y}{b}\right)^{2/S} = 1$$

- 

Superquadrics

- Superellipsoid

$$\left[\left(\frac{x}{a}\right)^{2/S_1}+\left(\frac{y}{b}\right)^{2/S_2}\right]^{S_2/S_1}+\left(\frac{x}{c}\right)^{2/S_1}=1$$

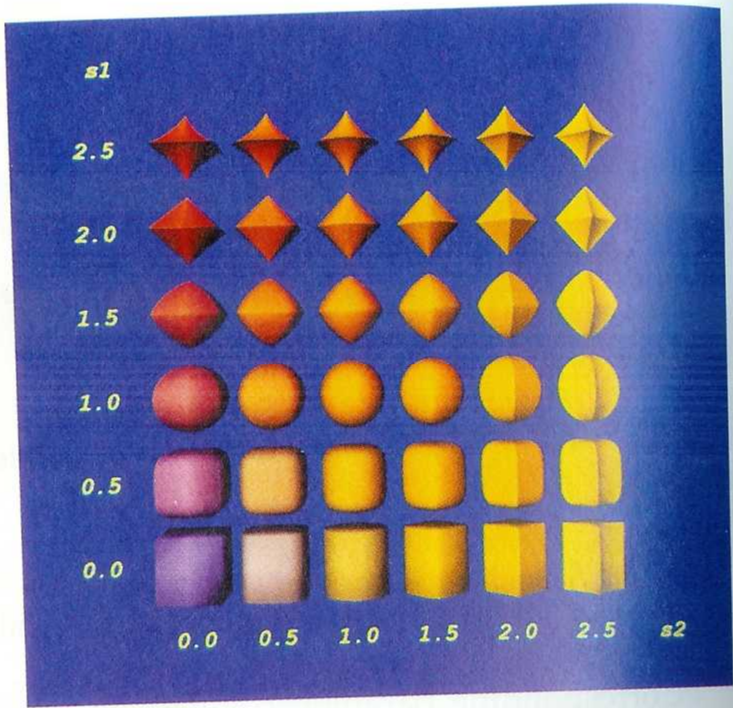
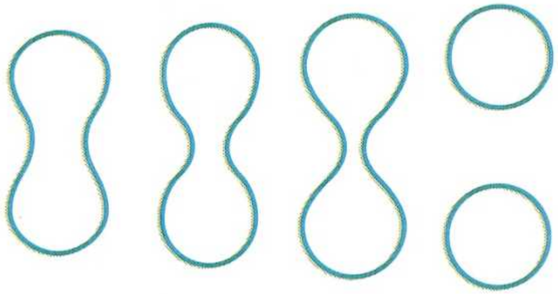
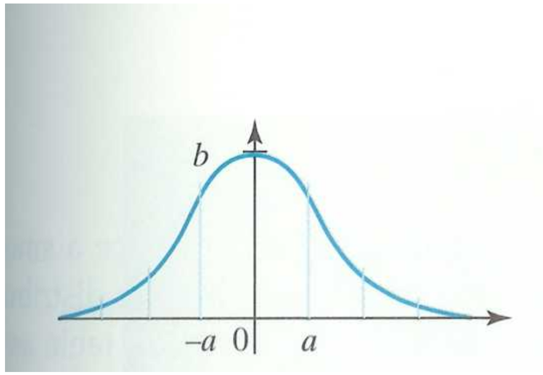


FIGURE 8-7 Superellipsoids plotted with values for parameters s_1 and s_2 ranging from 0.0 to 2.5 and with $r_x = r_y = r_z$.

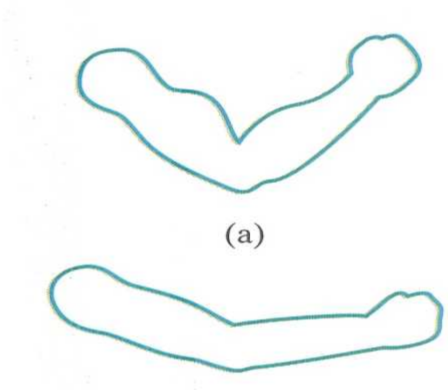
Blobby Objects

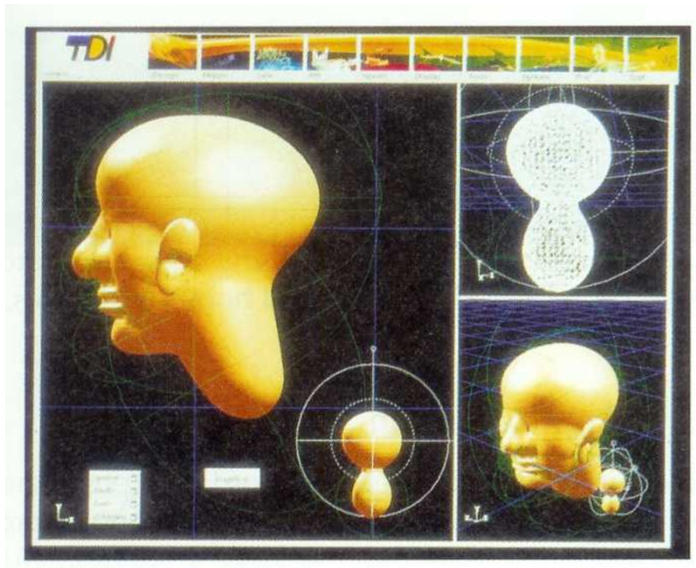
- A collection of density functions





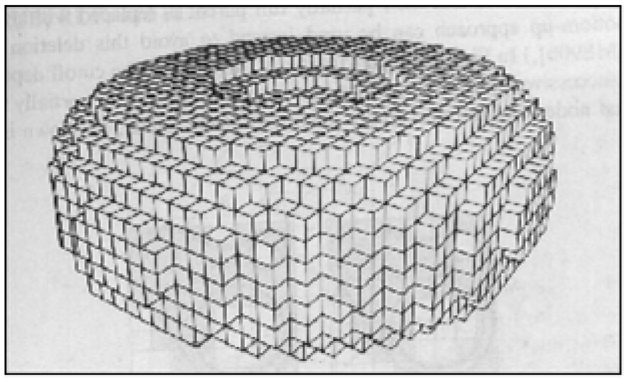
- Equi-density surfaces

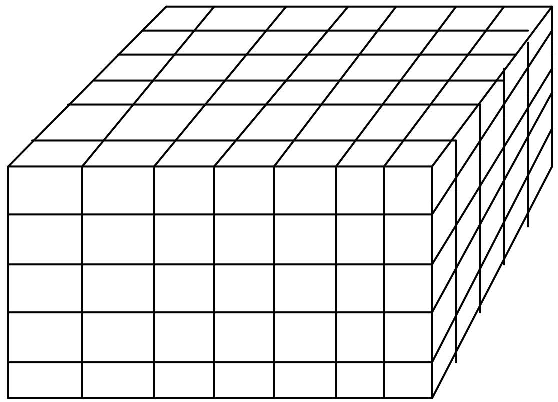




Spatial Partitioning

- Volume data
  - Use identical cells (voxels)
  - Space-filling tesselation with cubes or parallelopipeds
  - Expensive storage but simple data structure
  - Useful for medical imaging: volume visualization





Spatial Partitioning

- Octrees
  - Partition space into 8 cubes, recursively
  - Increase space efficiency of solid tesselations

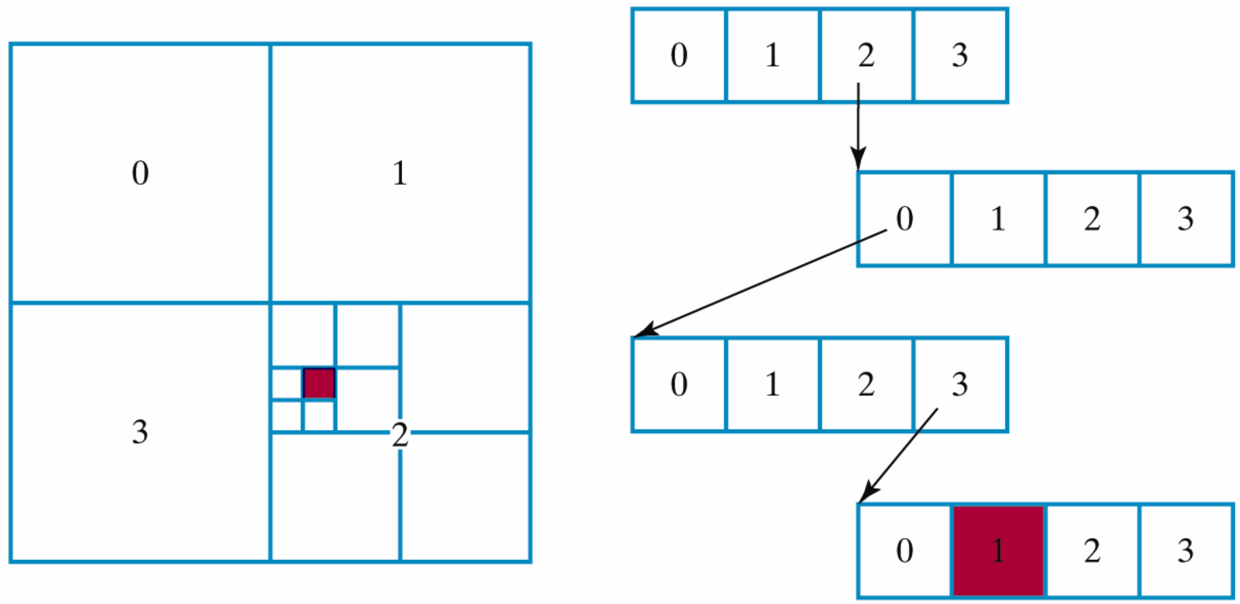
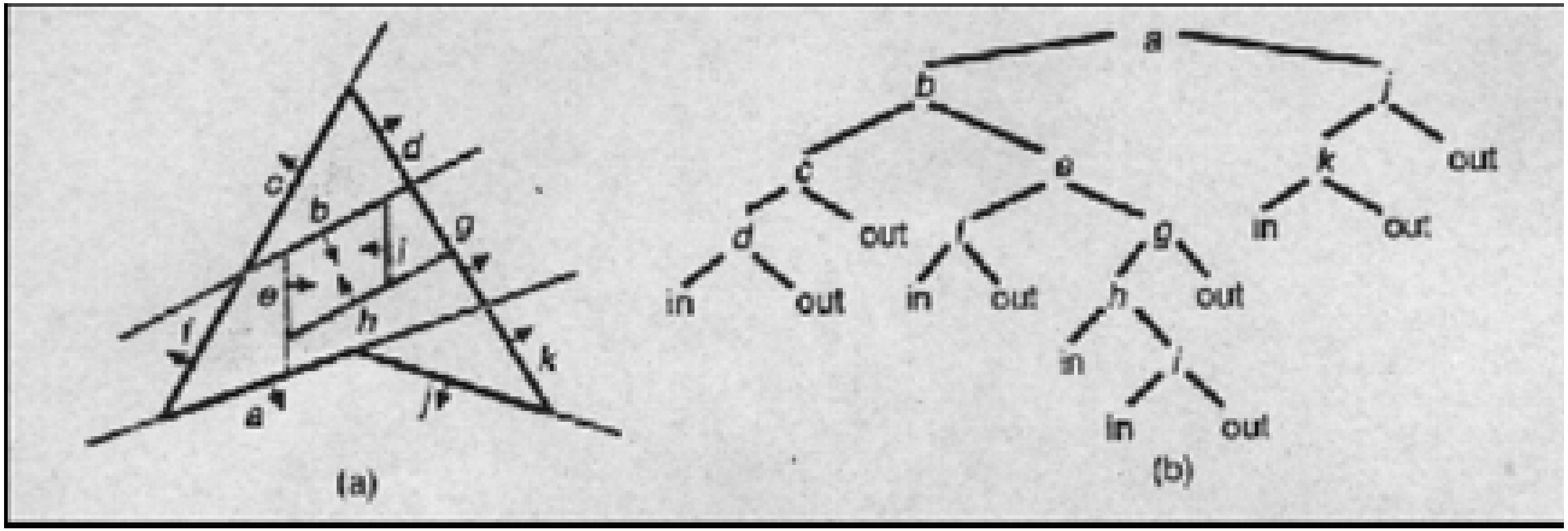


Figure 8-65

Quadtree representation for a square region of the *xy* plane that contains a single foreground-color area on a solid-color background.

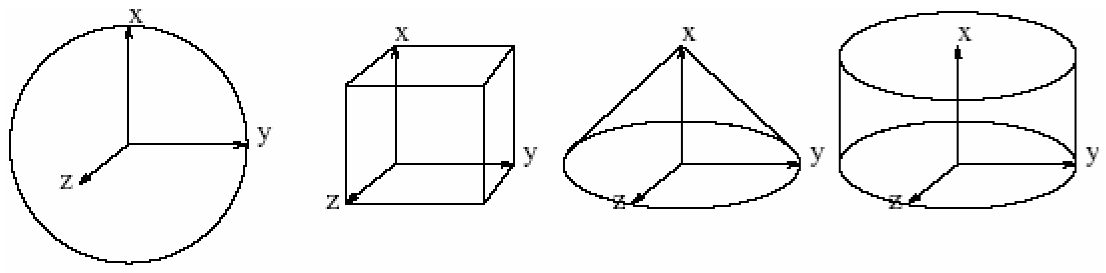
Spatial Partitioning

- Binary Space Partitioning (BSP) trees
  - Subdivide a scene into two sections at each step with a plane that can be at any position and orientation

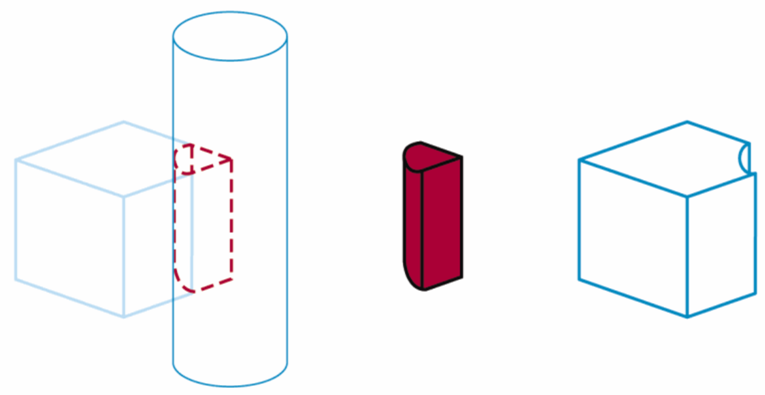


Constructive Solid Geometry

- Recursively combine simple primitives by boolean operations
  - Simple primitives

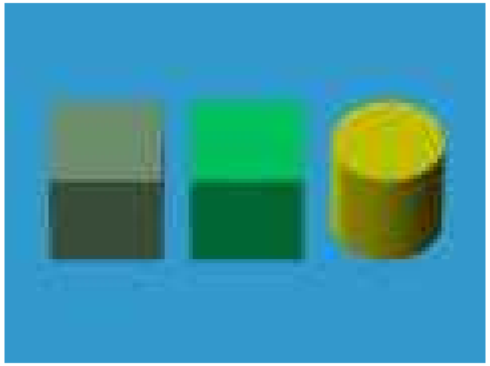


  - Transform or deform
  - Tree structure

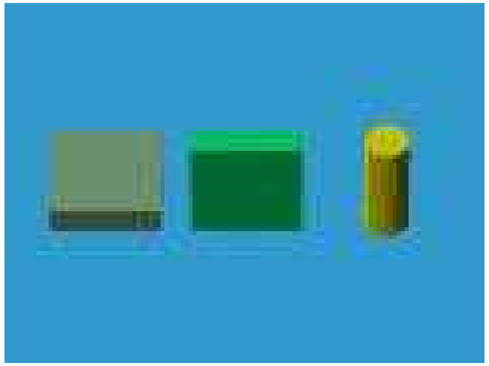


(a) (b) (c)

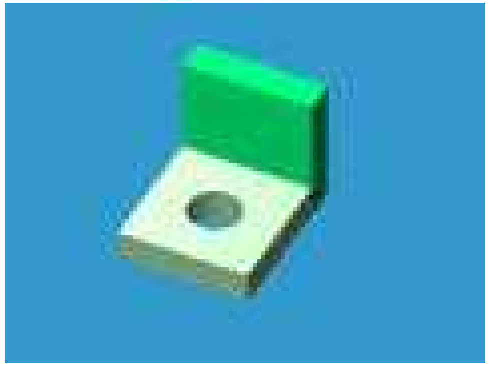
Constructive Solid Geometry



Primitives

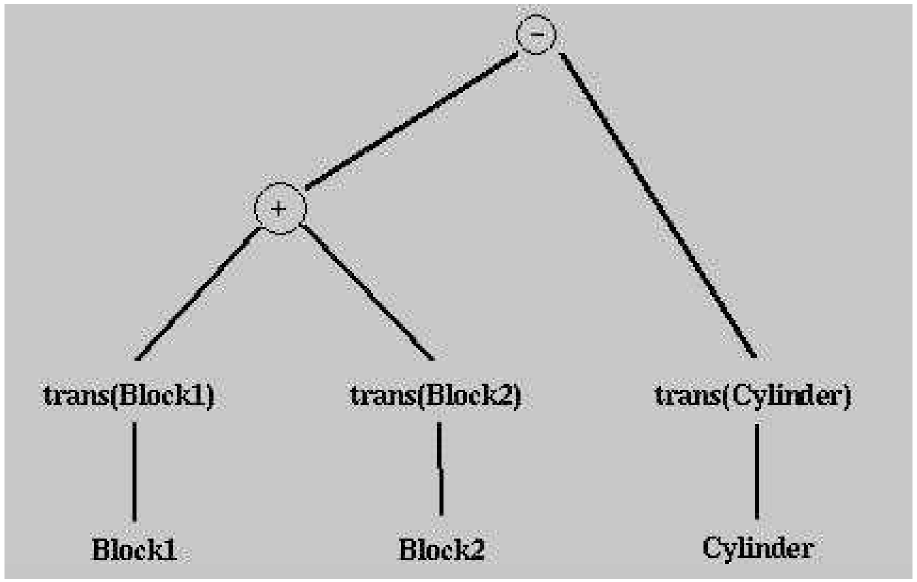


Transformed



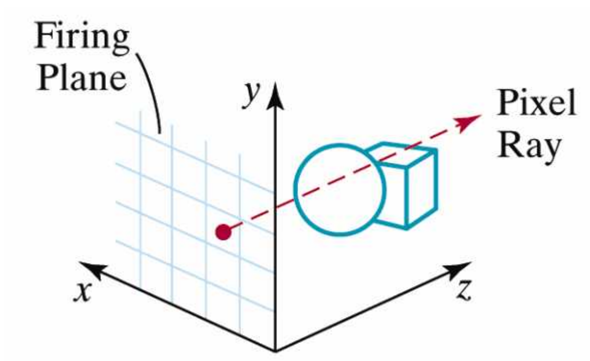
Combined

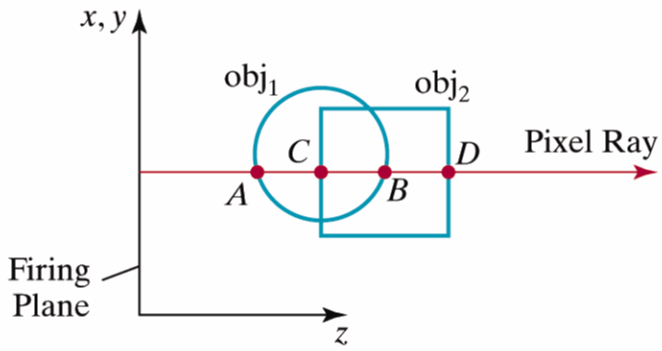
Tree structure



Constructive Solid Geometry

- Ray-casting methods for rendering CSG objects
  - Cast a ray through each pixel
  - Perform boolean operations along each ray

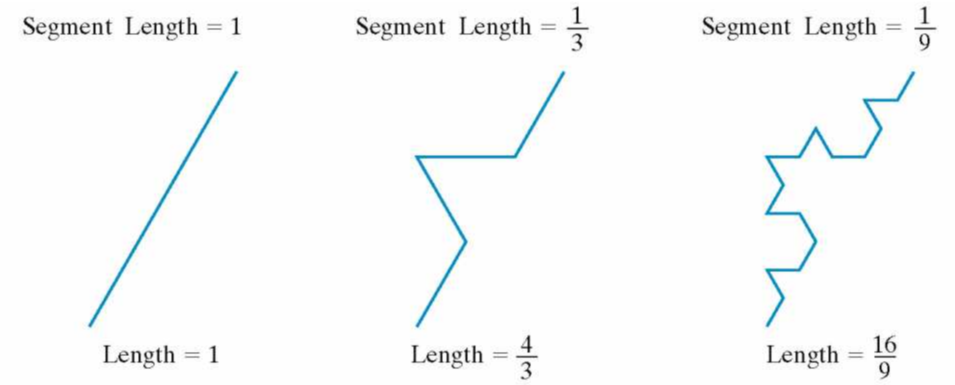




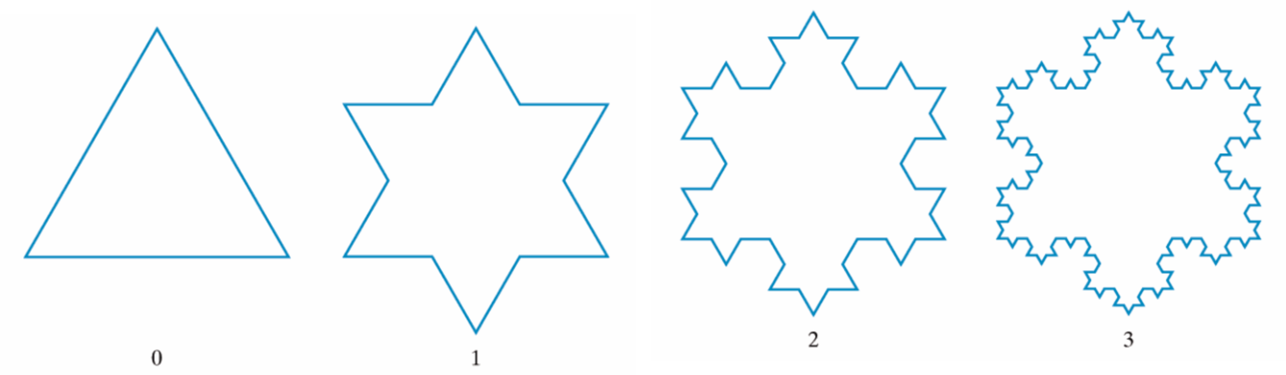
Operation	Surface Limits
Union	A, D
Intersection	C, B
Difference ($obj_2 - obj_1$)	B, D

Procedural Modeling

- Self-similar fractals
  - Substitution

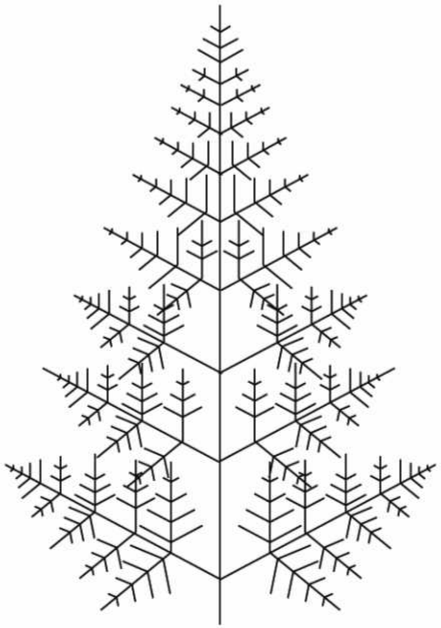


  - Example: Koch curve

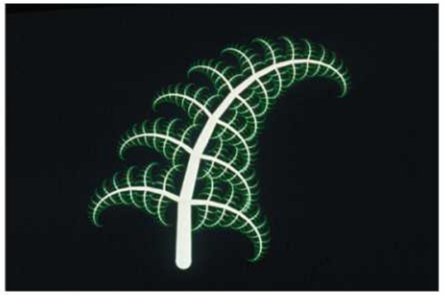


Procedural Modeling

- Substitution rules



(a)



(b)

Figure 8-76

Self-similar constructions for a fern. (*Courtesy of Peter Oppenheimer, Computer Graphics Lab, New York Institute of Technology*.)

Procedural Modeling

- Terrain by random perturbation

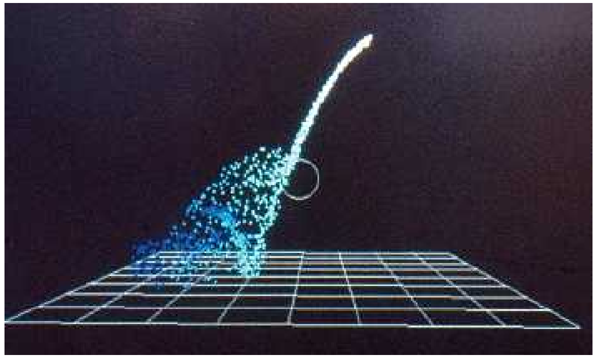
 

Procedural Modeling

- Natural scenes with trees, flowers, and grass

Physically Based Modeling

- Particle systems
  - Shape description is combined with physical simulation



Physically Based Modeling

- Procedural modeling + physically based simulation