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3D Object Representations

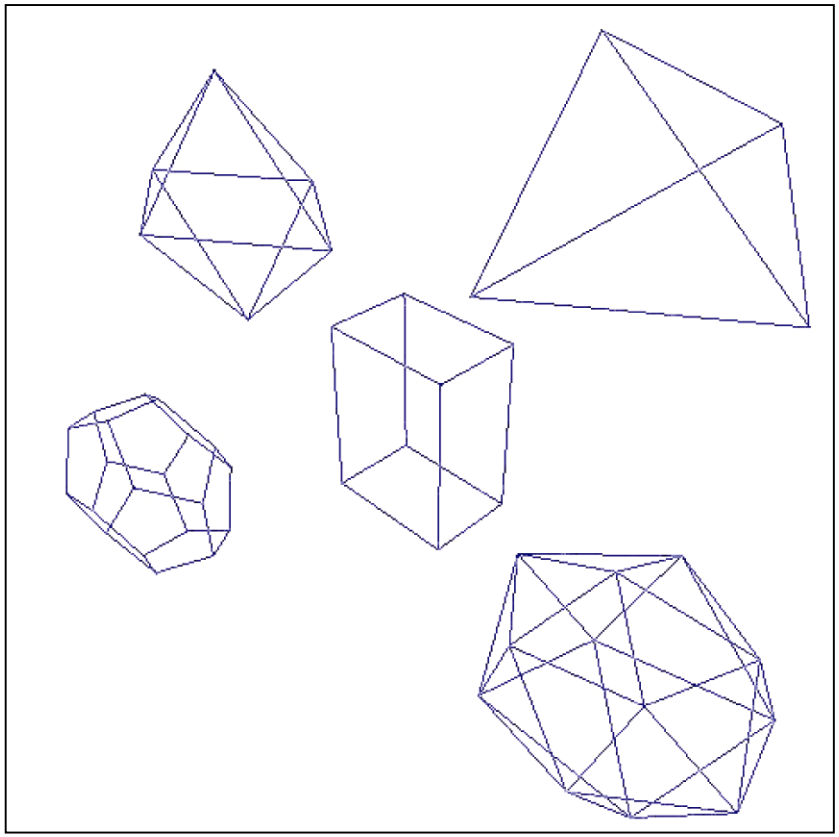
Outline

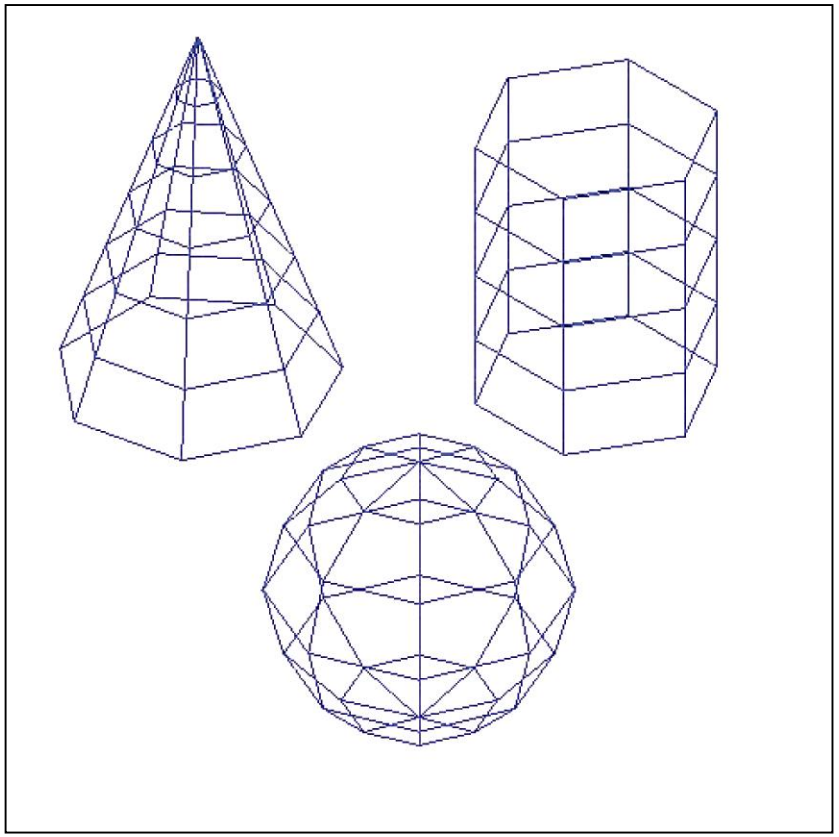
- How objects are modelled in 3D
  - Polyhedra
  - Quadric surfaces
  - Sweep representations
  - Constructive Solid Geometry (CSG)
  - Quadtree

Polyhedra

- Objects are simply a set of surface polygons that enclose an object interior
- Simplest and fastest way to render objects
- Often referred to as standard graphics objects
- In many cases packages allow us to define objects as curved surfaces etc but actually convert these to polygon meshes for display
- To define polyhedra we simply define the vertices of the polygons required

Polyhedra (contd.)





Quadric Surfaces

- A frequently used class of objects are quadric surfaces
- These are 3D surfaces described using quadratic equations
- Quadric surfaces include:
  - Spheres
  - Ellipsoids
  - Tori
  - Paraboloids
  - Hyperboloids

Quadric Surfaces - Spheres

- A spherical surface with radius r centred on the origin is defined as the set of points (x, y, z) that satisfy the equation

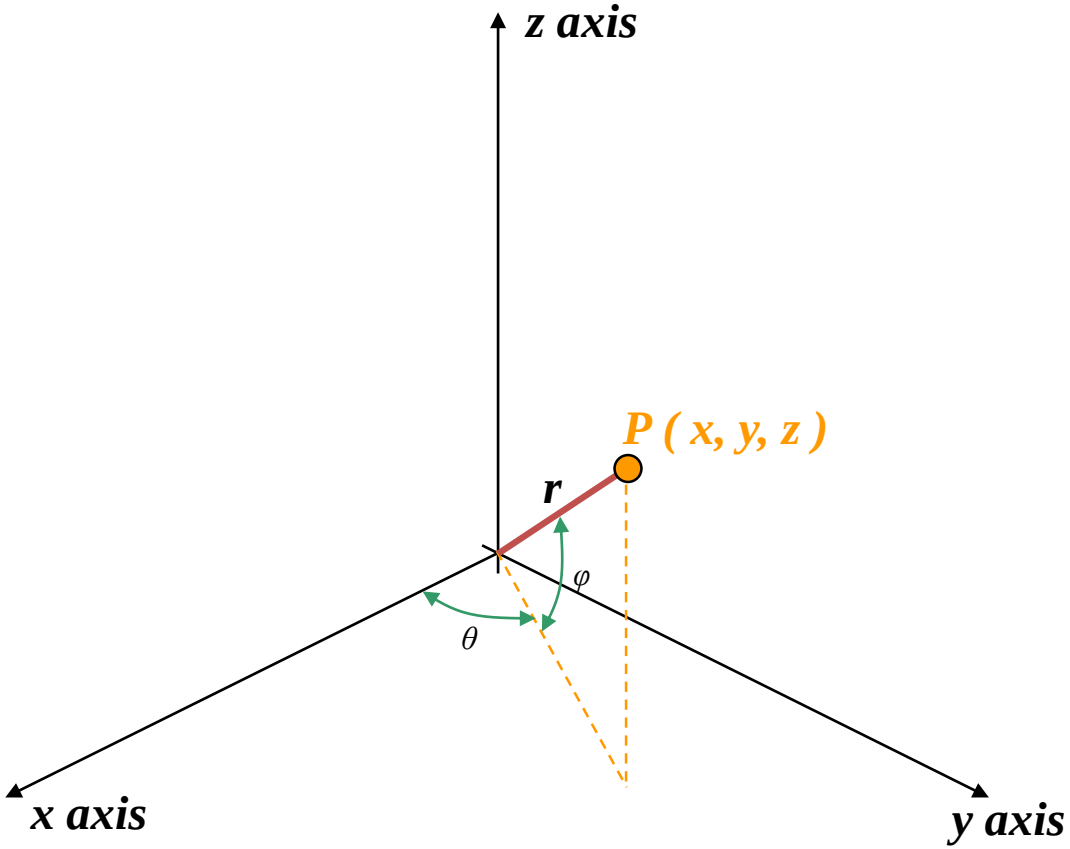
$$x^2 + y^2 + z^2 = r^2$$

- This can also be done in parametric form using latitude and longitude angles

$$x = r\cos\phi\cos\theta$$
$$y = r\cos\phi\sin\theta$$
$$z = r\sin\phi$$

$$-\pi/2 \le \phi \le \pi/2$$
$$-\pi \le \theta \le \pi$$

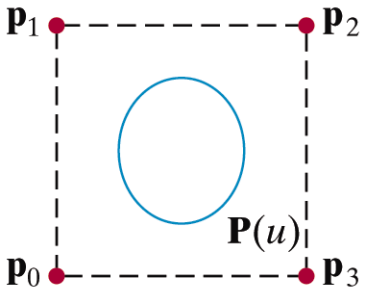
Quadric Surfaces – Spheres (Contd.)

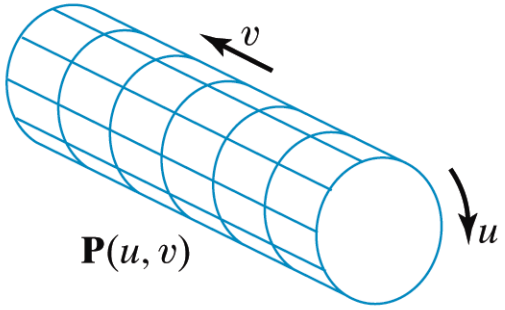


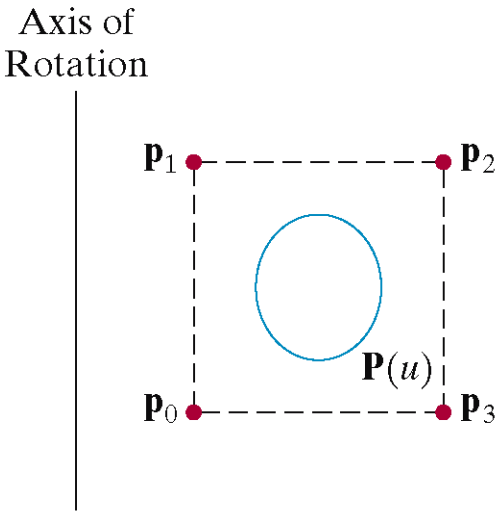
Sweep Representations

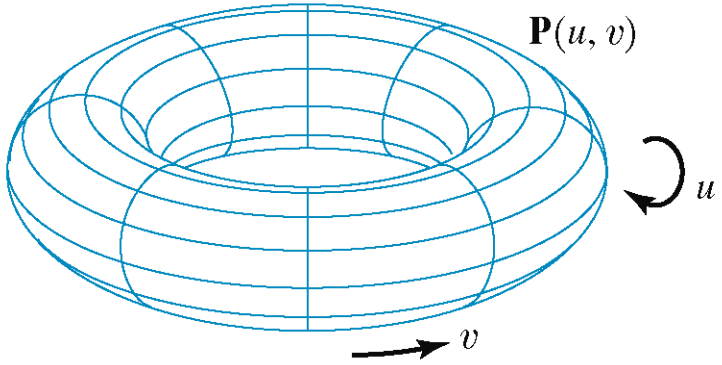
- Sweep representations are useful for constructing 3 dimensional objects that possess translational, rotational or other symmetries
- Objects are specified as a 2 dimensional shape and a sweep that moves that shape through a region of space

Sweep Representations - Examples





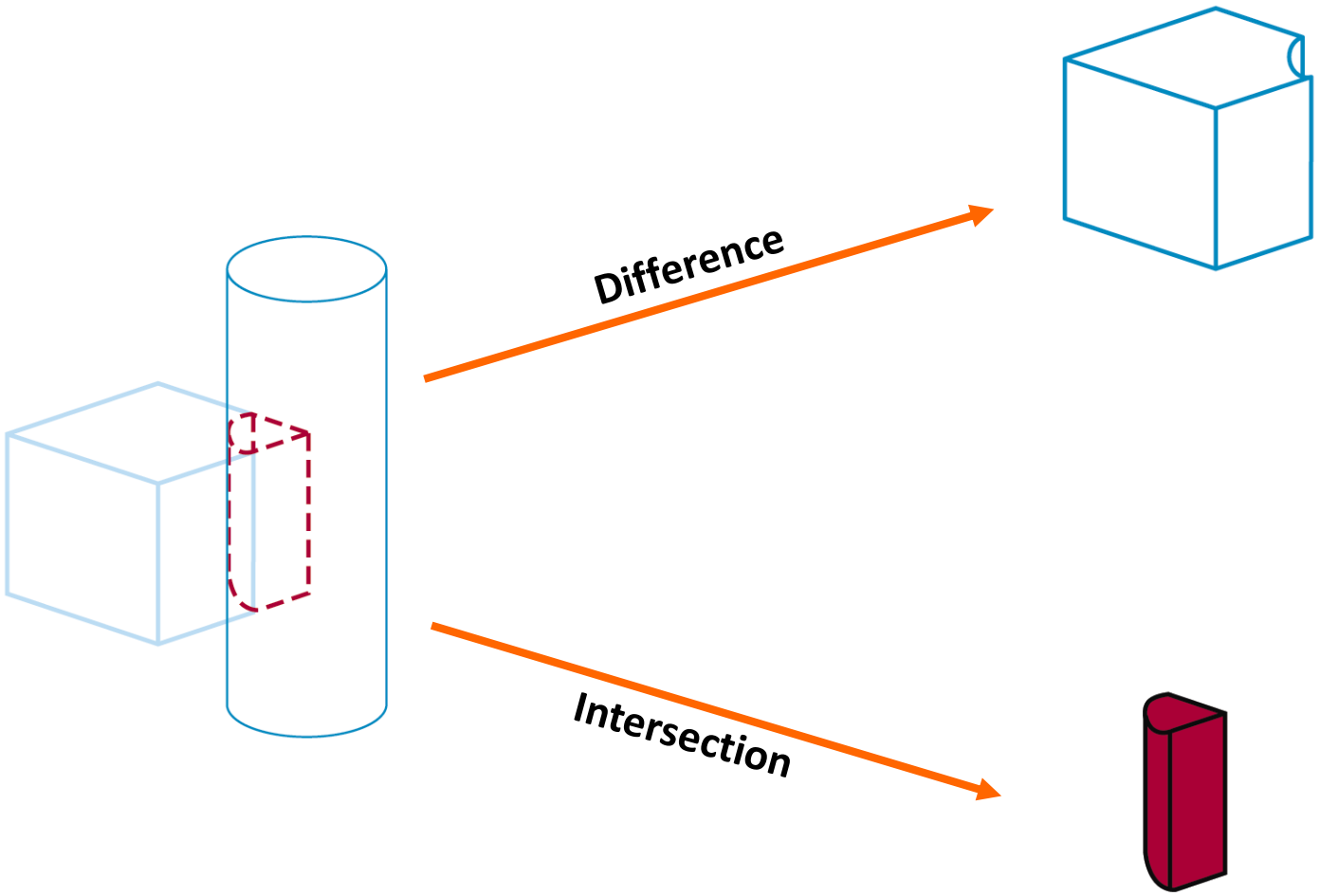




Constructive Solid Geometry Methods

- Constructive Solid Geometry (CSG) performs solid modeling by generating a new object from two three dimensional objects using a set operation
- Valid set operations include
  - Union
  - Intersection
  - Difference

Constructive Solid Geometry Methods

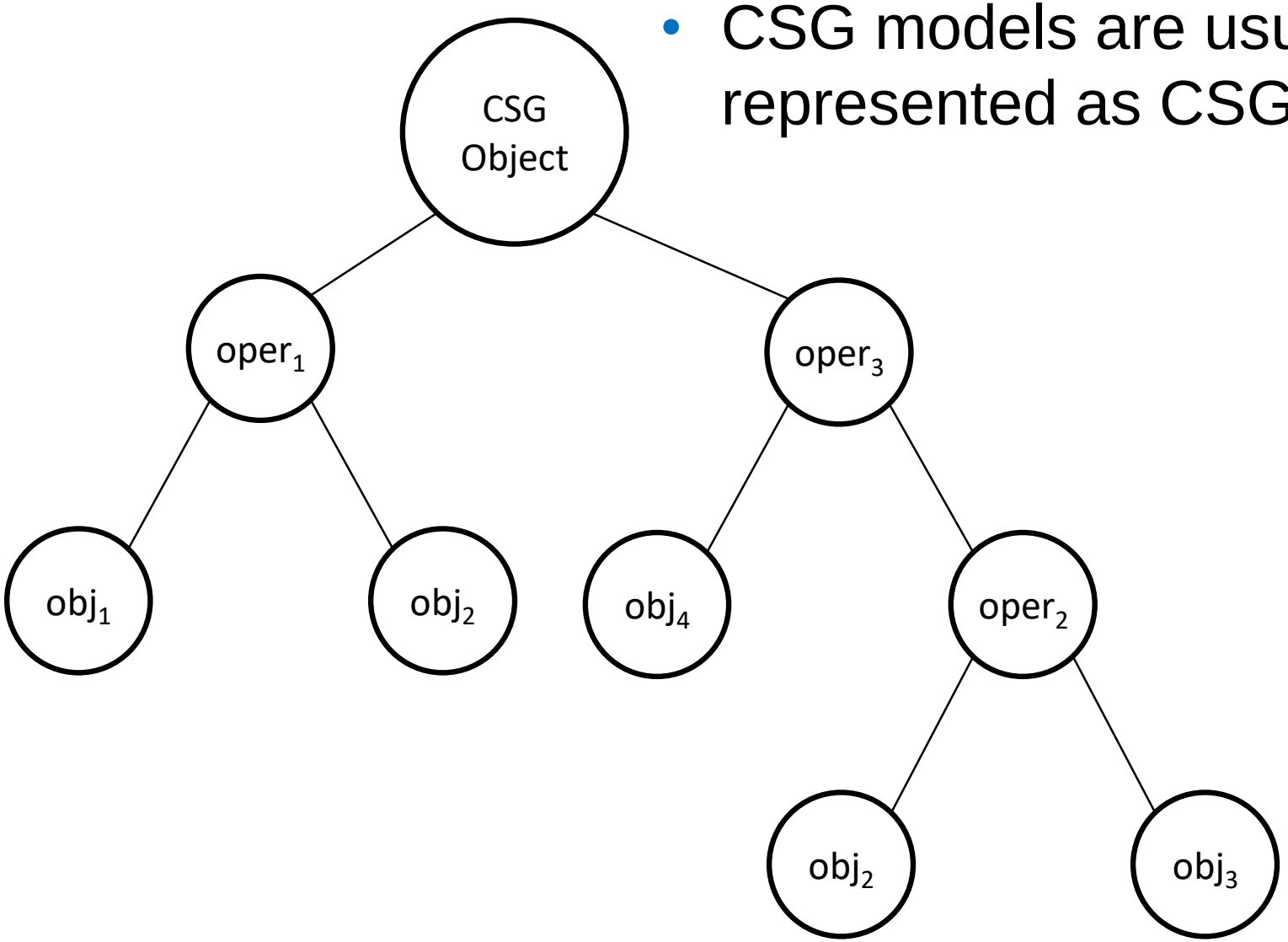


Constructive Solid Geometry Methods

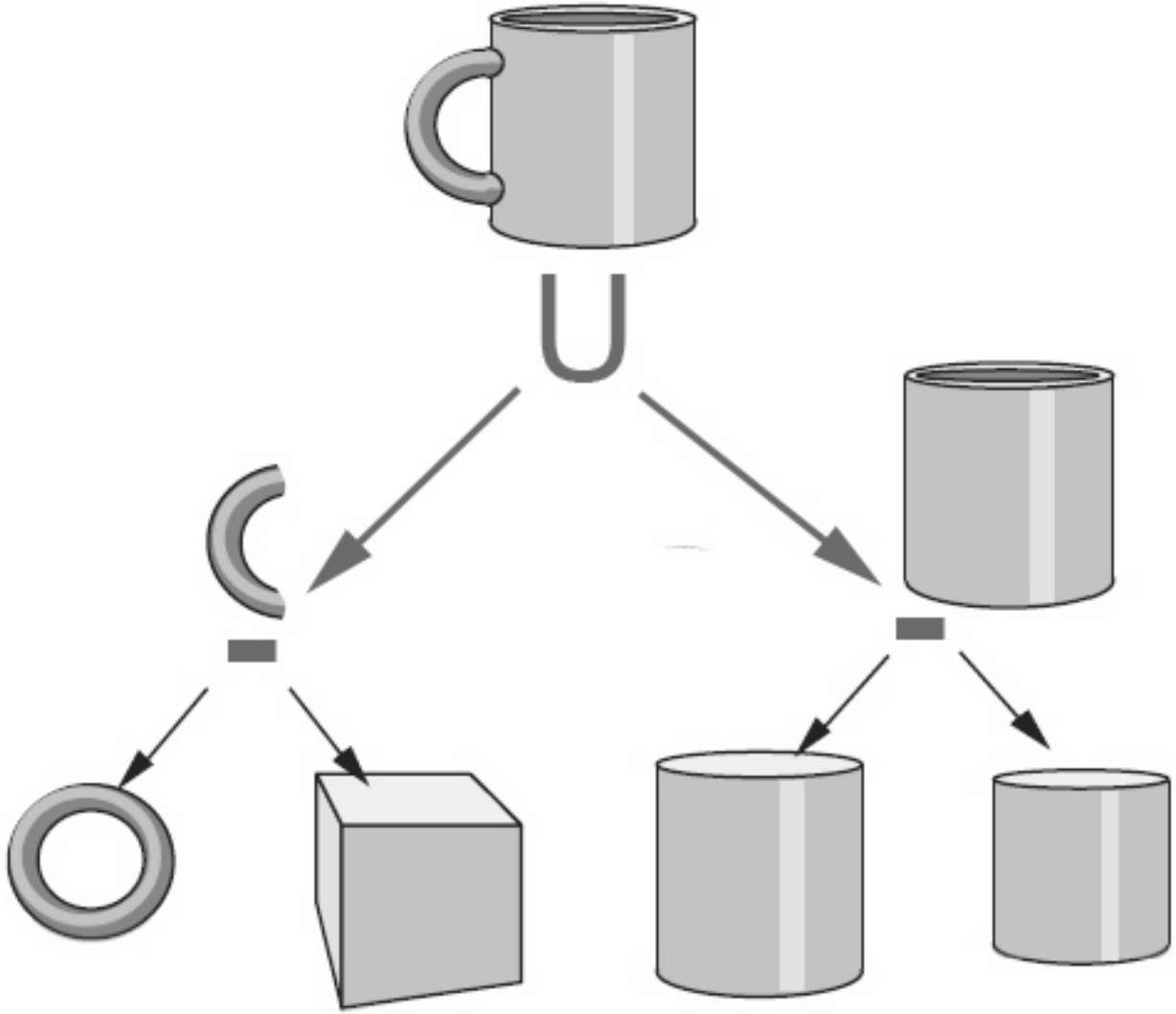
- CSG usually starts with a small set of primitives such as blocks, pyramids, spheres and cones
- Two objects re initially created and combined using some set operation to create a new object
- This object can then be combined with another primitive to make another new object
- This process continues until modeling complete

Constructive Solid Geometry Methods

- CSG models are usually represented as CSG trees



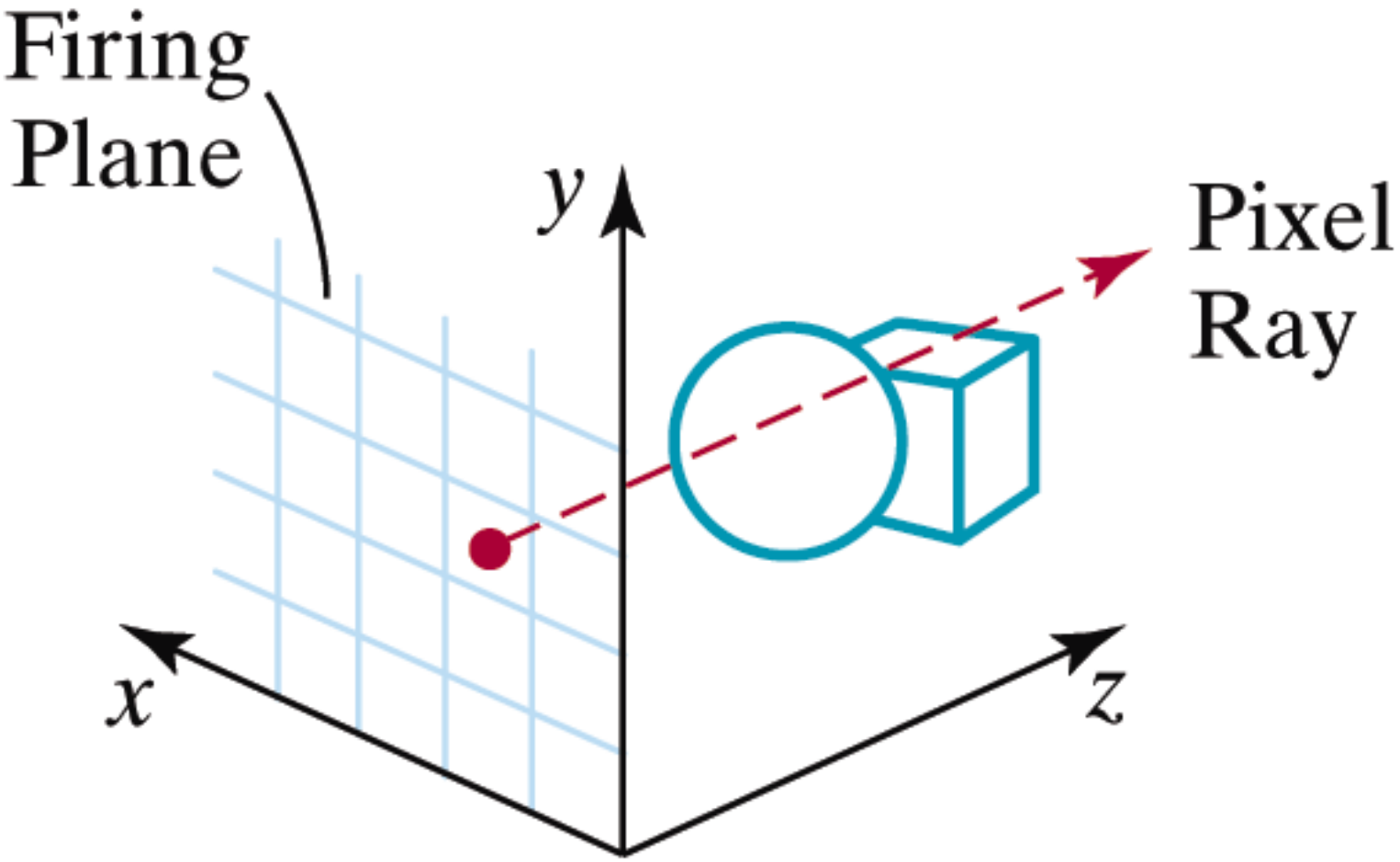
Constructive Solid Geometry Methods



Ray-Casting

- **Ray-casting** is typically used to implement CSG operators when objects are described with boundary representations
- Ray casting is applied by determining the objects that are intersected by a set of parallel lines emanating from the xy plan along the z axis
- The xy plan is referred to as the **firing plane**

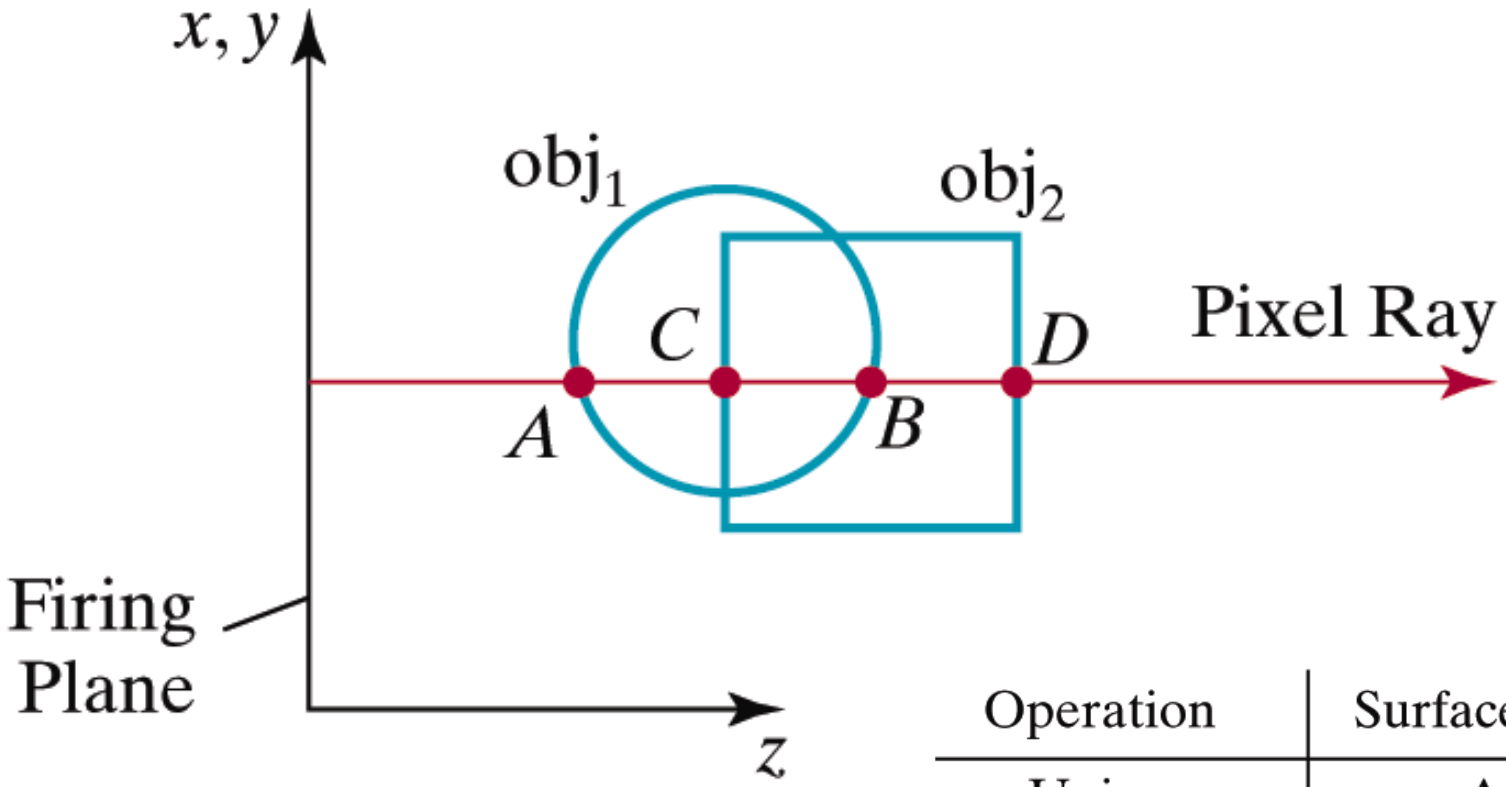
Ray-Casting (Cont…)



Ray-Casting (Cont…)

- Surface intersections along each ray are calculated and these are sorted according to distance from the firing plane
- The surface limits for the composite object are then determined by the specified set operation

Ray Casting Example



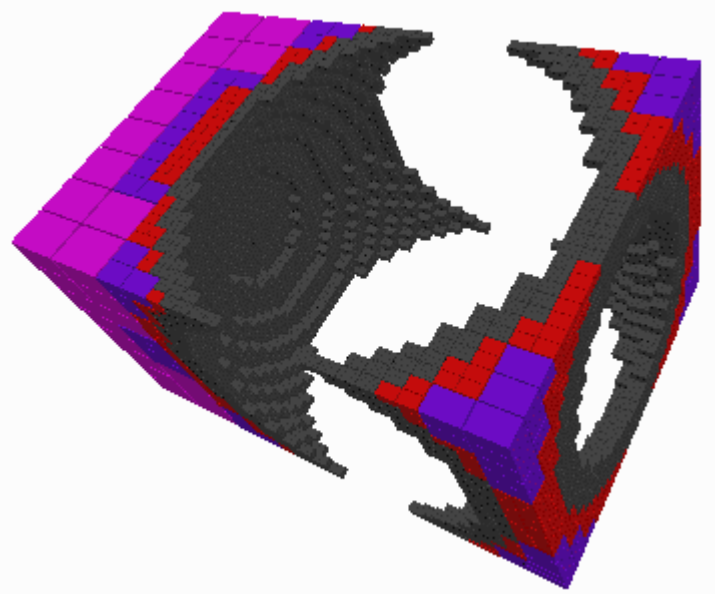
Operation	Surface Limits
Union	A, D
Intersection	C, B
Difference ($obj_2 - obj_1$)	B, D

Outline

- How objects are modelled in 3D
  - Polyhedra
  - Quadric surfaces
  - Sweep representations
  - Constructive Solid Geometry (CSG)
  - **Octree & Quadtree**

Octrees

Octrees are hierarchical tree structures used to represent solid objects



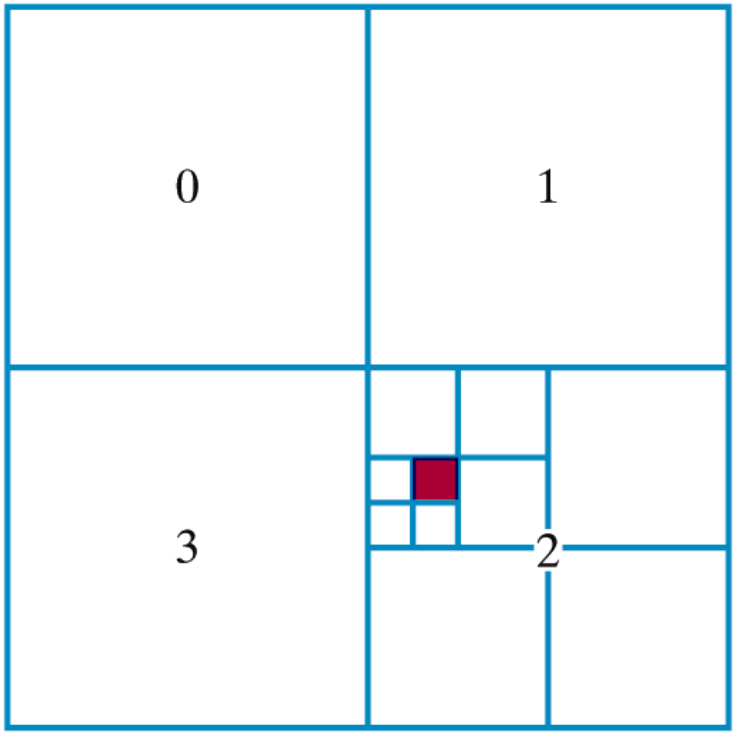
Octrees are particularly useful in applications that require cross sectional views – for example medical applications

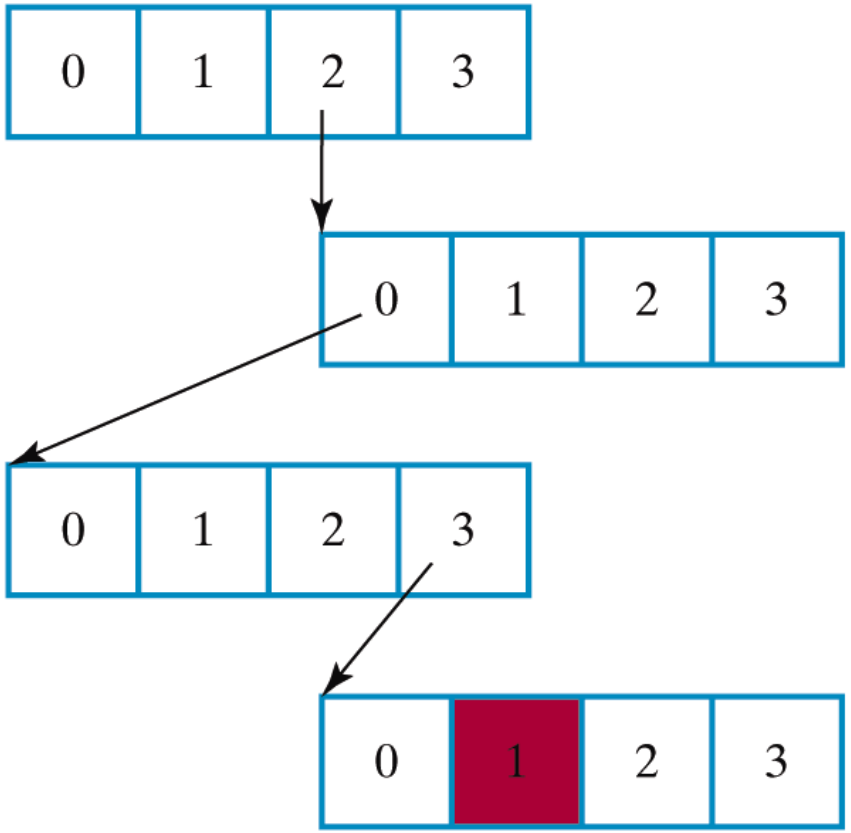
Octrees are typically used when the interior of objects is important

Octrees & Quadtrees

- Octrees are based on a two-dimensional representation scheme called quadtree encoding
- Quadtree encoding divides a square region of space into four equal areas until homogeneous regions are found
- These regions can then be arranged in a tree

Quadtree Example

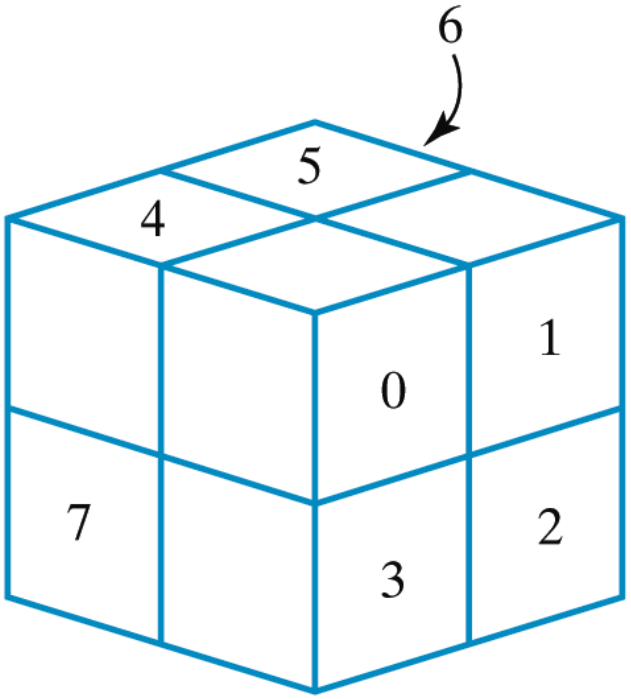




Octrees

- Quadtree encodings provide considerable savings in storage when large colour areas exist in a region of space
- An octree takes the same approach as quadtrees, but divides a cube region of 3D space into octants
- Each region within an octree is referred to as a volume element
- Division is continued until homogeneous regions are discovered

Octrees (cont…)



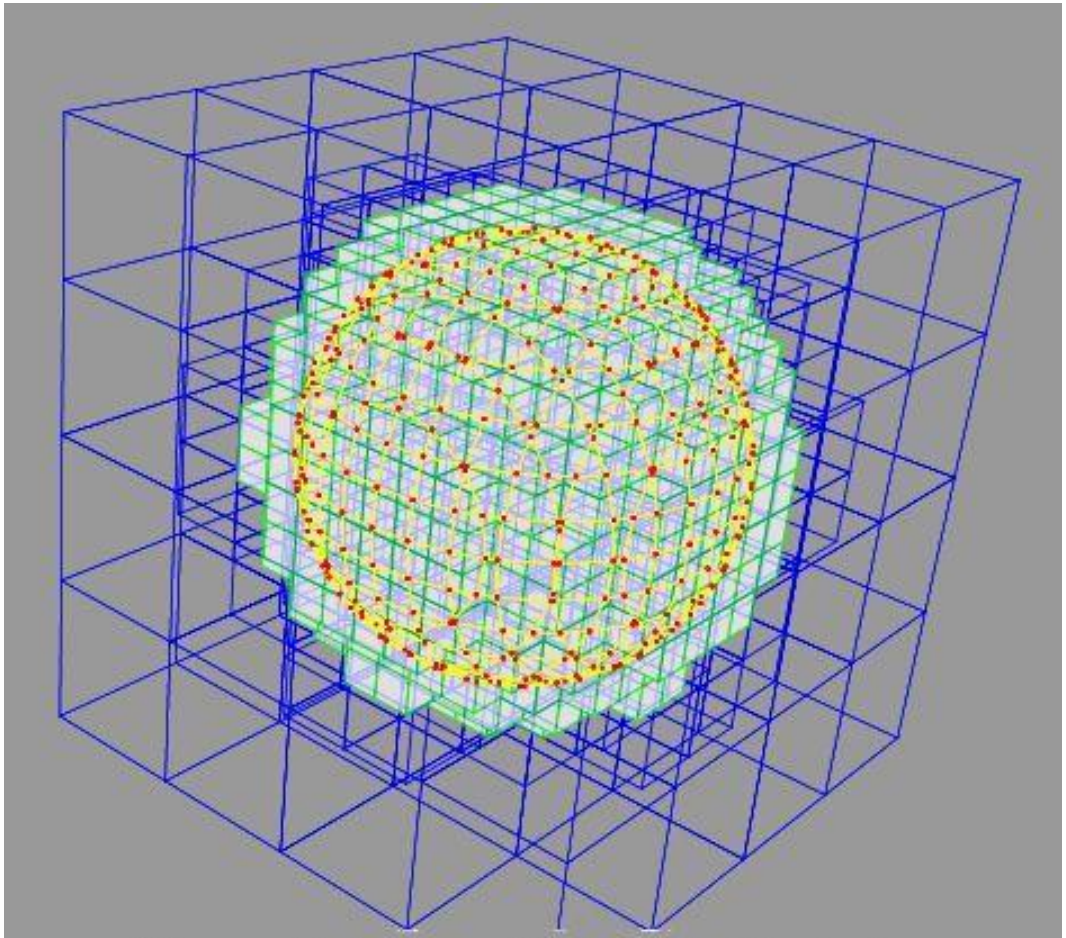
Region of a
Three-Dimensional
Space

Data Elements
in the Representative
Octree Node

Octrees (cont…)

- In 3 dimensions regions can be considered to be homogeneous in terms of color, material type, density or any other physical characteristics

Octree Examples



Octree containing pieces of an implicitly defined sphere; within each terminal node surface vertices are computed and connected to form a polygon