# 3D Modeling
## Solid Modeling

Shandong University

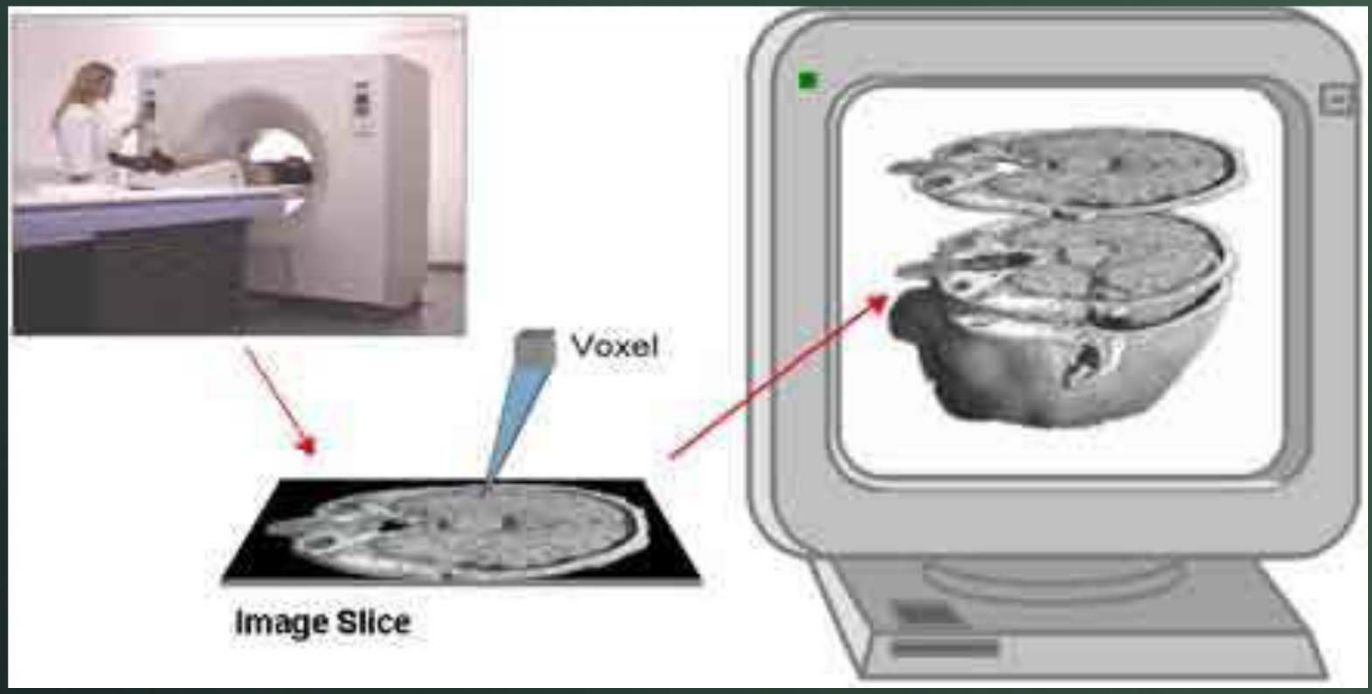
Spring 2013

# 3D Object Representations

- **Raw data**
  - Point cloud
  - Range image
  - Polygon soup
- **Surfaces**
  - Mesh
  - Subdivision
  - Parametric
  - Implicit
- **Solids**
  - Voxels
  - BSP tree
  - CSG
  - Sweep
- **High-level structures**
  - Scene graph
  - Skeleton
  - Application specific

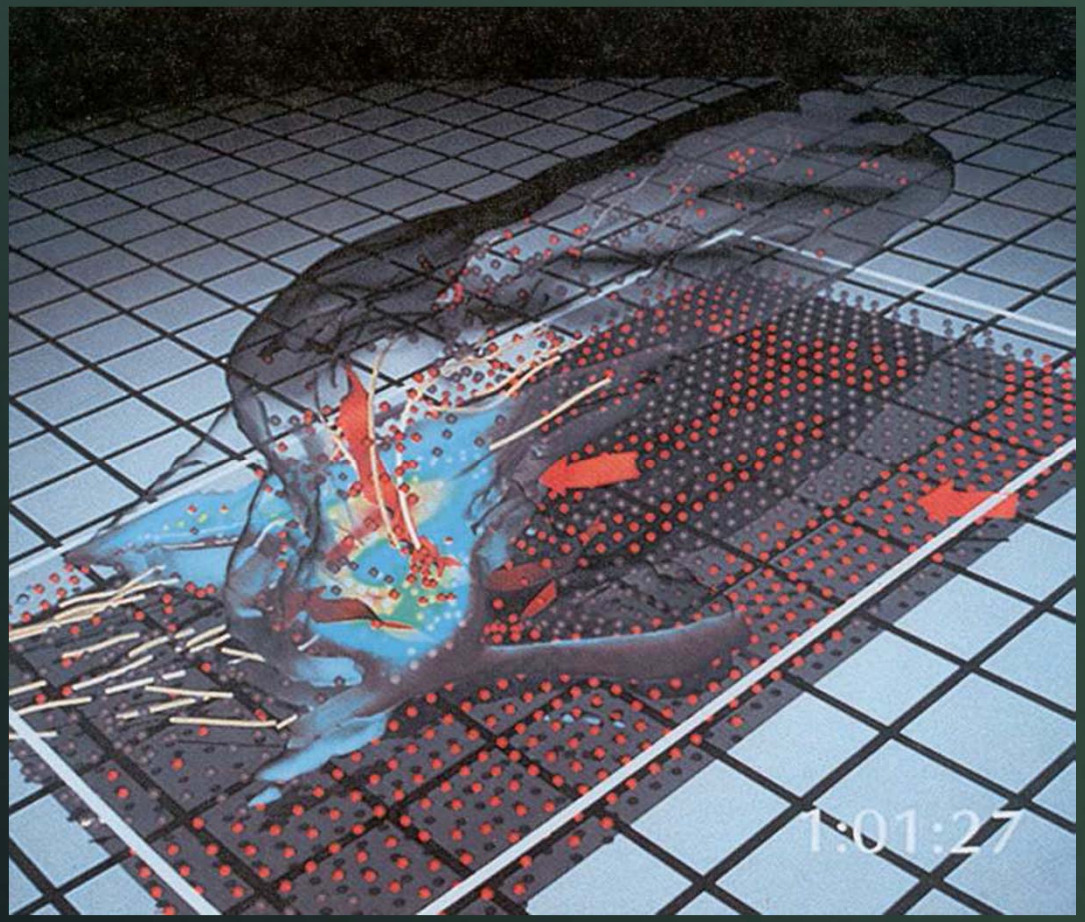
# Solid Modeling

- **Represent solid interiors of objects**



# Motivation 1

- **Some acquisition methods generate solids**

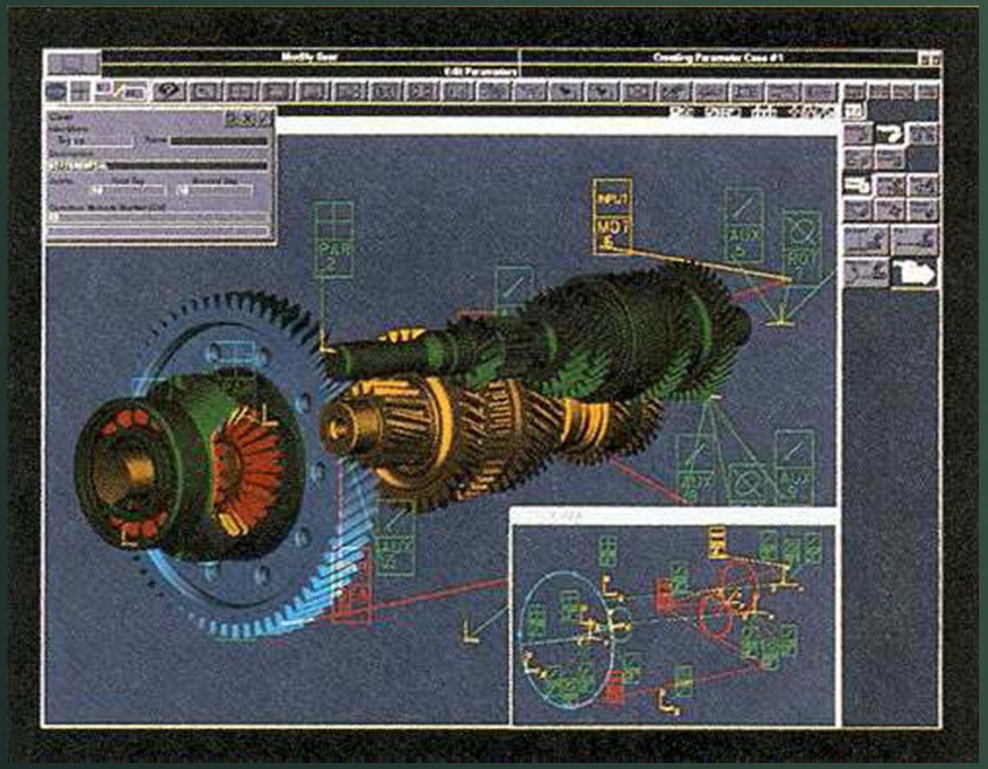


Airflow Inside a Thunderstorm
*(Bob Wilhelmson,*
*University of Illinois at Urbana-Champaign)*

Visible Human
*(National Library of Medicine)*

# Motivation 2

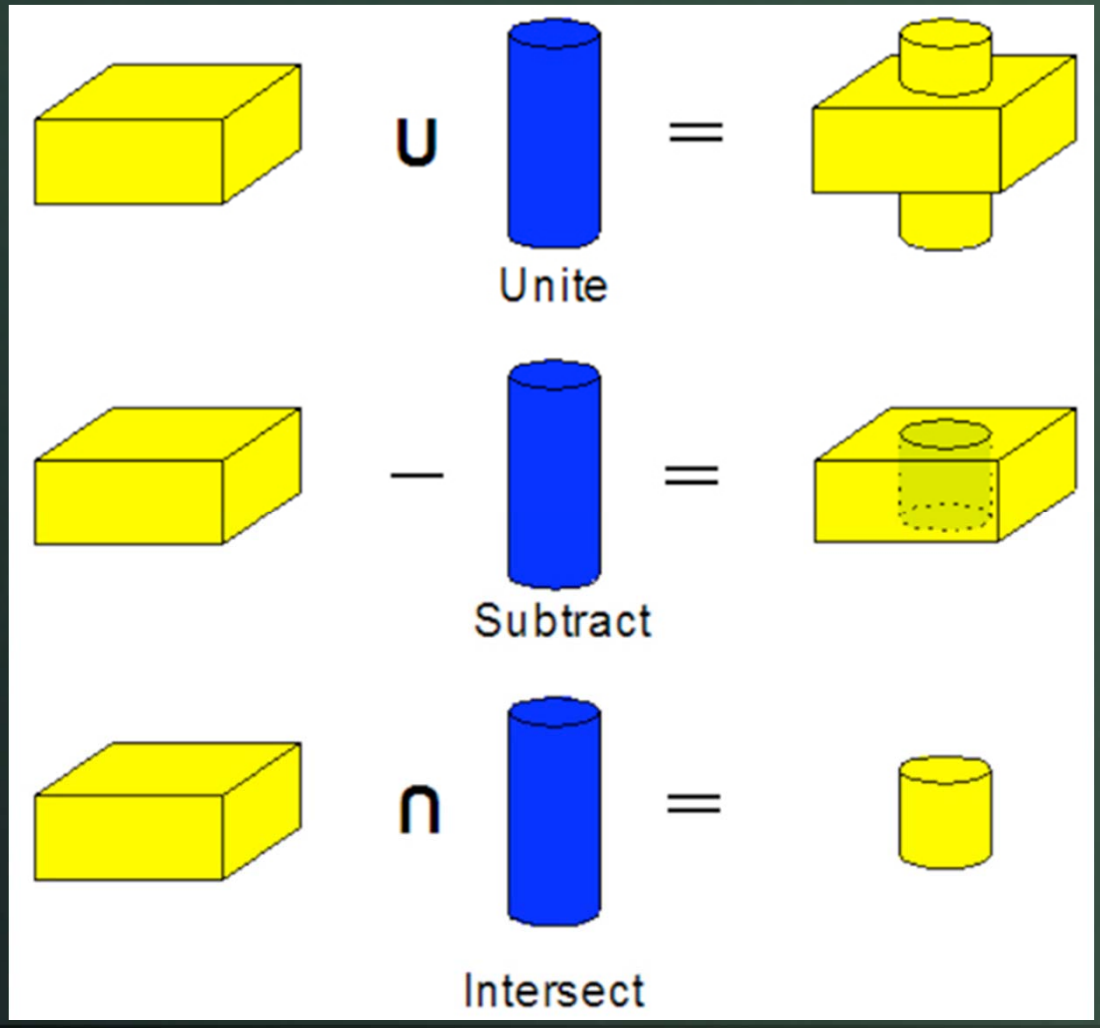
- **Some applications require solids**
  - **Examples: CAD/CAM**



Intergraph Corporation

# Motivation 3

- **Some operations are easier with solids**
  - **Example: union, difference, intersection**



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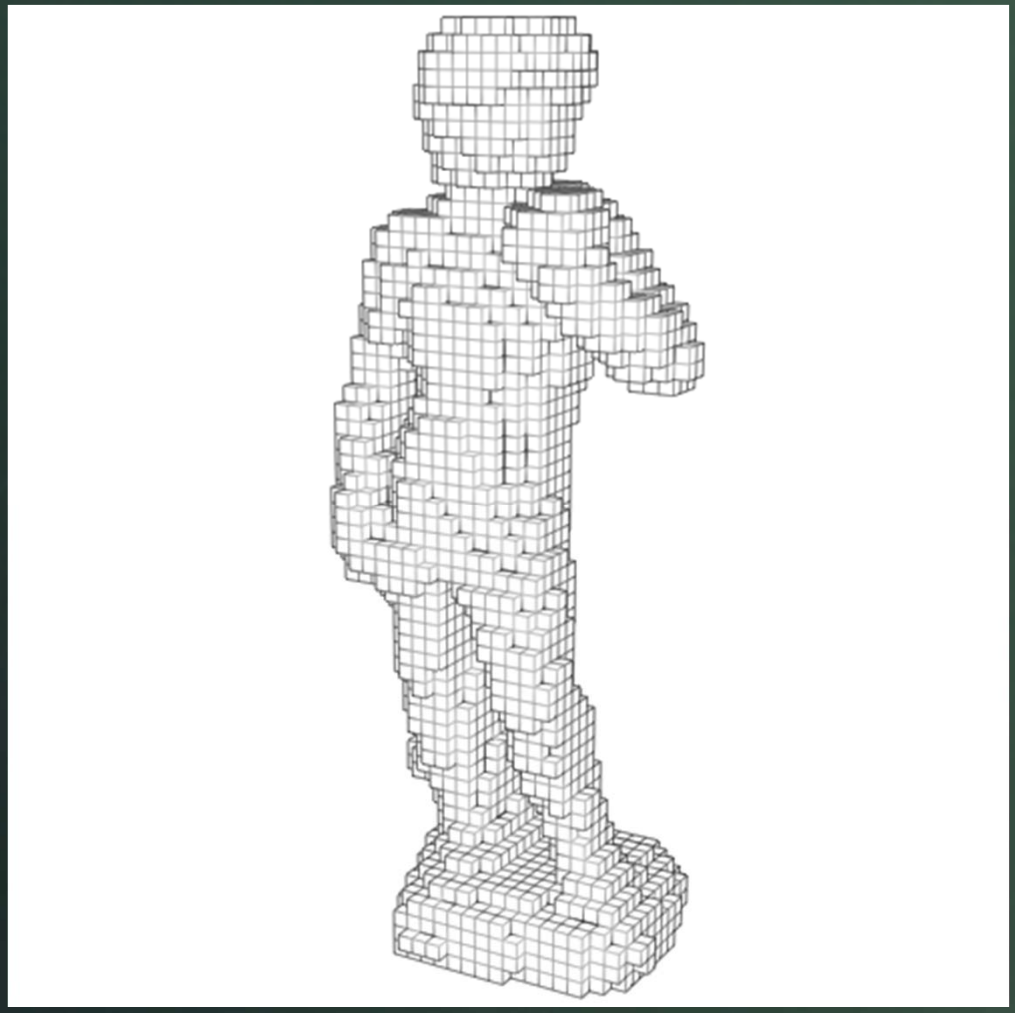
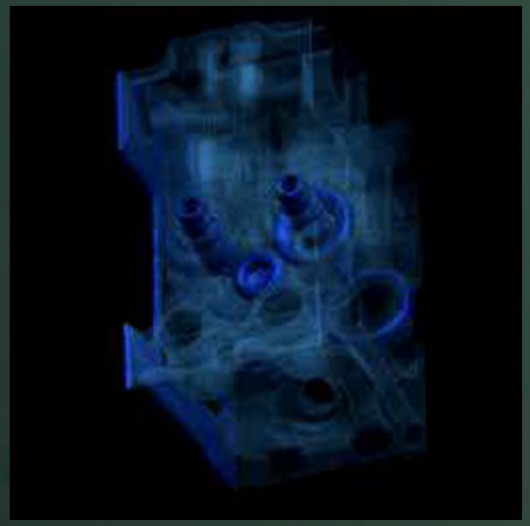
# Voxels

- **Regular array of 3D samples (like image)**
  - **Samples are called voxels (“volume pixels”)**



# Voxels

- **Store properties of solid object with each voxel**
  - **Occupancy**
  - **Color**
  - **Density**
  - **Temperature**
  - **etc.**

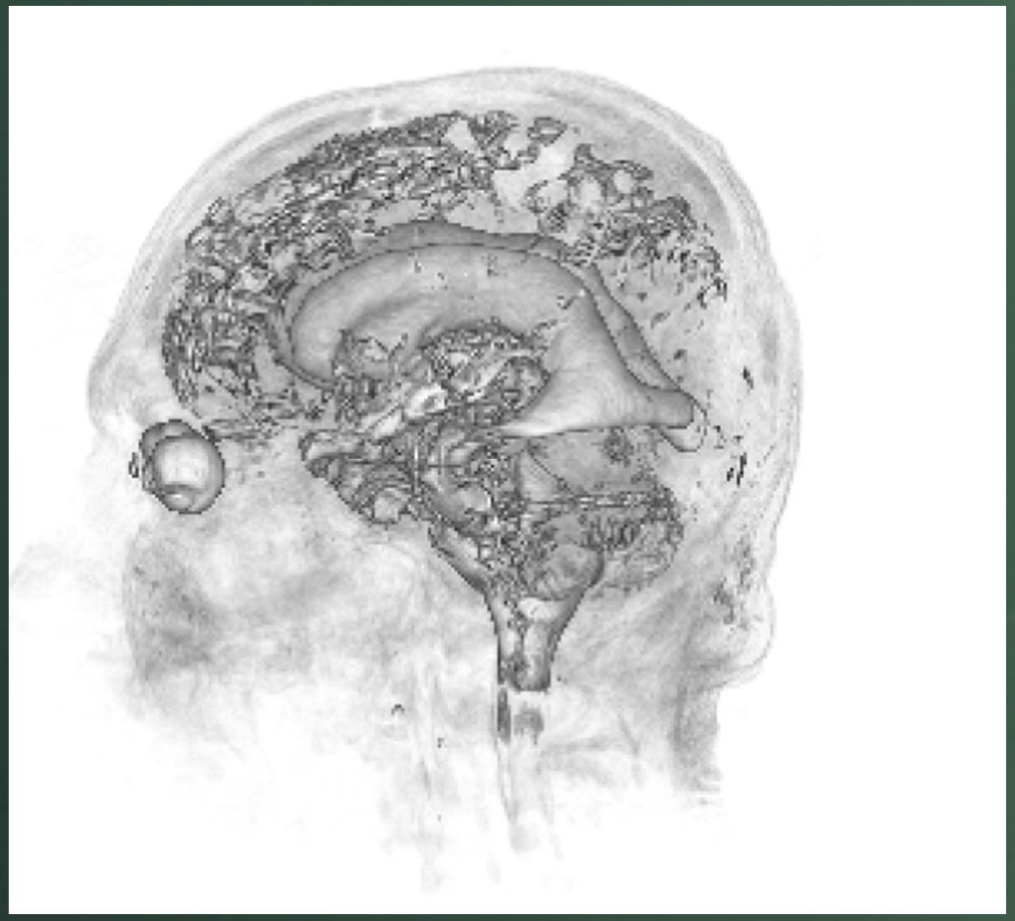


Engine Block
*Stanford University*

Visible Human
*(National Library of Medicine)*

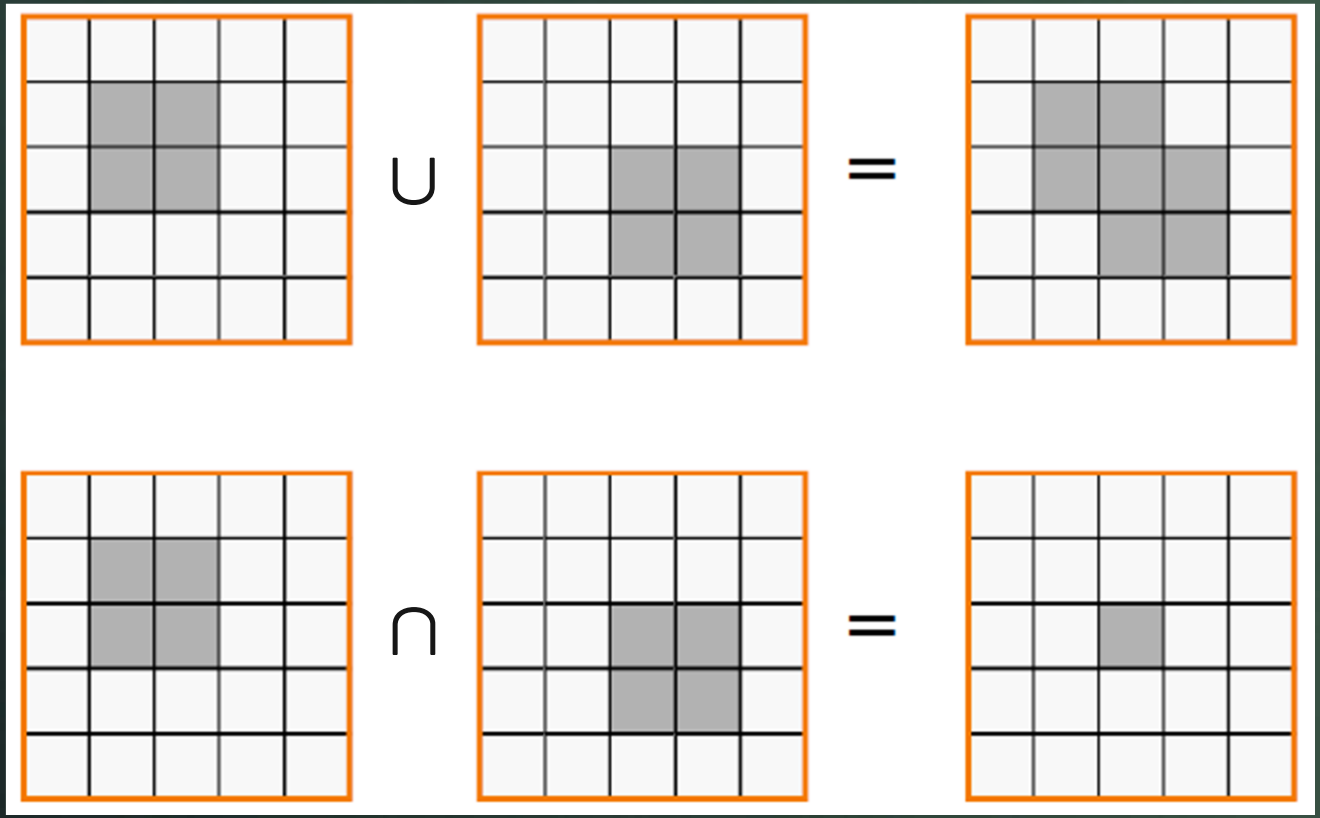
# Voxel Processing

- Signal processing (just like images)
  - Reconstruction
  - Resampling
- Typical operations
  - Blur
  - Edge detect
  - Warp
  - etc.
- Often fully analogous to image processing



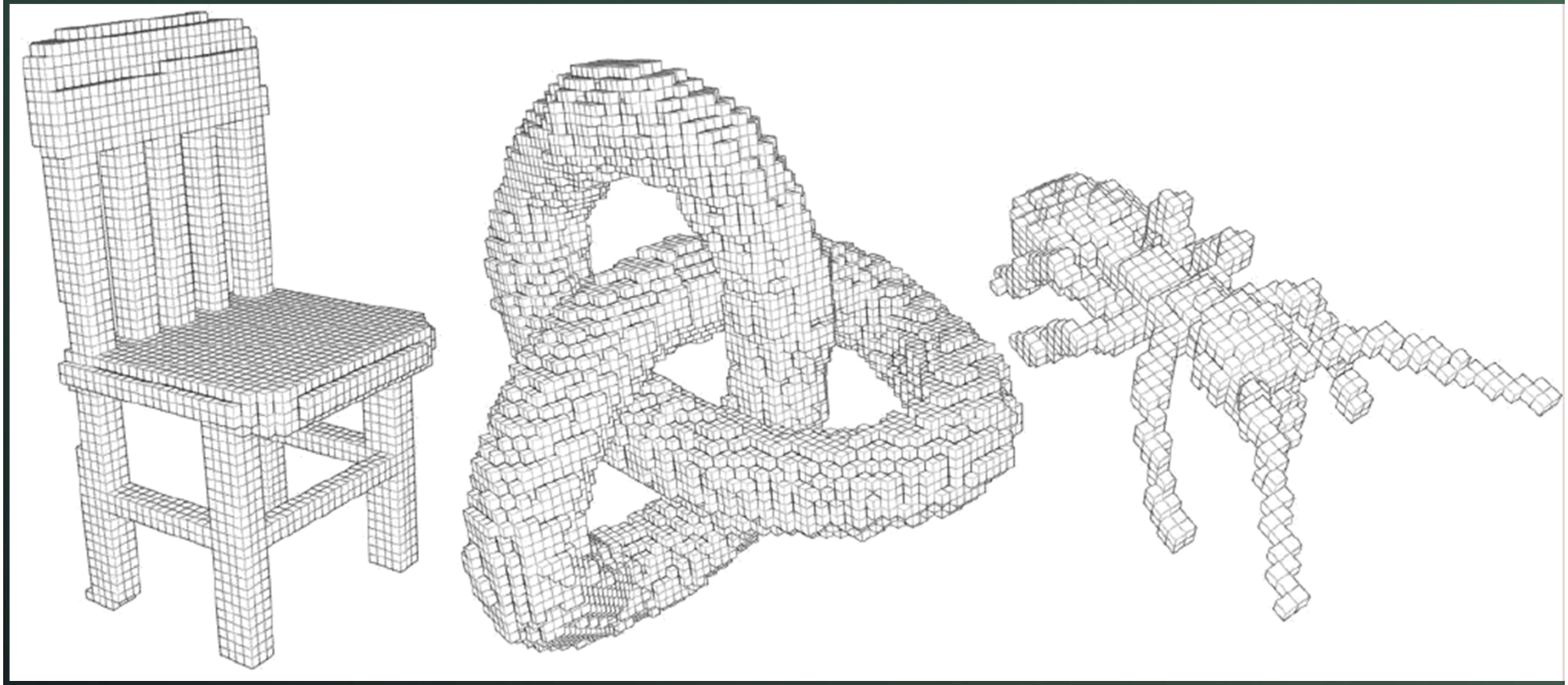
# Voxel Boolean Operations

- **Compare objects voxel by voxel**
  - **Trivial**



# Binary Voxel Visualization

- **Draw the faces between on and off voxels.**

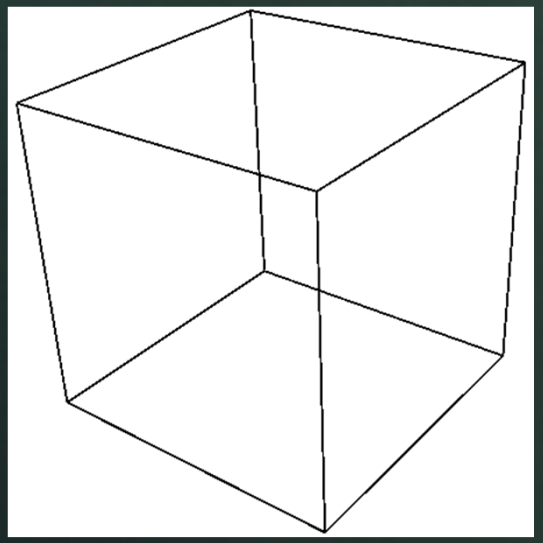


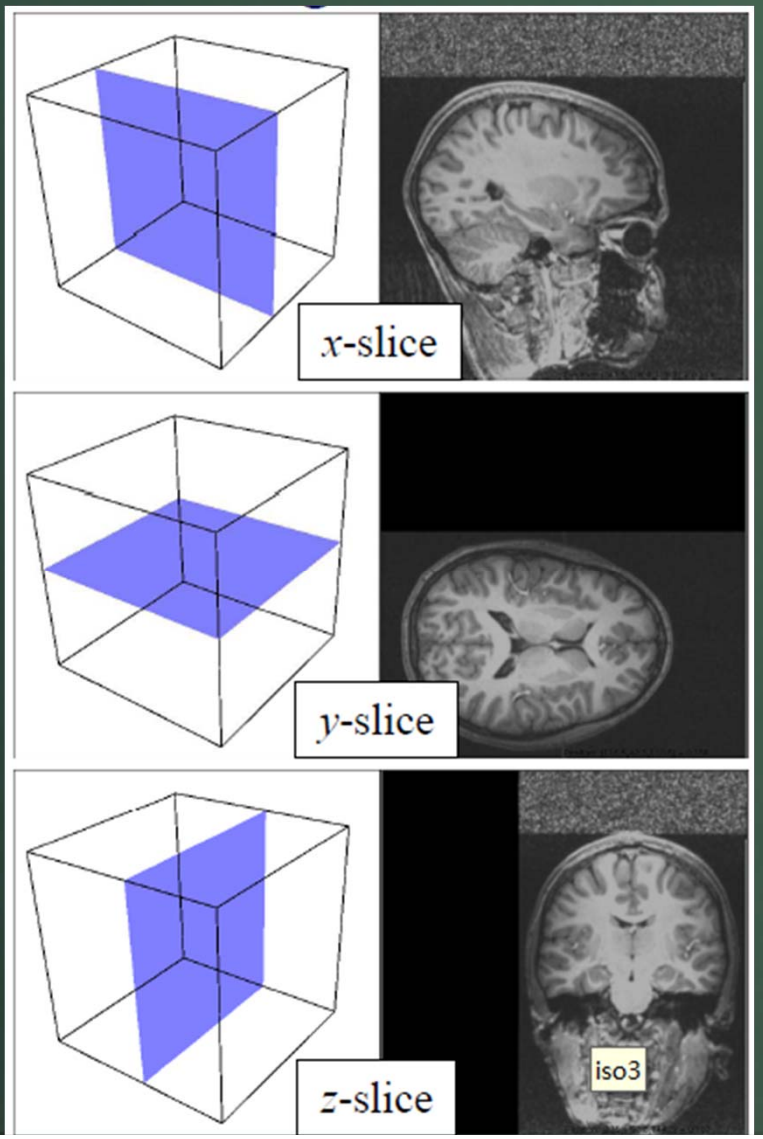
# Continuous Voxel Visualization

- **Slicing**
- **Ray-Casting**
- **Iso-Surface Extraction**

# Voxel Display

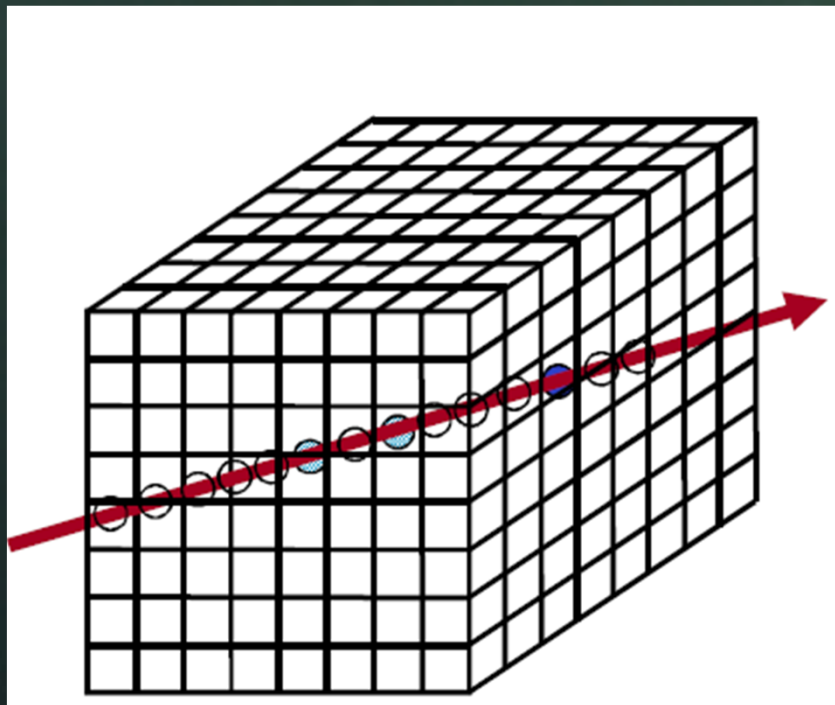
- **Slicing**
  - **Draw 2D image resulting from intersecting voxels with a plane**

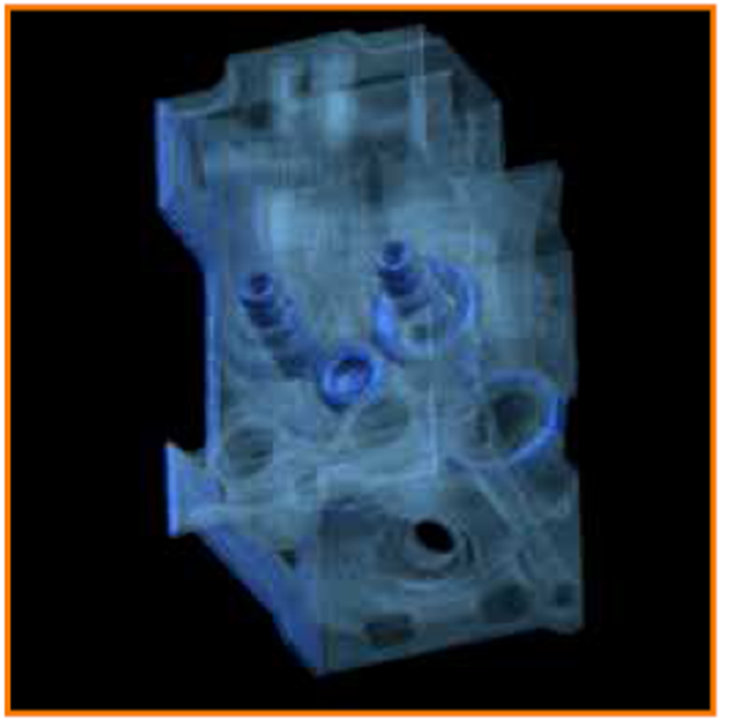




# Voxel Display

- **Ray casting**
  - **Integrate density along rays through pixels**





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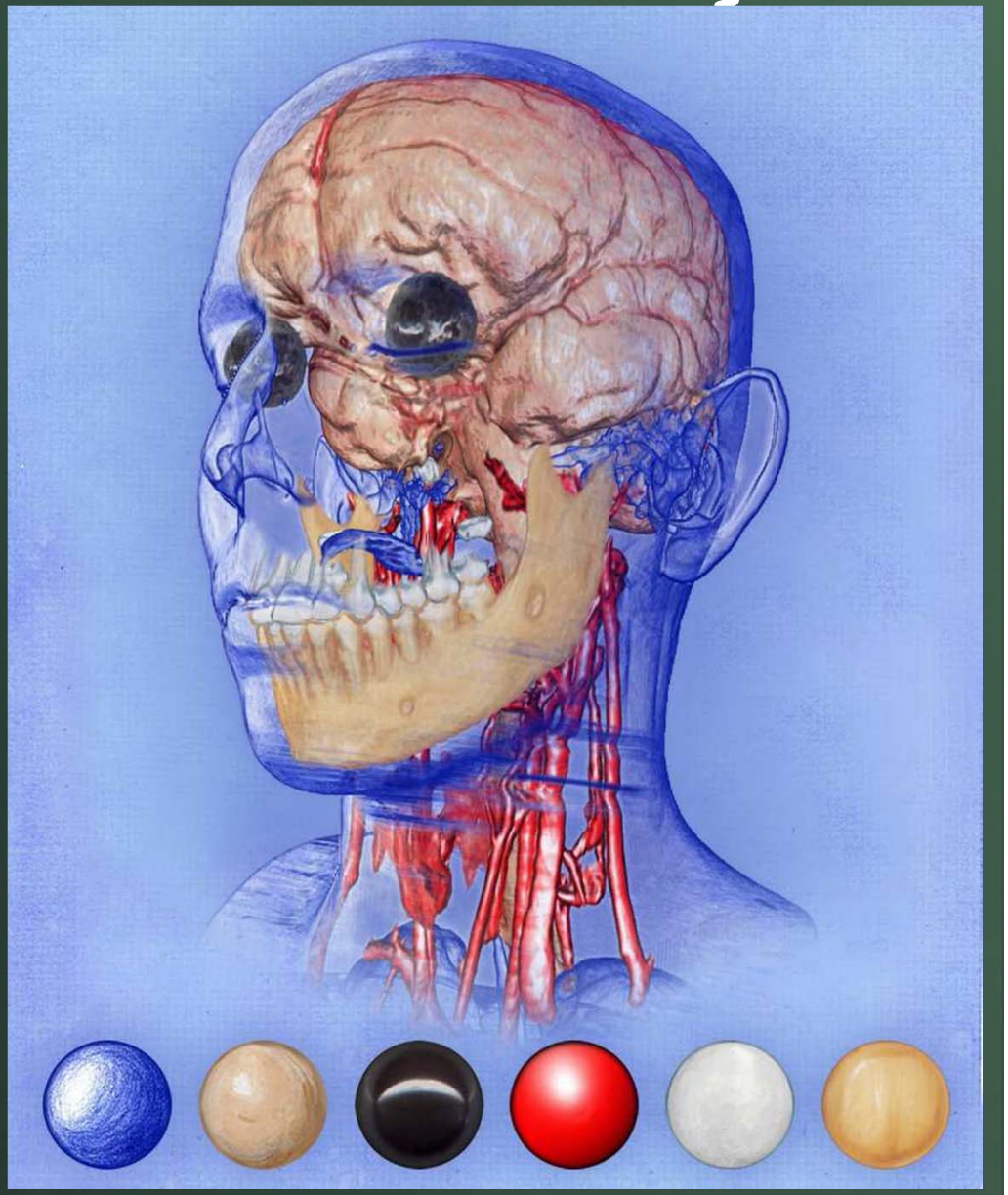
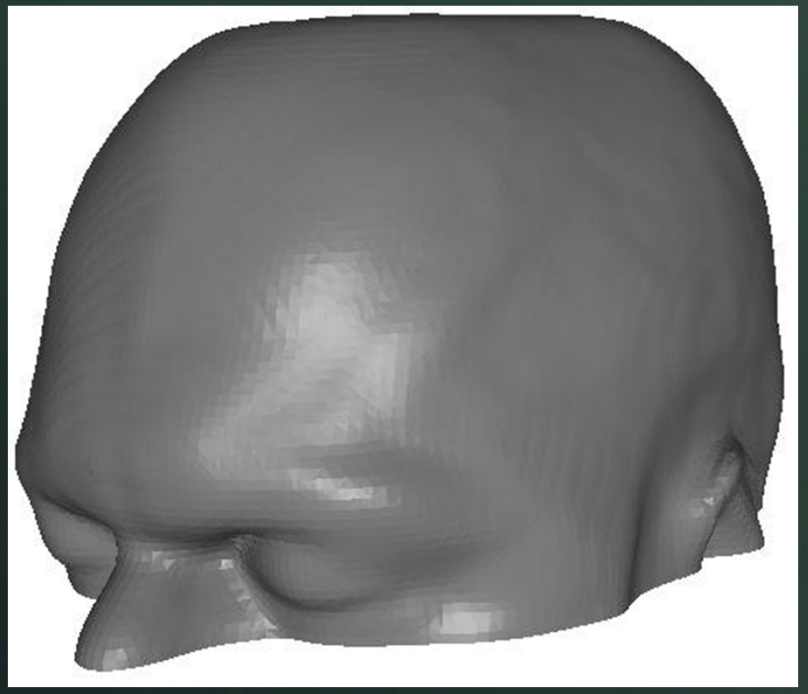
# Voxel Display

- **Extended ray-casting**
  - **Complex transfer functions**
  - **Map voxel densities to materials**

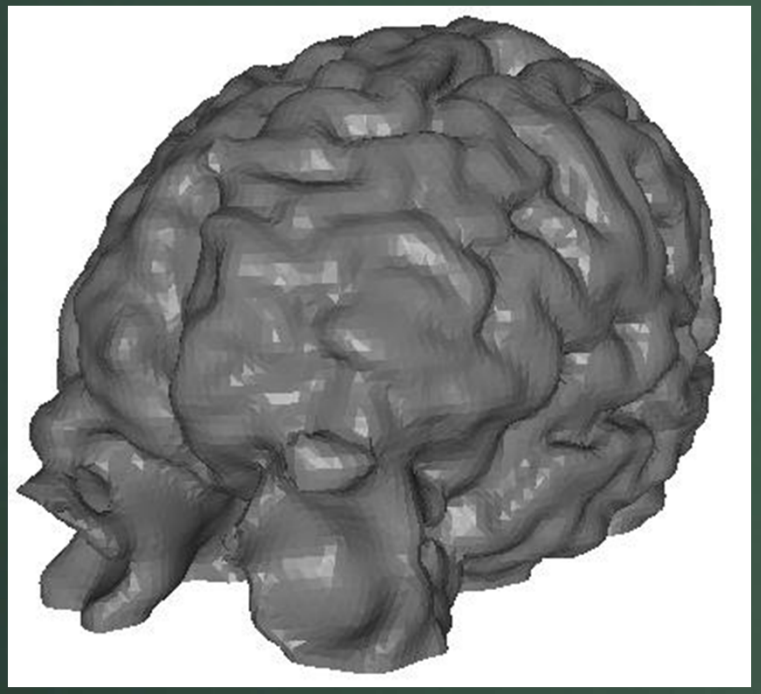


# Voxel Display

- **Iso-Surface Extraction**
  - **Treat the voxel grid as a regular sampling of some function F(x,y,z), and extract the iso-surface satisfying F(x,y,z)=δ.**



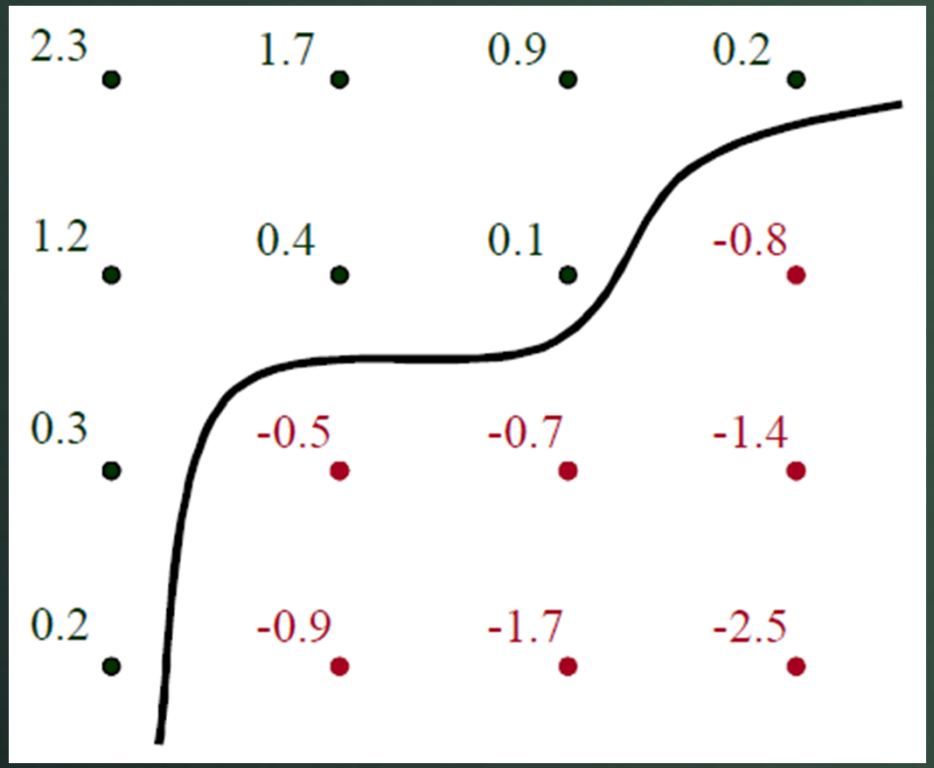
F(x,y,z)=δ1



F(x,y,z)=δ2

# Voxel Display

- **Isosurface rendering**
  - **Interpolate samples stored on regular grid**
  - **Isosurface at f(x,y,z) = 0 defines surface**



# Voxels

- Advantages
  - Simple, intuitive, unambiguous
  - Same complexity for all objects
  - Natural acquisition for some applications
  - Trivial boolean operations
- Disadvantages
  - Approximate
  - Not affine invariant
  - Expensive display
  - Large storage requirements

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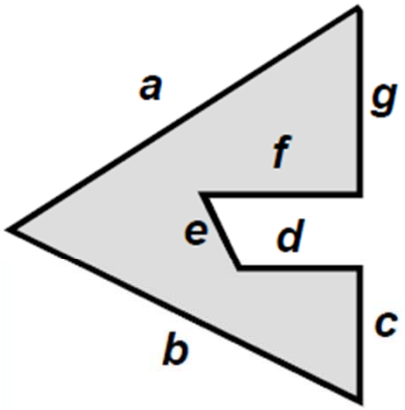
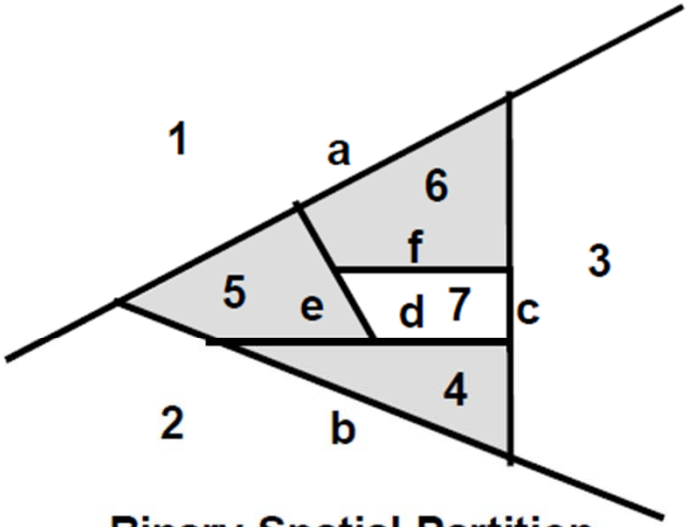
# BSP Trees

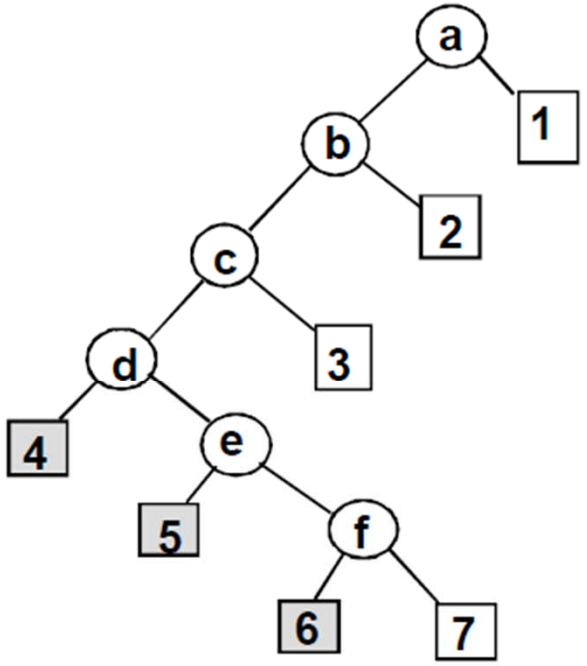
- **Binary space partitioning tree**
- **A method for recursively subdividing a space into convex sets by hyperplanes.**




Object




Binary Spatial Partition




Binary Tree

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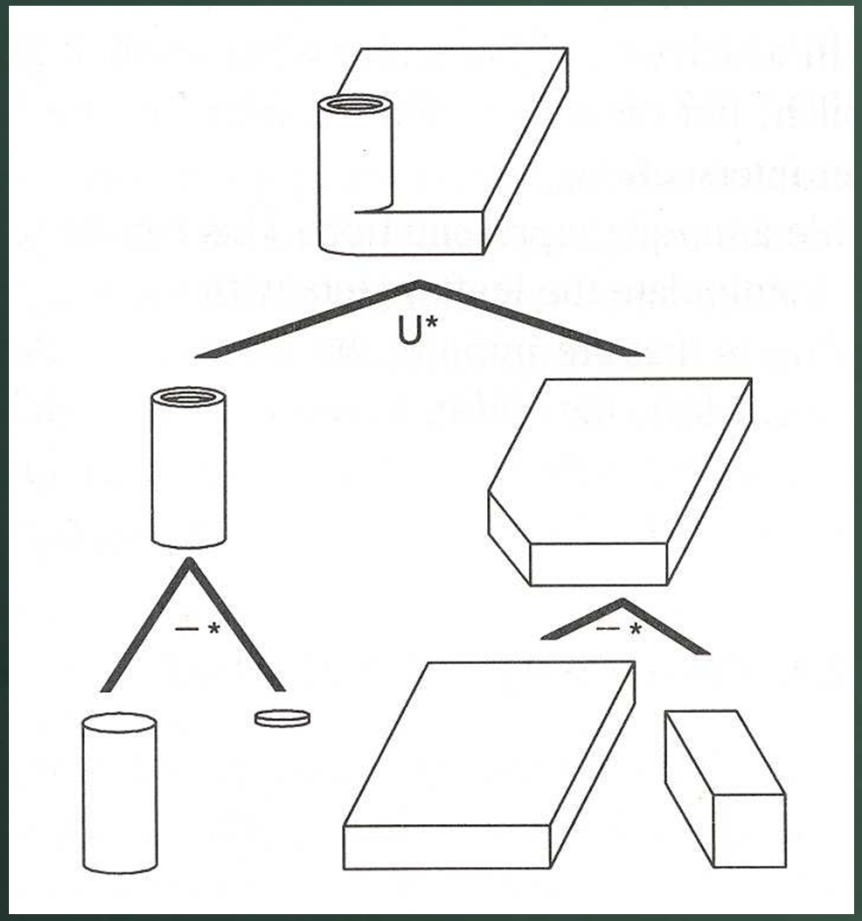
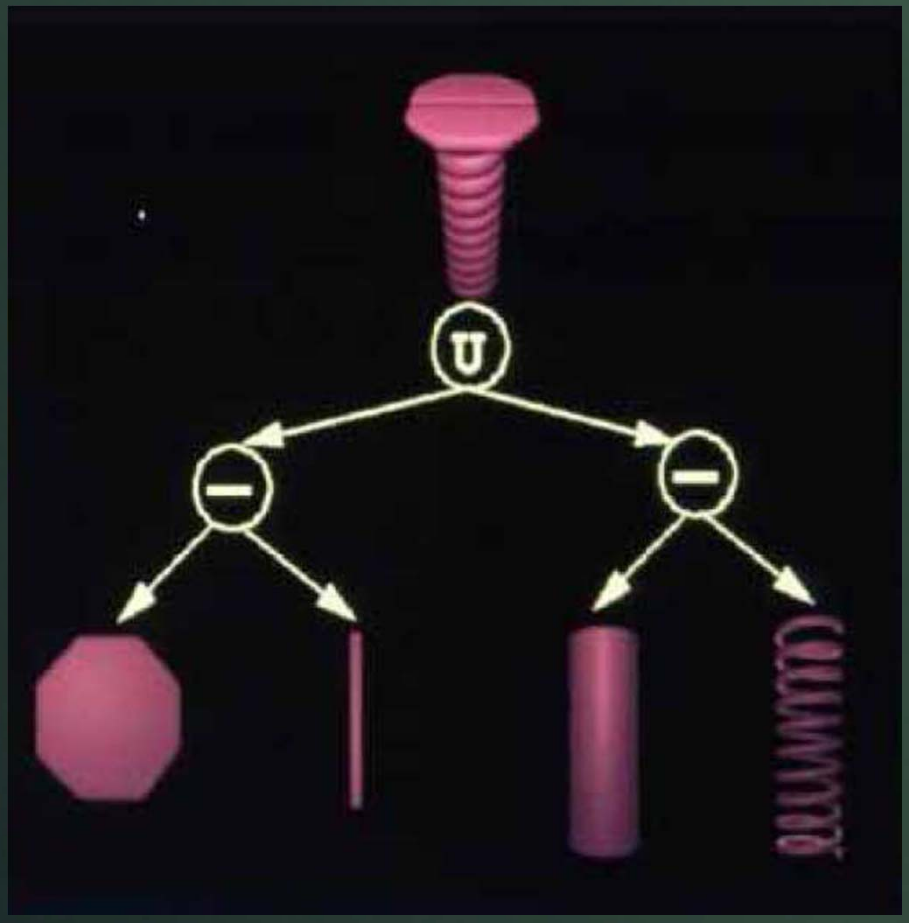
# Constructive Solid Geometry (CSG)

- **Represent solid object as hierarchy of boolean operations**
  - **Union**
  - **Intersection**
  - **Difference**



# CSG Acquisition

- **Interactive modeling programs**
  - **Intuitive way to design objects**



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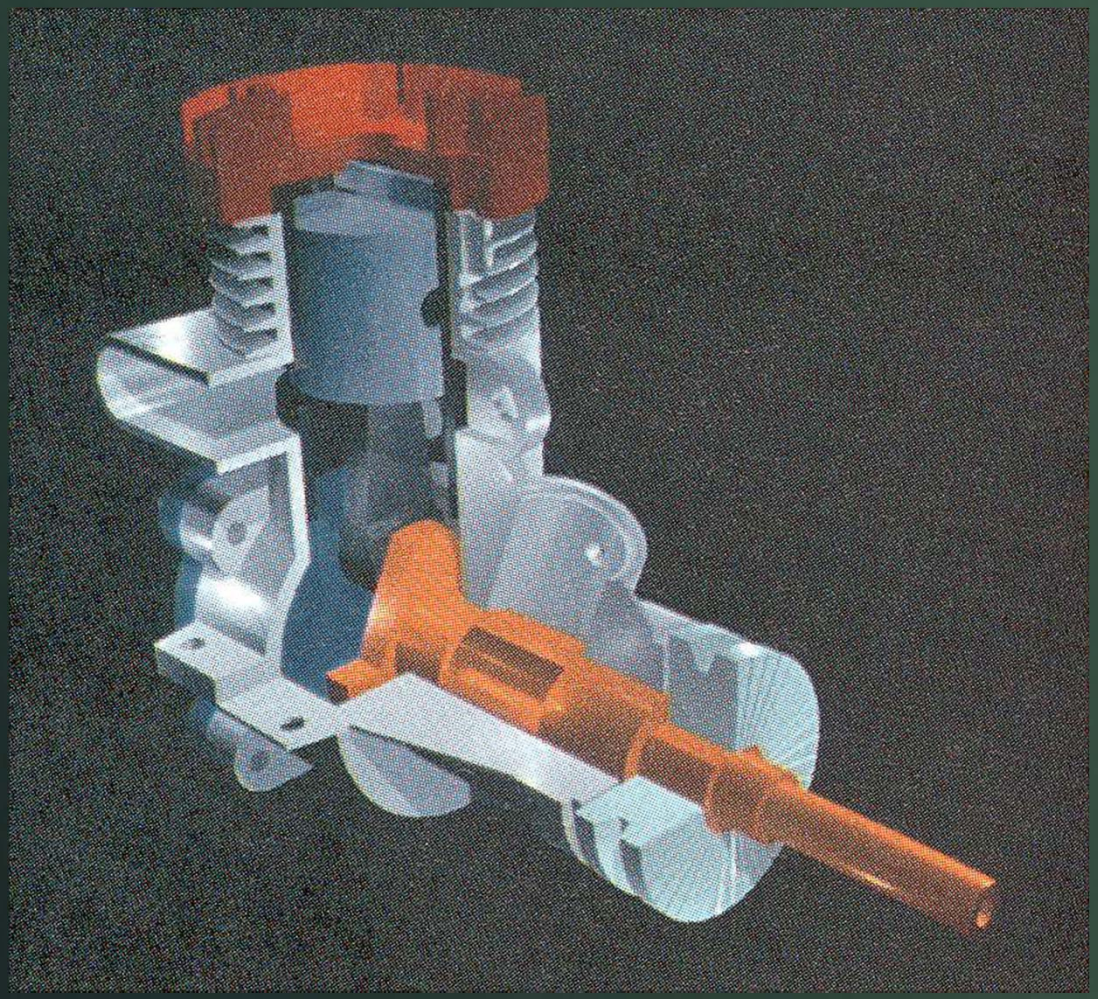
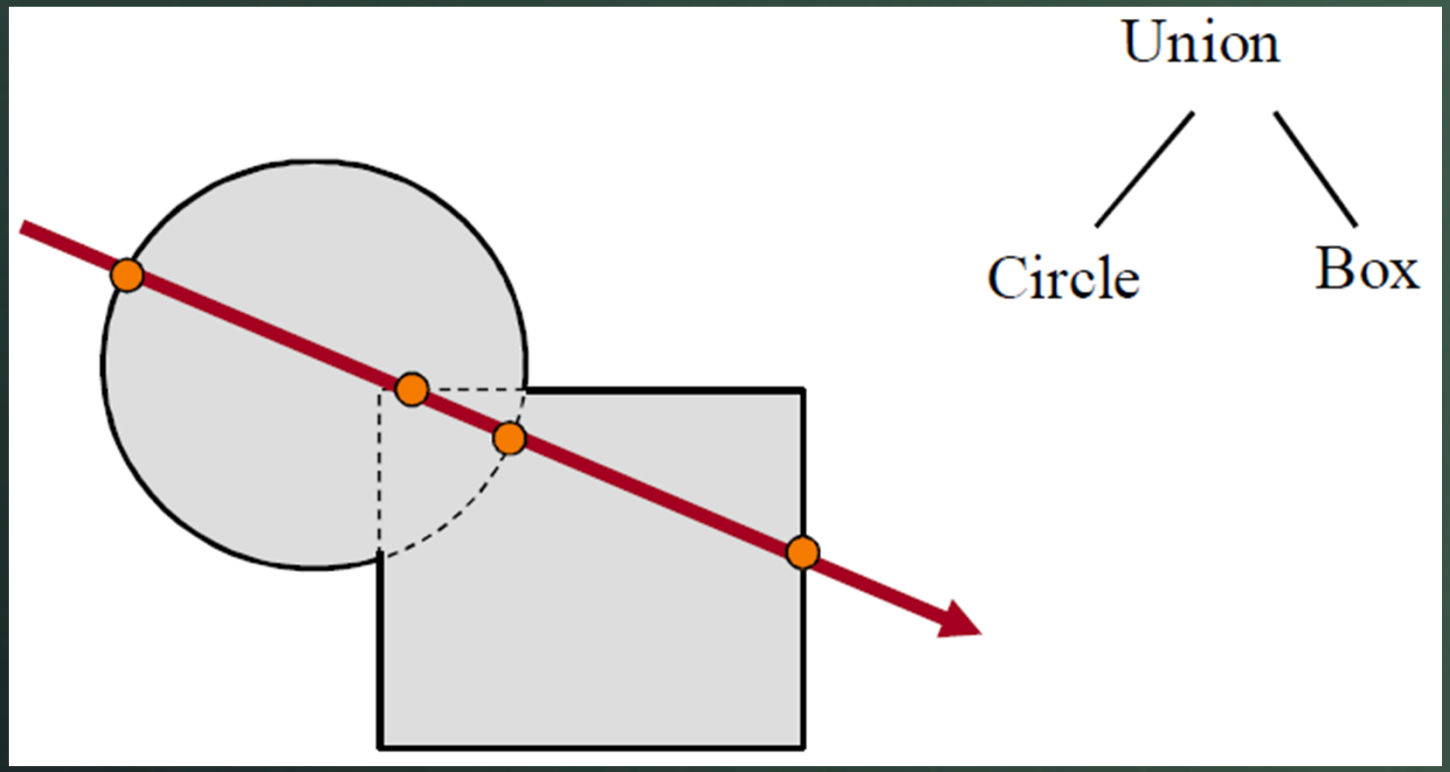


# CSG Display & Analysis

- **Ray casting**



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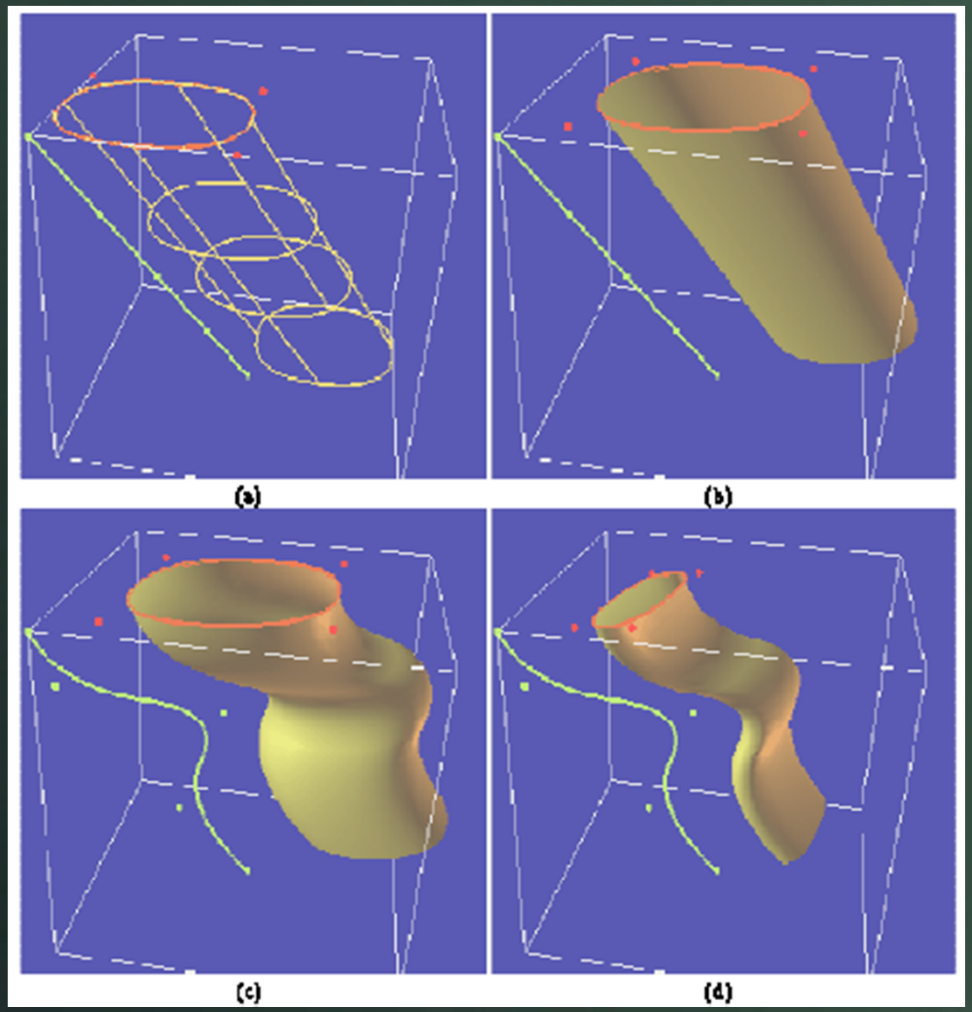
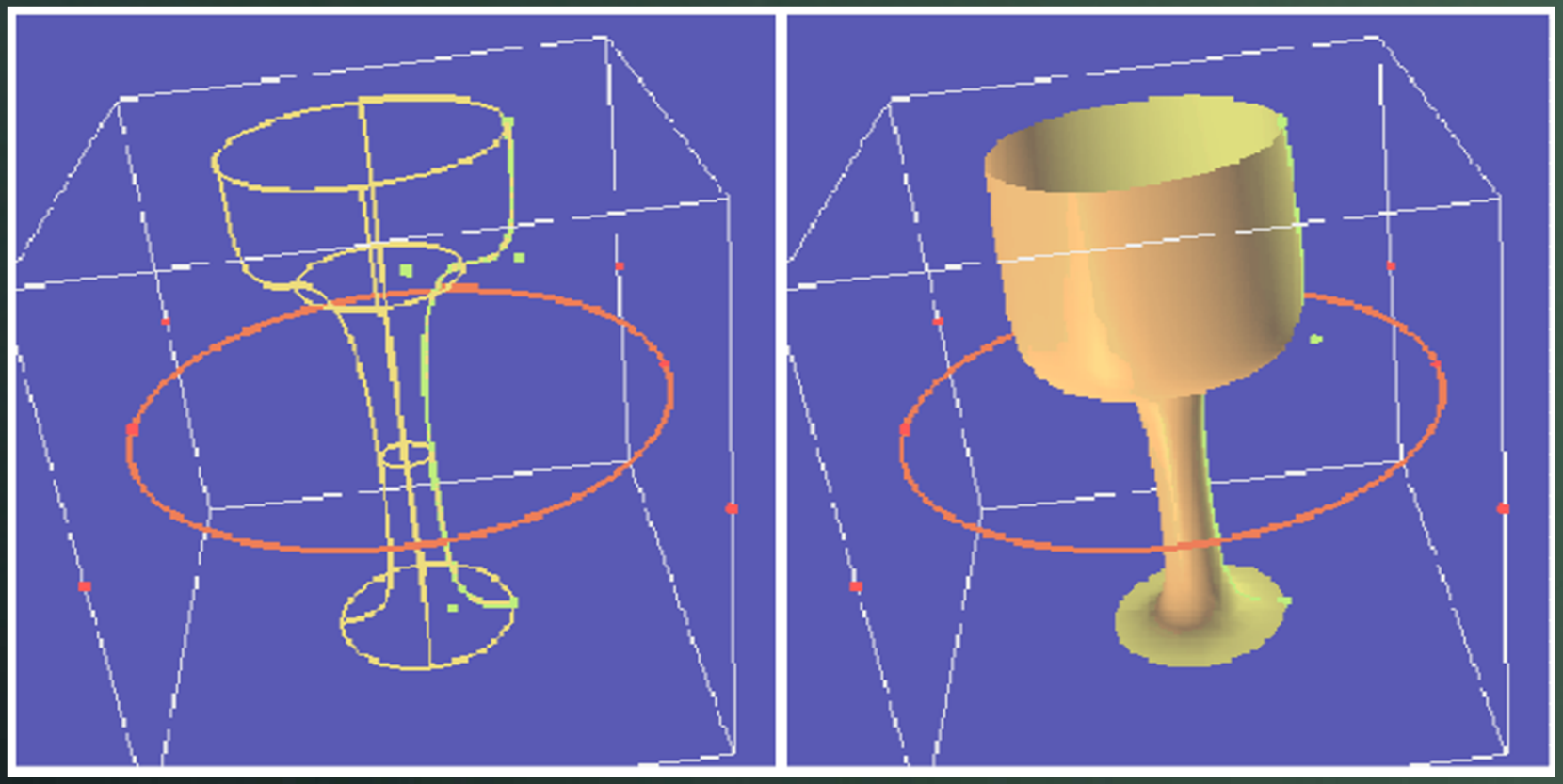
# Sweeps

- **Swept volume**
  - **Sweep one curve along path of another curve**



# Sweeps

- **Surface of revolution**
  - **Take a curve and rotate it about an axis**



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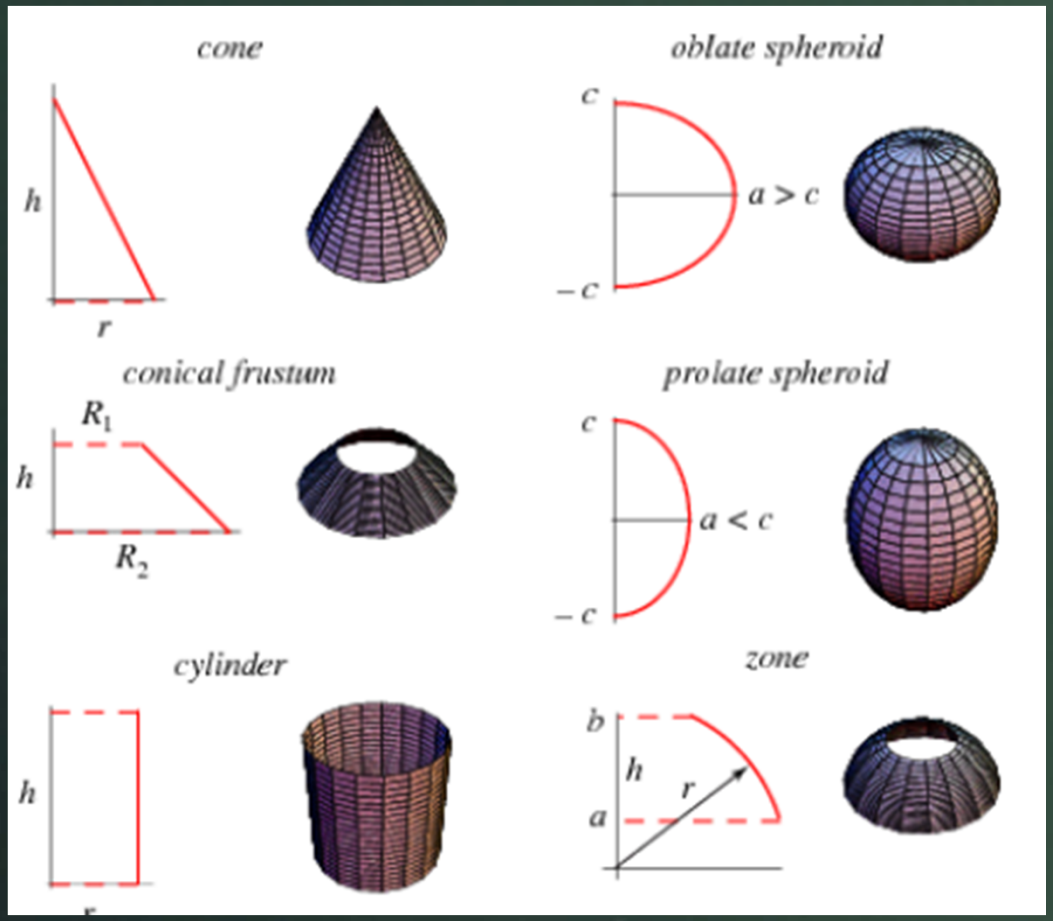
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