Computer Graphics

3D Object Representations

What to Specify for a 3D Shape?

- geometry
  - – shapes, positions
  - – connectivity, inside/outside
- material properties
  - – visuals, textures (plastic, wood, metal, etc.)
  - – other material properties (elasticity, mass, etc.)
- behaviour/animation
- more depending on the specific application

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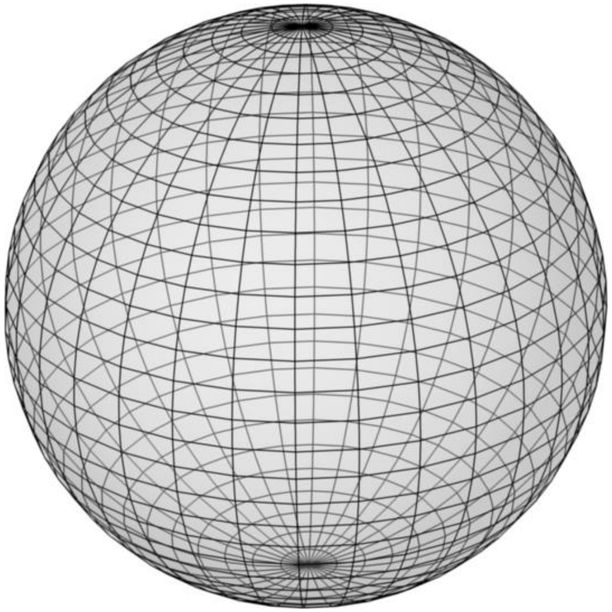

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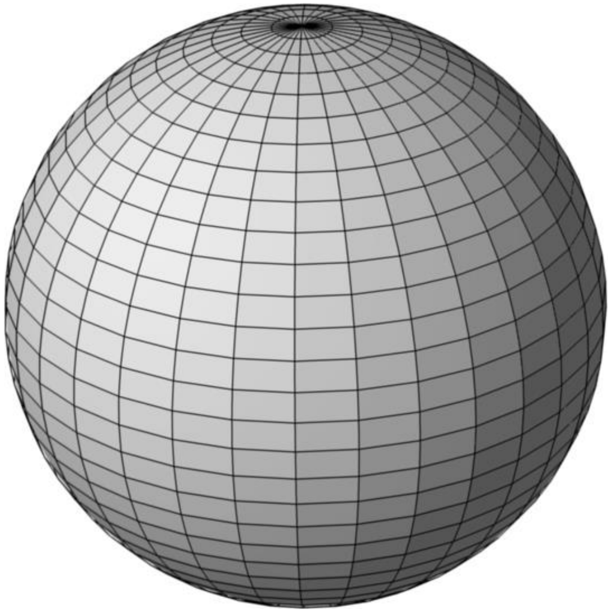

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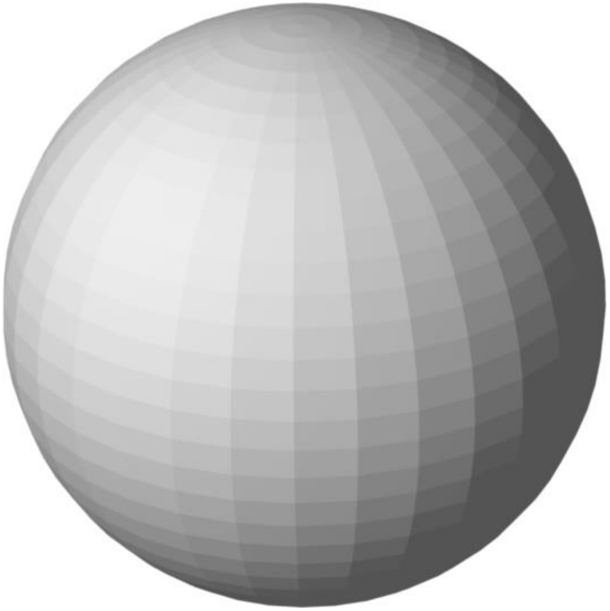

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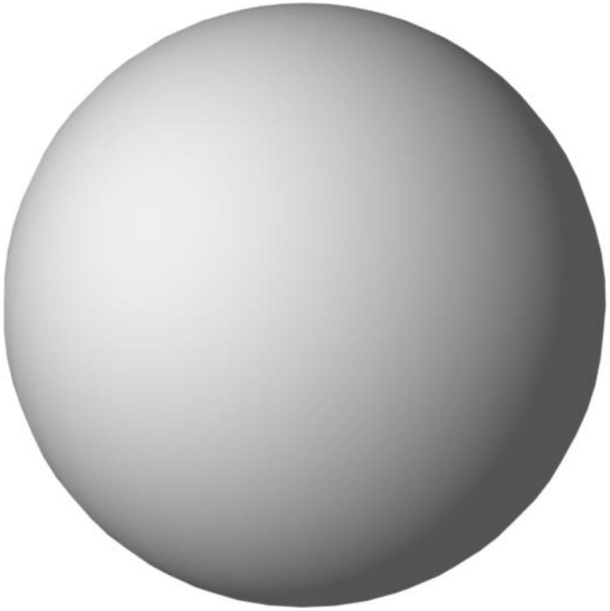

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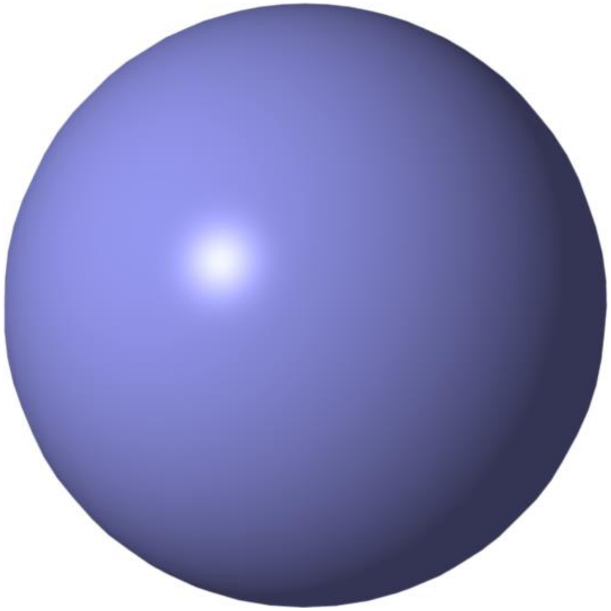

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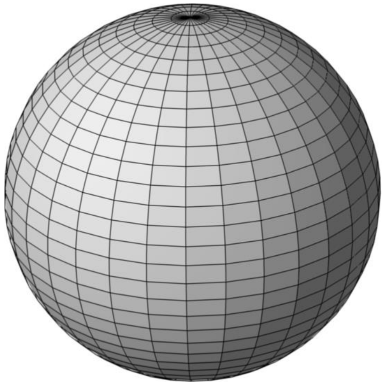
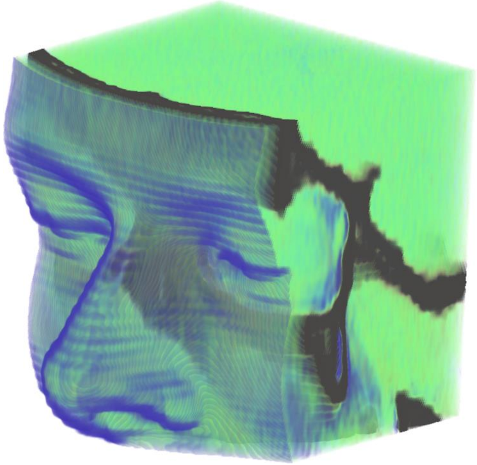
How to Specify a 3D Geometry?

- boundary representations (b-reps)
  - – meshes
  - – piecewise smooth surfaces

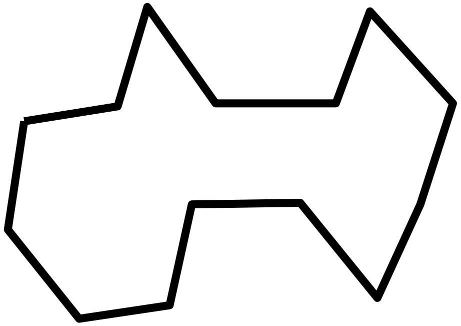


- volume representations
  - – voxel models
  - – implicit surfaces
  - – CSG: constructive solid geometry
  - – space partitioning
    - BSP trees: binary space partitioning
    - octrees



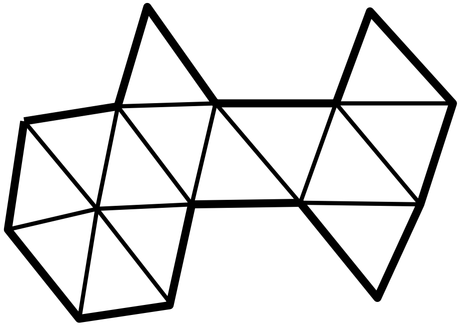
B-Reps: Polygonal Meshes

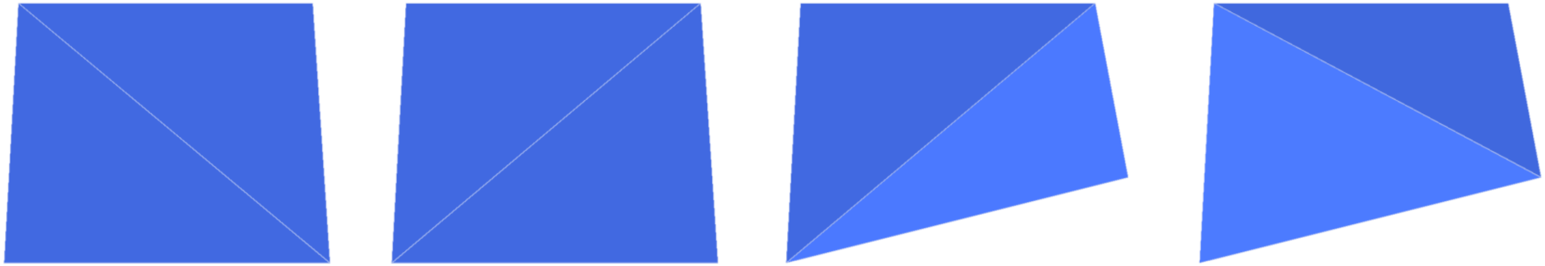
- polygons to define the surface of objects



B-Reps: Polygonal Meshes

- polygons to define the surface of objects
- triangle meshes
  - polygon with fewest vertices
  - always convex & planar → defines unique surface





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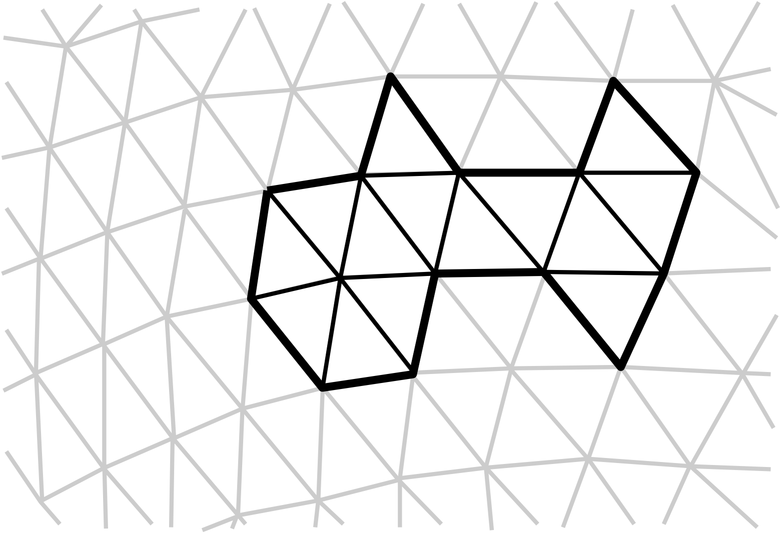

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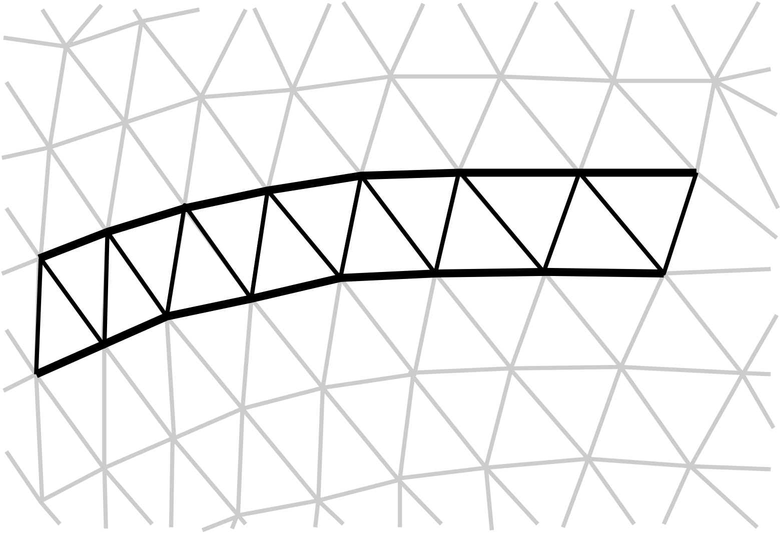

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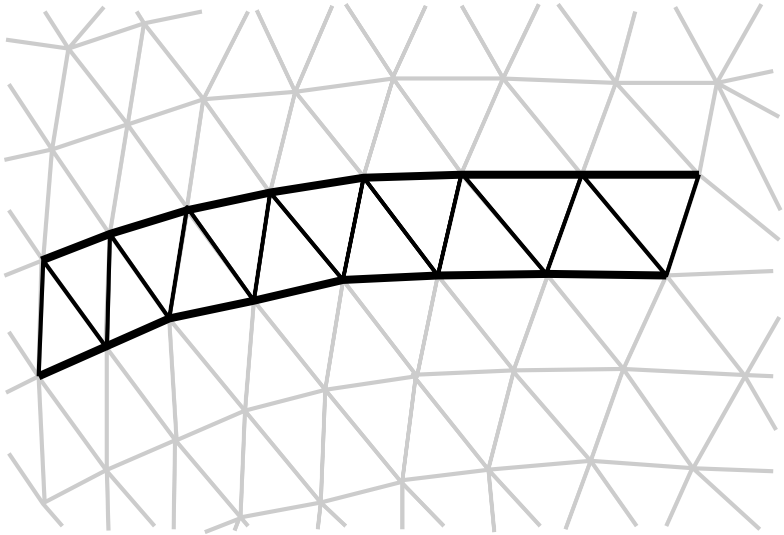
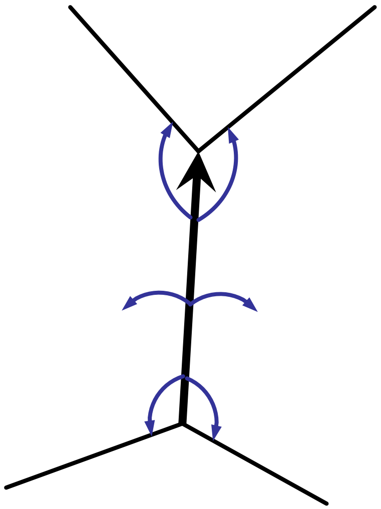
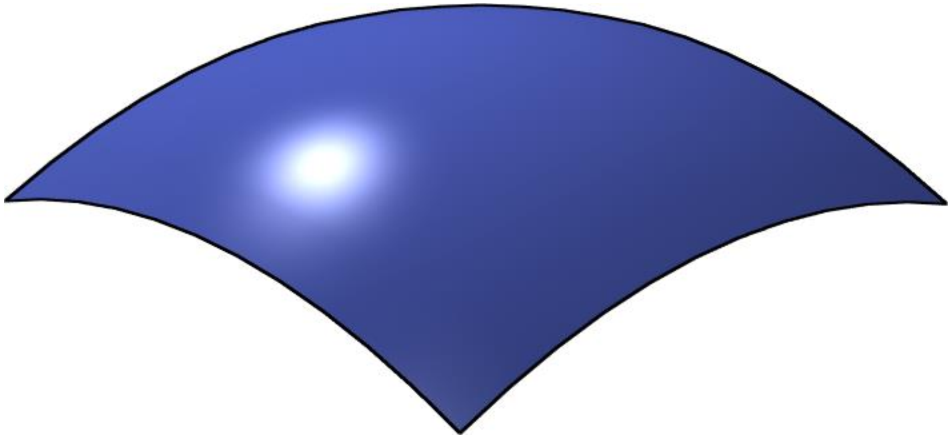
- more complex mesh data structures (e.g., Winged Edge)





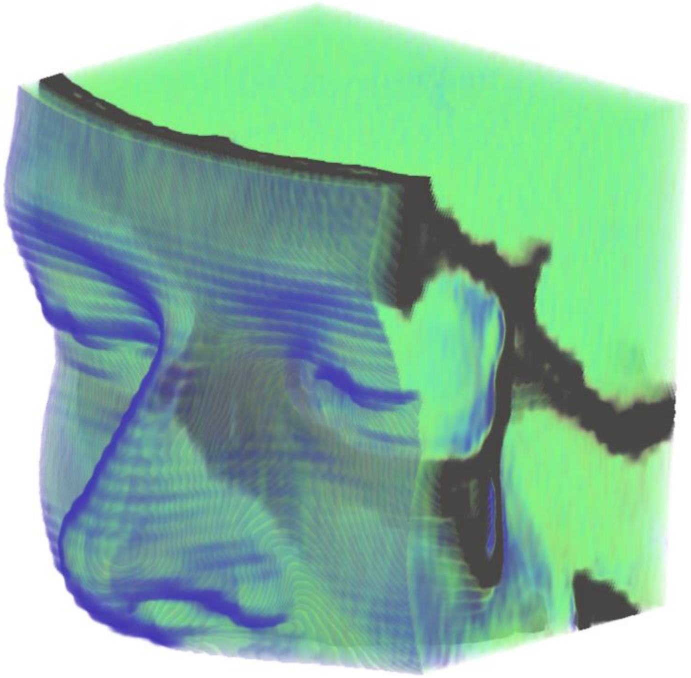
B-Reps: Piecewise Smooth Surfaces

- surface constructed from patches
- patches can be curved and are smooth
- patches satisfy a continuity constraint
- e.g., Bézier, Spline, NURBS surfaces



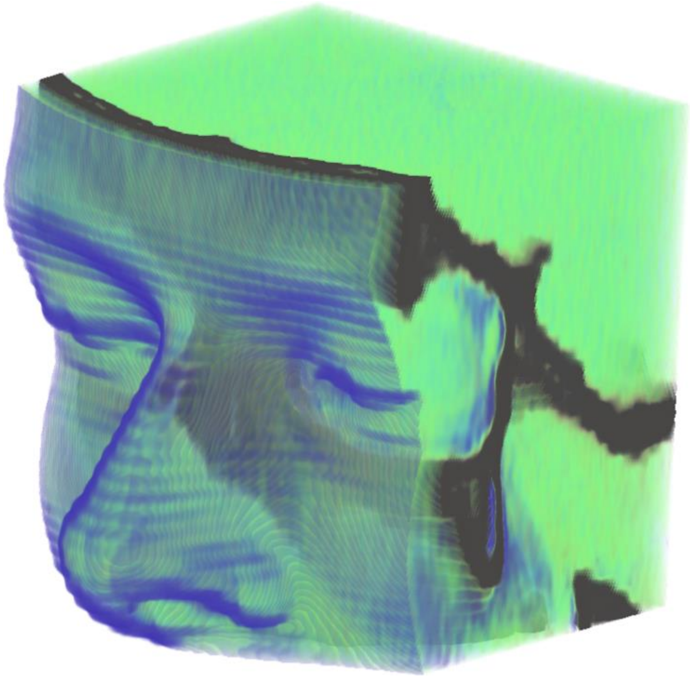
Volumes: Voxel Models

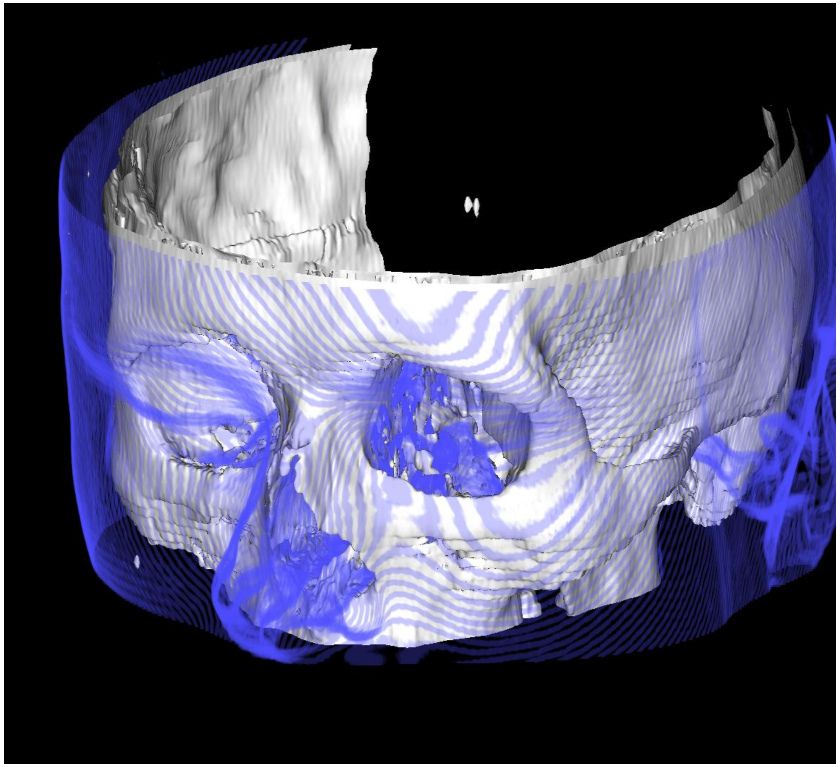
- sampling of a volume in regular intervals
- samples as cubes, or as general boxes
- several properties can be sampled



Volumes: Voxel Models

- shapes: *iso-value* to specify special level
- they define *iso-surfaces* inside the volume





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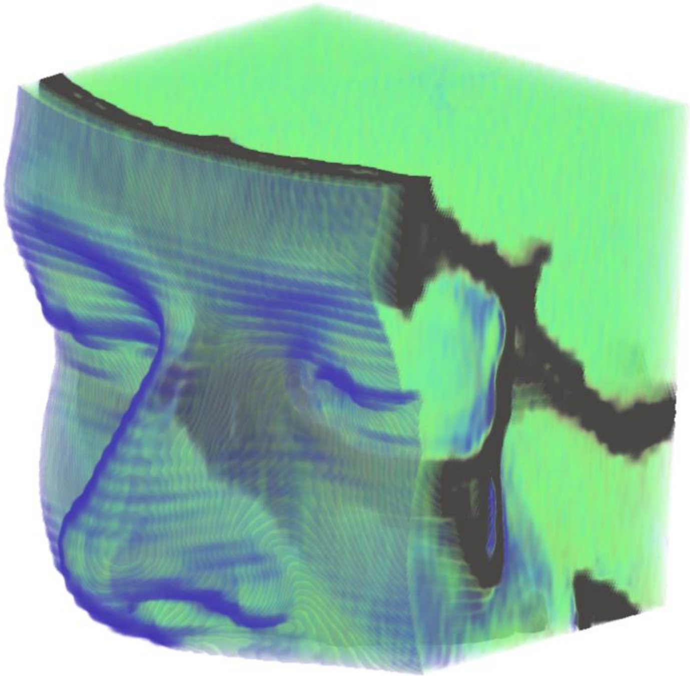
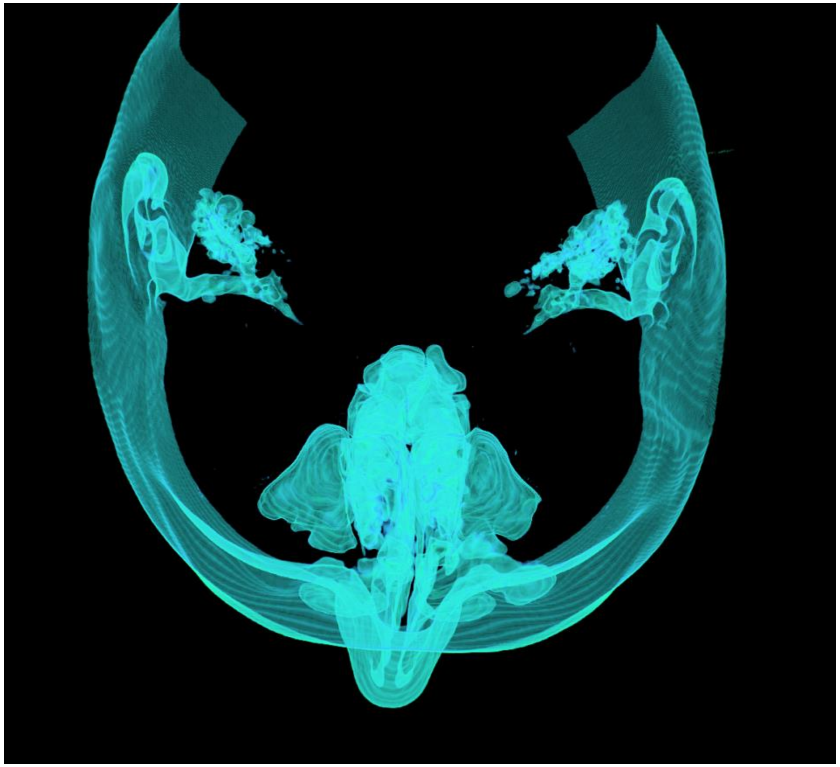
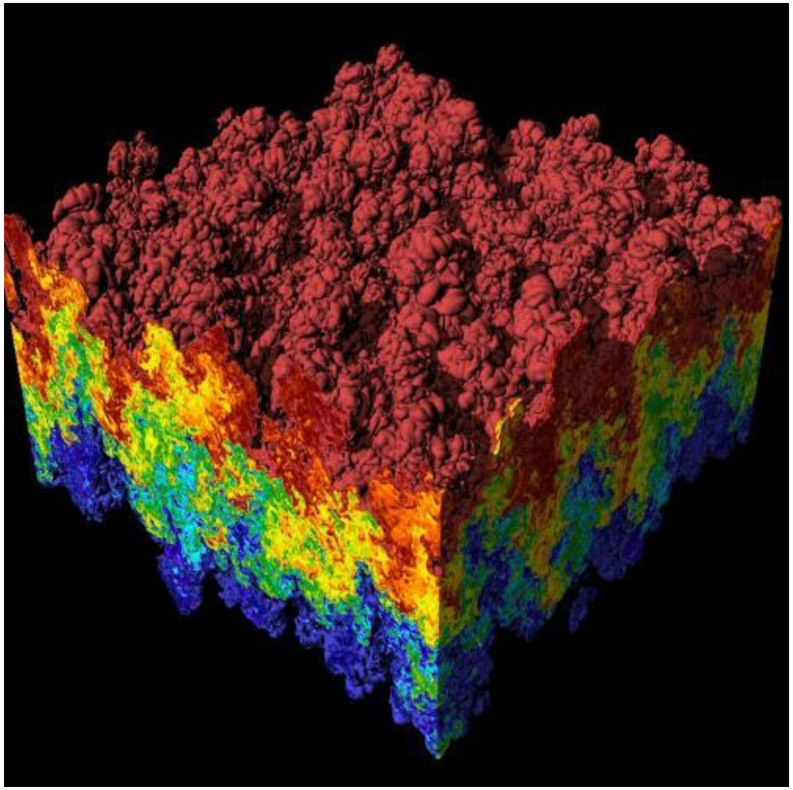
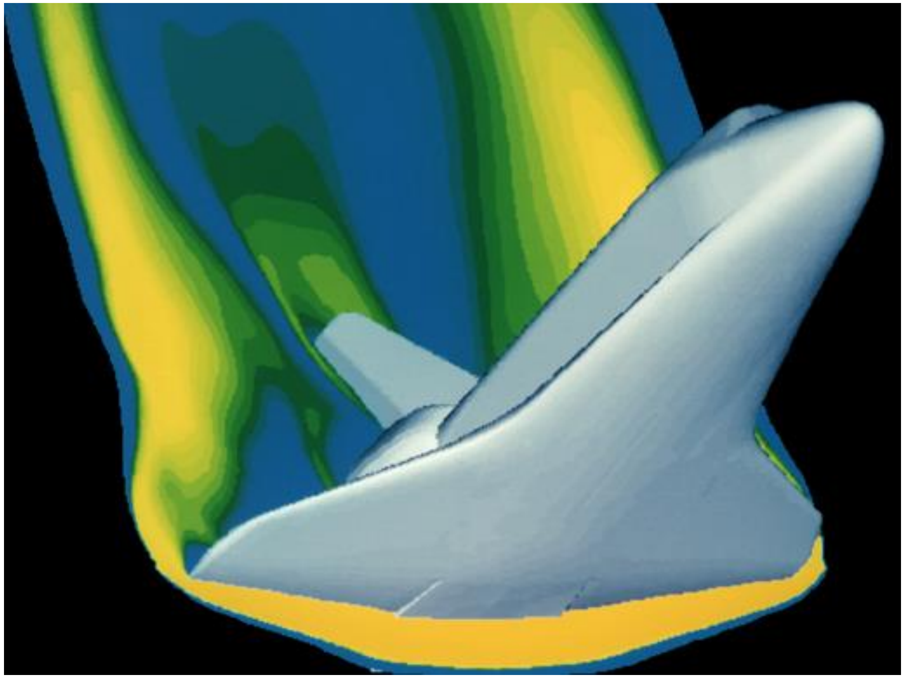




Volumes: Voxel Models

- heavily used in medical imaging (based on CT, MRI) and fluid dynamics etc.





Volumes: Implicit Surfaces

- description of shapes through implicit equations; e.g., sphere:

$$F(x,y,z) = \sqrt{x^2 + y^2 + z^2}$$

$$r = \sqrt{x^2 + y^2 + z^2}$$

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iso-value

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- use: mathematics, chemistry, hq rendering

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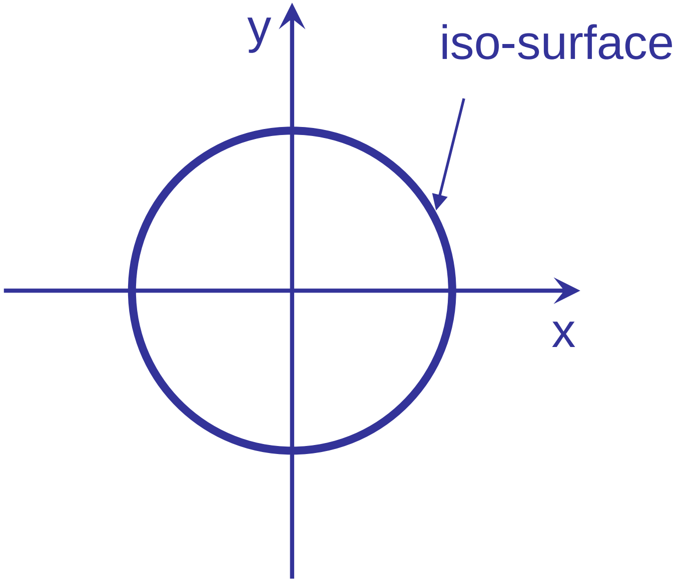

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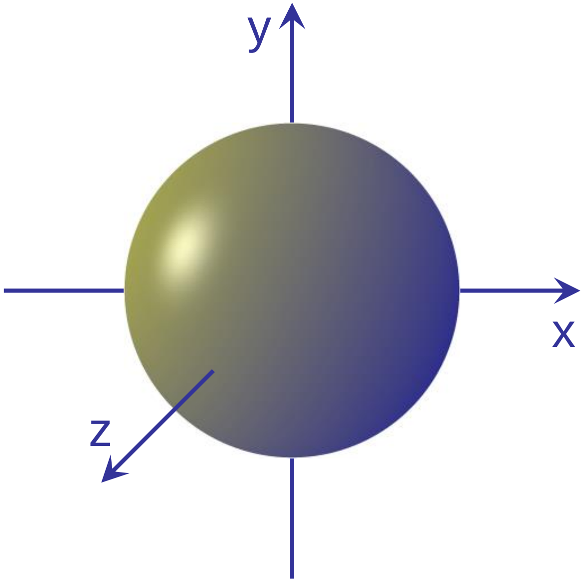

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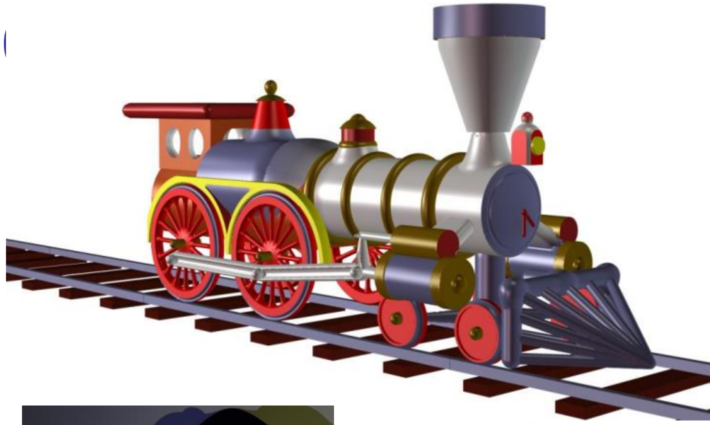

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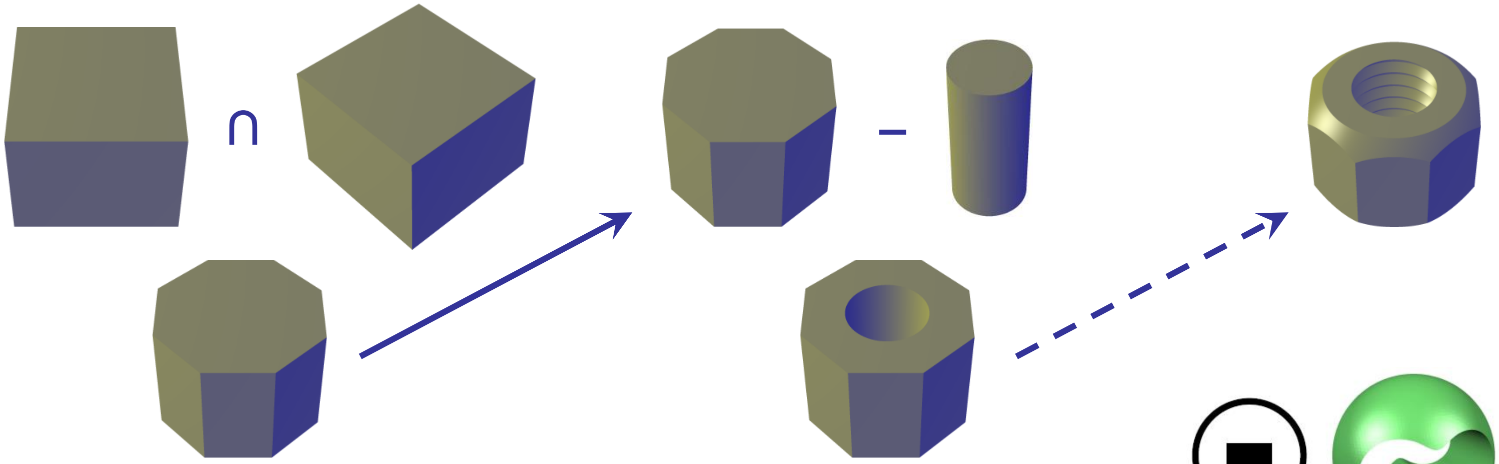
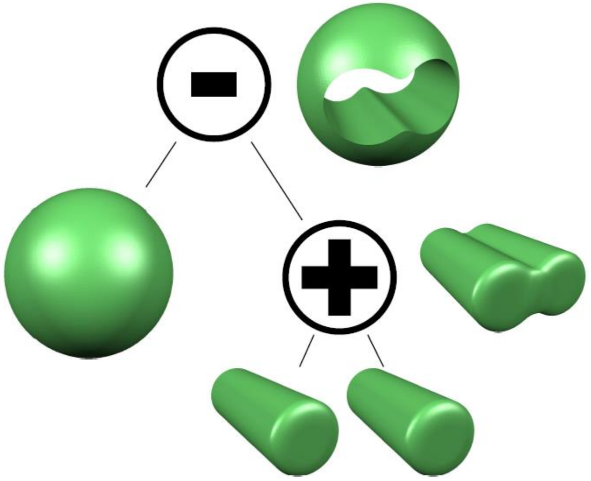
images courtesy of Brian Wyvill et al.

Volumes: Construct. Solid Geometry

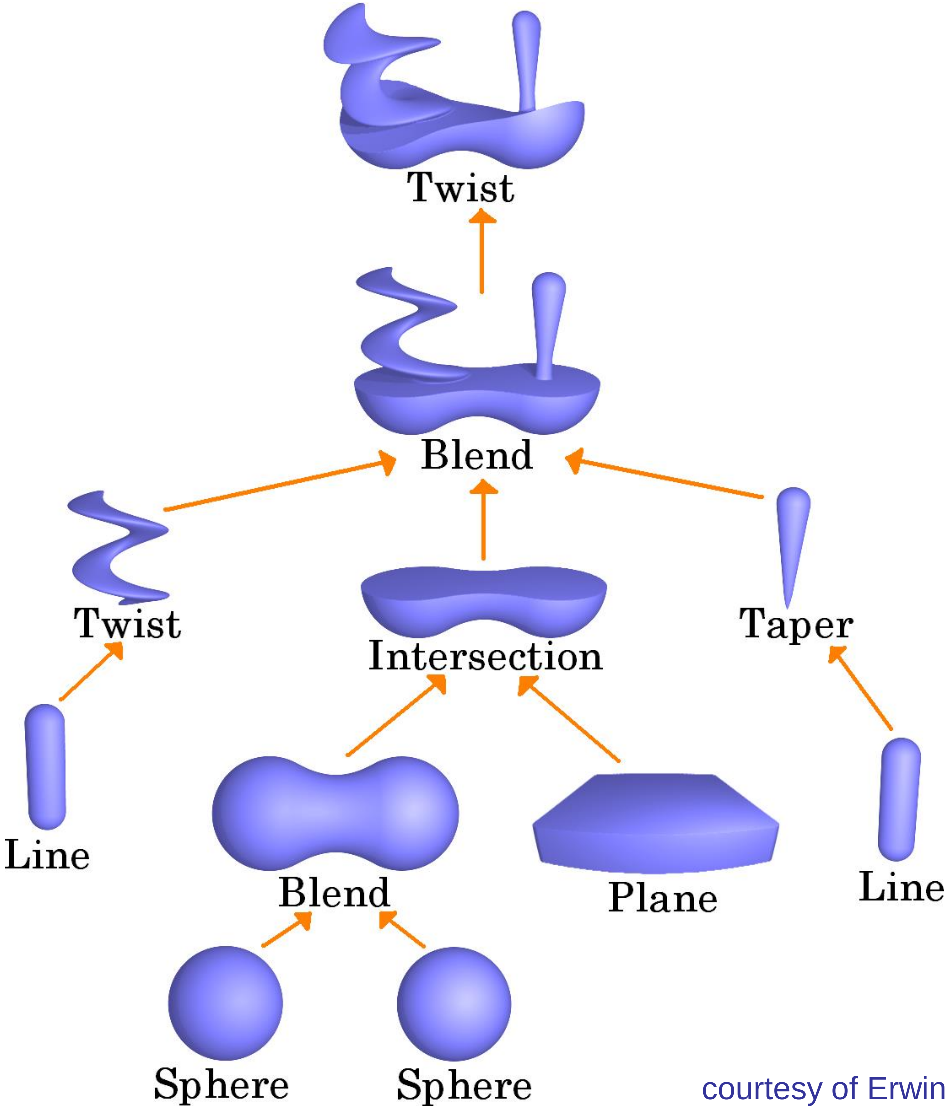
- Boolean operators to combine shapes
- unions, intersections, set differences



- build up CSG trees
- e.g., to build complex implicit models



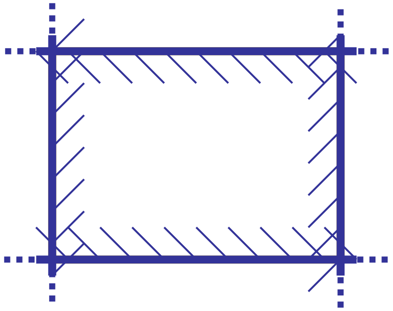
Implicit Surface CSG Trees: Blobtree



courtesy of Erwin de Groot and Brian Wyvill

Volumes: BSP and Octrees

- space partitioning: define sub-spaces
- **b**inary **s**pace **p**artitioning: half-spaces
  - – planes define borders between inside and outside; hierarchy
  - – only current subspace affected



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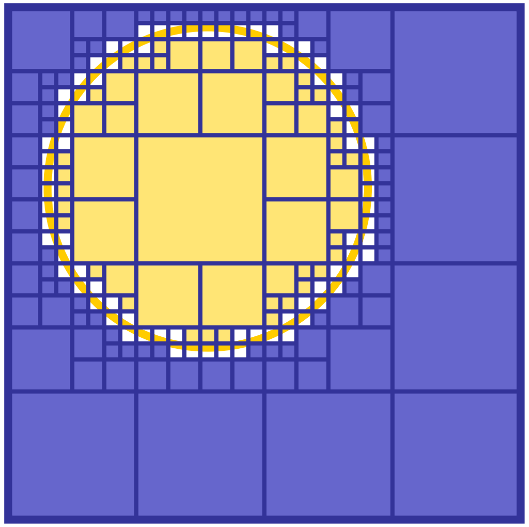
- octrees: partitioning on regular 2×2×2 grid (= 8)
  - mark cells inside, outside, or subdivide
  - 2D case: quadtrees (2×2)



Summary Object Representations

- two types: boundary and volumetric representations
- we mostly use boundary representations
  - these store the surface of the objects
  - polygon/triangle-based or curve-based
  - flexible
- volumetric models also store the “inside”
- in addition to geometry we also store many other properties