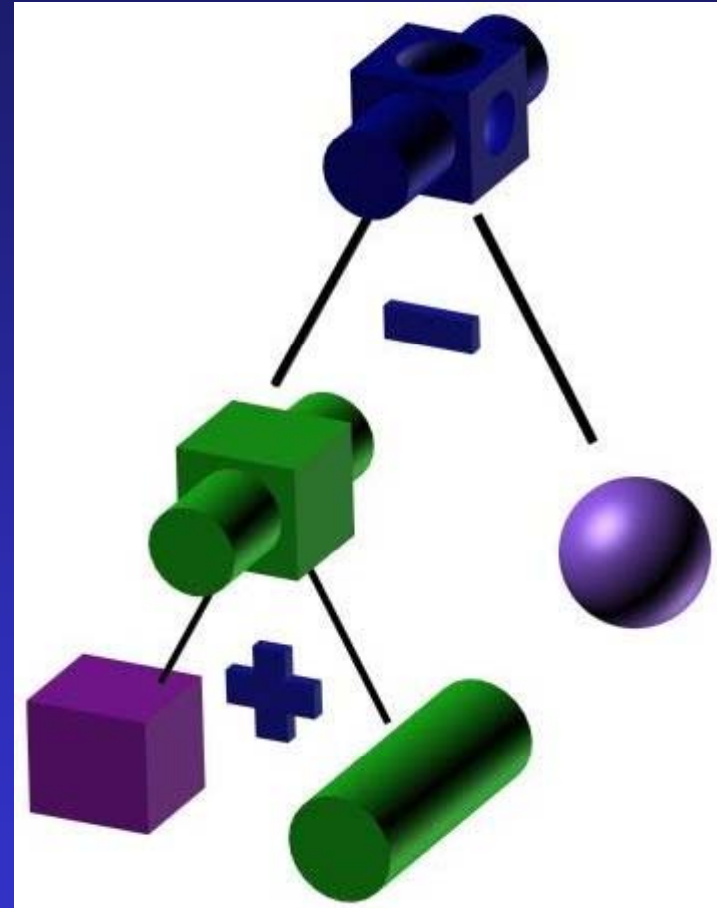


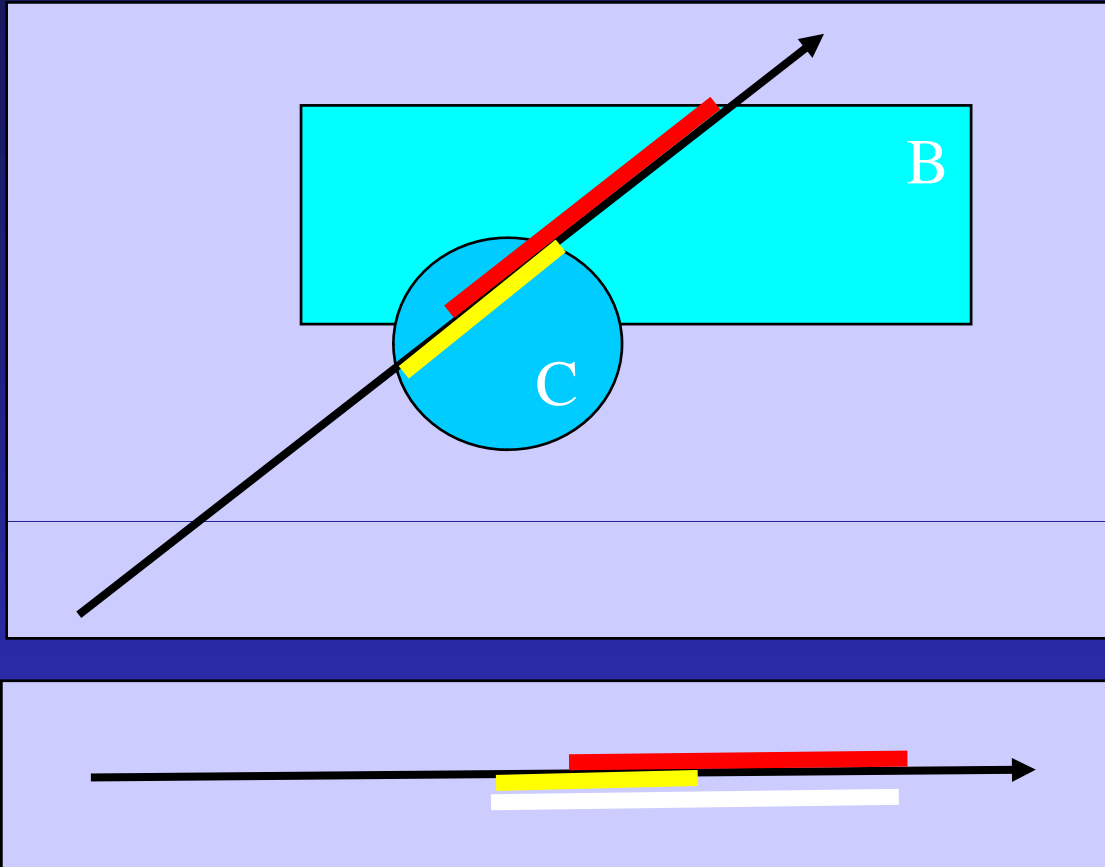
Constructive Solid Geometry

Ray Tracing CSG Models

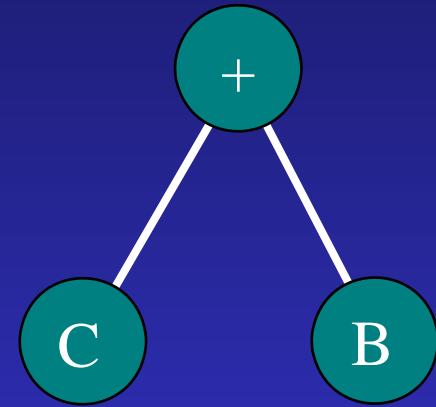


CSG

- Form object as booleans of primitive objects
 - Primitives: sphere, cube, cylinder, cone
 - Boolean operators: union, intersection, difference
- Tree structure used to manage operations
 - Leaf nodes are primitive objects
 - Intermediate nodes specify combination operator



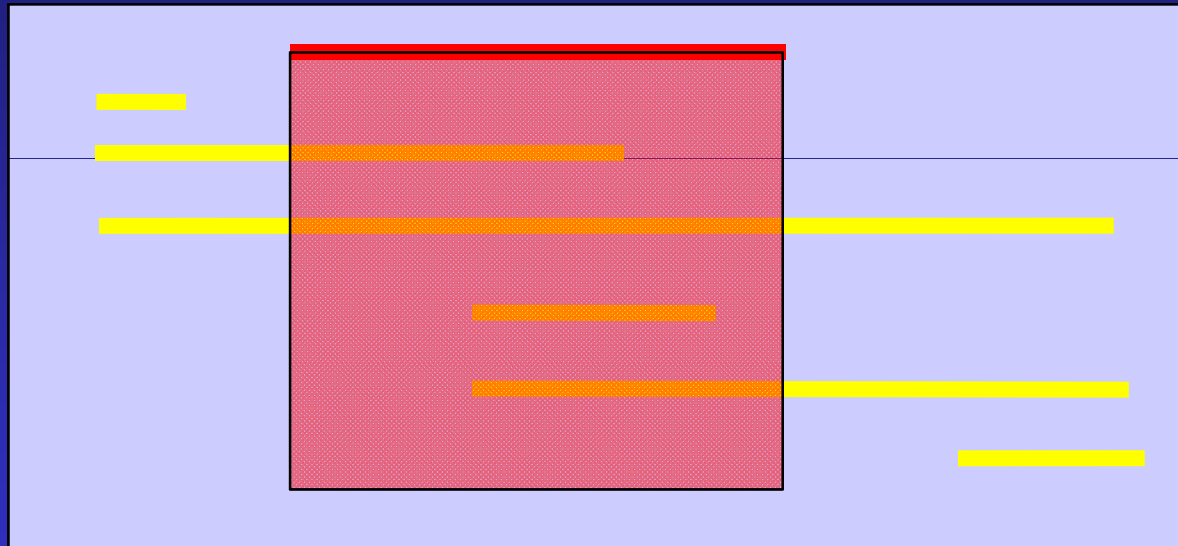
Union



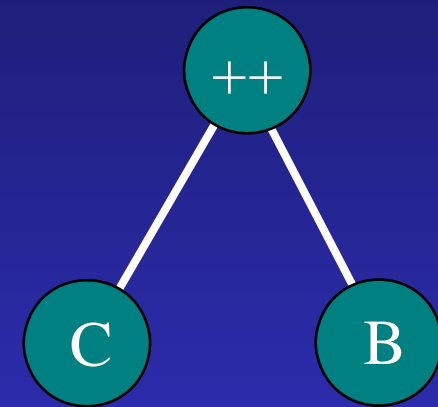
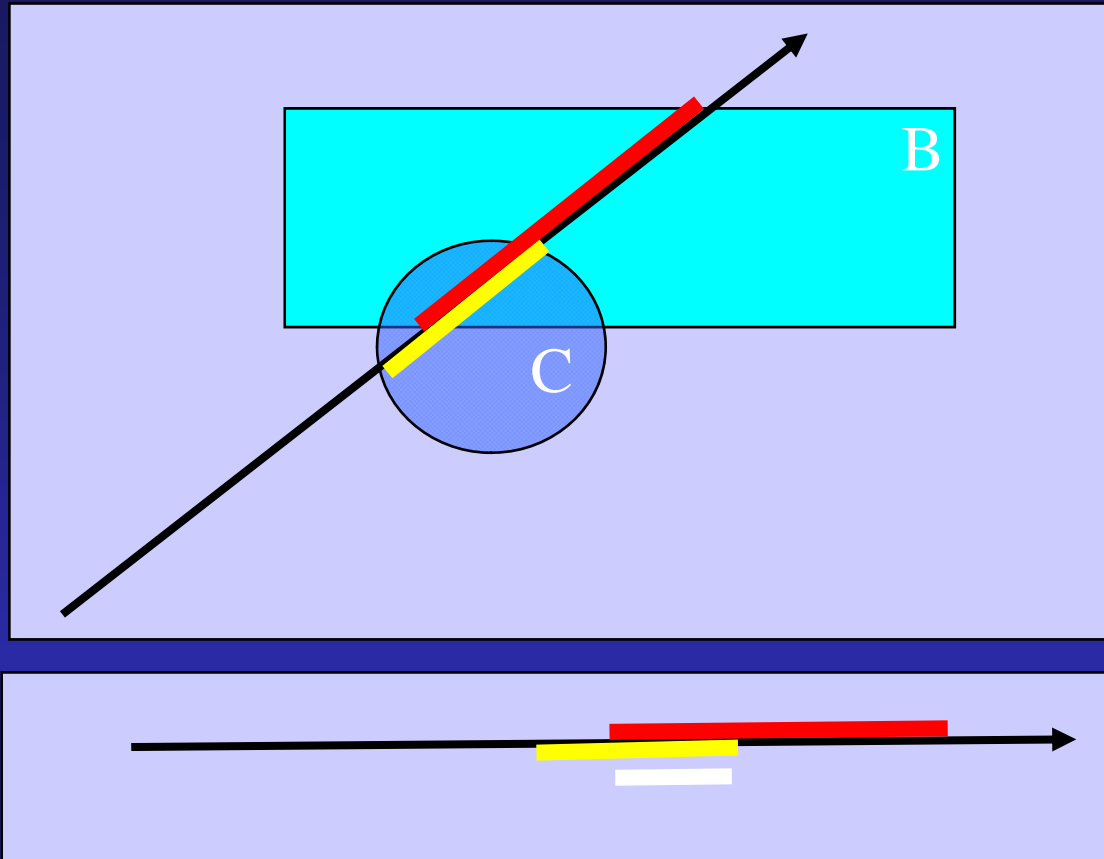
Ray intersects union: at first intersection

$$\text{Min} (t_{\min}^C, t_{\min}^B)$$

Possible ways for 2 spans to overlap



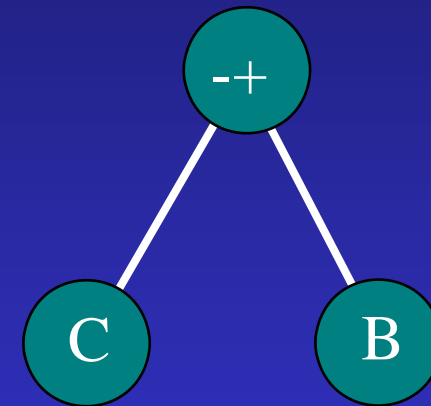
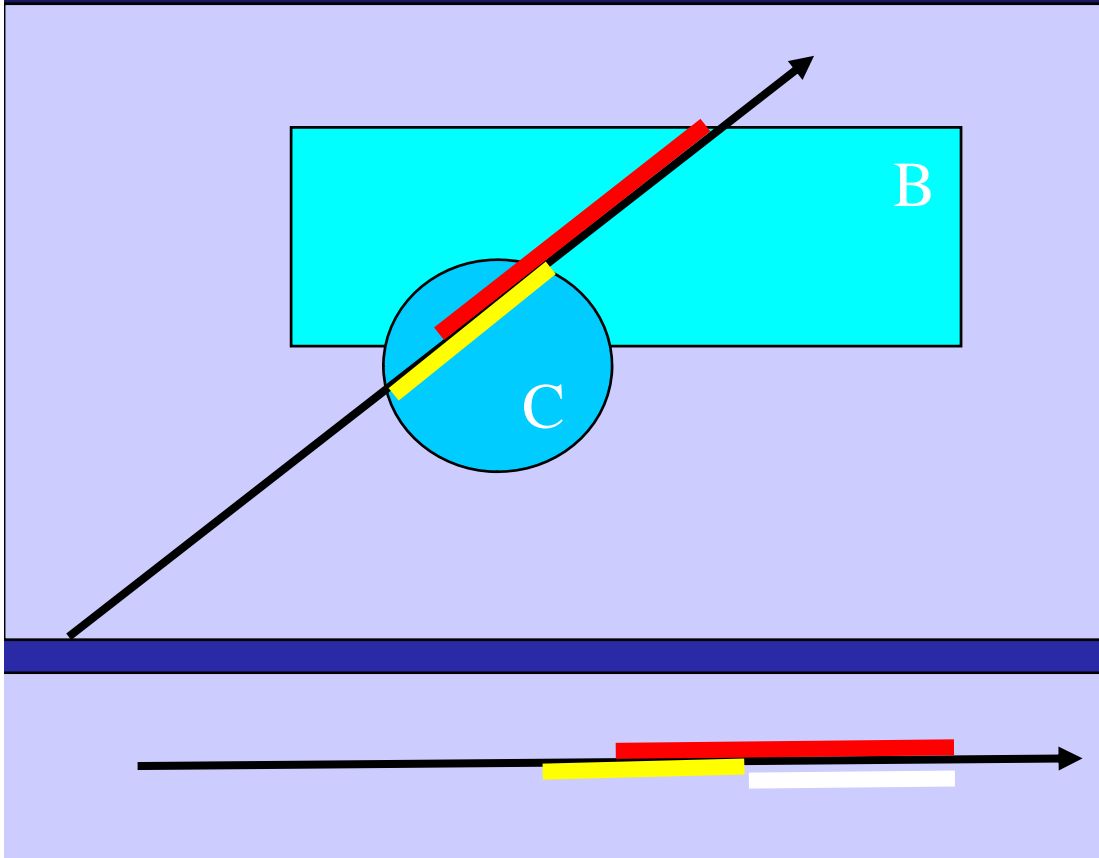
Intersection



First time in B and in C

If $((t_{\min}^C < t_{\min}^B) \text{ and } (t_{\max}^C > t_{\min}^B))$: t_{\min}^B
Else If $((t_{\min}^B < t_{\min}^C) \text{ and } (t_{\max}^B > t_{\min}^C))$: t_{\min}^C
Else: none

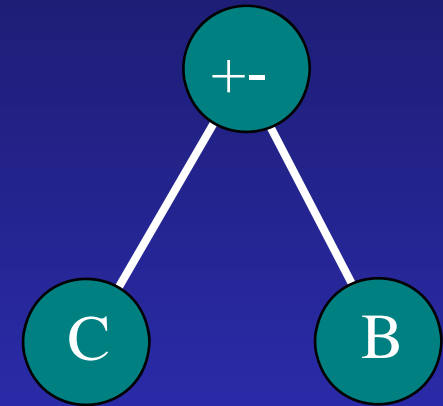
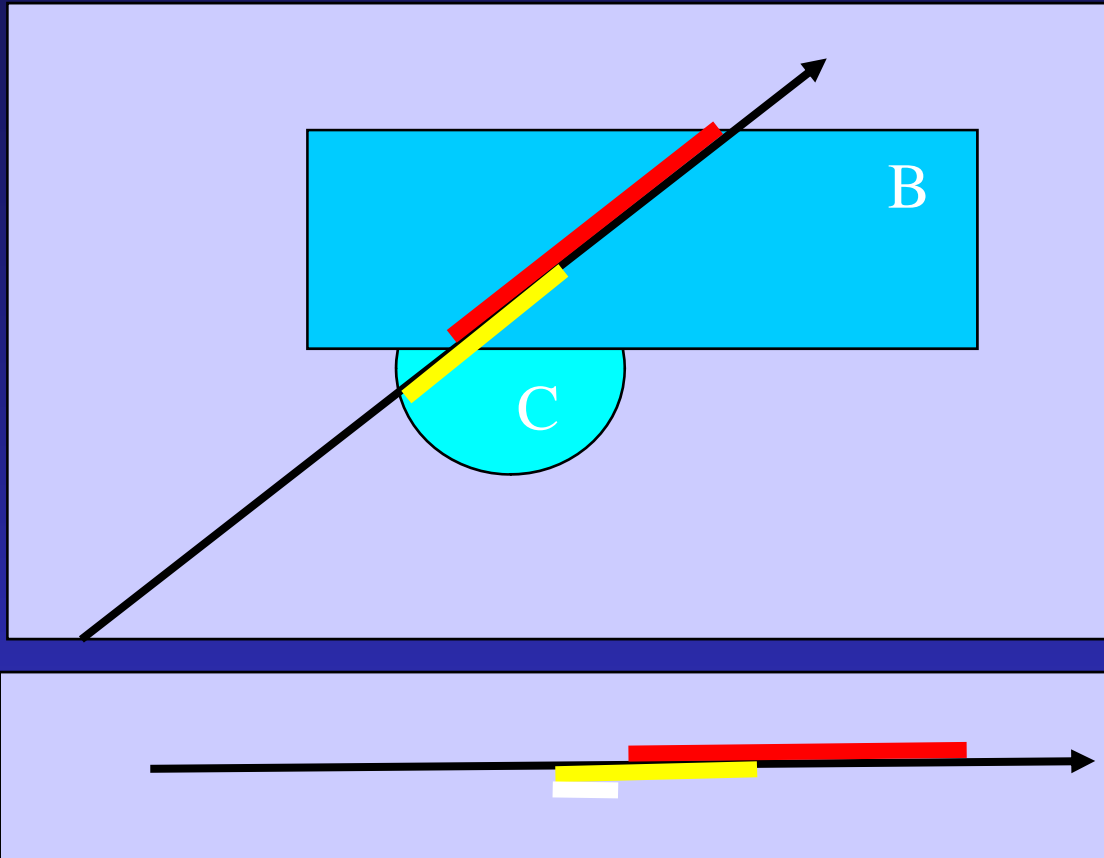
Difference



First time in B not in C

If $(t_{\min}^B < t_{\min}^C)$: t_{\min}^B
Else if $(t_{\max}^C < t_{\max}^B)$: t_{\max}^C
Else: none

Difference



First time in C not in B

If $(t_{\min}^C < t_{\min}^B)$: t_{\min}^C

Else if $(t_{\max}^B < t_{\max}^C)$: t_{\max}^B

Else: none

Primitives

Anything that can be intersected (easily) with a ray

Conics: solve analytically using $R(t)$

Convex polyhedra

A plane (a cutting plane is useful)

can be used as a *modeling tool* (boolean operations)

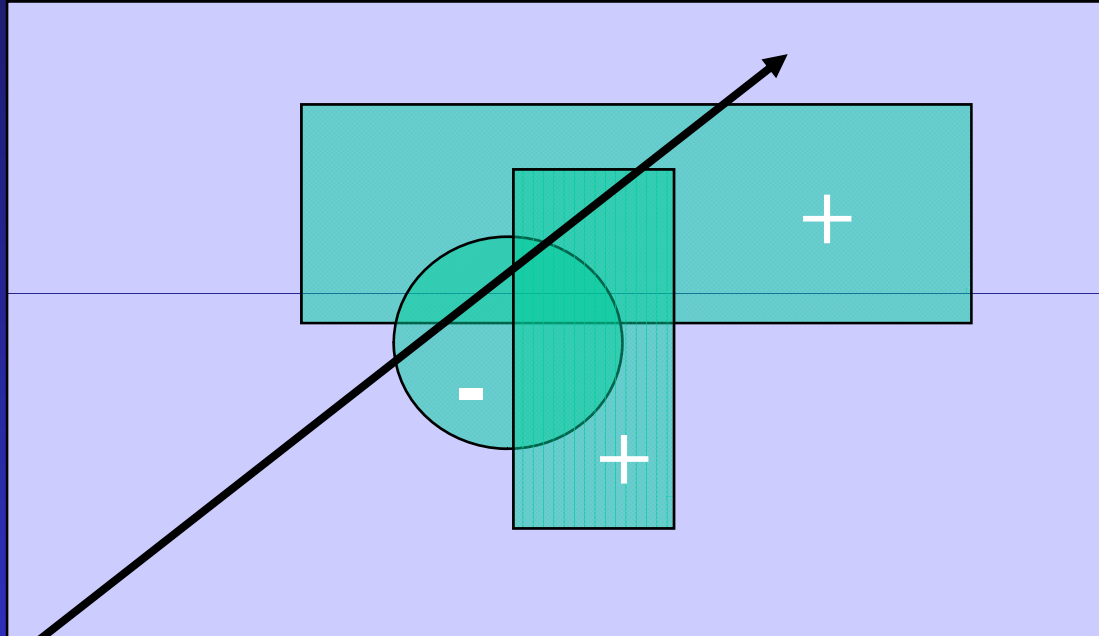
surface model (e.g., polyhedron) computed from CGS

or

Can be used as a model *representation*

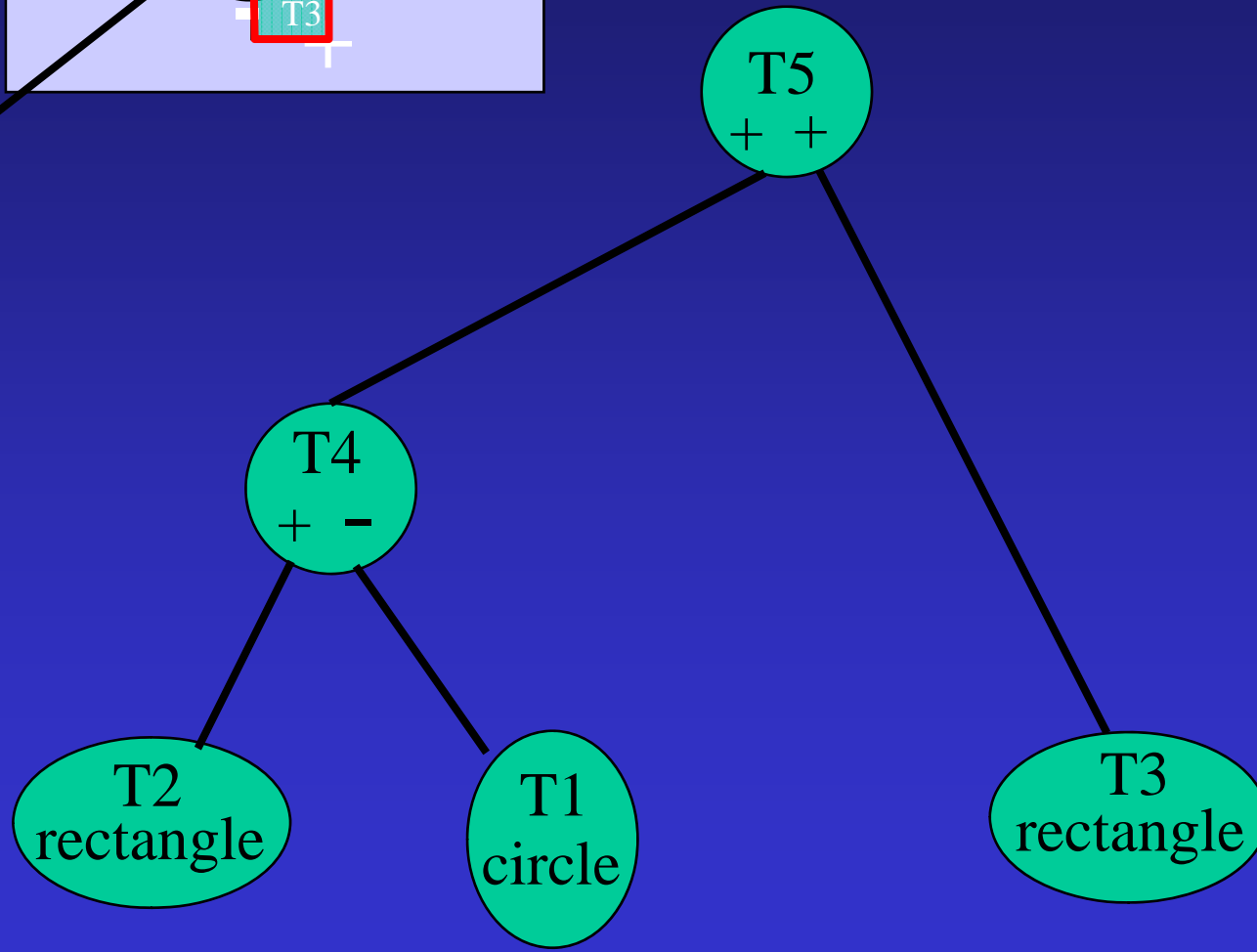
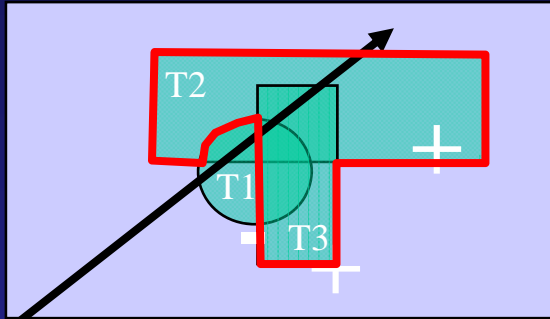
keep tree structure and ray trace directly

Controlling the Combinations

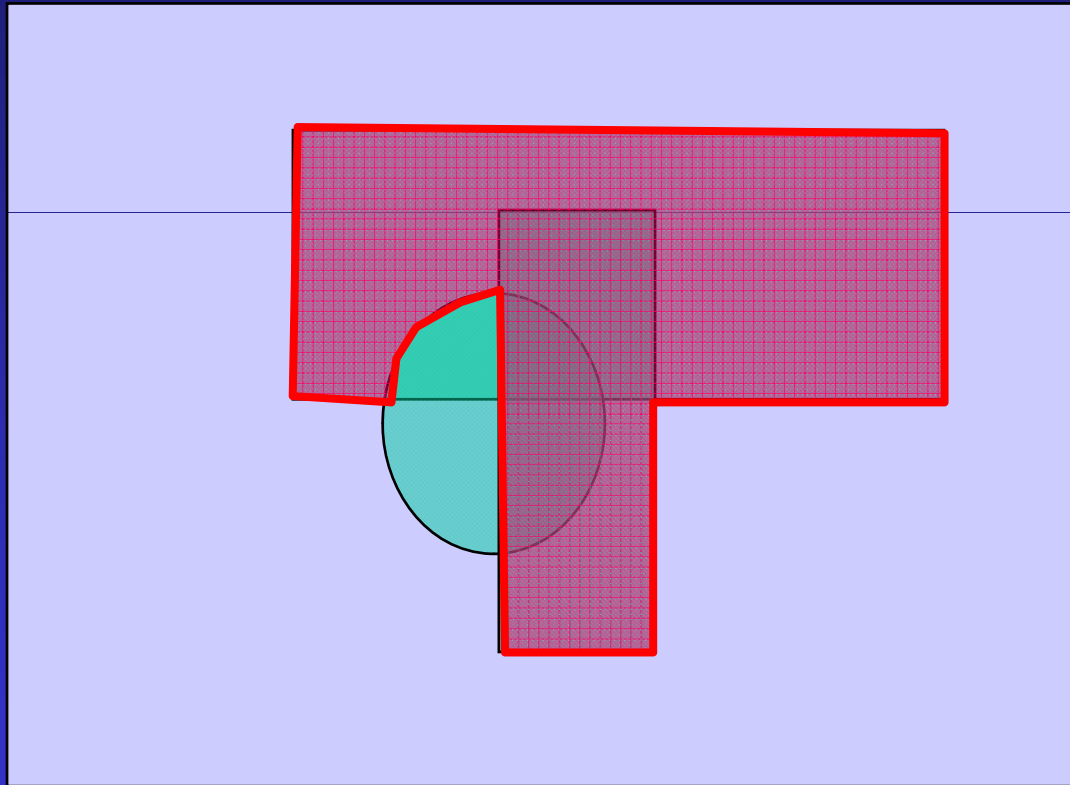


?

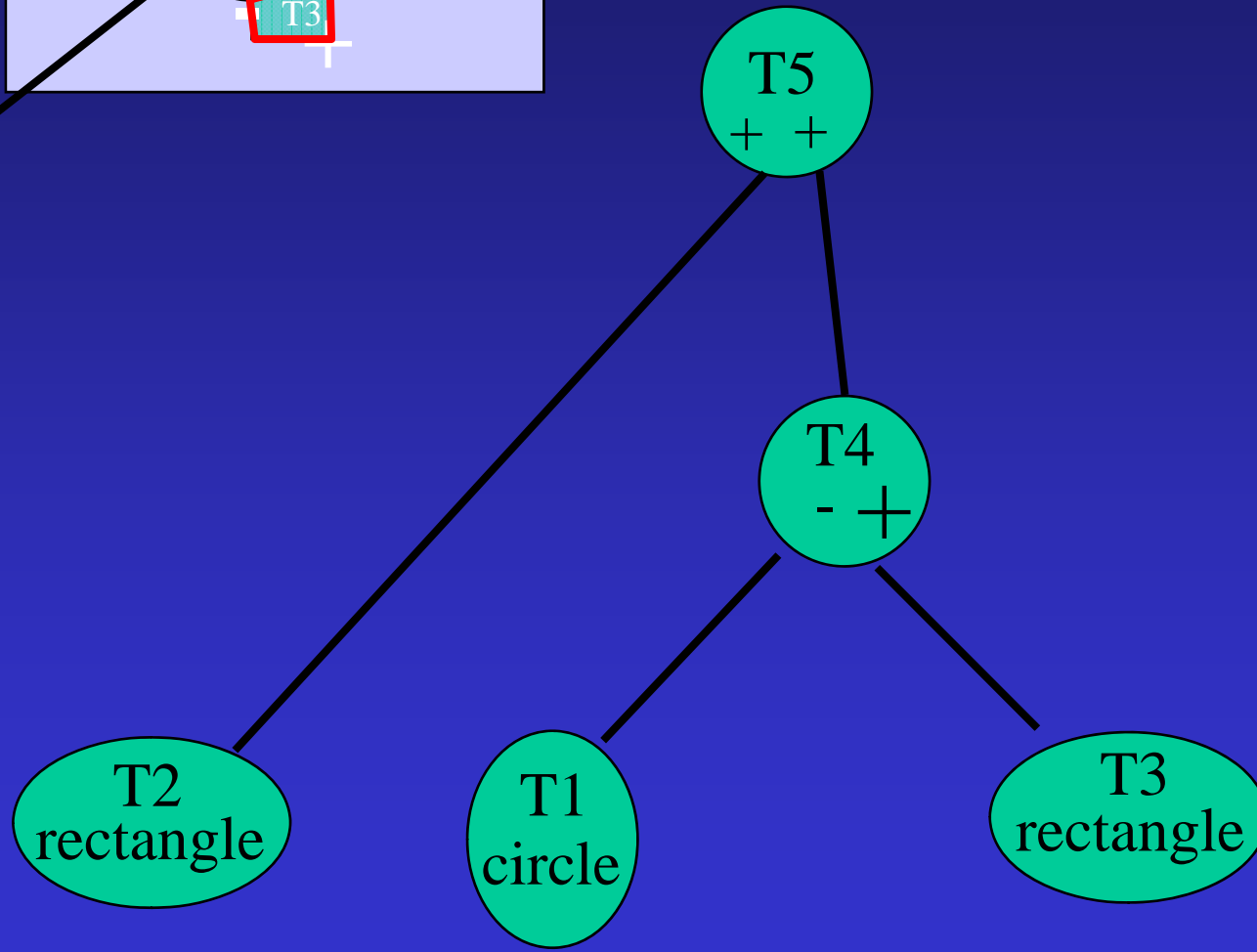
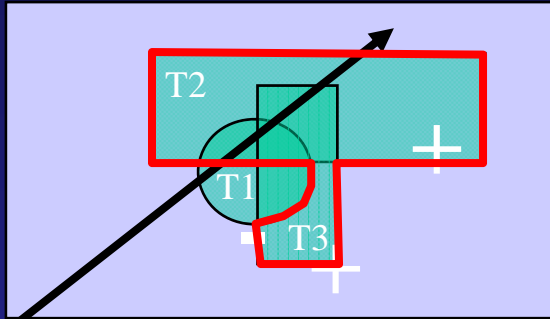
Tree Structure



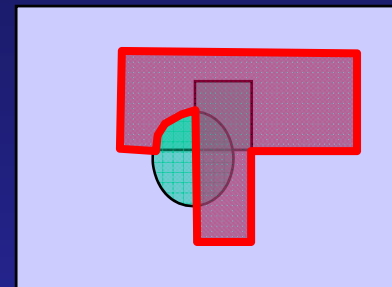
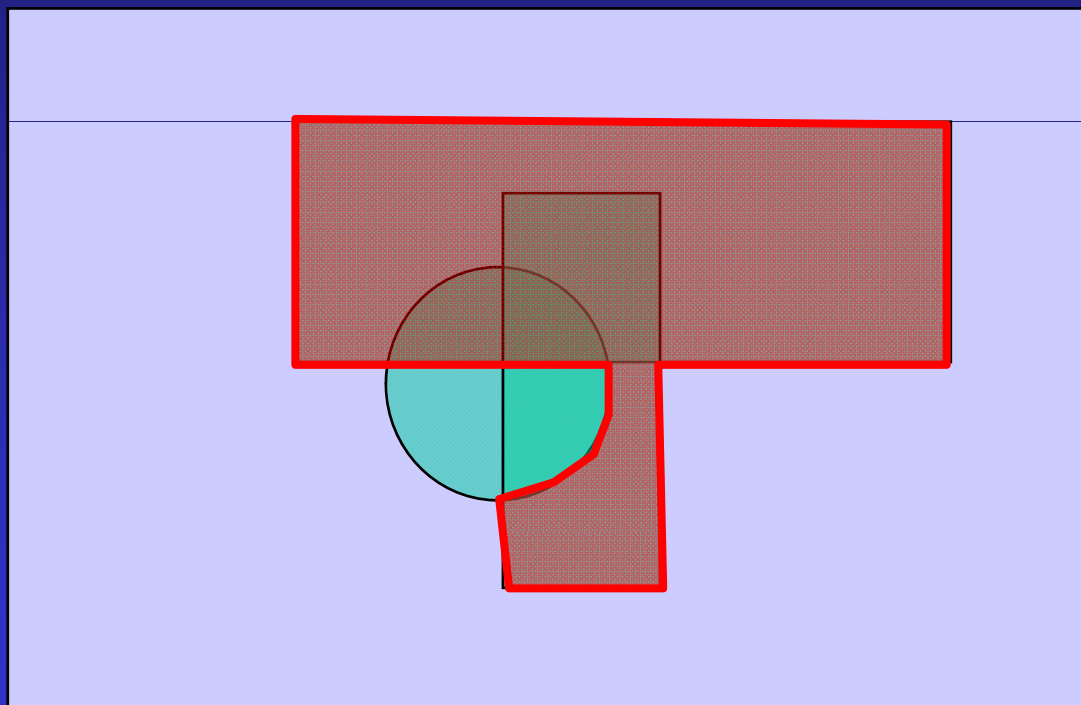
Tree Structure #1



Tree Structure



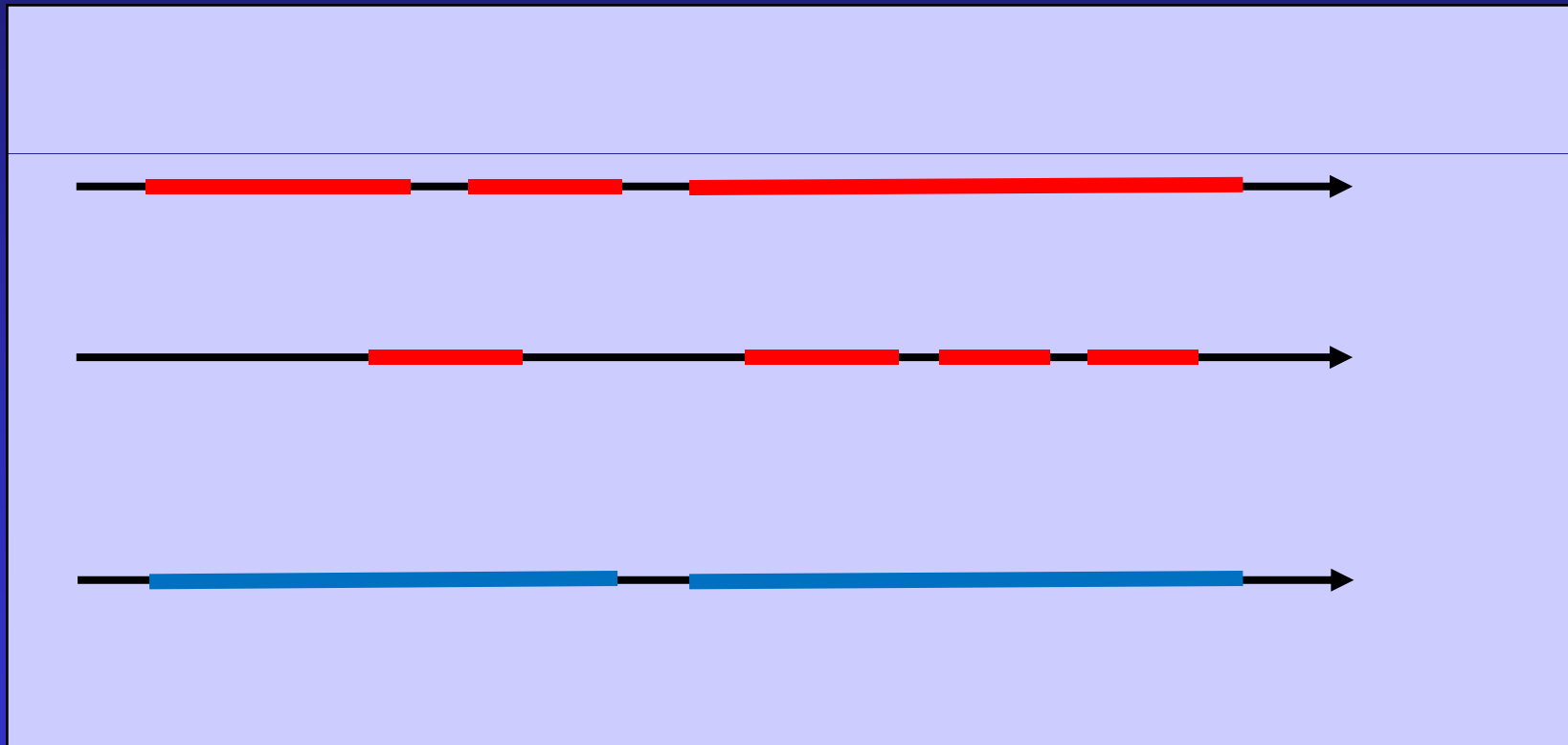
Tree Structure #2



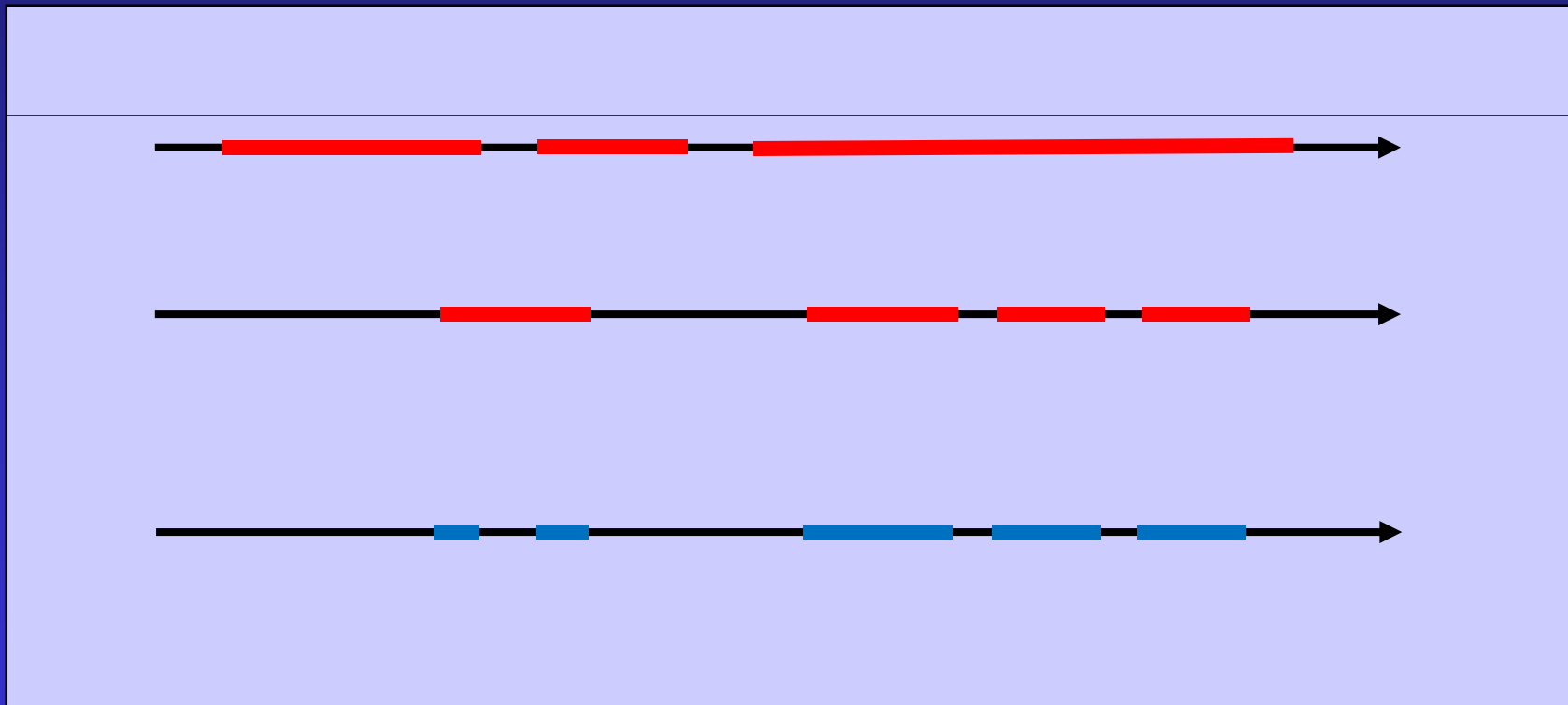
Tree Structure

- Intersect ray with leaf nodes (primitive objects)
- Combine intersection spans according to intermediate nodes
 - union
 - intersection
 - difference
- Might create multiple spans

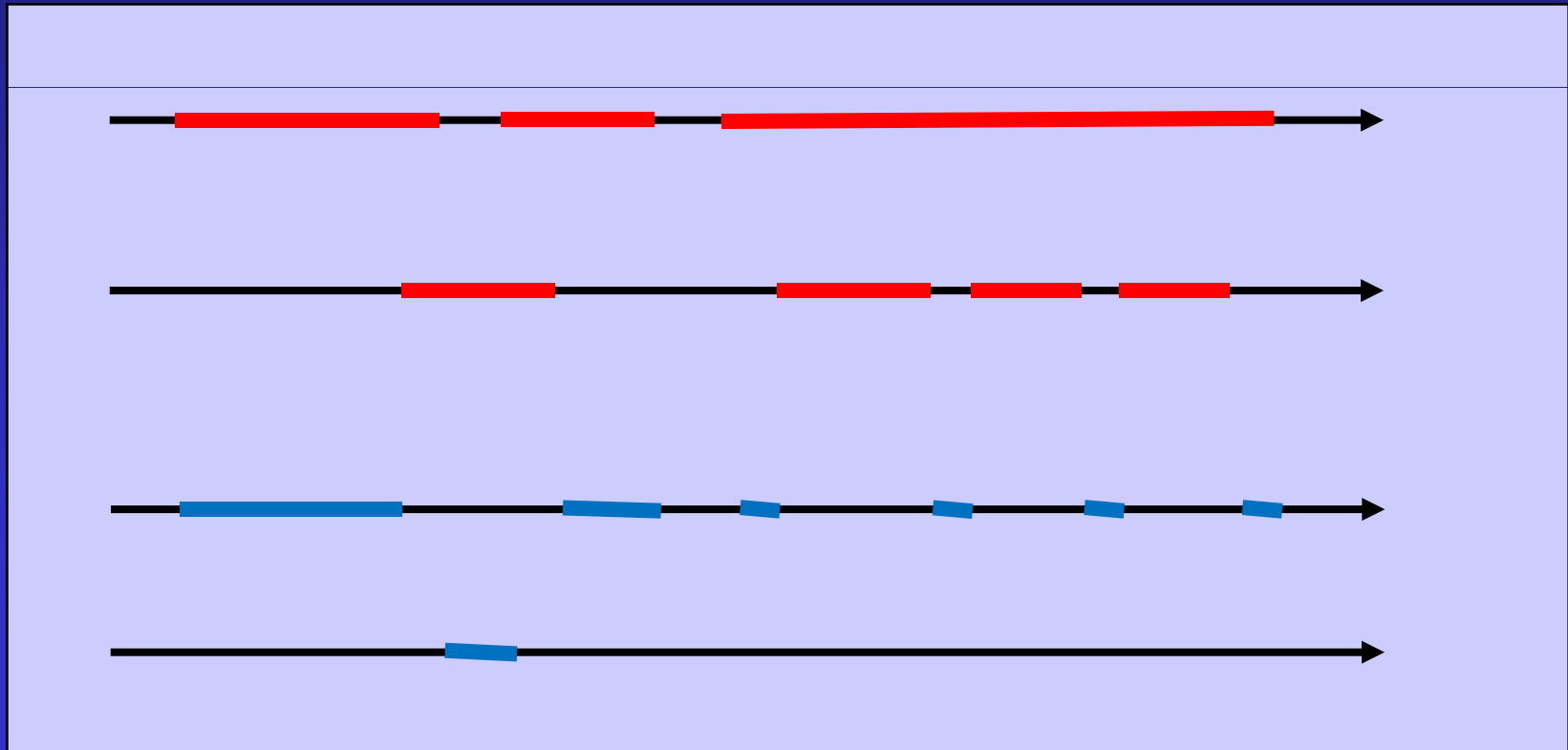
Union of Spans



Intersection of Spans



Difference of Spans



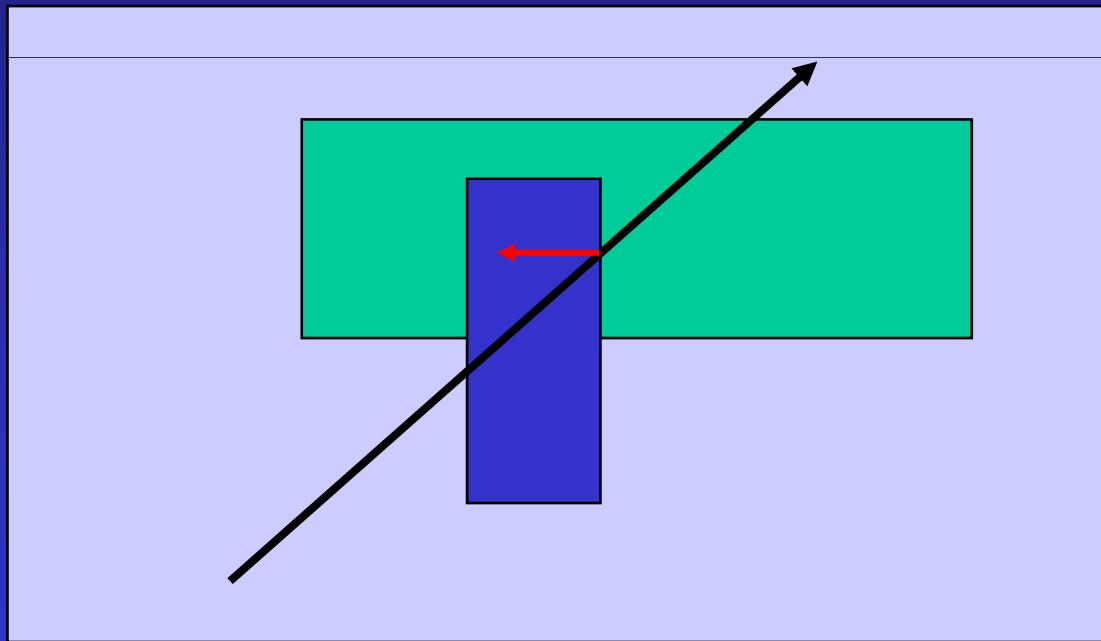
Normals of CSG intersections

Normal of some surface (or its negation)

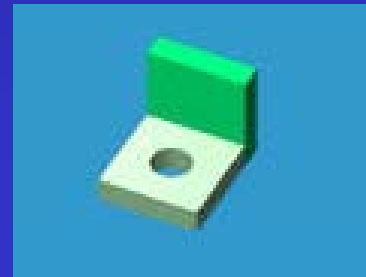
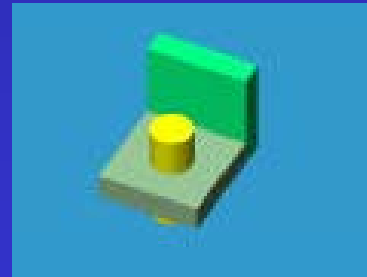
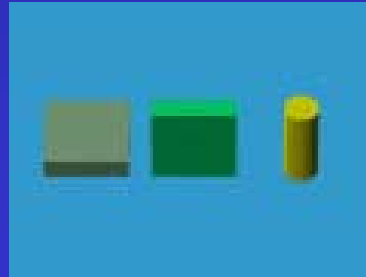
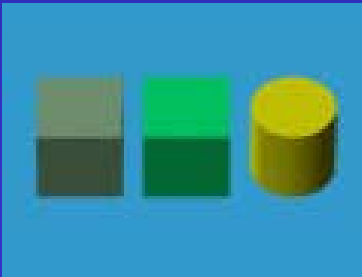
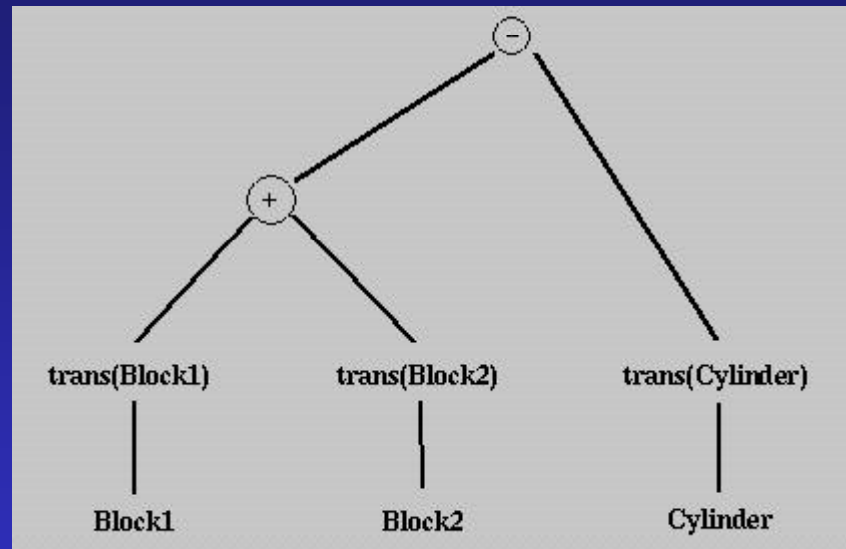
Union or intersection:
positive normal of intersected surface

Difference normals

- Intersection is one of:
 - t_{\min} of positive object – normal of surface
 - t_{\max} of negative object – negated normal



Add transformations to tree



<http://www.cs.mtu.edu/~shene/COURSES/cs3621/NOTES/model/csg.html>

CSE 681

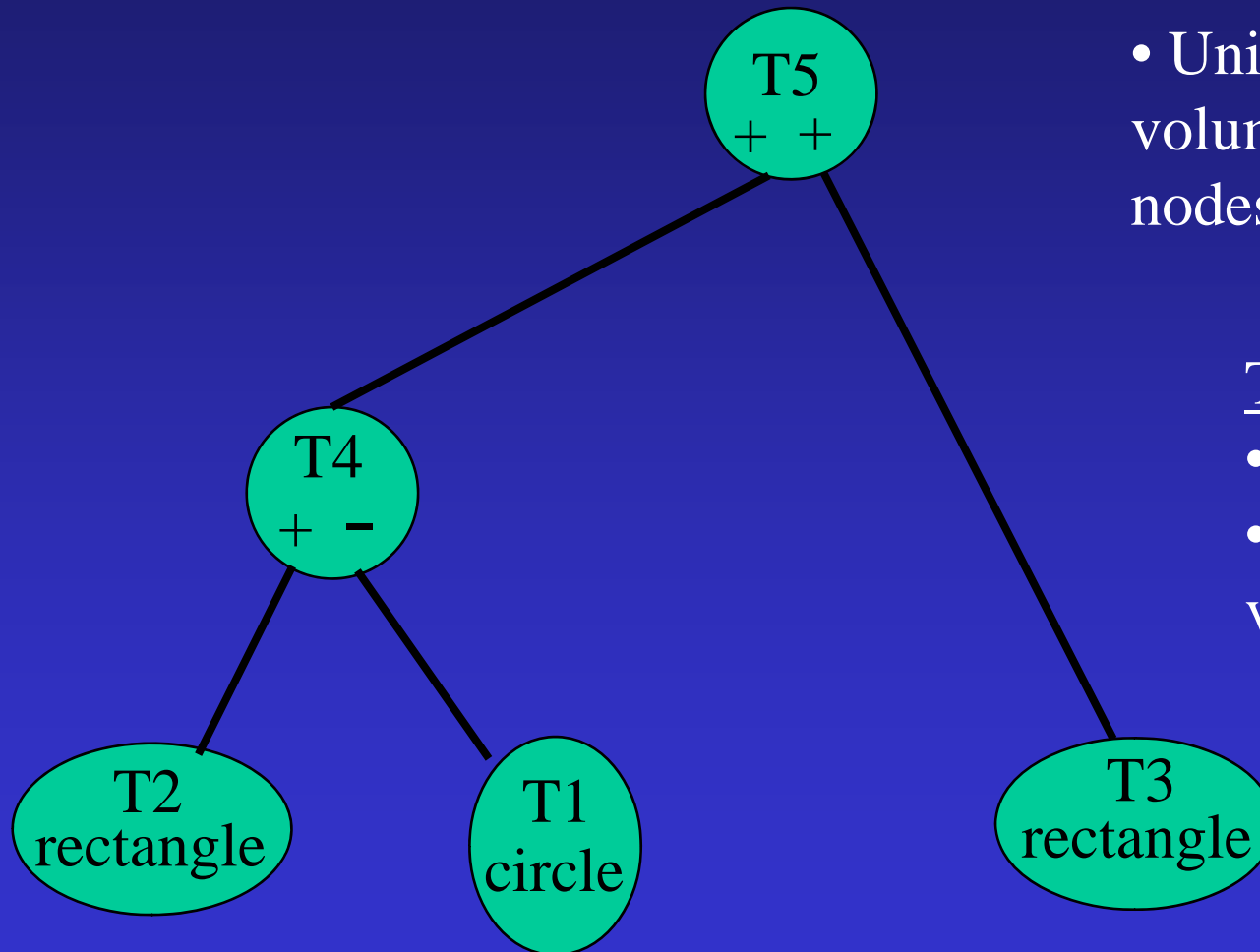
Bounding Volumes

Construction

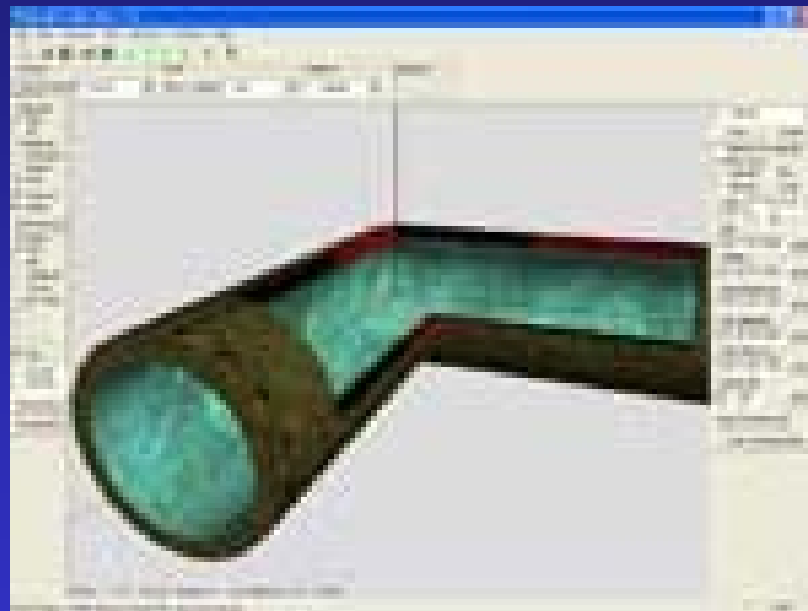
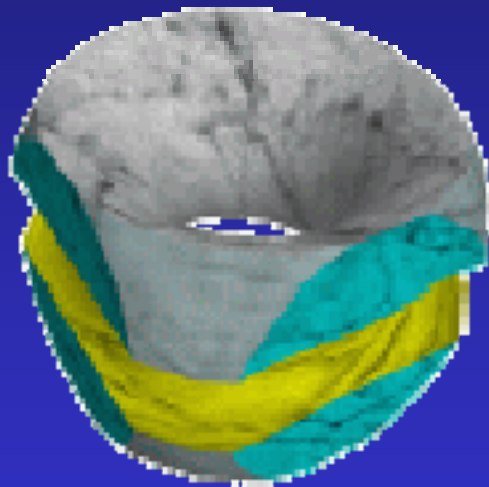
- Use bounding volumes at leaf nodes
- Union bounding volumes at interior nodes

Traversal

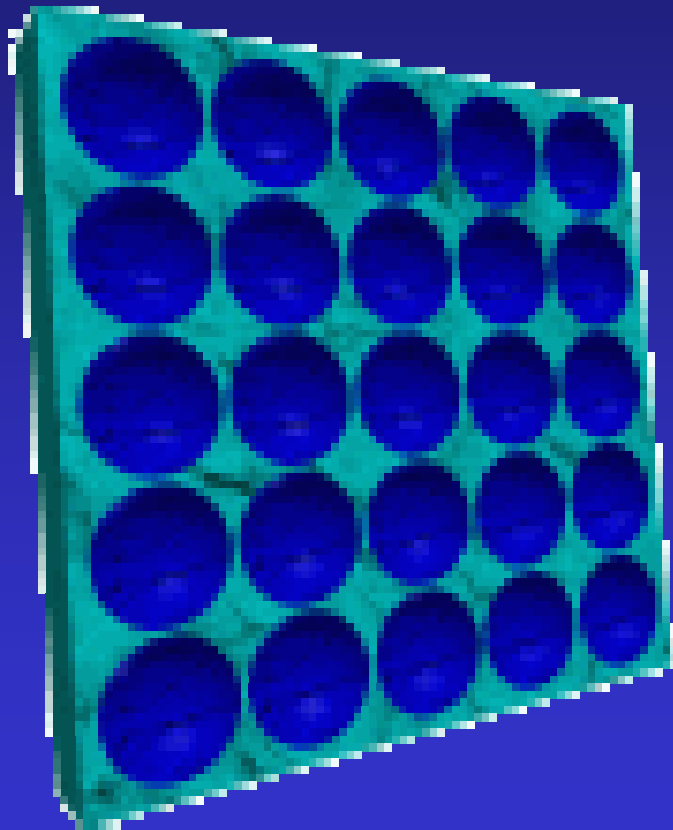
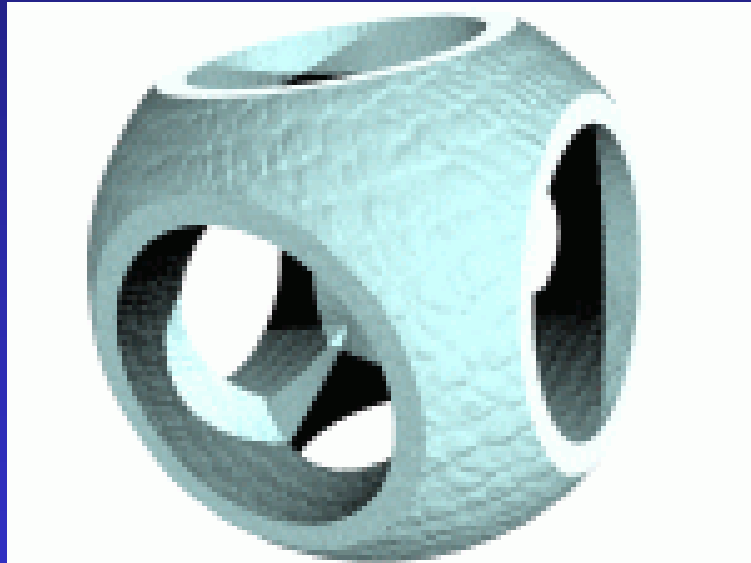
- Top-down
- Test bounding volume at interior



Examples



Examples



Examples

