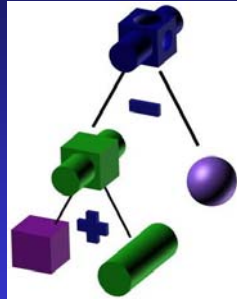


Constructive Solid Geometry

Ray Tracing CSG Models

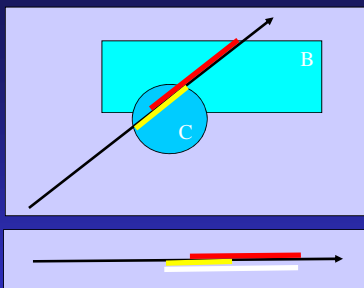


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CSG

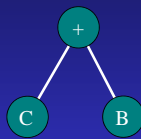
- Form object as booleans of primitive objects
 - Primitives: sphere, cube, cylinder, cone
 - Boolean operators: union, intersection, difference
- Tree structure used to manage operations
 - Leaf nodes are primitive objects
 - Intermediate nodes specify combination operator

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Ray intersects union: at first intersection

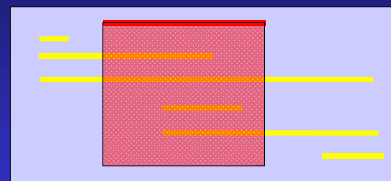
Union



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

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Possible ways for 2 spans to overlap



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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

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Difference

First time in B not in C

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

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Difference

First time in C not in B

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

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Primitives

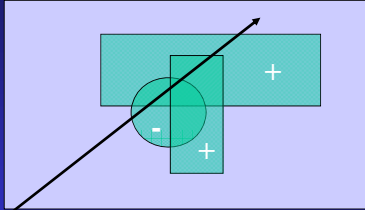
Anything that can be intersected (easily) with a ray

- 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

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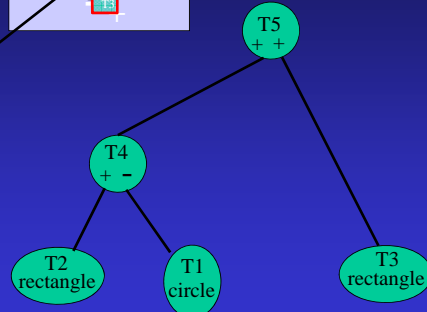
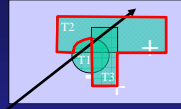
Controlling the Combinations



?

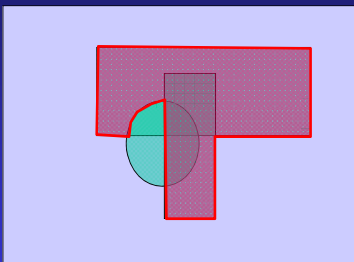
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Tree Structure



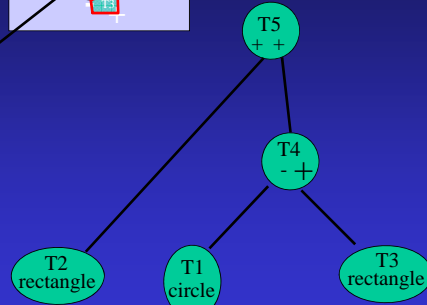
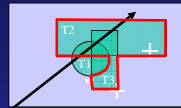
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Tree Structure #1



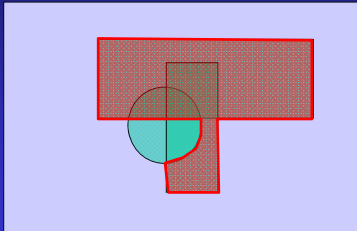
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Tree Structure



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Tree Structure #2



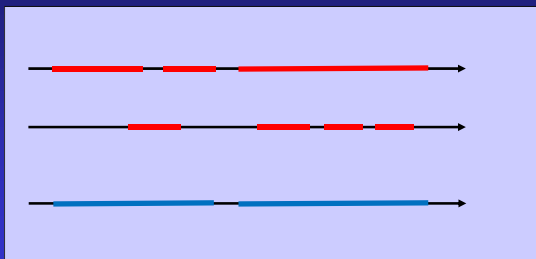
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Tree Structure

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

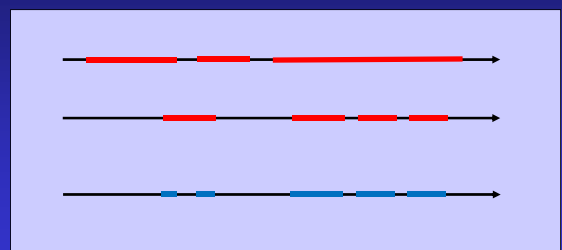
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Union of Spans



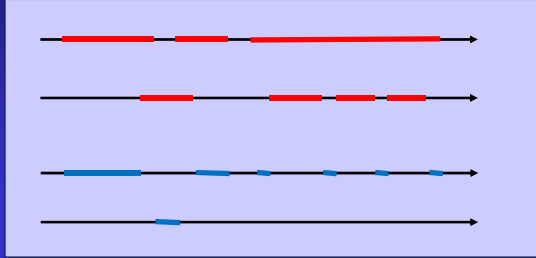
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Intersection of Spans



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Difference of Spans



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Normals of CSG intersections

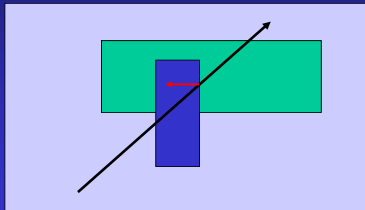
Normal of some surface (or its negation)

Union or intersection:
positive normal of intersected surface

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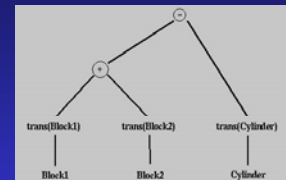
Difference normals

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



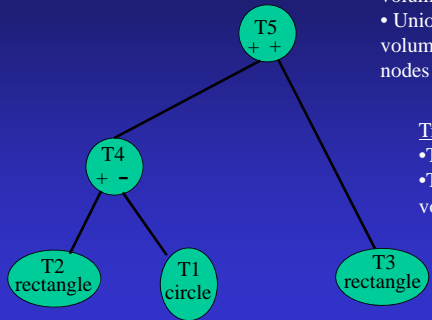
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Add transformations to tree



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



Construction

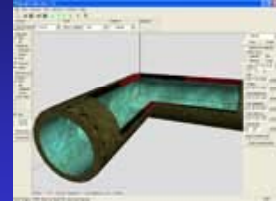
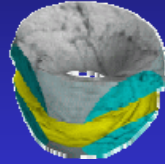
- Use bounding volumes at leaf nodes
- Union bounding volumes at interior nodes

Traversal

- Top-down
- Test bounding volume at interior

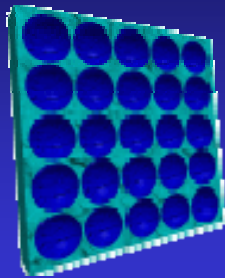
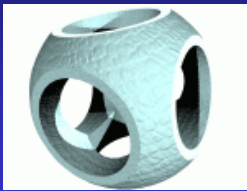
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Examples



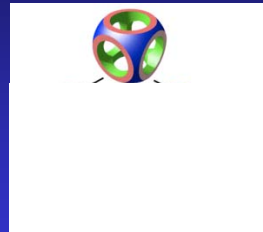
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Examples



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Examples



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