Constructive Solid Geometry

Ray Tracing CSG Models
CSG

- Form object as boolean 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
Ray intersects union: at first intersection

\[ \text{Min } (t^C_{\text{min}}, t^B_{\text{min}}) \]
Possible ways for 2 spans to overlap
First time in B and in C

If \((t_C^{\text{min}} < t_B^{\text{min}}) \text{ and } (t_C^{\text{max}} > t_B^{\text{min}})\):  \(t_B^{\text{min}}\)
Else If \((t_B^{\text{min}} < t_C^{\text{min}}) \text{ and } (t_B^{\text{max}} > t_C^{\text{min}})\):  \(t_C^{\text{min}}\)
Else: none

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First time in B not in C

If $((t^B_{\text{min}} < t^C_{\text{min}}))$: $t^B_{\text{min}}$

Else if $(t^C_{\text{max}} < t^B_{\text{max}})$: $t^C_{\text{max}}$

Else: none
First time in C not in B

If \((t^C_{\text{min}} < t^B_{\text{min}})\): \(t^C_{\text{min}}\)
Else if \((t^B_{\text{max}} < t^C_{\text{max}})\): \(t^B_{\text{max}}\)
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
Controlling the Combinations

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Tree Structure #1
Tree Structure

T5

T4

T2 rectangle

T1 circle

T3 rectangle
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

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Difference normals

• Intersection is one of:
  • $t_{\text{min}}$ of positive object – normal of surface
  • $t_{\text{max}}$ of negative object – negated normal
Add transformations to tree
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
Examples
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