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CS-184: Computer Graphics

Lecture #7: BSP and AABB Trees

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Slides Adapted from: Prof. James O'Brien

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BSP-Trees

- Binary Space Partition Trees
  - Split space along planes
  - Allows fast queries of some spatial relations
- Simple construction algorithm
  - Select a plane as sub-tree root
  - Everything on one side to one child
  - Everything on the other side to other child
  - Use random polygon for splitting plane

BSP-Trees

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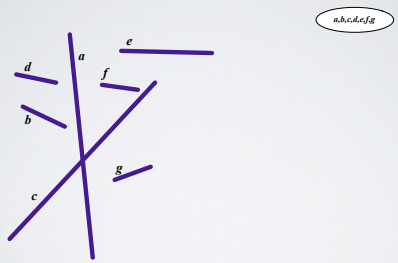
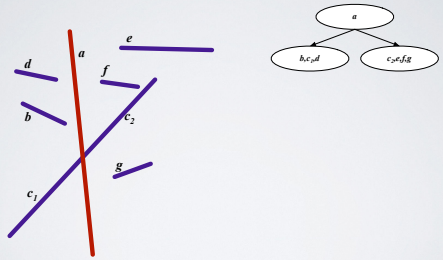


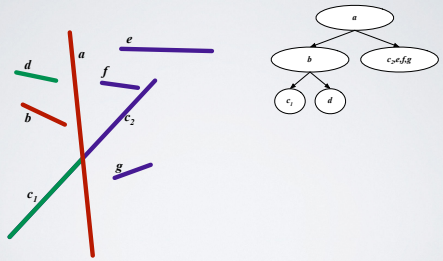
BSP-Trees

4



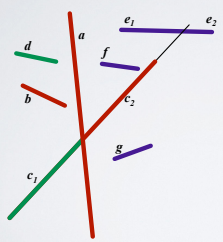
BSP-Trees

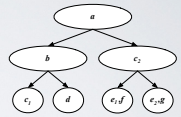
5



BSP-Trees

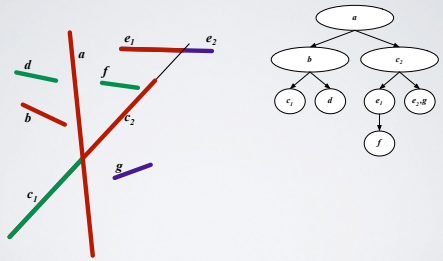
6





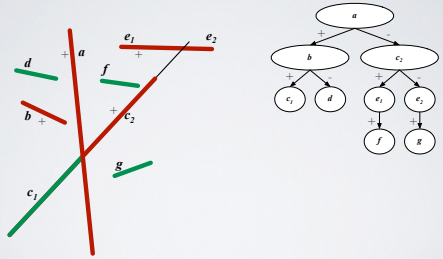
BSP-Trees

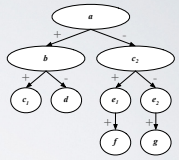
7



BSP-Trees

8





BSP-Trees

- Visibility Traversal
  - Variation of in-order-traversal
    - Child one
    - Sub-tree root
    - Child two
  - Select "child one" based on location of viewpoint
    - Child one on same side of sub-tree root as viewpoint

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BSP-Trees

Let's consider an example…

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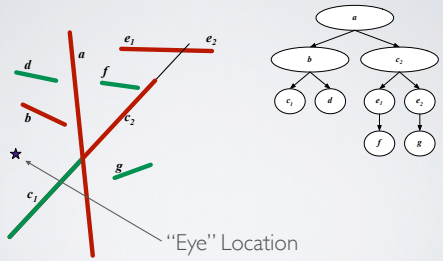
BSP-Trees



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BSP-Trees

A Simple Mechanism:

Perform depth-first search and save nodes when we pop them off the search stack

There are other ways to understand the traversal scheme, but I prefer this one due to its simplicity.

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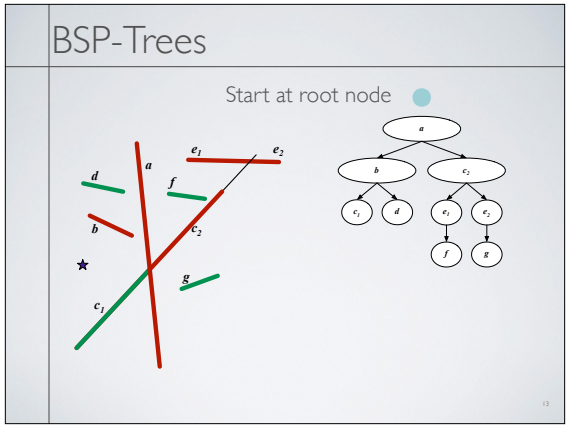
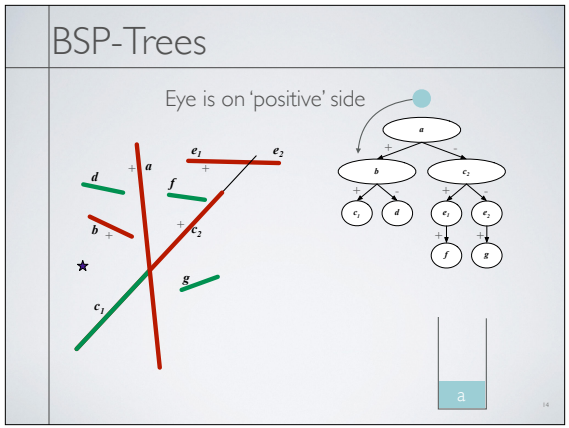
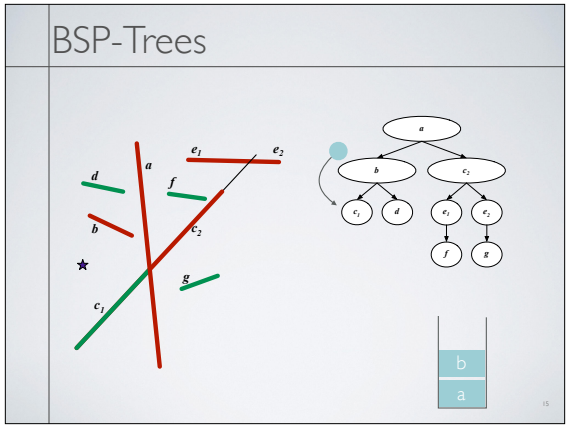

BSP-Trees
Start at root node
a
b
c2
c1
d
e1
e2
f
g

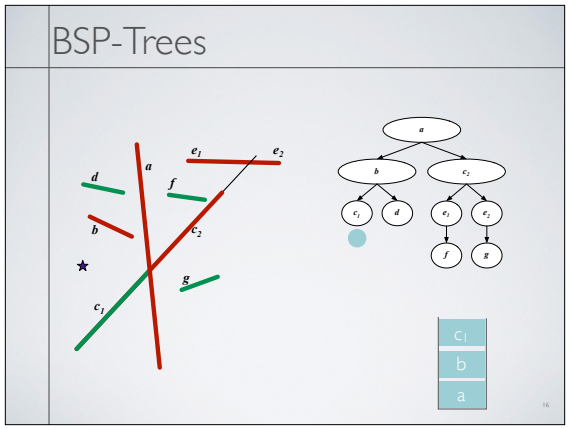
13


BSP-Trees
Eye is on 'positive' side
a
b
c2
c1
d
e1
e2
f
g
a

14


BSP-Trees
a
b
c2
c1
d
e1
e2
f
g
15

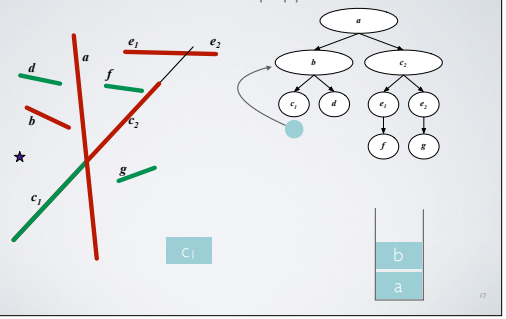
15


BSP-Trees
a
b
c2
c1
d
e1
e2
f
g
c1
b
a
16

16

BSP-Trees

Save nodes in order when popped



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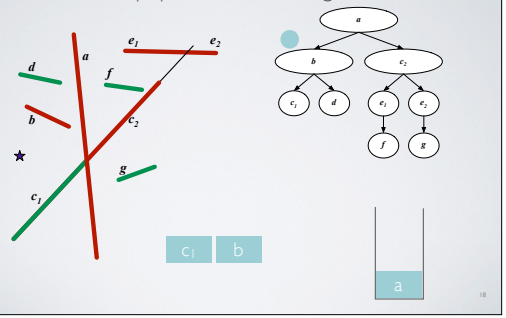
BSP-Trees

Remember to 'pop' before traversing children



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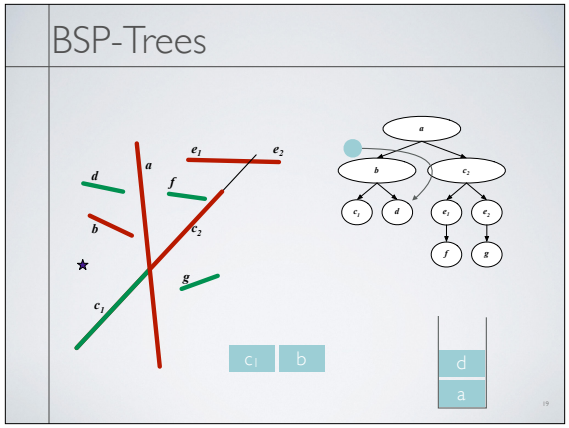
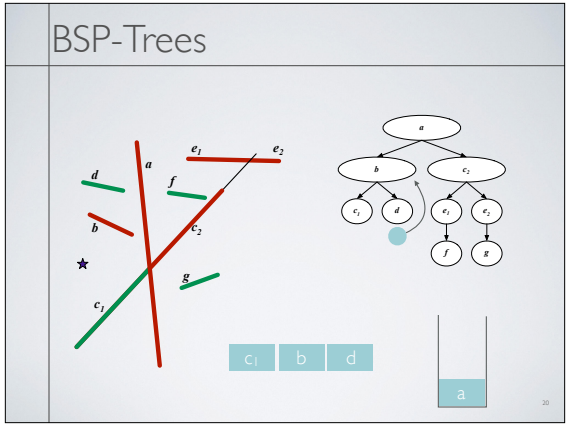
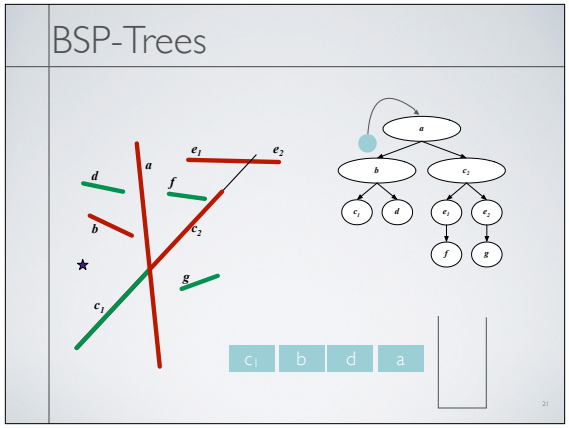

BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1
b
d
a
19

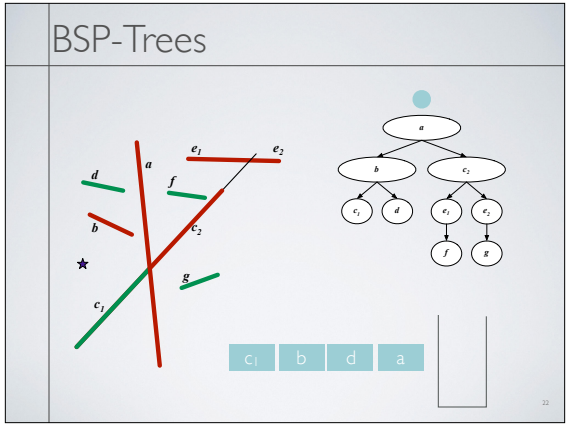
19


BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1
b
d
a
20

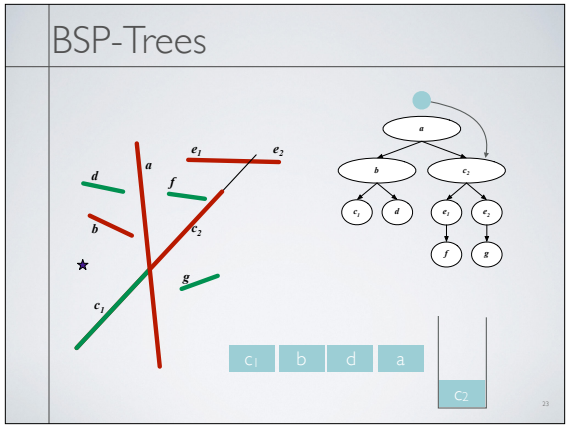
20


BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1
b
d
a

21


BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1
b
d
a

22



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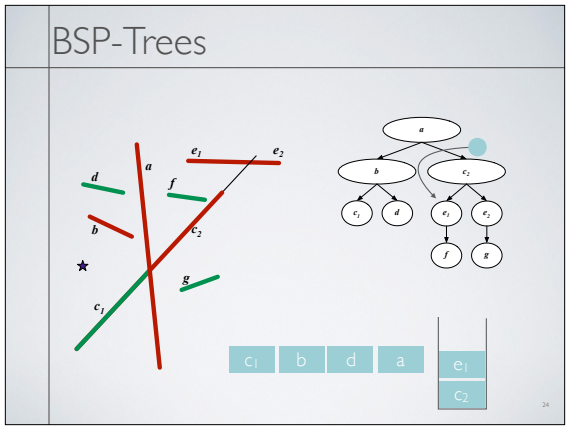

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BSP-Trees

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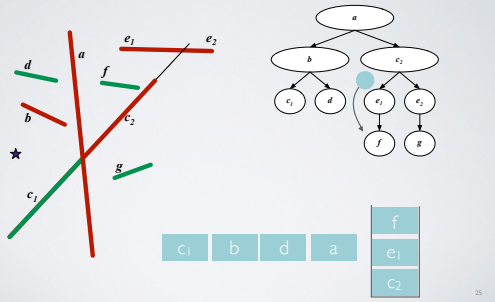

BSP-Trees

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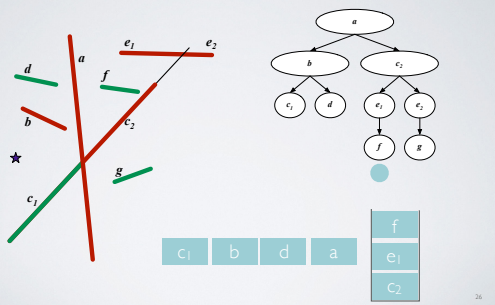

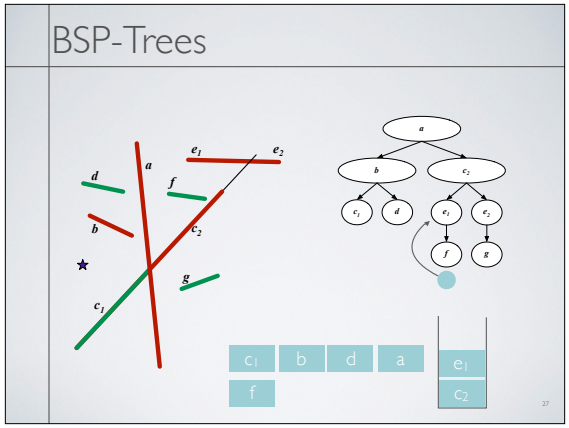

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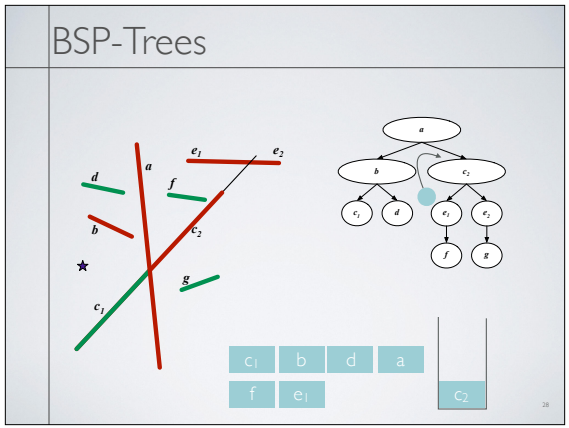

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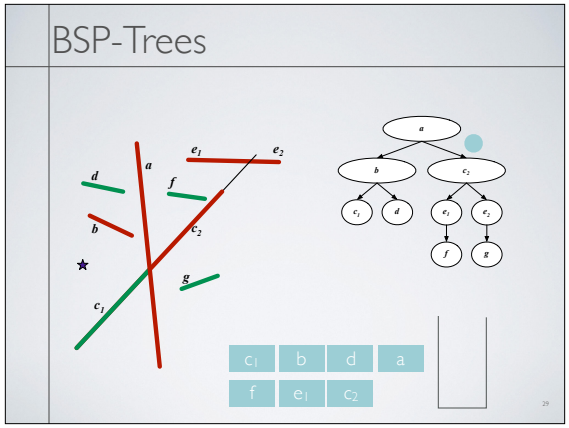

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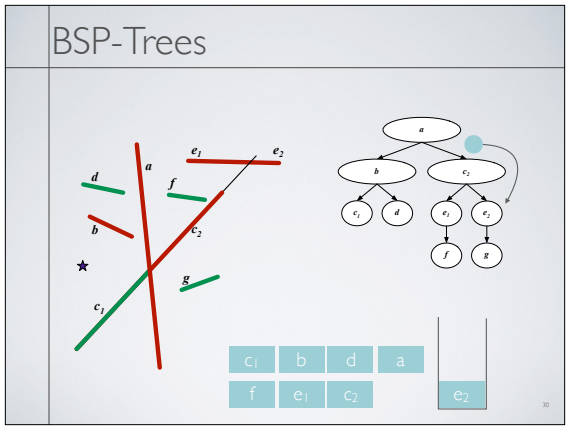

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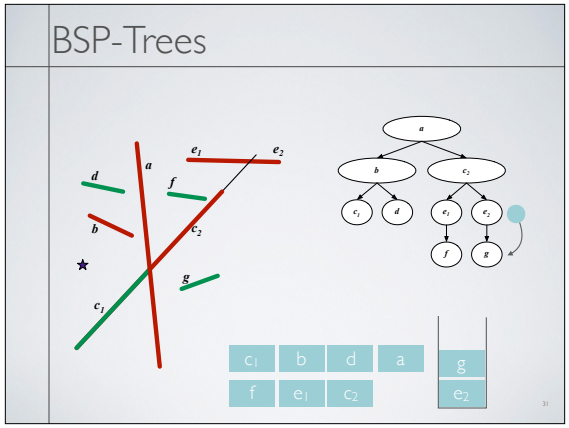
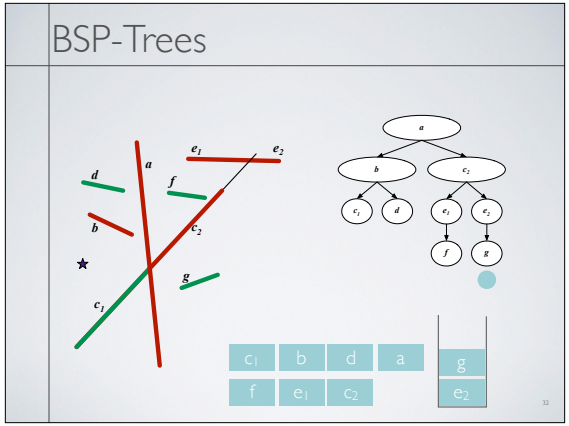
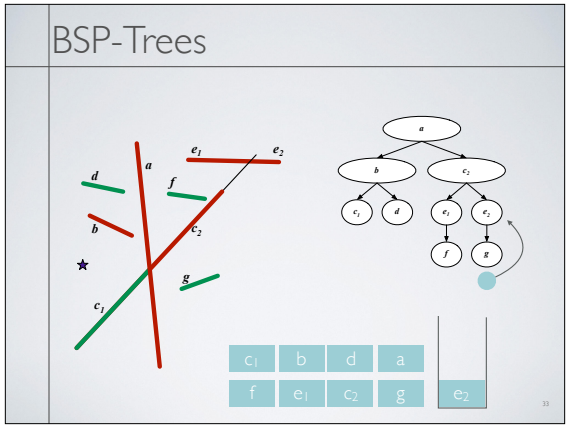

BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1 b d a
f e1 c2
g
e2

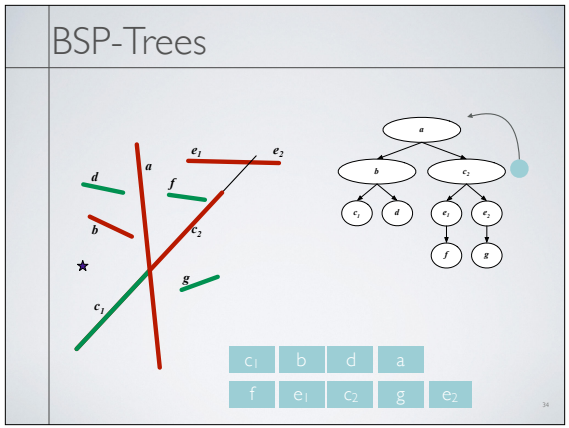
31


BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1 b d a
f e1 c2
g
e2

32


BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1 b d a
f e1 c2 g
e2
33

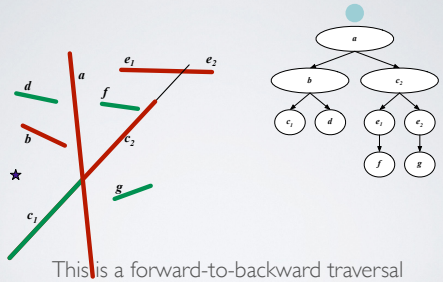
33


BSP-Trees
a
e1
e2
d
f
b
c2
g
c1
c1 b d a
f e1 c2 g e2
34

34

BSP-Trees

35



This is a forward-to-backward traversal

c1 b d a f e1 c2 g e2

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BSP-Trees

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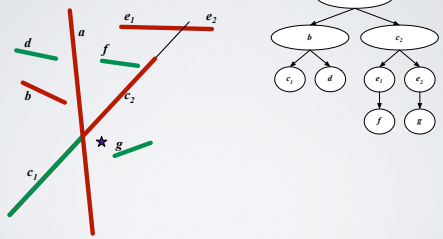

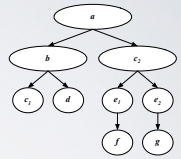

g e2 c2 f e1 a c1 b d

36

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On to another useful space partition…

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Your Ray Tracer

```
RayTrace(image)
   For ray in camera
     image[pixel] = Trace(ray)
Trace(ray)
     t_hit = infinity
     For object in scene
       t_hit = min(object.intersect(ray), t_hit)
     shade at t_hit
     possible calls to Trace(new_ray)
```

Your Ray Tracer

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```
RayTrace(image)
   For ray in camera
     image[pixel] = Trace(ray)
Trace(ray)
     t_hit = infinity
     For object in scene
       t_hit = min(object.intersect(ray), t_hit)
     shade at t_hit
     possible calls to Trace(new_ray)
```

Your Ray Tracer

40

```
RayTrace(image)
   For ray in camera
     image[pixel] = Trace(ray)
Trace(ray)
     t_hit = infinity
     For object in scene
       t_hit = min(object.intersect(ray), t_hit)
     shade at t_hit
     possible calls to Trace(new_ray)
```

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That's a lot of monkeys to test

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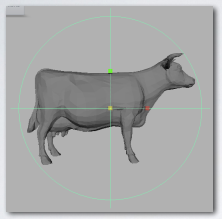
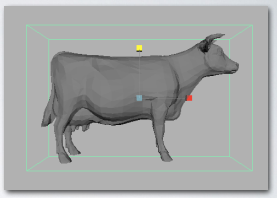
Bounding Shapes





- Bounding shape completely encloses associated object
- Rays cannot hit object w/o intersecting bounding shape
- Two objects cannot collide if shapes don't overlap
- Tradeoff: Simplicity -vs- tightness

Axis-Aligned Bounding Boxes

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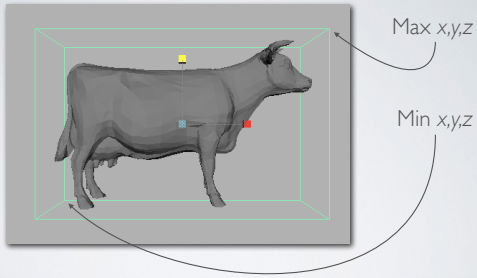

- Axis-aligned bounding box defined by min and max *x,y,z*

Axis-Aligned Bounding Boxes

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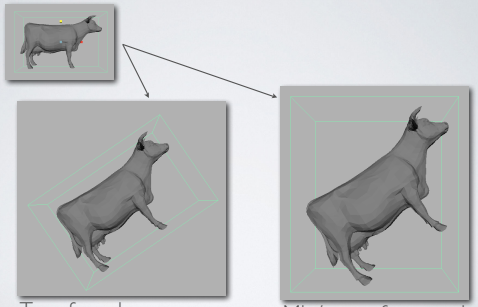

Transform box
Not axis-aligned

Min/max of new points
Linear cost to compute

Axis-Aligned Bounding Boxes

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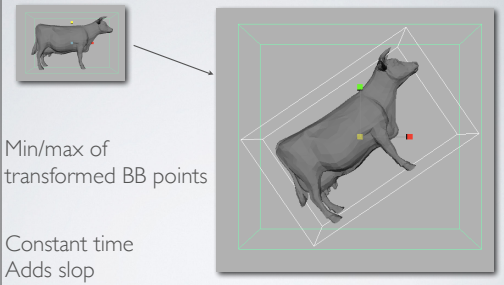

Min/max of
transformed BB points

Constant time
Adds slop
Cumulative slop if multiple transforms occur sequentially

Why would we do this?

Tightness

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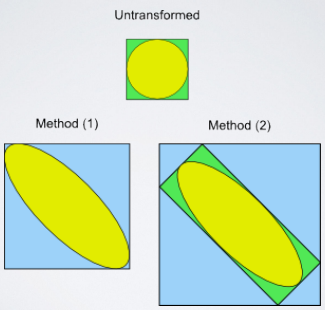

Box Intersection

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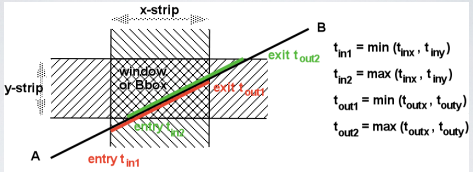

$t_{in1} = \min(t_{inx}, t_{iny})$

$t_{in2} = \max(t_{inx}, t_{iny})$

$t_{out1} = \min(t_{outx}, t_{outy})$

$t_{out2} = \max(t_{outx}, t_{outy})$

Line goes through window/Bbox if intervals overlap

Bounding Box of Bounding Boxes

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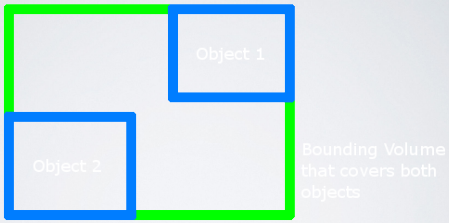

AABB Trees

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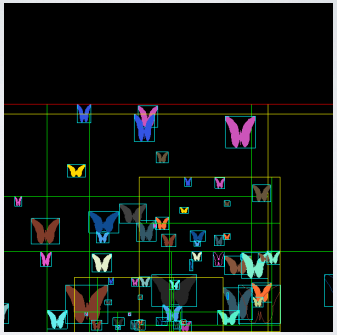

AABB Trees

One of many variations

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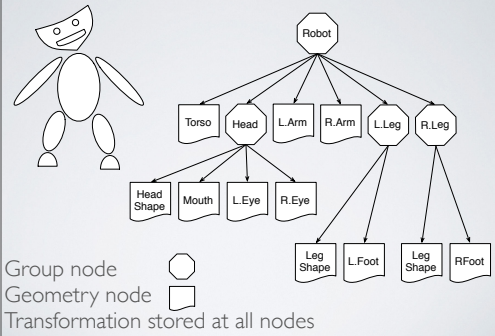
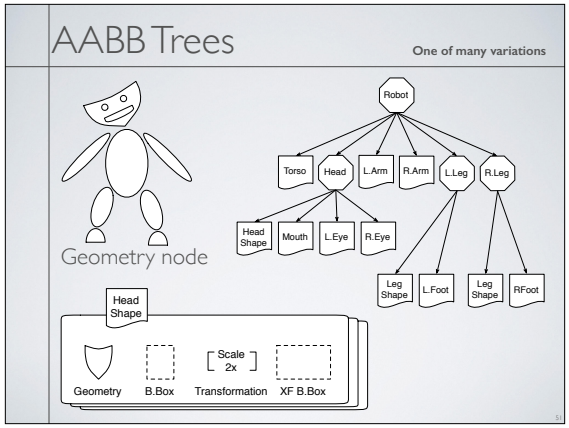
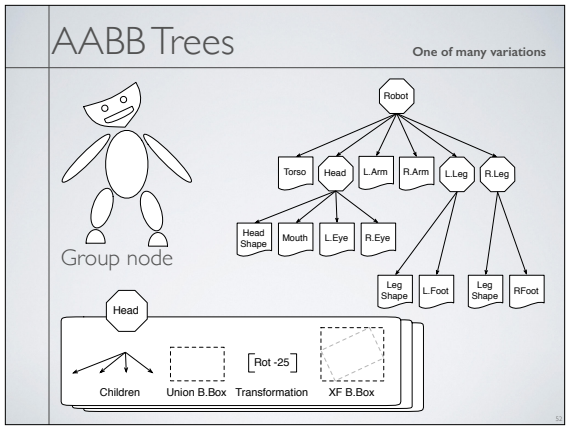


Group node
Geometry node
Transformation stored at all nodes


AABB Trees
One of many variations
Robot
Torso
Head
L.Arm
R.Arm
L.Leg
R.Leg
Head Shape
Mouth
L.Eye
R.Eye
Leg Shape
L.Foot
Leg Shape
RFoot
Geometry node
Head Shape
Scale 2x
Geometry
B.Box
Transformation
XF B.Box

51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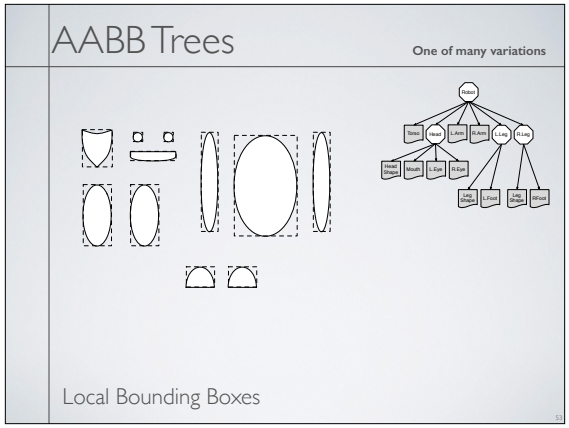
R.Arm
L.Leg
R.Leg
Head Shape
Mouth
L.Eye
R.Eye
Leg Shape
L.Foot
Leg Shape
RFoot
Group node
Head
Rot -25
Children
Union B.Box
Transformation
XF B.Box

52


AABB Trees
One of many variations
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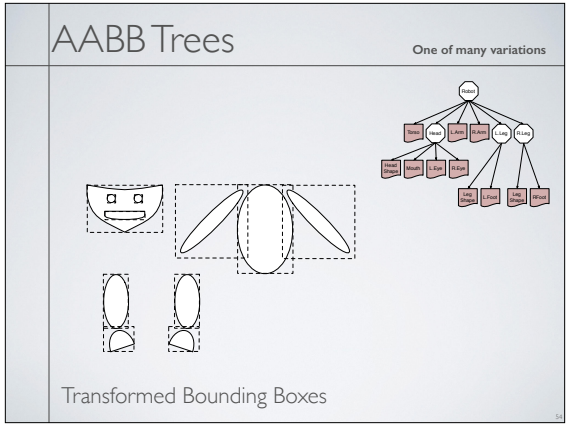
Torso
Head
L Arm
R Arm
L Leg
R Leg
Head Shape
Mouth
L Eye
R Eye
Leg Shape
L Foot
Leg Shape
R Foot
Local Bounding Boxes
53

53


AABB Trees
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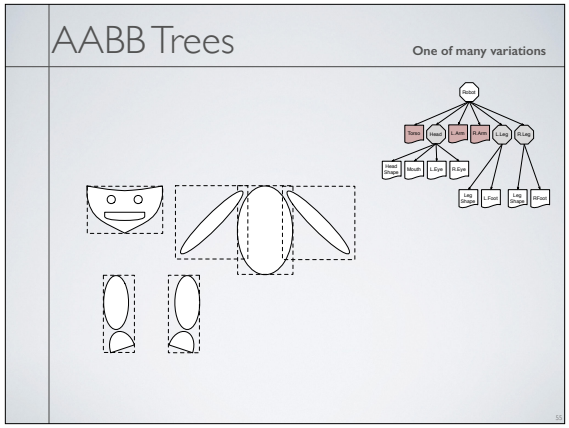
Torso
Head
L Arm
R Arm
L Leg
R Leg
Head Shape
Mouth
L Eye
R Eye
Leg Shape
L Foot
Leg Shape
R Foot
Transformed Bounding Boxes
54

54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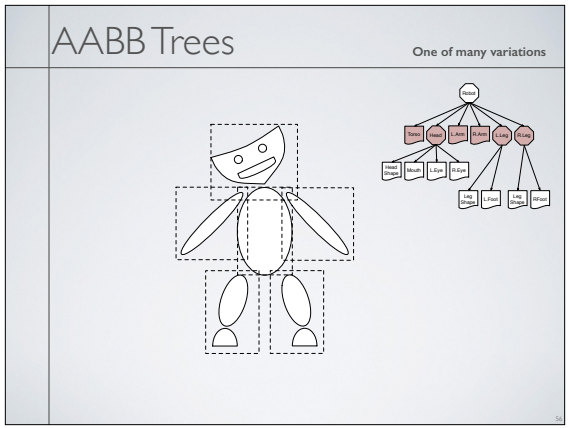
R-Arm
L-Leg
R-Leg
Head Shape
Mouth
L-Eye
R-Eye
Leg Shape
L-Foot
Leg Shape
R-Foot
55

55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R-Leg
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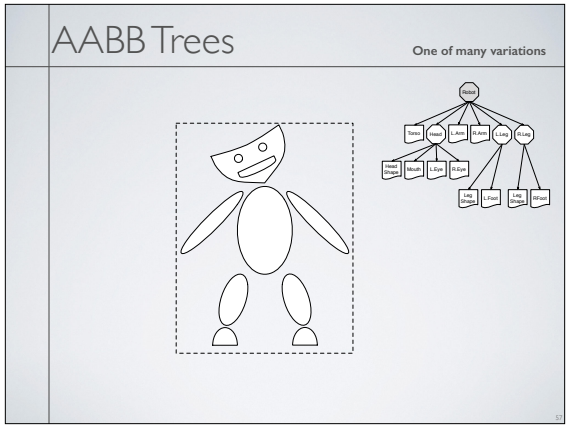
Mouth
L-Eye
R-Eye
Leg Shape
L-Foot
Leg Shape
R-Foot
56

56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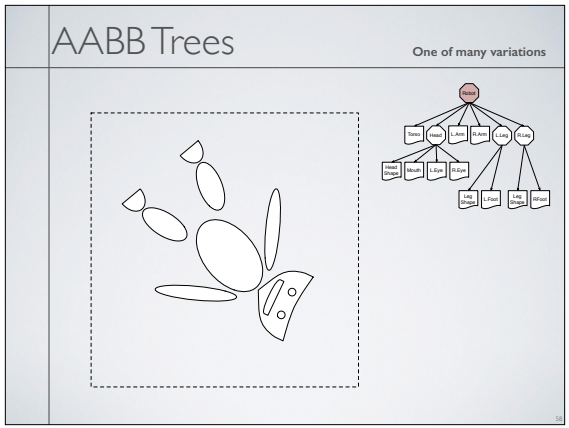
L-Eye
R-Eye
Leg Shape
L-Foot
Leg Shape
RFoot
57

57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L-Eye
R-Eye
Leg Shape
L-Foot
Leg Shape
RFoot
58

58

Ray Test Against Bound Tree

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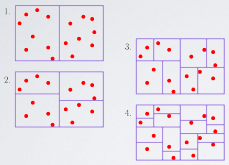
- `RayHitSubTree(&ray,node)`
  - `If RayHitsBB(ray,node.xfBB)`
    - `ixfRay = Inverse(node.xf)*ray`
    - `If RayHitsBB(ixfRay,node.BB)`
      - `If node is group`
        - `Foreach child in node.children`
          - `RayHitSubTree(ixfRay,child)`
      - `else // node not group`
        - `RayHitGeometry(ixfRay,node.geom)`
    - `ray.collisionInfo.update(ixfRay)`

Building the tree

60



- Sort (or QuickSelect) and split on one axis
- Repeat for the other axis
  - x,y,z

Other Schemes

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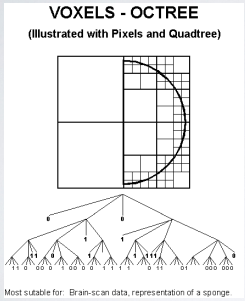
- Uniform Grid/Octrees
- Spatial Hierarchies
- Etc

Voxels/Octree

62



- Fun Links
- http://www.youtube.com/watch?v=6x8fYNFZsDQ
- http://www.youtube.com/watch?v=JI54WZtm0QE