Lecture 18 of 41
Scene Graphs: Rendering
Lab 3b: Shader

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Readings:
Next class: §5.3 – 5.5, Eberly 2e, CGA handout

Scene Graphs: Rendering
- State: transforms, bounding volumes, render state, animation state
- Managing renderer and animation state
- Rendering: object-oriented message passing overview

Next Class: Special Effects (SFX), Skinning, Morphing
Coming Up: More Videos (Lectures 19 & 20)
Review [3]: Principles of Traditional Animation
- Squash and Stretch
- Timing
- Anticipation
- Staging
- Follow Through and Overlapping Action
- Straight Ahead Action and Pose-to-Pose Action
- Slow In and Out
- Arcs
- Exaggeration
- Secondary action
- Appeal

Review [4]: Traditional Animation – Anticipation
- The preparation for an action.
  - Muscle contraction prior to extension
  - Bending over to lift a heavy object
  - Luxo’s dad responds to Luxo Jr. off screen before Luxo Jr. appears.

Review [5]: Keyframe Animation & Inbetweening
- Interpolate variables describing keyframes to determine poses for character "in-between"

Review [6]: Linear Interpolation aka Lerp
- Inbetweening:
  - Linear interpolation - usually not enough continuity

Review [7]: Articulated Figures
- Character poses described by set of rigid bodies connected by "joints"

Review [8]: Character Modeling
- Well-suited for humanoid characters
Review [9]: Bones & Joints

Articulated figure:

- Hip (hip rot)
- Knee (knee rot)
- Lower leg (knee rot)
- Foot (ankle rot)
- Hip rotate
- Lower leg rotate

Scene Graph Traversal

Scene Graph Rendering

Acknowledgements: Scene Graphs – Eberly 1st edition

David H. Eberly
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Geometric Tools, LLC
http://www.geometrictools.com

Review: What Information is in Scene Graphs?

- Transforms
- Bounding Volumes
- Render State
- Animation State

Figure 6.1: A simple tree with one grouping node.

Review: Kinds of Transforms

- Local
- World: Position Child C With Respect to Parent P (Depends on Local)

Both Together Part of Modelview Transformation

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See http://www.geometrictools.com for second edition
Traversing Scene Graph: World Transform of Node

The world transform of a node $N_i$ in the scene graph is just its local transform. The world position of a node $N_i$ in a path $N_2 \rightarrow \cdots \rightarrow N_i$, where $N_2$ is the root node, is generated recursively by the above definition as

$$\begin{pmatrix} w_{x2} \\ w_{y2} \\ w_{z2} \\ 1 \end{pmatrix} = \begin{pmatrix} w_{x1} \\ w_{y1} \\ w_{z1} \\ 1 \end{pmatrix} = \begin{pmatrix} M_{13} & M_{14} & \cdots & M_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ M_{n3} & M_{n4} & \cdots & M_{nn} \end{pmatrix} \begin{pmatrix} m_{12} & m_{13} \cdots & m_{1n} \\ m_{22} & m_{23} \cdots & m_{2n} \\ m_{32} & m_{33} \cdots & m_{3n} \\ \vdots & \vdots & \ddots & \vdots \\ m_{n2} & m_{n3} \cdots & m_{nn} \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$

Bounding Volumes [1]: Definition

- Bounding Volume Hierarchies (BVHs)
  - Root: entire scene
  - Interior node: rectangle (volume in general) enclosing other nodes
  - Leaves: primitive objects
- Often axis-aligned (e.g., axis-aligned bounding box aka AABB)
- Used
  - Visible surface determination (VSD) – especially occlusion culling
  - Other intersection testing: collisions, ray tracing

Bounding Volumes [2]: Types Covered in Eberly

- Spheres
- Oriented Boxes aka Oriented Bounding Boxes (OBBs)
- Capsules
- Lozenges
- Cylinders
- Ellipsoids

Renderer State

- Can Capture Render Information Hierarchically
- Example
  - Suppose subtree has all leaf nodes that want textures alpha blended
  - Can tag root of subtree with “alpha blend all”
  - Alternatively: tag every leaf
- How Traversal Works: State Accumulation
- Root-to-leaf traversal accumulates state to draw geometry
- Renderer checks whether state change is needed before leaf drawn
- Efficiency Considerations
  - Minimize state changes
  - Reason: memory copy (e.g., system to video memory) takes time

Animation State

- Can Capture Animation Information Hierarchically
- Example
  - Consider articulated figure from last lecture
  - Let each node represent joint of character model
    - Neck
    - Shoulder
    - Elbow
    - Wrist
    - Knee
  - Procedural Transformation
  - How It Works: Controllers
    - Each node has controller function/method
    - Manages quantity that changes over time (e.g., angle)

Updating Scene Graphs

- Need to Merge Bounding Volumes (Boxes, Lozenges, Capsules)
- Update Geometric State: UpdateGS
  - void Spatial::updateGS (float time, bool initEuler)
  - UpdateWorldData (null)
- UpdateWorldBound: Virtual Function, Controls Downward Pass
  - UpdateWorldBound: Also Virtual, Controls Upward Pass
  - PropagateBoundToRoot: Not Virtual, Simple Recursive Call
    - parent.UpdateWorldBound ()
    - parent.PropagateBoundToRoot ()
Rendering Scene Graphs [1]: View Frustum Culling

- By Spheres vs. By Oriented Boxes

Pseudocode

```
bool CallShadowPlane (SPHERE sphere, Plane plane)
{ return dot (sphere.x_pos, sphere.y_pos, sphere.z_pos, plane.x, plane.y, plane.z) ≤ plane.d; }
```

Can Also Cult by: Lozenges, Cylinders, Ellipsoids

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Main Draw Method

```cpp
void Renderer::Draw (Spatial scene)
{
    scene.onDraw(this->renderer);
}
```

Spatial::OnDraw(Renderer renderer)

Calls virtual function Draw(renderer)

Passed down

```
Geometry::Draw(Renderer renderer)
Node::Draw(Renderer renderer)
```

Can Also Cult by:

```
TriMesh::Draw(Renderer renderer)
```

Similarly for other derived classes

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Rendering Scene Graphs [2]: Message Passing

Summary

- Reading for Last Class: §5.1 – 5.2, Eberly 2e
- Reading for Today: §4.4 – 4.7, Eberly 2e
- Reading for Next Class:
  - Last Time: Introduction to Animation
    - Definition, overview, brief history, principles
    - Keyframes, interpolation, articulated figures for character modeling
    - Dynamics vs. kinematics, forward vs. inverse
  - Today: Scene Graph Rendering
    - State: transforms, bounding volumes, render state, animation state
    - Updating: merging bounding volumes
    - View frustum culling
    - Rendering: object-oriented message passing overview
  - Next Class: Special Effects (SFX), Skinning, Morphing: More Videos

Terminology

- Shading and Transparency in OpenGL: Alpha, Painter’s, A-buffering
- Animation – Modeling Change Over Time According to Known Actions
- Keyframe Animation
  - Keyframe
  - Interpolation
  - Character model
- State in Scene Graphs
  - Transforms – local & global TRS to orient parts of model
  - Bounding volumes – spheres, boxes, capsules, lozenges, ellipsoids
  - Renderer state – lighting, shading/textures/alpha
  - Animation state – TRS transformations (especially R), controllers
- Traversal: Moving through Data Structure, Calling Methods