CSE 167:
Introduction to Computer Graphics
Lecture #8: Scene Graph

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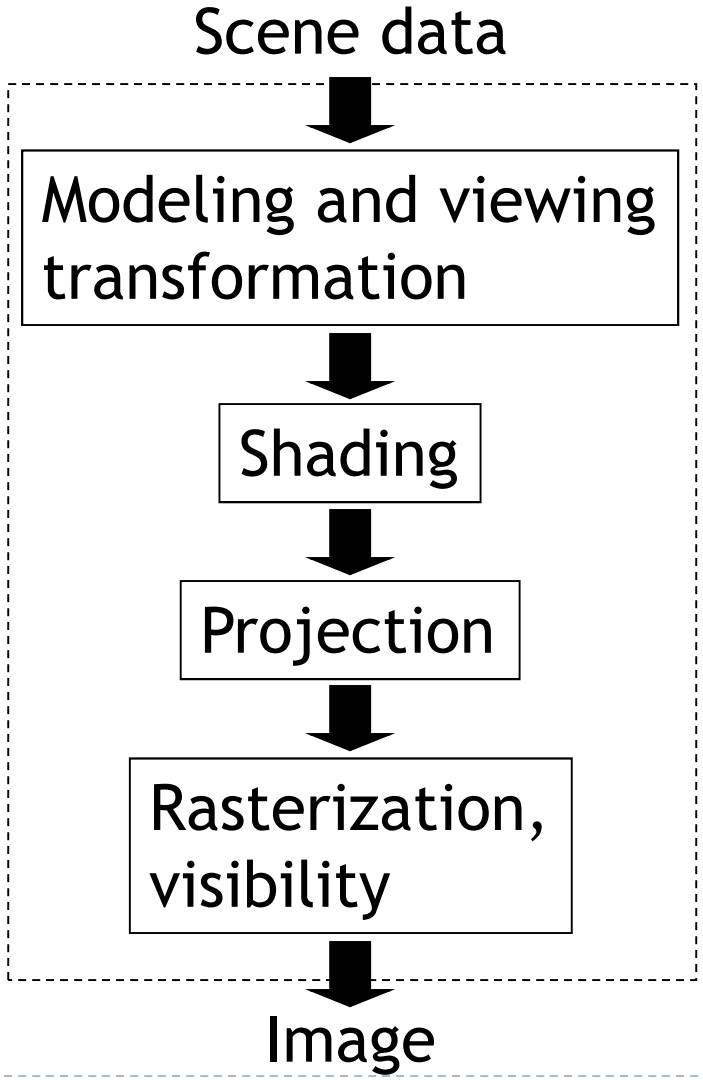
Announcements

- Thursday: Midterm exam
- Friday: Project 3 late grading

Lecture Overview

- Scene Graphs & Hierarchies
  - Introduction
  - Data structures
- Performance Optimization
  - Level-of-detail techniques
  - View Frustum Culling

Rendering Pipeline



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Graphics System Architecture

Interactive Applications

- Games, scientific visualization, virtual reality

Rendering Engine, Scene Graph API

- Implement functionality commonly required in applications
- Back-ends for different low-level APIs
- No broadly accepted standards
- Examples: OpenSceneGraph, NVSG, Java3D, Ogre

Low-level graphics API

- Interface to graphics hardware
- Highly standardized: OpenGL, Direct3D

Scene Graph APIs

- APIs focus on different types of applications
- OpenSceneGraph (www.openscenegraph.org)
  - Scientific visualization, virtual reality, GIS (geographic information systems)
- NVIDIA SceniX (https://developer.nvidia.com/scenix)
  - Optimized for shader support
  - Support for interactive ray tracing
- Java3D (http://java3d.java.net)
  - Simple, easy to use, web-based applications
- Ogre3D (http://www.ogre3d.org/)
  - Games, high-performance rendering

Commonly Offered Functionality

- Resource management
  - Content I/O (geometry, textures, materials, animation sequences)
  - Memory management
- High-level scene representation
  - Graph data structure
- Rendering
  - Optimized for efficiency (e.g., minimize OpenGL state changes)

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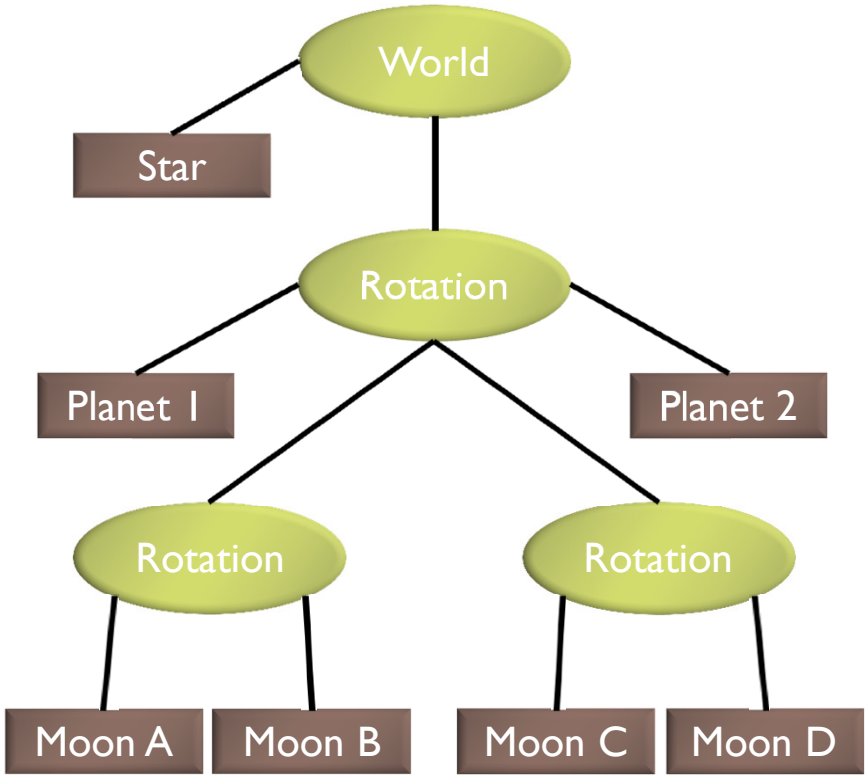
Scene Graphs

- Data structure for intuitive construction of 3D scenes
- So far, our GLUT-based projects store a linear list of objects
- This approach does not scale to large numbers of objects in complex, dynamic scenes

Solar System



- Draw the star
- Save the current matrix
-
  - Apply a rotation
  - Draw Planet One
  - Save the current matrix
  -
    - Apply a second rotation
    - Draw Moon A
    - Draw Moon B
  - Reset the matrix we saved
  - Draw Planet two
  - Save the current matrix
  -
    - Apply a rotation
    - Draw Moon C
    - Draw Moon D
  - Reset the matrix we saved
- Reset the matrix we saved

Example from http://www.gamedev.net

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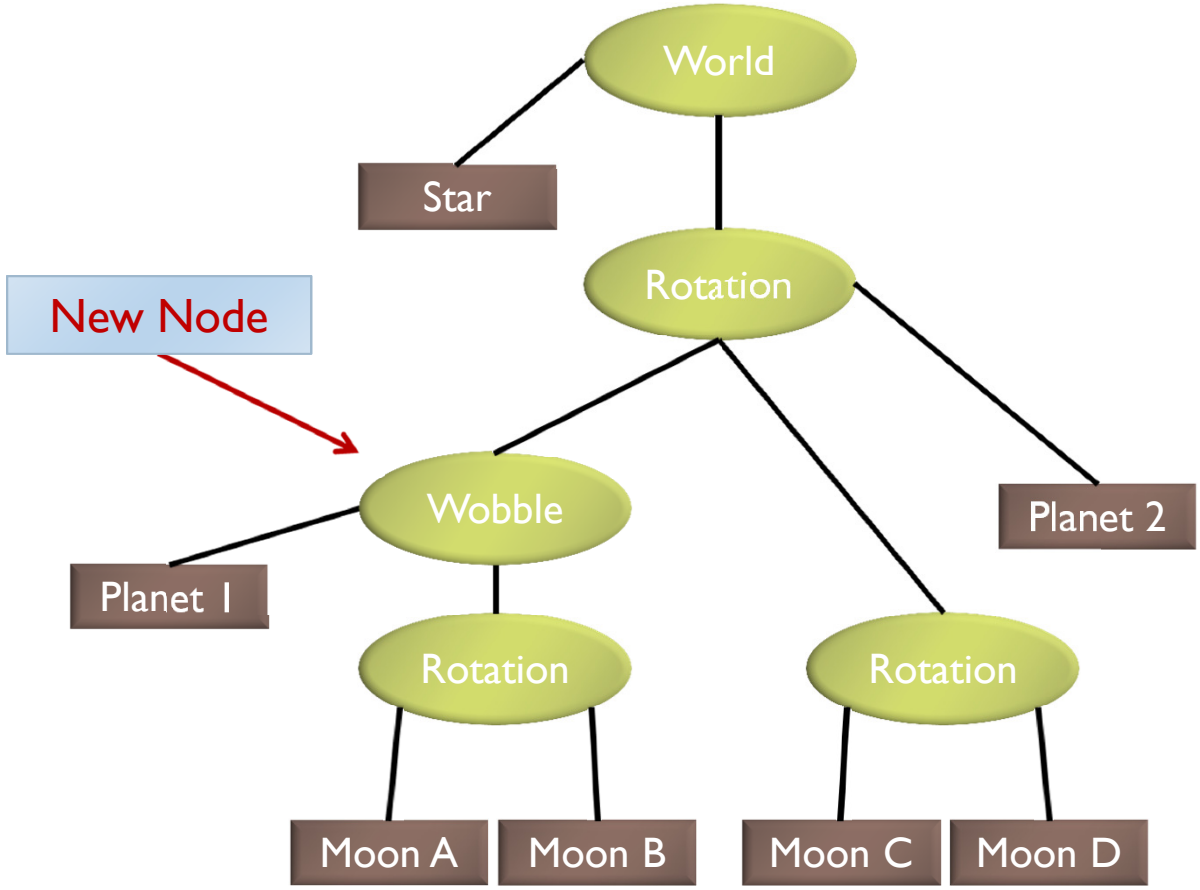
Solar System with Wobble



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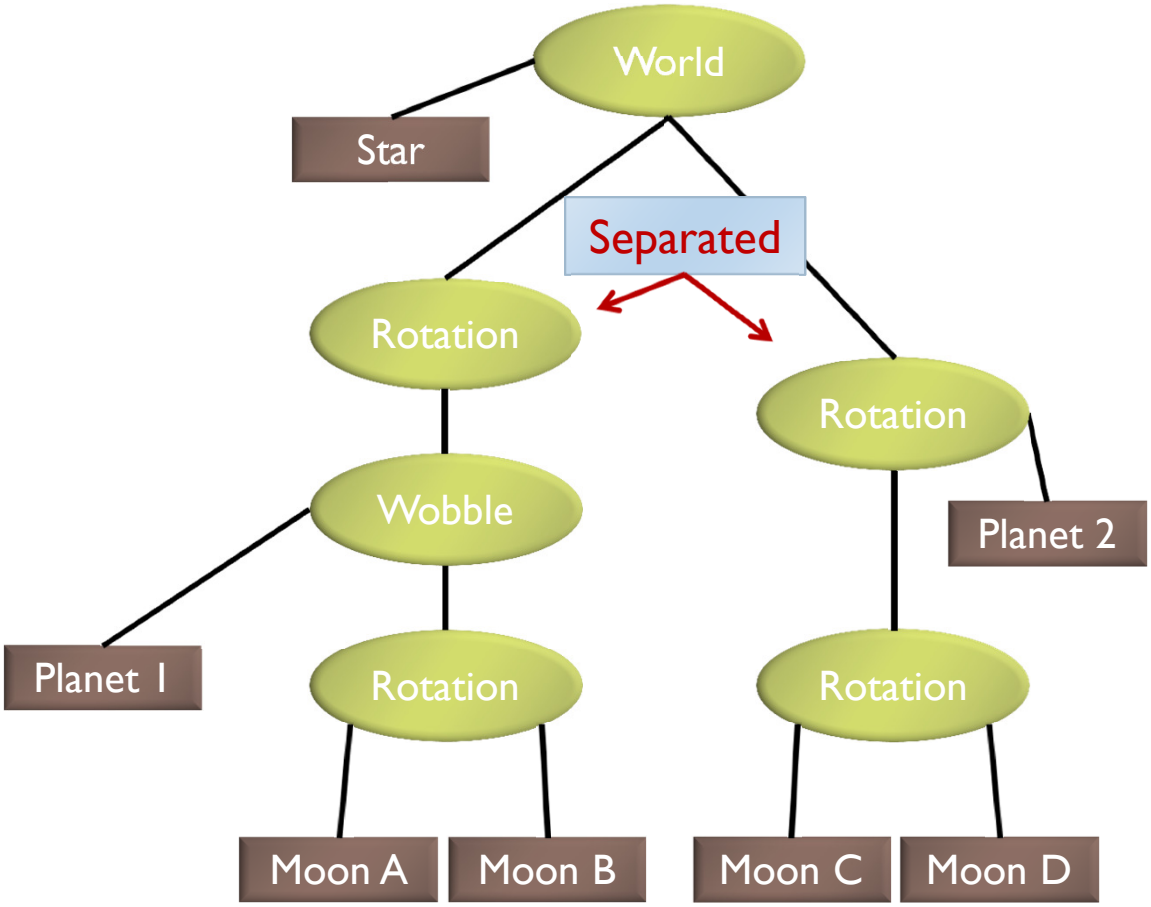
Planets rotating at different speeds



- Draw the Star
- Save the current matrix
- - Apply a rotation
  - - Save the current matrix
    - - Apply a wobble
      - Draw Planet 1
      - - Save the current matrix
        - - Apply a rotation
          - - Draw Moon A
            - Draw Moon B
        - Reset the Matrix
    - Reset the matrix
  - Reset the matrix
- Reset the matrix
- Save the current matrix
- - Apply a rotation
  - - Draw Planet 2
    - Save the current matrix
    - - Apply a rotation
      - Draw Moon C
      - Draw Moon D
    - Reset the current matrix
  - Reset the current matrix
- Reset the current matrix

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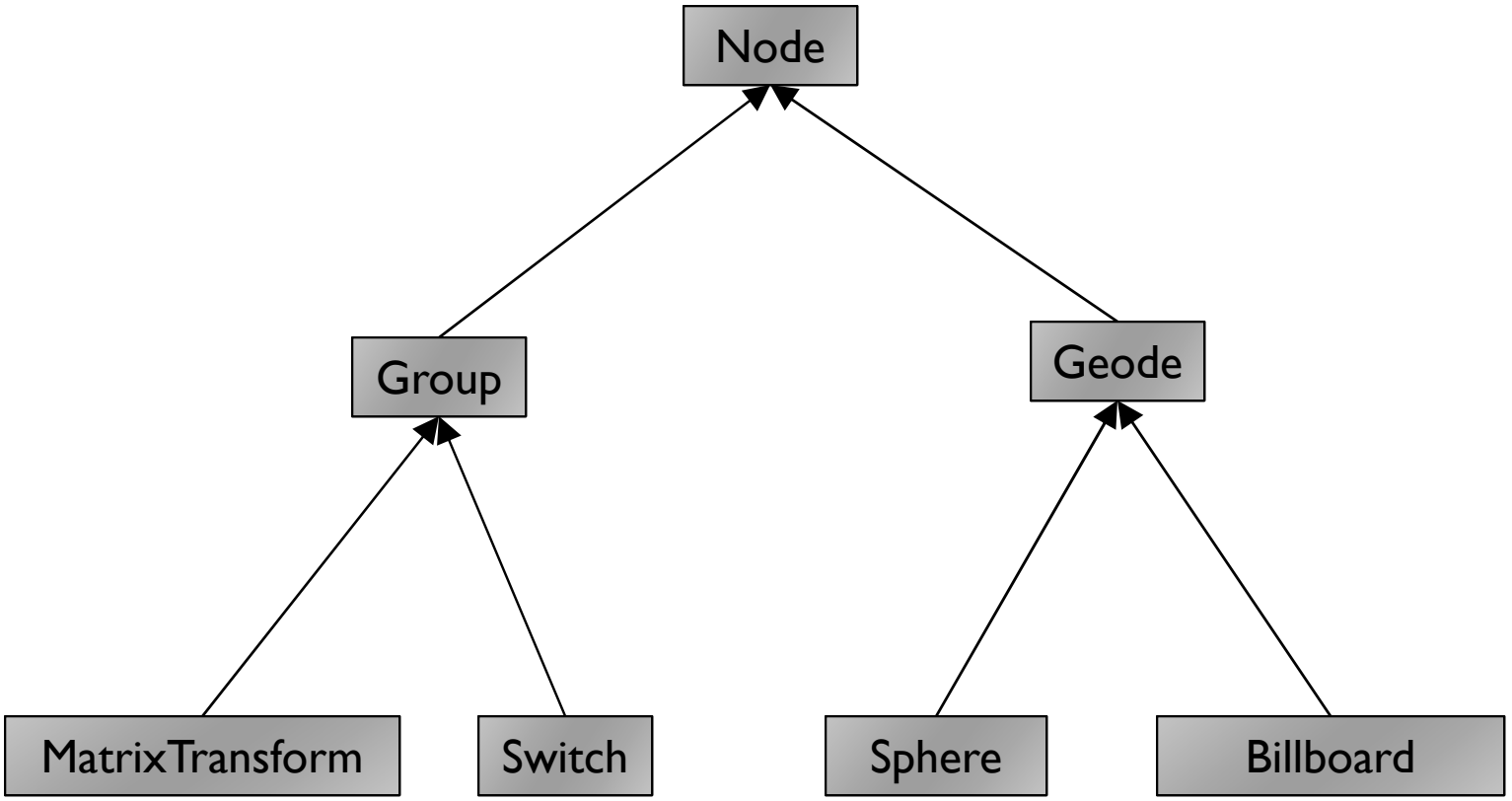
Data Structure

- Requirements
  - Collection of separable geometry models
  - Organized in groups
  - Related via hierarchical transformations
- Use a tree structure
- Nodes have associated local coordinates
- Different types of nodes
  - Geometry
  - Transformations
  - Lights
  - Many more

Class Hierarchy

- Many designs possible
- Design driven by intended application
  - Games
    - Optimized for speed
  - Large-scale visualization
    - Optimized for memory requirements
  - Modeling system
    - Optimized for editing flexibility

Sample Class Hierarchy



Inspired by OpenSceneGraph

Class Hierarchy

`Node`

- Common base class for all node types
- Stores node name, pointer to parent, bounding box

`Group`

- Stores list of children

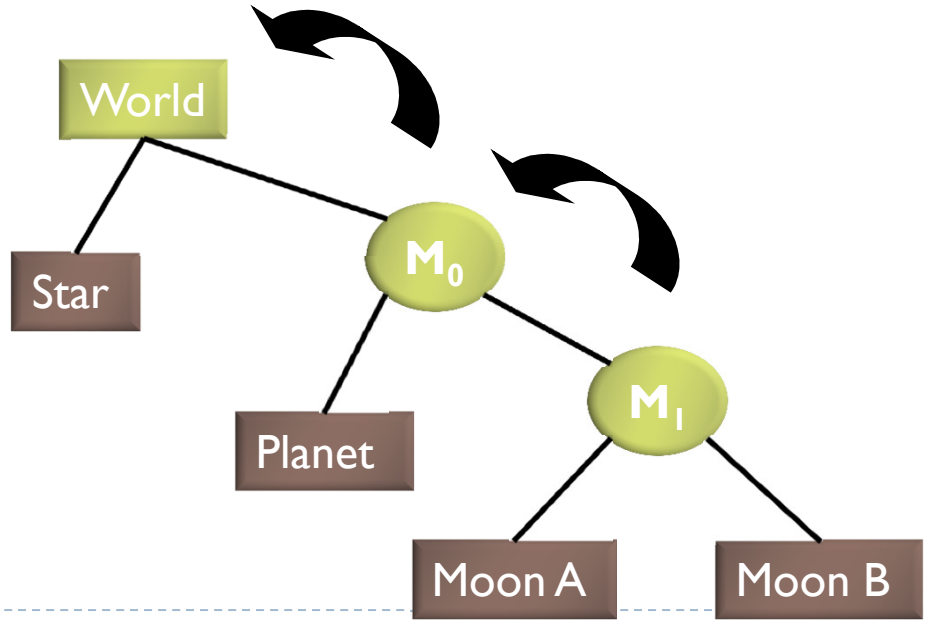
`Geode`

- Geometry Node
- Knows how to render a specific piece of geometry

Class Hierarchy

`MatrixTransform`

- Derived from Group
- Stores additional transformation **M**
- Transformation applies to sub-tree below node
- Monitor-to-world transformation $\mathbf{M_0 M_1}$



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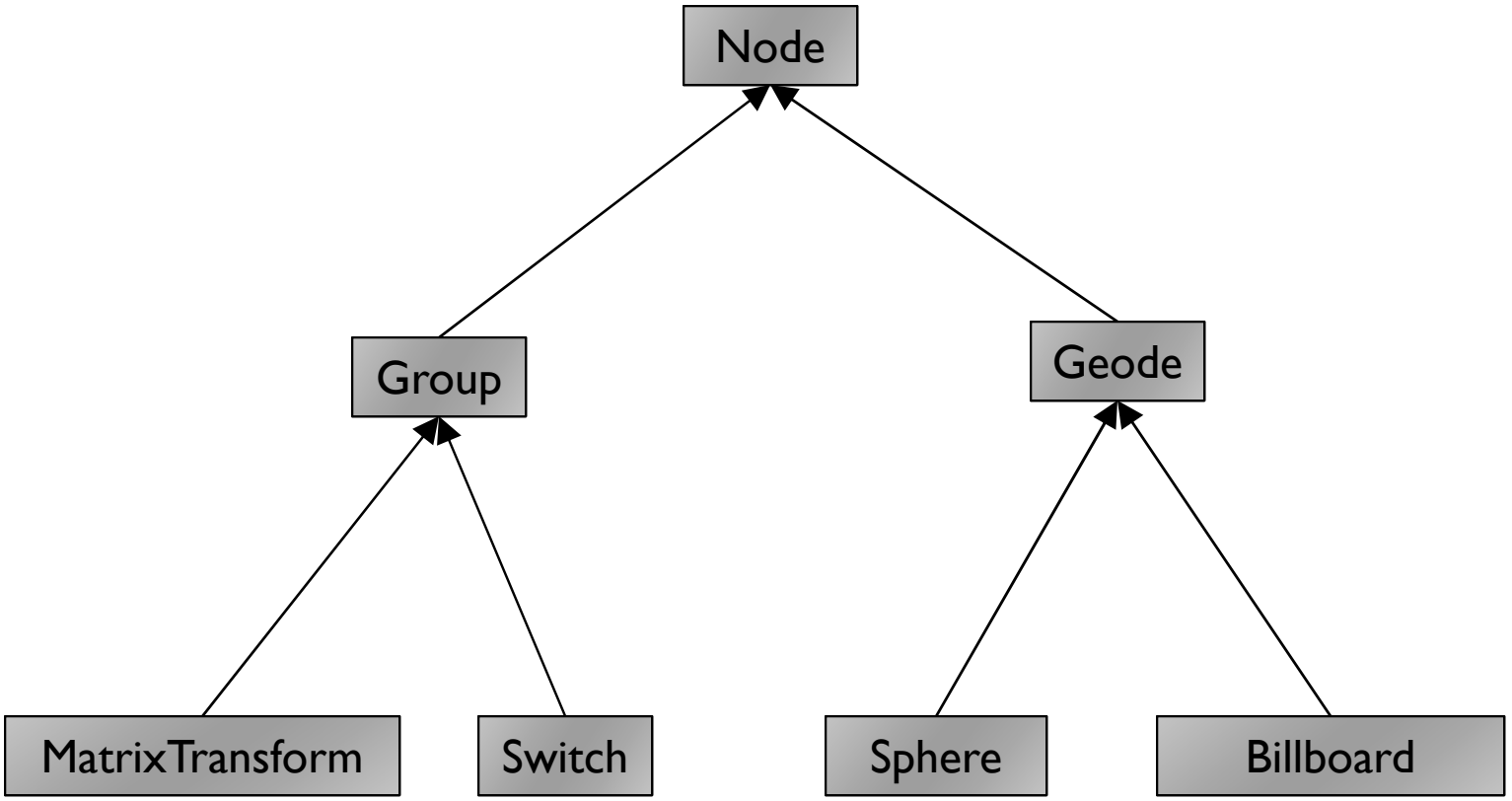

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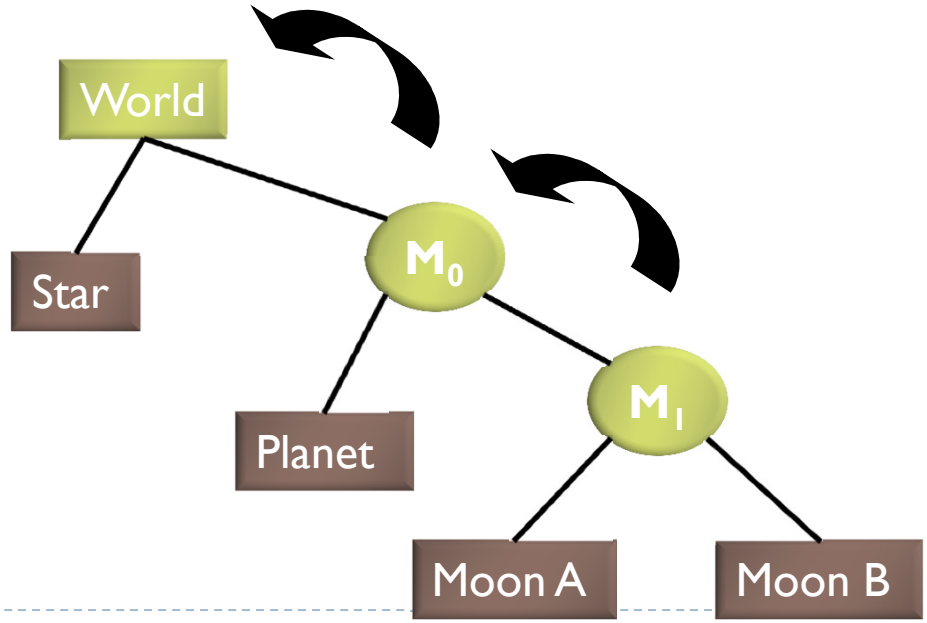

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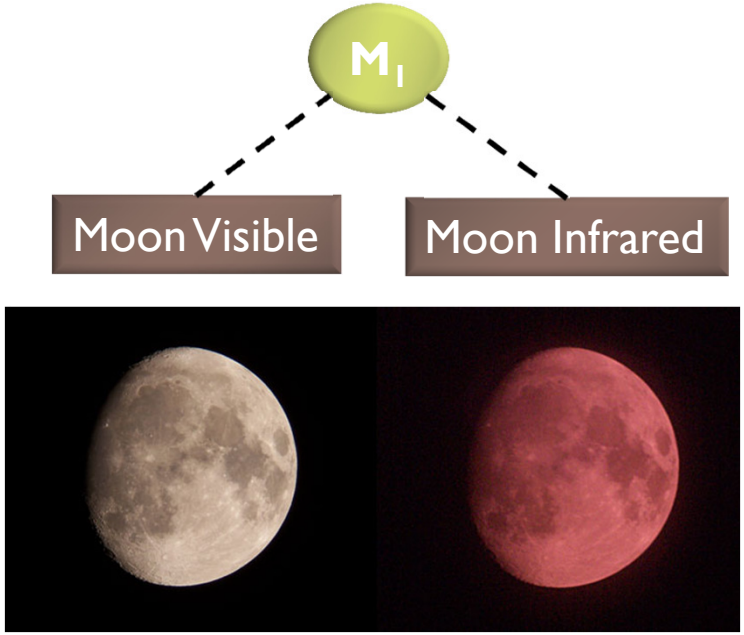
Class Hierarchy

`Switch`

- Derived from Group node
- Allows hiding (not rendering) all or subsets of its child nodes
- Can be used for state changes of geometry, or "key frame" animation



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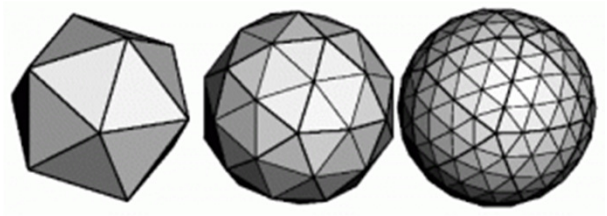
Class Hierarchy

`Sphere`

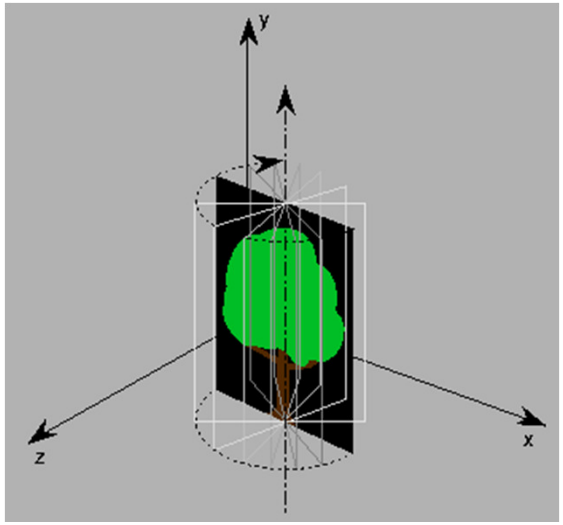
- Derived from Geode
- Pre-defined geometry with parameters, e.g., for tesselation level, solid/wireframe, etc.

`Billboard`

- Special geometry node to display an image always facing the viewer

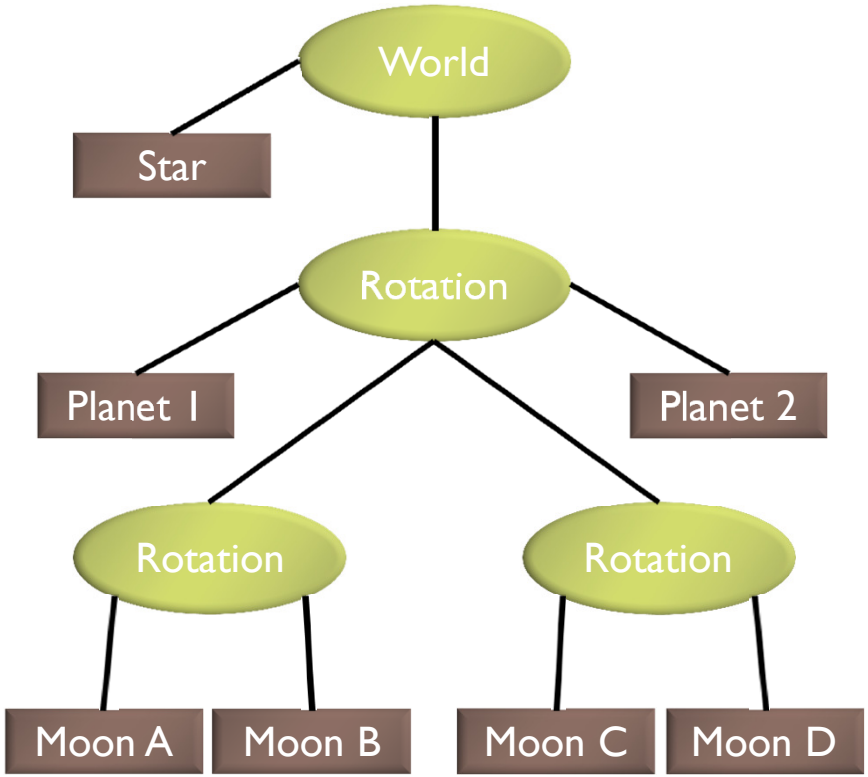


Sphere at different tessellation levels



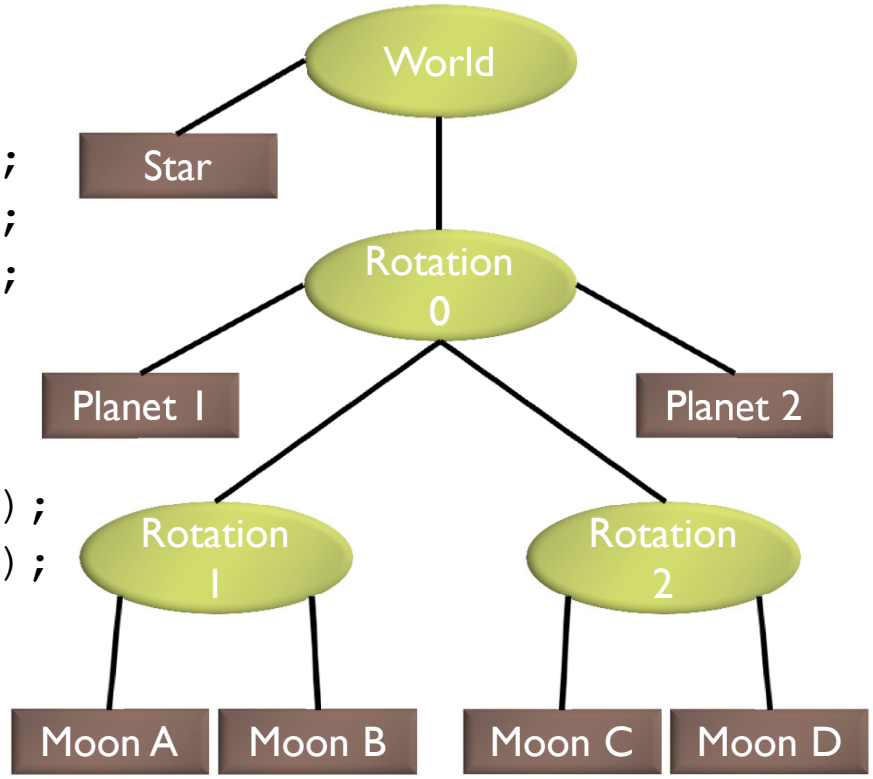
Billboarded Tree

Solar System



Source Code for Solar System

```
world = new Group();
world.addChild(new Star());
rotation0 = new MatrixTransform(…);
rotation1 = new MatrixTransform(…);
rotation2 = new MatrixTransform(…);
world.addChild(rotation0);
rotation0.addChild(rotation1);
rotation0.addChild(rotation2);
rotation0.addChild(new Planet(“1”));
rotation0.addChild(new Planet(“2”));
rotation1.addChild(new Moon(“A”));
rotation1.addChild(new Moon(“B”));
rotation2.addChild(new Moon(“C”));
rotation2.addChild(new Moon(“D”));
```



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Basic Rendering

- Traverse the tree recursively

```
Group::draw(Matrix4 C)
{
  for all children
    draw(C);
}

MatrixTransform::draw(Matrix4 C)
{
  C_new = C*M;   // M is a class member
  for all children
    draw(C_new);
}

Geode::draw(Matrix4 C)
{
  setModelView(C);
  render(myObject);
}
```

Initiate rendering with
`world->draw(IDENTITY);`

Modifying the Scene

- Change tree structure
  - Add, delete, rearrange nodes
- Change node parameters
  - Transformation matrices
  - Shape of geometry data
  - Materials
- Create new node subclasses
  - Animation, triggered by timer events
  - Dynamic "helicopter-mounted" camera
  - Light source
- Create application dependent nodes
  - Video node
  - Web browser node
  - Video conferencing node
  - Terrain rendering node

Benefits of a Scene Graph

- Can speed up rendering by efficiently using low-level API
  - Avoid state changes in rendering pipeline
  - Render objects with similar properties in batches (geometry, shaders, materials)
- Change parameter once to affect all instances of an object
- Abstraction from low level graphics API
  - Easier to write code
  - Code is more compact
- Can display complex objects with simple APIs
  - Example: osgEarth class provides scene graph node which renders a Google Earth-style planet surface