CSE 167: Introduction to Computer Graphics Lecture #10: Scene Graph

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Fall Quarter 2017

Announcements

- Project 2 late grading is tomorrow at 2pm

Lecture Overview

- Scene Graphs & Hierarchies
  - Introduction
  - Data structures

Graphics System Architecture

Interactive Applications

- Video 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, SceniX, Torque, Ogre

Low-level graphics API

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

Scene Graph APIs

- OpenSceneGraph (www.openscenegraph.org)
  - For scientific visualization, virtual reality, GIS (geographic information systems)
- NVIDIA SceniX
  - Optimized for shader support
  - Support for interactive ray tracing
  - http://www.nvidia.com/object/scenix-home.html
- Torque 3D
  - Open source game engine
  - For Windows and browser-based games
  - http://www.garagegames.com/products/torque-3d
- Ogre3D
  - Open source rendering engine
  - For Windows, Linux, OSX, Android, iOS, Javascript
  - http://www.ogre3d.org/

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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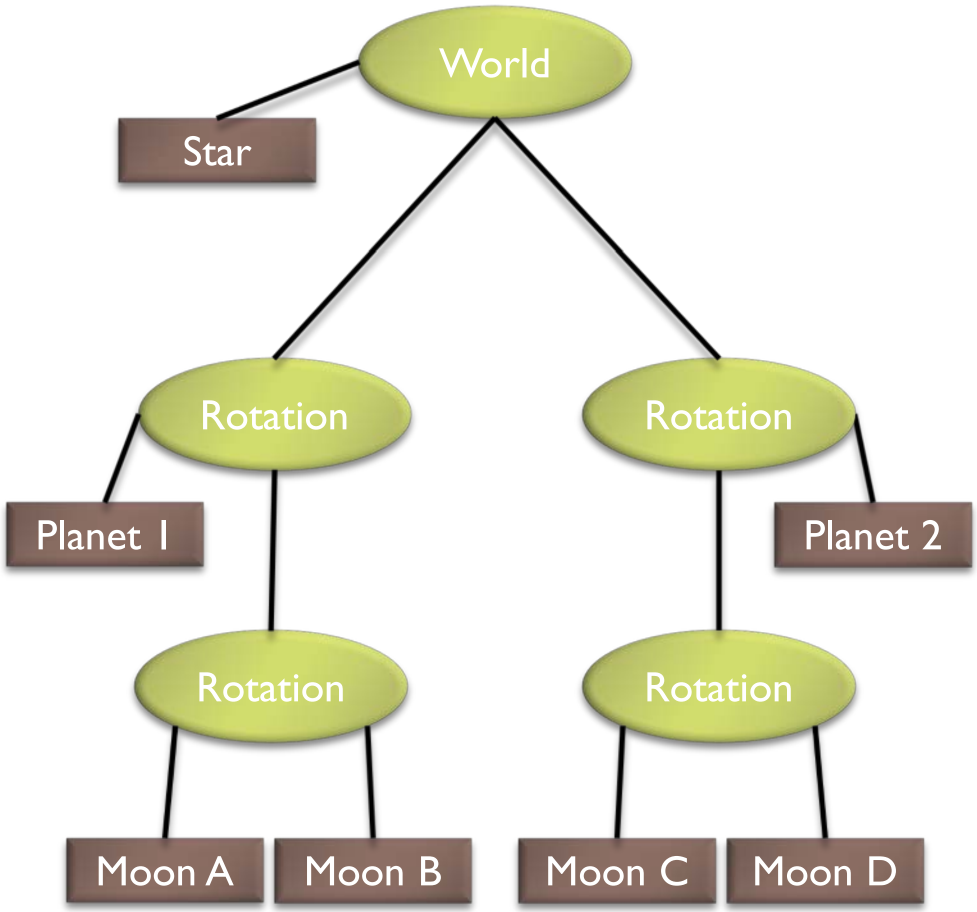
Scene Graphs

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

Example: Solar System



Source: http://www.gamedev.net

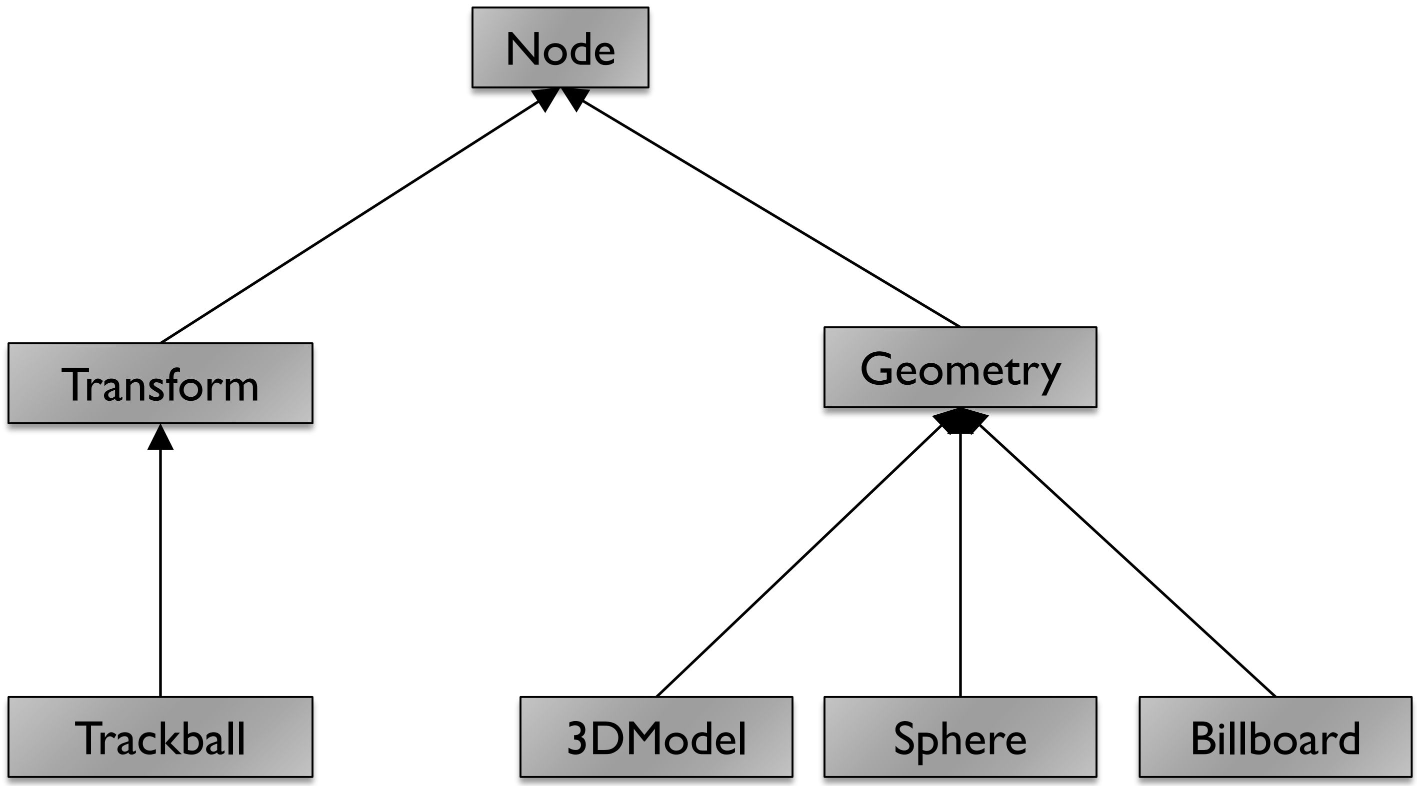
Data Structure

- 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



Class Hierarchy

`Node`

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

`Geometry`

- sets the modelview matrix to the current C matrix
- has a class method which draws its associated geometry

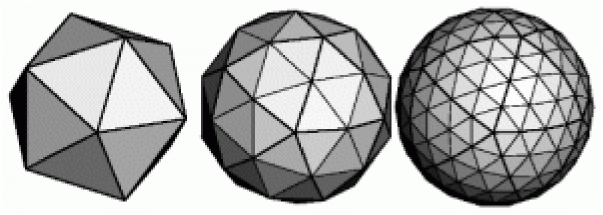
`Transform`

- Stores list of children
- Stores 4x4 matrix for affine transformation

Class Hierarchy

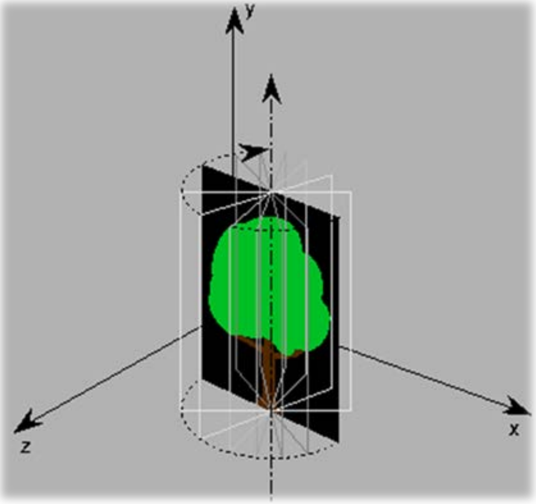
Sphere

- Derived from Geometry node
- Pre-defined geometry with parameters, e.g., for tesselation level (number of triangles), solid/wireframe, etc.



Billboard

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



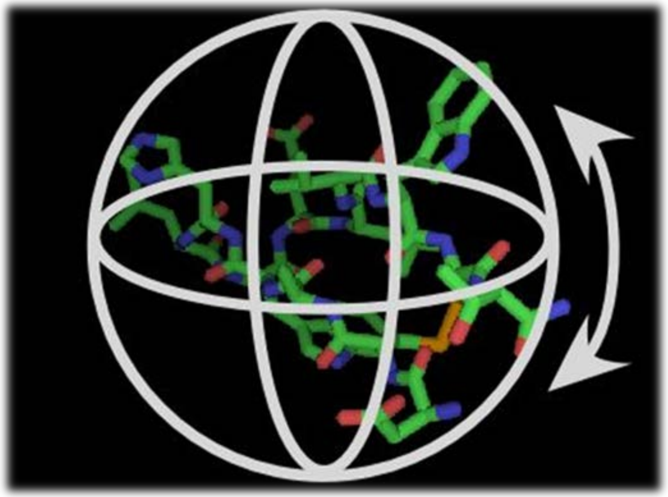
Class Hierarchy

`3DModel`

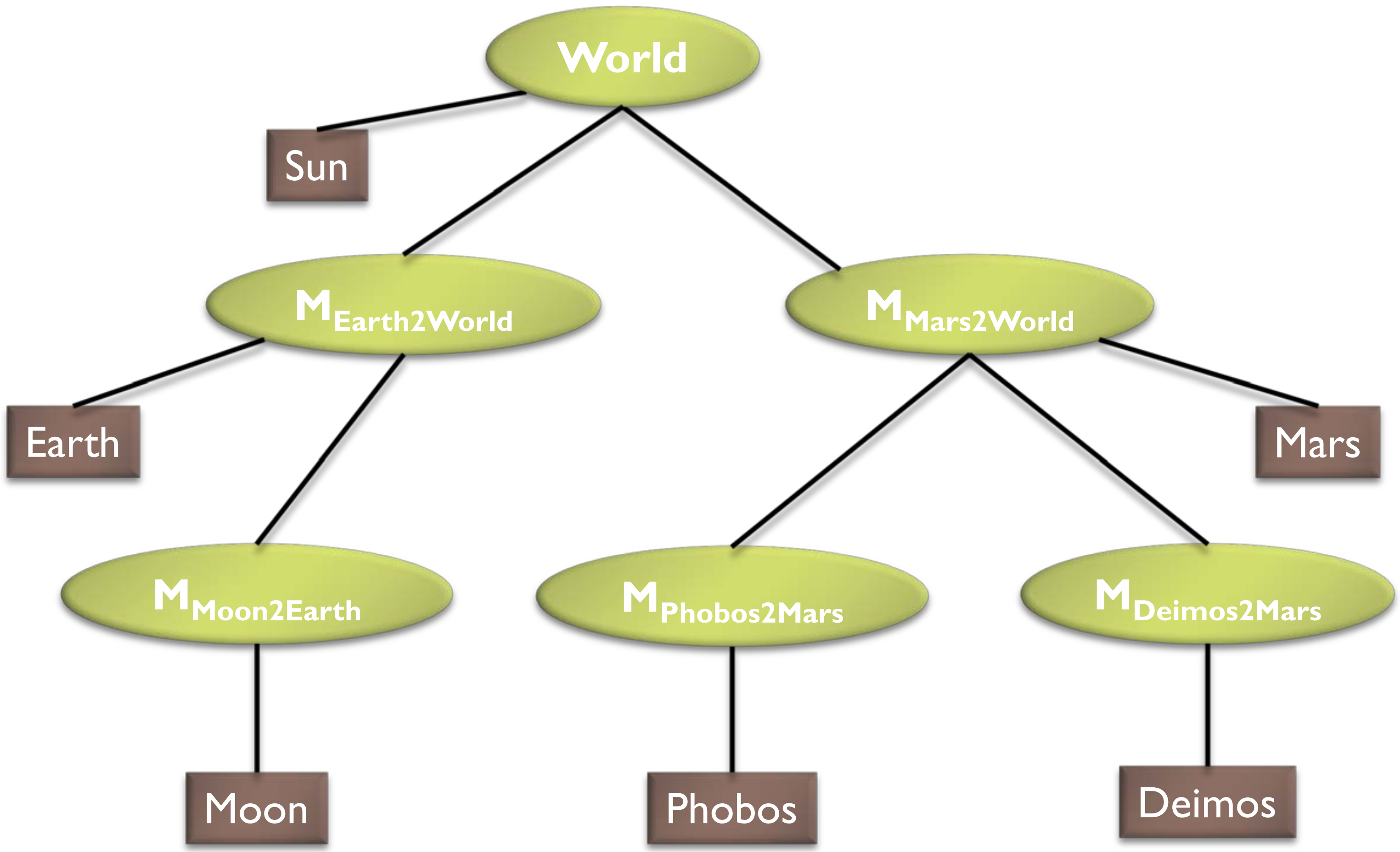
- Takes file name to load 3D model file

`Trackball`

- Creates the matrix transformation based on a virtual trackball controlled with the mouse



Scene Graph for Solar System



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Building the Solar System

```
// create sun:
world = new Transform();
world.addChild(new Model(“Sun.obj”));

// create planets:
earth2world = new Transform(…);
mars2world = new Transform(…);
earth2world.addChild(new Model(“Earth.obj”));
mars2world.addChild(new Model(“Mars.obj”));
world.addChild(earth2world);
world.addChild(mars2world);

// create moons:
moon2earth = new Transform(…);
phobos2mars = new Transform(…);
deimos2mars = new Transform(…);
moon2earth.addChild(new Model(“Moon.obj”));
phobos2mars.addChild(new Model(“Phobos.obj”));
deimos2mars.addChild(new Model(“Deimos.obj”));
earth2world.addChild(moon2earth);
mars2world.addChild(phobos2mars);
mars2world.addChild(deimos2mars);
```

Transformation Calculations

- moon2world = moon2earth * earth2world;
- phobos2world = phobos2mars * mars2world;
- deimos2world = deimos2mars * mars2world;

Scene Rendering

- Recursive draw calls

```
Transform::draw(Matrix4 M)
{
  M_new = M * MT;   // MT is a class member
  for all children
    draw(M_new);
}

Geometry::draw(Matrix4 M)
{
  setModelMatrix(M);
  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 with progressive refinement and data streaming from server.