Virtual Reality Technology and Programming

TNM053: Lecture 6: Scene Graphs

OpenGL and VR

- Basic primitives
- Complex transformations
- No visible interrelations
- No interactors
- Hard to manage complex scenes
- Hard to manage interaction

Example: A car

Define (display lists) for
- Body shape
- Wheel
- Wheel ‘nut’
In model space:
- Perform the transforms
- Insert the geometries

Process

Draw body
Push matrix
Transform to wheel \( i \) (=1 to 4)
Draw wheel
Push matrix
Transform to nut \( j \) (=1 to \( n \))
Draw nut
Pop matrix
Pop matrix

OpenGL and VR (2)

- VR
- Complex scenes
- Many related and connected objects
- Complex interactors
- OpenGL cannot easily give us this
- Scene Graphs can help

Scene Graph and OpenGL

Application

Scene Graph

OpenGL API

Hardware Renderer

Display
### Software: API’s
- Maverik - [http://aig.cs.man.ac.uk/systems/Maverik/](http://aig.cs.man.ac.uk/systems/Maverik/)
- OpenRM - [http://www.r3vis.com/](http://www.r3vis.com/)
- Open Scene Graph - [http://www.openscenegraph.org/](http://www.openscenegraph.org/)

### Software: Applications
- Ray Tracers
- Modellers / Animation Packages
- Virtual Reality Markup Language (VRML)
- Magma

### S.G. software provides...
- Wide selection of primitives
- Wide selection of materials
- Lots of interactors
- Lighting objects
- Cameras
- Viewers

- But that's not the point...

### The Scene Graph *itself* provides...
- High performance rendering for less effort
- Easy management of large numbers of objects in scene
- Ease of management of interaction
- Ease of management of modification

### What is a Scene Graph (1)
- Directed Acyclic Graph of objects.
- Hierarchical tree

### What is a Scene Graph (2)
- Often spatial ordering of objects
  - Helps with depth-sorting
  - Important for multipass rendering
- Moves the structure of the scene from the program into a data structure.
- Scene Graph API provides mechanism to manage this
## Why use a Scene Graph?
- Models are hierarchical in nature.
- Management of details.
- Convenience
- Facilitate rapid application development.
- Exploit reuse

## What's in a Scene Graph?
- A root
- Nodes
- Directed edges (parent to child)

## Nodes
- 3 Basic types:
  - Shape or geometry
  - Material or Property
  - Group
- Each has attached qualities (fields)
- Other control nodes
  - System dependent

## Shape/Geometry
- Defines a 3D geometric entity:
  - Point
  - Vector
  - Polygon ...
  - Other primitive:
    - Sphere
    - Cone
    - Cylinder
    - Curves (NURBS)

## Property
- Colour qualities:
  - Ambient
  - Specular
- Shininess
- Transparency
- Textures
- Transformations:
  - Scale
  - Rotation
  - Translation

## Group
- Node used to combine a sub-graph

![Scene Graph Diagram]
Ordering and Traversal

- Layout is less abstract than it seems!
- Traversal occurs according to rules:
  - Typically left-to-right
  - Typically ‘bottom-up’

Water Molecule example

- Typically left-to-right
- Typically ‘bottom-up’

(OpenInventor) water molecule in C++

- Groups:
  - SoGroup *waterMol = new SoGroup;
  - SoGroup *oxygen = new SoGroup;
  - SoGroup *hydrogen1 = new SoGroup;
  - SoGroup *hydrogen2 = new SoGroup;

- Shapes:
  - SoSphere *sphere1 = new SoSphere;
  - SoSphere *sphere2 = new SoSphere;
  - SoSphere *sphere3 = new SoSphere;

OpenInventor water molecule in C++ (2)

- Materials:
  - SoMaterial *redplastic = new SoMaterial;
  - SoMaterial *whiteplastic = new SoMaterial;

- Transforms:
  - SoTransform *Xform1 = new SoTransform;
  - SoTransform *Xform2 = new SoTransform

OpenInventor water molecule in C++ (3)

- Fill in fields for the Materials:
  - redplastic->ambientColor.setValue(1.0,0.0,0.0);
  - redplastic->diffuseColor.setValue(1.0,0.0,0.0);
  - redplastic->specularColor.setValue(0.5,0.5,0.5);
  - redplastic->shininess = 0.5;

- Similar for whiteplastic

OpenInventor water molecule in C++ (4)

- Fill in fields for the transforms:
  - Xform1->scaleFactor.setValue(0.75,0.75,0.75);
  - Xform1->translation.setValue(0.0,-1.2,0.0);
  - Xform2->translation.setValue(1.185,1.388,0.0);

- Leaves us with a bunch of nodes...
OpenInventor water molecule in C++ (5)

- Build the graph:
  - water->addChild(oxygen);
  - water->addChild(hydrogen1);
  - water->addChild(hydrogen2);
  - oxygen->addChild(redplastic);
  - oxygen->addChild(sphere1);
  - hydrogen1->addChild(whiteplastic);
  - hydrogen1->addChild(Xform1);
  - hydrogen1->addChild(sphere2);
  - hydrogen2->addChild(Xform2);
  - hydrogen2->addChild(sphere3);

OpenInventor water molecule in C++ (6)

- Add some initialization code
- Add a few more instances of water
- Run a molecular simulation to -10°C
- Add some code to trigger rendering
- And...

... Ice! (unit cell)

Points to note

- Why doesn't Xform2 have a scale field?
- Why doesn't hydrogen2 have a child "whiteplastic"?
- Traversal!
  - Traversal carries state
  - State is overwritten by nodes

Traversing the graph

Managing state

- Need to manage state:
  - in OpenGL use push and pop of matrix
  - In scene graphs use 'separator' nodes
- Separator node causes:
  - push entire state on entry
  - pop on exit
- Separator is derived from group
Managing state

Nodes can be shared.
- Saves space
- Reduces number of objects to be specified
- Makes updates easier and faster

Shared nodes

- Shape node shared
- Traversal unaffected
- State management !!

Other nodes

- Camera nodes
- Lights
- Control nodes:
  - Usually classed as ‘group’ nodes
- Manipulators/interactors

Camera nodes

- Derived from shape node
- Orthographic/Perspective
- Fields:
  - Position
  - Orientation
  - Viewport (angles/size)
  - Near/far clipping distances
  - Etc.
- Managed and traversed just like all nodes

Positioning cameras
Lights

- Types:
  - Point
  - Directional
  - Spot

- Fields:
  - Position
  - On/off
  - Colour
  - Intensity
  - Direction
  - Etc.

Control nodes

- Control the scene graph through defining branches of traversal

- In Inventor:
  - SoSwitch
  - SoBlinker
  - SoSelection
  - SoLevelOfDetail

SoSwitch

- One or more children
- A field determines which *one* to visit

SoBlinker

- Time-based
- Selects *one* of its children
- Use to define simple animations
SoBlinker

Control nodes: SoLevelOfDetail
- Left to right traversal of children
- Most detailed to least detailed
- Draw first whose *projected* 3D bounding box fits the specified range

So LevelOfDetail

Control nodes: SoSelection
- Node inserted into graph to manage object selection
  - Determines which objects can be selected
  - Permits child objects to be selected
  - Determines mode of selection:
    - single
      - clear list each time an object is selected
    - multi
      - add each selected object to list
      - Might have to use special key: shift key?

Manipulators/Interactors
- Draggers
  - E.g. scaler, rotator, translator etc.
  - Add to a group
  - Connect output field to (e.g.) shape fields
  - Scale, rotate or translate object
  - Can build in your own callbacks
- Manipulators
  - Subclass of other nodes (e.g. transform)
  - Include 'hidden' dragger

Manipulator: Trivial Example
Other, other nodes

- Many many types:
  - Culling controls
  - Transform controls
  - Texture controls
  - Transparency controls
  - Picking controls
  - Callback controls
- Typically system dependent

Engines

- Engines define relationships between fields.
- Used to interconnect parts of a scene graph
- Define complex relationships between objects
  - Physical modelling? - bouncing ball

Engines (2)

- Example:
  - Simple - Using blinker to animate a bird.
  - More complex - Connecting coordinates of one or more objects using a spring model to constrain movement.
  - Complex - connecting speed and coordinates of an object to detect collision and cause a bounce.

Benefits of scene graph based methods

- Fast, precise rendering
- Fast, precise culling
- Fast (easy) application updates
- Manageable interactors

Benefits: Rendering

- Scene graph describes whole, consistent state of the objects in the scene
- Scene graph traversal allows:
  - System knows position/size of each object in scene simultaneously
  - Perhaps uses bounding box information to speed up
  - System can order rendering correctly
  - Can apply multi-pass rendering for transparent objects

Benefits: Culling

- Scene graph describes whole, consistent state of the objects in the scene
- Scene graph traversal allows:
  - System knows position/size of each object in scene simultaneously
  - Can pre-cull occluded objects correctly
  - Can pre-cull back-face polygons
  - Can pre-calculate clipping
**Benefits: Updates**

- Scene graph knows about relations:
  - What is connected to what
  - What occludes what
  - What is where in the rendered image
- Updates:
  - Changes propagate to the final images
  - Minimize re-rendering
  - Maximize re-use

**Benefits: Interactors**

- OpenGL/GLUT:
  - 2D information comes back
  - Ok for 2D image
  - Not for 3D - hard to locate objects
- Scene graph:
  - Knows about objects in 3D scene
  - Can use 2d information to backtrack
  - Locates 3D object which is selected
  - Also allows use of 3D interaction within scene

**Summary**

- Scene graphs move objects from programmer control to database
- Saves a lot of programming
- Allows:
  - Easier definition of complex scenes
  - Easier definition of interaction
- Exploits:
  - Scene relationships of objects

**Summary (2)**

- Manage state carefully and...
- Connect 'engines' to node fields:
  - complex animation effects
  - Little effort required