Retained Mode Graphics

Two approaches to graphics

- Say "how"
  - Immediate mode: explicit commands
  - E.g., OpenGL
- Say "what"
  - Retained mode: define and change model
  - E.g., Inventor, Java-3D
  - A3: JOOGL (Java Object Oriented Graphics Library)

What's in a Geometric Model

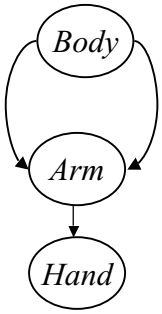
- Geometry
  - Spatial layout
  - Attributes
- Topology
  - Connectivity
  - Structure
- Application-specific data

Model part of app data structure

- App + graphical data structures
  - App ds changes => graphical ds changes
    => update screen
- Modern libs let you integrate them
  - Inventor, Java-3D

Hierarchy in Geometric Models

- Build model from pieces
  - Define each in "natural'' coordinates
  - Relate them to logical parents
  - Modularity
- Define a DAG
  - Nodes: part of model
  - Edges: relationships



Hierarchy Inheritance

- Transforms
  - Nested Coordinate systems
- Attributes
  - "red car"

Recall Assignments 1 and 2

- You had (simple) RM data structures!
  - 100 squares
  - Hierarchy of 7 objects
- Multiple uses
  - Rendering
  - Picking

Retained Mode Packages

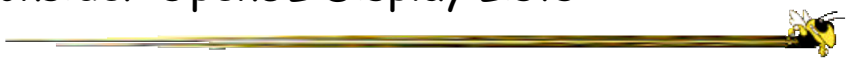
- Maintain graphical data structure
- Traverse graphical data structure
  - Auto redisplay, picking, intelligent handling of special nodes, optimizations
- Goal: Make your life easier!
  - You should be thinking: this is what I would just be doing anyway

Consider OpenGL Display Lists

- glNewList(int, mode)
- glEndList()
- glCallList(int)

- int glGenLists(num)

Consider OpenGL Display Lists



- Provide some of this
  - Contain geometry, attributes
  - Hierarchy (DAG)
  - Embed name stack commands for picking

Why aren't OpenGL DLs enough?

- "Simple replay, output only"
  - No intelligent handling, no optimizations
    - Lights? Cameras? Action?
  - No editing or automatic repair
  - Picking?
- Expensive to create/change

=> *Not real hierarchy!*

  - C macros vs. procedures

More Problems with DLs

- Attributes, geometry mixed together
  - Programmer must know where everything is
  - Less opportunity for optimization
  - Cannot integrate application data

Object-Oriented Approach

- Inventor, Java-3D, Repo-3D
  - Can be implemented in non-OO languages
    - (SOOGL, CS4451 Fall 99, in C)
- Objects for each "object"
  - Internal DAG nodes for structure
  - Leaf nodes are "things"
  - Properties attached to node

Major Objects

- Geometry
  - Spheres, boxes, polygons, cameras, lights, …
- Properties
  - Transformations
  - Attributes (rendering style, color, etc.)
  - Geometric Properties
- Groups
  - Structure

Rendering Graph into Window

- Special Object to attach a graph to a window
  - "Root Group", "View Platform", etc...
- Need at least
  - Camera
  - Window
  - Viewport
- JOOGL: subclass GLAnimCanvas, full viewport
  - Add camera and "root of graph" group

Properties

- Every property has a default value
- Attached to nodes
  - Define property value for graph rooted at current node
- Time-varying properties support animation

Advantage of Objects: Indirection of method calls

- Property value?
  - *type* get()
- Incorporate time directly
  - *type* get(int time)

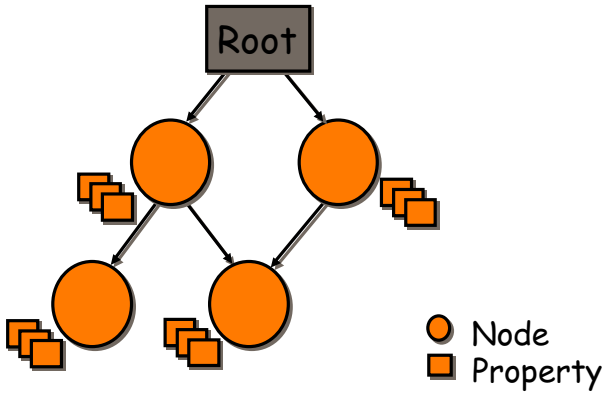
Always use Time-based Animation

- Base all animation on relative time
  - E.g., move from A to B over 2 seconds
  - E.g., flash red/green 4 times/second
- Adapts automatically to different machines
- Degrades gracefully

Variations of properties (Obliq-3D)

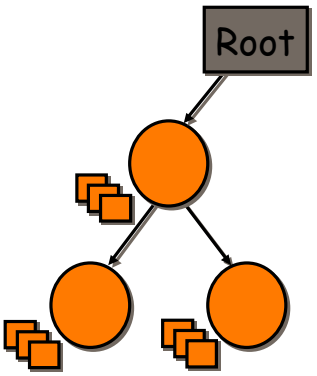
- For every type of property (color, transformation, float, int, ...)
  - Constant
  - Synchronous time-based animation
  - Arbitrary function

Example Graph



Graph Traversal: Rendering

- Save/restore state
- Traverse multiple times
- Decide when to render

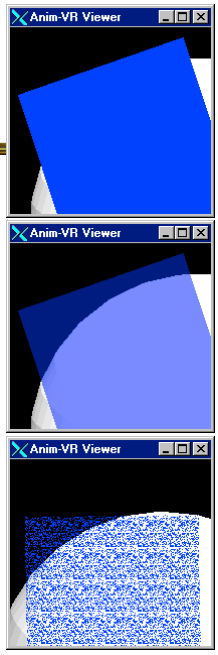


Graph Traversal: Handling Special Nodes During Rendering

- Dynamic Properties
- Lights
- Camera
- Transparency

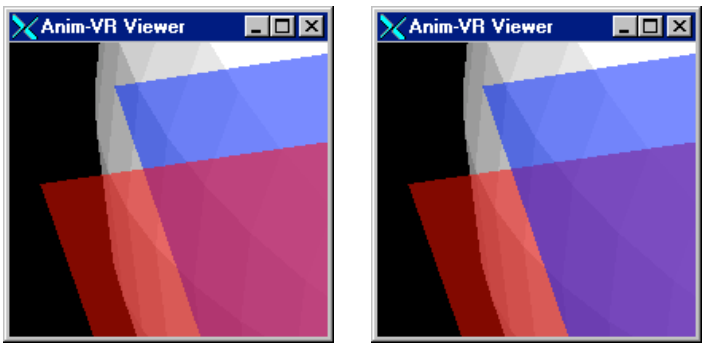
Handling Transparency

- Interpolated transparency
  - ie. OpenGL alpha values
  - $I = (1 - k_t)\, I_A + k_t\, I_B$
- Screen door transparency



Naive Rendering Fails: RM can possibly handle this

- Even if rendered after opaque
- If more than one, order matters!



Graph Traversal: Picking

- How to incorporate OpenGL Picking?

Optimizations: Elision

- Pruning
- Culling
- LOD

Optimization: Rendering

- State changes are expensive
- Display lists are expensive to create but faster to draw