Scene Graphs

CS 465 Lecture 9

Data structures with transforms

- Representing a drawing ("scene")
- List of objects
- Transform for each object
  - can use minimal primitives, e.g., ellipse is scaled circle
  - transform applies to points of object

E.g., Character animation

Dreamworks/Paramount—Transformers (screenshot: www.transformersmovie.com)

E.g., Modeling complex scenes

From "Matrix Revolutions"
**Example**

- Can represent drawing with flat list
  - but editing operations require updating many transforms

**Groups of objects**

- Treat a set of objects as one
- Introduce new object type: group
  - contains list of references to member objects
- This makes the model into a tree
  - interior nodes = groups
  - leaf nodes = objects
  - edges = membership of object in group

**The Scene Graph (tree)**

- A name given to various kinds of graph structures (nodes connected together) used to represent scenes
- Simplest form: tree
  - just saw this
  - every node has one parent
  - leaf nodes are identified with objects in the scene
Concatenation and hierarchy

- Transforms associated with nodes or edges
- Each transform applies to all geometry below it
  - want group transform to transform each member
  - members already transformed—concatenate
- Frame transform for object is product of all matrices along path from root
  - each object’s transform describes relationship between its local coordinates and its group’s coordinates
  - frame-to-canonical transform is the result of repeatedly changing coordinates from group to containing group

Instances

- Simple idea: allow an object to be a member of more than one group at once
  - transform different in each case
  - leads to linked copies
  - single editing operation changes all instances

Example

- Allow multiple references to nodes
  - reflects more of drawing structure
  - allows editing of repeated parts in one operation

Instancing is useful!
The Scene Graph (with instances)

- Instancing breaks tree structure:
  - an object that is instanced multiple times has more than one parent
- Transform tree becomes DAG
  - directed acyclic graph
  - group is not allowed to contain itself, even indirectly
- Transforms still accumulate along path from root
  - now paths from root to leaves are identified with scene objects

Implementing a hierarchy

- Object-oriented language is convenient
  - define shapes and groups as derived from single class
    
    ```java
    abstract class Shape {
        void draw();
    }
    
    class Square extends Shape {
        void draw() { // draw unit square
        }
    }
    
    class Circle extends Shape {
        void draw() { // draw unit circle
        }
    }
    
    class Group extends Shape {
        Transform t;
        ShapeList members;
        void draw(Transform t_c) {
            for (m in members) {
                m.draw(t_c * t);
            }
        }
    }
    ```

Implementing traversal

- Pass a transform down the hierarchy
  - before drawing, concatenate
    
    ```java
    abstract class Shape {
        void draw(Transform t_c);
    }
    
    class Square extends Shape {
        void draw(Transform t_c) {
            // draw t_c * unit square
        }
    }
    
    class Circle extends Shape {
        void draw(Transform t_c) {
            // draw t_c * unit circle
        }
    }
    
    class Group extends Shape {
        Transform t;
        ShapeList members;
        void draw(Transform t_c) {
            for (m in members) {
                m.draw(t_c * t);
            }
        }
    }
    ```

Basic Scene Graph operations

- Editing a transformation
  - good to present usable UI
- Getting transform of object in canonical (world) frame
  - traverse path from root to leaf
- Grouping and ungrouping
  - can do these operations without moving anything
    - group: insert identity node
    - ungroup: remove node, push transform to children
- Reparenting
  - move node from one parent to another
  - can do without altering position
Adding more than geometry

- Objects have properties besides shape
  - color, shading parameters
  - approximation parameters (e.g. precision of subdividing curved surfaces into triangles)
  - behavior in response to user input
  - Animation behavior/interpolator nodes
  - ...

- Setting properties for entire groups is useful
  - paint entire window green

- Many systems include some kind of property nodes
  - in traversal they are read as, e.g., "set current color"

Scene Graph variations

- Where transforms go
  - in every node
  - on edges
  - in group nodes only
  - in special Transform nodes

- Tree vs. DAG
- Nodes for cameras and lights?

Implementations

- Many modeling programs use scene graph data structures to manage complexity:
  - Maya
  - 3D studio max
  - ...

- Graphics APIs:
  - Open Inventor
  - Java3D
  - NVIDIA scene graph (NVSG)
  - ...