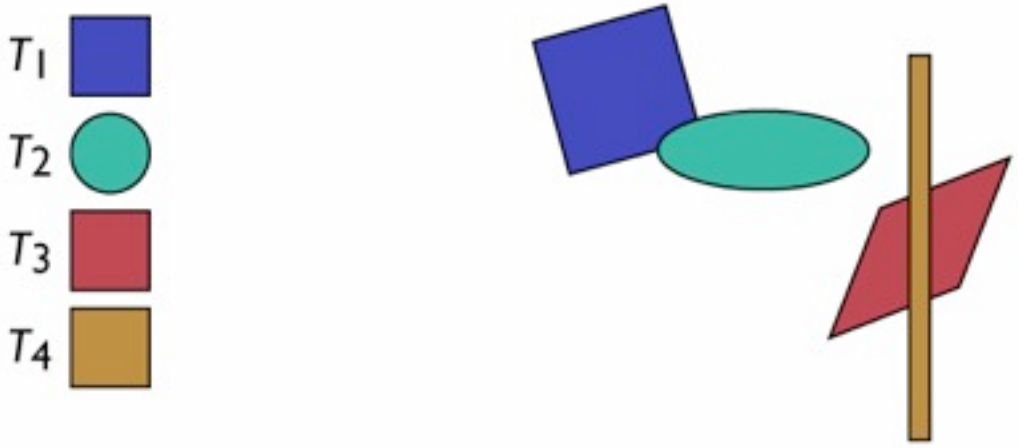
Transformation Hierarchies

CS 4620 Lecture 9

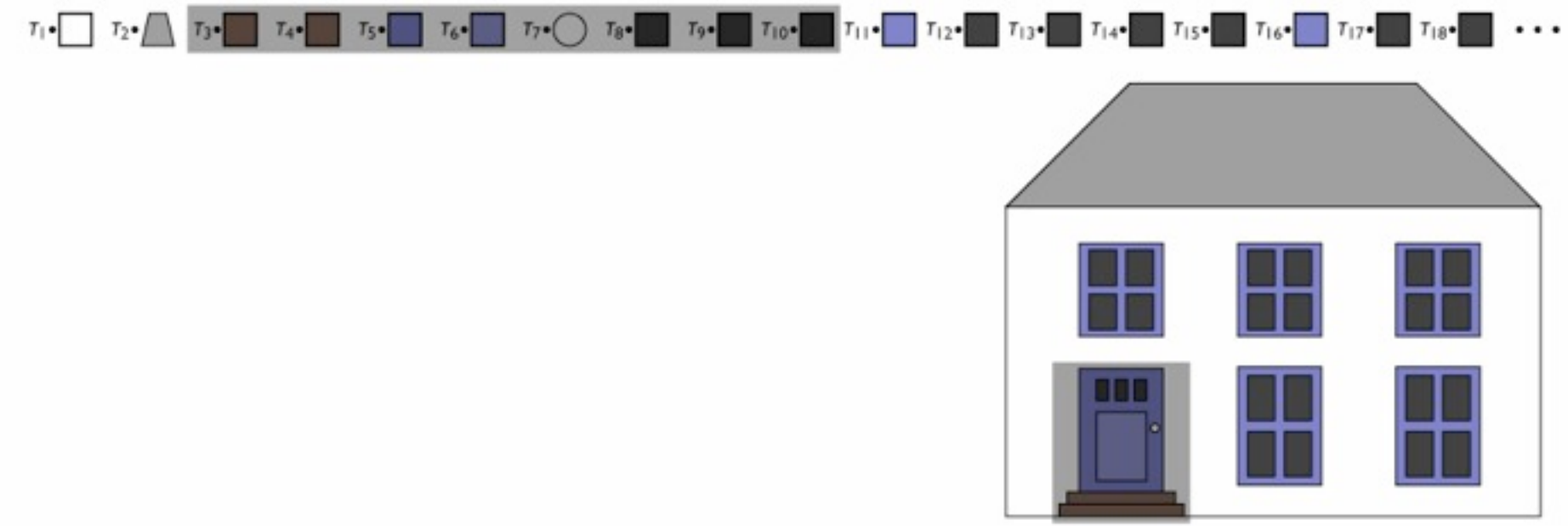
Data structures with transforms

- Representing a drawing ("scene")
- List of objects
- Transform for each object
  - can use minimal primitives: ellipse is transformed circle
  - transform applies to points of object



Example

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

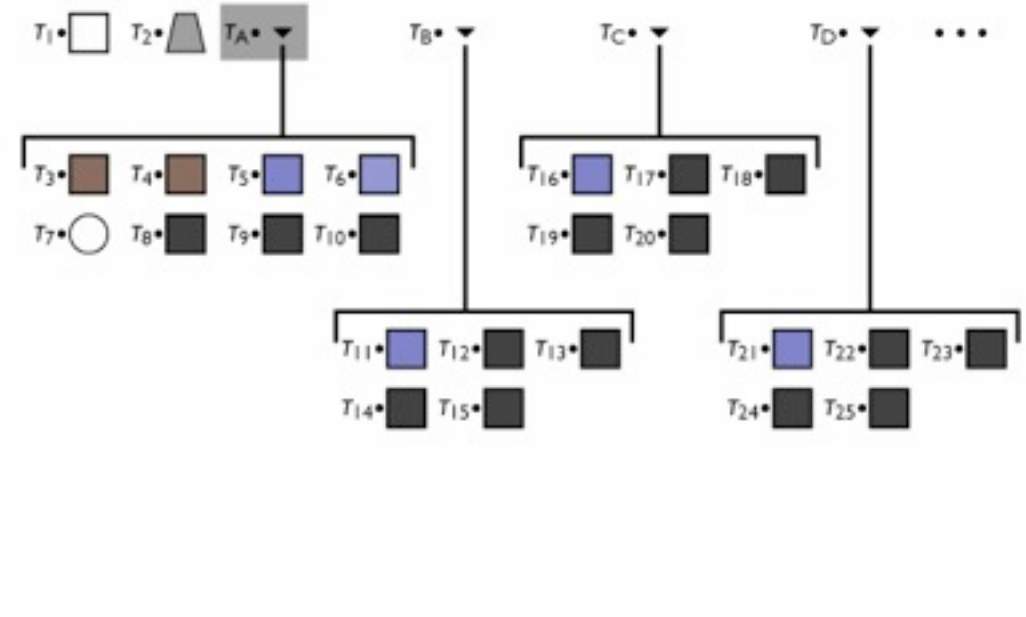


Groups of objects

- 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

Example

- Add group as a new object type
  - lets the data structure reflect the drawing structure
  - enables high-level editing by changing just one node

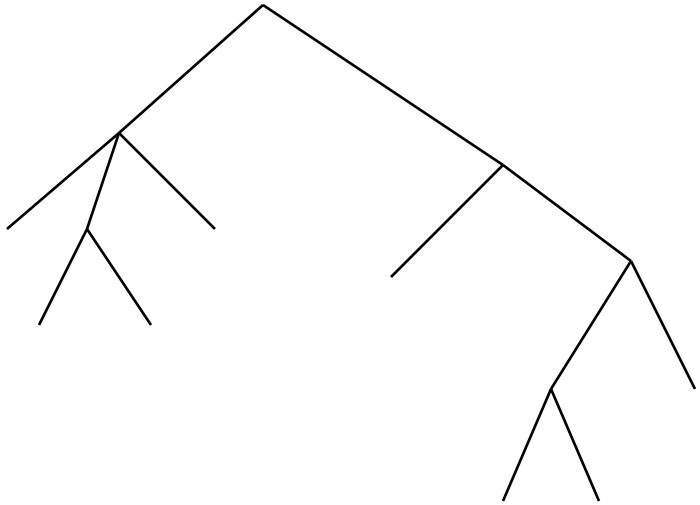


Demo

- Adobe Illustrator as typical 2D drawing program
- Groups create transformation hierarchy
- Selecting inside groups allows editing internal nodes

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

Variants of the Scene Graph

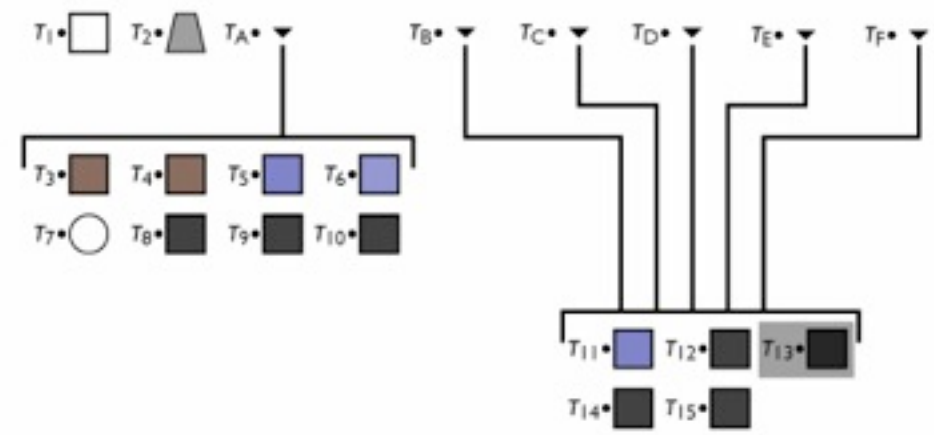
- Parenting
  - allow any object to have child objects
  - every object is effectively also a group
  - common in 3D modeling packages
- Instancing
  - allow objects to belong to multiple parents/groups
  - creates multiple copies of geometry

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

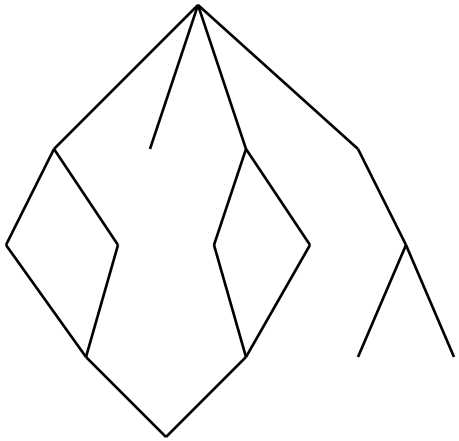
Example

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



The Scene Graph (with instances)

- With instances, there is no more tree
  - an object that is instanced multiple times has more than one parent
- Transform tree becomes DAG
  - **d**irected **a**cyclic **g**raph
  - 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

```
abstract class Shape {
   void draw();
}

class Square extends Shape {
   void draw() {
      // draw unit square
   }
}

class Circle extends Shape {
   void draw() {
      // draw unit circle
   }
}
```


Implementing traversal

- Pass a transform down the hierarchy
  - before drawing, concatenate

```
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
  - …
- 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?

