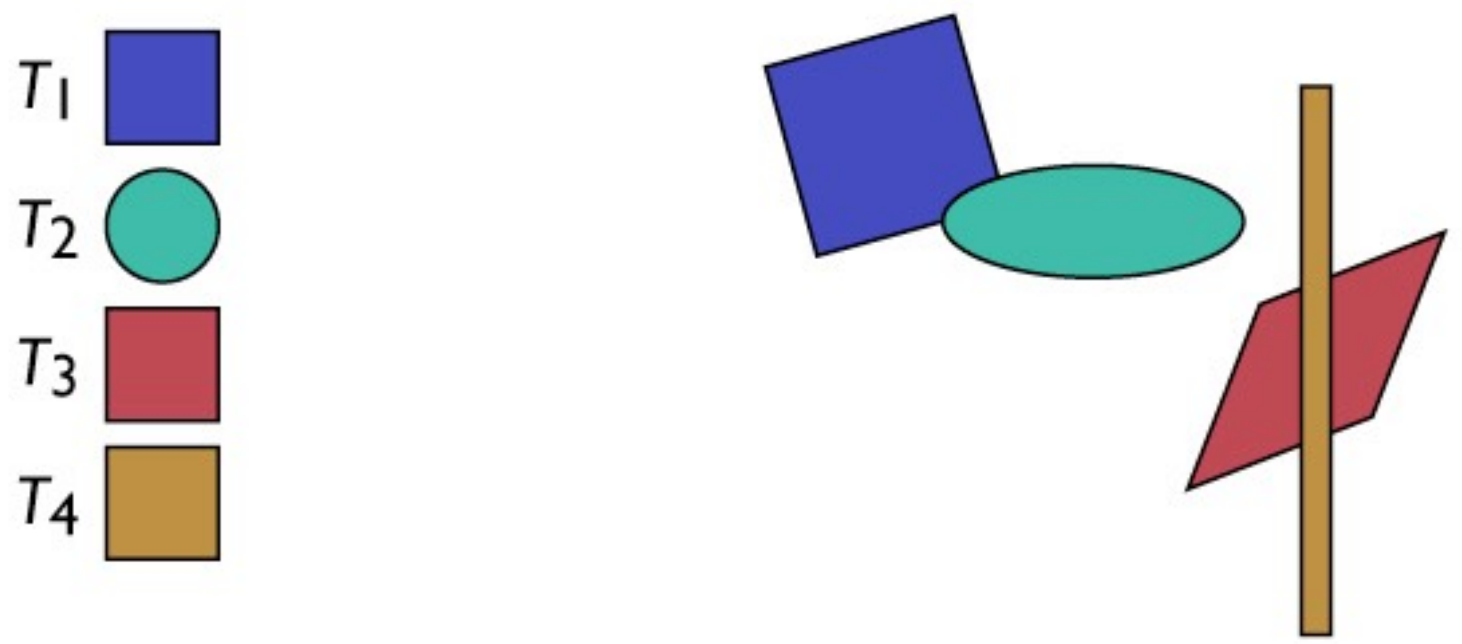
Scene Graphs

CS 4620 Lecture 17

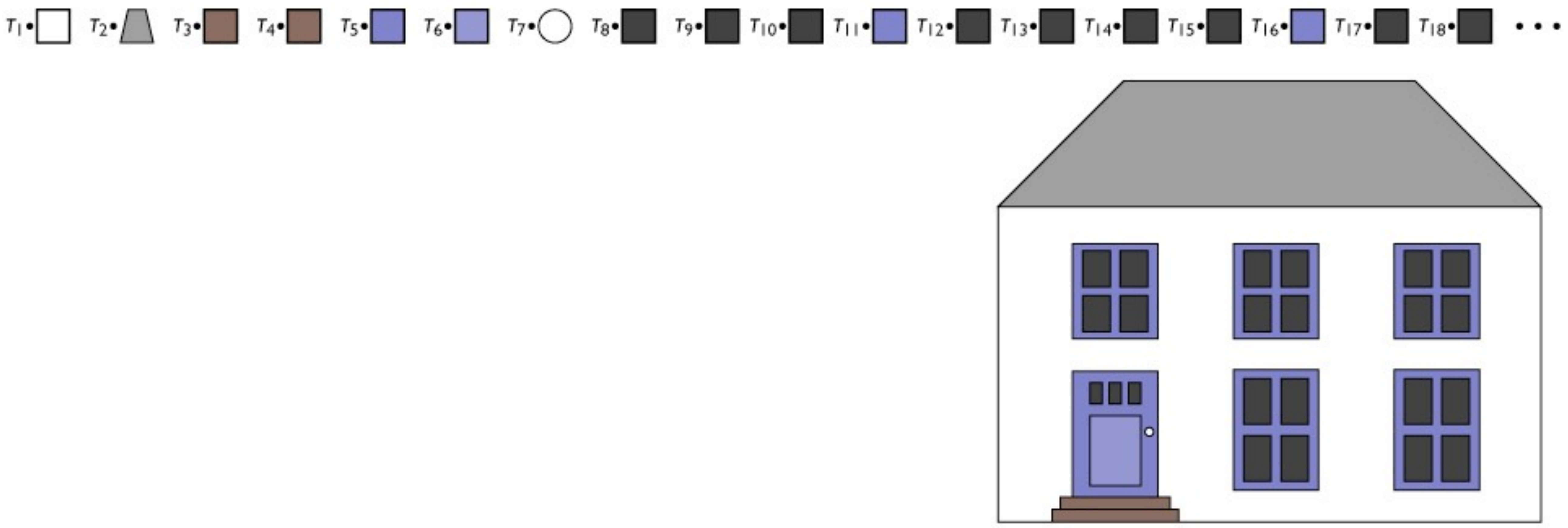
Data structures with transforms

- **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



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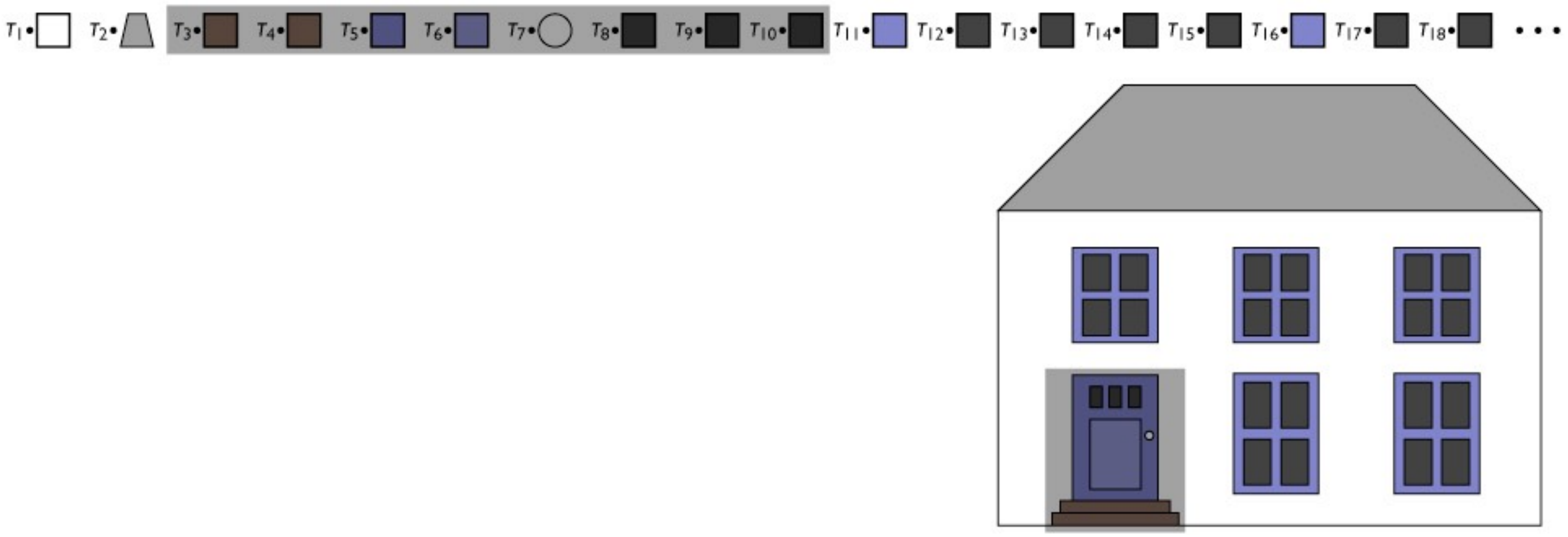
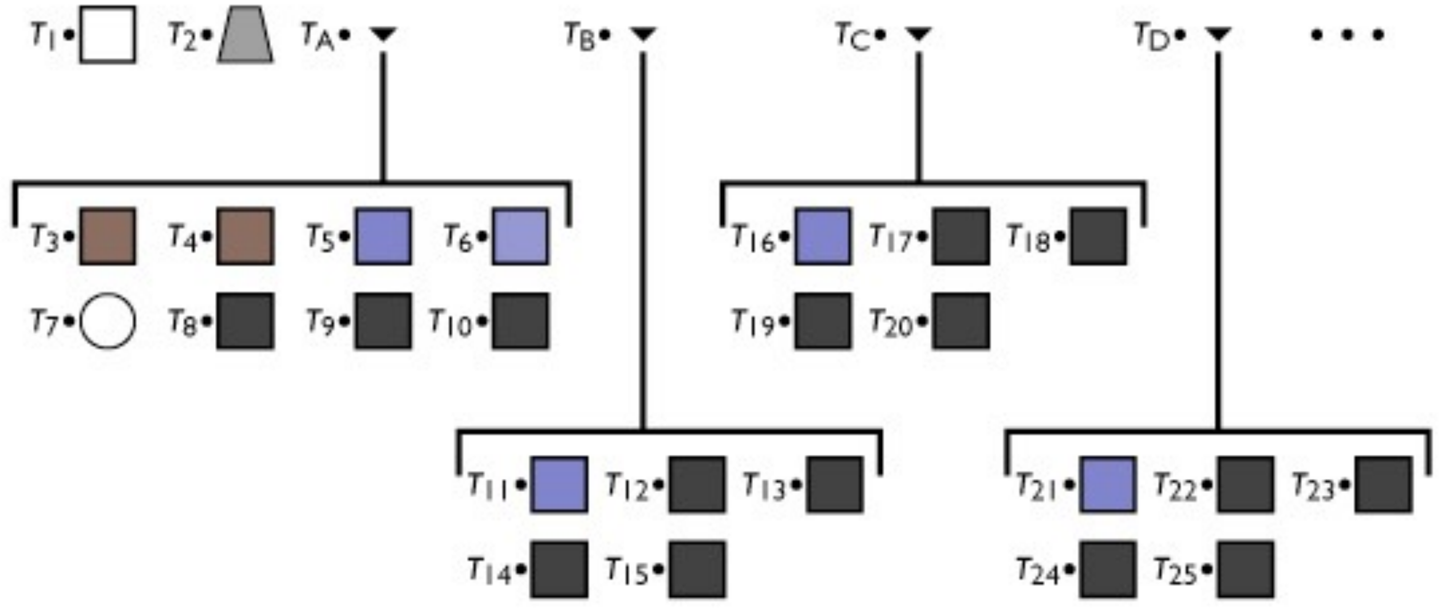


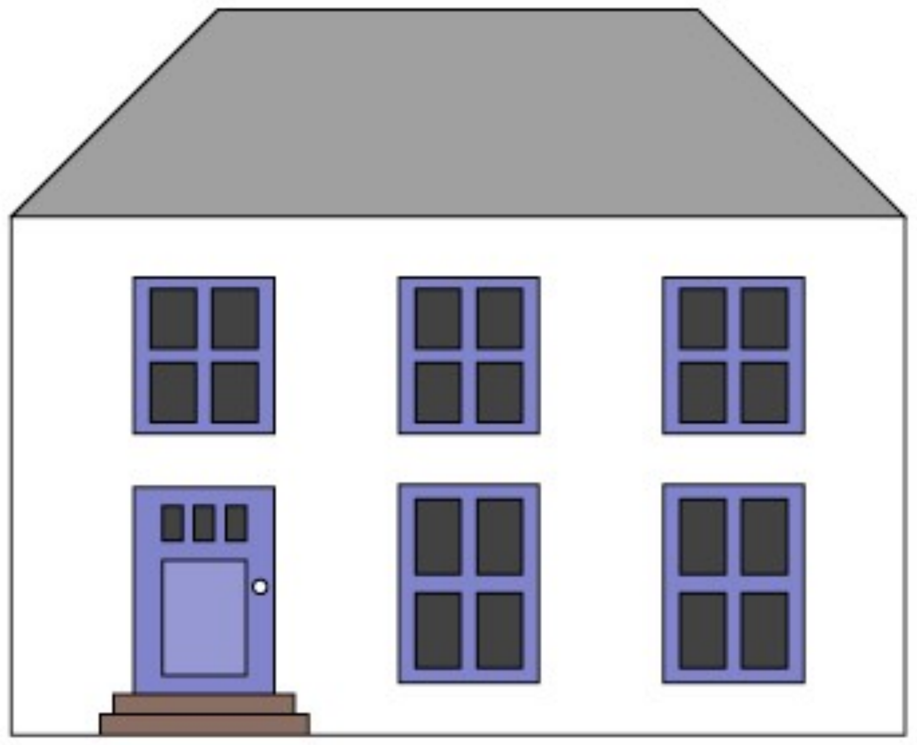
Groups of objects

- **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





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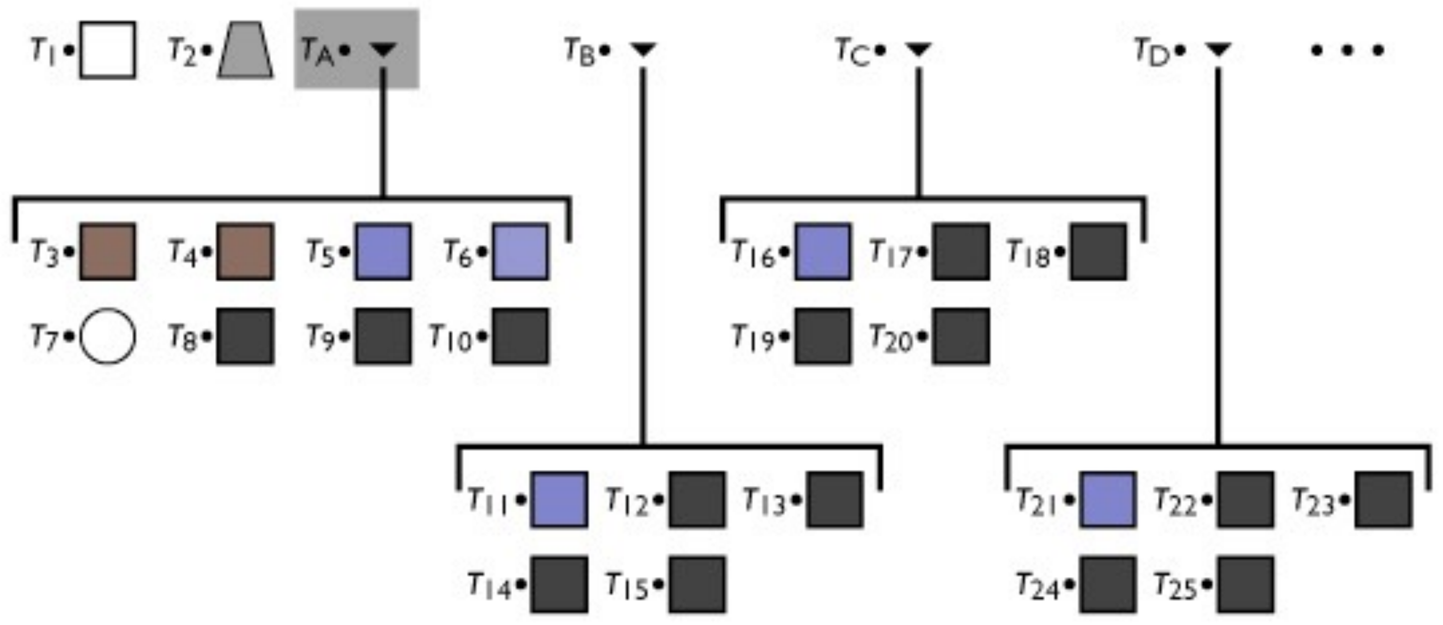
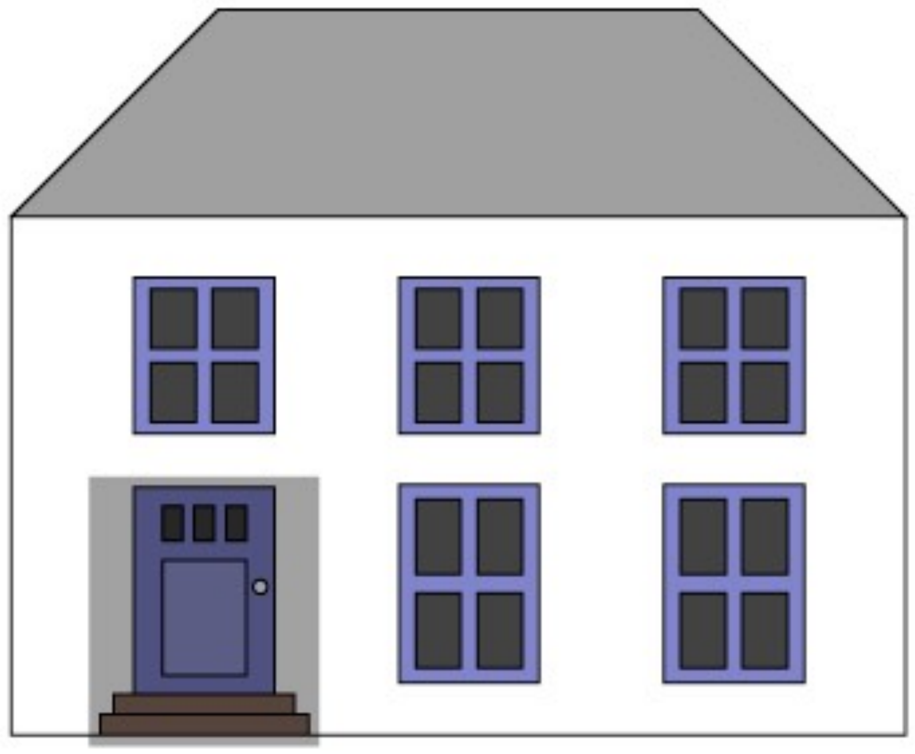


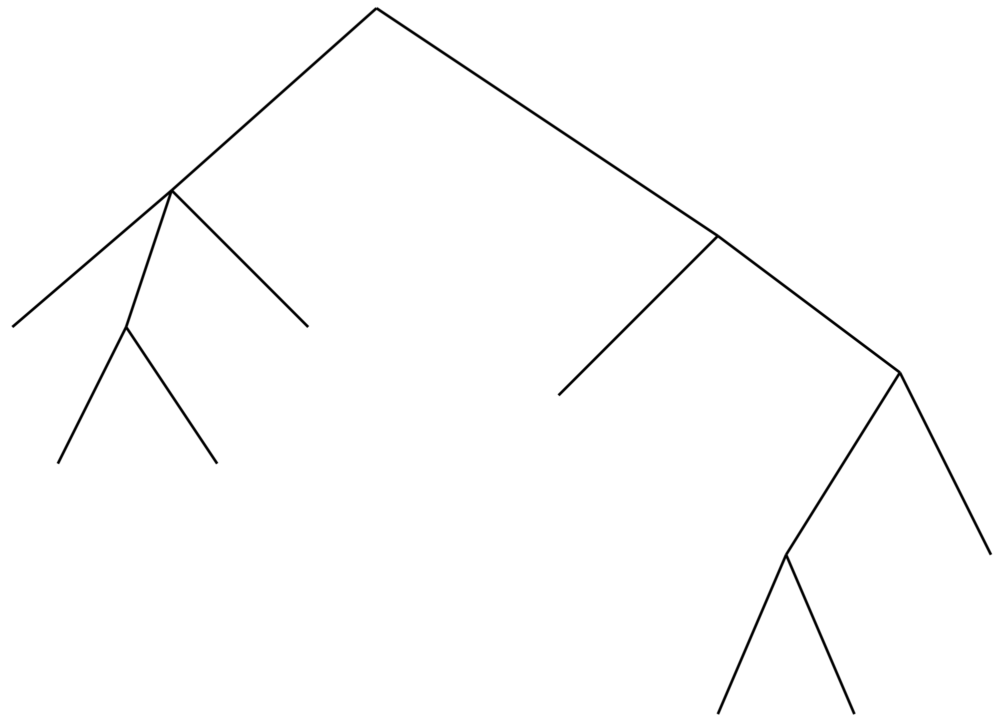


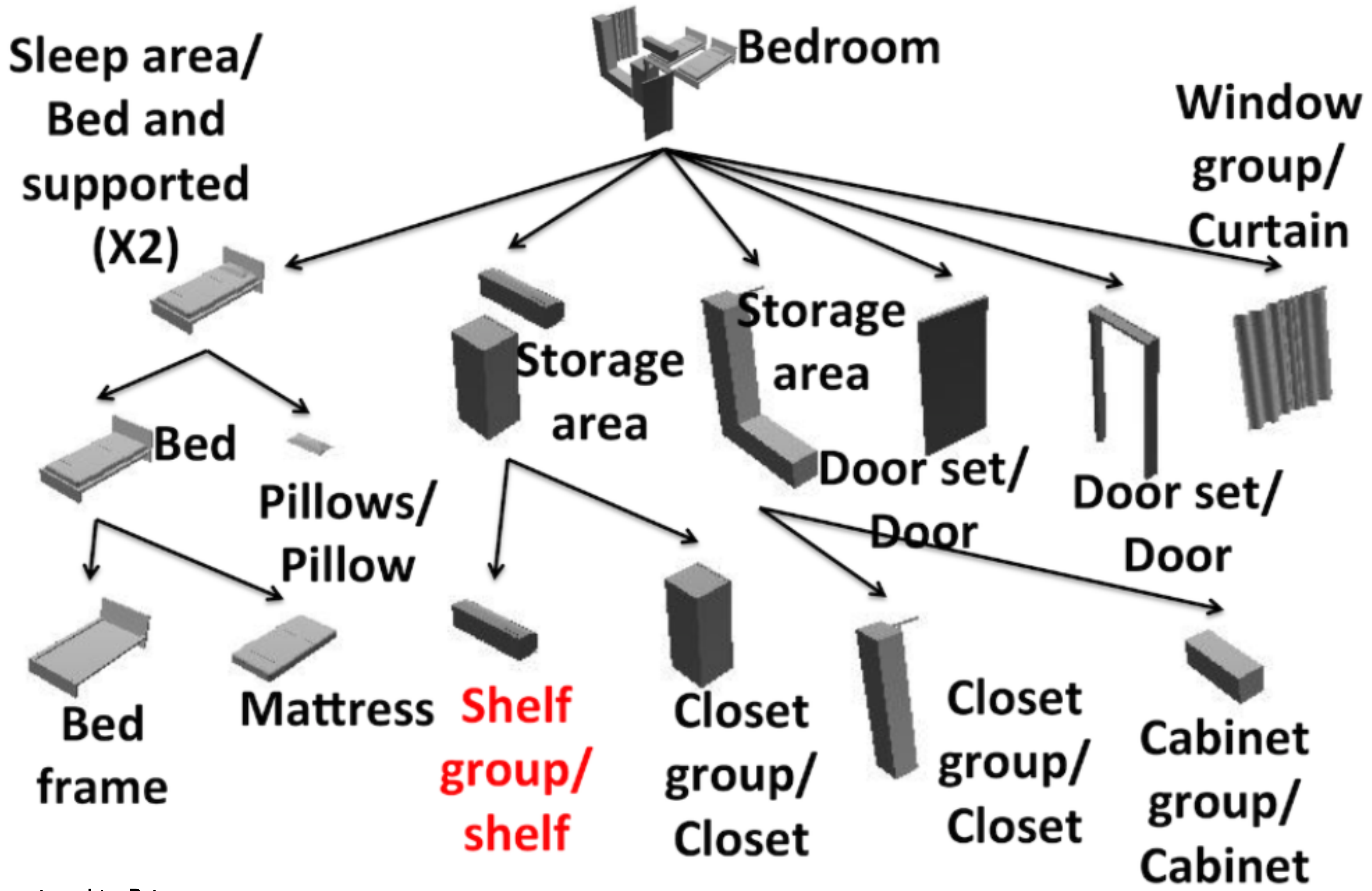
Demo

- **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





Tianqiang Liu, Princeton

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 all the way up to world

Variants of the Scene Graph

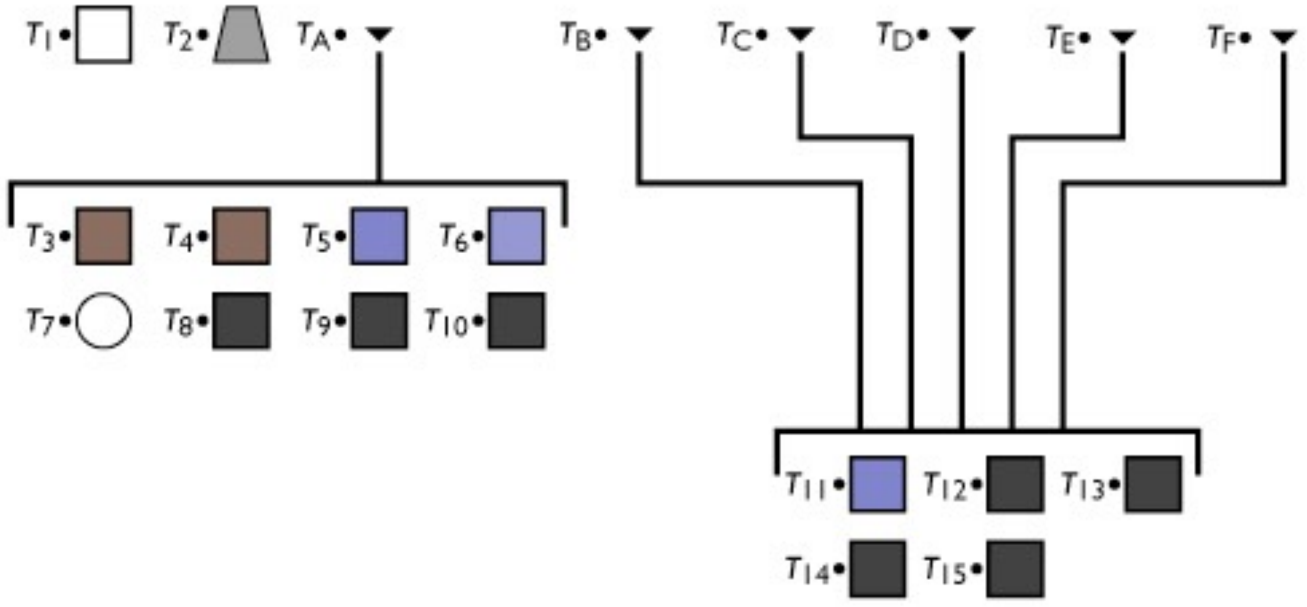
- **Parenting**
  - allow any object to have child objects
  - every object is effectively also a group
  - common in 3D modeling packages
- **Instancing**
  - allow objects to belong to multiple parents/groups
  - transform different in each case
  - leads to multiple linked copies of geometry
  - single editing operation changes all instances
  - instances share representation cost (memory)

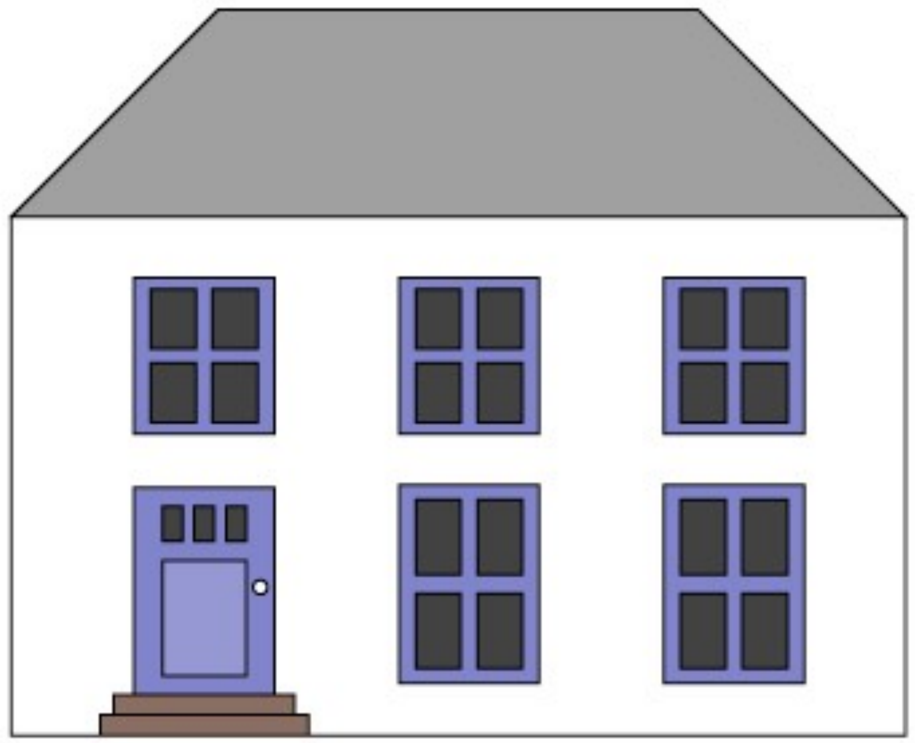
Instances

- **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





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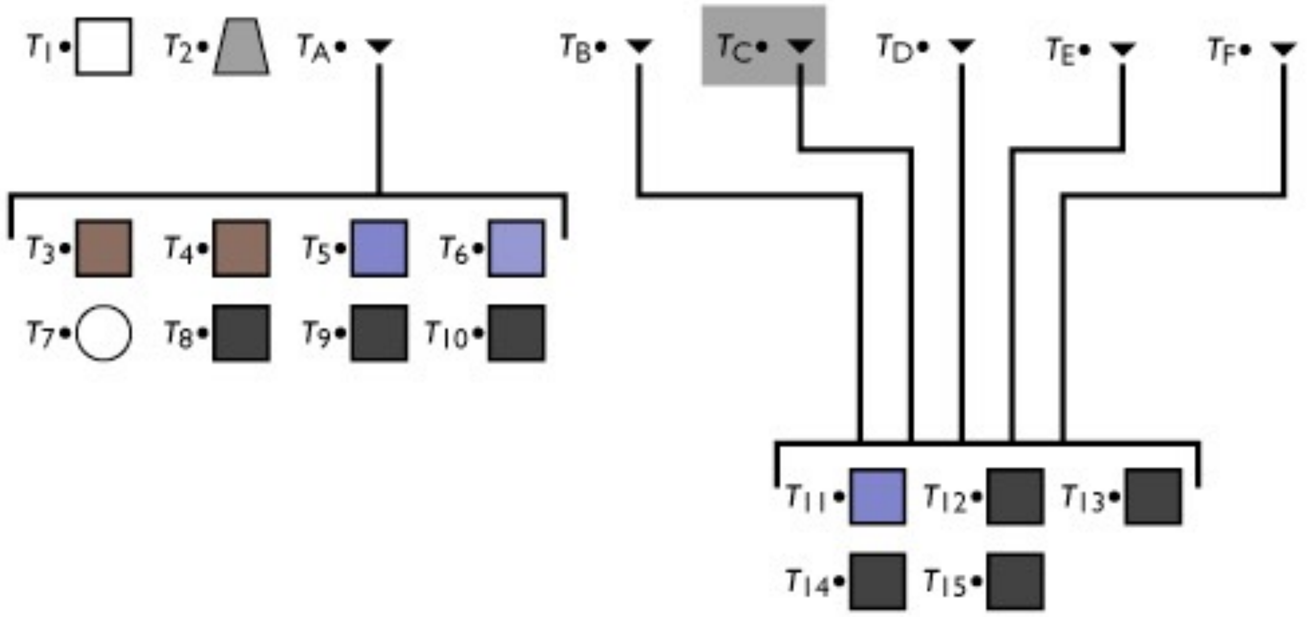

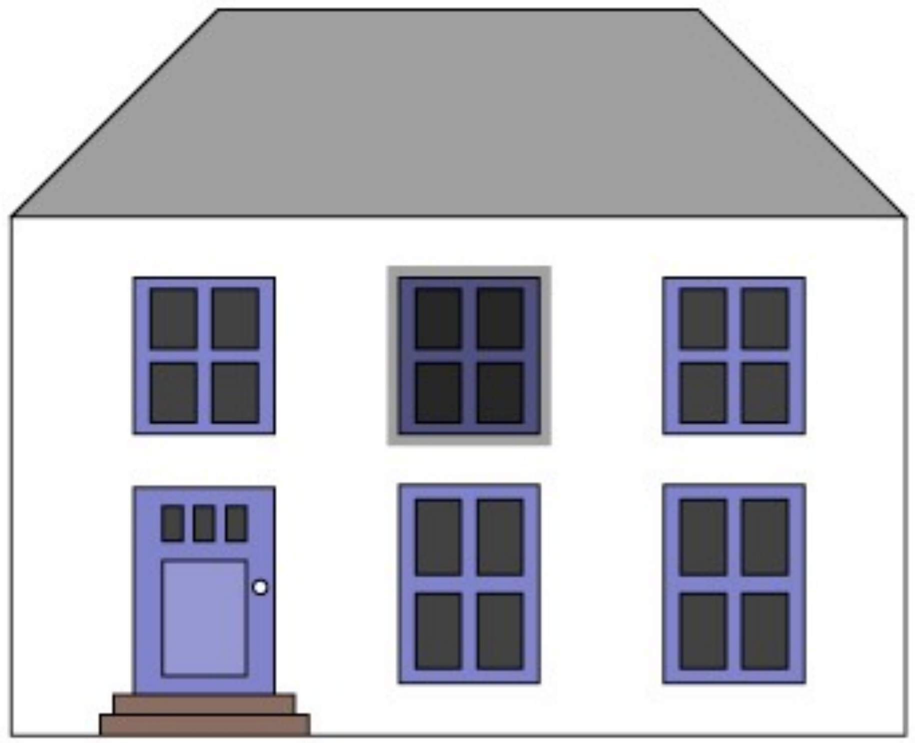

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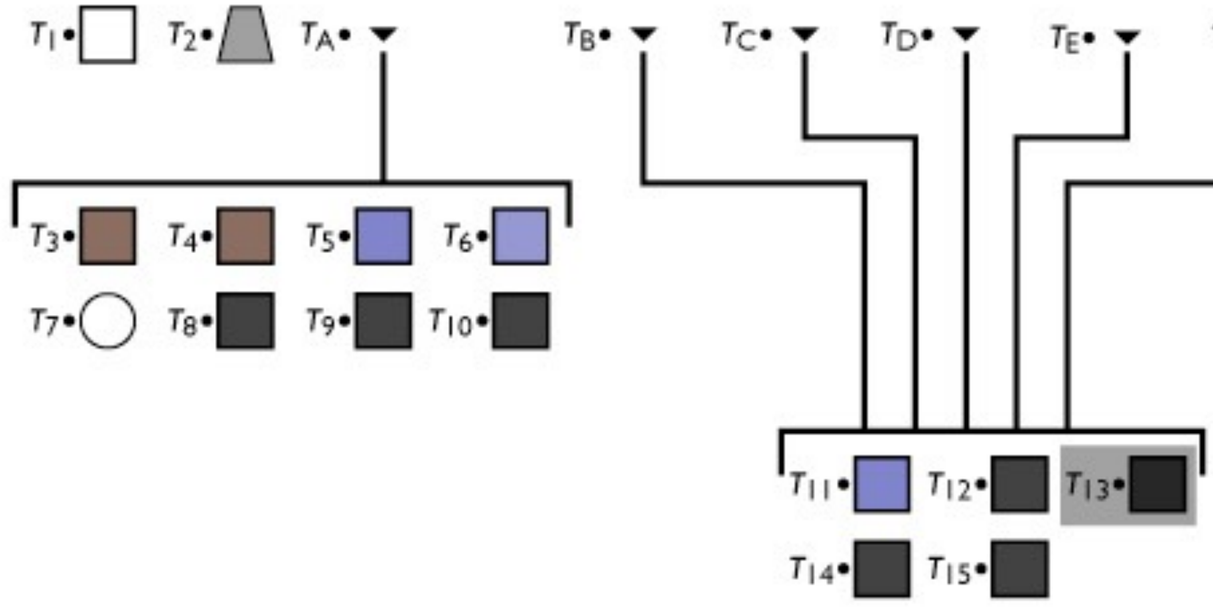
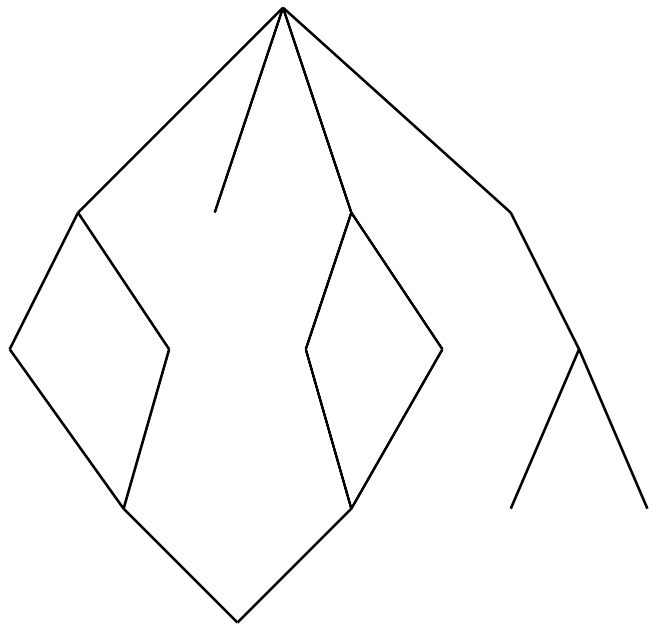


Jan-Walter Schliep, Burak Kahraman, Timm Dapper | Laubwerk via PBRT gallery

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 {
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```

```
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

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**
- **Nodes that set attributes**
  - e.g. "make everything in my subtree green"