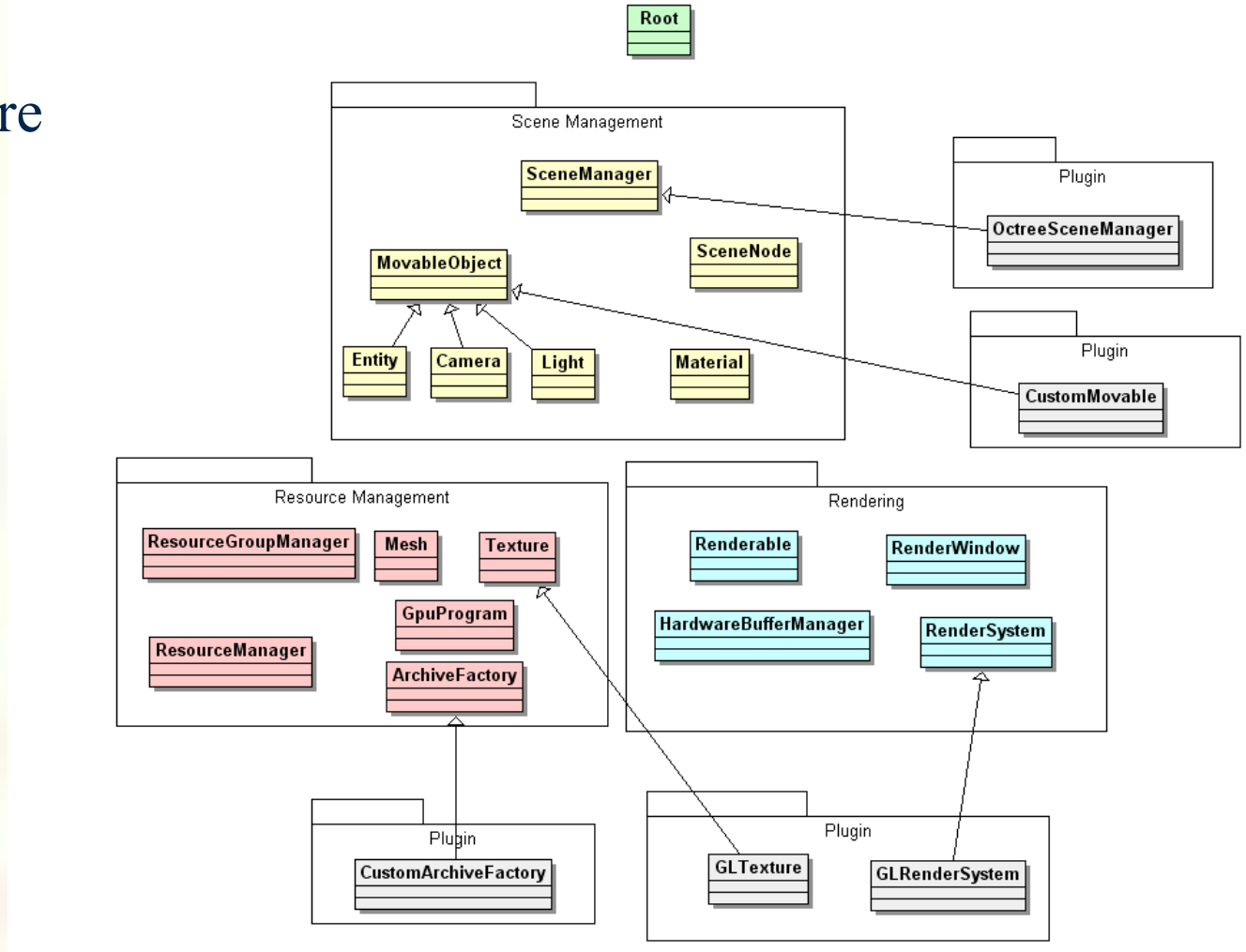
CS 378: Computer Game Technology

3D Engines and Scene Graphs

Spring 2012

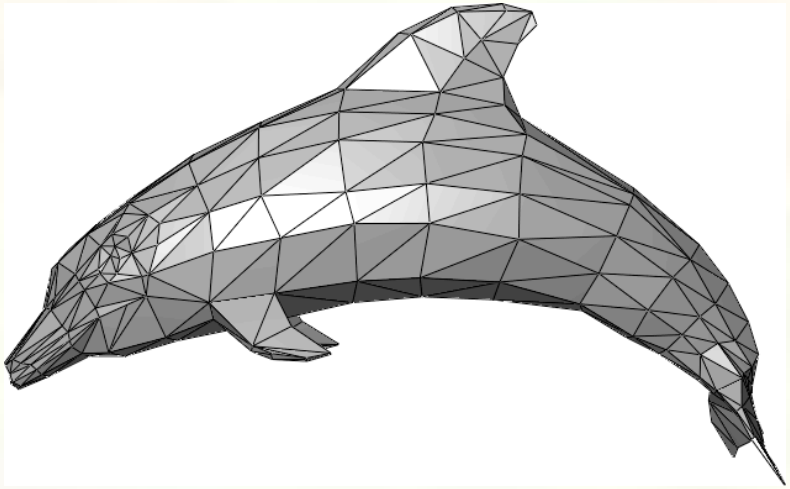
What's a 3d engine

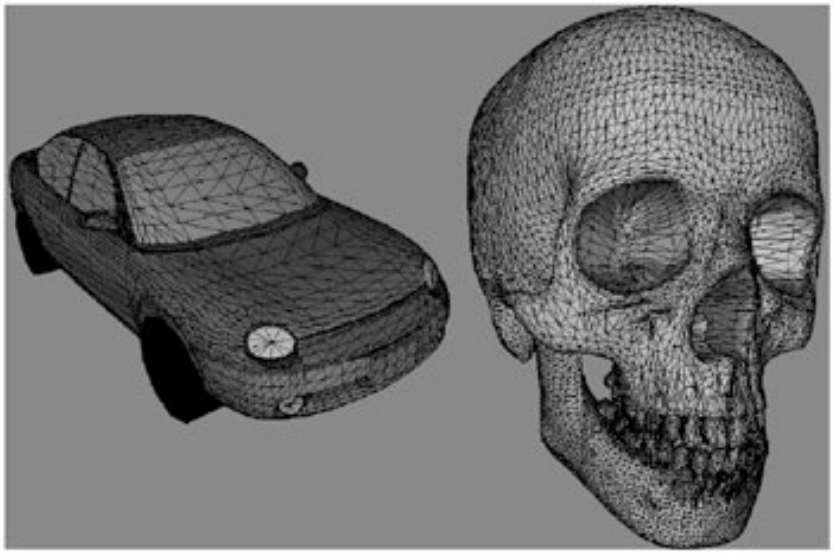
- OGRE Core Class Structure



What are the objects?

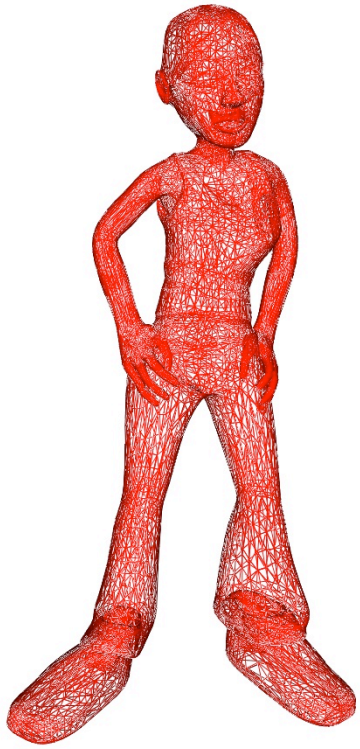
- Geometry - polygon (triangle, quad) meshes





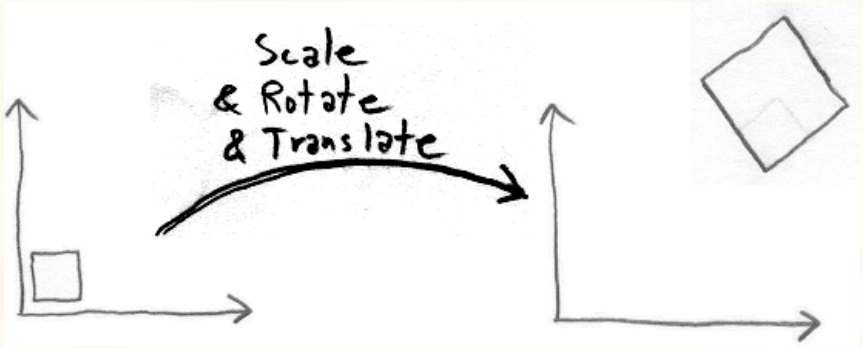
Hierarchical Modeling

- How can you make articulated characters move in the world?
  - Move the whole character wrt the world
  - Move legs, arms, head wrt body
  - Move hands wrt arms
  - Move upper vs. lower arm
  - Same for legs



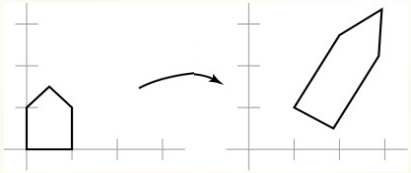
Symbols and instances

- Most graphics APIs support a few geometric **primitives**:
  - spheres
  - cubes
  - triangles
- These symbols are **instanced** using an **instance transformation**.

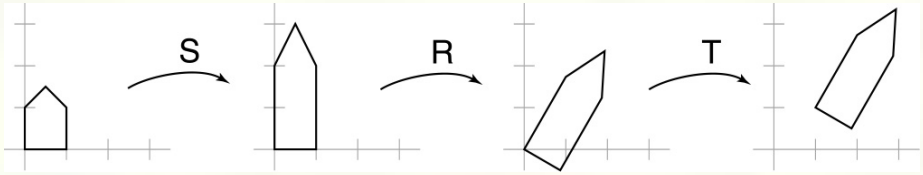


Use a series of transformations

- Ultimately, a particular geometric instance is transformed by one combined transformation matrix:



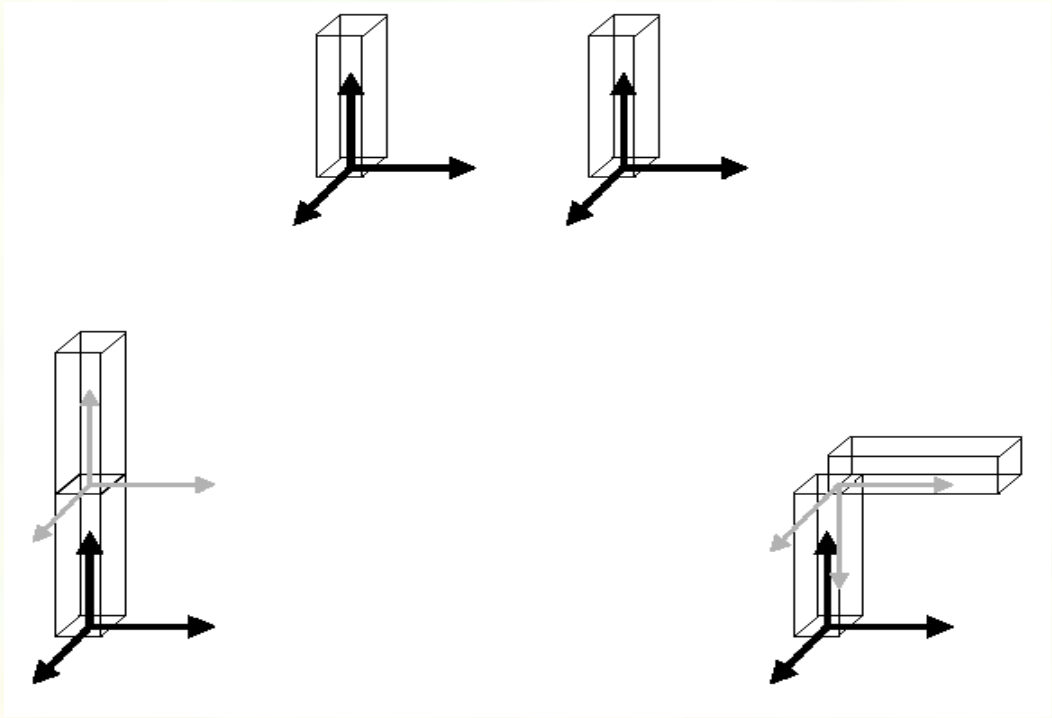
- But it's convenient to build this single matrix from a series of simpler transformations:

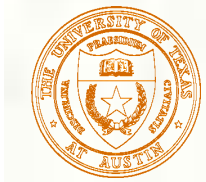


- We have to be careful about how we think about composing these transformations.

  (Mathematical reason: Transformation matrices don't commute under matrix multiplication)

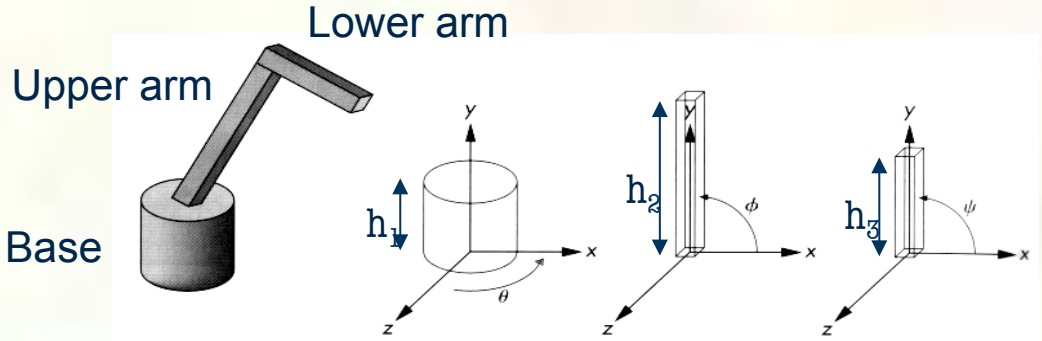
Connecting primitives





3D Example: A robot arm

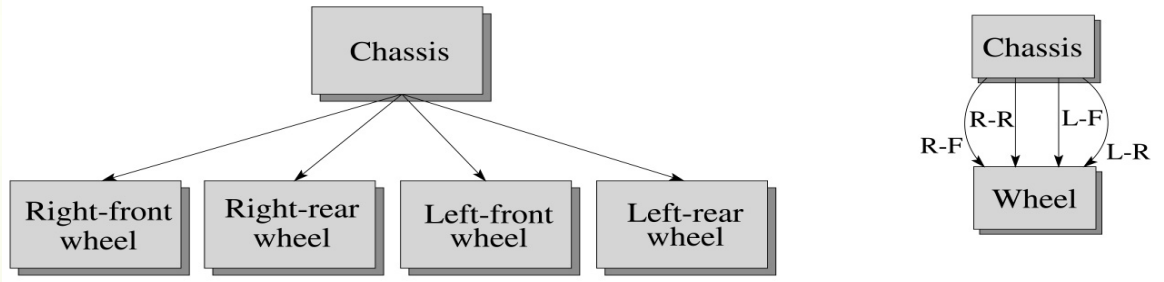
- Consider this robot arm with 3 degrees of freedom:
  - Base rotates about its vertical axis by θ
  - Upper arm rotates in its *xy*-plane by ϕ
  - Lower arm rotates in its *xy*-plane by ψ



- **Q:** What matrix do we use to transform the base?
- **Q:** What matrix for the upper arm?
- **Q:** What matrix for the lower arm?

Hierarchical modeling

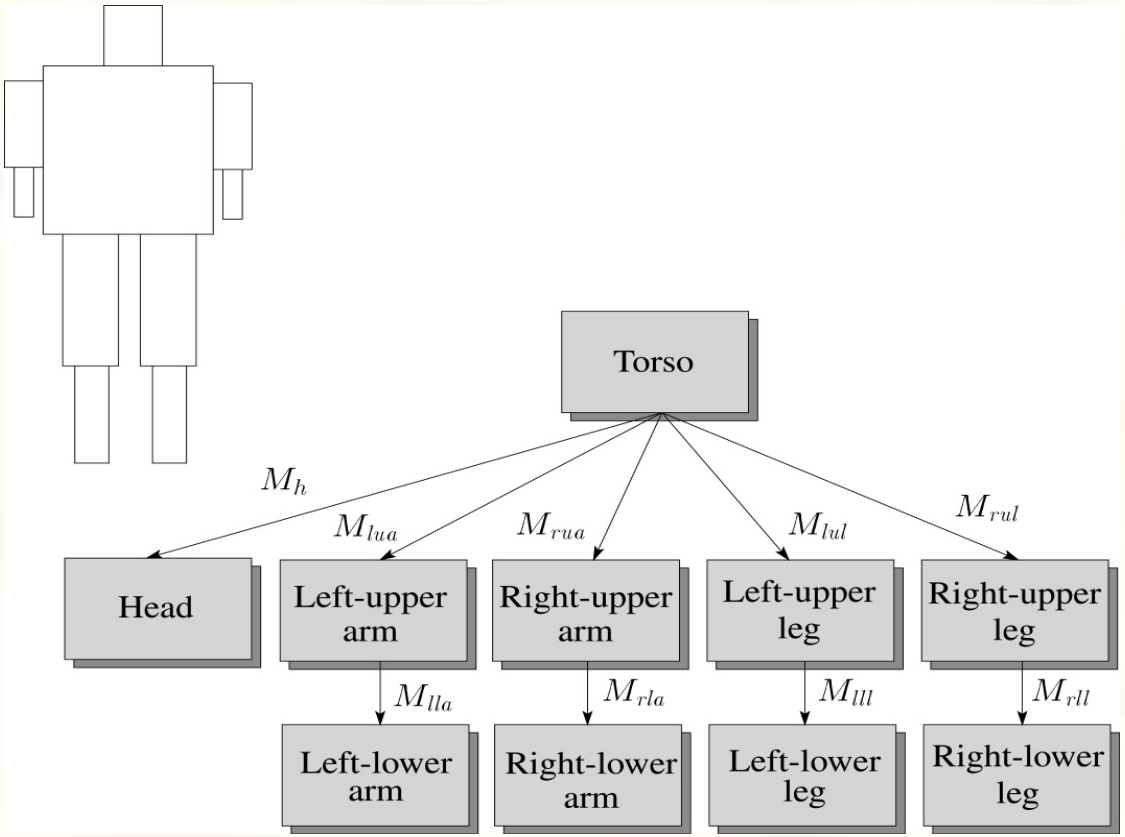
- Hierarchical models can be composed of instances using trees or DAGs:



  - edges contain geometric transformations
  - nodes contain geometry (and possibly drawing attributes)

How might we draw the tree for the robot arm?

A complex example: human figure



Q: What's the most sensible way to traverse this tree?

Human figure implementation, OpenGL

```
figure()
{
    torso();
    glPushMatrix();
        glTranslate( ... );
        glRotate( ... );
        head();
    glPopMatrix();
    glPushMatrix();
        glTranslate( ... );
        glRotate( ... );
        left_upper_arm();
        glPushMatrix();
            glTranslate( ... );
            glRotate( ... );
            left_lower_arm();
        glPopMatrix();
     glPopMatrix();
     . . .
}
```

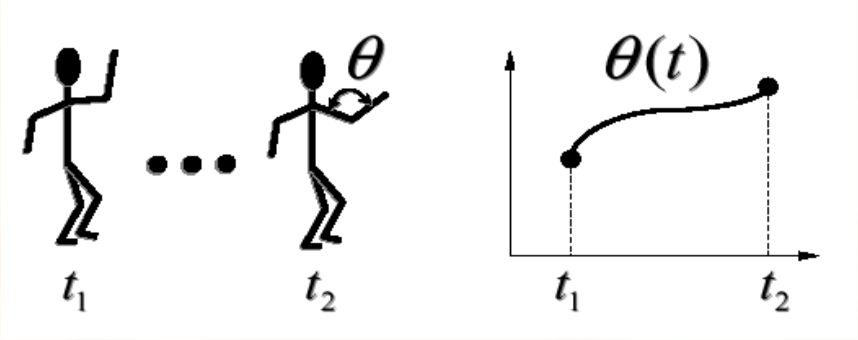
Animation

- The above examples are called **articulated models**:
  - rigid parts
  - connected by joints
- They can be animated by specifying the joint angles (or other display parameters) as functions of time.

Key-frame animation

- The most common method for character animation in production is **key-frame animation**.
  - Each joint specified at various **key frames** (not necessarily the same as other joints)
  - System does interpolation or **in-betweening**

- Doing this well requires:
  - A way of smoothly interpolating key frames: **splines**
  - A good interactive system
  - A lot of skill on the part of the animator



Scene graphs

- The idea of hierarchical modeling can be extended to an entire scene, encompassing:
  - many different objects
  - lights
  - camera position
- This is called a **scene tree** or **scene graph**.