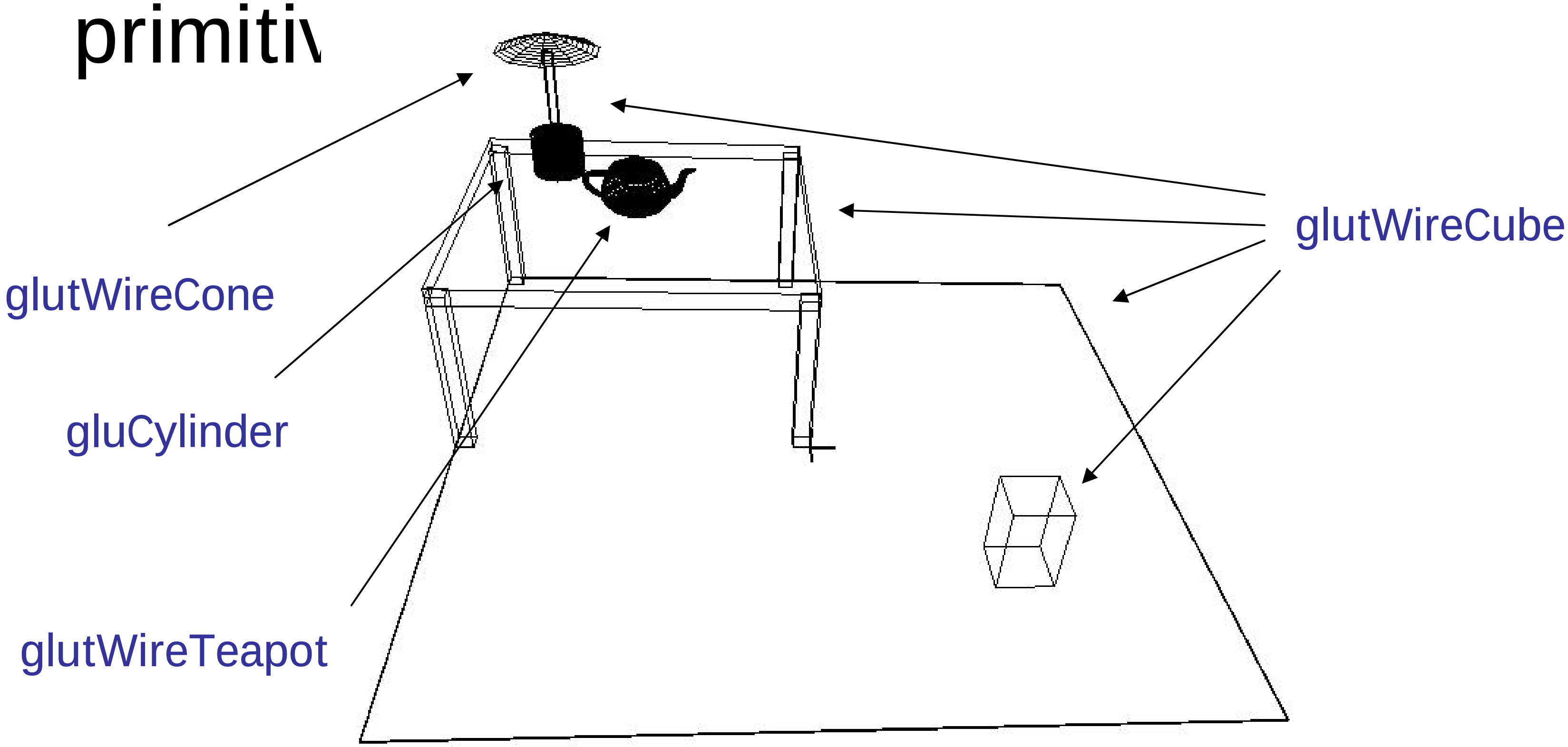
Using GLU/GLUT Objects

- GLU/GLUT provides very simple object primitiv



glutWireCone

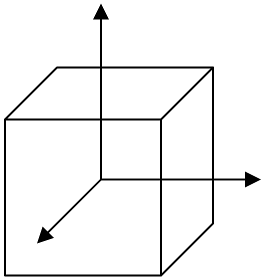
gluCylinder

glutWireTeapot

glutWireCube

GLU/GLUT Objects

- Each glu/glut object has its default size, position, and orientation
- You need to perform modeling transformation to make it right for you



glutWireCube(1.0) - ‘wire’ means wire frame

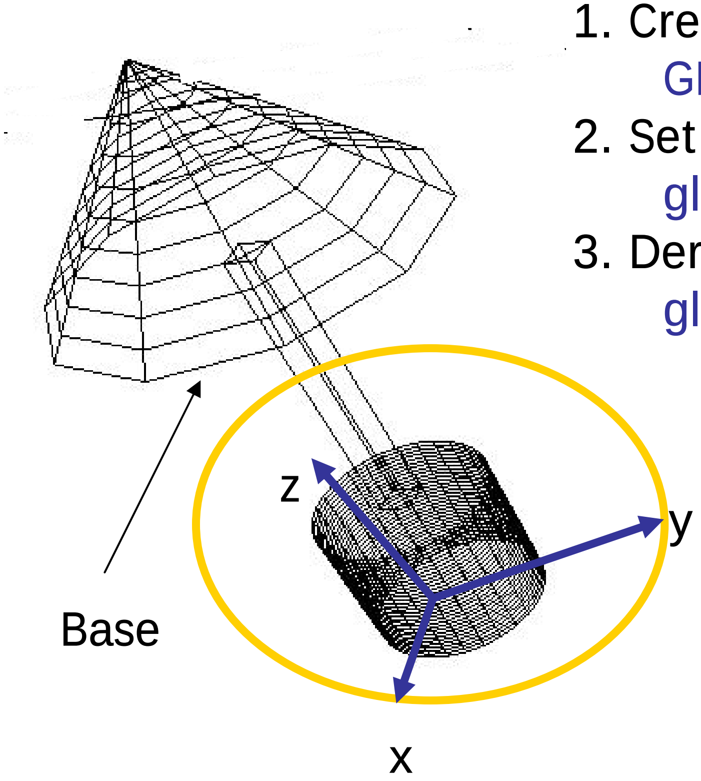
Put a 1x1x1 cube with its center at world (0,0,0)

To create a 2 x 0.1 x 2 table top - need to call glScalef(2, 0.1, 2) before you call glutWireCube(1.0)

gluCylinder()

sphere, cylinder,
disk, partial disk

- Three steps to create a cylinder



1. Create a GLU quadric object

```
GLUquadricObj *p = gluNewQuadric();
```

2. Set to wire frame mode

```
gluQuadricDrawStyle(GLU__LINE);
```

3. Derive a cylinder object from p

```
gluCylinder(p, base, top, height, slice, stacks)
```

base radius

top radius

height

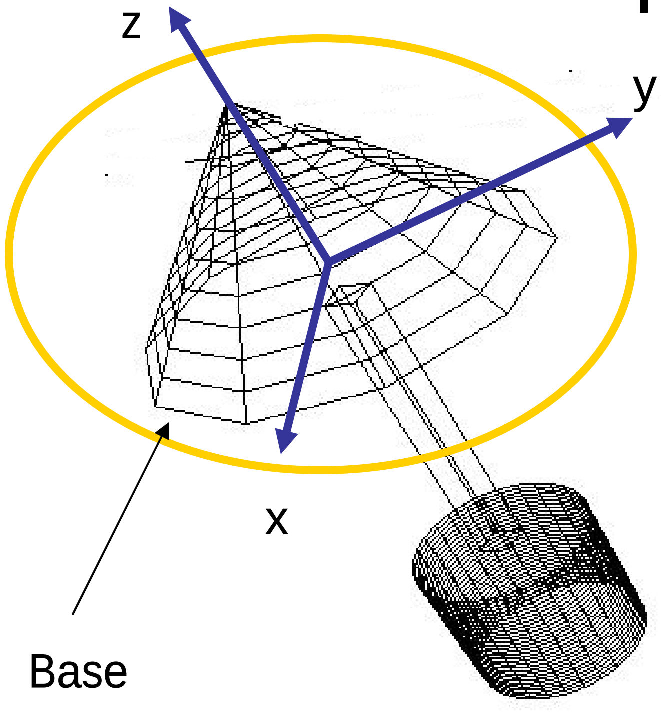
num. of vertical lines

num. of horizontal lines

The default position is also with base at z = 0 plane

glutWireCone()

- Use glutWireCone and gluCylinder to make a lamp



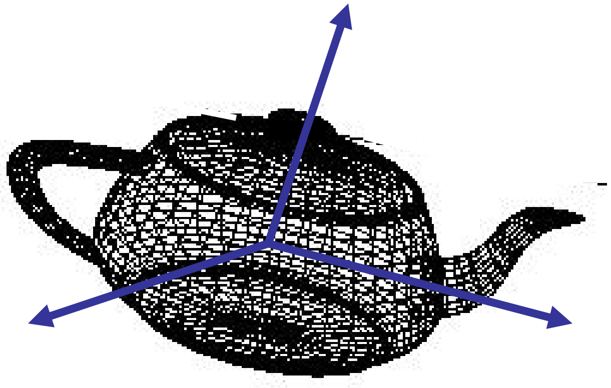
glutWireCone(base, height, slices, stacks)

- A polygon approximation of a cone.

Default position: its base at Z = 0 plane
base: the width of its base
height: the height of the cone
slices: the number of vertical lines used
to make up the cone
stace: the number of horizontal lines used
to make up the cone

glutWireTeapot()

- The famous Utah Teapot has become an unofficial computer graphics mascot



glutWireTeapot(0.5) -

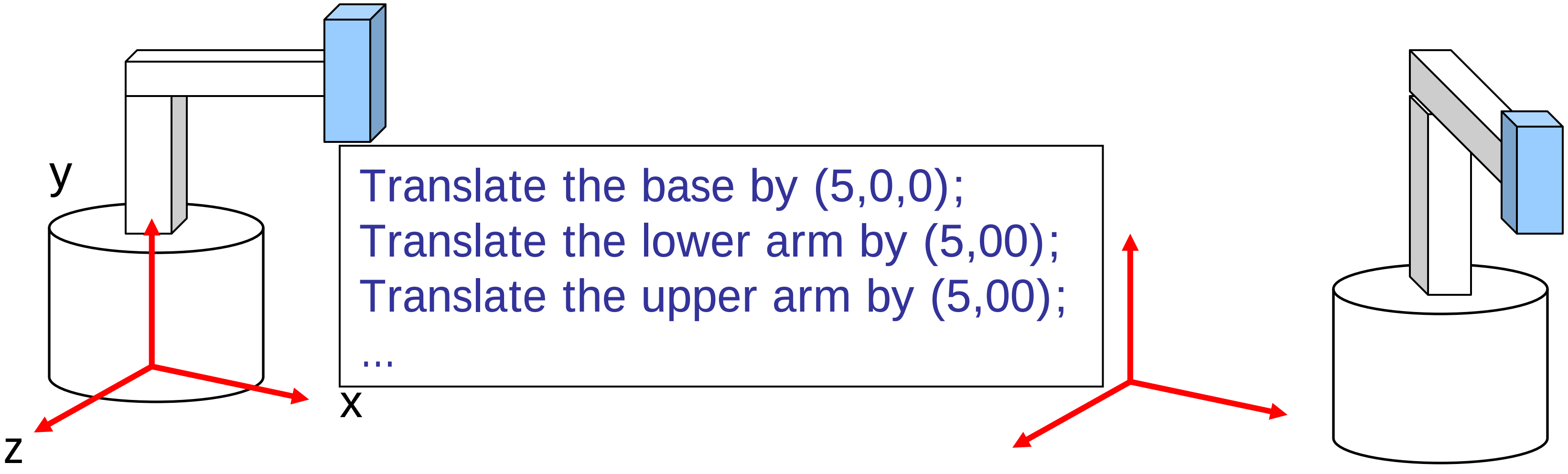
Create a teapot with size 0.5, and position its center at (0,0,0)

Again, you need to apply transformations to position it at the right spot

Transformations

- Two ways to specify transformations
  - (1) Each part of the object is transformed independently relative to the origin

Not the OpenGL Way!

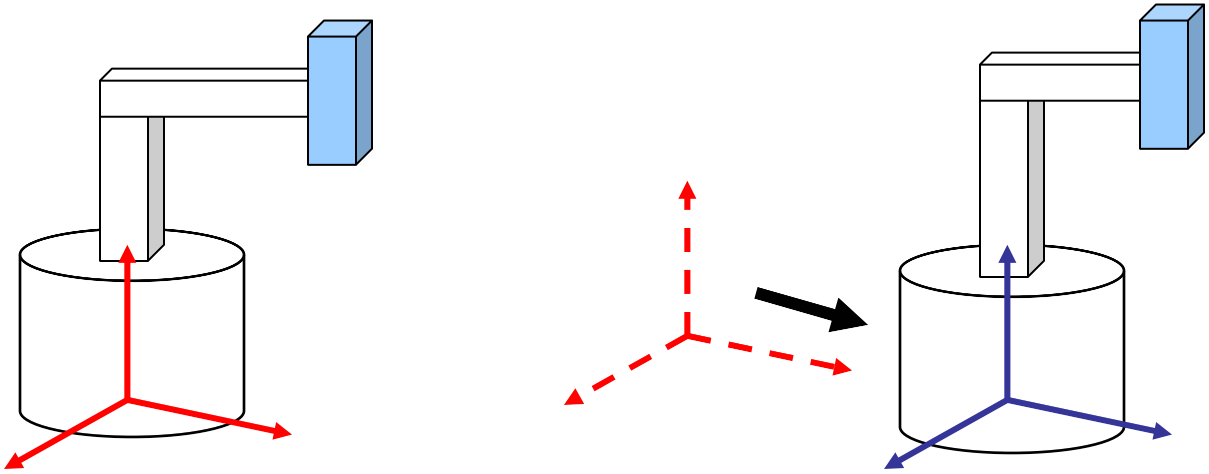


Translate the base by (5,0,0);
Translate the lower arm by (5,00);
Translate the upper arm by (5,00);
…

Relative Transformation

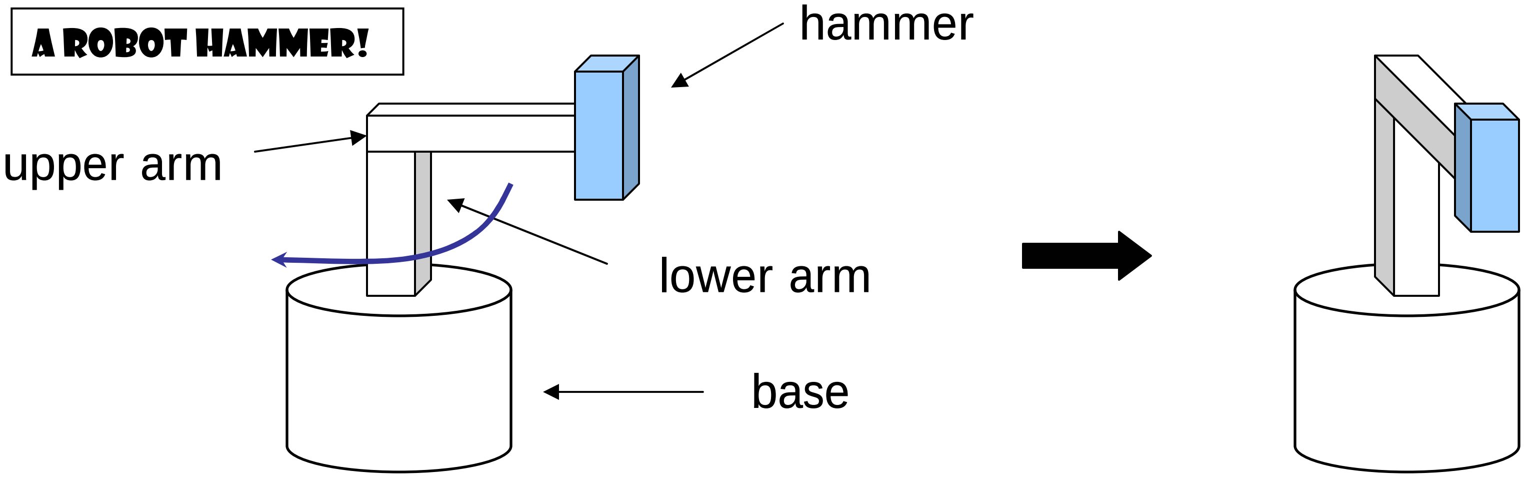
A better (and easier) way:

(2) Relative transformation: Specify the transformation for each object relative to its parent



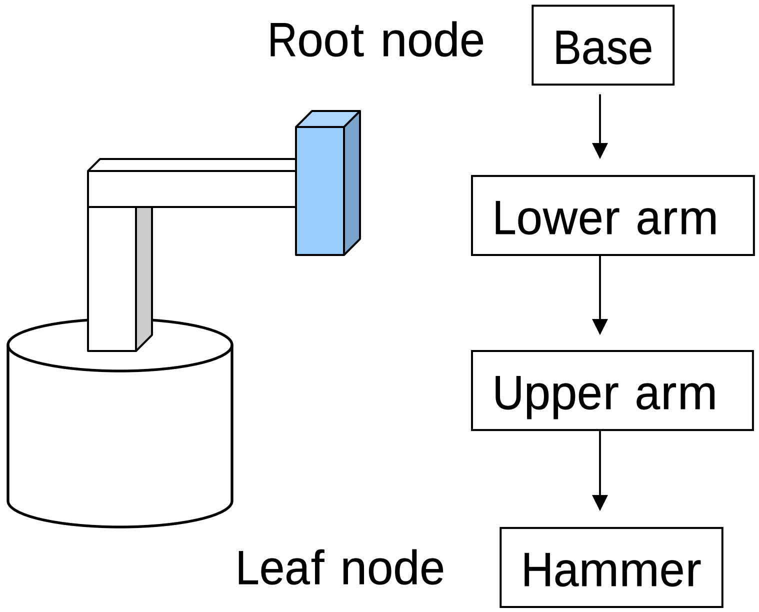
Object Dependency

- A graphical scene often consists of many small objects
- The attributes of an object (positions, orientations) can depend on others



Hierarchical Representation - Scene Graph

- We can describe the object dependency using a tree structure



Root node

Base

Lower arm

Upper arm

Hammer

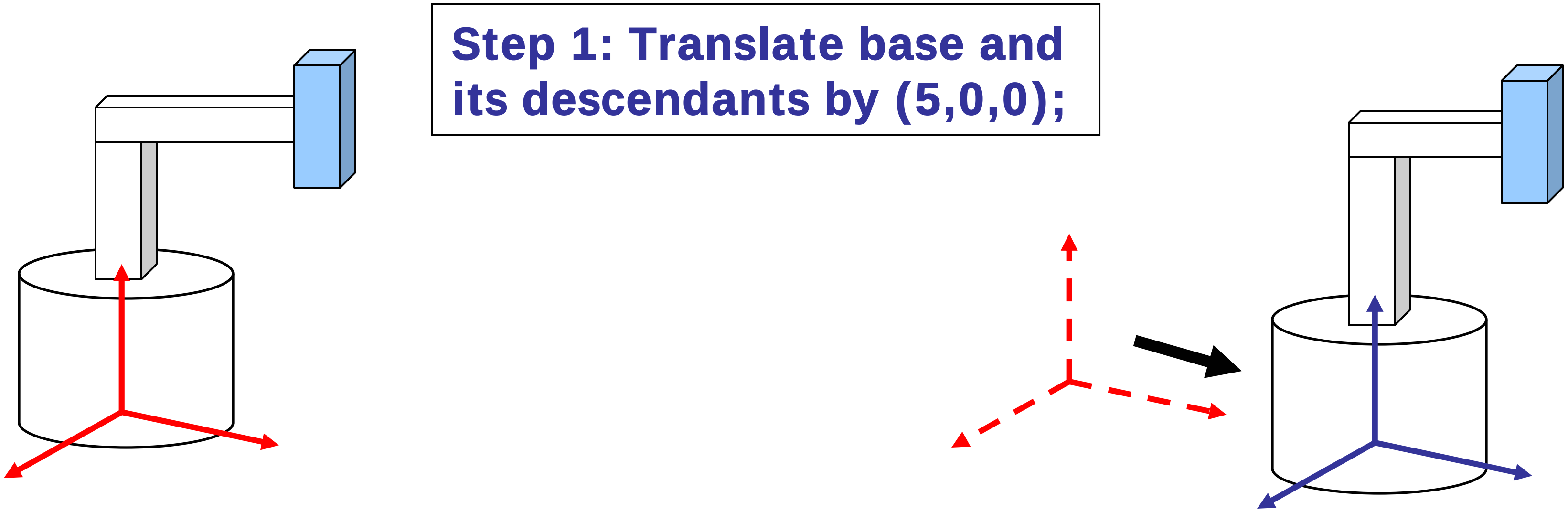
Leaf node

The position and orientation of
an object can be affected
by its parent, grand-parent,
grand-grand-parent … nodes

This hierarchical representation is referred to as Scene Graph

Relative Transformation

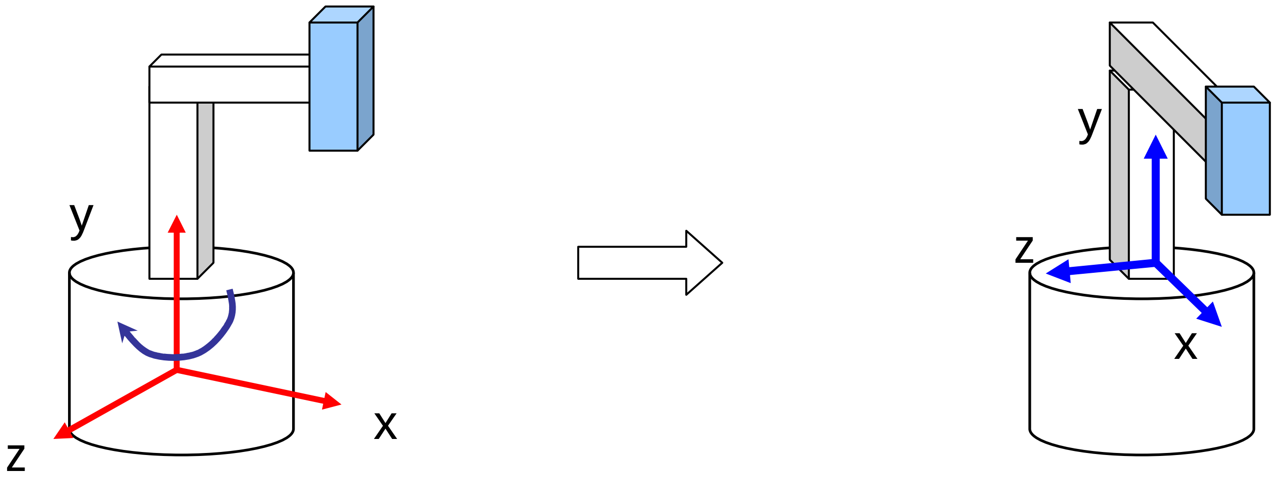
Relative transformation: Specify the transformation for each object relative to its parent



Step 1: Translate base and its descendants by (5,0,0);

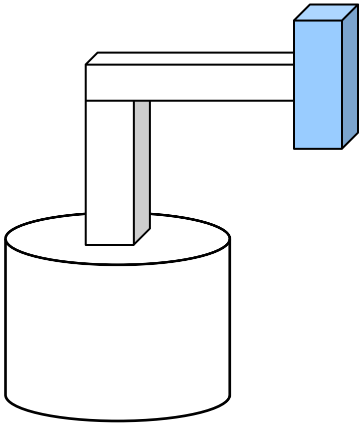
Relative Transformation (2)

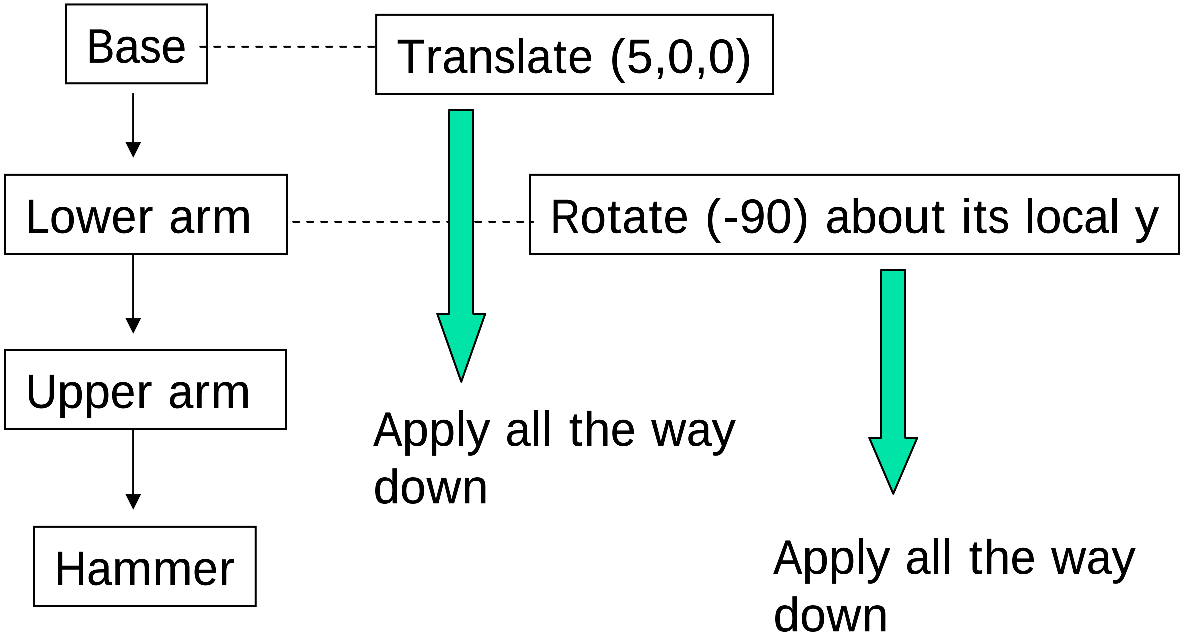
Step 2: Rotate the lower arm and all its descendants relative to its local y axis by -90 degree



Relative Transformation (3)

- Represent relative transformations using scene graph





Base

Lower arm

Upper arm

Hammer

Translate (5,0,0)

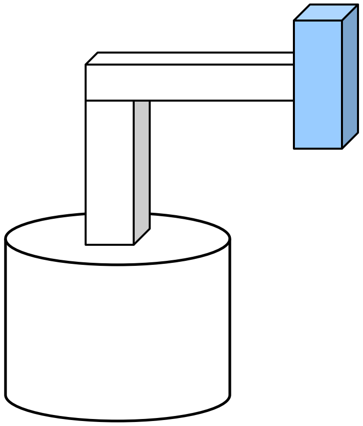
Apply all the way down

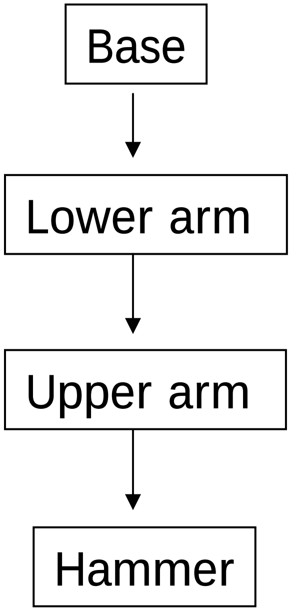
Rotate (-90) about its local y

Apply all the way down

Do it in OpenGL

- Translate base and all its descendants by (5,0,0)
- Rotate the lower arm and its descendants by -90 degree about the local y





Base

Lower arm

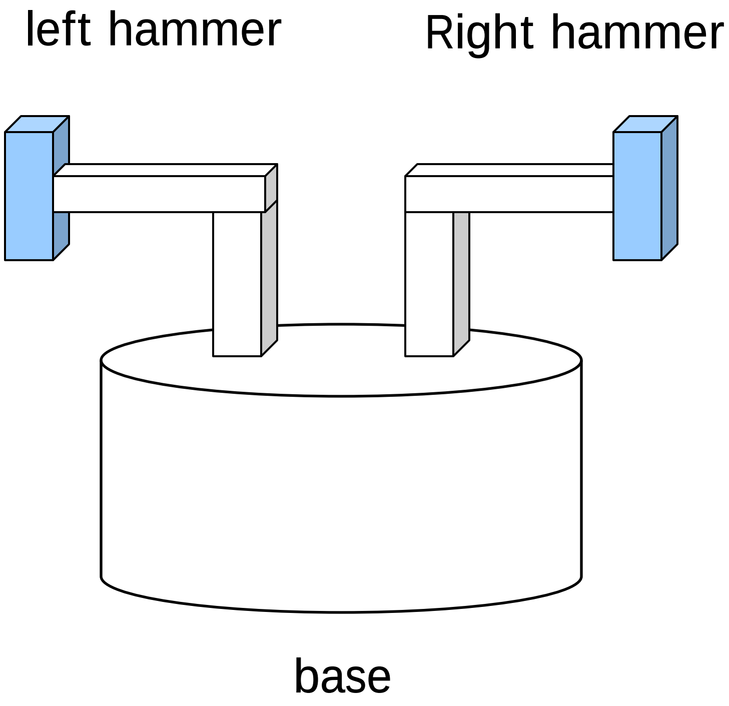
Upper arm

Hammer

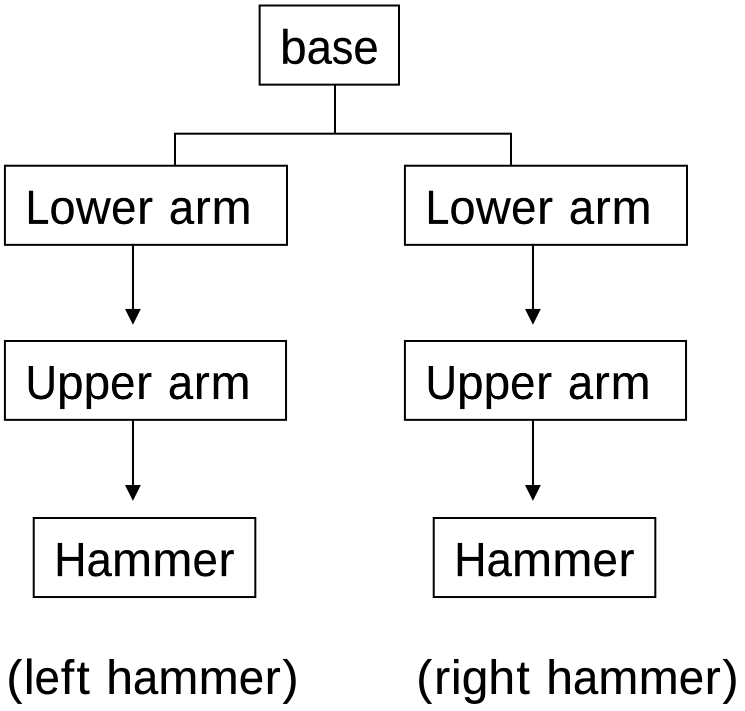
```
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();

... // setup your camera

glTranslatef(5,0,0);

Draw_base();

glRotatef(-90, 0, 1, 0);

Draw_lower _arm();
Draw_upper_arm();
Draw_hammer();
```

A more complicated example

- How about this model?



Scene Graph?



base

Lower arm

Lower arm

Upper arm

Upper arm

Hammer

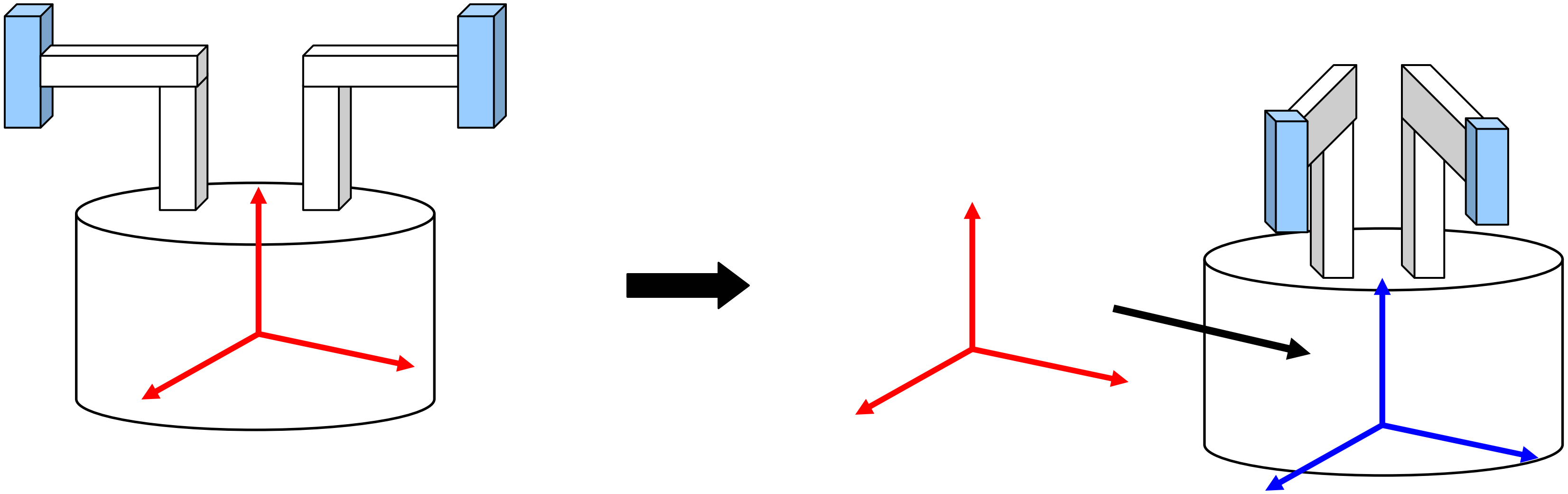
Hammer

(left hammer)

(right hammer)

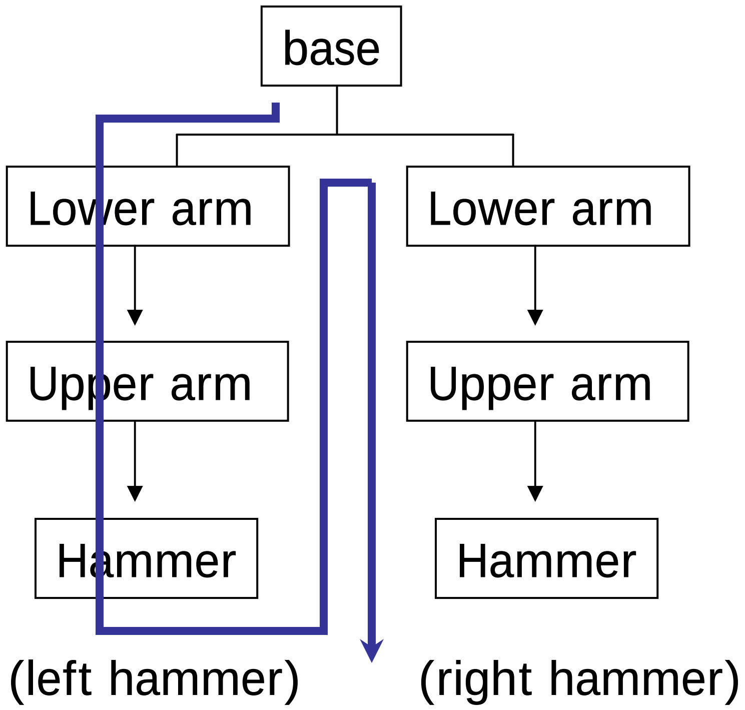
Do this ...

- Base and everything – translate (5,0,0)
- Left hammer – rotate 75 degree about the local y
- Right hammer – rotate -75 degree about the local y



Depth-first traversal

- Program this transformation by depth-first traversal



Depth First Traversal

Do _____ transformation(s)

Draw base

Do ______ transformation(s)

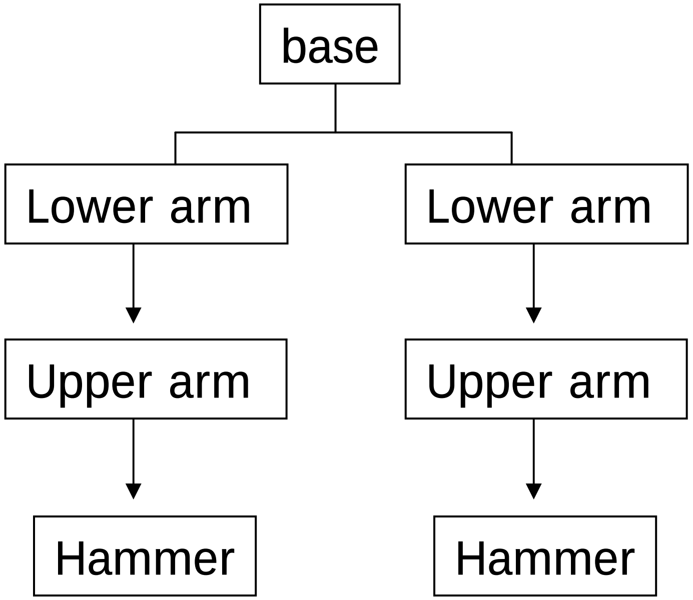
Draw left arm

Do ______ transformation(s)

Draw right arm

What are they?

How about this?



base

Lower arm

Upper arm

Hammer

Lower arm

Upper arm

Hammer

(left hammer)

(right hammer)

Translate(5,0,0)

Draw base

Rotate(75, 0, 1, 0)

Draw left hammer

~~**Rotate(-75, 0, 1, 0)**~~

Draw right hammer

What’s wrong?!

Something is wrong …

- What’s wrong? – We want to transform the right hammer relative to the base, not to the left hammer

How about this?

Do **Translate(5,0,0)**

Draw base

Do **Rotate(75, 0, 1, 0)**

Draw left hammer

What’s wrong?!

Do ~~**Rotate(-75, 0, 1, 0)**~~

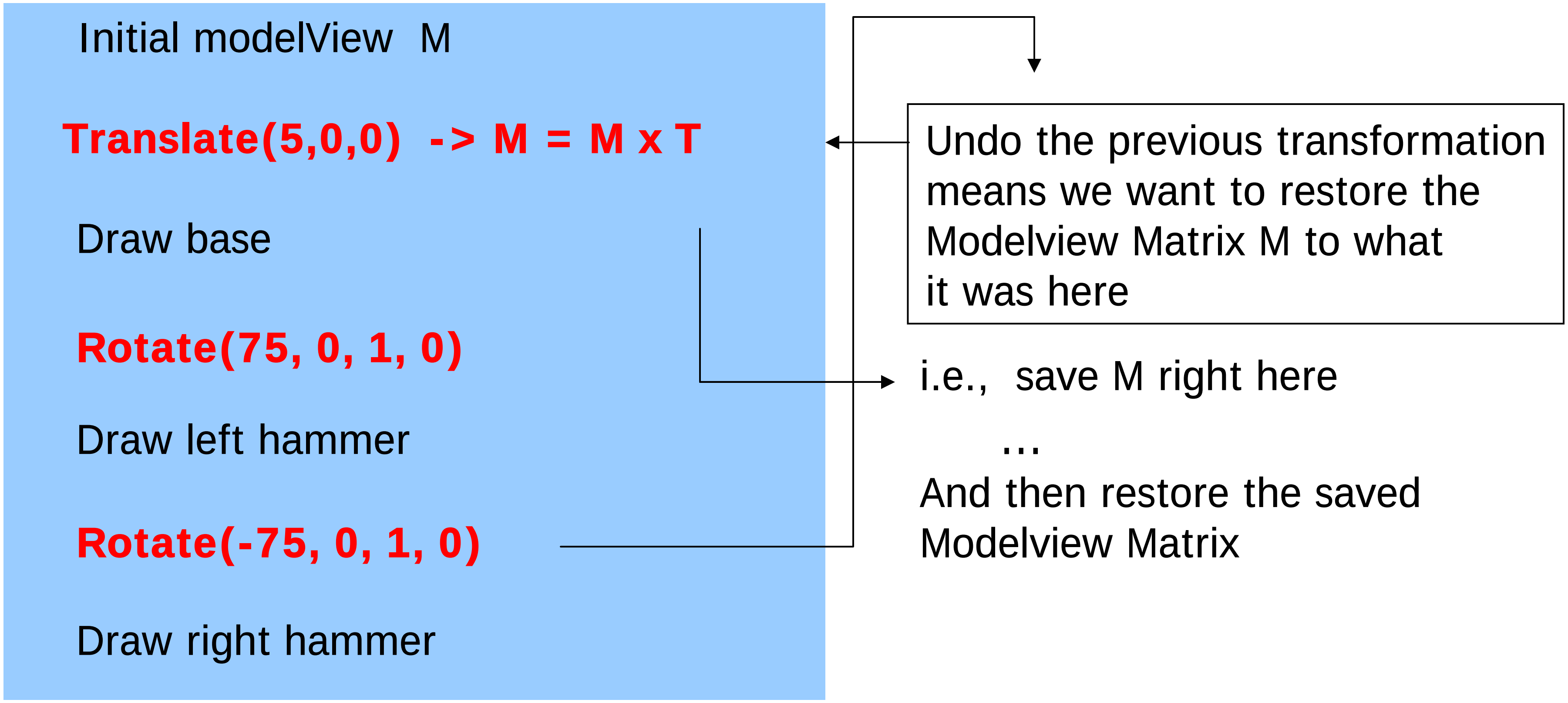
Draw right hammer

Need to undo this first

We should **undo the left hammer transformation** before we transform the right hammer

Undo the previous transformation(s)

- Need to save the modelview matrix right after we draw base



Initial modelView M

Translate(5,0,0) -> M = M x T

Draw base

Rotate(75, 0, 1, 0)

Draw left hammer

Rotate(-75, 0, 1, 0)

Draw right hammer

Undo the previous transformation means we want to restore the Modelview Matrix M to what it was here

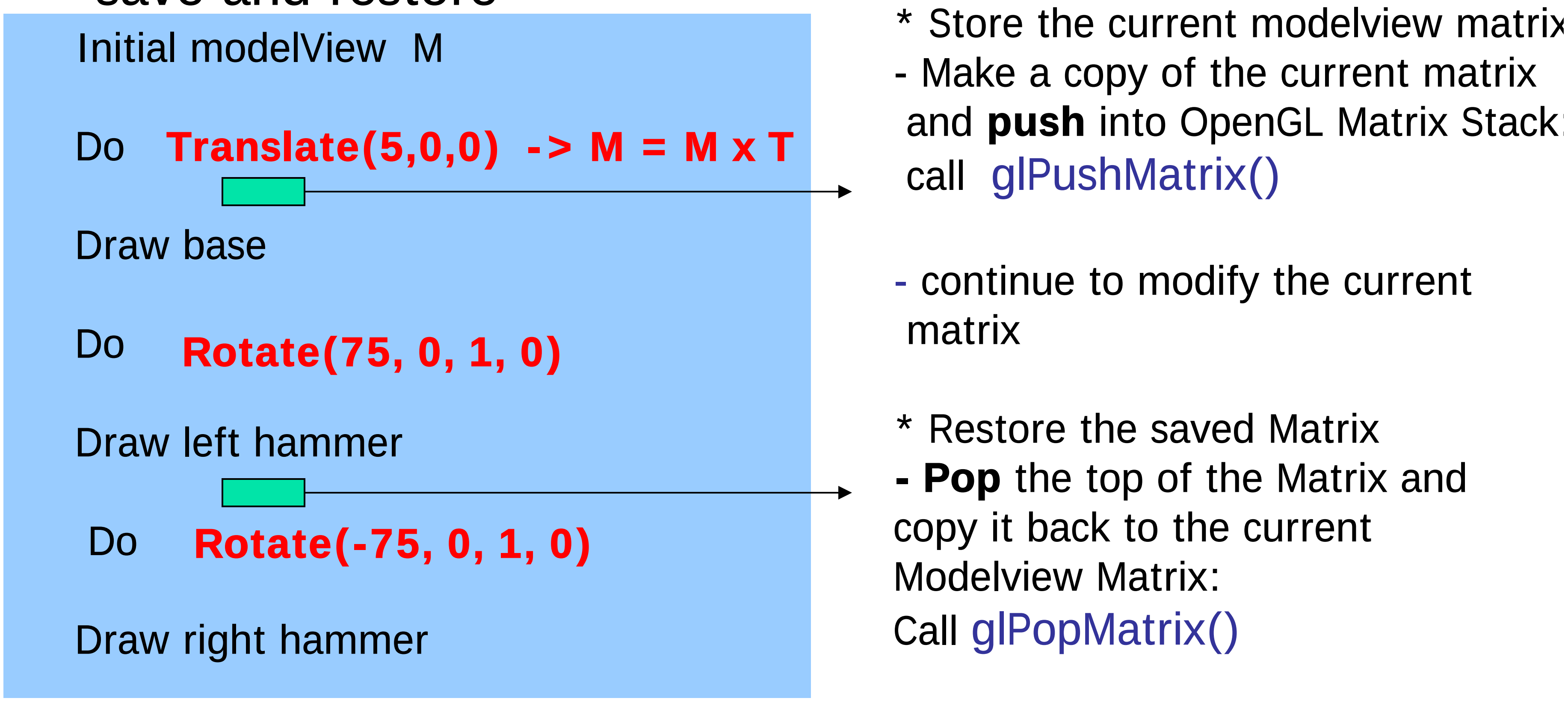
i.e., save M right here

…

And then restore the saved Modelview Matrix

OpenGL Matrix Stack

- We can use OpenGL Matrix Stack to perform matrix save and restore



Initial modelView M

Do **Translate(5,0,0) -> M = M x T**

Draw base

Do **Rotate(75, 0, 1, 0)**

Draw left hammer

Do **Rotate(-75, 0, 1, 0)**

Draw right hammer

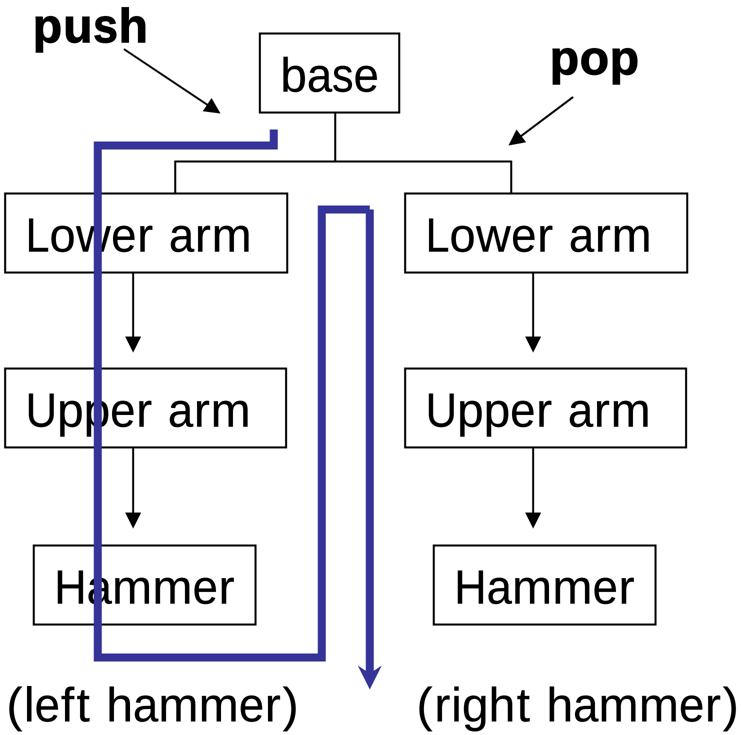
* Store the current modelview matrix
- Make a copy of the current matrix and **push** into OpenGL Matrix Stack:
call glPushMatrix()

- continue to modify the current matrix

* Restore the saved Matrix
- Pop the top of the Matrix and copy it back to the current Modelview Matrix:
Call glPopMatrix()

Push and Pop Matrix Stack

- A simple OpenGL routine:

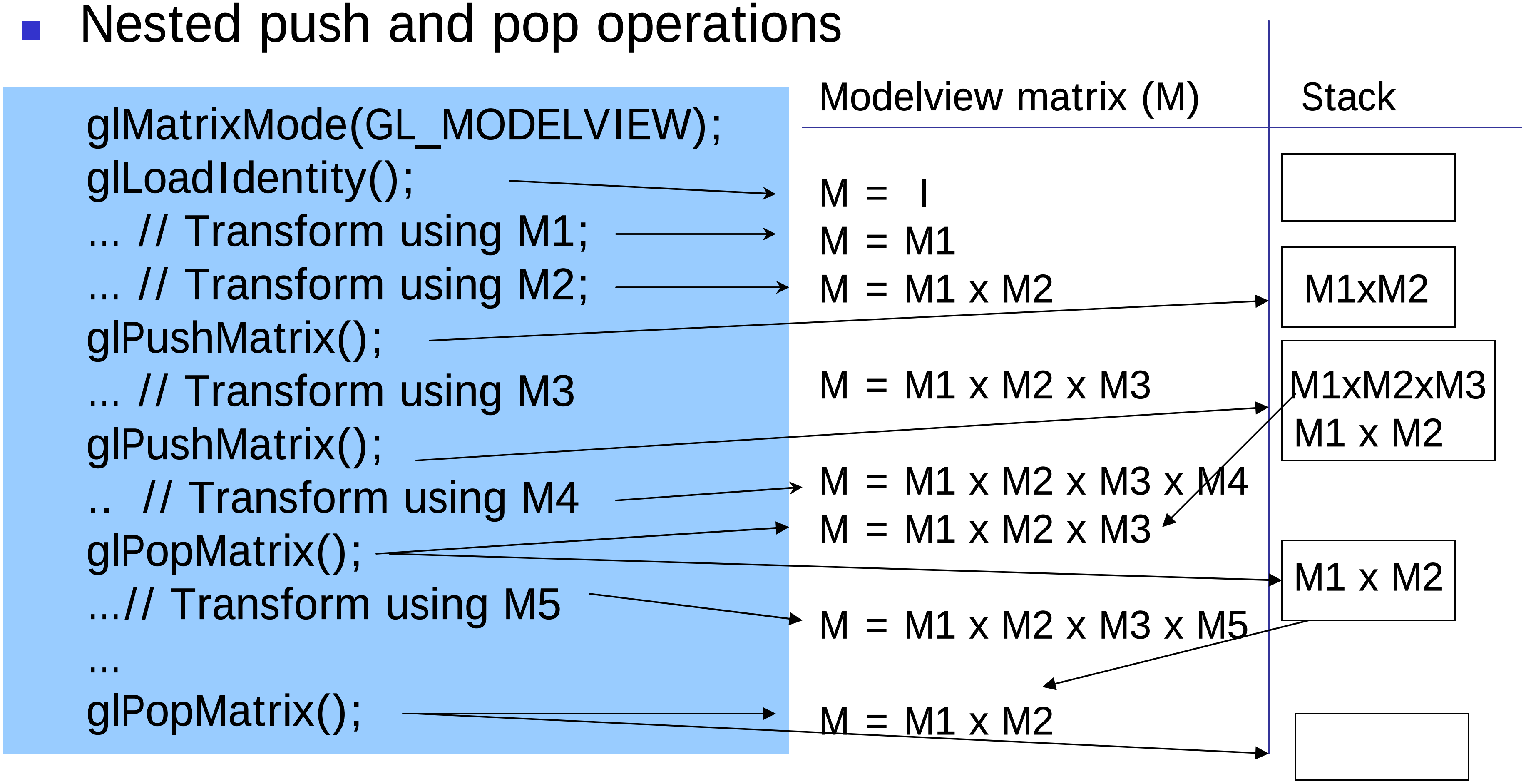


Depth First Traversal

```
glTranslate(5,0,0)
Draw_base();
glPushMatrix();

glRotate(75, 0,1,0);
Draw_left_hammer();

glPopMatrix();
glRotate(-75, 0,1,0);
Draw_right_hammer();
```

Push and Pop Matrix Stack

- Nested push and pop operations



```
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
... // Transform using M1;
... // Transform using M2;
glPushMatrix();
... // Transform using M3
glPushMatrix();
..  // Transform using M4
glPopMatrix();
...// Transform using M5
...
glPopMatrix();
```

Modelview matrix (M)

M = I
M = M1
M = M1 x M2
M = M1 x M2 x M3
M = M1 x M2 x M3 x M4
M = M1 x M2 x M3
M = M1 x M2 x M3 x M5
M = M1 x M2

Stack

M1xM2

M1xM2xM3
M1 x M2

M1 x M2