Hierarchical Modeling

Tuesday, October 29, 2013

Approaches & Transformation Stacks

- Polygonal Meshes (review)
- Constructive Solid Geometry
- Splines
- A relative to B relative to C …
  - Lecture notes draw upon OpenGL – legacy
  - Online example uses JavaScript Canvas

Transformation Stack
OpenGL for example

- The OpenGL state machine maintains two matrices
  - the MODELVIEW matrix
  - the PROJECTION matrix
- The transformation applied to data is the product of these two matrices.

$$\begin{bmatrix} p_1 & p_2 & p_3 & p_4 \\ p_5 & p_6 & p_7 & p_8 \\ p_9 & p_{10} & p_{11} & p_{12} \\ p_{13} & p_{14} & p_{15} & 1 \end{bmatrix} \begin{bmatrix} m_1 & m_2 & m_3 & m_4 \\ m_5 & m_6 & m_7 & m_8 \\ m_9 & m_{10} & m_{11} & m_{12} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

OpenGL Transformations (II)

- You can manipulate these matrices directly
- But I really don't recommend this approach

```
GLFLoat my_matrix1[4][4] = {{…},{…},…};
GLFLoat my_matrix2[4][4] = {{…},{…},…};
glMatrixMode(GL_MODELVIEW);
glLoadMatrix(&my_matrix1);
glMultMatrix(&my_matrix2);
```

Transformations (III)

- A much better approach.
- Start with a known matrix
  - Identity is nice!
- Then apply affine transformations to it

```
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
glTranslatef(dx, dy, dz);
glScalef(sx, sy, sz);
```


Under the Hood

- What do these routines do?

```
// glTranslate(dx, dy, dz)
GLfloat trans = {{1.0, 0.0, 0.0, dx},
                 {0.0, 1.0, 0.0, dy},
                 {0.0, 0.0, 1.0, dz},
                 {0.0, 0.0, 0.0, 1.0}};
glMultMatrix(trans);
```

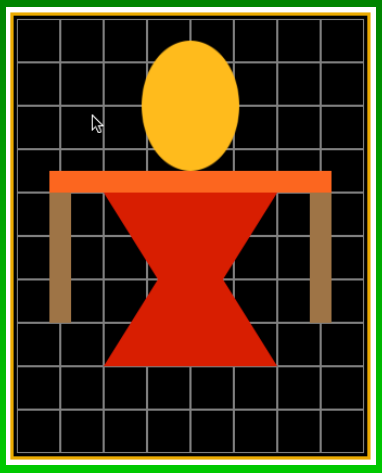
Matrix Stacks

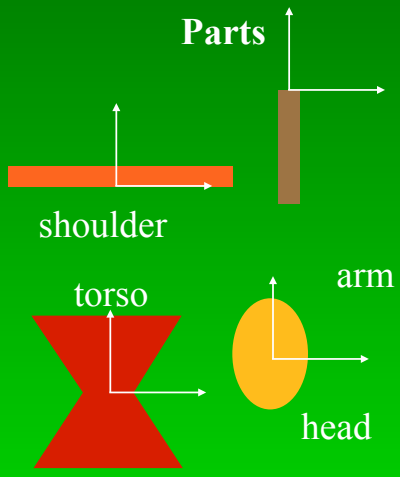
- General concept – realized in many APIs
- OpenGL MODELVIEW is a matrix stack
  - When you push a new matrix,
    - the top of the stack is replicated.
  - Now modify the current coordinate frame
  - Pop the stack
    - Return to the original coordinate system
- The PROJECTION matrix is also a stack

Manipulating Stacks

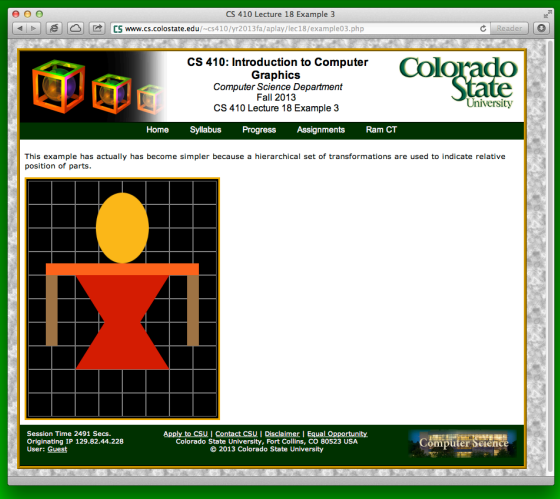
```
/* to select which matrix stack... */
void glMatrixMode(GL_MODELVIEW);

/* to push a new matrix onto the stack */
/* … a copy of previous top of stack */
void glPushMatrix();

/* Manipulate new top-level matrix */

/* pop new matrix off the stack */
void glPopMatrix();
```

JavaScript Example



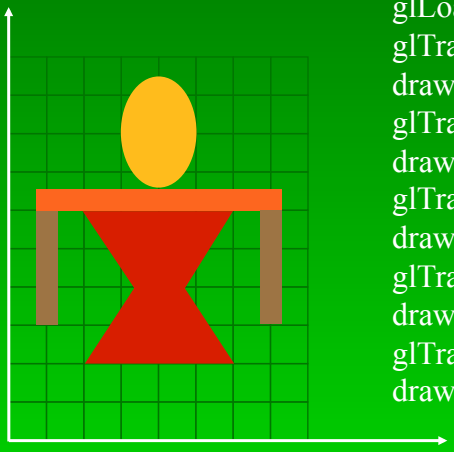


JavaScript Example



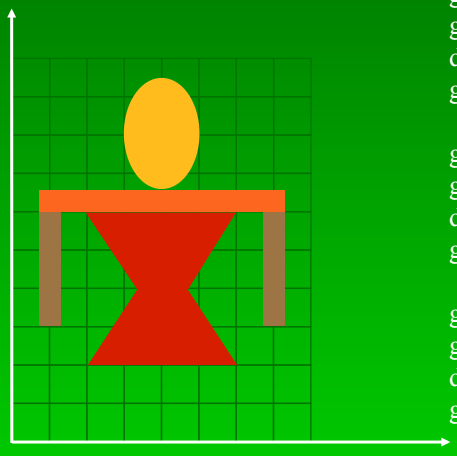
OpenGL Example

Dependent sequence



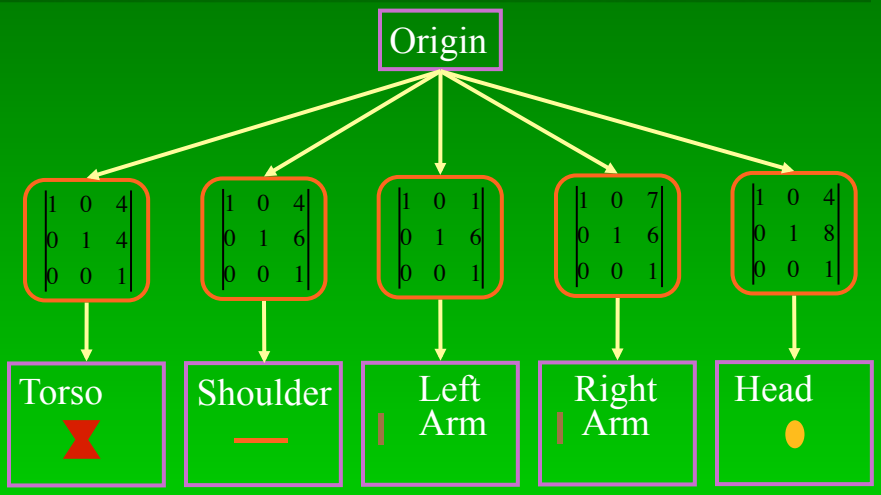
```
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
glTranslate(4,4,0);
drawTorso();
glTranslate(0,2,0);
drawShoulder();
glTranslate(3,0,0);
drawArm();
glTranslate(-6,0,0);
drawArm()
glTranslate(3,2,0);
drawHead();
```


A Bit Better - Parts Independent

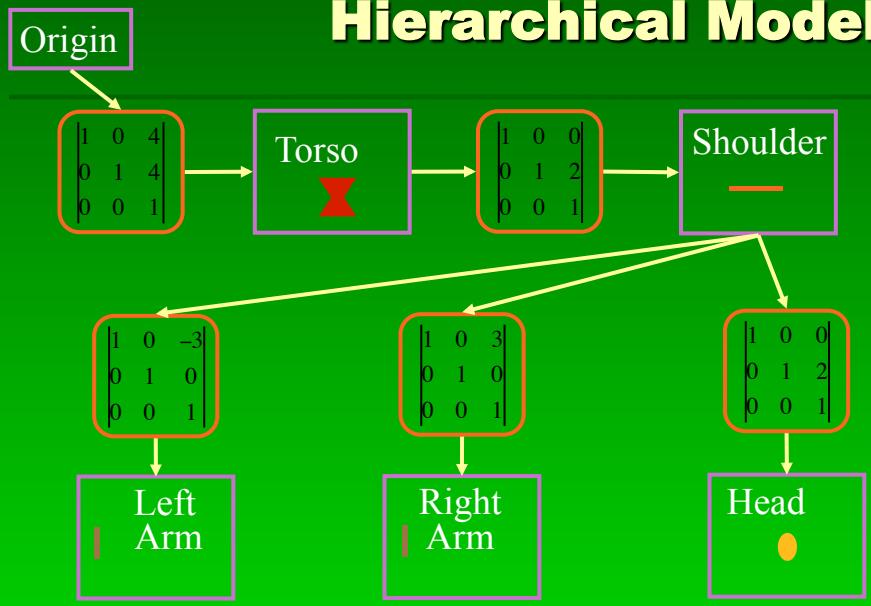


```
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();

glPushMatrix();
glTranslate(4,4);
drawTorso();
glPopMatrix();

glPushMatrix();
glTranslate(4,6);
drawShoulder();
glPopMatrix();

glPushMatrix();
glTranslate(1,6);
drawArm();
glPopMatrix();

glPushMatrix();
glTranslate(7,6);
drawArm();
glPopMatrix();

glPushMatrix();
glTranslate(4,8);
drawHead();
glPopMatrix();
```

Previous example as a Graph

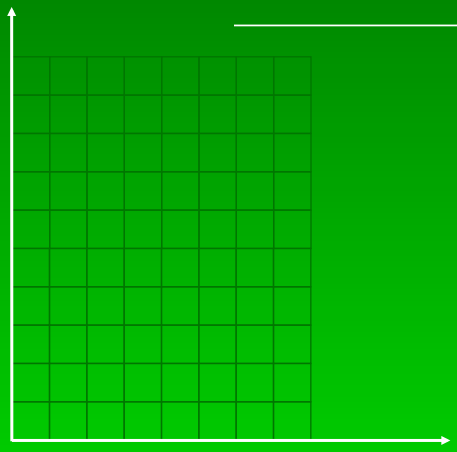


Hierarchical Model



Initialization

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



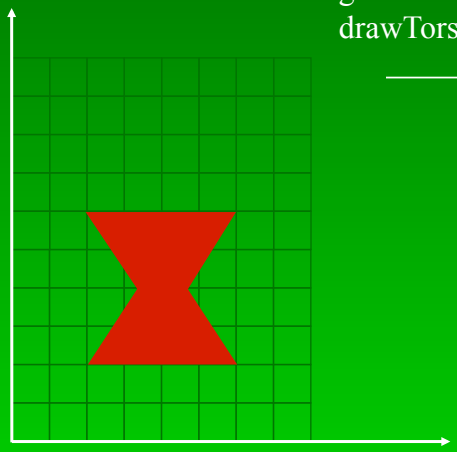
Stack

$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

MODELVIEW Transformation $\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$

Torso

```
glPushMatrix();
glTranslate(4,4);
glPushMatrix();
drawTorso();
```



Stack

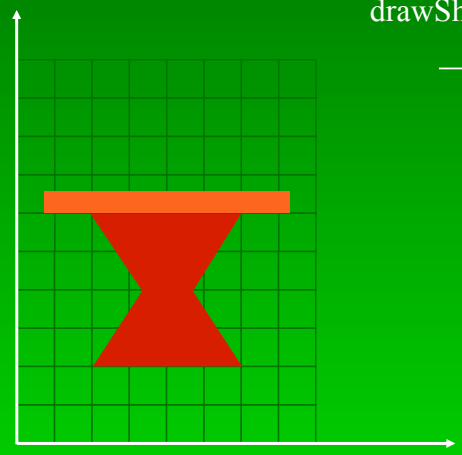
$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 4 \\ 0 & 0 & 1 \end{vmatrix}$$

MODELVIEW Transformation $\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 4 \\ 0 & 0 & 1 \end{vmatrix}$

Shoulders

```
glTranslate(0,2);
glPushMatrix();
drawShoulders();
```



Stack

$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

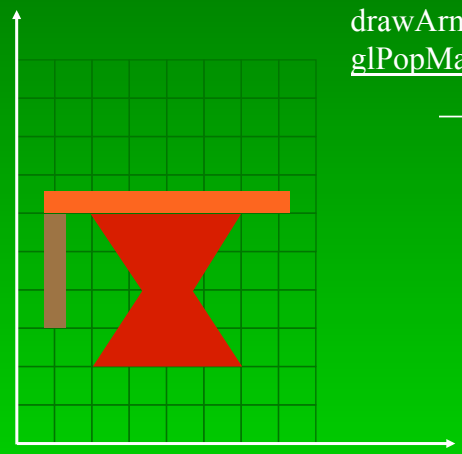
$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 4 \\ 0 & 0 & 1 \end{vmatrix}$$

$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 6 \\ 0 & 0 & 1 \end{vmatrix}$$

MODELVIEW Transformation $\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 6 \\ 0 & 0 & 1 \end{vmatrix}$

Left Arm

```
glPushMatrix();
gltranslate(-3,0);
drawArm();
glPopMatrix();
```



Stack

$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

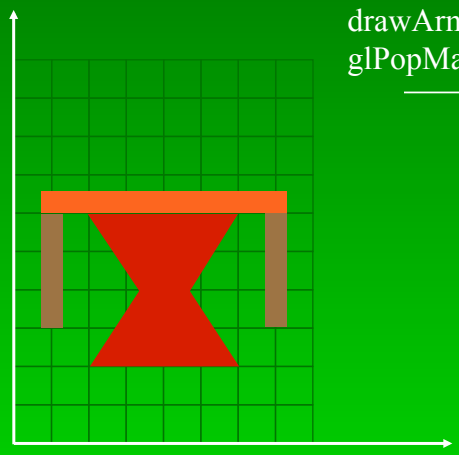
$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 4 \\ 0 & 0 & 1 \end{vmatrix}$$

$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 6 \\ 0 & 0 & 1 \end{vmatrix}$$

MODELVIEW Transformation $\begin{vmatrix} 1 & 0 & 1 \\ 0 & 1 & 6 \\ 0 & 0 & 1 \end{vmatrix}$

Right Arm

```
glPushMatrix();
gltranslate(3,0);
drawArm();
glPopMatrix();
```



Stack

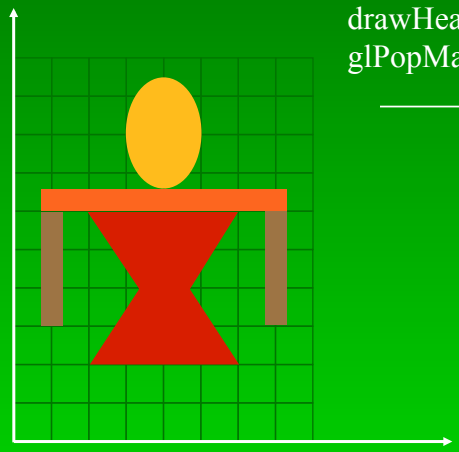
$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 6 \\ 0 & 0 & 1 \end{vmatrix}$$

MODELVIEW Transformation

$$\begin{vmatrix} 1 & 0 & 6 \\ 0 & 1 & 6 \\ 0 & 0 & 1 \end{vmatrix}$$

Head

```
glPushMatrix();
gltranslate(0,2);
drawHead();
glPopMatrix();
```



Stack

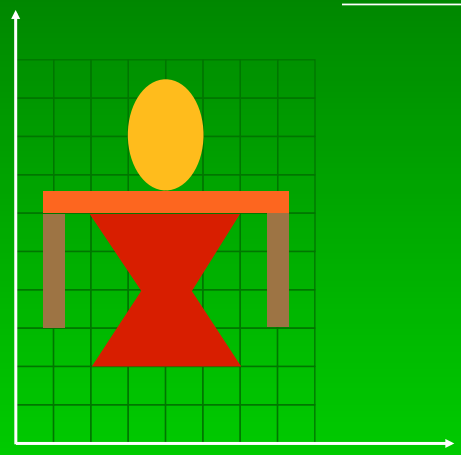
$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 6 \\ 0 & 0 & 1 \end{vmatrix}$$

MODELVIEW Transformation

$$\begin{vmatrix} 1 & 0 & 4 \\ 0 & 1 & 8 \\ 0 & 0 & 1 \end{vmatrix}$$

Cleanup

glPopMatrix();
glPopMatrix();



Stack

$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

MODELVIEW Transformation $\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$

Summary of OpenGL Code

```
glLoadIdentity();
glPushMatrix();
   gltranslate(4,4);
   drawTorso();
   glPushMatrix();
      gltranslate(0,2);
      drawShoulders();
      glPushMatrix();
         gltranslate(-3,0);
         drawArm();
      glPopMatrix();
      glPushMatrix();
         gltranslate(3,0);
         drawArm();
      glPopMatrix();
      glPushMatrix();
         gltranslate(0,2);
         drawHead();
      glPopMatrix();
   glPopMatrix();
glPopMatrix();
```

Indenting of code is a convenient way to indicate state of the transformation stack.

The four levels correspond with the four levels in the hierarchical model.