Introduction to Computer Graphics with WebGL

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Applying Transformations

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Using Transformations

• Example: Begin with a cube rotating
• Use mouse or button listener to change direction of rotation

• Start with a program that draws a cube in a standard way
  - Centered at origin
  - Sides aligned with axes
  - Will discuss modeling in next lecture
Where do we apply transformation?

• Same issue as with rotating square
  - in application to vertices
  - in vertex shader: send MV matrix
  - in vertex shader: send angles

• Choice between second and third unclear

• Do we do trigonometry once in CPU or for every vertex in shader
  - GPUs have trig functions hardwired in silicon
Rotation Event Listeners

```javascript
function render() {
  gl.clear( gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT );
  theta[axis] += 2.0;
  gl.uniform3fv(thetaLoc, theta);
  gl.drawArrays( gl.TRIANGLES, 0, NumVertices );
  requestAnimFrame( render);
}
```

```javascript
document.getElementById( "xButton" ).onclick = function () {  
  axis = xAxis;
};
document.getElementById( "yButton" ).onclick = function () {  
  axis = yAxis;
};
document.getElementById( "zButton" ).onclick = function () {  
  axis = zAxis;
};
```
Rotation Shader

Attribute vec4 vPosition;
Attribute vec4 vColor;
varying vec4 fColor;
uniform vec3 theta;

void main() {
    vec3 angles = radians( theta );
    vec3 c = cos( angles );
    vec3 s = sin( angles );
    // Remember: these matrices are column-major
    mat4 rx = mat4( 1.0, 0.0, 0.0, 0.0,
                    0.0, c.x, s.x, 0.0,
                    0.0, -s.x, c.x, 0.0,
                    0.0, 0.0, 0.0, 1.0 );
}
mat4 ry = mat4( c.y, 0.0, -s.y, 0.0,
0.0, 1.0, 0.0, 0.0,
s.y, 0.0, c.y, 0.0,
0.0, 0.0, 0.0, 1.0);

mat4 rz = mat4( c.z, -s.z, 0.0, 0.0,
s.z, c.z, 0.0, 0.0,
0.0, 0.0, 1.0, 0.0,
0.0, 0.0, 0.0, 1.0);

fColor = vColor;
gl_Position = rz * ry * rx * vPosition;
}
Smooth Rotation

- From a practical standpoint, we are often want to use transformations to move and reorient an object smoothly
  - Problem: find a sequence of model-view matrices $M_0, M_1, \ldots, M_n$ so that when they are applied successively to one or more objects we see a smooth transition
- For orientating an object, we can use the fact that every rotation corresponds to part of a great circle on a sphere
  - Find the axis of rotation and angle
  - Virtual trackball (see text)
Incremental Rotation

• Consider the two approaches
  - For a sequence of rotation matrices $R_0, R_1, \ldots, R_n$, find the Euler angles for each and use $R_i = R_{iz} R_{iy} R_{ix}$
    • Not very efficient
  - Use the final positions to determine the axis and angle of rotation, then increment only the angle

• Quaternions can be more efficient than either
Quaternions

• Extension of imaginary numbers from two to three dimensions
• Requires one real and three imaginary components \(i, j, k\)

\[ q = q_0 + q_1 i + q_2 j + q_3 k \]

• Quaternions can express rotations on sphere smoothly and efficiently. Process:
  - Model-view matrix \(\rightarrow\) quaternion
  - Carry out operations with quaternions
  - Quaternion \(\rightarrow\) Model-view matrix
Interfaces

• One of the major problems in interactive computer graphics is how to use a two-dimensional device such as a mouse to interface with three dimensional objects

• Example: how to form an instance matrix?

• Some alternatives
  - Virtual trackball
  - 3D input devices such as the spaceball
  - Use areas of the screen
    • Distance from center controls angle, position, scale depending on mouse button depressed