Introduction to Computer Graphics with WebGL

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WebGL Transformations

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Objectives

• Learn how to carry out transformations in WebGL
  - Rotation
  - Translation
  - Scaling

• Introduce MV.js transformations
  - Model-view
  - Projection
Pre 3.1 OpenGL Matrices

• In Pre 3.1 OpenGL matrices were part of the state
• Multiple types
  - Model-View (GL_MODELVIEW)
  - Projection (GL_PROJECTION)
  - Texture (GL_TEXTURE)
  - Color(GL_COLOR)
• Single set of functions for manipulation
• Select which to manipulated by
  - glMatrixMode(GL_MODELVIEW);
  - glMatrixMode(GL_PROJECTION);
Why Deprecation

- Functions were based on carrying out the operations on the CPU as part of the fixed function pipeline.
- Current model-view and projection matrices were automatically applied to all vertices using CPU.
- We will use the notion of a current transformation matrix with the understanding that it may be applied in the shaders.
Current Transformation Matrix (CTM)

- Conceptually there is a 4 x 4 homogeneous coordinate matrix, the current transformation matrix (CTM) that is part of the state and is applied to all vertices that pass down the pipeline.
- The CTM is defined in the user program and loaded into a transformation unit.

\[
p' = Cp
\]
CTM operations

- The CTM can be altered either by loading a new CTM or by postmultiplication
  - Load an identity matrix: $C \leftarrow I$
  - Load an arbitrary matrix: $C \leftarrow M$
  - Load a translation matrix: $C \leftarrow T$
  - Load a rotation matrix: $C \leftarrow R$
  - Load a scaling matrix: $C \leftarrow S$
  - Postmultiply by an arbitrary matrix: $C \leftarrow CM$
  - Postmultiply by a translation matrix: $C \leftarrow CT$
  - Postmultiply by a rotation matrix: $C \leftarrow CR$
  - Postmultiply by a scaling matrix: $C \leftarrow CS$
Start with identity matrix: $C \leftarrow I$
Move fixed point to origin: $C \leftarrow CT$
Rotate: $C \leftarrow CR$
Move fixed point back: $C \leftarrow CT^{-1}$

Result: $C = TR T^{-1}$ which is **backwards**.

This result is a consequence of doing postmultiplications. Let’s try again.
Reversing the Order

We want \( C = T^{-1} R T \)
so we must do the operations in the following order

\[
\begin{align*}
C & \leftarrow I \\
C & \leftarrow CT^{-1} \\
C & \leftarrow CR \\
C & \leftarrow CT
\end{align*}
\]

Each operation corresponds to one function call in the program.

Note that the last operation specified is the first executed in the program.
CTM in WebGL

- OpenGL had a model-view and a projection matrix in the pipeline which were concatenated together to form the CTM.
- We will emulate this process.
Using the ModelView Matrix

- In WebGL, the model-view matrix is used to
  - Position the camera
    - Can be done by rotations and translations but is often easier to use the `lookAt` function in MV.js
  - Build models of objects
- The projection matrix is used to define the view volume and to select a camera lens
- Although these matrices are no longer part of the OpenGL state, it is usually a good strategy to create them in our own applications

\[ q = P \times MV \times p \]
Create an identity matrix:

```javascript
var m = mat4();
```

Multiply on right by rotation matrix of `theta` in degrees where `(vx, vy, vz)` define axis of rotation

```javascript
var r = rotate(theta, vx, vy, vz)
m = mult(m, r);
```

Also have `rotateX`, `rotateY`, `rotateZ`

Do same with translation and scaling:

```javascript
var s = scale(sx, sy, sz)
var t = translate(dx, dy, dz);
m = mult(s, t);
```
Example

• Rotation about z axis by 30 degrees with a fixed point of (1.0, 2.0, 3.0)

\[
\text{var } m = \text{mult}(\text{translate}(1.0, 2.0, 3.0), \text{rotate}(30.0, 0.0, 0.0, 1.0));
\]
\[
m = \text{mult}(m, \text{translate}(-1.0, -2.0, -3.0));
\]

• Remember that last matrix specified in the program is the first applied
Arbitrary Matrices

• Can load and multiply by matrices defined in the application program.
• Matrices are stored as one dimensional array of 16 elements by MV.js but can be treated as 4 x 4 matrices in row major order.
• OpenGL wants column major data.
• `gl.uniformMatrix4f` has a parameter for automatic transpose by it must be set to false.
• `flatten` function converts to column major order which is required by WebGL functions.
Matrix Stacks

• In many situations we want to save transformation matrices for use later
  - Traversing hierarchical data structures (Chapter 9)

• Pre 3.1 OpenGL maintained stacks for each type of matrix

• Easy to create the same functionality in JS
  - push and pop are part of Array object

```javascript
var stack = [ ];
stack.push(modelViewMatrix);
modelViewMatrix = stack.pop();
```