Exploring Graphics with WebGL

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Abstract

These notes are intended to help me keep new material in my brain.

Contents

1 3D Graphics

1.1 Matrices, Vectors, and Coordinates

Homogeneous Vectors 3D vectors are in the form $< x, y, z, w >$ where $w = 0$ means the vector is a 3D point in space, and $w = 1$ means the vector is a direction.

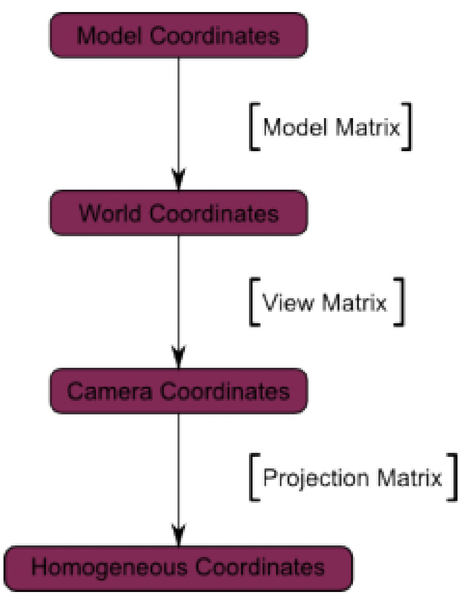
Matrices 3D graphics deals in 4x4 matrices. There are 3 standard matrices to understand:

The Model Matrix Move vectors from the model vector space (vectors defined relative to model) to the world vector space (vectors defined relative to the world)

The View Matrix Move vectors from world vector space to camera vector space (vectors defined relative to camera)

The Projection Matrix Move vectors camera vector space to homogeneous vector space (vectors defined in a cube of what's visible). Warps the view frustum and all within into a cube.

A useful graphic:



[1]

The ModelViewProjection matrix cumulates the above 3 matrix transformations into one.

Transformations Transformations are performed by matrix multiplication. In classic Linear Algebra form, $A\vec{x} = \vec{b}$ transfoms a vector $\vec{x}$ into vector $\vec{b}$. A transformation is applied to objects modeled by a collection of vertices by applying the transformatin to each vertex in the object. There are 3 kinds of transformations: Translation, Rotation, and Scaling.

Translation matrices take the form:

$$A = \begin{bmatrix} 1 & 0 & 0 & X \\ 0 & 1 & 0 & Y \\ 0 & 0 & 1 & Z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Where X, Y, and Z are the amount by which the vector operand's x, y, and z components are translated. For example, translate a vector position at $< 0, 0, 0 >$ 2 units in the x and y directions:

$$\begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 2 \\ 0 \\ 1 \end{bmatrix}$$

Notice that the resulting vector is also a position vector (4th element is 1). Applying a translation to a direction vector $< x, y, z, 0 >$ does not affect it.

Scaling matrices take the form:

$$A = \begin{bmatrix} X & 0 & 0 & 0 \\ 0 & Y & 0 & 0 \\ 0 & 0 & Z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Where X, Y, and Z represent the scaling factor applied to the operand vector's x, y, and z components. Notice the components can be scaled independently in one scaling transformation. Also the operand vector's w status is unaffected.

Multiple transformations can be cumulated into a single matrix via multiplication. For example:

$$TransformationMatrix = ScaleMatrix*RotateMatrix*TranslateMatrix$$

Notice the 3 transformations will be performed in order from left to right.

2 WebGL

Overview WebGL is a javascript API for rendering 3D content on an HTML5 canvas element. Allows faster rendering by using a computer's GPU.

2.1 Components of a WebGL Application

1. Create canvas element
2. Initialize a WebGL javascript context for it.
3. Create buffers of vertices to be rendered
4. Create matrices for transformations
5. Create shaders
6. Initialize shaders with params
7. Draw

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2.2 Buffers

Buffers are data structures that hold collections of vertices. They are loaded onto the GPU so future drawing operations on those vertices can be done fast. Some types: `ARRAY_BUFFER`, `ELEMENT_ARRAY_BUFFER`.

Buffers must be bound to the WebGL context's `ARRAY_BUFFER` member (The "current buffer"), and only one buffer may be bound and operated upon at any time. Binding loads them onto the GPU.

To load vertex data into a buffer: Create an array, convert to a Float32Array object, and load into the current `ARRAY_BUFFER` via .bufferData(). Also need to specify the item size (number of array fields per vertex: 3) and number of items (number of distint vertex positions). There is a seperate current `ELEMENT_ARRAY_BUFFER`.

An *element array buffer* specifies vertices in an array buffer that will be used to draw shapes. For example, you want to draw a square composed of 2 triangles but don't want to use triangle strips. Create an array buffer A of 4 vertices, then an array element buffer of 6 indicies (0,1,3, 0,2,3) in A to create the 2 triangles that make the square.

2.3 Shaders

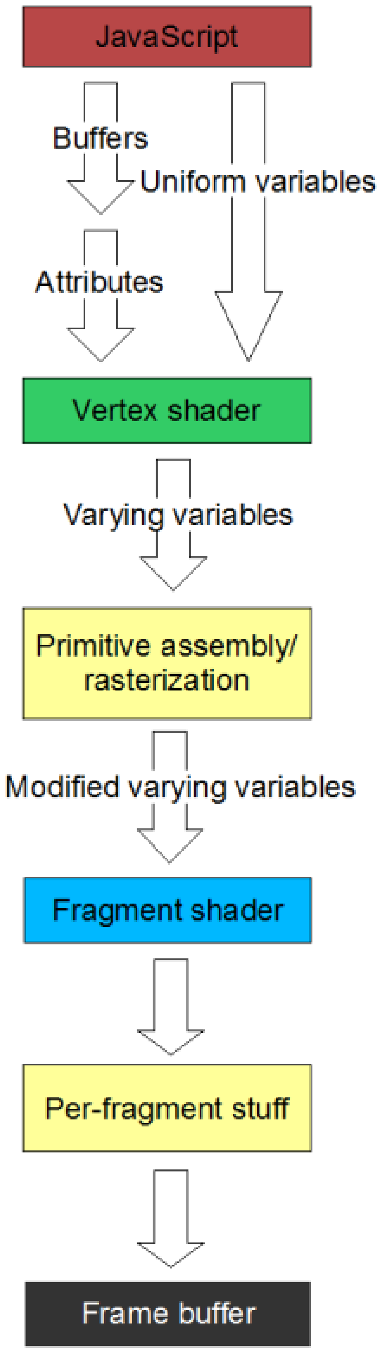
Shader programs are a mechanism for representing your models in a way the GPU can understand. Shader source code is written in GLSL not javascript.

Vertex Shader Handles conversion of 3D vertex coordinates to 2D clipspace coordinates. Called for every verted - can apply model-view and projection matrices to collections of vertices much faster on the GPU than through a javascript loop. Outputs *varying* variables (eg: `gl_Position` - a vertex's final coords).

Fragment Shader Handles coloring of fragments (triangle planes formed by 3 vertices). Called once for each pixel of the image. Performs linear interpolation between verteces =¿ fills in spaces and creates color gradients.

There are 3 qualifiers for shader variables: *Uniforms*, *Attributes*, and *Varyings*. Uniforms are the same across the entire frame being rendered (eg: projection and model-view matrices). Attributes are input values that vary from vertex to vertex, and are only accessible by vertex shader. Varyings are declared in vertex shader to be shared with fragment shader.

Here's a useful diagram of the rendering pipeline [2]:



How to get color to the fragment shader? You can't pass data to frag shader directly. Define a *varying* variable in the vector shader that will be passed along to the fragment shader for interpolation.

3 Useful Libraries

Three.js

glMatrix For optimized matrix and vector math.

References

[1] http://www.opengl-tutorial.org

[2] http://learningwebgl.com

[3] WebGL: Up And Running

[4] `http://www.khronos.org/files/webgl/webgl-reference-card-1_0.pdf`