OpenGL I: Shaders
Vertex Shader Applications

- Moving vertices
  - Morphing
  - Wave motion
  - Fractals

- Lighting
  - More realistic models
  - Cartoon shaders
Fragment Shader Applications

- Per fragment lighting calculations

per vertex lighting

per fragment lighting
Fragment Shader Applications

- Texture mapping

- Smooth shading
- Environment mapping
- Bump mapping
Writing Shaders

- First programmable shaders were programmed in an assembly-like manner
- OpenGL extensions added for vertex and fragment shaders
- Cg (C for graphics) C-like language for programming shaders
  - Works with both OpenGL and DirectX
  - Interface to OpenGL complex
- OpenGL Shading Language (GLSL)
GLSL

- OpenGL Shading Language
- Part of OpenGL 2.0 and up
- High level C-like language
- New data types
  - Matrices
  - Vectors
  - Samplers
- As of OpenGL 3.1, application must provide shaders
Simple Vertex Shader

input from application

```glsl
in vec4 vPosition;
void main(void)
{
    gl_Position = vPosition;
}
```

built in variable

must link to variable in application
void main(void)
{
    gl_FragColor = vec4(1.0, 0.0, 0.0, 1.0);
}

Data Types

- **C types:** int, float, bool
- **Vectors:**
  - `float vec2, vec3, vec4`
  - *Also* int (ivec) and boolean (bvec)
- **Matrices:** mat2, mat3, mat4
  - Stored by columns
  - Standard referencing m[row][column]
- **C++ style constructors**
  - `vec3 a = vec3(1.0, 2.0, 3.0)`
  - `vec2 b = vec2(a)`
Qualifiers

- GLSL has many of the same qualifiers such as const as C/C++
- Need others due to the nature of the execution model
- Variables can change
  - Once per primitive
  - Once per vertex
  - Once per fragment
  - At any time in the application
- Vertex attributes are interpolated by the rasterizer into fragment attributes
Attribute Qualifier

- Attribute-qualified variables can change at most once per vertex
- There are a few built in variables such as `gl_Position` but most have been deprecated
- User defined (in application program)
  - Use `in` qualifier to get to shader
  - `in float temperature`
  - `in vec3 velocity`
Uniform Qualifier

- Variables that are constant for an entire primitive
- Can be changed in application and sent to shaders
- Cannot be changed in shader
- Used to pass information to shader such as the bounding box of a primitive
Varying Qualifier

- Variables that are passed from vertex shader to fragment shader
- Automatically interpolated by the rasterizer
- Old style used the varying qualifier
  ```
  varying vec4 color;
  ```
- Now use `out` in vertex shader and `in` in the fragment shader
  ```
  out vec4 color;
  ```
Example: Vertex Shader

```c
const vec4 red = vec4(1.0, 0.0, 0.0, 1.0);
out vec3 color_out;
void main(void)
{
  gl_Position = vPosition;
  color_out = red;
}
```
in vec3 color_out;
out vec4 fragcolor;
void main(void)
{
    fragcolor = color_out;
    //gl_FragColor = color_out;  //old version
}
Operators and Functions

- **Standard C functions**
  - Trigonometric
  - Arithmetic
  - Normalize, reflect, length

- **Overloading of vector and matrix types**
  
  ```c
  mat4 a;
  vec4 b, c, d;
  c = b*a; // column vector stored as 1d array
  d = a*b; // row vector stored as 1d array
  ```
Swizzling and Selection

- Can refer to array elements by element using [] or selection (.) operator with
  - x, y, z, w
  - r, g, b, a
  - s, t, p, q
  - a[2], a.b, a.z, a.p are the same

- Swizzling operator lets us manipulate components
  - vec4 a;
  - a.yz = vec2(1.0, 2.0);