The GLSL API

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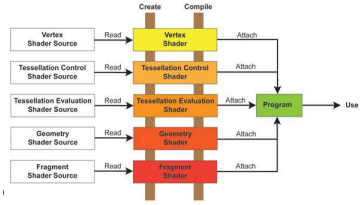
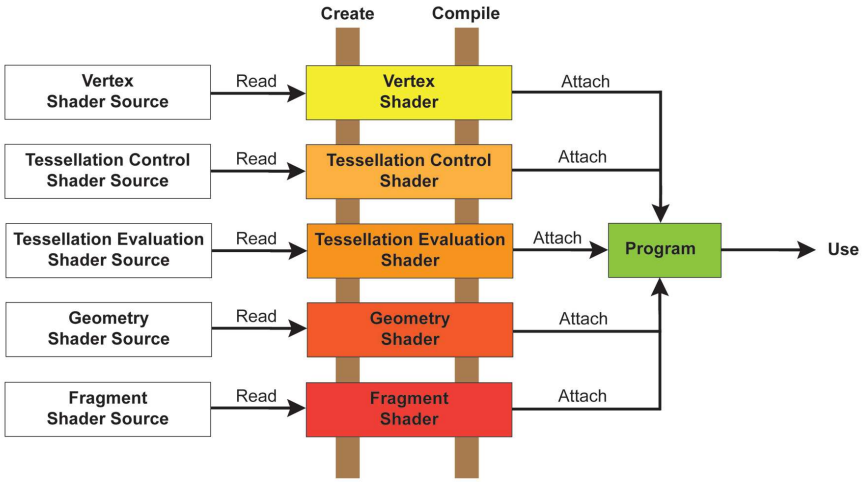


The GLSL Shader-Creation Process



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Initializing the GL Extension Wrangler (GLEW)
Do this for Windows and maybe Linux, *but not for Macs*


```
#include "glew.h"

. . .

GLenum err = glewInit();
if( err != GLEW_OK )
{
        fprintf( stderr, "glewInit Error\n" );
        exit( 1 );
}

fprintf( stderr, "GLEW initialized OK\n" );
fprintf( stderr, "Status: Using GLEW %s\n", glewGetString(GLEW_VERSION) );
```

Do this *immediately* after opening the window

GLEW cannot be initialized until a graphics window is open. Like OpenGL itself, GLEW's calls will not work unless it can see a graphics context (i.e., a graphics state).

http://glew.sourceforge.net

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Visual Studio Compilation Notes

If you are on your own ***Windows system***, you can get Visual Studio 2022 by going to:

https://azureforeducation.microsoft.com/devtools

Click the blue **Sign In** button on the right.

Login using your onid@oregonstate.edu username and password.

I recommend you get **Visual Studio 2022 Enterprise**. Don't get Express.

Note that *vscode* is not a compiler. It is a way to interface to your file system.

Once you have Visual Studio, download the class file **SampleWindows.zip**, unzip it on your system, and then double-click on the **.sln** file

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Linux Compilation Notes

If you are on your own ***Linux system***, compile using g++:

The typical g++ compile sequence is:

```
g++  -o sample  sample.cpp  -lGL  -lGLU  -lglut  -lm
```

Note that the second character in the sequences "-lGL", "-lGLU", and "-lglut" is an ell, i.e., a lower-case L. This is how you link in the OpenGL libraries.

Note that the second character in the 3-character sequence "-lm" is an ell, i.e., a lower-case L.
This is how you link in the math library.

Download the file **SampleLinux.tar**, un-tar it on your system (tar -xvf SampleLinux.tar), and then type ***make***

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Mac Compilation Notes

If you are on your own ***Apple Mac system***, compile using g++:

The typical g++ compile sequence is:

```
g++ -framework OpenGL -framework GLUT sample.cpp -o sample -Wno-deprecated
```

Download the file **SampleMac.tar**, un-tar it on your system (tar -xvf SampleMac.tar), and then type ***make***

The standard place to put OpenGL include files looks like this:
#include <GL/gl.h>

Apple changed this to:
#include <OpenGL/gl.h>

This change has been made in your sample code.

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Reading a Shader source file into a character array

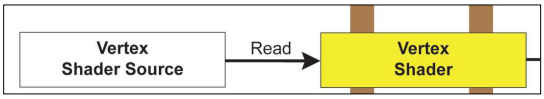
```
#include <stdio.h>
. . .
FILE *fp;
#ifdef  WIN32
        errno_t err = fopen_s( &fp, filename, "r" );
        if( err != 0 )  { . . . }
#else
        fp = fopen( filename, "r" );
        if( fp == NULL )  { . . . }
#endif

fseek( fp, 0, SEEK_END );           // move to the end of
int numBytes = ftell( fp );         // length of file

GLchar * buffer = new GLchar [numBytes+1];

rewind( fp );                       // same as:  “fseek( in, 0, SEEK_SET )”

fread( buffer, 1, numBytes, fp );
fclose( fp );
buffer[numBytes] = ‘\0‘;            // the entire file is now in a character string
```



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Creating and Compiling a Vertex Shader from that Character Buffer (Geometry and Fragment files work the same way)

This is the only part of this process that is specific to the type of shader it is

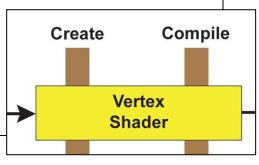
```
int status;
int logLength;

GLuint vertShader = glCreateShader( GL_VERTEX_SHADER );

glShaderSource( vertShader, 1, (const GLchar **)&buffer, NULL );
delete [ ] buffer;
glCompileShader( vertShader );
CheckGlErrors( "Vertex Shader 1" );

glGetShaderiv( vertShader, GL_COMPILE_STATUS, &status );
if( status == GL_FALSE )
{
        fprintf( stderr, “Vertex shader compilation failed.\n” );
        glGetShaderiv( vertShader, GL_INFO_LOG_LENGTH, &logLength );
        GLchar *log = new GLchar [logLength];
        glGetShaderInfoLog( vertShader, logLength, NULL, log );
        fprintf( stderr, “\n%s\n”, log );
        delete [ ] log;
        exit( 1 );
}
CheckGlErrors( "Vertex Shader 2" );
```

An array of strings



Creating Different Shader Types

```
GLuint shader = glCreateShader( GL_VERTEX_SHADER );

GLuint shader = glCreateShader( GL_GEOMETRY_SHADER );

GLuint shader = glCreateShader( GL_TESS_CONTROL_SHADER );

GLuint shader = glCreateShader( GL_TESS_EVALUATION_SHADER );

GLuint shader = glCreateShader( GL_FRAGMENT_SHADER );

GLuint shader = glCreateShader( GL_COMPUTE_SHADER );
```

Other than this, the rest of the create, compile, link process is the same for each shader type.

Macs don't know about GL_GEOMETRY_SHADER, GL_TESS_CONTROL_SHADER , or GL_TESS_EVALUATION_SHADER !

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How does that array-of-strings thing work?


```
GLchar *ArrayOfStrings[3];
ArrayOfStrings[0] = "#define SMOOTH_SHADING";
ArrayofStrings[1] = " . . . a commonly-used procedure . . . ";
ArrayofStrings[2] = " . . . the real vertex shader code . .. ";
glShaderSource( vertShader, 3, ArrayofStrings, NULL );
```

These are two ways to specify a *single* character string:

```
GLchar *buffer[1];
buffer[0] = " . . . the entire shader code . . . ";
glShaderSource( vertShader, 1, buffer, NULL );
```

```
GLchar *buffer = " . . . the entire shader code . . . ";
glShaderSource( vertShader, 1, (const GLchar **)&buffer, NULL );
```

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Why use an array of strings as the shader input, instead of just a single string?

1. You can use the same shader source and insert the appropriate "#defines" at the beginning
2. You can insert a common header file (≈ a .h file)
3. You can simulate a "#include" to re-use common pieces of code

if-tests vs. preprocessing

```
if( Mode == SmoothShading )
{ . . . }
else if( Mode == PhongShading )
{ . . . }
```

```
#ifdef SMOOTH_SHADING
{ . . . }
#endif

#ifdef PHONG_SHADING
{ . . . }
#endif
```

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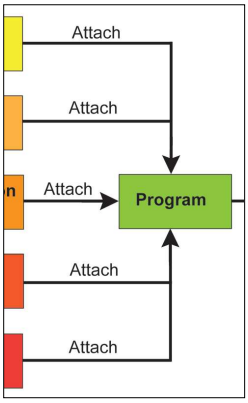
Creating the Program and Attaching the Shaders to It


```
GLuint program = glCreateProgram( );

glAttachShader( program, vertShader );

glAttachShader( program, fragShader );

glAttachShader( program, geomShader );
```



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Linking the Program and Checking its Validity


```
glLinkProgram( program );
CheckGlErrors( "Shader Program 1" );
glGetProgramiv( program, GL_LINK_STATUS, &status );
if( status == GL_FALSE )
{
        fprintf( stderr, "Link failed.\n" );
        glGetProgramiv( program, GL_INFO_LOG_LENGTH, &logLength );
        log = new GLchar [logLength];
        glGetProgramInfoLog( program, logLength, NULL, log );
        fprintf( stderr, "\n%s\n", log );
        delete [ ] log;
        exit( 1 );
}
CheckGlErrors( "Shader Program 2" );

glValidateProgram( program );
glGetProgramiv( program, GL_VALIDATE_STATUS, &status );
fprintf( stderr, "Program is %s.\n", status == GL_FALSE ? "invalid" : "valid" );
```

Making the Program Active


```
glUseProgram( program );
```

Making the Program Inactive
(use the fixed function pipeline instead)

```
glUseProgram( 0 );
```

Using Multiple Shader Programs

```
glUseProgram( program0 );
      <draw some stuff>

glUseProgram( program1 );
   <draw some more stuff>

glUseProgram( program2 );
   <draw some more stuff>

glUseProgram( program3 );
   <draw some more stuff>

glUseProgram( program4 );
   <draw some more stuff>

glUseProgram( program5 );
   <draw some more stuff>
```

A specified shader program is an “attribute” – it stays in effect until you change it

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Passing in Uniform (global) Variables

You first need to find the variable’s location in the shader program’s symbol table.

```
float lightLoc[3] = { 0., 100., 0. };

GLint location = glGetUniformLocation( program, “uLightLocation” );

if( location < 0 )
        fprintf( stderr, “Cannot find Uniform variable ‘uLightLocation’\n” );
else
        glUniform3fv( location, 1, lightLoc );
```

Then you need to fill it.

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Passing in Attribute (per-vertex) Variables

You first need to find the variable's location in the shader program's symbol table.

```
GLint location = glGetAttribLocation( program, "aArray" );

if( location < 0 )
{
        fprintf( stderr, "Cannot find Attribute variable 'aArray'\n" );
}
else
{
        glBegin( GL_TRIANGLES );
                glVertexAttrib2f( location, a0, b0 );
                glVertex3f( x0, y0, z0 );
                glVertexAttrib2f( location, a1, b1 );
                glVertex3f( x1, y1, z1 );
                glVertexAttrib2f( location, a2, b2 );
                glVertex3f( x2, y2, z2 );
        glEnd();
}
```

Then you need to fill it per-vertex.

Checking for Errors

```
void
CheckGlErrors( const char* caller )
{
        unsigned int glerr = glGetError();
        if( glerr == GL_NO_ERROR )
                return;
        fprintf( stderr, "GL Error discovered from caller '%s': ", caller );
        switch( glerr )
        {
                case GL_INVALID_ENUM:
                        fprintf( stderr, "Invalid enum.\n" );
                        break;
                case GL_INVALID_VALUE:
                        fprintf( stderr, "Invalid value.\n" );
                        break;
                case GL_INVALID_OPERATION:
                        fprintf( stderr, "Invalid Operation.\n" );
                        break;
                case GL_STACK_OVERFLOW:
                        fprintf( stderr, "Stack overflow.\n" );
                        break;
                case GL_STACK_UNDERFLOW:
                        fprintf(stderr, "Stack underflow.\n" );
                        break;
                case GL_OUT_OF_MEMORY:
                        fprintf( stderr, "Out of memory.\n" );
                        break;
                default:
                        fprintf( stderr, "Unknown OpenGL error: %d (0x%0x)\n", glerr, glerr );
        }
}
```

It's not a bad idea to do this in all your OpenGL programs, even without shaders!

A C++ Class to Handle Everything

In the globals:

```
GLSLProgram Hyper;
```

In InitGraphics( ):

```
Hyper.Init( );
bool valid = Hyper.Create( "hyper.vert", "hyper.geom", "hyper.frag" );
if( ! valid ) { . . . }
```

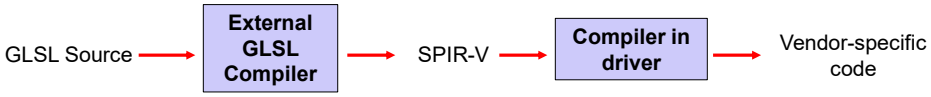
Using the shaders program in Display( ):

```
int Polar = 1;
float K = 3.f;
Hyper.Use( );

Hyper.SetUniformVariable( “uPolar", Polar );
Hyper.SetUniformVariable( “uK", K );
glBegin( GL_TRIANGLES );
        Hyper.SetAttributeVariable( “aTemperature”, T0 );
        glVertex3f( x0, y0, z0 );
        Hyper.SetAttributeVariable( “aTemperature”, T1 );
        glVertex3f( x1, y1, z1 );
        Hyper.SetAttributeVariable( “aTemperature”, T2 );
        glVertex3f( x2, y2, z2 );
glEnd( );

Hyper.UnUse( );
```


SPIR-V

SPIR-V is a file format that can be used to hold shader code that has been pre-compiled, but has not yet been turned into machine code. It was created as a way for software developers to pre-compile their code and then allow the vendor-specific driver to produce the final binary representation. There are four major advantages in doing things this way:

1. A software developer can more easily wring compiler errors from the code by having an external compiler that can be run independently from the application.
2. Vendors can still apply their optimization-magic in their device-specific drivers.
3. SPIR-V files can be read at the start of a program and be turned into machine code faster than the original GLSL files could have been turned into machine code.
4. Software developers can distribute their code without having to reveal the shaders' source code.



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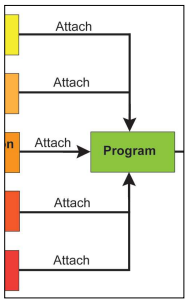
Reading SPIR-V-compiled Shaders

```
FILE *fp;
#ifdef  WIN32
        errno_t err = fopen_s( &fp, filename, "r" );
        if( err != 0 )  { . . . }
#else
        fp = fopen( filename, "r" );
        if( fp == NULL )  { . . . }
#endif

fseek( fp, 0, SEEK_END );
int numBytes = ftell( fp );     // length of file – guaranteed to be a multiple of 4
GLchar * buffer = new GLchar [numBytes];
rewind( fp );                   // same as:  “fseek( in, 0, SEEK_SET )”
fread( buffer, 1, numBytes, fp );
fclose( fp );

GLuint shaders[2]
glShaderBinary( 2, shaders, GL_SHADER_BINARY_FORMAT_SPIR_V, buffer, numbytes );
GLuint program = glCreateProgram( );
glAttachShader( program, shaders[0] );
glAttachShader( program, shaders[1] );
```



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SPIR-V:
Standard Portable Intermediate Representation for Vulkan

glslangValidator shaderFile -G [-H] [-I<dir>] [-S <stage>] -o shaderBinaryFile.spv

Shaderfile extensions:

.vert	**Vertex**
.tesc	**Tessellation Control**
.tese	**Tessellation Evaluation**
.geom	**Geometry**
.frag	**Fragment**
.comp	**Compute**

(Can be overridden by the –S option)

-V	Compile for Vulkan
-G	Compile for OpenGL
-I	Directory(ies) to look in for #includes
-S	Specify stage rather than get it from shaderfile extension
-c	Print out the maximum sizes of various properties

Windows: glslangValidator.exe
Linux: setenv LD_LIBRARY_PATH /usr/local/common/gcc-6.3.0/lib64/

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How do you know if SPIR-V compiled successfully?

Same as C/C++ -- the compiler gives you no nasty messages.

Also, if you care, legal .spv files have a magic number of **0x07230203**

So, if you do an **od –x** on the .spv file, the magic number looks like this:

0203 0723 . . .

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