04 GLSL Intro Lab

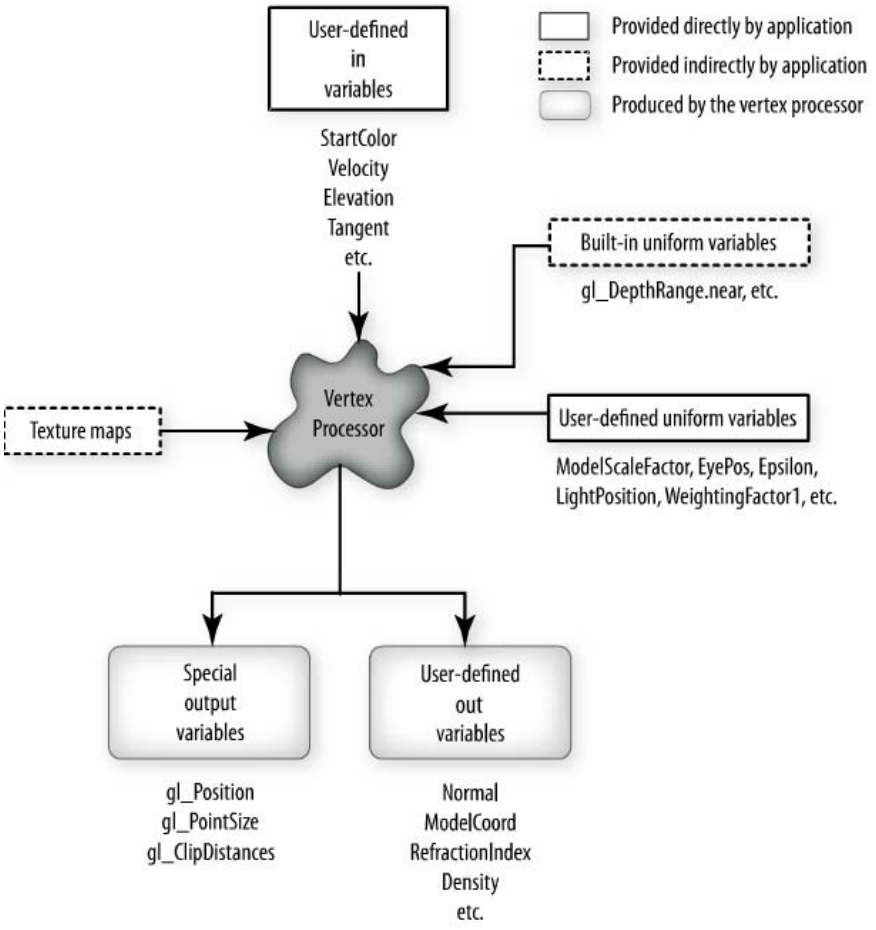
Lab 22/01/2015

Interactive Entertainment Technology

Vertices and Fragments

- A vertex is a location in space
  - The 3D (or 4D) points that describe what we are modelling
- A fragment can be considered to be a potential pixel that carries with it information including its colour and location and depth information , that is used to update the corresponding pixel in the frame buffer
  - A proto-pixel
- Fragments are generated as part of the rasterization process (some models consider the processing of fragments to occur separately).

Vertex Processor



- Input from:
  - User-defined variables
  - Uniform variables (built-in or user defined)
  - Texture maps
- Can also access
  - Built-in constants
- Output:
  - Built-in special variables
  - User defined **varying** variables
  - Special vertex shader output variables

Vertex Shaders

- Allow us to define operations to be performed on vertices
  - Basically a short program in (usually) a C-like language
  - Executed on each vertex as it passes down the pipeline, while the shader is loaded.
  - have access to the OpenGL State
- If defined completely replaces the fixed function pipelines' processing
  - This means that for each vertex the vertex shader must output all the information that the rasterizer needs to do its job
- The inputs are the vertex itself and any application information from the calling application that affects rendering on a per-vertex basis

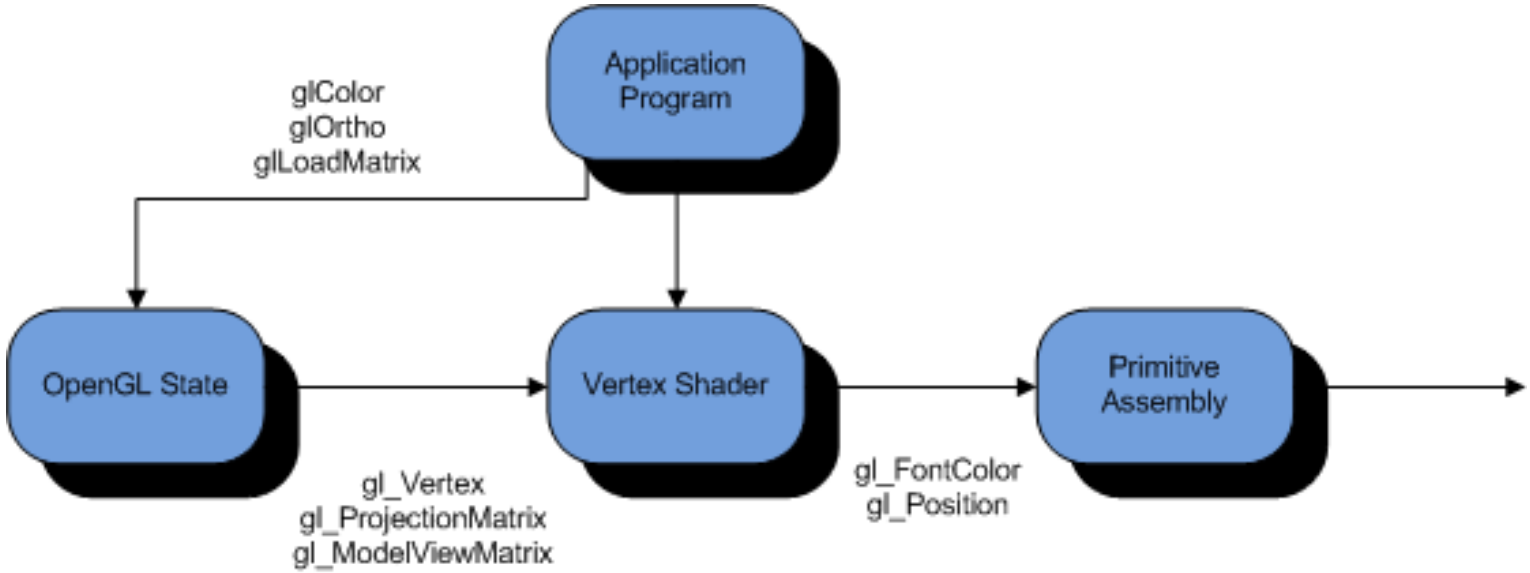
A Simple GLSL Vertex Shader

```
void main (void)
{
        gl_position = gl_ProjectionMatrix * gl_ModelViewMatrix * gl_Vertex;
}
```

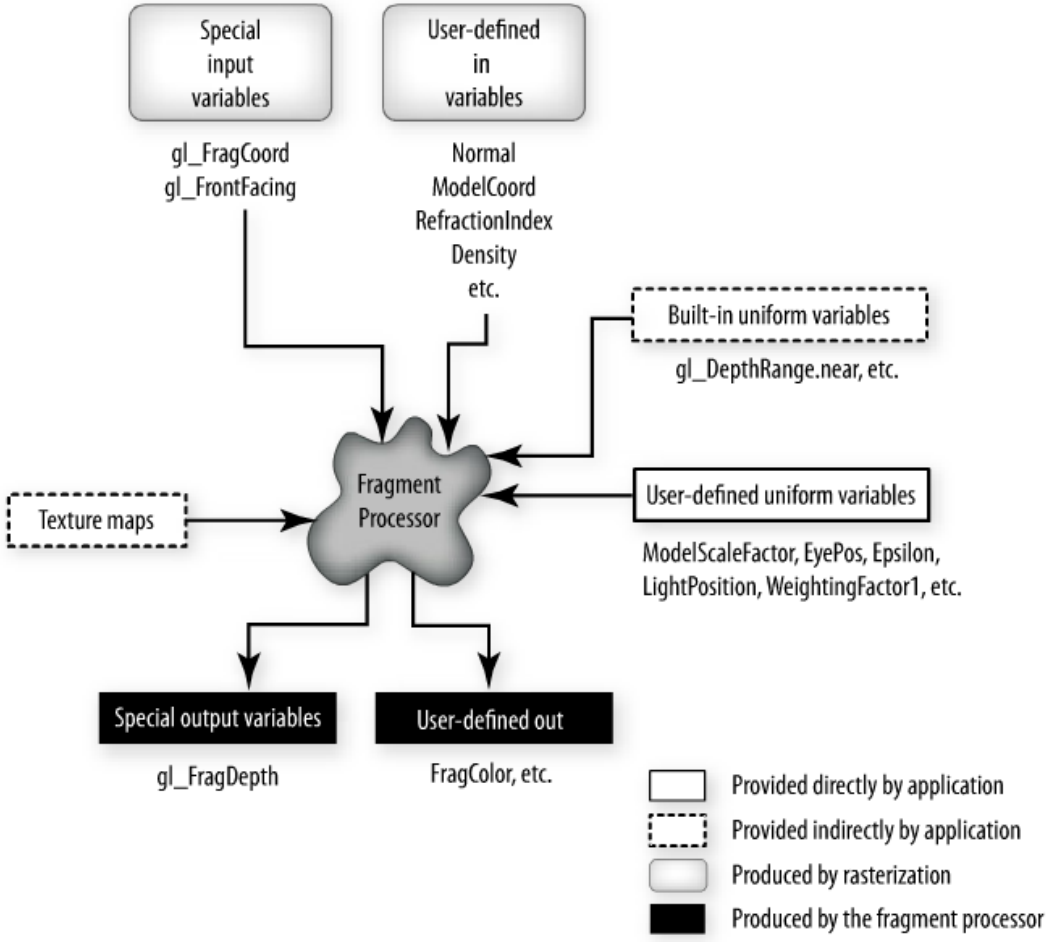
- GLSL includes it's own data types such as mat4 which represents a 4x4 matrix
- The above code reproduces some functionality of the fixed pipeline.
  - positions the vertex based on the modelview matrix and performs a projection based on the Projection Matrix
  - it does not set colour or any other attributes (colour could later be set by the fragment vertex shade)
  - N.B. the variables prefixed with gl are part of the OpenGL state and need not be declared

Vertex Shader Architecture

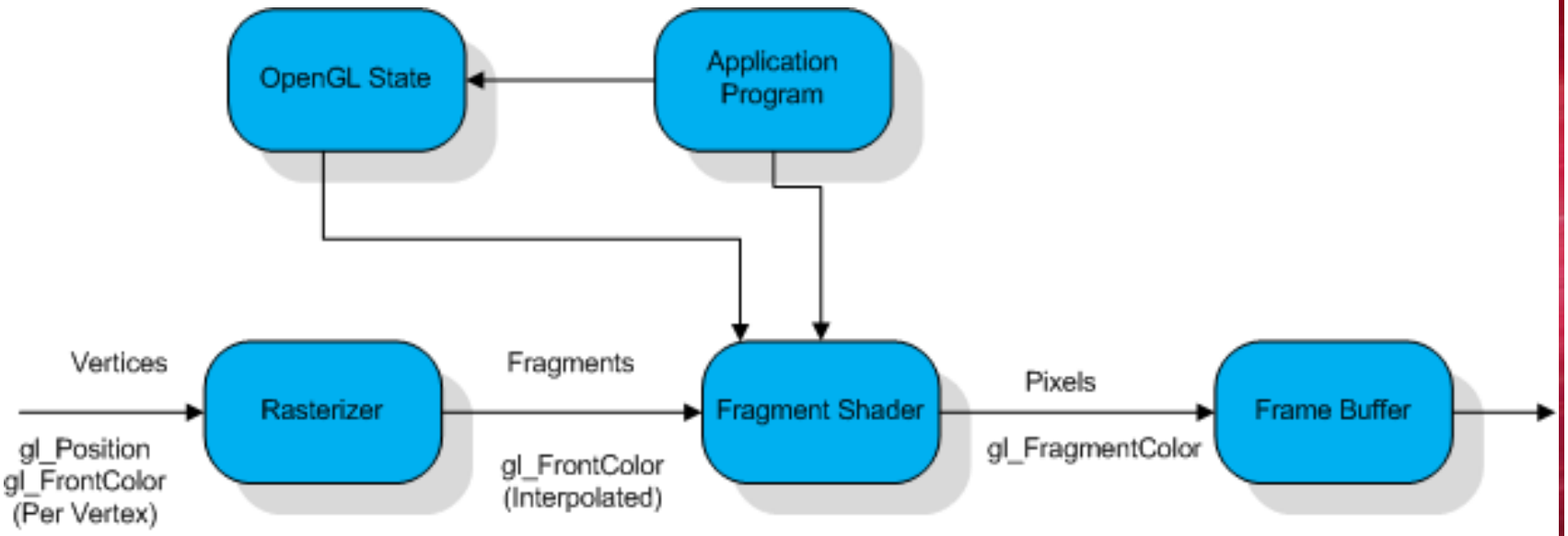
- Every time glVertex3f(...) or some variant is called the shader executes



Fragment Processor



Fragment Shader Architecture



A Simple Fragment Shader

- In GLSL they have the same syntax as vertex shader programs

```
void main()
{
     gl_FragColour  = gl_FrontColor;
}
```

- But they work slightly differently to a vertex program.
  - gl_FrontColor is not a value generated by the vertex shader, but is produced by interpolating the colours between vertices

Using Shader Programs

- The Shader Program needs to be loaded and linked from the OpenGL Application.

Create (empty) shader objects by caling **glCreateShader**

Provide source code for these shaders by calling **glShaderSource**

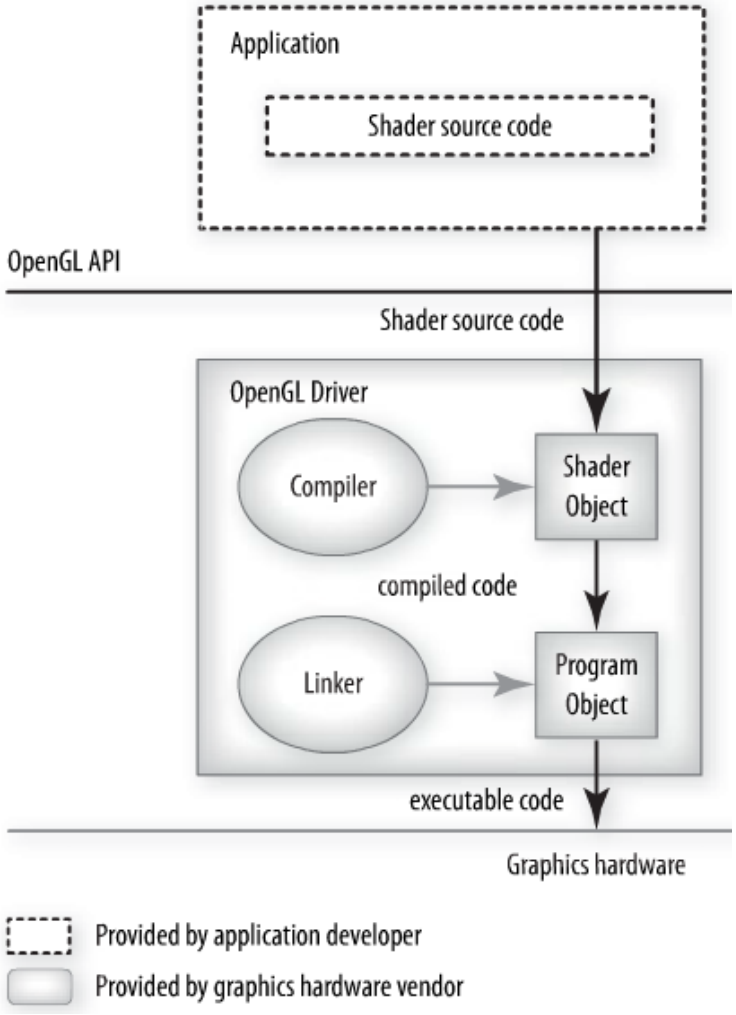
Compile each of the shaders by calling **glCompileShader**

Create program object by calling **glCreateProgram**

Attach all the shader objects to the program by calling **glAttachShader**

Link the Program by calling **glLinkProgram**

Install the executable program as part of OpenGL's current state by using **glUseProgram**



Minimum Code

```
GLuint myProgObj;
myProgObj = glCreateProgram();
GLchar vertexProg[] =       “my_vertex_shader_filename”;
GLuint myVertexObj;
myVertexObj = glCreateShader(GL_VERTEX_SHADER);
glShaderSource(myVertexObj,1, vertexProg, NULL);
glCompileShade(myVertexObj);
glAttachObject(myProgObj, myVertexObj);
...
glLinkProgram(myProgObj);
glUseProgram(myProgObj);
```

- Once the above code has been run subsequent graphics primitives will be drawn with the shaders you provide rather than with OpenGL’s defined fixed functionality pipeline

Shader Data Types

- Shaders can be considered small independent programs which can be loaded onto hardware.
- The have some of their own data types
  - **float , bool , int**
  - Vectors of length 2 3 or 4
    - **vec2, vec3, vec4**
  - Matrices , 2x2, 3.x3 , 4x4
    - **mat2, mat3 , mat4**
- To **access** the first 3 components (i.e. A **vec3**) of variable myVec defined as **vec4**
  - **myVec.xyz**

Attribute Types

- Vertex **Attributes**
  - Information which only apply to vertices.
    - *Generic vertex attributes*: e.g. normal, color, texure coords
    - Custom Attributes can also be declared.
    - Attributes can be read and set in the application and shader
- Special Output Variables
  - gl_Position, gl_PointSize, gl_ClipDistance
- **Uniforms** are variables which hold true across a whole primitive
  - Reserved prefix gl_
  - Cannot be updated within a vertex shader

Varying

- **Varying** variables are used to convey data from a vertex shader to a fragment shader

```
const vec4 red = vec4(1.0,0.0,0.0,1.0);
varying vec4 color_out;
void main(void)
{
     gl_position = gl_ModelViewProjectionMatrix *gl_vertex;
     color_out  = red
}
```

- The Corresponding Fragment Shader

```
varying vec4 color_out;
void main(void)
{
      gl_FragColor = color_out;
}
```

Built in functions

- Trigonometry ... Sin cos tan, convert from degrees to radians etc
  - genType **sin (genType *angle)***
- Maths
  - genType **pow (genType *x, genType y)***
    - returns x to the power of y
  - genType **sqrt (genType *x)***
  - ***mod, min max floor etc***
- Geometric
  - vec3 **cross (vec3 *x, vec3 y)***
  - float **dot (genType *x, genType y)***
  - ***distance, length, normlize face forwards***
  - genType **reflect (genType *I, genType N)***
  - genType **refract(genType *I, genType N, float eta)***
- For more see the GLSL spec

Built in variables

- gl_Position
  - Must be defined in every vertex shader
- gl_FragColor
  - Must be defined in every fragment shader
- gl_Vertex
  - Stores the position of the incoming vertex (in local coordinates)
- gl_FrontColor
  - The front color of the fragment
- gl_ModelViewMatrix
- gl_ProjectionMatrix
- gl_ModelViewProjectionMatrix
- vec4 ftransform(void);
  - replicates fixed function
- http://www.khronos.org/files/opengl-quick-reference-card.pdf

Samplers [Not for this lab]

- For accessing textures
  - They basically create a pointer handle to a texture to use when looking up what texture colour is to be used
  - e.g. ***sampler1D, sampler2D , sampler3D***
  - ***samplerCube*** - for cube map textures
  - ***sampler1DShadow, sampler2DShadow*** - for shadow maps
- Uniform sampler2D source

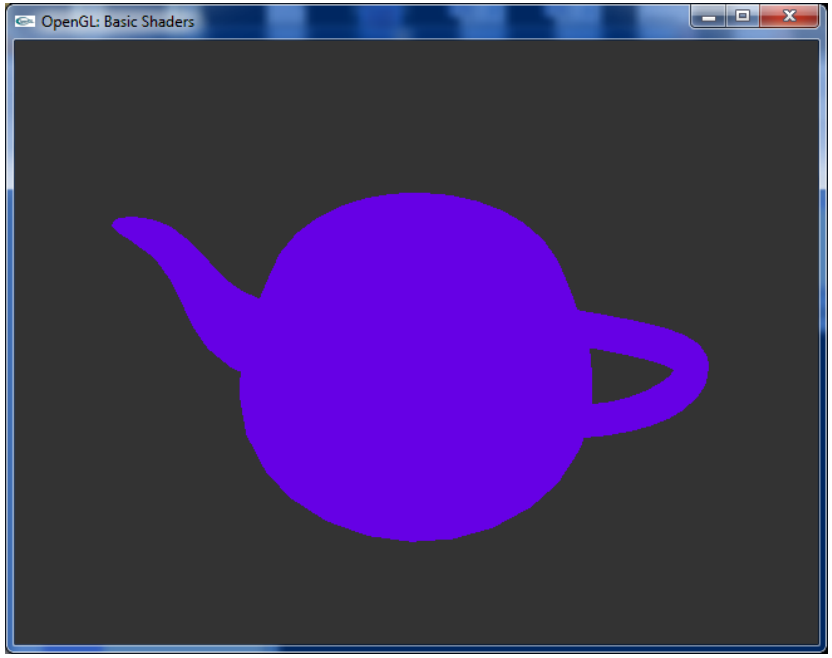
  vec2 texcoords(0.7,0.5);

  gl_FragColor = texture2D(source, texcoords)
- There are many texture lookup functions such as ***texture2D***, ***texture3D*** etc which take samplers as a parameter

Default Shader

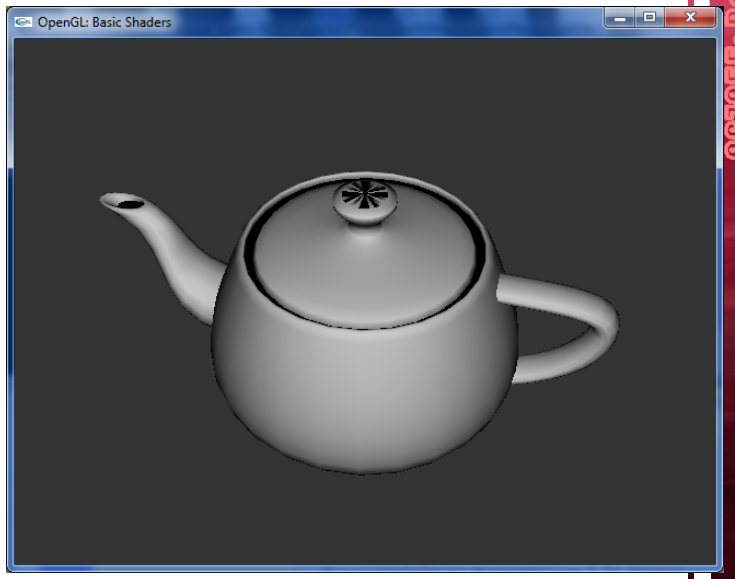
```
//vertex shader
void main(void)
{
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```

```
//fragment shader
void main(void)
{
   gl_FragColor = vec4( 0.4, 0.0,
0.9, 1.0 );
}
```



Diffuse Shader: VS

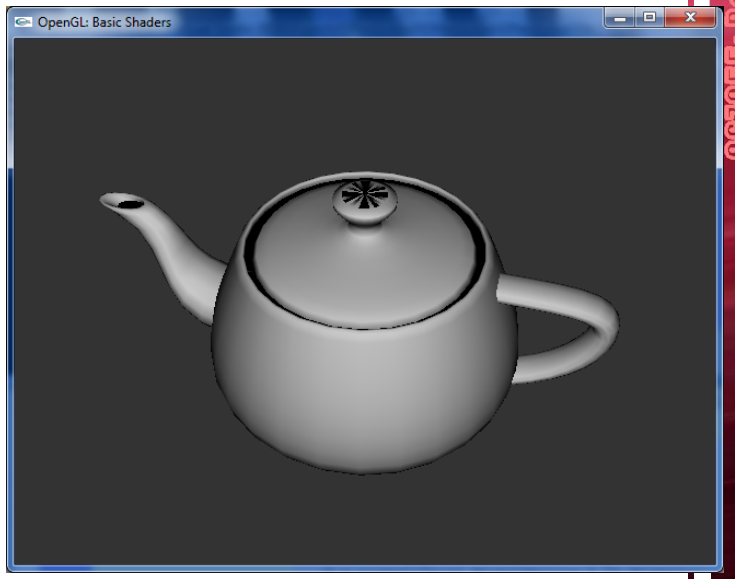
```
varying vec3 N;
varying vec3 v;

void main(void)
{
   v = vec3(gl_ModelViewMatrix * gl_Vertex);
   N = normalize(gl_NormalMatrix * gl_Normal);
   gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```



From: http://www.opengl.org/sdk/docs/tutorials/ClockworkCoders/lighting.php

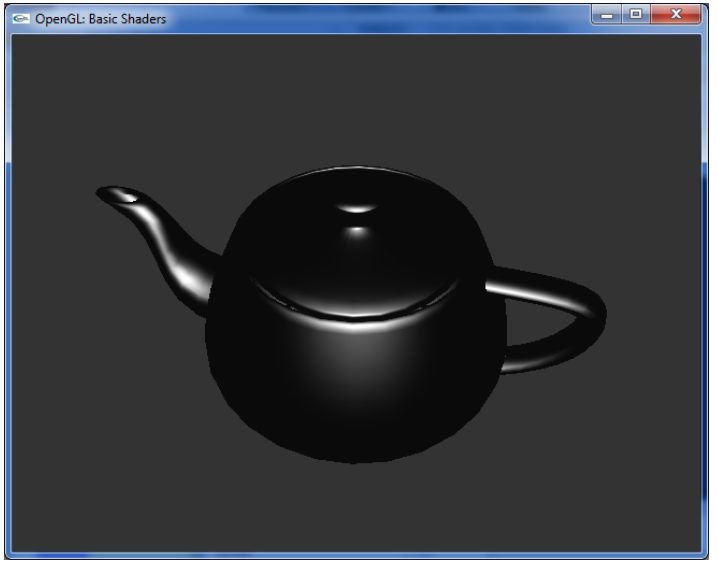
Diffuse Shader: FS

```
varying vec3 N;
varying vec3 v;

void main(void)
{
  vec3 L = normalize(gl_LightSource[0].position.xyz - v);
  vec4 Idiff = gl_FrontLightProduct[0].diffuse * max(dot(N,L), 0.0);
  Idiff = clamp(Idiff, 0.0, 1.0);

  gl_FragColor = Idiff;
}
```



From: http://www.opengl.org/sdk/docs/tutorials/ClockworkCoders/lighting.php

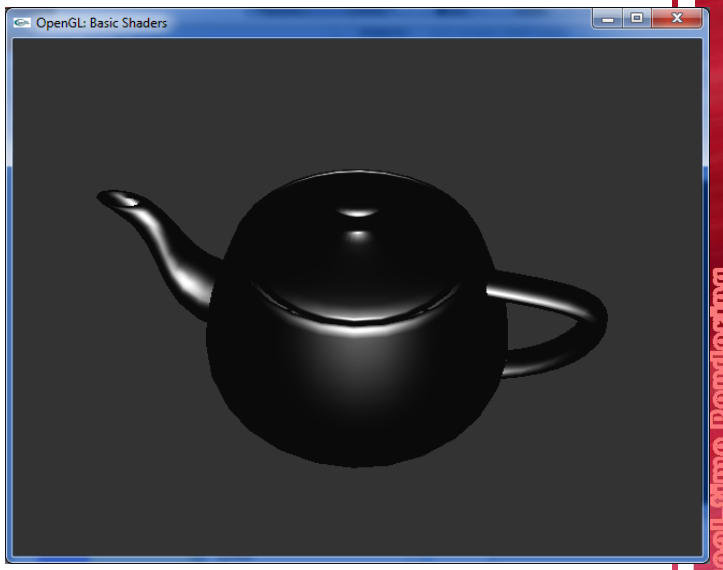
Phong Shader: VS




```
varying vec3 N;
varying vec3 v;

void main(void)
{
   v = vec3(gl_ModelViewMatrix * gl_Vertex);
   N = normalize(gl_NormalMatrix * gl_Normal);
    gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```

From: http://www.opengl.org/sdk/docs/tutorials/ClockworkCoders/lighting.php

Phong Shader: FS




```
varying vec3 N;
varying vec3 v;

void main (void)
{
  vec3 L = normalize(gl_LightSource[0].position.xyz - v);
  // we are in Eye Coordinates, so EyePos is (0,0,0)
  vec3 E = normalize(-v);
  vec3 R = normalize(-reflect(L,N));

  //calculate Ambient Term:
  vec4 Iamb = gl_FrontLightProduct[0].ambient * gl_FrontMaterial.ambient;

  //calculate Diffuse Term:
  vec4 Idiff = gl_FrontLightProduct[0].diffuse * max(dot(N,L), 0.0) * gl_FrontMaterial.diffuse;
  Idiff = clamp(Idiff, 0.0, 1.0);

  // calculate Specular Term:
  vec4 Ispec = gl_FrontLightProduct[0].specular * pow(max(dot(R,E),0.0), gl_FrontMaterial.shininess);
  Ispec = clamp(Ispec, 0.0, 1.0);

  // write Total Color:
  gl_FragColor = Iamb + Idiff + Ispec;
}
```

From: http://www.opengl.org/sdk/docs/tutorials/ClockworkCoders/lighting.php

Aside: Varying Variables in GLSL

- **Varying** variables are used to convey data that needs to be interpolated from a vertex shader to a fragment shader
  - defined at each vertex and interpolated across a graphics primitive to produce a perspective correct value at each fragment.
  - must be declared in both the vertex shader and the fragment shader with the same type.
  - output values from vertex shaders and the input values for fragment shaders.

Example vertex shader

```
const vec4 red = vec4(1.0,0.0,0.0,1.0);
varying vec4 color_out;
void main(void)
{
   gl_position =
gl_ModelViewProjectionMatrix
          *gl_vertex;
   color_out  = red
}
```

And the corresponding fragment shader

```
varying vec4 color_out;
void main(void)
{
   gl_FragColor = color_out;
}
```

The Lab

Basic GLSL

Basic Setup

- Start up a Win32 Console Application in Visual C++ 201X
  - In the application wizard, under “Application Settings” make sure you tick “Empty Project”
- You will need,
  - GL Utility Toolkit (GLUT: http://user.xmission.com/~nate/glut.html)
  - GL Extension Wrangler GLEW: (http://glew.sourceforge.net/index.html)
  - Best get the versions from here:
    - https://www.scss.tcd.ie/Michael.Manzke/CS7055/gl
    - Download files and place them in the following locations

Glut.h	to	C:\Program Files (x86)\Microsoft Visual Studio 10.0\VC\include\GL
Glut.lin	to	C:\Program Files (x86)\Microsoft Visual Studio 10.0\VC\lib\
Glut32.dll	to	C:\Windows\System32\ OR C:\Windows\SysWOW64\ (64 Bit)
bin/glew32.dll	to	%SystemRoot%/system32
lib/glew32.lib	to	C:\Program Files (x86)\Microsoft Visual Studio 10.0\VC\lib\
include/GL/glew.h	to	C:\Program Files (x86)\Microsoft Visual Studio 10.0\VC\include\GL
include/GL/wglew.h	to	C:\Program Files (x86)\Microsoft Visual Studio 10.0\VC\include\GL

Sample Code

- Get the sample code from:
  - https://www.scss.tcd.ie/Michael.Manzke/CS7055/Lab1
  - This includes
    - Base code:
    - Basic vertex shader: base.vert
    - Basic fragment shader: guraud.frag

- It should show you the basic setup for an OpenGL/GLUT program with GLSL.
- Also included is a code for a basic vertex shader and pixel shader
- Compile and run this.

Assignment 1

- Worth ~6%, should approximately take 5hours.
- Set-up a OpenGL/GLUT program with GLSL and run some basic shaders.
- You should create a demo of a scene with a simple rotating object rendered with 3 different shaders.
- All the work is expected to be done in the shader, although you may pass in variables from the application. Note that you are not required to use textures (yet)
- Some examples:
  - Toon rendering
  - Basic Phong or Gouraud
  - Gooch Shading
  - Blinn-Phong Shading
  - http://www.lighthouse3d.com/tutorials/
- 80% for the lab reuirements (see also next slide) and 20% will go for any novel use of the shader, any interesting shaders, placement in a more complex scene (N.B. try not to get too carried away)

Submission

- This is a small assignment worth ~6% of the module
- You should demo it briefly in the lab next week at 15:00 29 th Januar y.
- For all labs henceforth there will be a 20% penalty for each unexplained day late of the demo (you should notify me by email in advance of the deadline)
- Also make a short youtube video of it. Email me the link.
  - At this stage, we just want to make sure you have everything set up to do this
  - You can use a camera capture program like camstudio OR (better) find a library that will export GL frames directly to video or image sequences (some examples are GL2AVI or AVIGenerator)
    - http://www.codeproject.com/Articles/1418/A-class-to-easily-generate-AVI-video-with-OpenGL-a

Notes

- Almost everything you need is provided in the sample for the application program. You may need to pass in some values for some of the shaders.
- For further details you can follow the lighthouse3D tutorial at
  - http://www.lighthouse3d.com/tutorials/glsl-tutorial/

- Some Builds Errors may result due to incompatible version of GLEW and GLUT libs/dlls preent on your system. You may have to get these from respective sites and possibly recompile them for your individual setup.

Further things to look at [Optional]

- Textures:
  - we will look at this in a later lab but you may want to skip ahead if you have time.
  - Unfortunately OpenGL does not have image-file data structures or loaders so you have to find some yourself. e.g. DevIL
  - The last part of the lighthouse3D tutorial discusses what you need to do in OpenGL/GLSL to set this up.
- Geometry:
  - You might want to see if you can create/load your own 3D geometry using vertex primitives. Current practice is to use vertex buffer objects

Resources

- Lighthouse 3D GLUT/GLSL Tutorials
  - http://www.lighthouse3d.com/opengl/glut/
  - http://www.lighthouse3d.com/opengl/glsl/
- GLEW
  - Automatically sets up whichever OpenGL extensions are available (i.e. Enables calls to shader hardware if it exists)
  - http://glew.sourceforge.net/
- nVidia OpenGL SDK
  - Contains Examples (which also use the GLEW library)
  - http://developer.nvidia.com/page/opengl.html
- DevIL – an open image library (e.g. for textures)
  - http://openil.sourceforge.net/