Computer Graphics (CS 543)
Lecture 2 (Part 1): Shader Setup & GLSL Introduction

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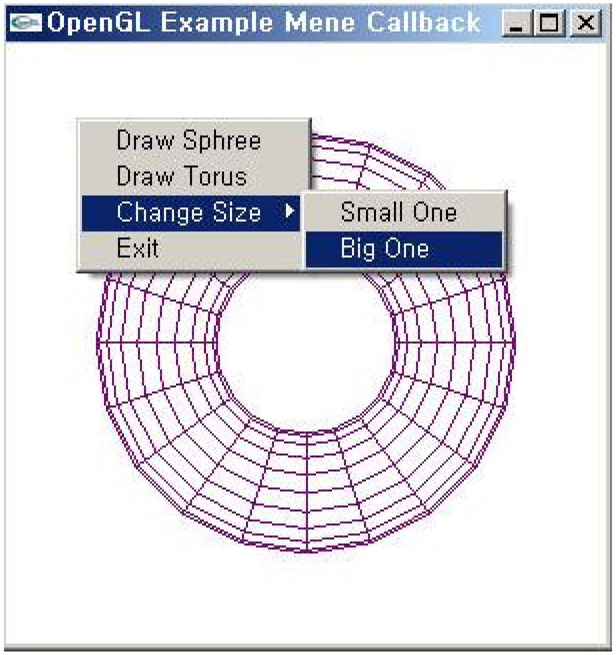
Menus

- Adding menu that pops up on mouse click

1. Create menu using **`glutCreateMenu(myMenu);`**

2. Use **`glutAddMenuEntry`** adds entries to menu

3. Attach menu to mouse button (left, right, middle) using **`glutAttachMenu`**



Menus

- Example:

Shows on menu

Checked in mymenu

```
glutCreateMenu(myMenu);
 glutAddMenuEntry("Clear Screen", 1);
 glutAddMenuEntry("Exit", 2);
 glutAttachMenu(GLUT_RIGHT_BUTTON);

 ….

 void mymenu(int value){
     if(value == 1){
         glClear(GL_COLOR_BUFFER_BIT);
         glFlush( );
     }
     if (value == 2) exit(0);
}
```

GLUT Interaction using other input devices

- Tablet functions (mouse cursor must be in display window)

```
glutTabletButton (tabletFcn);
…..
void tabletFcn(Glint tabletButton, Glint action, Glint
   xTablet, Glint yTablet)
```

- Spaceball functions
- Dial functions
- Picking functions: use your finger
- Menu functions: minimal pop-up windows within your drawing window
- Reference: *Hearn and Baker, 3rd edition (section 20-6)*

Adding Interaction

- So far, OpenGL programs just render images
- Can add user interaction
- Examples:
  - User hits ‘h’ on keyboard -> Program draws house
  - User clicks mouse left button -> Program draws table

Types of Input Devices

- **String:** produces string of characters e.g. keyboard

- **Locator:** User points to position on display. E.g mouse

Types of Input Devices

- **Valuator:** generates number between 0 and 1.0
- **Pick:** User selects location on screen (e.g. touch screen in restaurant, ATM)

Using Keyboard Callback for Interaction

- 1. register callback in main( ) function

```
glutKeyboardFunc( myKeyboard );
```

ASCII character of pressed key

x,y location of mouse

- 2. implement keyboard function

```
void myKeyboard(char key, int x, int y )
{    // put keyboard stuff here
   ………..
    switch(key){   // check which key
       case 'f':
         // do stuff
       break;

       case 'k':
          // do other stuff
       break;

    }
………………
}
```

Note: Backspace, delete, escape keys checked using their ASCII codes

Keyboard Interaction

- For function, arrow and other special-purpose keys, use

```
glutSpecialFunc (specialKeyFcn);
…
Void specialKeyFcn (Glint specialKey, GLint, xMouse,
                                    Glint yMouse)
```

- Example: if (**`specialKey == GLUT_KEY_F1)`**// F1 key pressed
  - **`GLUT_KEY_F1, GLUT_KEY_F12, ….`** for function keys
  - **`GLUT_KEY_UP, GLUT_KEY_RIGHT, ….`** for arrow keys keys
  - **`GLUT_KEY_PAGE_DOWN, GLUT_KEY_HOME, ….`** for page up, home keys
- Complete list of special keys designated in **`glut.h`**

Mouse Interaction

- Declare prototype
  - **`myMouse(int button, int state, int x, int y)`**
  - **`myMovedMouse`**
- Register callbacks:
  - **`glutMouseFunc(myMouse):`** mouse button pressed
  - **`glutMotionFunc(myMovedMouse):`** mouse moves with button pressed
  - **`glutPassiveMotionFunc(myMovedMouse):`** mouse moves with no buttons pressed
- Button returned values:
  - GLUT_LEFT_BUTTON, GLUT_MIDDLE_BUTTON, GLUT_RIGHT_BUTTON
- State returned values:
  - GLUT_UP, GLUT_DOWN
- X,Y returned values:
  - x,y coordinates of mouse location

Mouse Interaction Example

- Each mouse click generates separate events
- Store click points in **global** or **static** variable in mouse function
- **Example:** draw (or select) rectangle on screen
- Mouse y returned assumes y=0 at top of window
- OpenGL assumes y=0 at bottom of window. Solution? Flip mouse y

```
void myMouse(int button, int state, int x, int y)
{
   static GLintPoint corner[2];
   static int numCorners = 0;   // initial value is 0
   if(button == GLUT_LEFT_BUTTON && state == GLUT_DOWN)
   {
        corner[numCorners].x = x;
        corner[numCorners].y = screenHeight – y; //flip y coord
        numCorners++;
```

Screenheight is height of drawing window

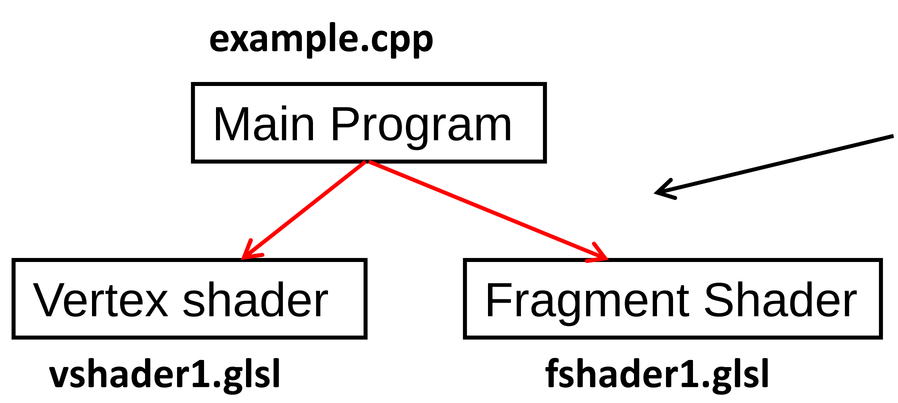
Mouse Interaction Example (continued)

```
  if(numCorners == 2)
  {
       // draw rectangle or do whatever you planned to do
       Point3 points[4] = corner[0].x, corner[0].y,
                          corner[1].x, corner[0].y,
                          corner[1].x, corner[1].y,
                           corner[0].x, corner[1].y);

        glDrawArrays(GL_QUADS, 0, 4);

       numCorners == 0;
  }
  else if(button == GLUT_RIGHT_BUTTON && state == GLUT_DOWN)
       glClear(GL_COLOR_BUFFER_BIT); // clear the window
  glFlush( );
}
```

Recall: OpenGL Program: Shader Setup

- **`initShader( )`**: our homegrown shader initialization
  - Used in main program, connects and link vertex, fragment shaders
  - Shader sources read in, compiled and linked

```
Gluint = program;

GLuint program = InitShader( "vshader1.glsl", "fshader1.glsl" );
glUseProgram(program);
```



What's inside **initShader??**
Next!

Coupling Shaders to Application (initShader function)

1. Create a program object
2. Read shaders
3. Add + Compile shaders
4. Link program (everything together)
5. Link variables in application with variables in shaders
   - Vertex attributes
   - Uniform variables

Step 1. Create Program Object

- Container for shaders
  - Can contain multiple shaders, other GLSL functions

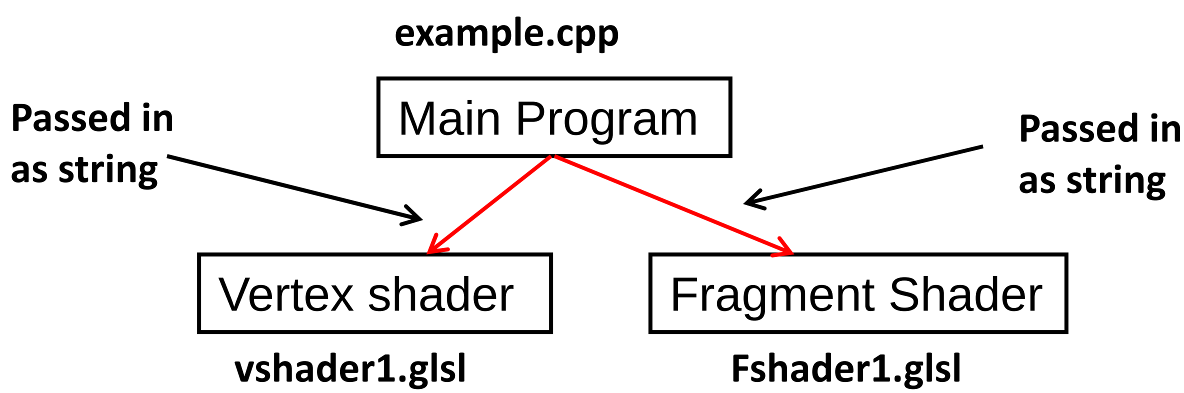
```
GLuint myProgObj;

myProgObj = glCreateProgram();
```

Create container called **Program Object**

Main Program

Step 2: Read a Shader

- Shaders compiled and added to program object



- Shader file code passed in as null-terminated string using the function **`glShaderSource`**
- Shaders in files (vshader.glsl, fshader.glsl), write function **`readShaderSource`** to convert shader file to string

Shader Reader Code?

```
#include <stdio.h>

static char* readShaderSource(const char* shaderFile)
{
    FILE* fp = fopen(shaderFile, "r");

    if ( fp == NULL ) { return NULL; }

    fseek(fp, 0L, SEEK_END);
    long size = ftell(fp);

    fseek(fp, 0L, SEEK_SET);
    char* buf = new char[size + 1];
    fread(buf, 1, size, fp);

    buf[size] = '\0';
    fclose(fp);

    return buf;
}
```

Step 3: Adding + Compiling Shaders

```
GLuint myVertexObj;
Gluint myFragmentObj;
```

Declare shader object (container for shader)

```
GLchar vShaderfile[] = “vshader1.glsl”;
Glchar fShaderfile[] = “fshader1.glsl”;
```

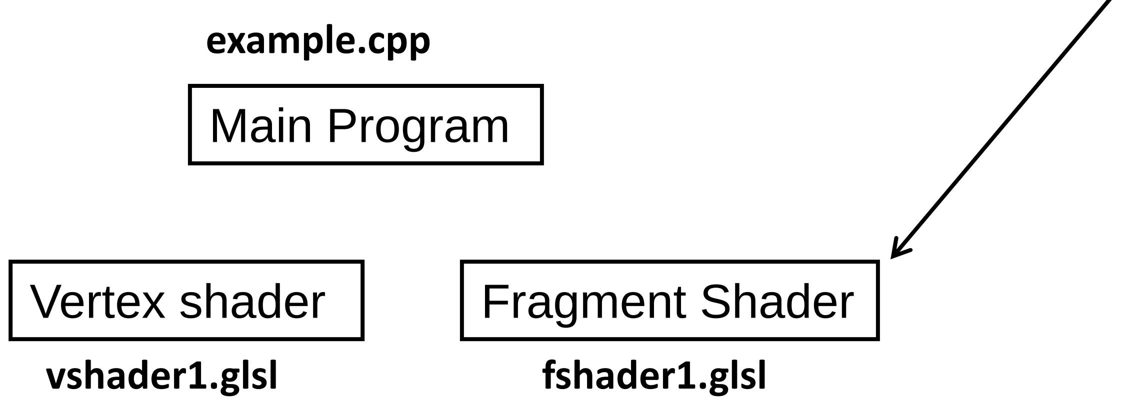
Store **names** of Shader files

```
GLchar* vSource = readShaderSource(vShaderFile);
GLchar* fSource = readShaderSource(fShaderFile);
```

Read shader files, Convert **code** to string

```
myVertexObj = glCreateShader(GL_VERTEX_SHADER);
myFragmentObj = glCreateShader(GL_FRAGMENT_SHADER);
```

Create empty Shader objects



Step 3: Adding + Compiling Shaders
Step 4: Link Program

Read shader code **strings** into shader objects

```
glShaderSource(myVertexObj, 1, vSource, NULL);
glShaderSource(myFragmentObj, 1, fSource, NULL);
```

Compile shader objects

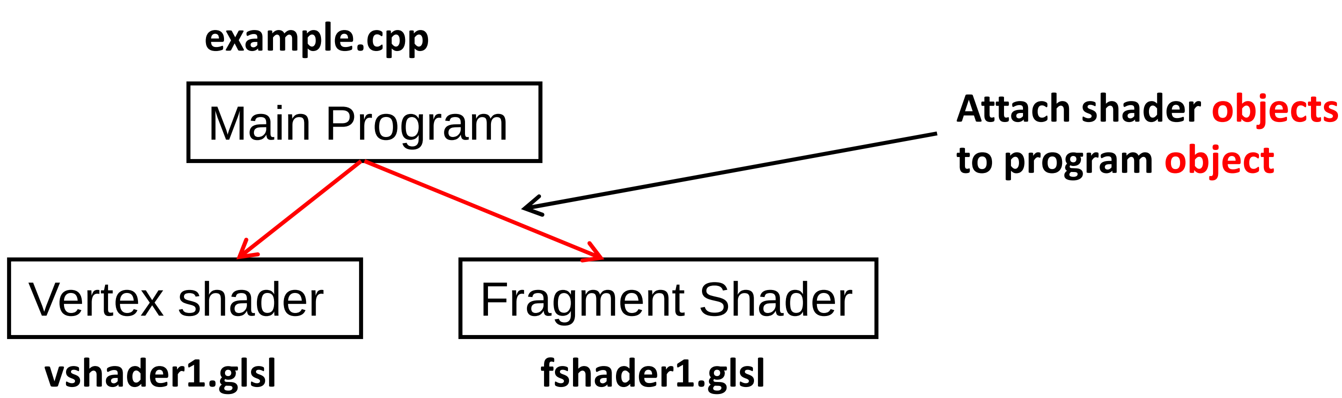
```
glCompileShader(myVertexObj);
glCompileShader(myFragmentObj);
```

Attach shader **objects** to program **object**

```
glAttachShader(myProgObj, myVertexObj);
glAttachShader(myProgObj, myFragmentObj);
```

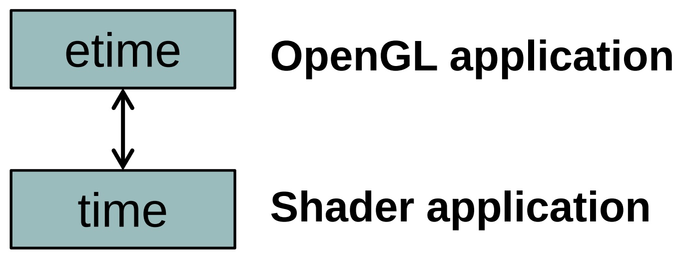
Link Program

```
glLinkProgram(myProgObj);
```



Uniform variables

- **Uniform**-qualified variables cannot change = **constants**
- Sometimes want to connect variable in OpenGL application to variable in shader
- Example?
  - Check "elapsed time" variable (etime) in OpenGL application
  - Use elapsed time variable (time) in shader for calculations



Uniform variables

- First declare **etime** variable in OpenGL application, get time

```
float etime;

etime = 0.001*glutGet(GLUT_ELAPSED_TIME);
```

Elapsed time since program started

- Use corresponding variable **time** in shader

```
uniform float time;
attribute vec4 vPosition;

main( ){
    vPosition.x  += (1+sin(time));
    gl_Position = vPosition;
}
```

- Need to connect **etime** in application and **time** in shader!!

Connecting **etime** and **time**

- Linker forms table of shader variables, each with an index
- Application can get index from table, tie it to application variable
- In application, find location of shader **time** variable in linker table

```
Glint timeParam;

timeParam = glGetUniformLocation(program, "time");
```

423	time

- Connect **location** of shader variable **time** location to **etime**!

```
glUniform1(timeParam, etime);
```

423	etime

Location of shader variable time

Application variable, etime

Vertex Attributes

- Vertex attributes (vertex position, color) are named in the shaders
- Similarly for vertex attributes

Get location of vertex attribute **vPosition**

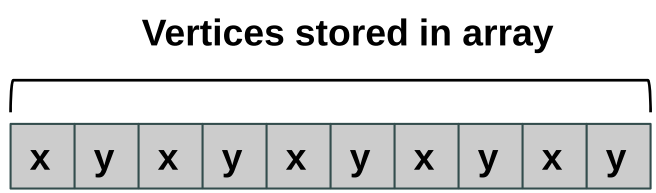
```
#define BUFFER_OFFSET( offset ) ((GLvoid*) (offset))

GLuint loc = glGetAttribLocation( program, "vPosition" );
glEnableVertexAttribArray( loc );
glVertexAttribPointer( loc, 2, GL_FLOAT, GL_FALSE, 0,
                                      BUFFER_OFFSET(0) );
```

Enable vertex array attribute at location of **vPosition**

Specify vertex array attribute at location of **vPosition**

glVertexAttribPointer

- Vertices are packed as array of values



Padding between Consecutive vertices

```
glVertexAttribPointer( loc, 2, GL_FLOAT, GL_FALSE, 0,BUFFER_OFFSET(0) );
```

Location of **vPosition** in table of variables

2 elements of floats per vertex

Data not normalized to 0-1 range

Data starts at offset from start of array

GLSL

- OpenGL Shading Language
- Vertex and Fragment shaders written in GLSL
- Part of OpenGL 2.0 and up
- High level C-like language
- As of OpenGL 3.1, application must use shaders

```
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;
}
```

Example code
of vertex shader

Data Types

- C types: int, float, bool
- Vectors:
  - float vec2, vec3, vec4
  - Also int (ivec2, ivec3, ivec4) and boolean (bvec2, bvec3,bvec4)
- Matrices: mat2, mat3, mat4
  - Stored by columns
  - Standard referencing m[row][column]
- C++ style constructors
  - vec3 a =vec3(1.0, 2.0, 3.0)

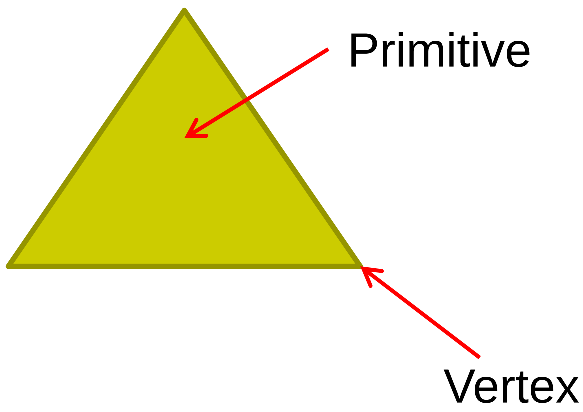
Pointers

- No pointers in GLSL
- Can use C structs that are copied back from functions
- Matrices and vectors are basic types
  - can be passed in and out from GLSL functions
- Example

```
mat3 func(mat3 a)
```

Qualifiers

- GLSL has many C/C++ qualifiers such as `const`
- Supports additional ones
- Variables can change
  - Once per primitive
  - Once per vertex
  - Once per fragment
  - At any time in the application

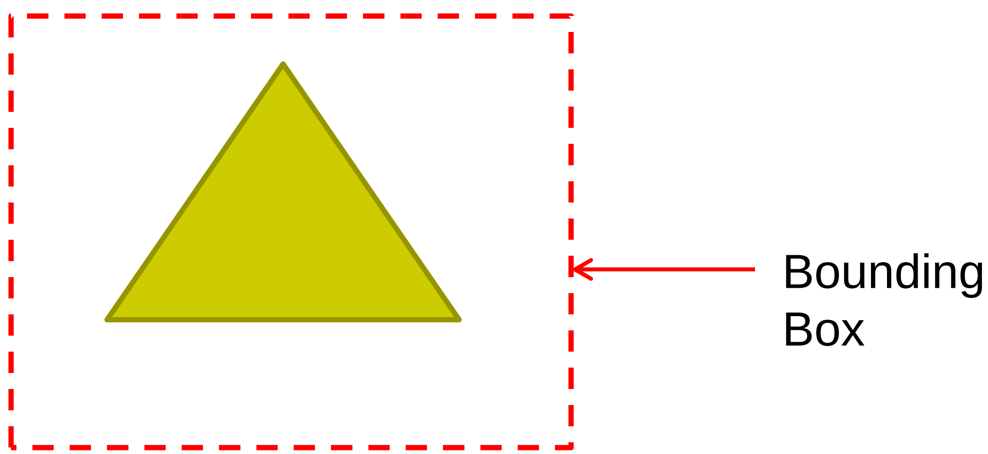


Attribute Qualifier

- 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`**

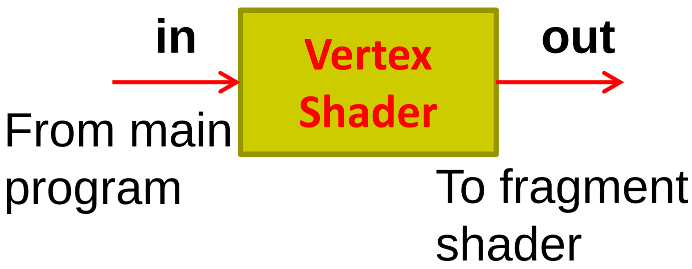
Uniform Qualified

- 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

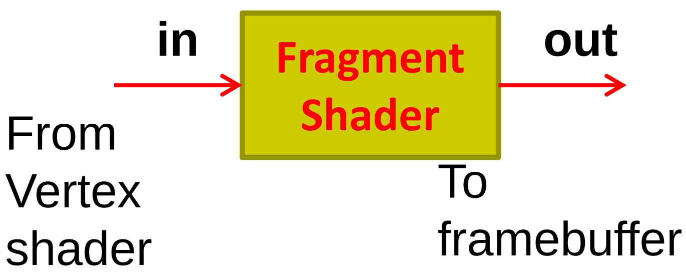


Passing values

- call by **value-return.** Two possibilities
  - **in:** variables copied in
  - **out:** returned values are copied back
- **inout** (deprecated)
- **Example:** vertex shader using **out**




```
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;
}
```



Operators and Functions

- Standard C functions
  - Trigonometric: cos, sin, tan, etc
  - Arithmetic: log, min, max, abs, etc
  - Normalize, reflect, length
- Overloading of vector and matrix types

```
mat4 a;
vec4 b, c, d;
c = b*a;     // a column vector stored as a 1d array
d = a*b;    // a row vector stored as a 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
  - **`vec4 a;`**
  - **`a[2], a.b, a.z, a.p`** are the same
- **Swizzling** operator lets us manipulate components

```
a.yz = vec2(1.0, 2.0);
```

References

- Angel and Shreiner, Interactive Computer Graphics, 6th edition, Chapter 2
- Hill and Kelley, Computer Graphics using OpenGL, 3rd edition, Chapter 2