Computer Graphics (CS 543)
Lecture 1 (Part 3): Introduction to OpenGL/GLUT (Part 2)

Prof Emmanuel Agu

Computer Science Dept.

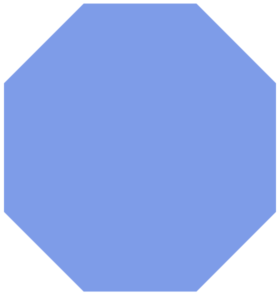
Worcester Polytechnic Institute (WPI)

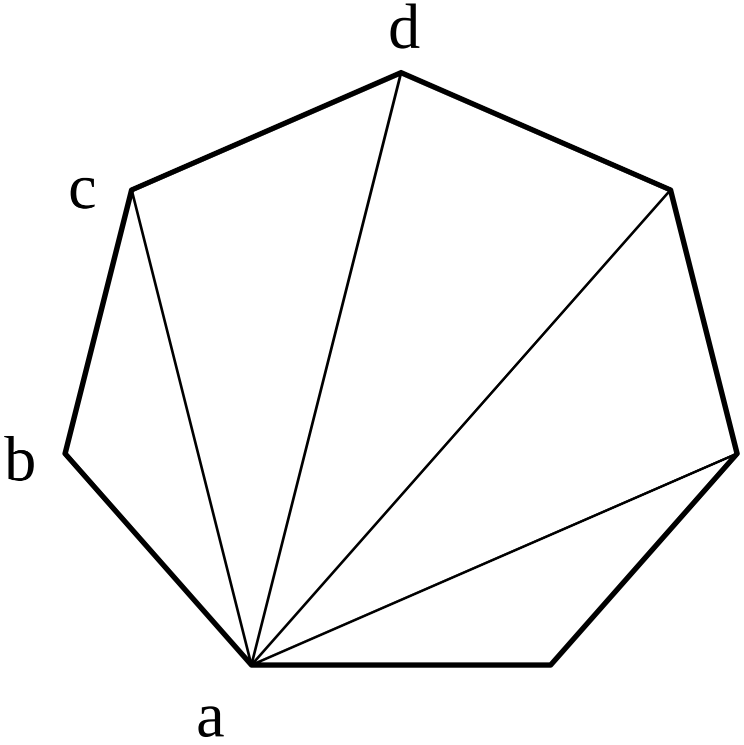
Triangulation

- Generally OpenGL breaks polygons down into triangles which are then rendered. Example

`glDrawArrays`(GL_POLYGON,..)

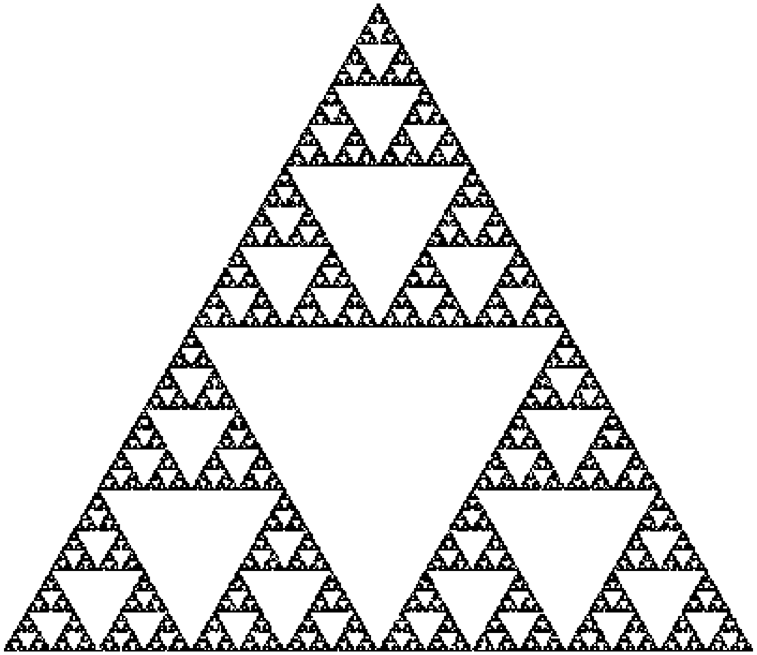
– convex filled polygon





Sierpinski Gasket Program

- Any sequence of points put into array points[ ] will be drawn
- Can generate interesting sequence of points
  - Put in array points[ ], draw!!
- Sierpinski Gasket: Popular fractal



Sierpinski Gasket

Start with initial triangle with corners (*x1, y1, 0*), (*x2, y2, 0*) and (*x3, y3, 0*)

1. Pick initial point **p** = (*x, y, 0*) at random inside a triangle
2. Select on of 3 vertices at random
3. Find **q,** halfway between **p** and randomly selected vertex
4. Draw dot at **q**
5. Replace **p** with **q**
6. Return to step 2

Actual Sierpinski Code

```
#include “vec.h”    // include point types and operations
#include <stdlib.h> // includes random number generator

void Sierpinksi( )
{
    const int NumPoints = 5000;
    vec2 points[NumPoints];

    // Specifiy the vertices for a triangle
    vec2 vertices[3] = {
        vec2( -1.0, -1.0 ), vec2( 0.0, 1.0 ), vec2( 1.0, -1.0 )
    };
```

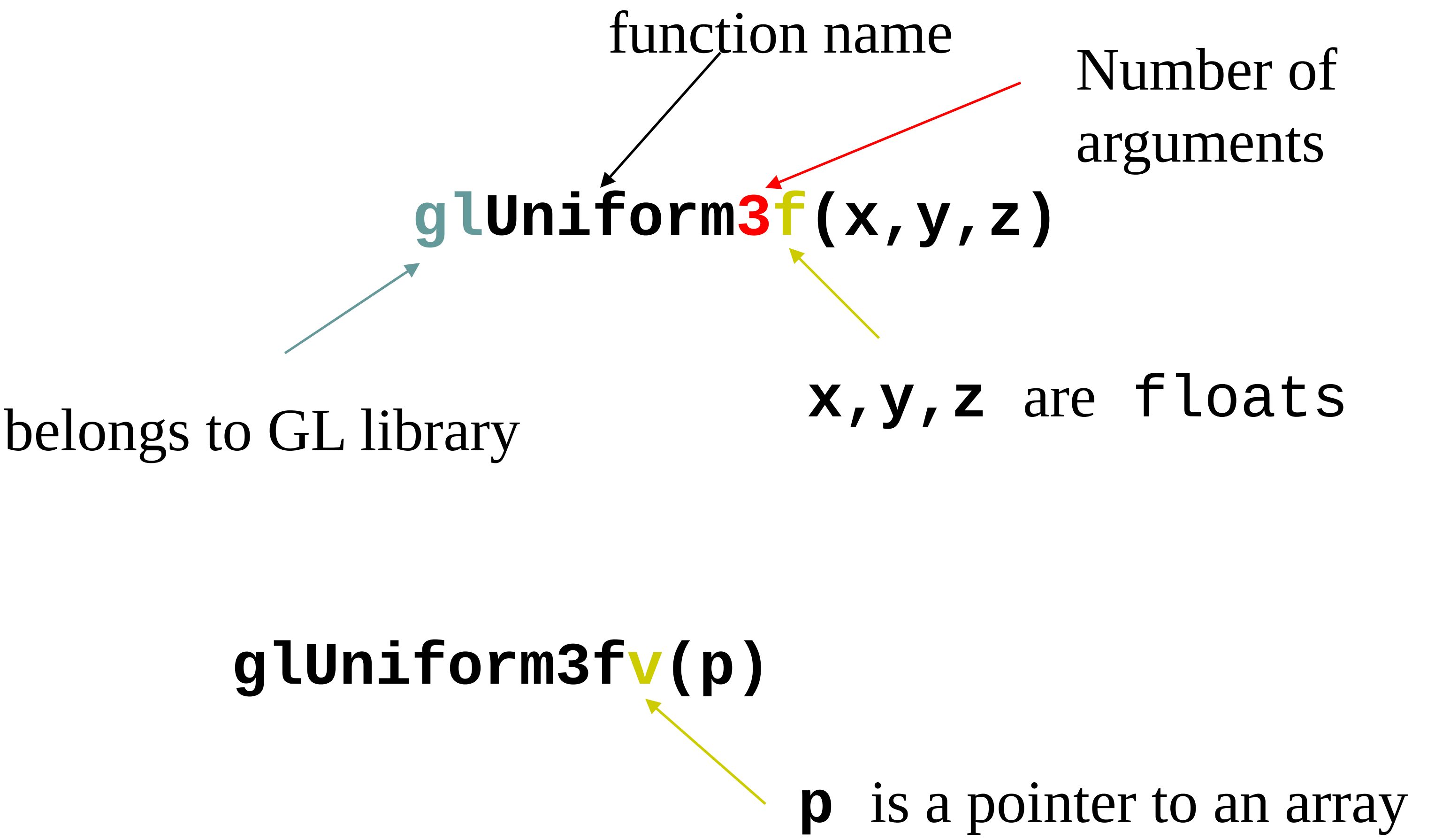
Actual Sierpinski Code

```
// An arbitrary initial point inside the triangle
points[0] = point2(0.25, 0.50);

// compute and store N-1 new points
for ( int i = 1; i < NumPoints; ++i ) {
    int j = rand() % 3;   // pick a vertex at random

    // Compute the point halfway between the selected vertex
    //   and the previous point
    points[i] = ( points[i - 1] + vertices[j] ) / 2.0;
}
```

Lack of Object Orientation

- OpenGL is not object oriented
- Multiple functions for each command
  - `glUniform3f`
  - `glUniform2i`
  - `glUniform3dv`

OpenGL function format



function name

Number of arguments

`glUniform3f(x,y,z)`

belongs to GL library

`x,y,z` are `floats`

`glUniform3fv(p)`

`p` is a pointer to an array

Recall: Single Buffering

- If display mode set to single framebuffers
- Any drawing into framebuffer is seen by user. How?
    - **glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);**
        - Single buffering with RGB colors
- Drawing may not be drawn to screen until call to **glFlush( )**

```
void mydisplay(void){
      glClear(GL_COLOR_BUFFER_BIT); // clear screen
      glDrawArrays(GL_POINTS, 0, N);
      glFlush( );
}
```

Drawing sent to screen

Double Buffering

- Set display mode to double buffering (create front and back framebuffers)
  - `glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB);`
    - Double buffering with RGB colors

- Front buffer displayed on screen, back buffers not displayed
- Drawing into back buffers (not displayed) until swapped in using **`glutSwapBuffers( )`**

```
void mydisplay(void){
      glClear(GL_COLOR_BUFFER_BIT); // clear screen
      glDrawArrays(GL_POINTS, 0, N);
      glutSwapBuffers( );
}
```

Back buffer drawing swapped in, becomes visible here

OpenGL Data Types

C++	OpenGL
Signed char	GLByte
Short	GLShort
Int	GLInt
Float	GLFloat
Double	GLDouble
Unsigned char	GLubyte
Unsigned short	GLushort
Unsigned int	GLuint

Example: Integer is 32-bits on 32-bit machine
but 64-bits on a 64-bit machine

Recall: 3. Create GPU Buffer for Vertices

- Already learnt to create off-screen GPU memory for vertex data called ***Vertex Buffer Objects***
- Steps:
  1. **Create VBO and give it name (unique ID number)**

```
GLuint buffer;
glGenBuffers(1, &buffer); // create one buffer object
```

Number of Buffer Objects to return

  2. **Make VBO created the currently active one**

```
glBindBuffer(GL_ARRAY_BUFFER, buffer); //data is array
```

- May set up VBO in an **init( )** function!!

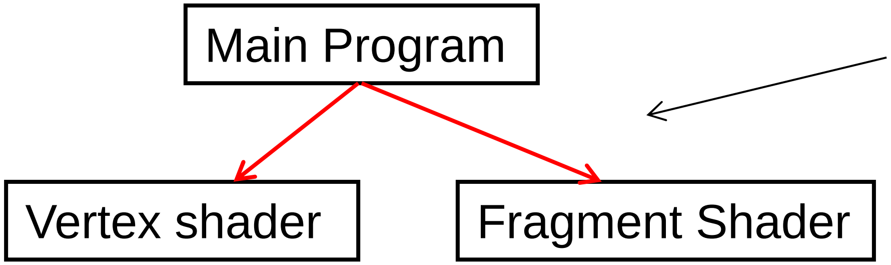
What other Initialization do we Need?

- Also set clear color and other OpenGL parameters
- Also set up shaders as part of initialization
  - Read
  - Compile
  - Link
- Remember: every OpenGL program must now write shaders that our OpenGL program will read in
- Also need two shaders:
  - **Vertex shader:** program that is run once on **each vertex**
  - **Fragment shader:** program that is run once on **each pixel**

OpenGL Program: Shader Setup

- OpenGL programs now have 3 parts:
  - Main OpenGL program, vertex shader, fragment shader
  - In main program, specify and link in names of vertex, fragment shader
  - initShader( ) is homegrown shader initialization

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



initShader( )
Homegrown, connects main
Program to shader files
More on this later!!

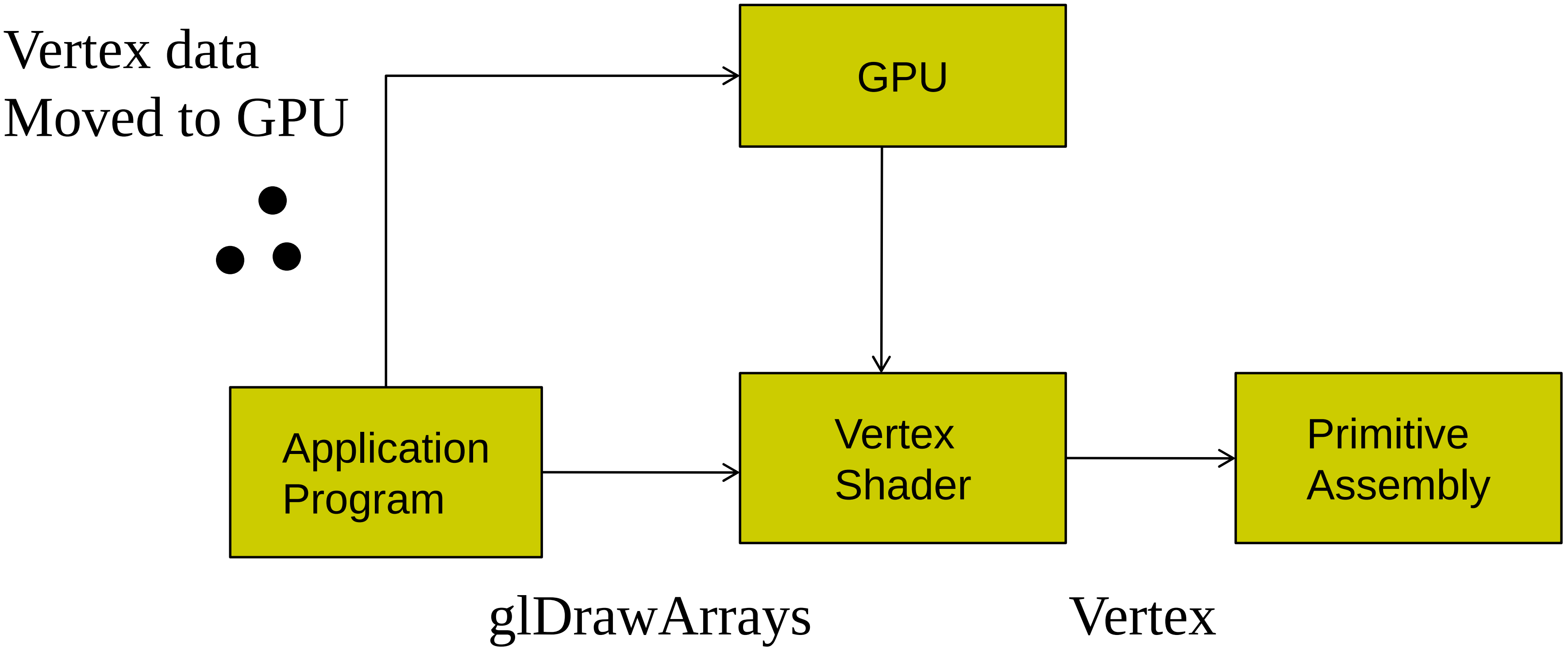
Putting it all Together

- First, we create container called **program object**

```
Gluint = program;

program = InitShader(“vsource.glsl”, “fsource.glsl”);
glUseProgram(program);
```

- Shader sources are read in, compiled and linked
- During linking, names of all shader variables are bound to indices in tables
- Vertex shader and Fragment shader in same directory as main program
- Main program reads in vertex shader and fragment shader (as strings) and uses them for rendering

Execution Model



Vertex data
Moved to GPU

GPU

Application Program

Vertex Shader

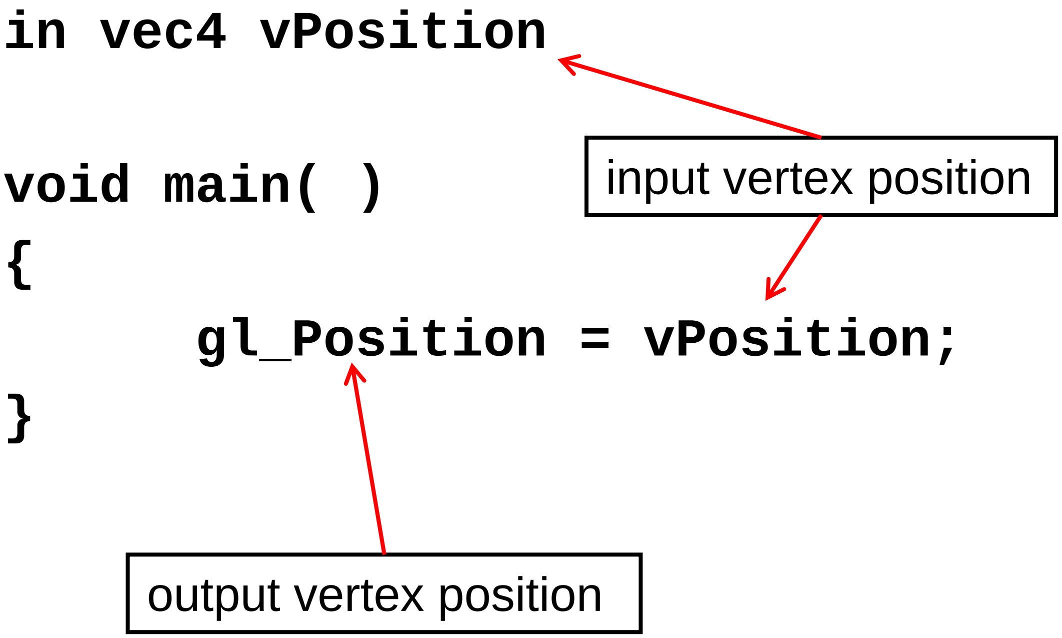
Primitive Assembly

glDrawArrays

Vertex

Vertex Shader

- We write a simple “pass-through” shader (does nothing)
- Save to file on disk called **vsource.glsl**

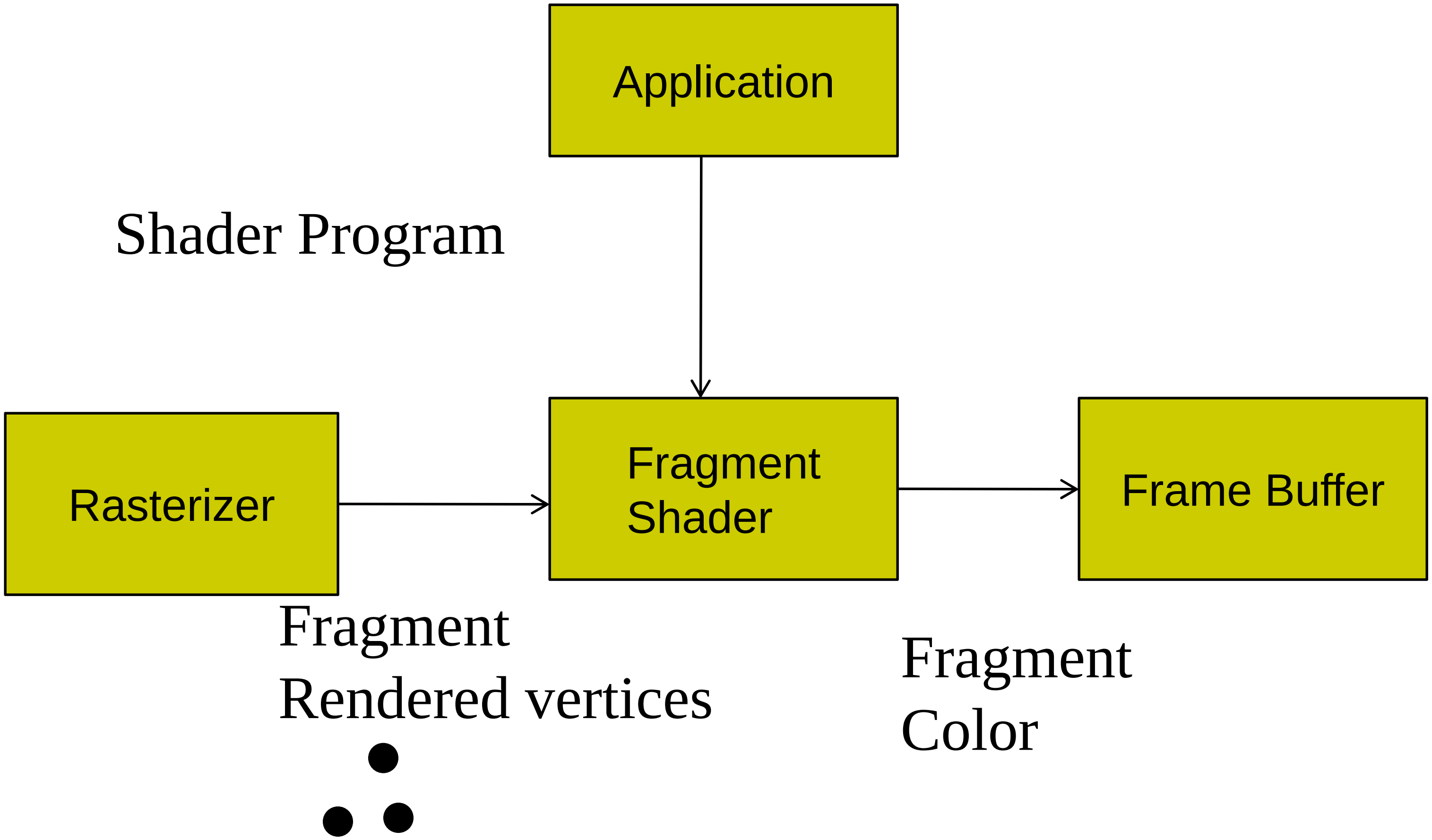


```
in vec4 vPosition

void main( )
{
      gl_Position = vPosition;
}
```

input vertex position

output vertex position

Execution Model



Application

Shader Program

Rasterizer

Fragment Shader

Frame Buffer

Fragment
Rendered vertices

Fragment
Color

Fragment Shader

- We write a simple fragment shader (sets color to red)
- Save to file on disk called **fsource.glsl**

```
void main( )
{
      gl_FragColor = vec(1.0, 0.0, 0.0, 1.0);
}
```

Set each drawn fragment color to red

Keyboard Interaction

- Declare prototype
  - myKeyboard(unsigned int key, int x, int y)
- Register callback:
  - glutKeyboardFunc(myKeyboard): when keyboard is pressed
- Key values:
  - ASCII value of key pressed
- X,Y values:
  - Coordinates of mouse location
- Large **`switch`** statement to check which key

Example: Keyboard Callback

- Using keyboard to control program?
- 1. register callback in main( ) function

```
glutKeyboardFunc( myKeyboard );
```

- 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( );
}
```

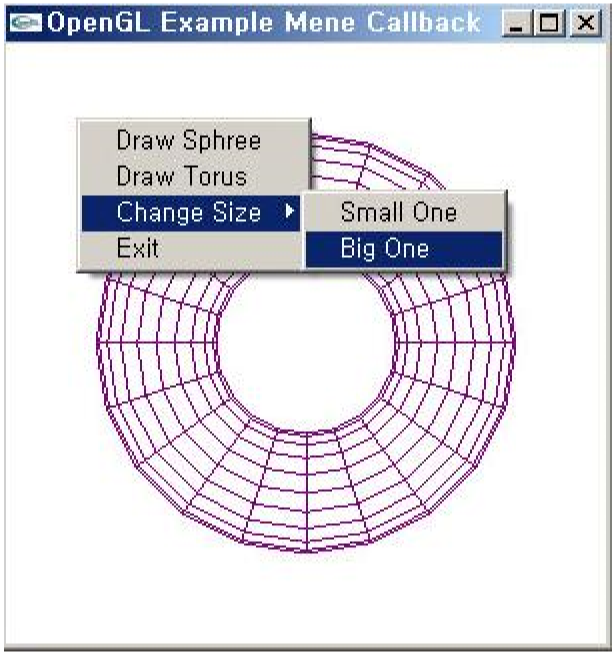
Menus

- 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)*

References

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