Graphics Programming using OpenGL

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OpenGL and GLUT Overview

What Is OpenGL?

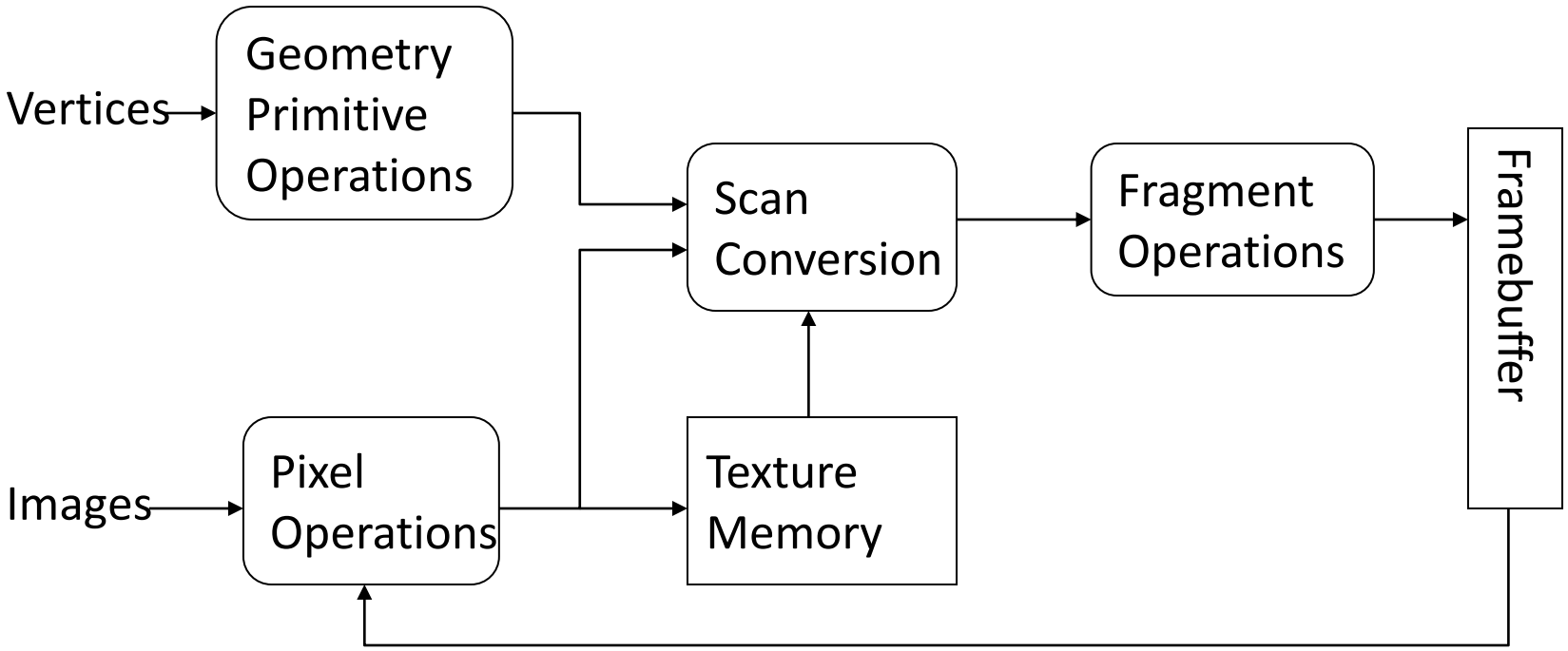
- Graphics rendering API
  - Fast, Simple
  - Window system independent
  - Operating system independent
  - Standard, available on many platforms
  - Geometric and pixel processing
  - high-quality color images composed of geometric and image primitives

OpenGL and GLUT Overview

OpenGL as a Renderer

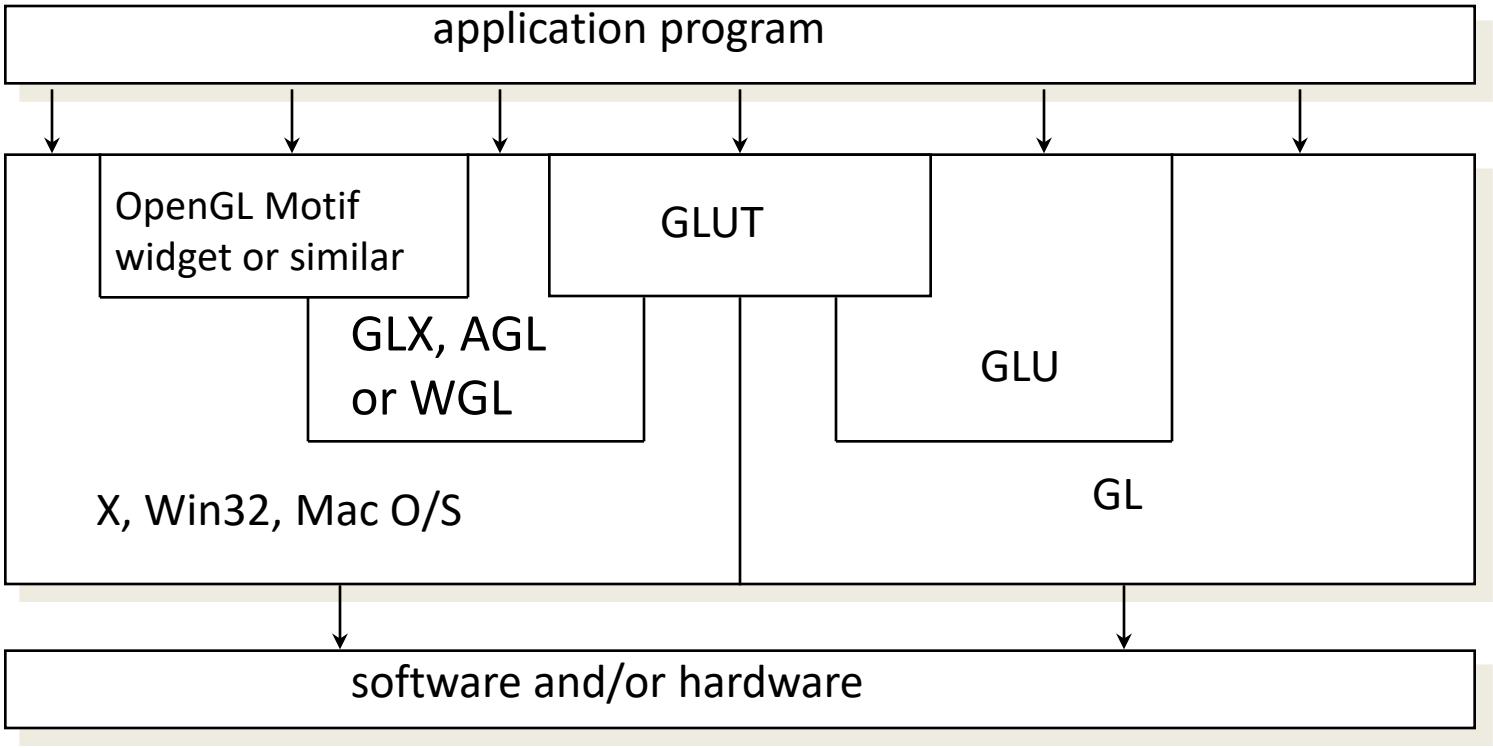
- Geometric primitives
  - points, lines and polygons
- Image Primitives
  - images and bitmaps
  - separate pipeline for images and geometry
    - linked through texture mapping
- Rendering depends on state
  - colors, materials, light sources, etc.

OpenGL Rendering Pipeline



OpenGL and GLUT Overview

Related APIs



OpenGL and GLUT Overview

Related APIs

- AGL, GLX, WGL
  - glue between OpenGL and windowing systems
- GLU (OpenGL Utility Library)
  - part of OpenGL
  - NURBS, tessellators, quadric shapes, etc.
- GLUT (OpenGL Utility Toolkit)
  - portable windowing API
  - not officially part of OpenGL

GLUT Basics

- Provides functionality common to all window systems
  - Simple, open-source library that works everywhere
  - Configure and open window
  - Input processing: keyboard, mouse, etc.
  - Register input callback functions
  - render
  - resize
  - Enter event processing loop

Basic Interaction Code

Preliminaries

- Headers Files

```
#include <GL/gl.h>
#include <GL/glu.h>
#include <GL/glut.h>
```

- Libraries
- Enumerated Types
  - OpenGL defines numerous types for compatibility
    - GLfloat, GLint, GLenum, etc.

Program Structure

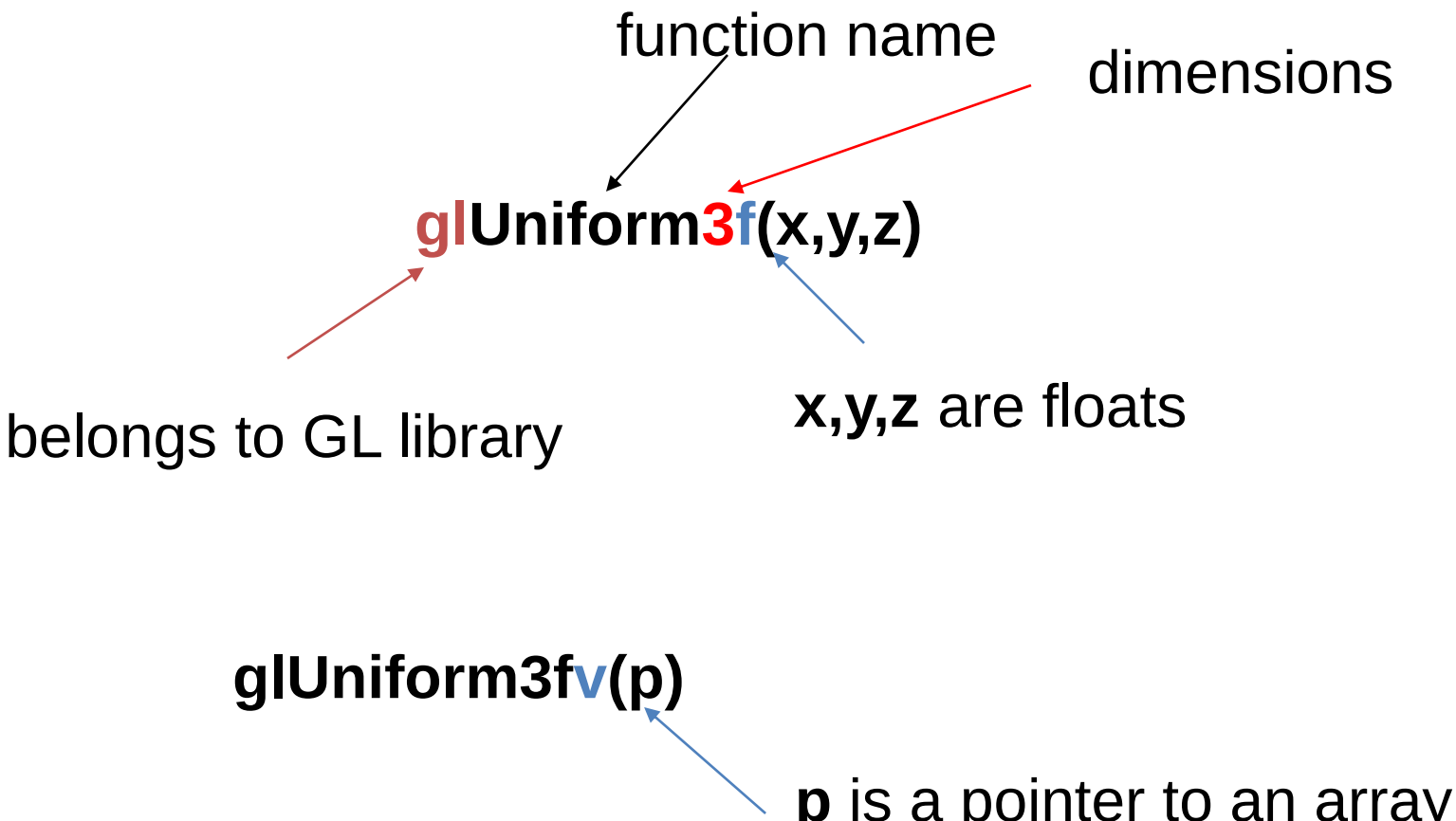
- Most OpenGL programs have a similar structure that consists of the following functions
  - main():
    - specifies the callback functions
    - opens one or more windows with the required properties
    - enters event loop (last executable statement)
  - init(): sets the state variables
    - Viewing
    - Attributes
  - initShader(): read, compile and link shaders
  - callbacks
    - Display function
    - Input and window functions

Basic Interaction Code

OpenGL Functions

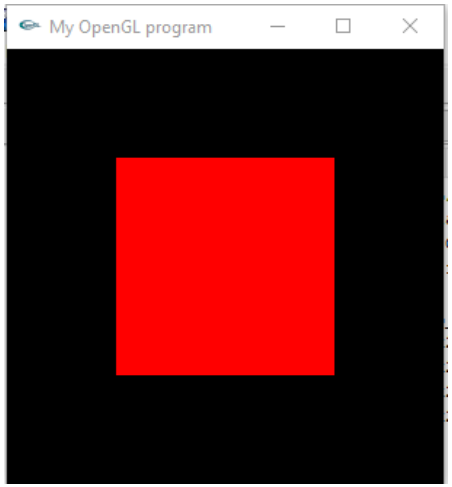
- Primitives
  - Points
  - Line Segments
  - Triangles
- Attributes
- Transformations
  - Viewing
  - Modeling
- Control (GLUT)
- Input (GLUT)
- Query

OpenGL function Format



Basic Interaction Code

A Simple Program



- Generate a red square on a solid background

```
#include <GL/glut.h>
void mydisplay(){
        glClear(GL_COLOR_BUFFER_BIT);
        glColor3f(1.0f, 0.0f, 0.0f);
        glBegin(GL_POLYGON);
                glVertex2f(-0.5f, -0.5f);
                glVertex2f( 0.5f, -0.5f);
                glVertex2f( 0.5f,  0.5f);
                glVertex2f(-0.5f,  0.5f);
        glEnd();
        glFlush();
}
int main(int argc, char** argv){
        glutCreateWindow("My OpenGL program");
        glutDisplayFunc(mydisplay);
        glutMainLoop();
}
```

Viewing in OpenGL

- Viewing consists of two parts
  - Object positioning: model view transformation matrix
  - View projection: projection transformation matrix
- OpenGL supports both perspective and orthographic viewing transformations
- OpenGL's camera is always at the origin, pointing in the –z direction
- Transformations move objects relative to the camera
- Matrices right-multiply top of stack.
  (Last transform in code is first actually applied)

Viewing in OpenGL

```
#include <GL/glut.h>
#include <stdlib.h>
int mouseoldx, mouseoldy ; // For mouse motion
GLdouble eyeloc = 2.0 ; // Where to look from; initially 0 -2, 2
void init (void) {
        glClearColor (0.0, 0.0, 0.0, 0.0); // select clearing color
        glMatrixMode(GL_PROJECTION); //initialize viewing values
        glLoadIdentity();

        glMatrixMode(GL_MODELVIEW) ;
        glLoadIdentity() ;
        gluLookAt(0,-eyeloc,eyeloc,0,0,0,0,1,1) ;
}
```

Basic Interaction Code

Callback functions for events

```
/* Defines what to do when various keys are pressed */
void keyboard (unsigned char key, int x, int y) {
        switch (key) {
            case 27:  exit(0) ;break ;// Escape to quit
            default:  break ;
  }
}
/* Reshapes the window appropriately */
void reshape(int w, int h){
        glViewport (0, 0, (GLsizei) w, (GLsizei) h);
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
        gluPerspective(30.0, (GLdouble)w/(GLdouble)h, 1.0, 10.0) ;
}
```

Basic Interaction Code

Callback functions for events: Mouse motion

```
/* Defines a Mouse callback to zoom in and out.  This is done by modifying gluLookAt
   The actual motion is in mousedrag, mouse simply sets state for mousedrag      */
   void mouse(int button, int state, int x, int y) {
        if (button == GLUT_LEFT_BUTTON) {
            if (state == GLUT_UP) {     // Do Nothing ;   }
        else if (state == GLUT_DOWN) {
            mouseoldx = x ; mouseoldy = y ; // so we can move wrt x , y
          }
        }
        else if (button == GLUT_RIGHT_BUTTON && state == GLUT_DOWN){
            // Reset gluLookAt
          eyeloc = 2.0 ;
          glMatrixMode(GL_MODELVIEW) ;
          glLoadIdentity() ;
          gluLookAt(0,-eyeloc,eyeloc,0,0,0,0,1,1) ;
          glutPostRedisplay() ;
        }
   }
```

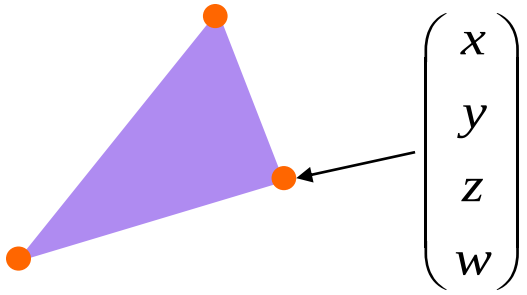
Basic Interaction Code

Callback functions for events: Mouse drag

```
void mousedrag(int x, int y) {
    int yloc = y - mouseoldy  ; // the y coord to zoom in/out
    eyeloc  += 0.005*yloc ;     // Where do we look from
    if (eyeloc < 0) eyeloc = 0.0 ;
    mouseoldy = y ;
    /* Set the eye location */
    glMatrixMode(GL_MODELVIEW) ;
    glLoadIdentity() ;
    gluLookAt(0,-eyeloc,eyeloc,0,0,0,0,1,1) ;
    glutPostRedisplay() ;
}
```

Representing Geometric Objects

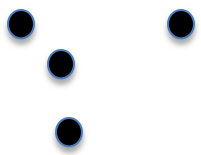
- Geometric objects are represented using vertices
- A vertex is a collection of generic attributes
  - positional coordinates
  - colors
  - texture coordinates
  - any other data associated with that point in space



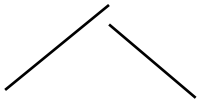
- Position stored in 4 dimensional homogeneous coordinates
- Vertex data must be stored in vertex buffer objects (VBOs)
- VBOs must be stored in vertex array objects (VAOs)

Representing Geometric Objects

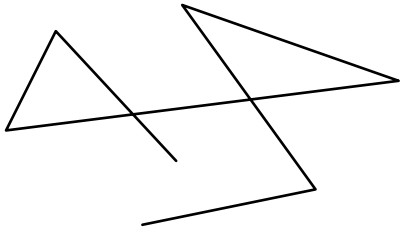
OpenGL Primitives



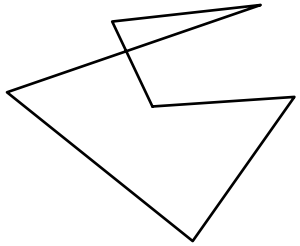
GL_POINTS



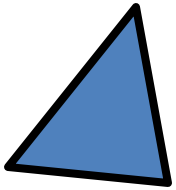
GL_LINES



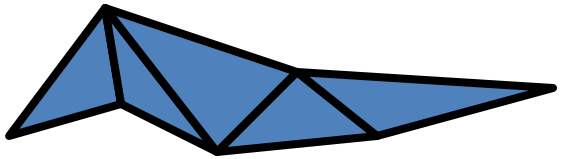
GL_LINE_STRIP



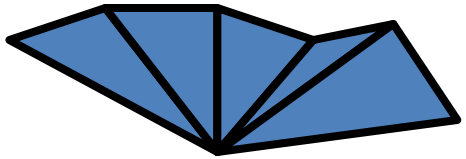
GL_LINE_LOOP



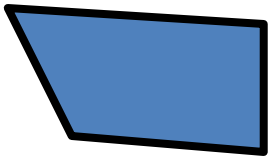
GL_TRIANGLES



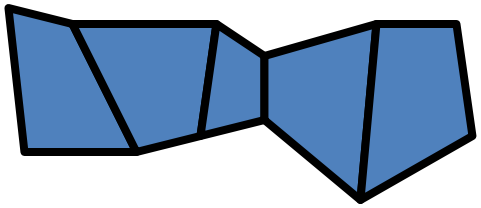
GL_TRIANGLE_STRIP



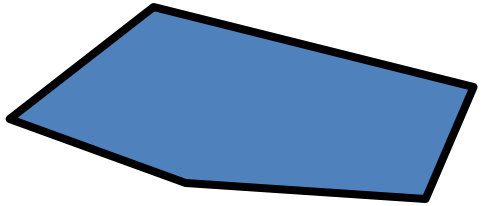
GL_TRIANGLE_FAN



GL_QUADS



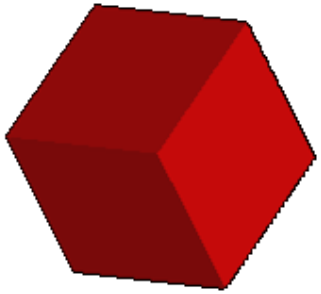
GL_QUAD_STRIP



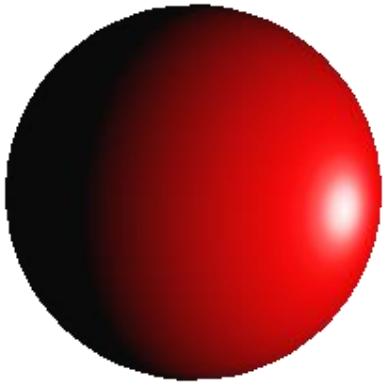
GL_POLYGON

Representing Geometric Objects

GLUT 3D Primitives



Cube



Sphere

Teapot

And others…

Representing Geometric Objects

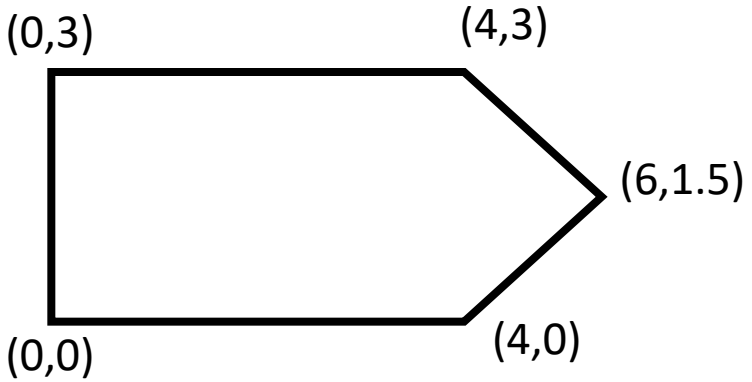
Geometry

- Points (GL_POINTS)
  - Stored in Homogeneous coordinates
- Line segments (GL_LINES)
- Polygons
  - Simple, convex (take your chances with concave)
  - Tessellate, GLU for complex shapes
  - Rectangles: glRect
- Special cases (strips, loops, triangles, fans, quads)
- More complex primitives (GLUT): Sphere, teapot, cube,…

Representing Geometric Objects

Specifying Geometry

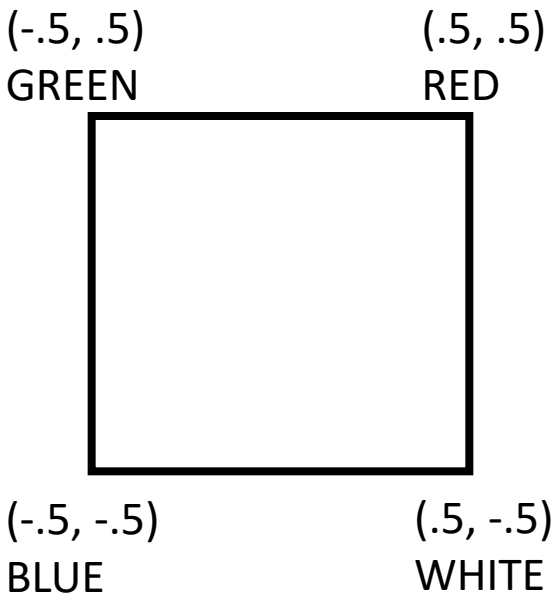
```
glBegin(GL_POLYGON) ;
    glVertex2f (4.0, 0.0) ;
    glVertex2f (6.0, 1.5) ;
    glVertex2f (4.0, 3.0) ;
    glVertex2f (0.0, 3.0) ;
    glVertex2f (0.0, 0.0) ;
    // glColor, glIndex, glNormal, glMaterial…
    // Other GL commands invalid between begin and end
glEnd() ;
```



Representing Geometric Objects

Drawing in Display()

```
void display(void){
   glClear (GL_COLOR_BUFFER_BIT);
    glBegin(GL_POLYGON);
      glColor3f (1.0, 0.0, 0.0);
      glVertex3f (0.5, 0.5, 0.0);
      glColor3f (0.0, 1.0, 0.0);
      glVertex3f (-0.5, 0.5, 0.0);
      glColor3f (0.0, 0.0, 1.0);
      glVertex3f (-0.5, -0.5, 0.0);
      glColor3f (1.0, 1.0, 1.0);
      glVertex3f (0.5, -0.5, 0.0);
   glEnd();
   glFlush () ;
}
```



Graphics Programming using OpenGL

Thank You…!