Introduction To OpenGL

OpenGL –What? and Why?

- An application programming interface (API)
- A (low-level) Graphics rendering API
- It considers primitive objects: points, line-segments, curves and polygons
- Cross-platform.
- Easier to learn compared to “Microsoft’s Direct3D (DirectX)”, Java3D
- Hardware-based device drivers widely supported.
- Captures the low-level pipeline

Primary Functionalities in OpenGL

- Geometric description of objects.
- Composition or lay-out of objects.
- Color specification and lighting calculations
- Rasterization or sampling – calculating the pixel color and depth values from the above mathematical descriptions
- User-interaction / user interfaces
- OpenGL can render(display) Geometric primitives, Bitmaps and Images

Naming Conventions

- OpenGL core functions are prefixed with gl
- OpenGL utility functions are prefixed with glu
- OpenGL typedef defined types are prefixed with GL
- OpenGL constants are all caps and prefixed with GL_

Basic Header Files

```
// #include <Windows.h> // Uncomment for Windows systems
#include <GL/glew.h>
#include <GL/freeglut.h>
```

- **freeglut.h** contains the core OpneGL functions (gl.h) as well as the utility functions (glu.h)
- The OpenGL Extension Wrangler Library (GLEW) is a cross-platform open-source C/C++ extension loading library.
- #include <windows.h> is required for running openGL programs in windows
- GLEW **provides efficient run-time mechanisms for determining which OpenGL extensions are supported on the target platform**.
- In addition, we often need to include header files that are required by the C++ code.

```
#include <stdio.h>
#include <stdlib.h>
#include <iostream>
#include <math.h>
```

Display Window Management using GLUT

- Since we are uisng OpenGL Utility toolkit, our first step is to initialize GLUT

glutInit(&argc, argv)

- Next, the display window needs to be created with a given title.

glutCreateWindow("Hello, GL");

- Set the window position:

glutInitWindowPosition(50, 100);

- Set the Window Size

glutInitWindowSize(400, 300);

- Buffering and choice of color mode

glutInitDisplayMode(GLUT_SINGLE|GLUT_RGB);

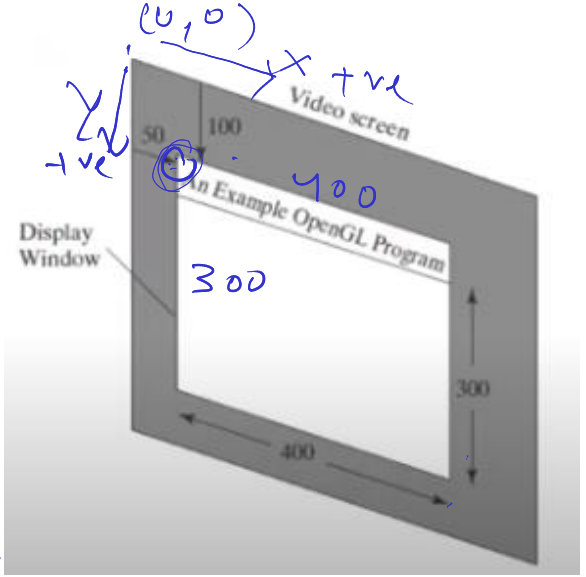
- The above command specifies that a single refresh buffer should

Be used for the display window and color mode uses RGB pattern

- Background color:

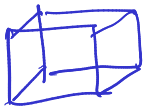
glClearColor(1.0,1.0,1.0,0.0);

GlClearColor(r,g,b,a)



Display Window Management using GLUT

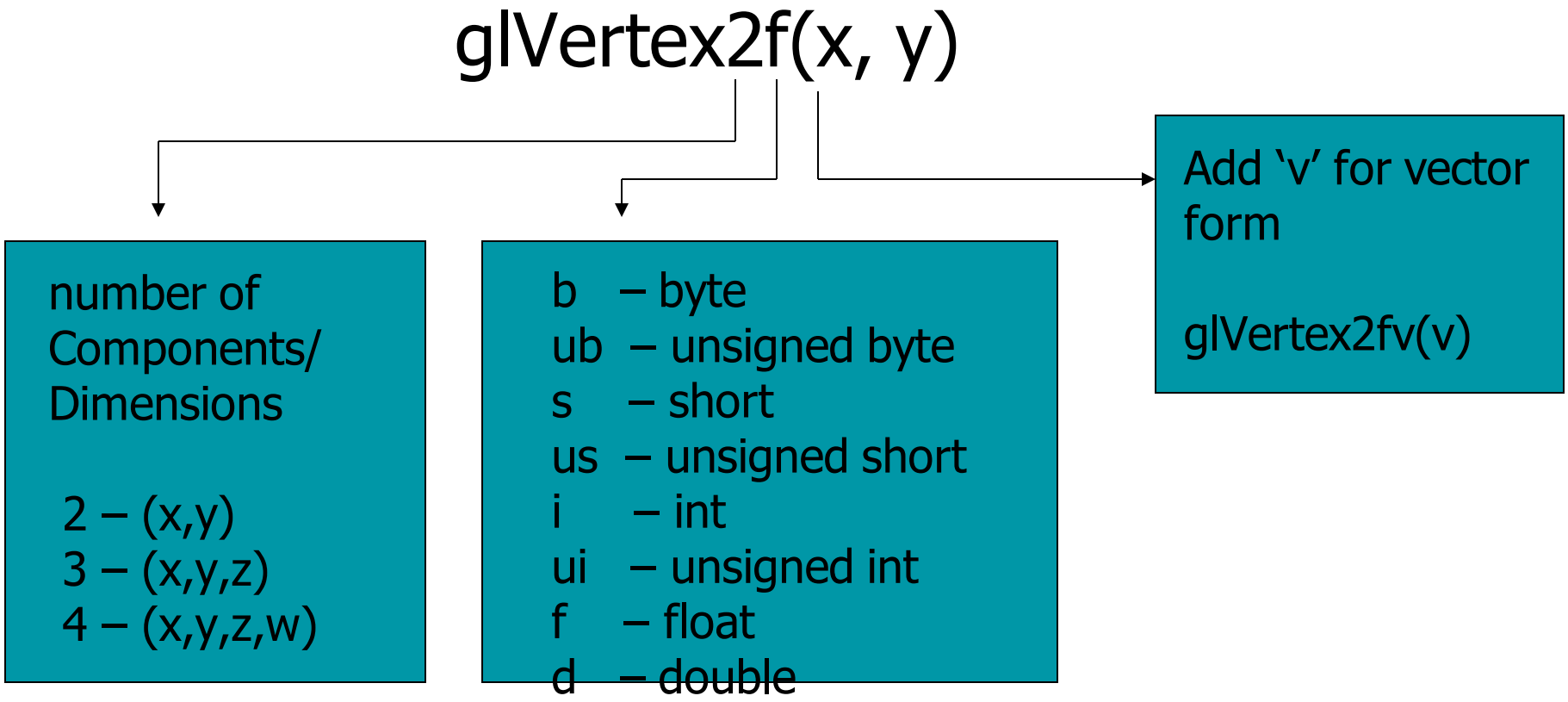
- Although **glClearColor** assigns a color to the display window, it doesn't put the display window on the screen. We need to invoke the following OpenGL function to do the same
  glClear(GL_COLOR_BUFFER_BIT);
- Object color: **glColor3f(0.0,0.4,0.2); --> glColor3f(r,g,b)**
- We can set the projection mode and other viewing parameters using the following functions:
  glMatrixMode(GL_PROJECTION);
  gluOrtho2D (0.0,200.0,0.0,150.0);
- World coordinate rectangle will be shown within the display window. Anything outside the coordinate range will not be shown.



Display Window Management using GLUT

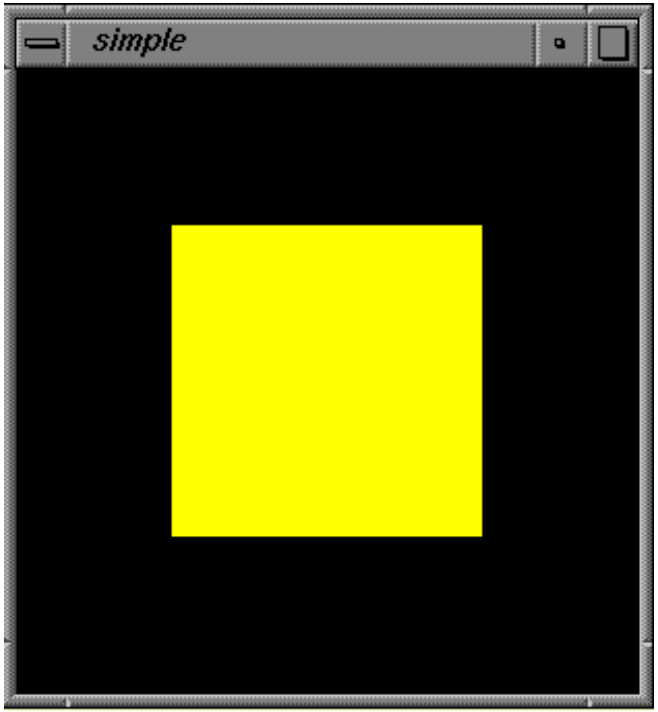
- We need to specify what the display window is to contain
- We first create the picture using OpenGL functions, then pass the picture definition to the GLUT routine **glutDisplayFunc(function)**
  glutDisplayFunc(lineSegment);
- But, the display window is not yet on the screen. To complete the window processing operation, following function is called at the end.
  glutMainLoop();

OpenGL Command Formats



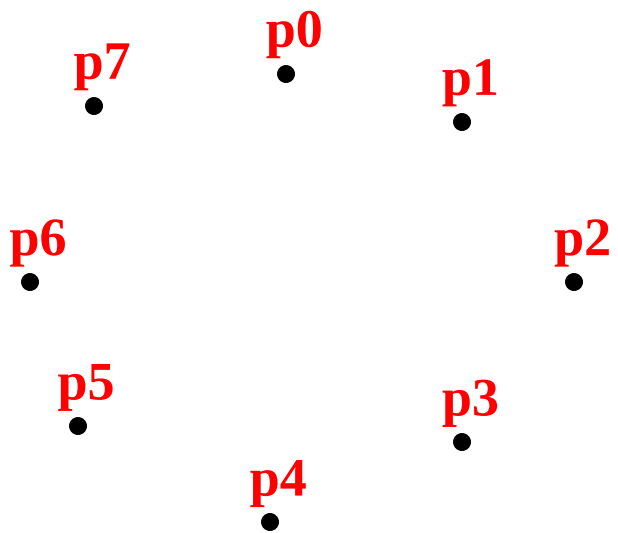
First Program using OpenGL –To display square

```
void Display()
{
  glColor3f(1.0f, 1.0f, 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();
}
```



Plotting Points

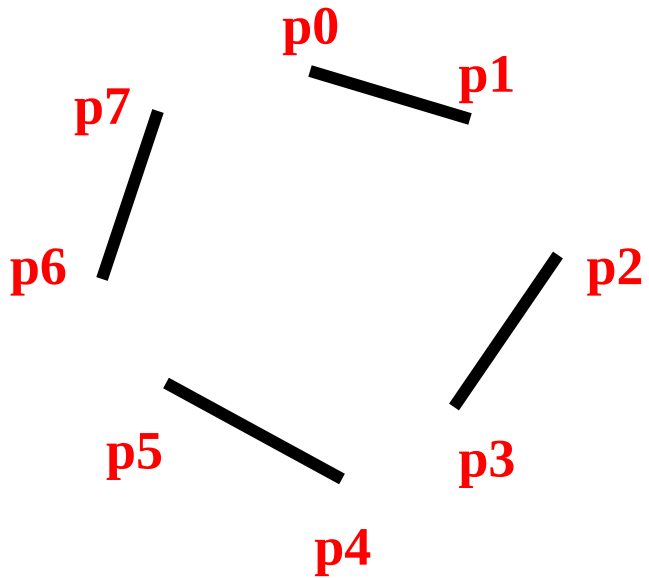
```
glBegin(GL_POINTS);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```



Drawing Line Segments

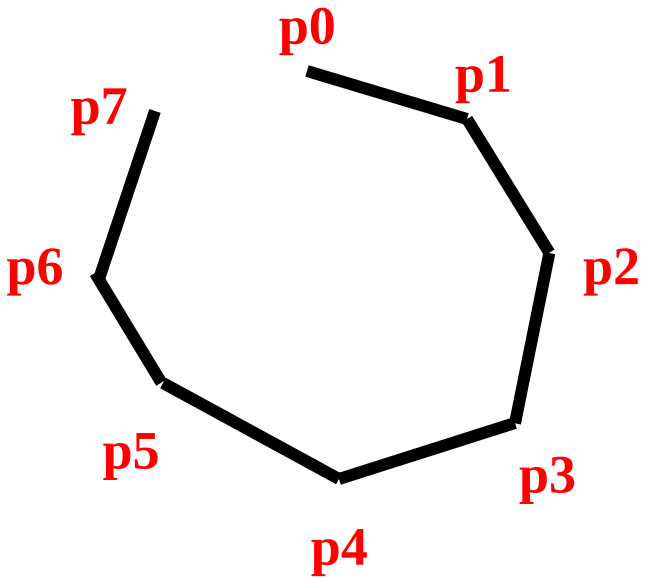
```
glBegin(GL_LINES);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```

glVertex2fv(p8);
glVertex2fv(p9)



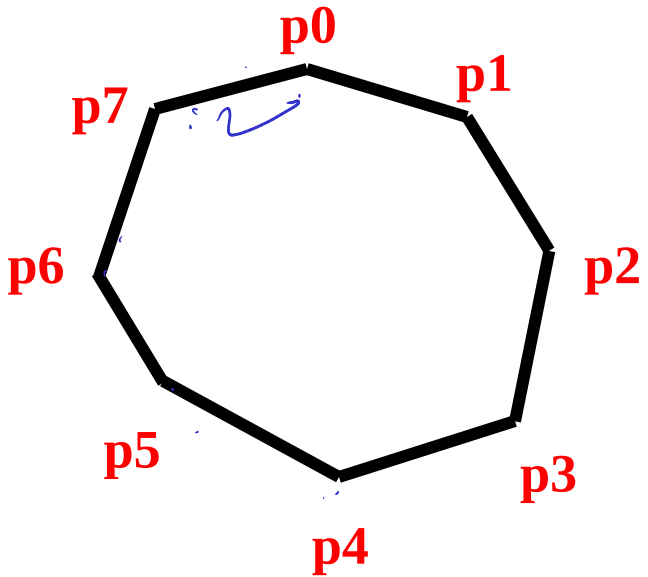
Drawing Polylines(line strip)

```
glBegin(GL_LINE_STRIP);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```



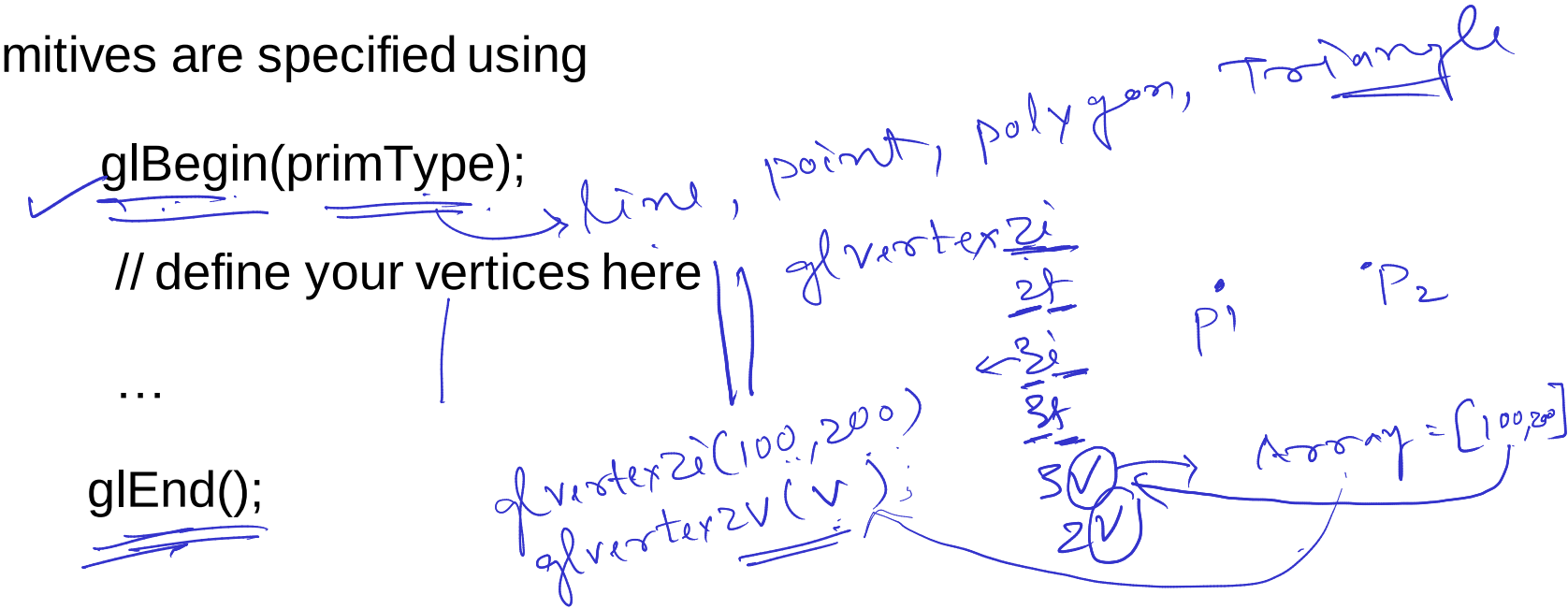
Drawing Line-Loop

```
glBegin(GL_LINE_LOOP);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```



Syntax to Specigy Geometric Primitives

- Primitives are specified using
  - glBegin(primType);
  - // define your vertices here
  - …
  - glEnd();



- primType: GL_POINTS, GL_LINES, GL_TRIANGLES, GL_QUADS, …

OpenGL: Front/Back Rendering

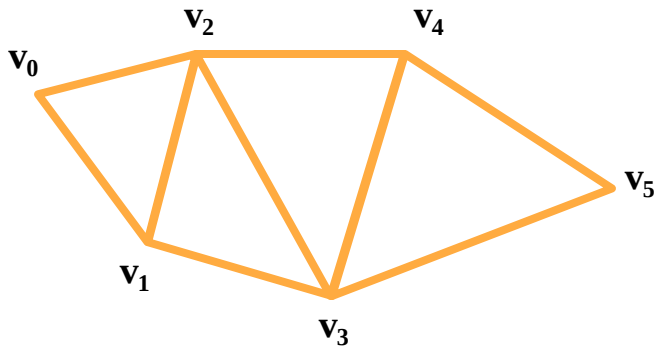
- Each polygon has two sides, front and back
- OpenGL can render the two differently
- The ordering of vertices in the list determines which is the front side
- When looking at the front side, the vertices go counter clock wise

Drawing Multiple Triangles

- You can draw multiple triangles between glBegin(GL_TRIANGLES) and glEnd():
  - float v1[3], v2[3], v3[3], v4[3];
  - glBegin(GL_TRIANGLES);
  - glVertex3fv(v1); glVertex3fv(v2); glVertex3fv(v3);
  - glVertex3fv(v1); glVertex3fv(v3); glVertex3fv(v4);
  - glEnd();
- The same vertex is used (sent, transformed, colored) many times (6 on average)

To Draw Triangle Strip

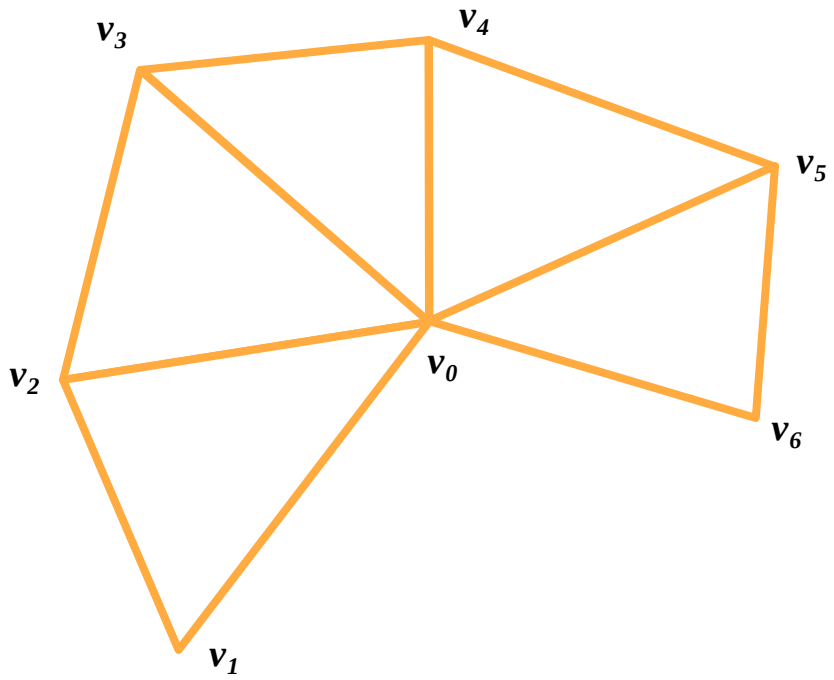
```
glBegin(GL_TRIANGLE_STRIP);
    glVertex3fv(v0);
    glVertex3fv(v1);
    glVertex3fv(v2);
    glVertex3fv(v3);
    glVertex3fv(v4);
    glVertex3fv(v5);
glEnd();
```



triangle 0 is v0, v1, v2
triangle 1 is v2, v1, v3 (*why not v1, v2, v3?*)
triangle 2 is v2, v3, v4
triangle 3 is v4, v3, v5 (again, **not** v3, v4, v5); Anti-clock wise; start from Top-Left

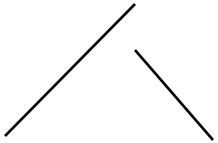
To Draw Triangle Fan

```
glBegin(GL_TRIANGLE_STRIP);
        glVertex3fv(v0);
        glVertex3fv(v1);
        glVertex3fv(v2);
        glVertex3fv(v3);
        glVertex3fv(v4);
        glVertex3fv(v5);
       glVertex3fv(v5);    glEnd();
```

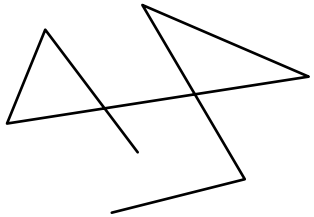


All primitives –Represented by vertices

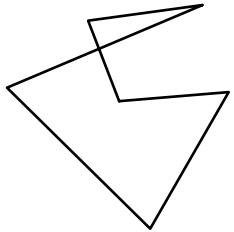
GL_POINTS



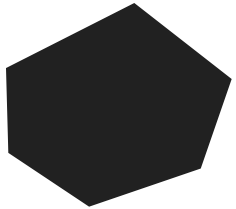
GL_LINES



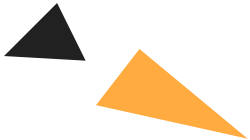
GL_LINE_STRIP



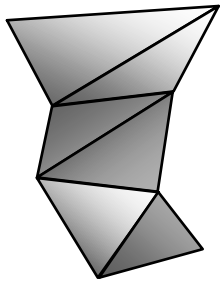
GL_LINE_LOOP



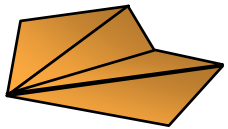
GL_POLYGON



GL_TRIANGLES

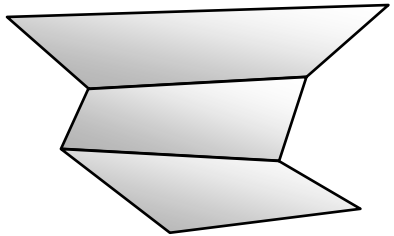


GL_TRIANGLE_STRIP



GL_TRIANGLE_FAN

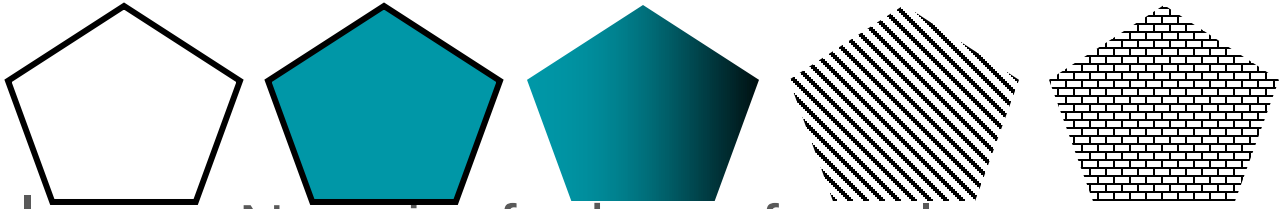
GL_QUADS



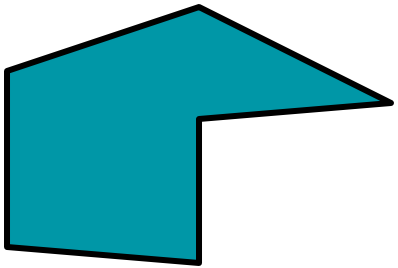
GL_QUAD_STRIP

Polygons: Simple Vs Non Simple

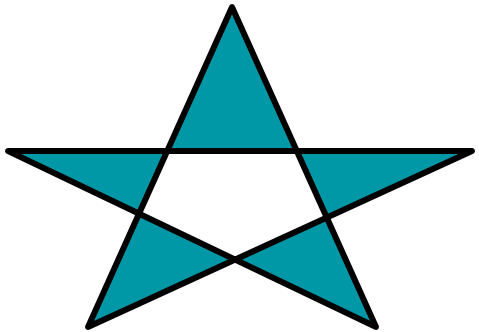
- Polygon: Object that is closed as in a line loop, but that has an interior



- Simple Polygon: No pair of edges of a polygon cross each other
- Simple:

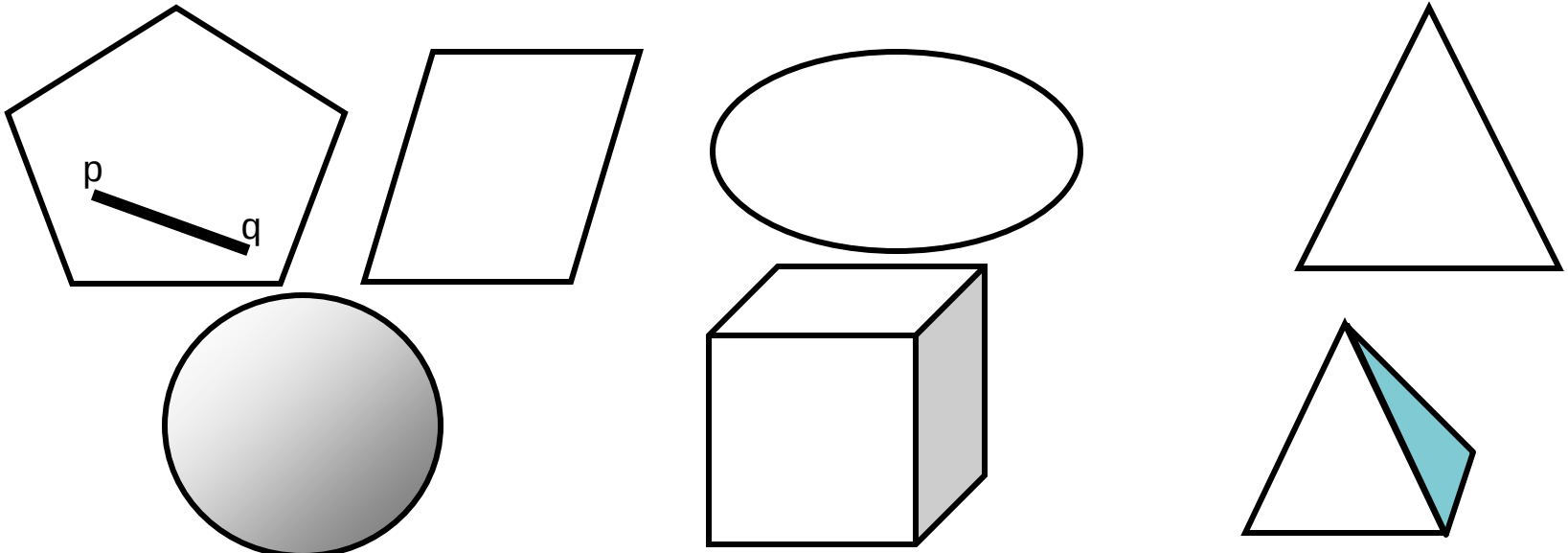


Non Simple:



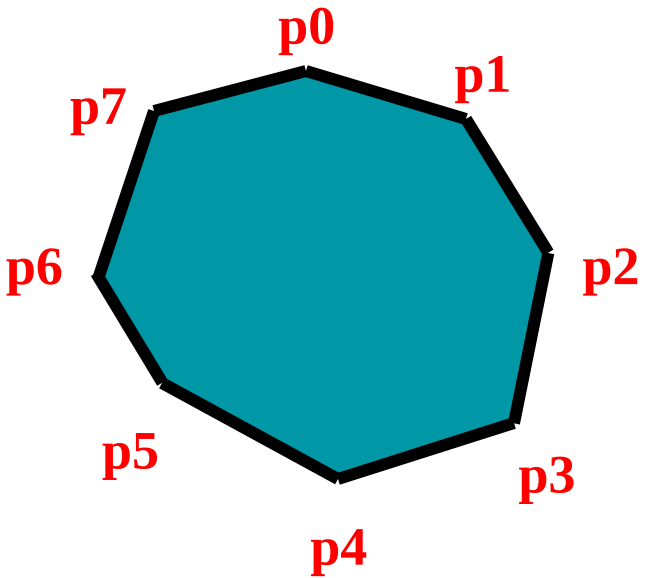
Convex Objects

- Defn: For every pair of points (p,q) in the object, If all points on the line segment joining p and q are inside the object, or on its boundary, then the object is convex



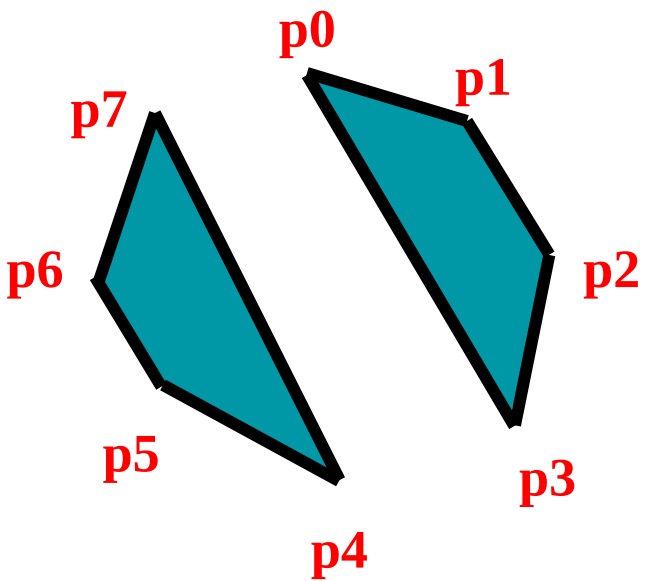
Drawing Polygon

```
glBegin(GL_POLYGON);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```



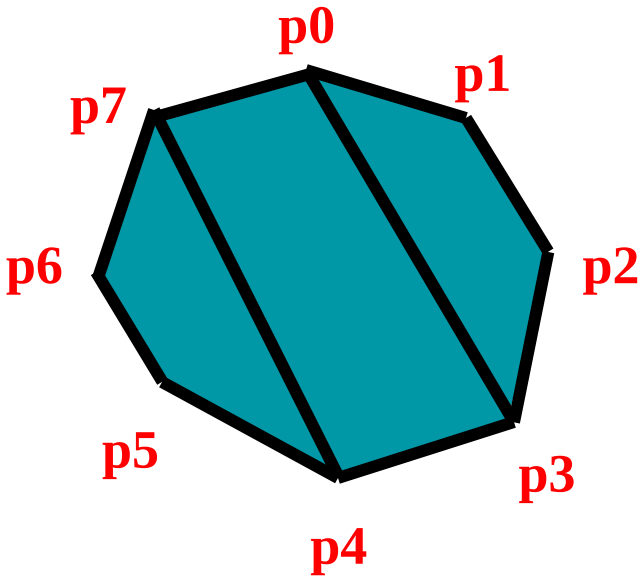
Drawing Quadrilaterals

```
glBegin(GL_QUADS);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```



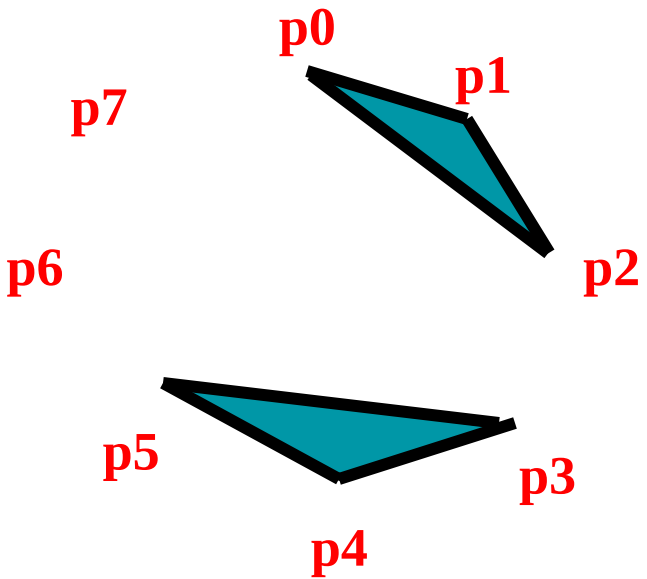
Drawing Quadrilateral strip

```
glBegin(GL_QUAD_STRIP);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p0);
   glVertex2fv(p4);
   glVertex2fv(p7);
   glVertex2fv(p5);
   glVertex2fv(p6);
glEnd();
```



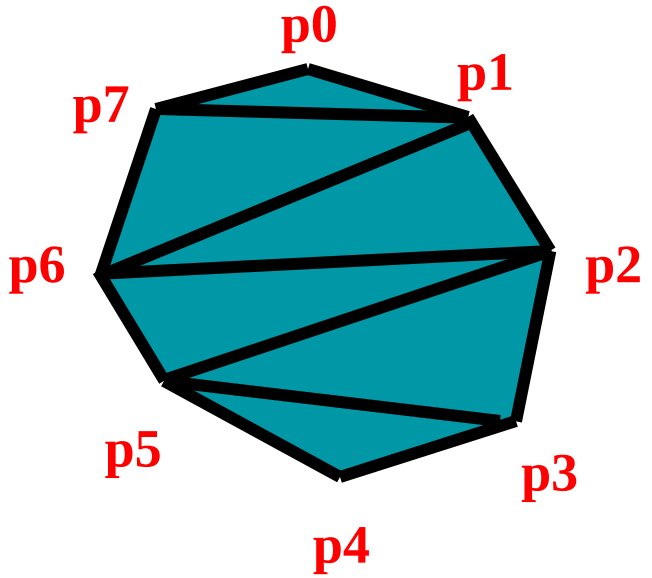
Drawing Triangle

```
glBegin(GL_TRIANGLES);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```



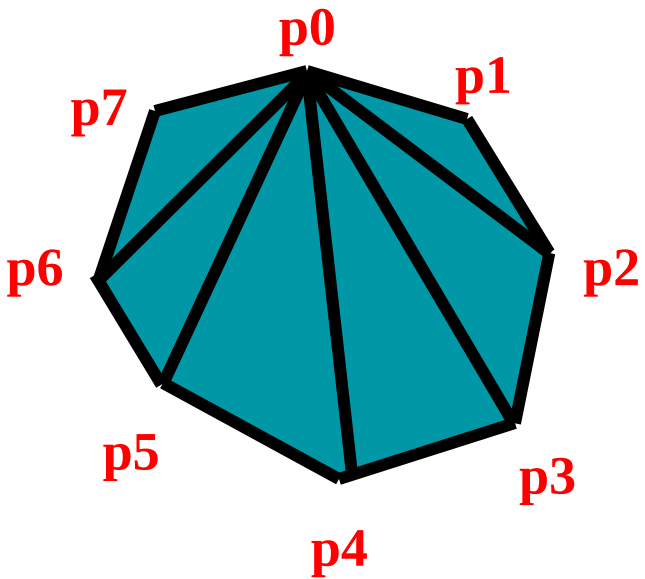
Drawing Triangle Strip

```
glBegin(GL_TRIANGLE_STRIP);
   glVertex2fv(p0);
   glVertex2fv(p7);
   glVertex2fv(p1);
   glVertex2fv(p6);
   glVertex2fv(p2);
   glVertex2fv(p5);
   glVertex2fv(p3);
   glVertex2fv(p4);
glEnd();
```



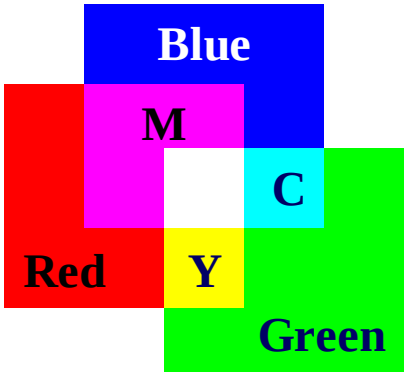
Drawing Triangle Fan

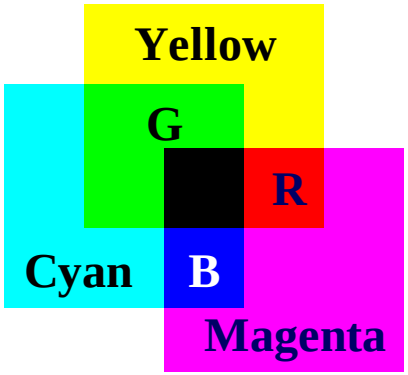
```
glBegin(GL_TRIANGLE_FAN);
   glVertex2fv(p0);
   glVertex2fv(p1);
   glVertex2fv(p2);
   glVertex2fv(p3);
   glVertex2fv(p4);
   glVertex2fv(p5);
   glVertex2fv(p6);
   glVertex2fv(p7);
glEnd();
```

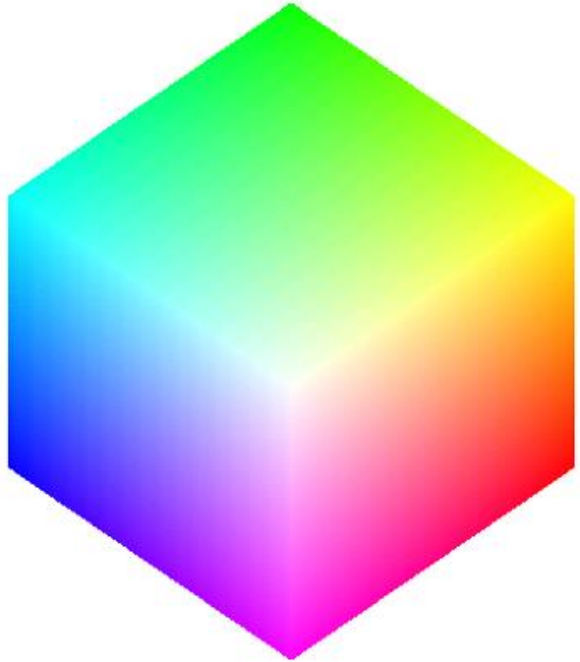


Attributes of Rendering

- Color, pattern of filling, etc.







OpenGL’s State Machine

- All rendering attributes are encapsulated in the OpenGL State
  - rendering styles
  - shading
  - lighting
  - texture mapping

Manipulating OpenGL State

- Appearance is controlled by current state
  - for each (primitive to render) {
    - update OpenGL state
    - render primitive }
- Manipulating vertex attributes is the most common way to manipulate state
    - glColor*() / glIndex*()
    - glNormal*()
    - glTexCoord*()

Controlling current state

- Setting State
  - glPointSize(size);
  - glLineStipple(repeat, pattern);
  - glShadeModel(GL_SMOOTH);
- Enabling Features
  - glEnable(GL_LIGHTING);
  - glDisable(GL_TEXTURE_2D

Specifying Colour Attribute

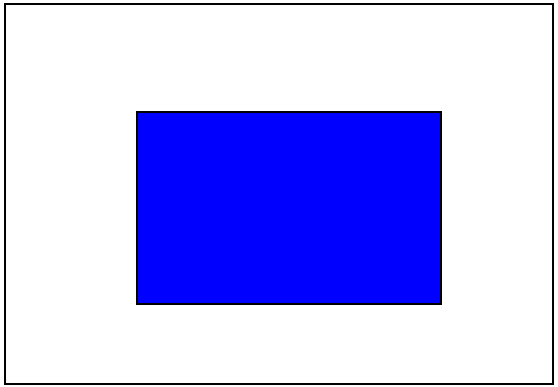
```
Void DrawBlueQuad( )
{
  glColor3f(0.0f, 0.0f, 1.0f);
  glBegin(GL_QUADS);

        glVertex2f(0.0f, 0.0f);

        glVertex2f(1.0f, 0.0f);

        glVertex2f(1.0f, 1.0f);

        glVertex2f(0.0f, 1.0f);
  glEnd();
}
```



This type of operation is called *immediate-mode rendering*;

- Each command happens immediately
- Although you may not see the result if you use double buffering
  - Things get drawn into the back buffer

Specifying Colour attribute

```
glColor3f(0.1, 0.5, 1.0);

glVertex3fv(v0); glVertex3fv(v1); glVertex3fv(v2);
```

- To produce a smoothly shaded triangle:

```
glColor3f(1, 0, 0); glVertex3fv(v0);

glColor3f(0, 1, 0); glVertex3fv(v1);

glColor3f(0, 0, 1); glVertex3fv(v2);
```

- In OpenGL, colors can also have a fourth component α (opacity or 1-transparency); Generally want α = 1.0 (opaque);