# Graphics Programming

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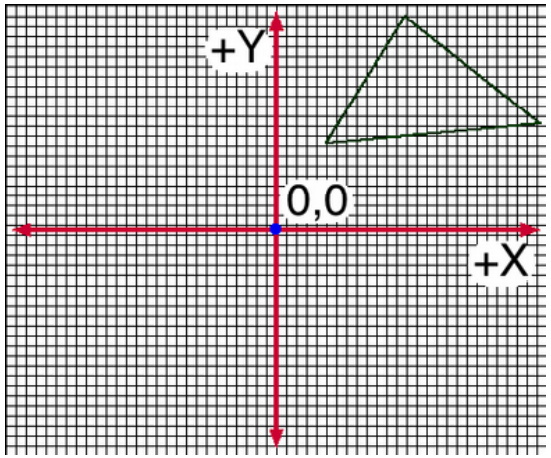
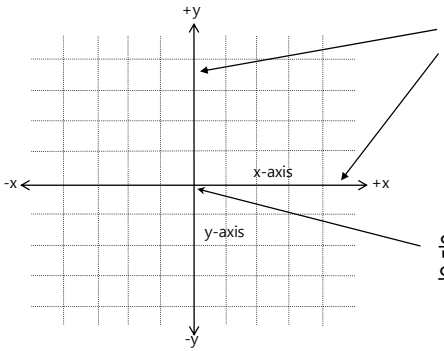
## Coordinate Systems




## 2D Cartesian Coordinate Systems

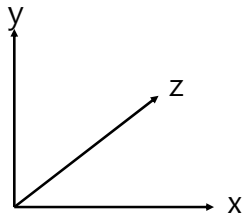
- Cartesian Coordination Systems



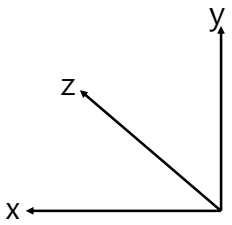

Two axes: **x-axis** and **y-axis**, two straight lines perpendicular to each other, both pass through origin and extends infinitely in two opposite directions

원점 (Origin)은 **좌표계**의 중심에 위치하고 있고 값은 (0, 0)이다.

## 3D Cartesian Coordinate Systems

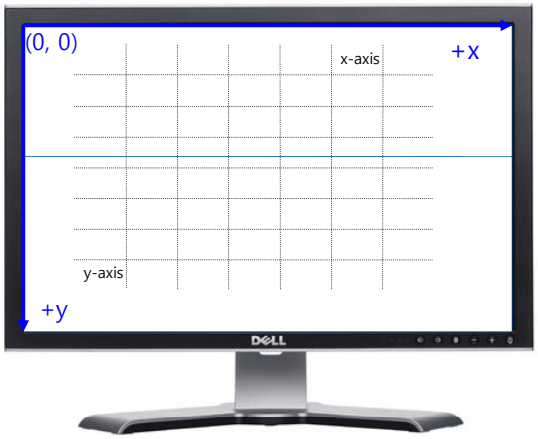



- 왼손 좌표계 (Left-handed coordinate system)는 x+는 오른쪽, y+는 위쪽, z+는 화면안쪽.



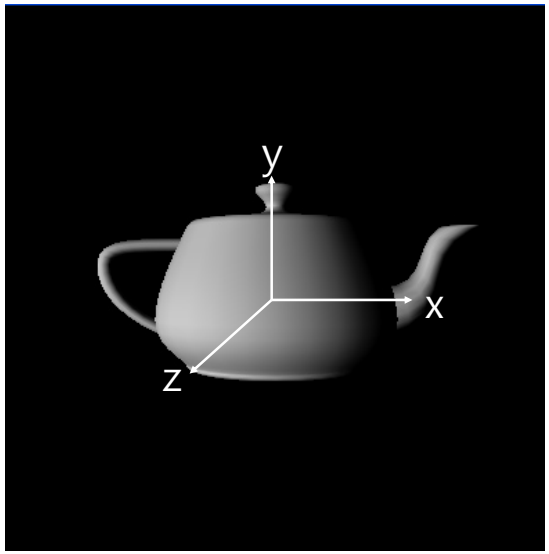

- 오른손 좌표계 (Right-handed coordinate system)는 x+는 왼쪽, y+는 위쪽, z+는 화면안쪽.

## Screen Coordinate System



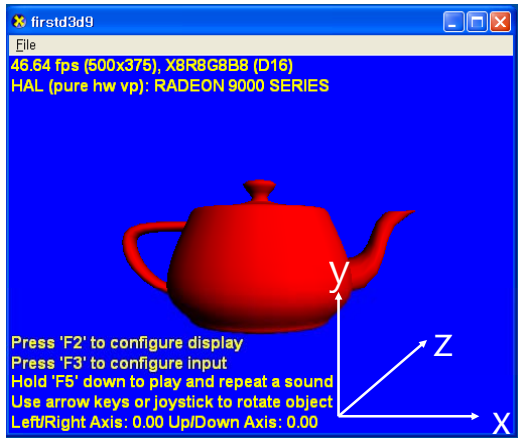

- Screen coordinate system은 원점 (Origin)이 화면의 좌측상단에 위치하고 값은 (0, 0)이다. x+ 오른쪽. y+ 아래쪽.
- 1 unit = 1 pixel

## 3D Coordinate Systems



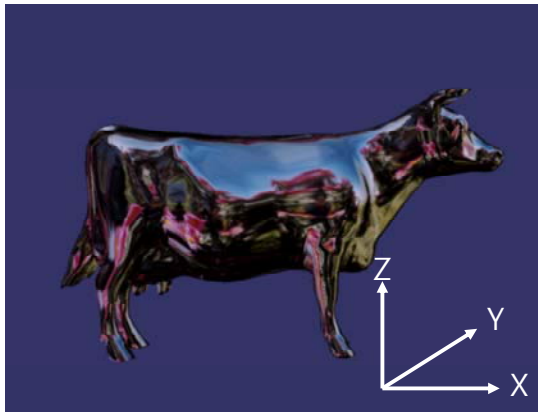

- OpenGL은 오른손 좌표계 (Right-handed coordinate system)
- x+ 오른쪽. y+ 위쪽. z+ 화면 밖으로 나오는 방향.

## 3D Coordinate Systems



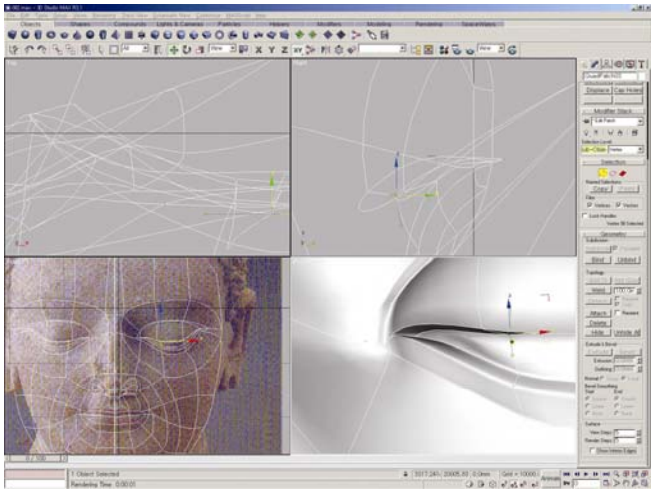

- Direct3D는 왼손 좌표계 (Left-handed coordinate system).
- x+ 오른쪽. y+ 위쪽. z+ 화면 안쪽으로 들어가는 방향.

## 3D Coordinate Systems



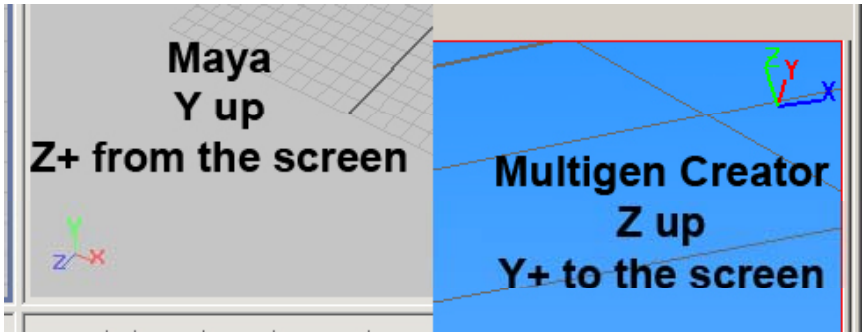

- Open Scene Graph (OSG)은 오른손 좌표계 (Right-Handed Coordinate System) x+ 오른쪽. y+ 화면 안으로 향하는 방향. z+ 위쪽.

## 3D Coordinate Systems



- 3D Studio Max 은 오른손 좌표계 (Right-Handed Coordinate System) x+ 오른쪽. y+ 화면 안으로 향하는 방향. z+ 위쪽.

## 3D Coordinate Systems




- Maya - same as OpenGL
- Multigen Creator – same as OSG

## Graphics Programming

- OpenGL & GLUT API를 사용한 그래픽스 프로그래밍 소개
- OpenGL Programming Guide "red book"
- OpenGL Reference Manual "blue book"
- OpenGL Shading Language "orange book"

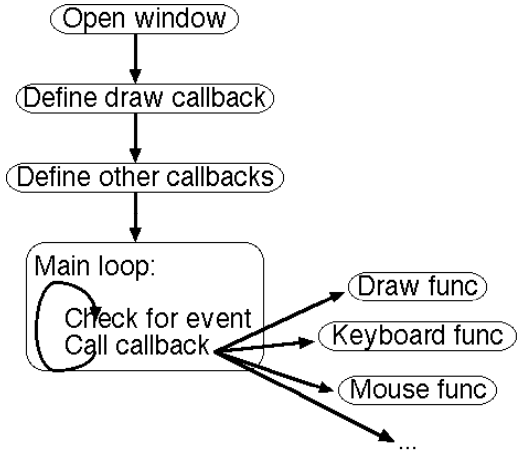
## OpenGL

- OpenGL은 그래픽스 파이프라인 (graphics *pipeline*)을 모델로 사용하는 3D graphics library이다.
- OpenGL은 window system에 독립적인 API
- OpenGL은 operating system에 독립적인 API
- OpenGL libraries:
  - GL - graphics
  - GLU - utilities
  - GLX (X window)/ WGL (Windows)/ AGL (Mac) / PGL (IBM) – windowing toolkits
  - GLUT – multi-platform windowing API

## GLUT (OpenGL Utility Toolkit)

- Mark J. Kilgard가 개발한 portable windowing and interaction API
  - Prefix "glut"로 시작
  - 대부분의 window system에 보편적인 기능들을 wrapping한 상위 interface제공 (portable across all PC and workstation OS platforms)
  - OpenGL이 제공하는 범위보다 상위 수준의 utility function도 제공
  - UNIX/X-window에서 개발된 code를 그대로 재사용 가능
  - Win32, MFC, Xlib을 알 필요가 없음
  - 그러나 Window system의 기능을 제한적으로만 이용 가능

## GLUT Program Structure




## GLUT Callbacks

- GLUT defines a basic program structure - an *event loop*, with *callback functions*.
- *Callback,* a function that you provide for other code to call when needed; the "other code" is typically in a library
- GLUT uses callbacks for drawing, keyboard & mouse input, and other events.
- Whenever the window must be redrawn, your drawing callback is called.
- Whenever an input event occurs, your corresponding callback is called.

## GLUT Callbacks

- glutDisplayFunc
- glutPostRedisplay
- glutIdleFunc
- glutTimerFunc
- glutGetModifiers
- glutIgnoreKeyRepeat
- glutKeyboardFunc
- glutKeyboardUpFunc
- glutSpecialFunc
- glutSpecialUpFunc

## GLUT Callbacks

- Handling *Display* Callbacks
  - glutDisplayFunc(void (*func)(void))
    - Specifies a function that would draw the graphical contents
    - Argument: display function name
- Handling *Input* Events
  - glutReshapeFunc(void (*func)(int w, int h))
    - What action should be taken when the window is resized
  - glutKeyboardFunc(void (*func)(unsigned char key, int x, int y))
  - glutMouseFunc(void (*func)(int button, int state, int x, int y))
    - Handle keyboard key and mouse button
  - glutMotionFunc(void (*func)(int x, int y))
    - What to do when the mouse is moved while a mouse button is pressed

## The *Reshape* Event Callback

- This callback sets up OpenGL to display images in a window of the new size
- The value w is the new width, and the value h is the new height

```
void reshape(int w, int h)
  {
  glViewport(0, 0, w, h);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  gluOrtho2D(0.0, w, 0.0, h);
  }
```

## The *Keyboard* Event Callback

- This callback simply causes the program to exit when the user hits the ESC key

```
void keyboard(unsigned char key, int x, int y)
{
  switch (key): /* q-key exits the program */
   {
      case 'q':
         exit(0);
   }
}
```

## GLUT Functions

- glutMainLoop(void)
  - Enter the GLUT event processing loop
- glutPostRedisplay()
  - Ensures that the window gets drawn at most once each time GLUT goes through the event loop.
  - In general, never call the display callback directly, but rather use the glutPostRedisplay() whenever the display needs to be redrawn.

## OpenGL API

- 그래픽스 함수 (Graphics Functions)
  - 기본 요소 함수 (Primitive functions)
  - 속성 함수 (Attribute functions)
  - 관측 함수 (Viewing functions) – chap5
  - 변환 함수 (Transformation functions) – chap4
  - 입력 함수 (Input functions) – GLUT chap3
  - 제어 함수 (Control functions) – GLUT
  - 질의 함수 (Query functions)

## Graphics Functions

- 기본 요소 함수 (Primitive functions)
  - 저수준 객체 (Low-level object)을 정의
  - Points, line segments, polygons, pixels, texts, curves, surfaces
- 속성 함수 (Attribute functions)
  - 기본 요소가 화면상에 나타날 수 있는 방법을 제어
  - Color, line thickness, pattern to fill the polygon, ..
- 관측 함수 (Viewing functions)
  - 합성카메라 (synthetic camera)모델 - 카메라 위치, 방향, 렌즈
  - Viewport, clipping, ..
- 변환 함수 (Transformation functions)
  - 물체의 회전(rotation), 이동(translation), 크기변환 (scaling)

## Graphics Functions

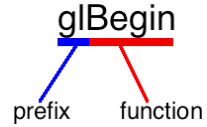
- 입력 함수 (Input functions)
  - 키보드, 마우스, 테블렛 등 입력장치를 다루는 함수
- 제어 함수 (Control functions)
  - 윈도우 시스템과 통신을 가능하게 하고, 프로그램 초기화, 에러처리 등
  - Close, open, resolution setting, mode setting, ..
- 질의 함수 (Query functions)
  - 그래픽스 시스템의 내부적인 상태 (internal states)이나 속성 (properties) 정보

## OpenGL Syntax

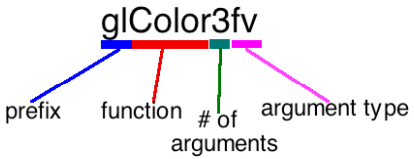
- Basic OpenGL Syntax
  - 함수(function)에 prefix " gl " 사용
    - E.g.: glBegin, glClear, glCopyPixels, glPolygonMode
  - 기호상수(symbolic constant)에 prefix "GL" 사용 & 각각의 단어는 '_'로 연결
    - E.g.: GL_2D, GL_RGB, GL_CCW, GL_POLYGON, GL_AMBIENT_AND_DIFFUSE
  - 자료타입 (data type)에 prefix "GL"
    - E.g. GLbyte, GLshort, GLint, GLfloat, GLdouble, GLboolean

## OpenGL Functions

- OpenGL함수 이름은 "gl"로 시작
- 함수 인자 (argument)가 하나인 경우:

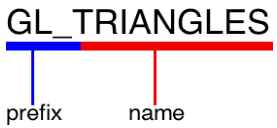



- 함수 인자 (argument)를 여러 개 받는 경우:




## OpenGL Constants

- OpenGL의 상수 (Constant)는 함수 인자에 사용
- 상수의 이름은 전부 대문자를 사용하며 "GL"로 시작:




e.g. glBegin()에 들어갈 수 있는 인자들 (arguments)의 예:

- GL_POINTS
- GL_LINES
- GL_TRIANGLES
- GL_POLYGON

## OpenGL State

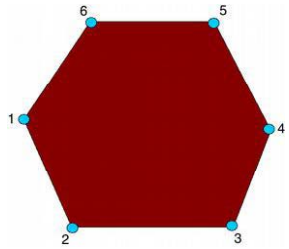
- GL rendering consists of geometry + state
- Both are passed to graphics hardware via function calls
- To draw something, the necessary state attributes (e.g. color) are set first. Then, the geometry (e.g. triangle data) is passed
- State is retained until changed.
- State changes do not affect any geometry already drawn.

## OpenGL State

- State:
  - Color
  - Drawing style
  - Material properties
  - Light sources
  - Texture
  - Transformations

## OpenGL Geometry

- 가상의 공간을 구성하는 각 물체를 표현하는데 있어 가장 기본이 되는 요소
- 실시간 그래픽스에서는 주로 가장 단순한 형태의 표현 방법인 linear primitives를 사용
  - Point, vertex
  - Line segments
  - Polygon
  - Polyhedron



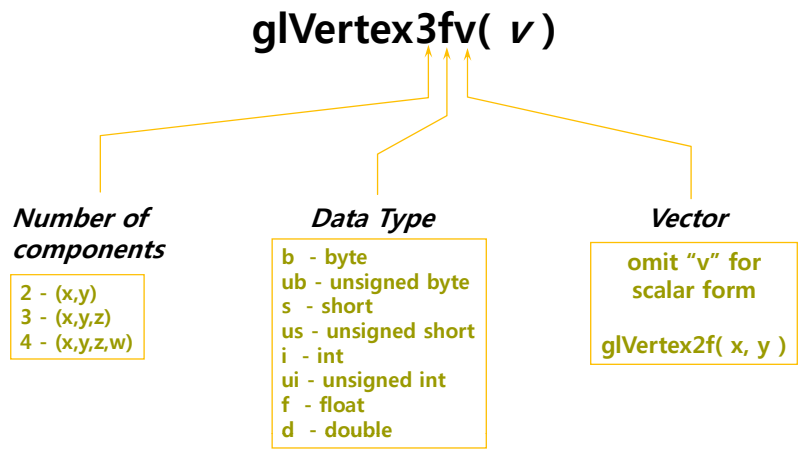

## OpenGL Geometry

- 기하학적 객체를 정의하기 위해서는:

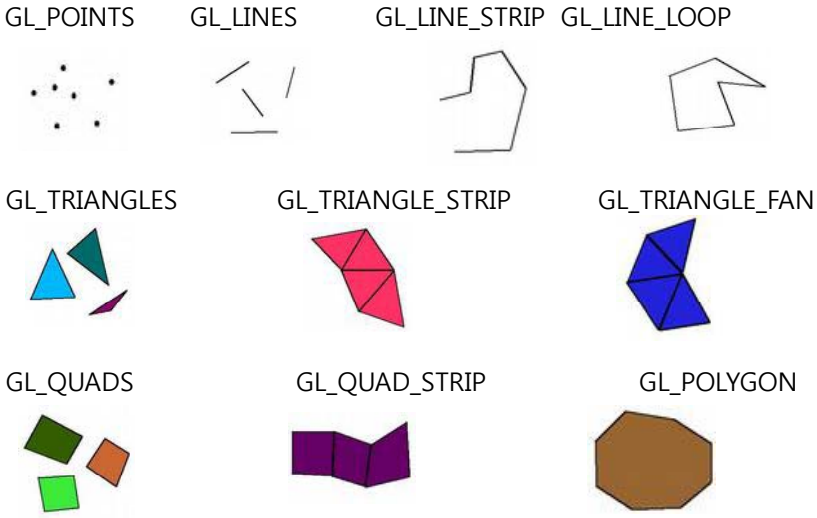
```
glBegin(...);
glVertex*(...);
...
glEnd();
```

- void glBegin(GLenum mode)
  void glEnd(void)
  - 도형을 그리려면, glBegin()과 glEnd() 사이에 그 도형의 각 정점(vertex)의 좌표치를 설정하는 함수를 둠. mode에 GL_POINTS, GL_LINES, GL_POLYGON 등 도형의 타입을 지정.
- void glVertex*()
  - 이 함수는 2차원의 좌표치를 설정하는 사용. 인수의 형태는 Gldouble임. Float 형태는 glVertex2f(..)를 int 형태는 glVertex2i(..)를 사용함.

## OpenGL Geometry




## OpenGL Geometry Primitives



## OpenGL Point Function

```
glBegin(GL_POINTS);
        glVertex2i (50, 100);
        glVertex2i (75, 150);
        glVertex2i (100, 200);
glEnd();
```

---

```
GLint pt1[2] = {50, 100};
GLint pt2[2] = {75, 150};
GLint pt3[2] = {100, 200};
 glBegin(GL_POINTS);
        glVertex2iv(pt1);
        glVertex2iv(pt2);
        glVertex2iv(pt3);
glEnd();
```

## OpenGL Point Function

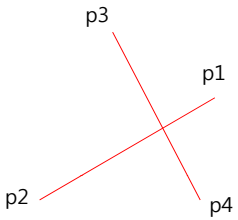
```
glBegin(GL_POINTS);
        glVertex3f(-78.05, 909.72, 14.60);
        glVertex3f(261.91, -5200.67, 188.33);
glEnd();
```

---

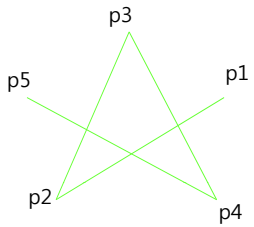
```
class wcPt2D {
public:
        GLfloat x, y;
};
wcPt2D pointPos;

pointPos.x = 120.75;
pointPos.y = 45.30;
glBegin(GL_POINTS);
        glVertex2f(pointPos.x, pointPos.y);
glEnd();
```

## OpenGL Line Function

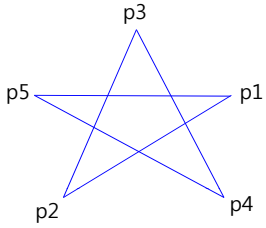
```
glBegin(GL_LINES);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p3);
    glVertex2iv(p4);
    glVertex2iv(p5);
glEnd();
```




```
glBegin(GL_LINE_STRIP);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p3);
    glVertex2iv(p4);
    glVertex2iv(p5);
glEnd();
```

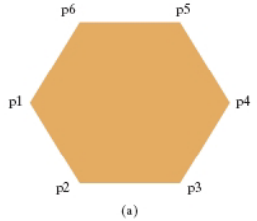



```
glBegin(GL_LINE_LOOP);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p3);
    glVertex2iv(p4);
    glVertex2iv(p5);
glEnd();
```

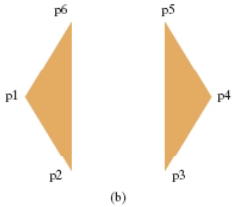



## OpenGL Filling Polygon

```
glBegin(GL_POLYGONS);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p3);
    glVertex2iv(p4);
    glVertex2iv(p5);
    glVertex2iv(p6);
glEnd();
```

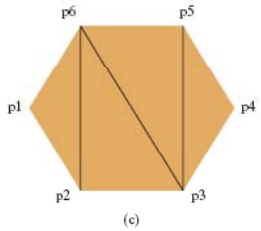



```
glBegin(GL_TRIANGLES);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p6);
    glVertex2iv(p3);
    glVertex2iv(p4);
    glVertex2iv(p5);
glEnd();
```

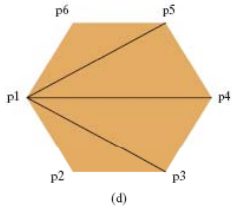


## OpenGL Filling Polygon

```
glBegin(GL_TRIANGLE_STRIP);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p6);
    glVertex2iv(p3);
    glVertex2iv(p5);
    glVertex2iv(p4);
glEnd();
```



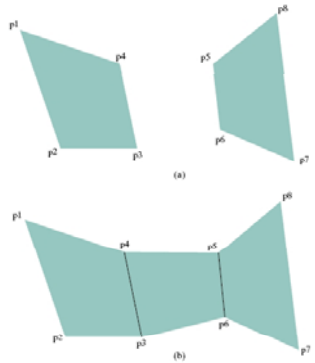

```
glBegin(GL_TRIANGLE_FAN);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p3);
    glVertex2iv(p4);
    glVertex2iv(p5);
    glVertex2iv(p6);
glEnd();
```




## OpenGL Filling Polygon

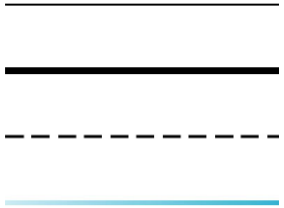
```
glBegin(GL_QUADS);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p3);
    glVertex2iv(p4);
    glVertex2iv(p5);
    glVertex2iv(p6);
    glVertex2iv(p7);
    glVertex2iv(p8);
glEnd();
```

```
glBegin(GL_QUAD_STRIP);
    glVertex2iv(p1);
    glVertex2iv(p2);
    glVertex2iv(p4);
    glVertex2iv(p3);
    glVertex2iv(p5);
    glVertex2iv(p6);
    glVertex2iv(p8);
    glVertex2iv(p7);
glEnd();
```

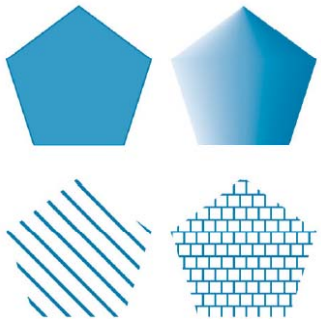


## OpenGL Attributes

- 각 기하학적 기본요소 (geometry primitive)는 속성을 갖고 있다. 속성은 기본 요소가 화면상에 나타날 수 있는 방법을 제어한다.
  - Color
  - Line thickness
  - Line styles
  - Polygon patterns



선의 두께나 스타일



다각형 표시방법

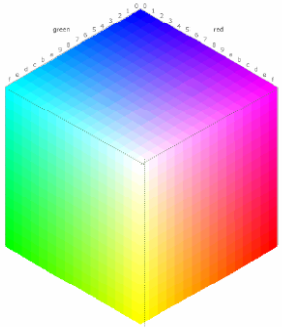
## OpenGL Attributes

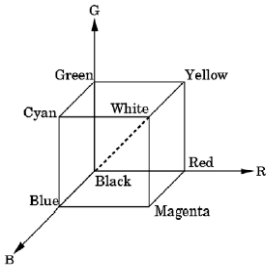
- Vertex
  - 점의 크기 - glPointSize(GLfloat size)
- Line
  - 선분의 폭 – glLineWidth(GLfloat width)
  - 점선의 스타일 – glLineStipple(GLint factor, GLushort pattern)
- Polygon
  - 외형과 사용면 지정 – glPolygonMode(GLenum face, GLenum mode)
    - Face: GL_FRONT_AND_BACK, GL_FRONT, GL_BACK
    - Mode: GL_POINT, GL_LINE, GL_FILL
  - 앞면 지정 – glFrontFace(GLenum mode)
    - Mode: GL_CCW, GL_CW
  - 스티플링 – glPolygonStipple(const GLubyte *mask)
    - Mast: 32x32 비트 윈도우 정렬 스티플 패턴

# OpenGL Attributes

- OpenGL Color Model
  - RGB (Red Green Blue) or RGBA(Red Green Blue Alpha)
  - RGB 색이 따로 분리돼서 framebuffer에 저장되어 있음.

```
glColor3f(1.0, 0.0, 0.0);          //색값은 0.0 ~ 1.0
glColor3ub(255, 0.0, 0.0); //색값은 0~255
```

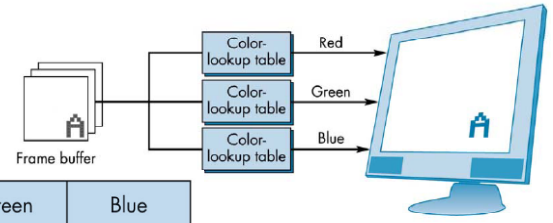





# OpenGL Attributes

- OpenGL Color Model
  - Color Index는 메모리를 적게 사용함. 현재는 크게 쓰이지 않음.

```
glIndexi(element);
```




| Input | Red | Green | Blue |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | $2^m - 1$ | 0 | 0 |
| . | 0 | $2^m - 1$ | 0 |
| . | . | . | . |
| . | . | . | . |
| $2^k - 1$ | . | . | . |
| | $m$ bits | $m$ bits | $m$ bits |