# OpenGL 그래픽스 라이브러리

서울대학교 컴퓨터공학부
김명수
http://cse.snu.ac.kr/mskim
http://3map.snu.ac.kr

# OpenGL 관련 사이트 및 프로그래밍 실습 예제

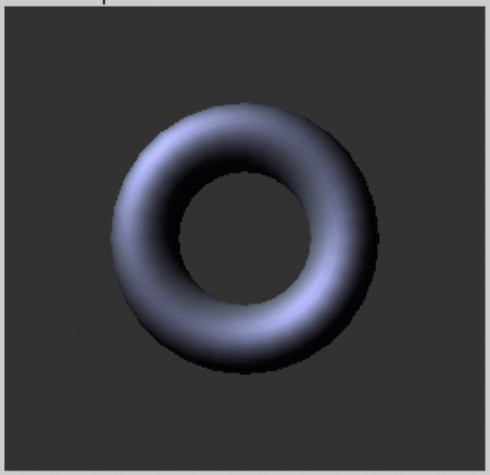
http://www.opengl.org

http://www.cs.utah.edu/~narobins/opengl.html

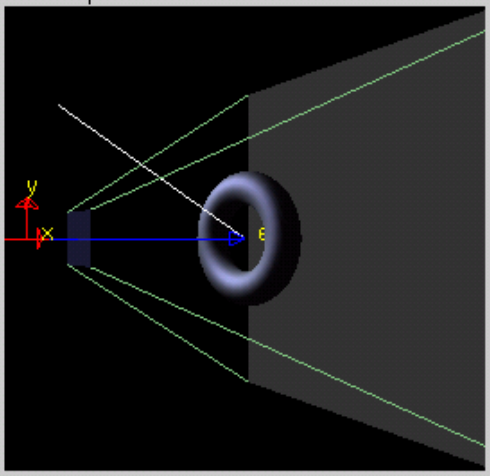
# 프로그램 실습 예제

Light & Material

Screen-space view



World-space view




Command manipulation window

```
GLfloat light_pos[ ] = {  -2.00 , 2.00  , 2.00  , 1.00  };
GLfloat light_Ka[ ] = {  0.00  , 0.00  , 0.00  , 1.00  };
GLfloat light_Kd[ ] = {  1.00  , 1.00  , 1.00  , 1.00  };
GLfloat light_Ks[ ] = {  1.00  , 1.00  , 1.00  , 1.00  };

glLightfv(GL_LIGHT0, GL_POSITION, light_pos);
glLightfv(GL_LIGHT0, GL_AMBIENT, light_Ka);
glLightfv(GL_LIGHT0, GL_DIFFUSE, light_Kd);
glLightfv(GL_LIGHT0, GL_SPECULAR, light_Ks);

GLfloat material_Ka[ ] = { 0.11  , 0.06  , 0.11  , 1.00  };
GLfloat material_Kd[ ] = { 0.43  , 0.47  , 0.54  , 1.00  };
GLfloat material_Ks[ ] = { 0.33  , 0.33  , 0.52  , 1.00  };
GLfloat material_Ke[ ] = { 0.00  , 0.00  , 0.00  , 0.00  };
GLfloat material_Se =  10  ;

glMaterialfv(GL_FRONT, GL_AMBIENT, material_Ka);
glMaterialfv(GL_FRONT, GL_DIFFUSE, material_Kd);
glMaterialfv(GL_FRONT, GL_SPECULAR, material_Ks);
glMaterialfv(GL_FRONT, GL_EMISSION, material_Ke);
glMaterialfv(GL_FRONT, GL_SHININESS, material_Se);
```

Click on the arguments and move the mouse to modify values.

# 프로그램 예제

```
void main( int argc, char** argv )
{
  int mode = GLUT_RGB|GLUT_DOUBLE;
  glutInitDisplayMode( mode );
  glutCreateWindow( argv[0] );
  init();
  glutDisplayFunc( display );
  glutReshapeFunc( resize );
  glutKeyboardFunc( key );
  glutIdleFunc( idle );
  glutMainLoop();
}
```

```
void init( void )
{
  glClearColor( 0.0, 0.0, 0.0, 1.0 );
  glClearDepth( 1.0 );

  glEnable( GL_LIGHT0 );
  glEnable( GL_LIGHTING );
  glEnable( GL_DEPTH_TEST );
}
```

# 프로그램 예제

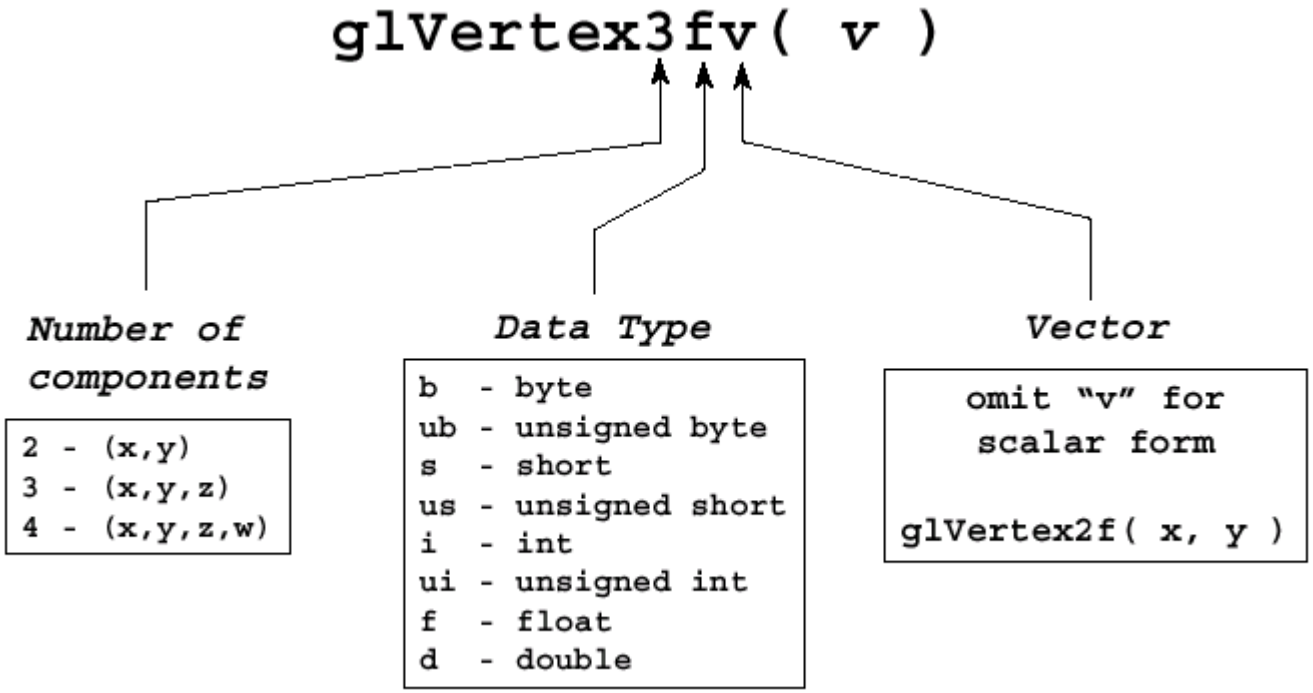
```
void display( void )
{
  glClear( GL_COLOR_BUFFER_BIT );
  glBegin( GL_TRIANGLE_STRIP );
    glVertex3fv( v[0] );
    glVertex3fv( v[1] );
    glVertex3fv( v[2] );
    glVertex3fv( v[3] );
  glEnd();
  glutSwapBuffers();
}
```

```
void keyboard( char key, int x, int y )
{
  switch( key ) {
    case 'q' : case 'Q' :
      exit( EXIT_SUCCESS );
      break;

    case 'r' : case 'R' :
      rotate = GL_TRUE;
      break;
  }
}
```

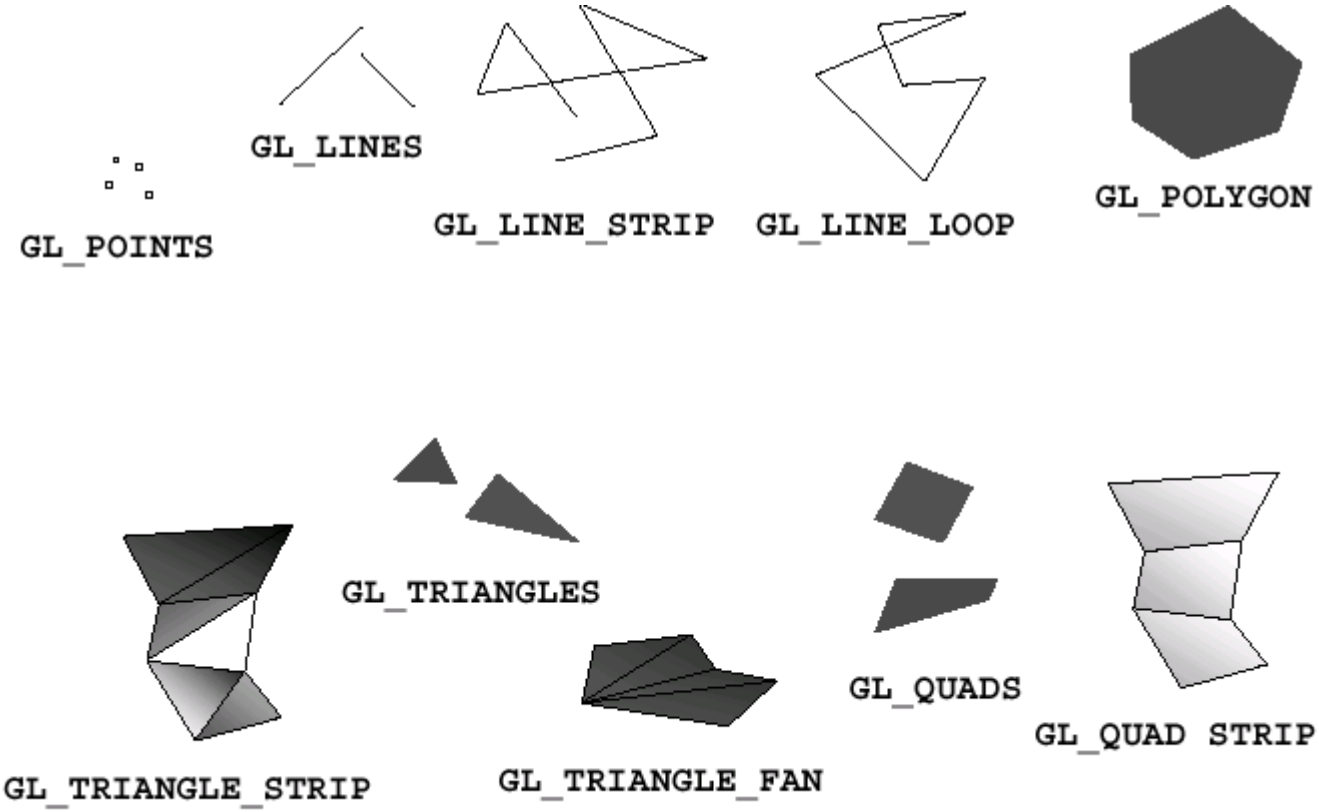
# 평면에서의 사각형의 정의

```
void drawRhombus( GLfloat color[] )
{
    glBegin( GL_QUADS );
    glColor3fv( color );
    glVertex2f( 0.0, 0.0 );
    glVertex2f( 1.0, 0.0 );
    glVertex2f( 1.5, 1.118 );
    glVertex2f( 0.5, 1.118 );
    glEnd();
}
```

# 명령어의 형식


glVertex3fv( v )
Number of components
2 - (x,y)
3 - (x,y,z)
4 - (x,y,z,w)
Data Type
b - byte
ub - unsigned byte
s - short
us - unsigned short
i - int
ui - unsigned int
f - float
d - double
Vector
omit "v" for scalar form
glVertex2f( x, y )

# 기하학적 기본요소들

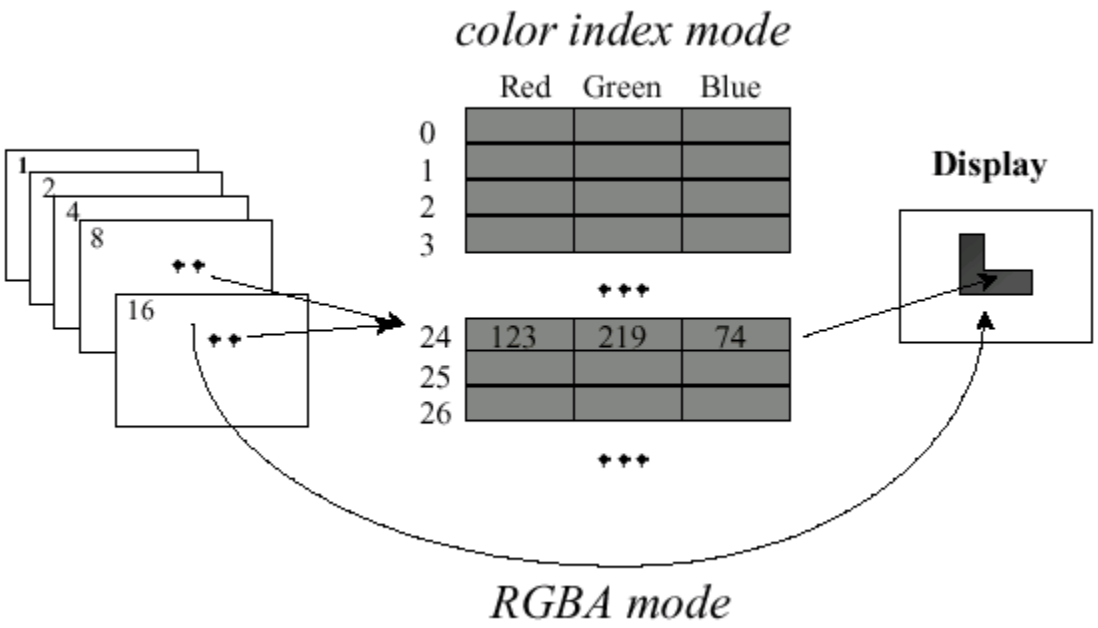

GL_POINTS
GL_LINES
GL_LINE_STRIP
GL_LINE_LOOP
GL_POLYGON
GL_TRIANGLES
GL_TRIANGLE_STRIP
GL_TRIANGLE_FAN
GL_QUADS
GL_QUAD STRIP

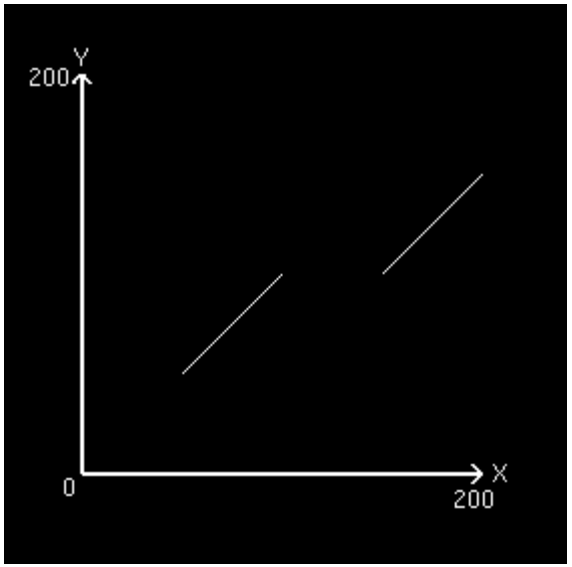
# 기본요소의 구성

```
GLfloat red, greed, blue;
Glfloat coords[3];
glBegin( primType );
for ( i = 0; i < nVerts; ++i ) {
  glColor3f( red, green, blue );
  glVertex3fv( coords );
}
glEnd();
```

| | |
|---|---|
| GL_POINTS | GL_LINE_STRIP |
| GL_LINES | GL_LINE_LOOP |
| GL_POLYGON | GL_TRIANGLE_STRIP |
| GL_TRIANGLES | GL_TRIANGLE_FAN |
| GL_QUADS | GL_QUAD_STRIP |

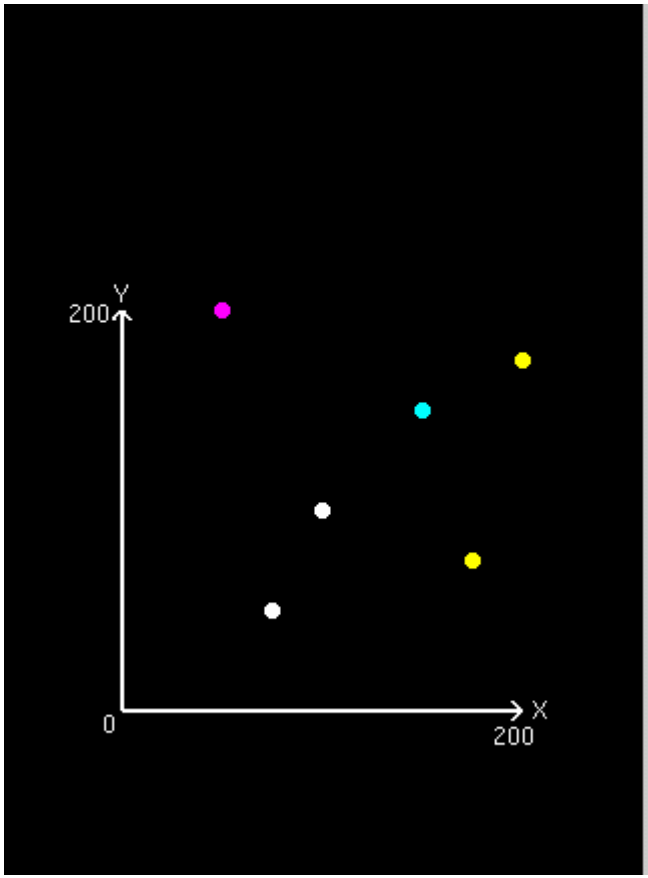
# 칼라모델



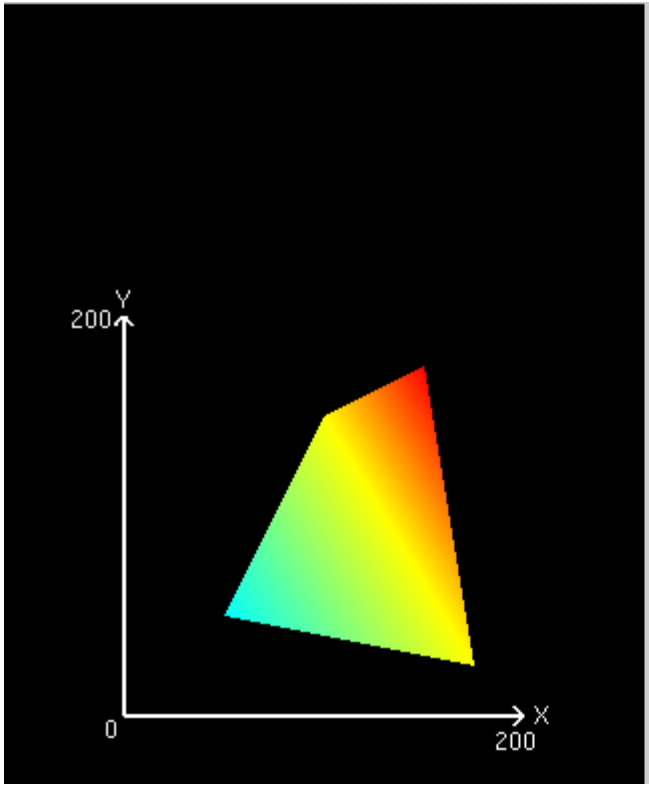

```
glBegin (GL_LINES);
glColor3f   (1.00   , 1.00   , 1.00   );
glVertex2f (50.0   , 50.0   );
glVertex2f (100.0 , 100.0 );
glColor3f   (1.00   , 1.00   , 1.00   );
glVertex2f (150.0 , 100.0 );
glVertex2f (200.0 , 150.0 );
glEnd();
```

# 구성 예제



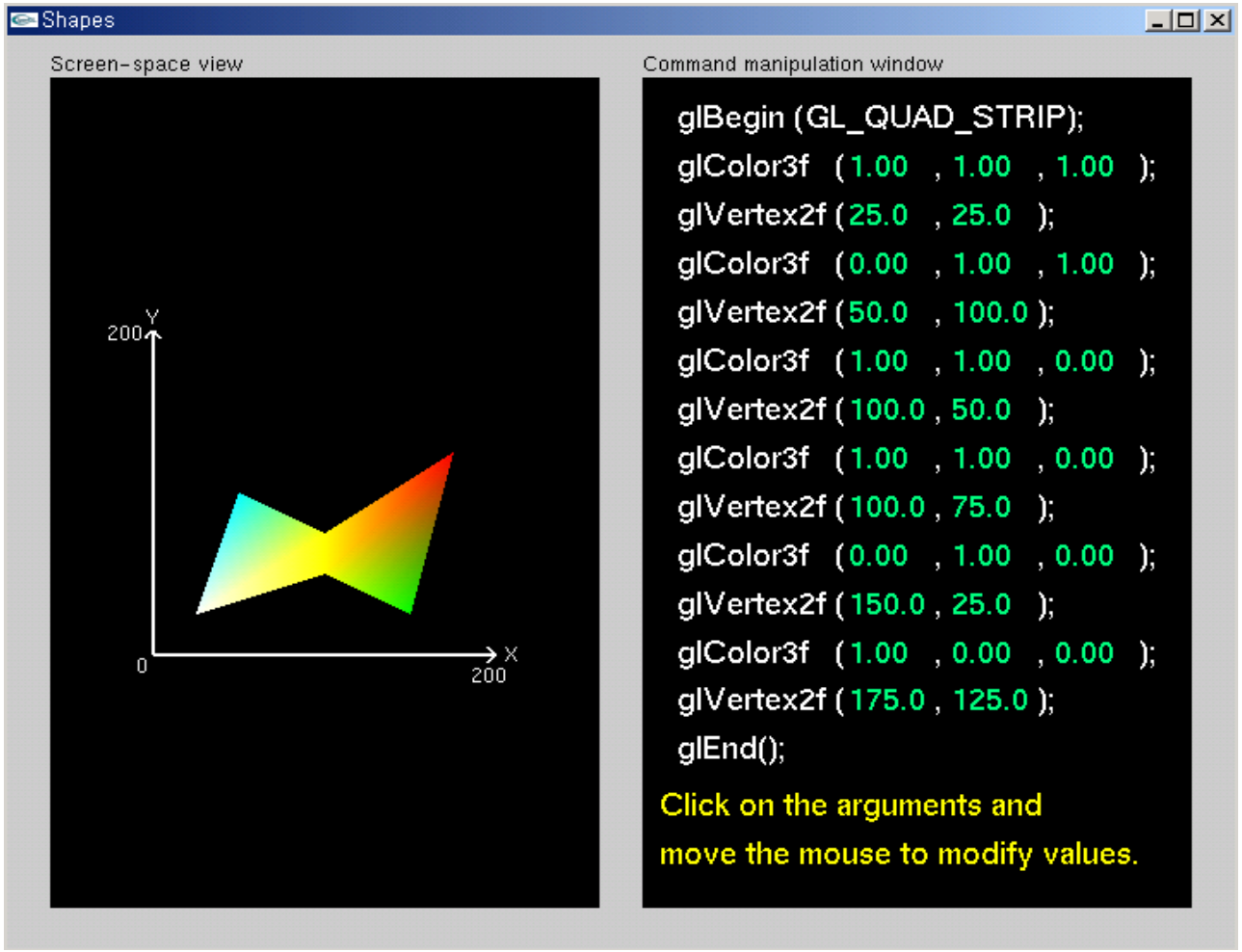

```
glBegin (GL_POINTS);
glColor3f   (1.00  , 1.00  , 1.00  );
glVertex2f (100.0 , 100.0 );
glColor3f   (1.00  , 1.00  , 0.00  );
glVertex2f (200.0 , 175.0 );
glColor3f   (1.00  , 0.00  , 1.00  );
glVertex2f (50.0  , 200.0 );
glColor3f   (0.00  , 1.00  , 1.00  );
glVertex2f (150.0 , 150.0 );
glColor3f   (1.00  , 1.00  , 1.00  );
glVertex2f (75.0  , 50.0  );
glColor3f   (1.00  , 1.00  , 0.00  );
glVertex2f (175.0 , 75.0  );
glEnd();
```

# 구성 예제

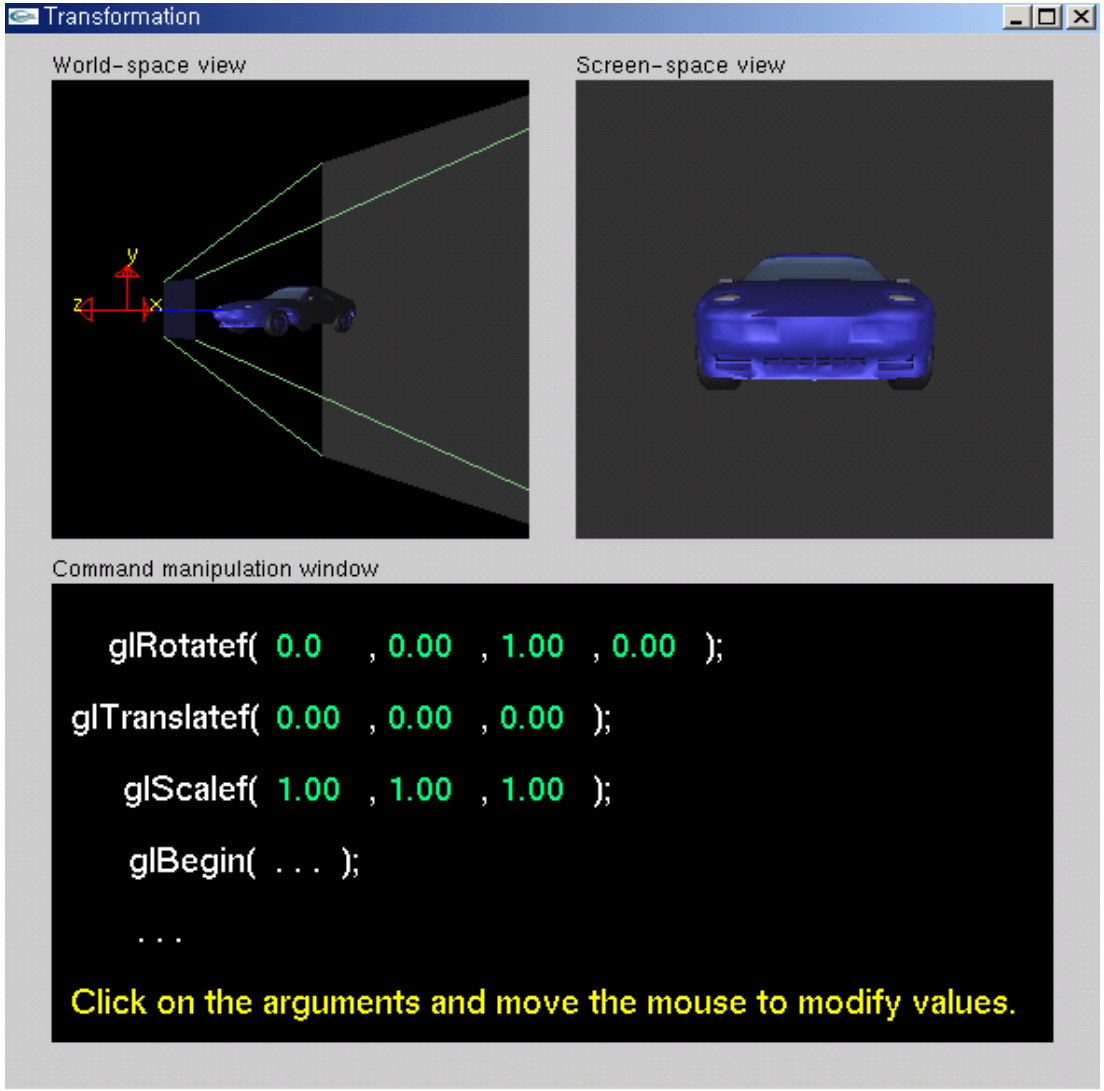



```
glBegin (GL_TRIANGLE_STRIP);
glColor3f   (0.00   , 1.00   , 1.00   );
glVertex2f (50.0   , 50.0   );
glColor3f   (1.00   , 1.00   , 0.00   );
glVertex2f (100.0 , 150.0 );
glColor3f   (1.00   , 1.00   , 0.00   );
glVertex2f (175.0 , 25.0   );
glColor3f   (1.00   , 0.00   , 0.00   );
glVertex2f (150.0 , 175.0 );
glEnd();
```

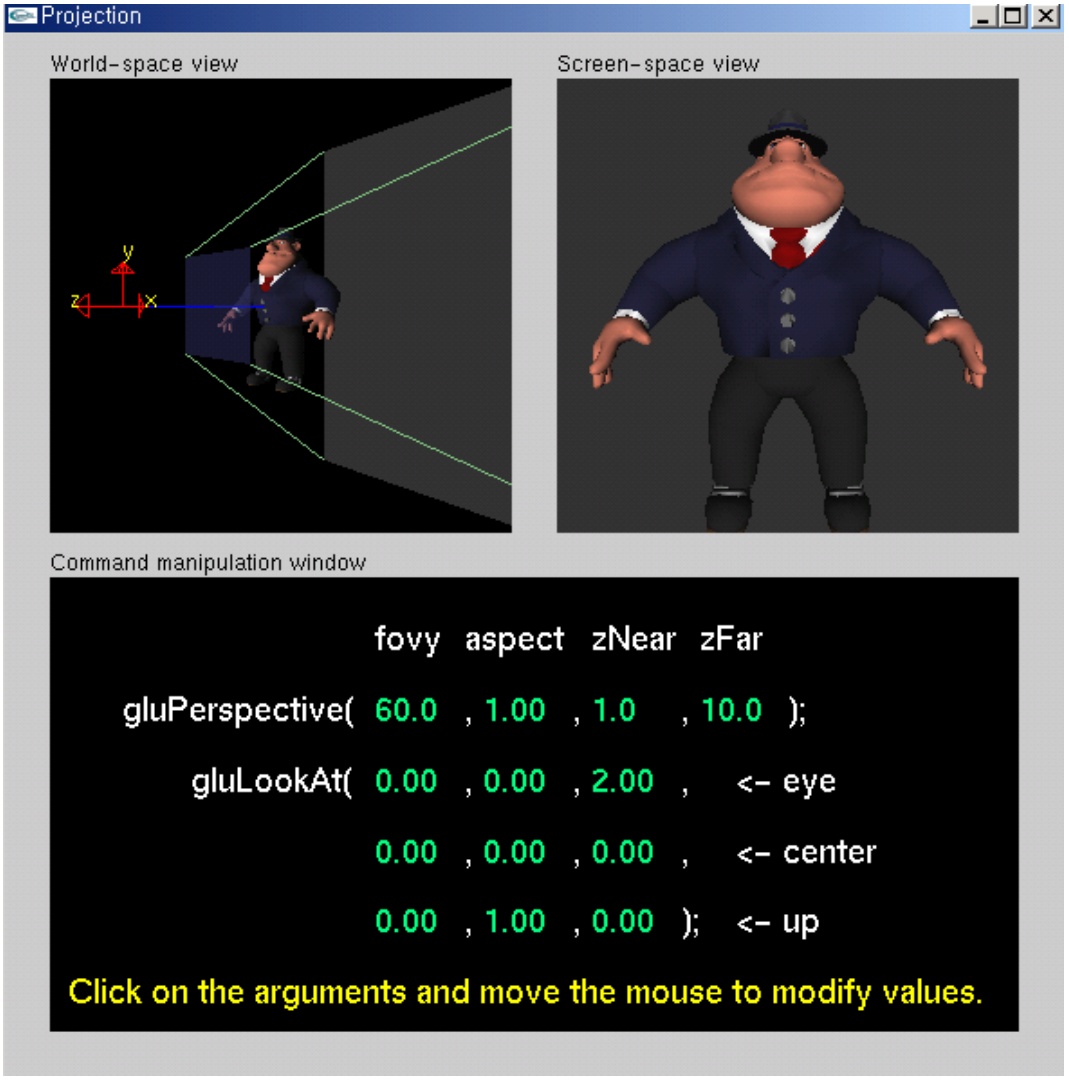
# 프로그램 실습 예제


Shapes
Screen-space view
Command manipulation window
Y
200
0
X
200
glBegin (GL_QUAD_STRIP);
glColor3f (1.00 , 1.00 , 1.00 );
glVertex2f (25.0 , 25.0 );
glColor3f (0.00 , 1.00 , 1.00 );
glVertex2f (50.0 , 100.0 );
glColor3f (1.00 , 1.00 , 0.00 );
glVertex2f (100.0 , 50.0 );
glColor3f (1.00 , 1.00 , 0.00 );
glVertex2f (100.0 , 75.0 );
glColor3f (0.00 , 1.00 , 0.00 );
glVertex2f (150.0 , 25.0 );
glColor3f (1.00 , 0.00 , 0.00 );
glVertex2f (175.0 , 125.0 );
glEnd();
Click on the arguments and
move the mouse to modify values.

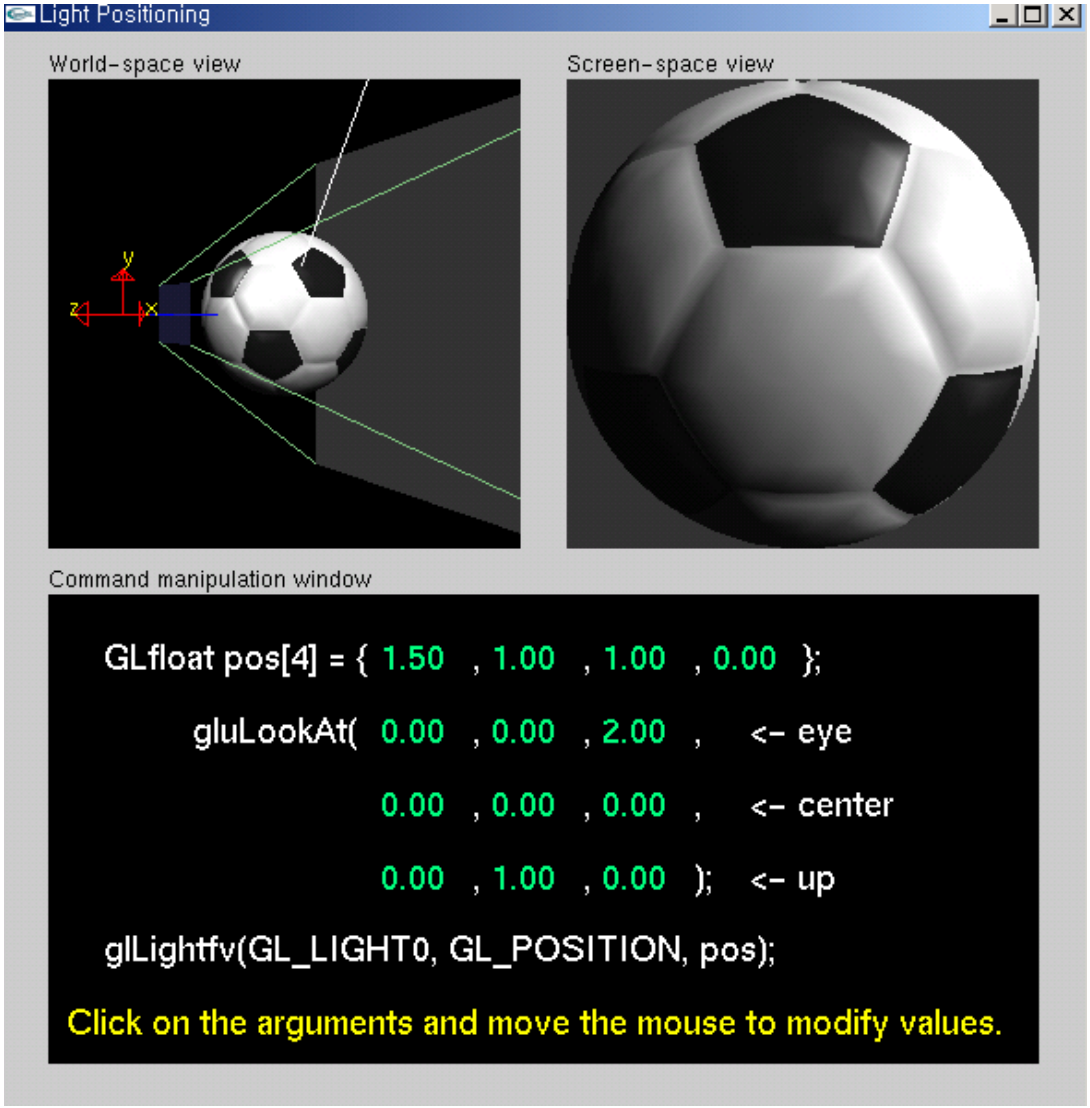
# 프로그램 실습 예제


Transformation
World-space view
Screen-space view
y
z
x
Command manipulation window
glRotatef( 0.0 , 0.00 , 1.00 , 0.00 );
glTranslatef( 0.00 , 0.00 , 0.00 );
glScalef( 1.00 , 1.00 , 1.00 );
glBegin( . . . );
. . .
Click on the arguments and move the mouse to modify values.

# 프로그램 실습 예제


Projection
World-space view
Screen-space view
y
z
x
Command manipulation window
fovy aspect zNear zFar
gluPerspective( 60.0 , 1.00 , 1.0 , 10.0 );
gluLookAt( 0.00 , 0.00 , 2.00 , <- eye
0.00 , 0.00 , 0.00 , <- center
0.00 , 1.00 , 0.00 ); <- up
Click on the arguments and move the mouse to modify values.

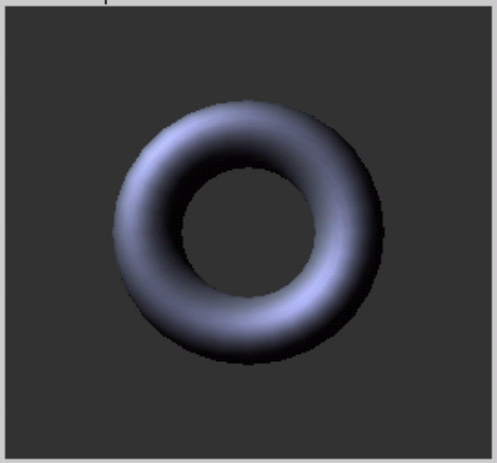
# 프로그램 실습 예제


Light Positioning
World-space view
Screen-space view
y
z
x
Command manipulation window
GLfloat pos[4] = { 1.50 , 1.00 , 1.00 , 0.00 };
gluLookAt( 0.00 , 0.00 , 2.00 , <- eye
0.00 , 0.00 , 0.00 , <- center
0.00 , 1.00 , 0.00 ); <- up
glLightfv(GL_LIGHT0, GL_POSITION, pos);
Click on the arguments and move the mouse to modify values.

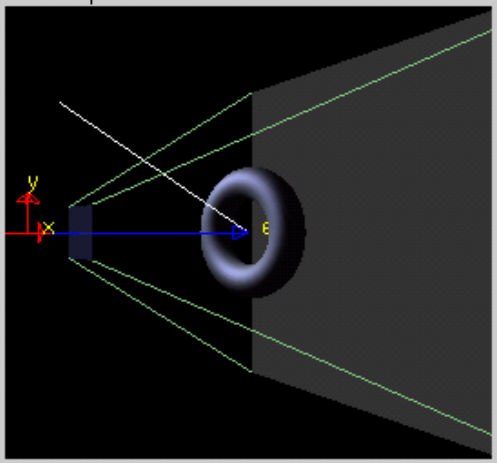
# 프로그램 실습 예제

Light & Material

Screen-space view



World-space view




Command manipulation window

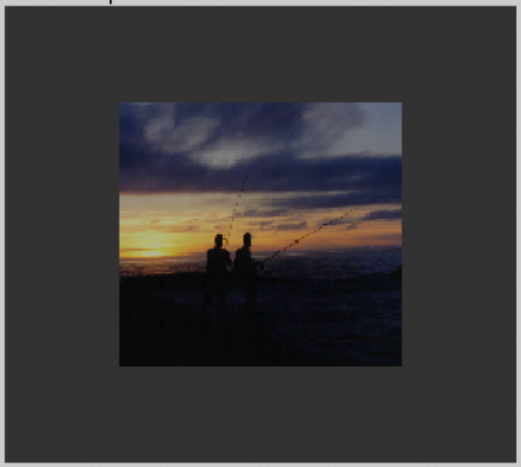
```
GLfloat light_pos[ ] = {  -2.00 , 2.00  , 2.00  , 1.00  };
GLfloat light_Ka[ ] = {  0.00  , 0.00  , 0.00  , 1.00  };
GLfloat light_Kd[ ] = {  1.00  , 1.00  , 1.00  , 1.00  };
GLfloat light_Ks[ ] = {  1.00  , 1.00  , 1.00  , 1.00  };

glLightfv(GL_LIGHT0, GL_POSITION, light_pos);
glLightfv(GL_LIGHT0, GL_AMBIENT, light_Ka);
glLightfv(GL_LIGHT0, GL_DIFFUSE, light_Kd);
glLightfv(GL_LIGHT0, GL_SPECULAR, light_Ks);

GLfloat material_Ka[ ] = { 0.11  , 0.06  , 0.11  , 1.00  };
GLfloat material_Kd[ ] = { 0.43  , 0.47  , 0.54  , 1.00  };
GLfloat material_Ks[ ] = { 0.33  , 0.33  , 0.52  , 1.00  };
GLfloat material_Ke[ ] = { 0.00  , 0.00  , 0.00  , 0.00  };
GLfloat material_Se =  10  ;

glMaterialfv(GL_FRONT, GL_AMBIENT, material_Ka);
glMaterialfv(GL_FRONT, GL_DIFFUSE, material_Kd);
glMaterialfv(GL_FRONT, GL_SPECULAR, material_Ks);
glMaterialfv(GL_FRONT, GL_EMISSION, material_Ke);
glMaterialfv(GL_FRONT, GL_SHININESS, material_Se);
```

Click on the arguments and move the mouse to modify values.

# 프로그램 실습 예제

Texture

Screen-space view



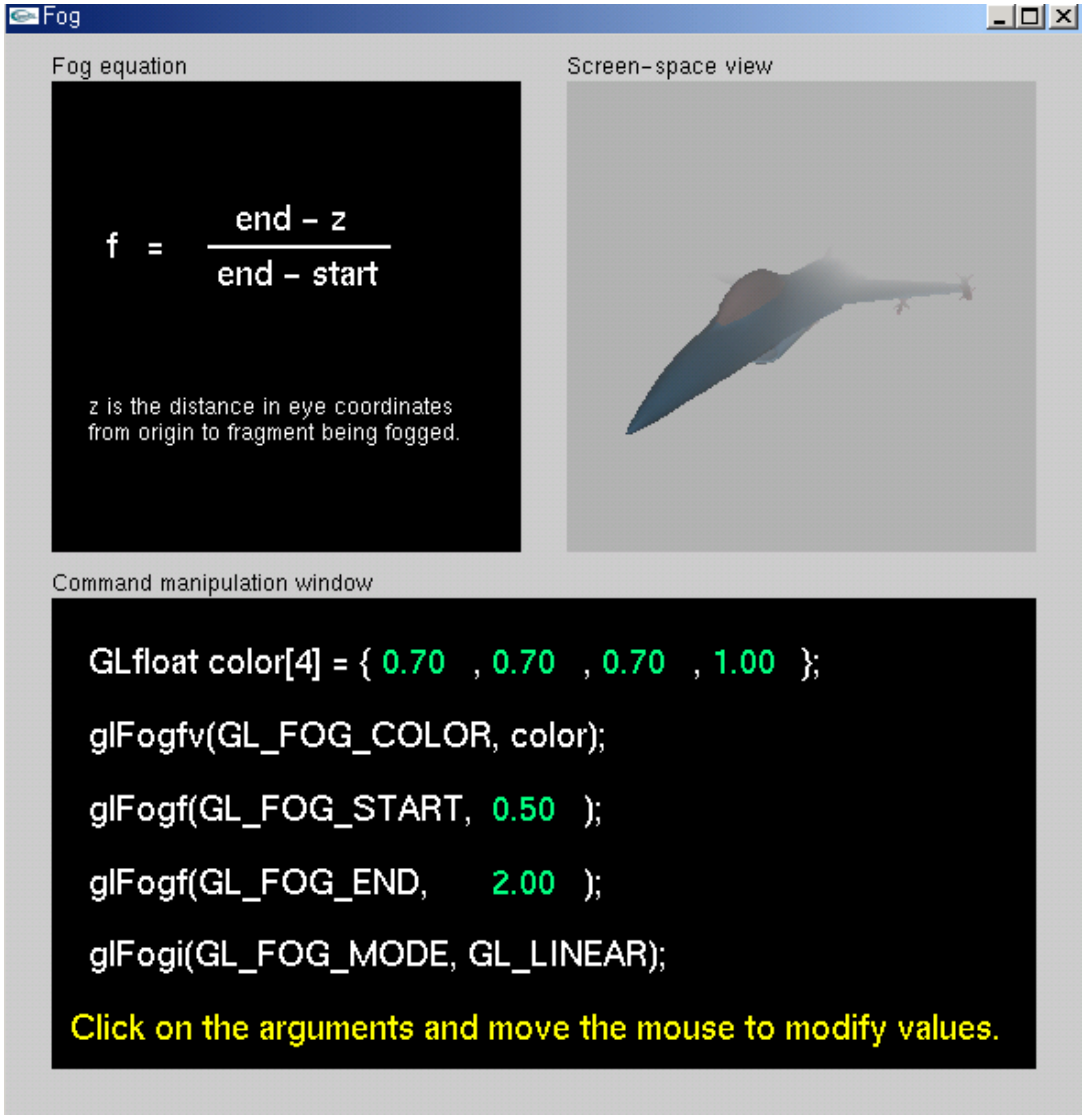
Texture-space view


Command manipulation window

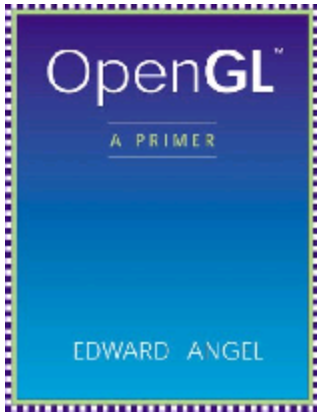
```
GLfloat border_color[ ] = {  1.00 ,  0.00 ,  0.00 ,  1.00 };
GLfloat env_color[ ] = {     0.00 ,  1.00 ,  0.00 ,  1.00 };

glTexParameterfv(GL_TEXTURE_2D, GL_TEXTURE_BORDER_COLOR, border_color);
glTexEnvfv(GL_TEXTURE_ENV, GL_TEXTURE_ENV_COLOR, env_color);

glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER,  GL_NEAREST);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER,  GL_NEAREST);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S,  GL_REPEAT);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T,  GL_REPEAT);
glTexEnvi(GL_TEXTURE_ENV, GL_TEXTURE_ENV_MODE,  GL_MODULATE);

glEnable(GL_TEXTURE_2D);
gluBuild2DMipmaps(GL_TEXTURE_2D, 3, w, h, GL_RGB, GL_UNSIGNED_BYTE, image);
glColor4f(  0.60 , 0.60 , 0.60 , 1.00 );
glBegin(GL_POLYGON);
glTexCoord2f( 0.0 , 0.0 ); glVertex3f( -1.0 , -1.0 , 0.0 );
glTexCoord2f( 1.0 , 0.0 ); glVertex3f( 1.0 , -1.0 , 0.0 );
glTexCoord2f( 1.0 , 1.0 ); glVertex3f( 1.0 , 1.0 , 0.0 );
glTexCoord2f( 0.0 , 1.0 ); glVertex3f( -1.0 , 1.0 , 0.0 );
glEnd();
```

Click on the arguments and move the mouse to modify values.

# 프로그램 실습 예제


Fog
Fog equation
f = (end − z) / (end − start)
z is the distance in eye coordinates
from origin to fragment being fogged.
Screen-space view
Command manipulation window
GLfloat color[4] = { 0.70 , 0.70 , 0.70 , 1.00 };
glFogfv(GL_FOG_COLOR, color);
glFogf(GL_FOG_START, 0.50 );
glFogf(GL_FOG_END, 2.00 );
glFogi(GL_FOG_MODE, GL_LINEAR);
Click on the arguments and move the mouse to modify values.

# OpenGL 프로그래밍 실습 예제




http://www.cs.unm.edu/~angel

ftp://ftp.cs.unm.edu/pub/angel/BOOK/THIRD_EDITION/PROGRAMS/

# 프로그램 실습 예제

```
#include <stdlib.h>
#include <GL/glut.h>


    GLfloat vertices[][3] = {{-1.0,-1.0,-1.0},{1.0,-1.0,-1.0},
    {1.0,1.0,-1.0}, {-1.0,1.0,-1.0}, {-1.0,-1.0,1.0},
    {1.0,-1.0,1.0}, {1.0,1.0,1.0}, {-1.0,1.0,1.0}};

    GLfloat normals[][3] = {{-1.0,-1.0,-1.0},{1.0,-1.0,-1.0},
    {1.0,1.0,-1.0}, {-1.0,1.0,-1.0}, {-1.0,-1.0,1.0},
    {1.0,-1.0,1.0}, {1.0,1.0,1.0}, {-1.0,1.0,1.0}};

    GLfloat colors[][3] = {{0.0,0.0,0.0},{1.0,0.0,0.0},
    {1.0,1.0,0.0}, {0.0,1.0,0.0}, {0.0,0.0,1.0},
    {1.0,0.0,1.0}, {1.0,1.0,1.0}, {0.0,1.0,1.0}};
```

# 프로그램 실습 예제

```
void polygon(int a, int b, int c , int d)
{

/* draw a polygon via list of vertices */

    glBegin(GL_POLYGON);
        glColor3fv(colors[a]);
        glNormal3fv(normals[a]);
        glVertex3fv(vertices[a]);
        glColor3fv(colors[b]);
        glNormal3fv(normals[b]);
        glVertex3fv(vertices[b]);
        glColor3fv(colors[c]);
        glNormal3fv(normals[c]);
        glVertex3fv(vertices[c]);
        glColor3fv(colors[d]);
        glNormal3fv(normals[d]);
        glVertex3fv(vertices[d]);
    glEnd();
```

```
void colorcube(void)
{

/* map vertices to faces */

    polygon(0,3,2,1);
    polygon(2,3,7,6);
    polygon(0,4,7,3);
    polygon(1,2,6,5);
    polygon(4,5,6,7);
    polygon(0,1,5,4);
}
```

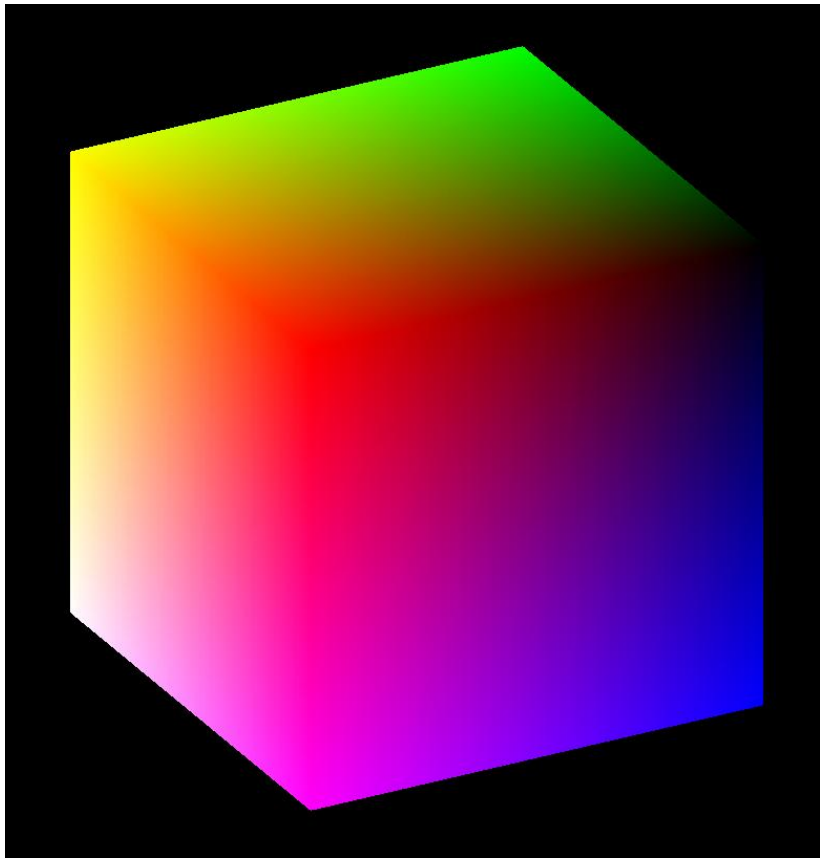
# 프로그램 실습 예제

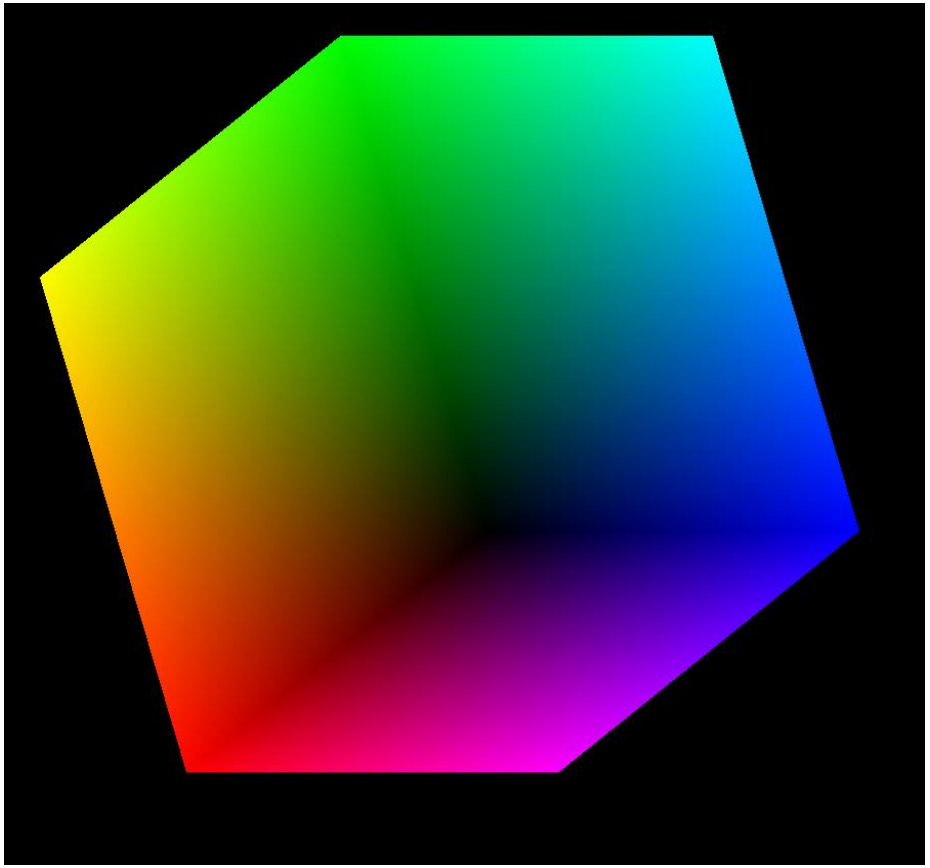
```
static GLfloat theta[] = {0.0,0.0,0.0};
static GLint axis = 2;

void display(void)
{
/* display callback, clear frame buffer and z buffer,
   rotate cube and draw, swap buffers */

 glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
    glLoadIdentity();
    glRotatef(theta[0], 1.0, 0.0, 0.0);
    glRotatef(theta[1], 0.0, 1.0, 0.0);
    glRotatef(theta[2], 0.0, 0.0, 1.0);

 colorcube();

 glFlush();
    glutSwapBuffers();
}
```

# 프로그램 실습 예제

```
void
main(int argc, char **argv)
{
    glutInit(&argc, argv);

/* need both double buffering and z buffer */

    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
    glutInitWindowSize(500, 500);
    glutCreateWindow("colorcube");
    glutReshapeFunc(myReshape);
    glutDisplayFunc(display);
       glutIdleFunc(spinCube);
       glutMouseFunc(mouse);
       glEnable(GL_DEPTH_TEST); /* Enable hidden--surface--removal */
    glutMainLoop();
}
```

# 프로그램 실습 예제





# 프로그램 실습 예제

## 숨은면 제거가 되지 않은 경우