Graphics Programming

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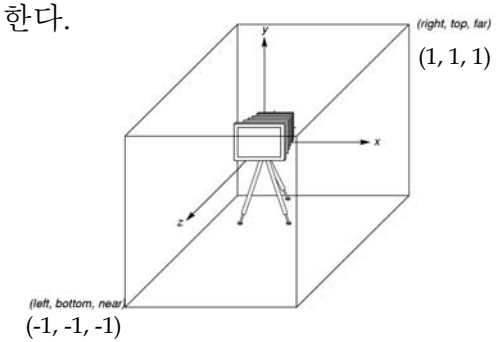
OpenGL Camera

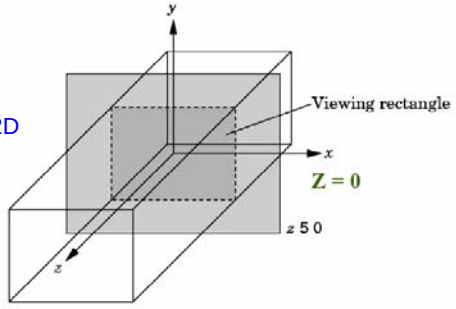
- OpenGL에서는 카메라가 물체의 공간(drawing coordinates)의 원점(origin)에 위치하며 z- 방향으로 향하고 있다.
- 관측공간을 지정하지 않는다면, 디폴트로 2x2x2 입방체의 viewing volume을 사용한다.



Viewing functions

- 직교 투영 (Orthographic parallel projection)
  - void glOrtho(GLdouble left, GLdouble right, GLdouble bottom, GLdouble top, GLdouble zNear, GLdouble zFar);
  - void gluOrtho2D(GLdouble left, GLdouble right, GLdouble bottom, GLdouble top); - 2차원 그래픽스에 사용

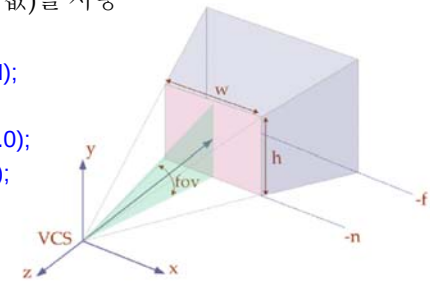
```
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
gluOrtho2D(0.0, 50.0, 0.0, 50.0); //2D
glMatrixMode(GL_MODELVIEW);

glMatrixMode(GL_PROJECTION);
glLoadIdentity();
glOrtho(-10, 10, -10, 10, -10, 10);
glMatrixMode(GL_MODELVIEW);
```



Viewing functions

- 원근 투영 (Perspective projection)
  - void glFrustum(GLdouble left, GLdouble right, GLdouble bottom, GLdouble top, GLdouble zNear, GLdouble zFar);
  - void gluPerspective(GLdouble fovy, GLdouble aspect, GLdouble zNear, GLdouble zFar); - 상하좌우값을 설정하는 대신 y방향의 시선각도 (FOV)와 종횡비(가까운 쪽 클리핑 평면의 너비를 높이로 나눈 값)를 사용

```
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
gluPerspective(60.0, 1.0, 1.0, 10.0);
glMatrixMode(GL_MODELVIEW);
```



Viewport functions

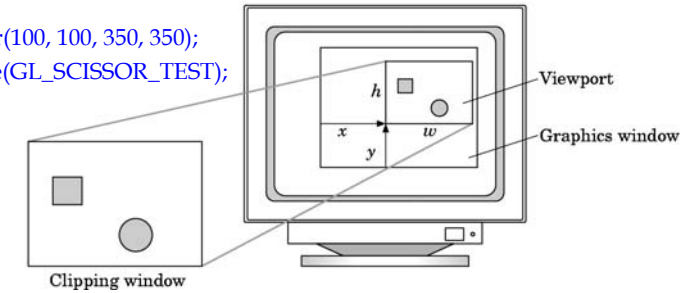
- 뷰포트 (Viewport)
  - 윈도우 내부에 설정한 공간. 그리기가 뷰포트 내부로 제한됨.
- void glViewport(GLint x, GLint y, GLsizei width, GLsizei height)
  - 윈도우를 처음 생성할 때 전체 윈도우에 해당하는 픽셀 영역을 뷰포트로 설정; 이보다 작은 영역을 뷰포트로 설정할 때는 glViewport() 사용. 일반적으로 윈도우 전체를 뷰포트로 사용.
  - Reshape function이 있을 경우, glViewport()가 반드시 포함되어야 함.

```
glViewport(0, 0, glutGet(GLUT_WINDOW_WIDTH),
   glutGet(GLUT_WINDOW_HEIGHT));
```

Viewport functions

- void glScissor(GLint x, GLint y, GLsizei width, GLsizei height)
  - 윈도우의 직사각형 분할 및 그 분할 내에서의 그릴 때의 제한 사항 등을 정의
  - 일반적으로 glViewport()와 동일하게 정의함

```
glScissor(100, 100, 350, 350);
glEnable(GL_SCISSOR_TEST);
```

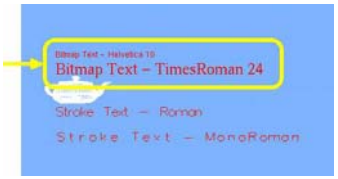


Text Functions

- GLUT에 정의된 문자 집합 제공. 문자열에는 획(stroke)과 래스터 (raster) 두 종류가 있다.
- Bitmap font (raster font) text
  - void glutBitmapCharacter(void *font, int character);
  - font 인자
    - 고정폭 폰트 - E.g. GLUT_BITMAP_8_BY_13, GLUT_BITMAP_9_BY_15
    - 10, 12, 18 포인트 비례 간격 폰트 – e.g. GLUT_BITMAP_TIMES_ROMAN_10
  - character인자는 ASCII
- Stroke font text
  - void glutStrokeCharacter(void *font, int character);
  - font 인자
    - GLUT_STROKE_ROMAN, GLUT_STROKE_MONO_ROMAN

Bitmap Text

- glutBitmapCharacter()는 비트맵 (bitmap = arrays of pixel data) 폰트를 사용하여 문자를 그린다.
- 비트맵 문자의 위치는 glRasterPos*를 사용하여 지정한다.
  - glRasterPos2f(x, y)
  - glRasterPos3f(x, y, z)
- 비트맵의 문자는 크기가 변하지 않는다. (unaffected by scaling or perspective)
- 화면에 일정한 곳에 위치하고 있다. 만약 래스터 위치가 뷰포트 밖에 위치하고 있다면 비트맵 문자는 그려지지 않는다.

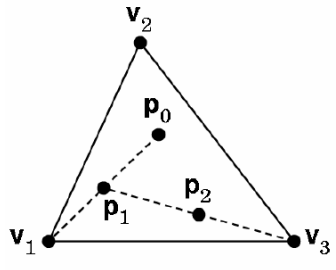


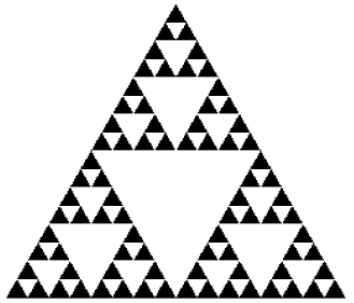
Stroke Text

- glutStrokeCharacter() 는 3차원 선으로 문자를 그린다.
- 따라서, GL의 변환 (즉, position, size, and orientation)에 의해 영향을 받는다.
- glutStrokeCharacter()는 다음 글자(character)를 그리기 위해 자체적으로 transformation을 한다.

Sierpinski Gasket

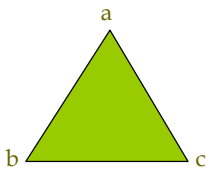
- A sample problem of drawing of the Sierpinski gasket
  1. Pick an initial point at random inside the triangle, P0
  2. Select one of the 3 vertices at random, v1
  3. Find the point halfway, P1
  4. Display this new point
  5. Replace the initial point with this new point
  6. Return to step 2



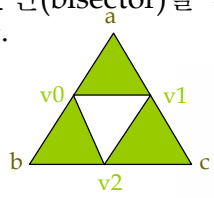


Sierpinski Gasket (2D)

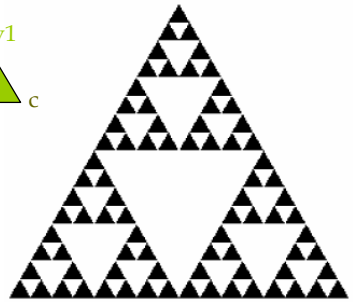
- 삼각형에서 시작한다.



- 삼각형 각 변의 이등분선(bisector)을 연결하고, 중앙의 작은 삼각형을 지운다.



- 반복 (Repeat)

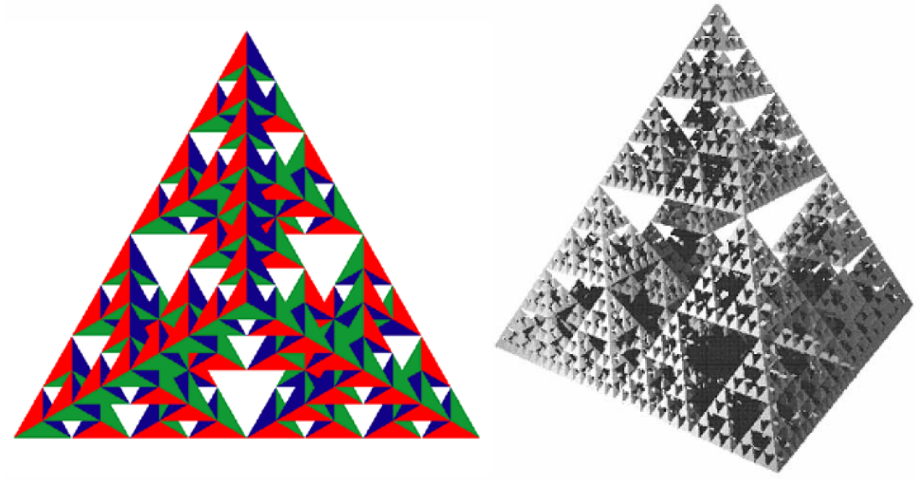


Sierpinski Gasket (2D)

```
/* recursive subdivision of triangle to form Sierpinski gasket */
#include <GL/glut.h>

/* initial triangle */
GLfloat v[3][2]={{-1.0, -0.58}, {1.0, -0.58}, {0.0, 1.15}};
int n;

void triangle( GLfloat *a, GLfloat *b, GLfloat *c)
{
/* specify one triangle */
     glVertex2fv(a);
     glVertex2fv(b);
     glVertex2fv(c);
}

void divide_triangle(GLfloat *a, GLfloat *b, GLfloat *c, int m)
{
/* triangle subdivision using vertex numbers */
   GLfloat v0[2], v1[2], v2[2];
   int j;
   if(m>0)
   {
      for(j=0; j<2; j++) v0[j]=(a[j]+b[j])/2;
      for(j=0; j<2; j++) v1[j]=(a[j]+c[j])/2;
      for(j=0; j<2; j++) v2[j]=(b[j]+c[j])/2;
      divide_triangle(a, v0, v1, m-1);
      divide_triangle(c, v1, v2, m-1);
      divide_triangle(b, v2, v0, m-1);
   }
   else triangle(a,b,c); /* draw triangle at end of recursion */
}
```

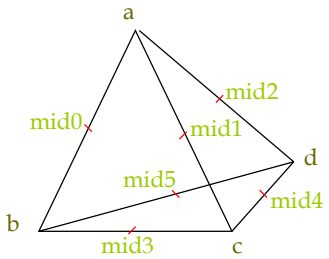
```
void display()
{
   glClear(GL_COLOR_BUFFER_BIT);
   glBegin(GL_TRIANGLES);
   divide_triangle(v[0], v[1], v[2], n);
   glEnd();
   glFlush();
}

void myinit()
{
   glMatrixMode(GL_PROJECTION);
   glLoadIdentity();
   gluOrtho2D(-2.0, 2.0, -2.0, 2.0);
   glMatrixMode(GL_MODELVIEW);
   glClearColor (1.0, 1.0, 1.0, 1.0);
   glColor3f(0.0,0.0,0.0);
}

int main(int argc, char **argv)
{
   n=atoi(argv[1]); /* or set number of subdivision steps here */
   glutInit(&argc, argv);
   glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);
   glutInitWindowSize(500, 500);
   glutCreateWindow("Sierpinski Gasket");
   glutDisplayFunc(display);
   myinit();
   glutMainLoop();
}
```

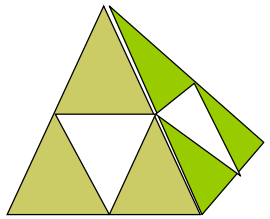
3D Gasket



3D Gasket

- 3D Gasket은 각각의 4면에서 subdivision을 한다.





- 사면체 (solid tetrahedron) 내부의 작은 사면체를 지운다.

3D Gasket

```
/* recursive subdivision of a tetrahedron to form 3D Sierpinski
gasket */
#include <stdlib.h>
#include <GL/glut.h>

/* initial tetrahedron */
GLfloat v[4][3]={{0.0, 0.0, 1.0}, {0.0, 0.942809, -0.33333},
    {-0.816497, -0.471405, -0.333333},
    {0.816497, -0.471405, -0.333333}};
GLfloat colors[4][3] = {{1.0, 0.0, 0.0}, {0.0, 1.0, 0.0},
                {0.0, 0.0, 1.0}, {0.0, 0.0, 0.0}};
int n;
void triangle(GLfloat *va, GLfloat *vb, GLfloat *vc)
{
    glVertex3fv(va);
    glVertex3fv(vb);
    glVertex3fv(vc);
}

void tetra(GLfloat *a, GLfloat *b, GLfloat *c, GLfloat *d)
{
  glColor3fv(colors[0]);
  triangle(a, b, c);
  glColor3fv(colors[1]);
  triangle(a, c, d);
  glColor3fv(colors[2]);
  triangle(a, d, b);
  glColor3fv(colors[3]);
  triangle(b, d, c);
}
```

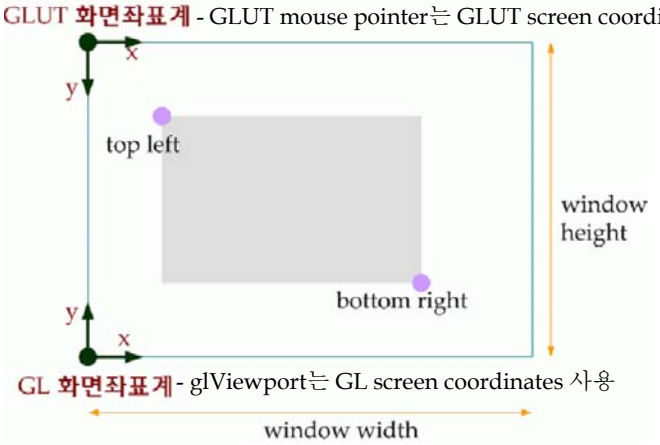
```
void divide_tetra(GLfloat *a, GLfloat *b, GLfloat *c, GLfloat *d,
int m)
{
  GLfloat mid[6][3];
  int j;
  if(m>0)
  {
    /* compute six midpoints */
    for(j=0; j<3; j++) mid[0][j]=(a[j]+b[j])/2;
    for(j=0; j<3; j++) mid[1][j]=(a[j]+c[j])/2;
    for(j=0; j<3; j++) mid[2][j]=(a[j]+d[j])/2;
    for(j=0; j<3; j++) mid[3][j]=(b[j]+c[j])/2;
    for(j=0; j<3; j++) mid[4][j]=(c[j]+d[j])/2;
    for(j=0; j<3; j++) mid[5][j]=(b[j]+d[j])/2;

    /* create 4 tetrahedrons by subdivision */
    divide_tetra(a, mid[0], mid[1], mid[2], m-1);
    divide_tetra(mid[0], b, mid[3], mid[5], m-1);
    divide_tetra(mid[1], mid[3], c, mid[4], m-1);
    divide_tetra(mid[2], mid[4], d, mid[5], m-1);
  }
  else(tetra(a,b,c,d)); /* draw tetrahedron at end of recursion */
}
```

```
void display()
{
  glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
  glBegin(GL_TRIANGLES);
  divide_tetra(v[0], v[1], v[2], v[3], n);
  glEnd();
  glFlush();
}

void myReshape(int w, int h)
{
  glViewport(0, 0, w, h);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  if (w <= h)
    glOrtho(-2.0, 2.0, -2.0 * (GLfloat) h / (GLfloat) w, 2.0 * (GLfloat) h / (GLfloat) w, -10.0, 10.0);
  else
    glOrtho(-2.0 * (GLfloat) w / (GLfloat) h, 2.0 * (GLfloat) w / (GLfloat) h, -2.0, 2.0, -10.0, 10.0);
  glMatrixMode(GL_MODELVIEW);
  glutPostRedisplay();
}

int main(int argc, char **argv)
{
  n=atoi(argv[1]); /* or enter number of subdivision steps here */
  glutInit(&argc, argv);
  glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB | GLUT_DEPTH); Z-buffer algorithm 사용
  glutInitWindowSize(500, 500);
  glutCreateWindow("3D Gasket");
  glutReshapeFunc(myReshape);
  glutDisplayFunc(display);
  glEnable(GL_DEPTH_TEST);
  glClearColor (1.0, 1.0, 1.0, 1.0);
  glutMainLoop();
}
```

RECAP - GLUT Coordinate Systems

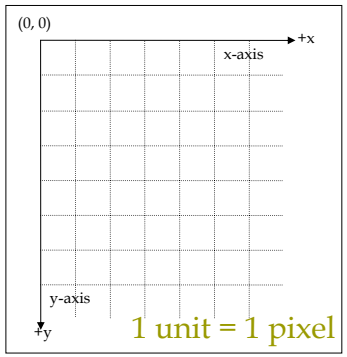
- Drawing commands that specify locations:
- glutInitWindowPosition
  - Position to open a new window at, given in "desktop screen pixel coordinates"
- glWindowPos
  - Position for glDrawPixels, given in "window pixel coordinates"
- glRasterPos
  - Position for glDrawPixels, given in "drawing coordinates"
- glVertex
  - Position of a shape's vertex, given in "drawing coordinates"

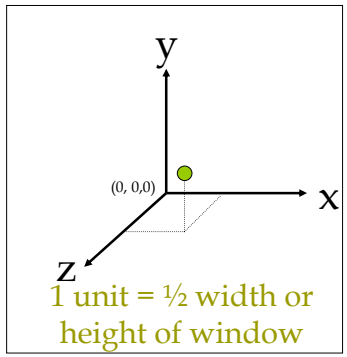
RECAP – GL/GLUT Coordinate Systems



RECAP – Coordinate Systems

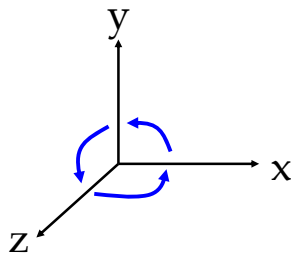
- Screen coordinate systems = GLUT mouse pointer coordinate systems
- OpenGL drawing coordinate systems





RECAP – RHS Coordinate Systems

- Right Hand Coordinate System (RHS) – z+가 화면 앞으로 튀어나오는 방향.
- Counter clockwise 방향으로 rotation을 함.
- X-축으로 rotation을 하면, Y->Z 방향의 회전이 positive
- Y-축으로 rotation을 하면, Z->X 방향의 회전이 positive
- Z-축으로 rotation을 하면, X->Y 방향의 회전이 positive



RECAP – LHS Coordinate Systems

- Left Hand Coordinate System (LHS) – z+가 화면안으로 들어가는 방향.
- Clockwise 방향으로 rotation을 함.
- X-축으로 rotation을 하면,
  Y->Z 방향의 회전이 positive
- Y-축으로 rotation을 하면,
  Z->X 방향의 회전이 positive
- Z-축으로 rotation을 하면,
  X->Y 방향의 회전이 positive