Programming with OpenGL Part 2: Complete Programs

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Objectives

- Refine the first program
  - Alter the default values
  - Introduce a standard program structure
- Simple viewing
  - Two-dimensional viewing as a special case of three-dimensional viewing
- Fundamental OpenGL primitives
- Attributes

Program Structure

- Most OpenGL programs have a similar structure that consists of the following functions
  - **`main()`**:
    - defines 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
  - callbacks
    - Display function
    - Input and window functions

Simple.c revisited

- In this version, we will see the same output but have defined all the relevant state values through function calls with the default values
- In particular, we set
  - Colors
  - Viewing conditions
  - Window properties

main.c

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

int main(int argc, char** argv)
{
 glutInit(&argc,argv);
 glutInitDisplayMode(GLUT_SINGLE|GLUT_RGB);
 glutInitWindowSize(500,500);
 glutInitWindowPosition(0,0);
 glutCreateWindow("simple");
 glutDisplayFunc(mydisplay);

 init();

 glutMainLoop();
}
```

includes `gl.h`

define window properties

display callback

set OpenGL state

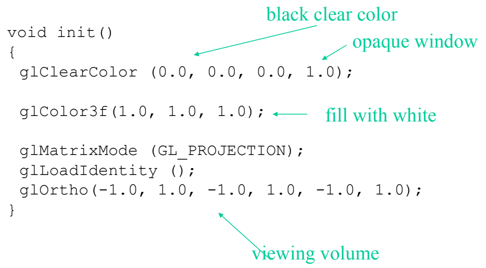
enter event loop

GLUT functions

- **`glutInit`** allows application to get command line arguments and initializes system
- **`gluInitDisplayMode`** requests properties of the window (the *rendering context*)
  - RGB color
  - Single buffering
  - Properties logically ORed together
- **`glutWindowSize`** in pixels
- **`glutWindowPosition`** from top-left corner of display
- **`glutCreateWindow`** create window with title “simple”
- **`glutDisplayFunc`** display callback
- **`glutMainLoop`** enter infinite event loop

`“Glu” is GL utility`

init.c



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

 glColor3f(1.0, 1.0, 1.0);

 glMatrixMode (GL_PROJECTION);
 glLoadIdentity ();
 glOrtho(-1.0, 1.0, -1.0, 1.0, -1.0, 1.0);
}
```

black clear color

opaque window

fill with white

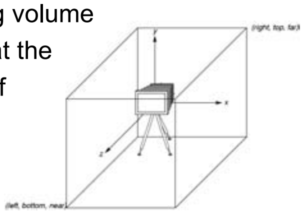
viewing volume

Coordinate Systems

- The units of in **`glVertex`** are determined by the application and are called *world* or *problem coordinates*
- The viewing specifications are also in world coordinates and it is the size of the viewing volume that determines what will appear in the image
- Internally, OpenGL will convert to *camera coordinates* and later to *screen coordinates*

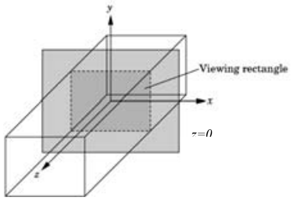
OpenGL Camera

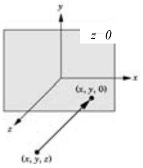
- OpenGL places a camera at the origin pointing in the negative z direction
- The default viewing volume is a box centered at the origin with a side of length 2



Orthographic Viewing

In the default orthographic view, points are projected forward along the z axis onto the plane $z=0$





Transformations and Viewing

- In OpenGL, the projection is carried out by a projection matrix (transformation)
- There is only one set of transformation functions so we must set the matrix mode first
  `glMatrixMode (GL_PROJECTION)`
- Transformation functions are incremental so we start with an identity matrix and alter it with a projection matrix that gives the view volume

```
glLoadIdentity ();
 glOrtho(-1.0, 1.0, -1.0, 1.0, -1.0, 1.0);
```

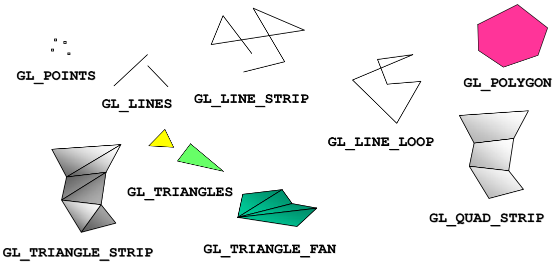
Two- and three-dimensional viewing

- In **`glOrtho(left, right, bottom, top, near, far)`** the near and far distances are measured from the camera
- Two-dimensional vertex commands place all vertices in the plane z=0
- If the application is in two dimensions, we can use the function
  `gluOrtho2D(left, right,bottom,top)`
- In two dimensions, the view or clipping volume becomes a *clipping window*

mydisplay.c

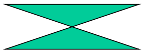
```
void mydisplay()
{
 glClear(GL_COLOR_BUFFER_BIT);
 glBegin(GL_POLYGON);
     glVertex2f(-0.5, -0.5);
     glVertex2f(-0.5, 0.5);
     glVertex2f(0.5, 0.5);
     glVertex2f(0.5, -0.5);
 glEnd();
 glFlush();
}
```

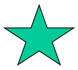
OpenGL Primitives



Polygon Issues

- OpenGL will only display polygons correctly that are
  - Simple: edges cannot cross
  - Convex: All points on line segment between two points in a polygon are also in the polygon
  - Flat: all vertices are in the same plane
- User program must check if above true
- Triangles satisfy all conditions


nonsimple polygon

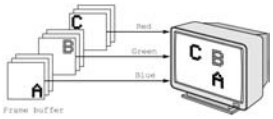

nonconvex polygon

Attributes

- Attributes are part of the OpenGL and determine the appearance of objects
  - Color (points, lines, polygons)
  - Size and width (points, lines)
  - Stipple pattern (lines, polygons)
  - Polygon mode
    - Display as filled: solid color or stipple pattern
    - Display edges

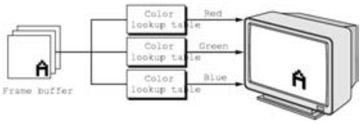
RGB color

- Each color component stored separately in the frame buffer
- Usually 8 bits per component in buffer
- Note in **`glColor3f`** the color values range from 0.0 (none) to 1.0 (all), while in **`glColor3ub`** the values range from 0 to 255



Indexed Color

- Colors are indices into tables of RGB values
- Requires less memory
  - indices usually 8 bits
  - (not as important as when OpenGL was formed)
    - Memory inexpensive
    - Need more colors for shading



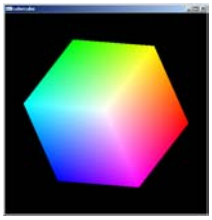
Color and State

- The color as set by **`glColor`** becomes part of the state and will be used until changed
  - Colors and other attributes are not part of the object but are assigned when the object is rendered
- We can create conceptual *vertex colors* by code such as

```
glColor
glVertex
glColor
glVertex
```

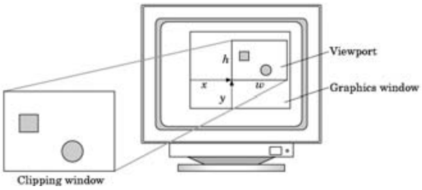
Smooth Color

- Default is *smooth* shading
  - OpenGL interpolates vertex colors across visible polygons
- Alternative is *flat shading*
  - Color of first vertex determines fill color
- **`glShadeModel`**
  `(GL_SMOOTH)`
  or **`GL_FLAT`**



Viewports

- Do not have use the entire window for the image: **`glViewport(x,y,w,h)`**
- Values in pixels (screen coordinates)


Viewport
Graphics window
h
x
w
y
Clipping window