Programming with OpenGL
Part 2: Complete Programs

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Objectives

- Build a complete first program
  - Introduce shaders
  - Introduce a standard program structure
- Simple viewing
  - Two-dimensional viewing as a special case of three-dimensional viewing
- Initialization steps and program structure

Program Structure

- Most OpenGL programs have a similar structure that consists of the following functions
  - **`main()`**:
    - specifies 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
  - **`initShader()`**: read, compile and link shaders
  - callbacks
    - Display function
    - Input and window functions

simple.c revisited

- **`main()`** function similar to last lecture
  - Mostly GLUT functions
- init() will allow more flexible colors
- initShader() will hides details of setting up shaders for now
- Key issue is that we must form a data array to send to GPU and then render it

main.c

```
#include <GL/glew.h>
#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);
  glewInit();
  init();
  glutMainLoop();
}
```

includes `gl.h`

specify window properties

display callback

set OpenGL state and initialize shaders

enter event loop

GLUT functions

- **glutInit** allows application to get command line arguments and initializes system
- **gluInitDisplayMode** requests properties for 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

Immediate Mode Graphics

- Geometry specified by vertices
  - Locations in space(2 or 3 dimensional)
  - Points, lines, circles, polygons, curves, surfaces
- Immediate mode
  - Each time a vertex is specified in application, its location is sent to the GPU
  - Old style uses **`glVertex`**
  - Creates bottleneck between CPU and GPU
  - Removed from OpenGL 3.1

Retained Mode Graphics

- Put all vertex and attribute data in array
- Send array to GPU to be rendered immediately
- Almost OK but problem is we would have to send array over each time we need another render of it
- Better to send array over and store on GPU for multiple renderings

Display Callback

- Once we get data to GLU, we can initiate the rendering with a simple callback

```
void mydisplay()
{
   glClear(GL_COLOR_BUFFER_BIT);
   glDrawArrays(GL_TRIANGLES, 0, 3);
   glFlush();
}
```

- Arrays are buffer objects that contain vertex arrays

Vertex Arrays

- Vertices can have many attributes
    - Position
    - Color
    - Texture Coordinates
    - Application data
- A vertex array holds these data
- Using types in **`vec.h`**

```
point2 vertices[3] = {point2(0.0, 0.0),
      point2( 0.0, 1.0), point2(1.0, 1.0)};
```

Vertex Array Object

- Bundles all vertex data (positions, colors, ..,)
- Get name for buffer then bind

```
Glunit abuffer;
glGenVertexArrays(1, &abuffer);
glBindVertexArray(abuffer);
```

- At this point we have a current vertex array but no contents
- Use of glBindVertexArray lets us switch between VBOs

Buffer Object

- Buffers objects allow us to transfer large amounts of data to the GPU
- Need to create, bind and identify data

```
Gluint buffer;
glGenBuffers(1, &buffer);
glBindBuffer(GL_ARRAY_BUFFER, buffer);
glBufferData(GL_ARRAY_BUFFER,
          sizeof(points), points);
```

- Data in current vertex array is sent to GPU

Initialization

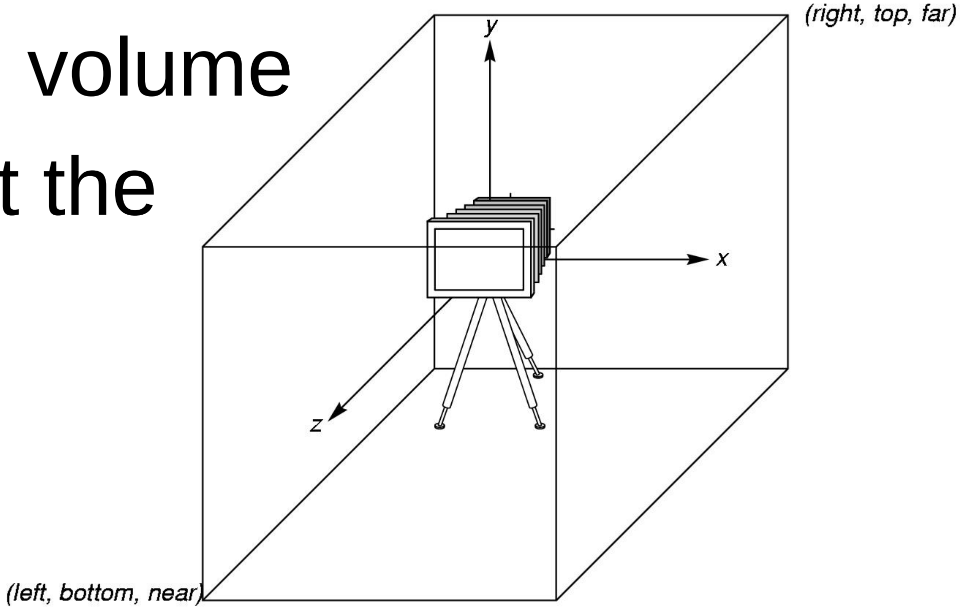
- Vertex array objects and buffer objects can be set up on **init()**
- Also set clear color and other OpeGL parameters
- Also set up shaders as part of initialization
  - Read
  - Compile
  - Link
- First let’s consider a few other issues

Coordinate Systems

- The units in `points` are determined by the application and are called *object, world, model* or *problem coordinates*
- Viewing specifications usually are also in object coordinates
- Eventually pixels will be produced in *window coordinates*
- OpenGL also uses some internal representations that usually are not visible to the application but are important in the shaders

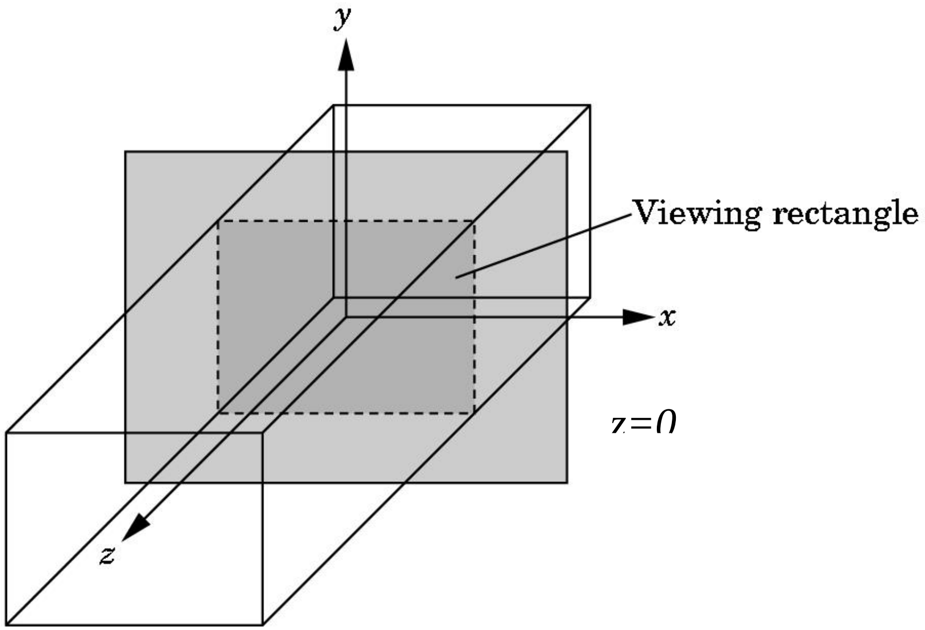
OpenGL Camera

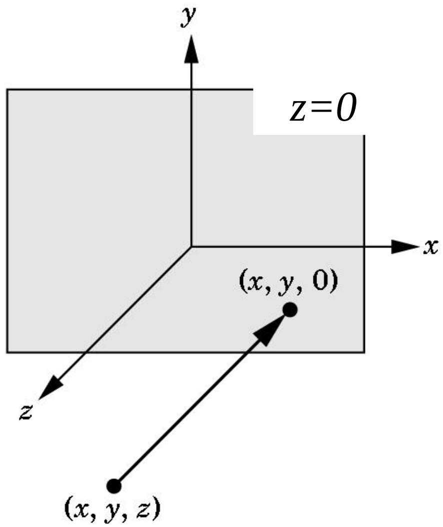
- OpenGL places a camera at the origin in object space pointing in the negative z direction
- The default viewing volume is a box centered at the origin with sides of length 2



Orthographic Viewing

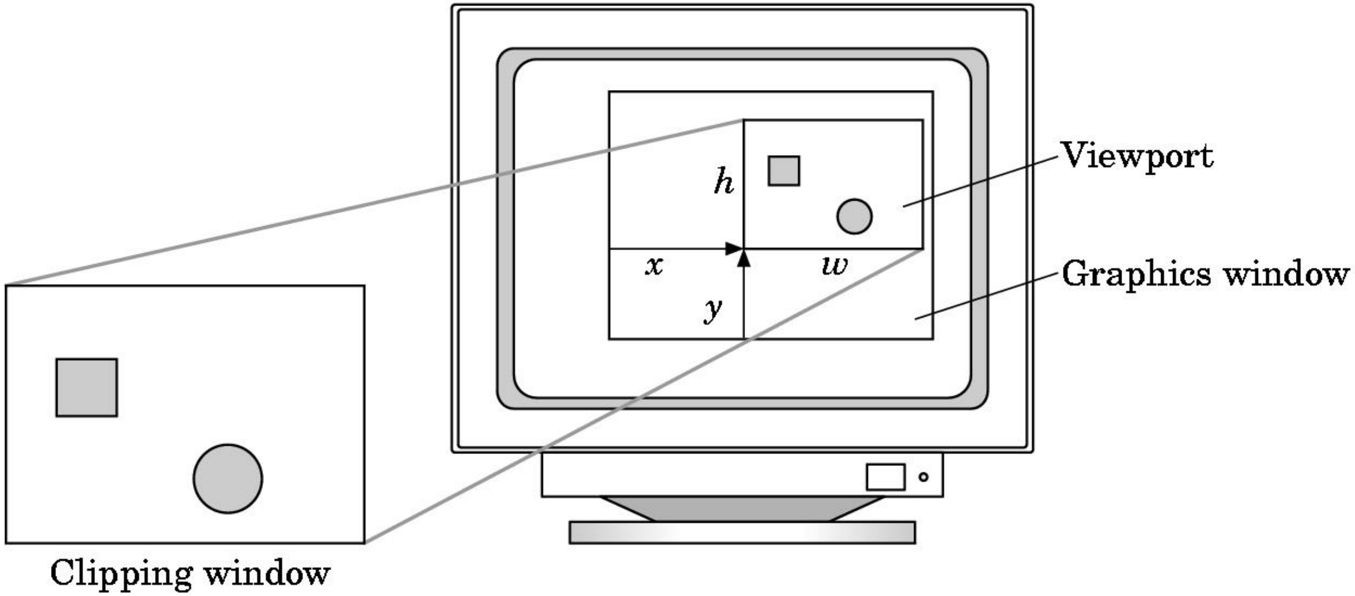
In the default orthographic view, points are projected forward along the z axis onto the plane $z=0$





Viewports

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



Transformations and Viewing

- In OpenGL, projection is carried out by a projection matrix (transformation)
- Transformation functions are also used for changes in coordinate systems
- Pre 3.0 OpenGL had a set of transformation functions which have been deprecated
- Three choices
  - Application code
  - GLSL functions
  - vec.h and mat.h