Viewing

Chapter 5

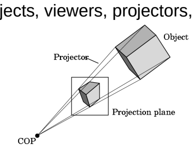
- Introduction:
  - We have completed our discussion of the first half of the synthetic camera model
    - specifying objects in three dimensions
  - We now investigate the multitude of ways in which we can describe our virtual camera.
    - First, we look at the types of views we can create, and why we need more than one type of view.
    - Then we examine how an application viewer can create a particular view in within OpenGL.

1. Classical Computer Viewing

- Before looking at the interface between computer graphics systems and application programmers for 3D viewing, we take a slight diversion to consider classical viewing.
  - There are two reasons to do this
    - First, many jobs that were formerly done by hand drawing - such as animation in movies, architectural rendering, .. Are now done routinely with the aid of compute graphics.
      - Practitioners of these fields need to produce classical views.

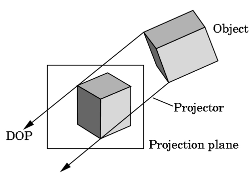
- Second, the relationship between classical and computer viewing shows many advantages of, and a few difficulties with, the approach used by most APIs.

- When we introduced the synthetic camera model in Chapter 1, we covered some elements:
  - objects, viewers, projectors, and a projection plane



  - The projectors meet at the center of projection (COP)
    - this corresponds to the center of the lens in the camera, or in the eye

- Both classical and computer graphics allow the viewer to be an infinite distance from the objects
  - Note, as we move the COP to infinity, the projectors become parallel and the COP can be replaced with a direction of projection (DOP)

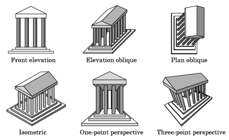


- Although computer graphics systems have two fundamental types of viewing
  - (parallel and perspective),
- classical graphics appears to permit a host of different views ranging from:
  - multiview orthographic projections, one- two- and three-point perspectives

- This seeming discrepancy arises
  - in classical graphics due to the desire to show a specific relationship among an object, the viewer, and the projection plane
  - as opposed to the computer graphics approach of complete independence of all specifications

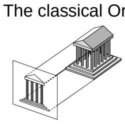
1.1 Classical Viewing

- When an architect draws an image of a building,
  - they know which sides they wish to display,
  - and thus where they should place the viewer
- Each classical view is determined by a specific relationship between the objects and the viewer.

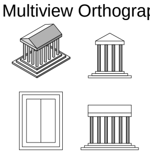


1.2 Orthographic Projections

- The classical Orthographic projection

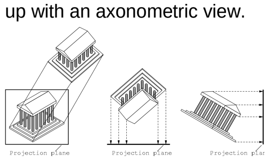


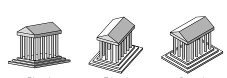
- Multiview Orthographic projections



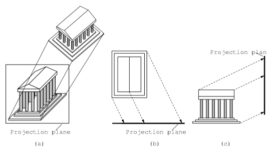
1.3 Axonometric Projections

- If we allow the projection plane to be at any angle (not just parallel with a face of the object) we end up with an axonometric view.

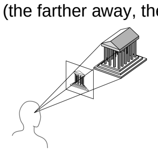




- 1.4 Oblique Projections
  - These are the most general parallel views
    - projectors can make an arbitrary angle with the projection plane.



- 1.5 Perspective Viewing
  - All perspective views are characterized by diminution of size.
    - (the farther away, the smaller they are)

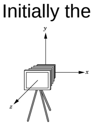


2. Positioning of the Camera

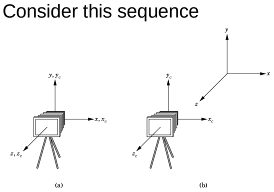
- We can now return to 3D graphics from a computer perspective
  - We now examine the API that OpenGL provides for three-dimensional graphics, and show how other APIs differ
  - In this section we deal with positioning the camera.
  - In Section 5.4 we discuss how we specify the desired projection.

- In OpenGL, the model-view and projection matrices are concatenated together to form the matrix that applies to geometric entities such as vertices.
  - We have seen how to use the model-view matrix
    - to position objects in space.
  - The other is to convert from the reference frame used for modeling to the frame of the camera

■ 2.1 Positioning of the Camera Frame
- Initially the camera is at the origin



- Consider this sequence

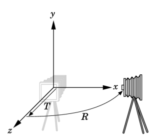


- At any given time, the state of the model-view matrix encapsulates the relation between the camera frame and the world frame.
- Although combining the modeling and viewing transformations into a single matrix may initially cause confusion, on closer examination this approach is a good one.
- The obvious next problems are how we specify the desired position of the camera and how we implement camera positioning in OpenGL

- Here, we find it convenient to think in terms of moving the default camera relative tot he world frame.
- We will outline three approaches to this.

- The First Approach:
  - Specify the position indirectly by applying a sequence of rotations and translations to the model-view matrix
  - This is a direct application of the instance transformations we presented in Chapter 4

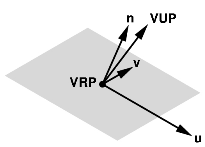
- We must be careful for two reasons:
  - First, we usually want to define the camera *before* we position the objects in the scene.
  - Second, transformations on the camera may appear to be backward from what we might expect.



  - glMatrixMode(GL_MODELVIEW);
  - glLoadIdentity( );
  - glTranslatef(0.0, 0.0, -d);
  - glRotatef(-90.0, 0.0, 1.0, 0.0)

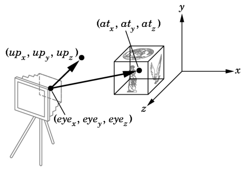
■ 2.2 Two Viewing APIs

- We can take a different approach to positioning the camera -- an approach used by PHIGS, ...
  - We describe the camera's position and orientation in the world frame
    - It's desired location is centered at the view-reference point (VRP)
    - It's orientation is specified with the view-plane normal (VPN) and the view-up vector (VUP)



■ 2.3 The Look-At Function

- The use if the VRP, VPN, and VUP is but one way to provide an API for specifying the position of a camera.
  - In many situations, a more direct method is appropriate.



  - gluLookAt(eyex, eyey, eyez, atx, aty, atz, upx, upy, upz);

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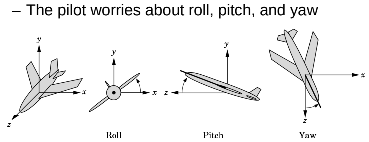
■ 2.4 Other Viewing APIs

- In many applications, neither of the viewing interfaces that we have presented is appropriate.
  - Consider a flight simulator:
    - The pilot worries about roll, pitch, and yaw



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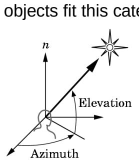
- Viewing in many applications is most naturally specified in polar coordinates -- rather than rectilinear coordinates.
  - Applications involving objects that rotate about other objects fit this category.



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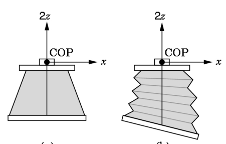
3. Simple Projections

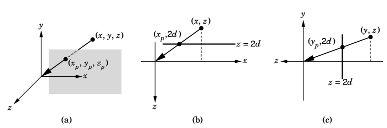
- With a real camera, once we position it, we still must select a lens.
  - In computer graphics we select the type of lens and the size of the film by selecting the type of projection and the viewing parameters.
- Most APIs distinguish between parallel and perspective views by providing different functions for the two cases.
  - In OpenGL we can set the projection matrix with a glLoadMatrix function, or we can other functions for the most common viewing conditions

■ 3.1 Perspective Projections

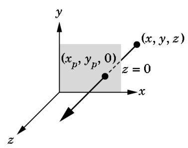
- Suppose that we are in the camera frame with the camera located at the origin pointed in the negative z direction.



- As we saw in Chapter 2, we can place the projection plane in front of the center of projection. If we do so, we get the following views:

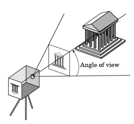


- 3.2 Orthogonal Projections
  - Orthogonal or orthographic projections are a special case of parallel projections, in which the projectors are perpendicular to the view of the plane.

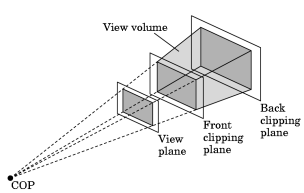


4. Projections in OpenGL

- The projections we just developed did not take into account the properties of the camera:
  - the focal length of its lens,
  - the size of the film plane
- View Volume

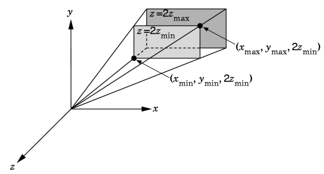


- Most graphics APIs define clipping parameters through the specification of a projection.
- The resulting view volume is a frustum -- which is a truncated pyramid.



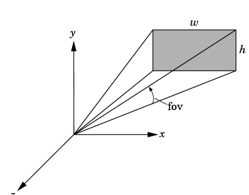
■ 4.1 Perspectives in OpenGL

- In OpenGL we have two functions for specifying perspective views and one for specifying parallel views.
- We can specify our camera view by:
  - glFrustrum(xmin, xmax, ymin, ymax, near, far)



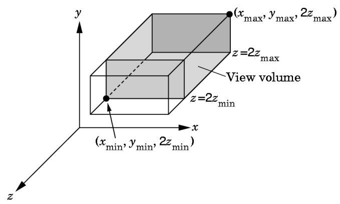
- Because the projection matrix determined by these specifications multiplies the present matrix, we must first select the matrix mode.
-
  - A typical sequence is
    - glMatrixMode(GL_PROJECTION);
    - glLoadIdentity( );
    - glFrustrum(xmin, xmax, ymin, ymax, near, far);

- In many applications, it is natural to specify the angle or field of view
- gluPerspective(fovy, aspect, near, far);



■ 4.2 Parallel Viewing in OpenGL

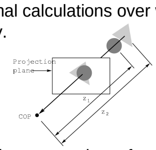
- The only parallel-viewing function provided by OpenGL is the orthographic viewing function
  - glOrtho(xmin, xmax, ymin, ymax, near, far)



5. Hidden-Surface Removal

- Hidden surface removal algorithms can be divided into two broad classes:
  - Object-space algorithms
    - attempt to order the surfaces of the objects in the scene such that drawing surfaces in a particular order provides the correct image.
  - Image-space algorithms
    - work as part of the projection process and seek to determine the relationship among object points on each projector
    - z-buffer fits into this category.

- The major advantage of z-buffer is
  - that its worst case complexity is proportional to the number of polygons.
  - It can be implemented with a small number of additional calculations over what we have to do anyway.



  - Typically you use these functions:
    - glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
    - glEnable(GL_DEPTH_TEST);
    - glClear(GL_DEPTH_BUFFER_BIT);

6. Walking Through a Scene

- Let us modify the version of our color-cube program from Chapter 4
  - Old Version:
    - the cube rotated about the origin.
    - Orthographic projection
  - In this version
    - perspective projection
    - allow the camera to move.


```
void keys(unsigned char key, int x, int y)
{
   if(key == ‘x’) viewer[0] -= 1.0;
   if(key == ‘X’) viewer[0] += 1.0;
   if(key == ‘y’) viewer[1] -= 1.0;
   if(key == ‘Y’) viewer[1] += 1.0;
   if(key == ‘z’) viewer[2] -= 1.0;
   if(key == ‘Z’) viewer[2] += 1.0;
}
```



```
void display(void)
{
   glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
   glLoadIdentity( );
   gluLookAt(viewer[0], viewer[1], viewer[2],
             0.0, 0.0, 0.0, 0.0, 1.0 , 0.0);
   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( );
}
```

```
void myReshape(int w, int h)
{
  glViewport(0,0,w,h);
  glLoadMatrix(GL_PROJECTION);
  glLoadIdentity( );
  if(w<=h)
    glFrustrum(-2.0, 2.0, -2.0 * (Glfloat)h/(Glfloat)w,
                  2.0*(Glfloat(h)/(Glfloat)w, 2.0, 20.0);
  else
    glFrustrum(-2.0, 2.0, -2.0 * (Glfloat)w/(Glfloat)h,
                  2.0*(Glfloat)w/(Glfloat)h, 2.0, 20.0);
  glMatrixMode(GL_MODELVIEW);
}
```


9. Projections and Shadows

- The creation of simple shadows is an interesting application of projection matrices.
- This section covers how to re-project the polygon casting the shadow onto the ground
  - this re-projection is called a shadow polygon.

- For a simple environment, this technique works well, however, when objects cast shadows on other objects, this method becomes impractical.
- In chapter 9 we address a more general shadow-creation method that requires more work.

10. Summary

- We have come a long way.
  - We can now write complete, nontrivial, three dimensional applications.
  - Probably the most instructive activity that you can do now is to write such an application.
- In Chapter 6 we consider the interaction of light with the materials that characterize our objects.

11. Suggested Readings

- Foley (90), Watt (93) and Hern&Baker (94) derive canonical projection transformations
  - All follow the PHIGS orientation, so the API is slightly different from the one used here.
    - Most differ in whether they use column or row matrices, in where the COP is located, and in whether the projection is in the positive or negative z direction.
- See the *OpenGL Programmer's Guide* (97) for further discussion of the use of the model-view and projection matrices

Exercises -- Due next class