# The View Frustum

## Lecture 9
## Sections 2.6, 5.1, 5.2

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Wed, Sep 14, 2011

# Outline

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# The View Frustum

**Definition (Frustum)**

A frustum is a truncated pyramid.

**Definition (The View Frustum)**

The view frustum is the region of world coordinate space that contains the part of the scene that will be rendered.

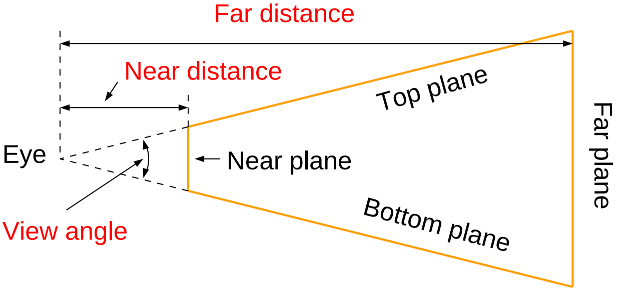
- The view frustum is bounded by six planes.
  - Left and right planes
  - Top and bottom planes
  - Near and far planes

# Outline

# Creating the View Frustum

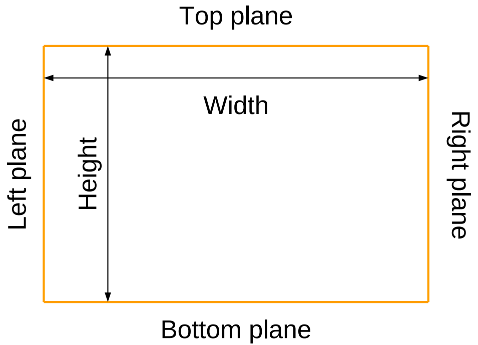
- The function `gluPerspective()` establishes the size and shape (but not the position) of the view frustum.
- It takes four parameters.
  - The vertical view angle.
  - The aspect ratio (width/height).
  - The distance to the near plane.
  - The distance to the far plane.
- This function produces the projection matrix and multiplies it by the current projection matrix.

# Creating the View Frustum




Side view of the view frustum.

# Creating the View Frustum




Aspect Ratio = Width/Height

Front view of the view frustum, from the eye point.

# Creating the View Frustum

- The aspect ratio is the width divided by the height.
- Typical aspect ratios are $4/3$ and $5/4$.
- For example, if the screen has a resolution of $1024 \times 768$, then its aspect ratio is $4/3$.

```
gluPerspective(45.0, 4.0/3.0, 1.0, 1000.0);
```

# Creating the View Frustum

**Example (Creating the View Frustum)**

```
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
gluPerspective(45.0, 4.0/3.0, 1.0, 1000.0);
```

# Creating the View Frustum

- The view frustum for a perspective projection may also be created using the function `glFrustum()`.

```
glFrustum(left, right, bottom, top,
    near, far);
```

- *left*, *right*, *top*, and *bottom* are the $x$ and $y$ boundary values at the near plane.
- *near* and *far* are always given as positive distances from the viewpoint.

# Outline

# Orthogonal Projections

- The view frustum produces a perspective view on the screen.
  - The eye is at the center of the projection.
- On the other hand, an orthogonal projection projects along parallel lines.
  - It is as though the view point is at infinity.

# Orthogonal Projections

- To create an orthogonal projection, use `gluOrtho()` instead of `gluPerspective()`.

```
glOrtho(left, right, bottom, top,
    near, far);
```

- Again, *near* and *far* are always given as positive distances from the viewpoint.
- *left*, *right*, *top*, and *bottom* are the $x$ and $y$ coordinates of the planes.

# Perspective and Orthogonal Projections

## Example (Perspective and Orthogonal Projections)

- The code.
- The executable.

# Outline

# Positioning the View Frustum

- The function `gluLookAt()` positions the view frustum in space.
- It takes nine parameters, representing two points and a vector, expressed in world coordinates.
  - The eye point, or position of the camera.
  - The look point.
  - The up vector, or orientation.

# Positioning the View Frustum

- In eye coordinates,
  - The eye point is at $(0, 0, 0)$,
  - The look point is $(0, 0, -1)$,
  - The up vector is $(0, 1, 0)$.
- The `gluLookAt()` function computes the transformation matrix from world coordinates to eye coordinates.

# Positioning the View Frustum

- In world coordinates,
  - The eye point is wherever we want the camera to be.
  - The look point is often the origin.
  - The up vector is almost always $(0, 1, 0)$.

```
gluLookAt(5.0, 2.0, 5.0,
          0.0, 0.0, 0.0,
          0.0, 1.0, 0.0);
```

# Positioning the View Frustum

- In world coordinates,
  - The eye point is wherever we want the camera to be.
  - The look point is often the origin.
  - The up vector is almost always $(0, 1, 0)$.

```
gluLookAt(5.0, 2.0, 5.0,
          0.0, 0.0, 0.0,
          0.0, 1.0, 0.0);
```

# Positioning the View Frustum

- In world coordinates,
  - The eye point is wherever we want the camera to be.
  - The look point is often the origin.
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```
gluLookAt(5.0, 2.0, 5.0,
          0.0, 0.0, 0.0,
          0.0, 1.0, 0.0);
```

# Positioning the View Frustum

- In world coordinates,
  - The eye point is wherever we want the camera to be.
  - The look point is often the origin.
  - The up vector is almost always $(0, 1, 0)$.

```
gluLookAt(5.0, 2.0, 5.0,
          0.0, 0.0, 0.0,
          0.0, 1.0, 0.0);
```

# Outline

# The View Matrix

- The `gluLookAt()` function creates the view matrix and multiplies the current matrix by it.
- The result is the modelview matrix.
- In a literal sense, it "moves" the entire scene, thereby creating the illusion that the camera has moved.

# The View Matrix

- For this reason, it is important to call `gluLookAt()`
  - *after* loading the identity matrix and
  - *before* performing any other transformations.
- Typically, this is one of the first things done in the `display()` function.

# Outline

# Controlling the Camera Position

- The camera may be movable or fixed.
- If it is movable, then it is usually controlled by spherical coordinates with the look point at the center.
  - Distance from the look point (`camDist`).
  - Pitch angle (`camPitch`).
  - Yaw angle (`camYaw`).

# Controlling the Camera Position

- The following formulas compute the $x$, $y$, and $z$ coordinates of the camera.

$$\begin{aligned} x &= r\cos\varphi\sin\theta \\ y &= r\sin\varphi \\ z &= r\cos\varphi\cos\theta \end{aligned}$$

where $r$ = distance, $\varphi$ = pitch angle, and $\theta$ = yaw angle.

# Controlling the Eye Position

## Example (Controlling the Eye Position)

```
//  Convert degrees to radians
    float yaw = camYaw*PI/180.0;
    float pitch = camPitch*PI/180.0;

//  Compute rectangular coordinates
    float eye.x = camDist*cos(pitch)*sin(yaw);
    float eye.y = camDist*sin(pitch);
    float eye.z = camDist*cos(pitch)*cos(yaw);

//  Position the camera
    gluLookAt(eye.x, eye.y, eye.z,
         look.x, look.y, look.z,
         0.0, 1.0, 0.0);
```

# The keyboard() Function

## Example (The keyboard() Function)

```
void keyboard(unsigned char key, int x, int y)
{
    switch (key)
    {
        case '+': case '=':
            camDist /= zoomFactor;
            break;
        case '-': case '_':
            camDist *= zoomFactor;
            break;
                :
    }
    glutPostRedisplay();
    return;
}
```

# The `special()` Function

## Example (The `special()` Function)

```
void special(int key, int x, int y)
{
    switch (key)
    {
        case GLUT_KEY_LEFT:
            camYaw -= yawIncr;
            break;
        case GLUT_KEY_RIGHT:
            camYaw += yawIncr;
            break;
                  ⋮
    }
    glutPostRedisplay();
    return;
}
```

# Controlling the Camera Position

## Example (Controlling the Camera Position)

- The code.
- The executable.

# Controlling the Look Point

- In a similar way we can control the look point instead of the camera location.
- The mouse to make the camera to pan left, right, up, or down.
- The $+$ and $-$ keys move the camera (and the look point) forward or backward.
- How do we calculate the $x$, $y$, and $z$ coordinates of the look point?

# Controlling the Look Point

**Example (Controlling the Look Point)**

- The code.
- The executable.

# Outline

# Homework

## Homework

- Read Section 2.6 – orthographic viewing.
- Read Sections 5.1 - 5.2 – perspective viewing.