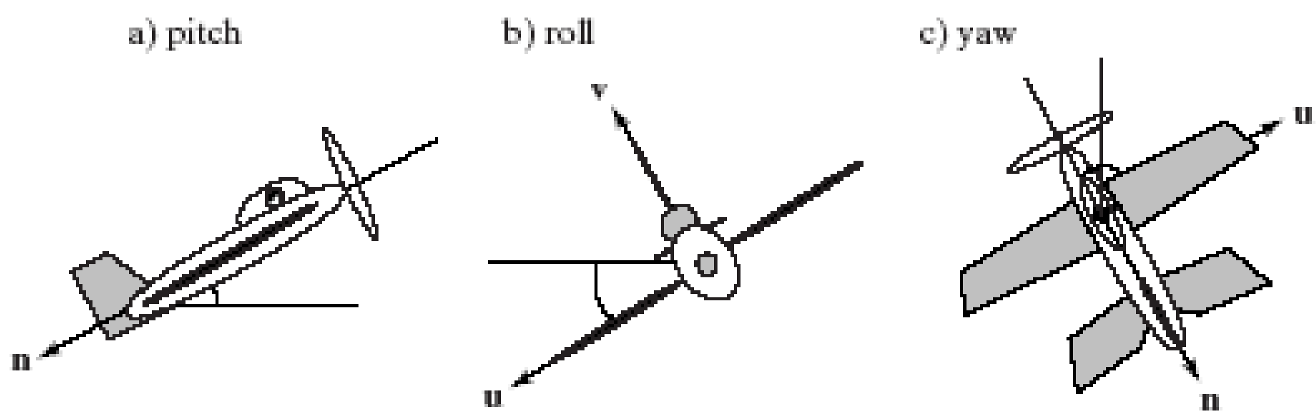
Other Camera Controls

- The LookAt function is only for positioning camera
- Other ways to specify camera position/movement
  - Yaw, pitch, roll
  - Elevation, azimuth, twist
  - Direction angles

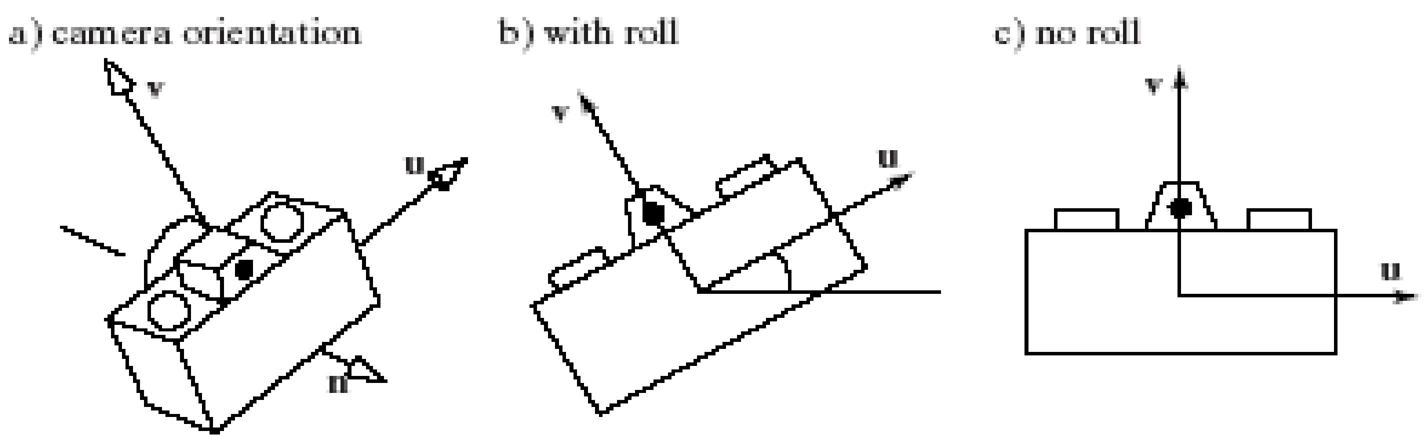
Flexible Camera Control

- Sometimes, we want camera to move
- Like controlling an airplane’s orientation
- Adopt aviation terms:
  - **Pitch:** nose up-down
  - **Roll:** roll body of plane
  - **Yaw:** move nose side to side



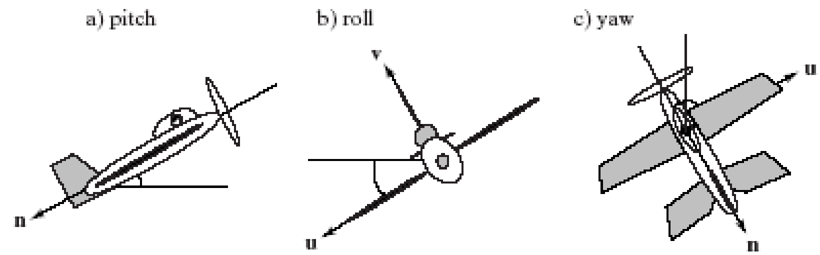
Yaw, Pitch and Roll Applied to Camera

- Similarly, yaw, pitch, roll with a camera



Flexible Camera Control

- Create a **camera** class



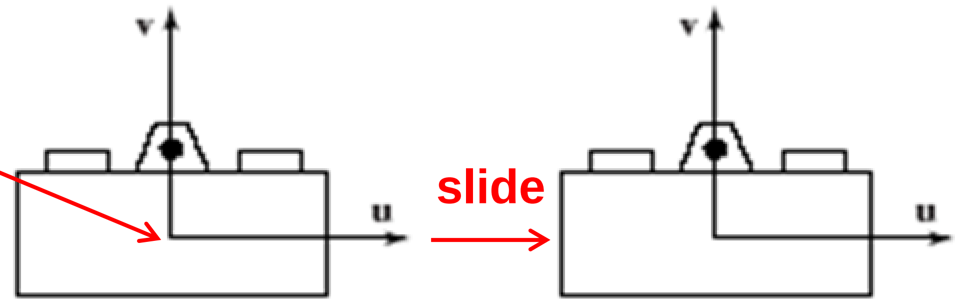

```
class Camera
   private:
        Point3 eye;
        Vector3 u, v, n;…. etc
```

- Camera functions to specify pitch, roll, yaw. E.g

```
cam.slide(1, 0, 2); // slide camera backward 2 and  right 1
cam.roll(30);   // roll camera 30 degrees
cam.yaw(40);   // yaw it 40 degrees
cam.pitch(20);  // pitch it 20 degrees
```

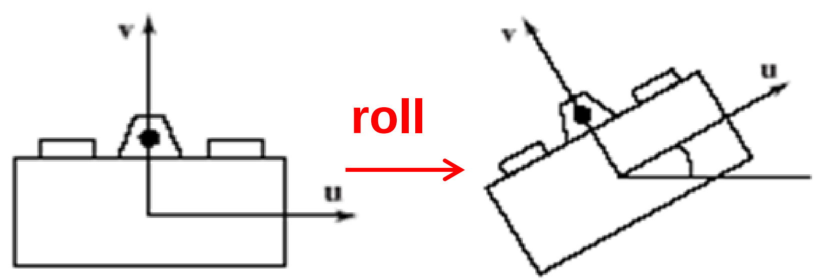
Recall: Final LookAt Matrix

- Slide along u, v or n
- Changes eye position
- Changes these components



$$\begin{vmatrix} ux & uy & uz & -\mathbf{e}\cdot\mathbf{u} \\ vx & vy & vz & -\mathbf{e}\cdot\mathbf{v} \\ nx & ny & nz & -\mathbf{e}\cdot\mathbf{n} \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

- Pitch, yaw, roll rotates u, v or n
- Changes u, v or n



Implementing Flexible Camera Control

- Camera class: maintains current (u,v,n) and eye position

```
class Camera
private:
        Point3 eye;
        Vector3 u, v, n;…. etc
```

- User inputs desired roll, pitch, yaw angle or slide
  1. Roll, pitch, yaw: calculate modified vector (u’, v’, n’)
  2. Slide: Calculate new eye position
  3. Update lookAt matrix, Load it into CTM

Example: Camera Slide

- Recall: the axes are unit vectors
- User changes eye by delU, delV or delN
- eye = eye + changes (delU, delV, delN)
- Note: function below combines all slides into one

  E.g moving camera by ***D*** along its u axis = **eye + *D*u**

```
void camera::slide(float delU, float delV, float delN)
{
   eye.x += delU*u.x + delV*v.x + delN*n.x;
   eye.y += delU*u.y + delV*v.y + delN*n.y;
   eye.z += delU*u.z + delV*v.z + delN*n.z;
   setModelViewMatrix( );
}
```

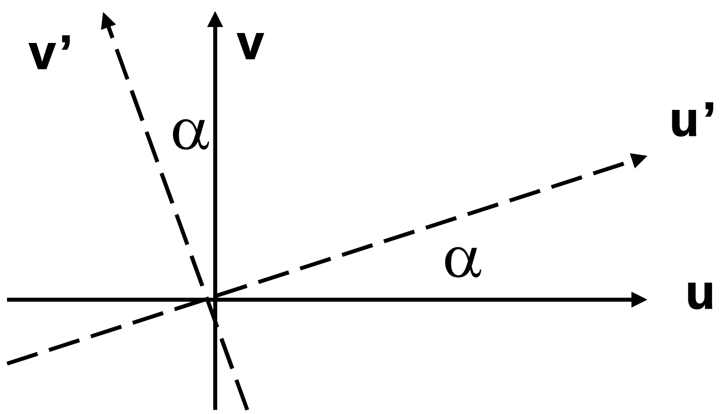
Load Matrix into CTM

$$\begin{pmatrix} ux & uy & uz & -\mathbf{e}\cdot\mathbf{u} \\ vx & vy & vz & -\mathbf{e}\cdot\mathbf{v} \\ nx & ny & nz & -\mathbf{e}\cdot\mathbf{n} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
void Camera::setModelViewMatrix(void)
{  // load modelview matrix with camera values
   mat4 m;
   Vector3 eVec(eye.x, eye.y, eye.z);// eye as vector
   m[0] = u.x; m[4] = u.y; m[8] = u.z;  m[12] = -dot(eVec,u);
   m[1] = v.x; m[5] = v.y; m[9] = v.z;  m[13] = -dot(eVec,v);
   m[2] = n.x; m[6] = n.y; m[10] = n.z; m[14] = -dot(eVec,n);
   m[3] = 0;   m[7] = 0;   m[11] = 0;   m[15] = 1.0;
   CTM = m; // Finally, load matrix m into CTM Matrix
}
```

- Slide changes **eVec**,
- roll, pitch, yaw, change **u, v, n**
- Call setModelViewMatrix after slide, roll, pitch or yaw

Example: Camera Roll



$$\mathbf{u}' = \cos(\alpha)\mathbf{u} + \sin(\alpha)\mathbf{v}$$

$$\mathbf{v}' = -\sin(\alpha)\mathbf{u} + \cos(\alpha)\mathbf{v}$$

```
void Camera::roll(float angle)
{  // roll the camera through angle degrees
   float cs = cos(3.142/180 * angle);
   float sn = sin(3.142/180 * angle);
   Vector3 t = u; // remember old u
   u.set(cs*t.x – sn*v.x, cs*t.y – sn.v.y, cs*t.z – sn.v.z);
   v.set(sn*t.x + cs*v.x, sn*t.y + cs.v.y, sn*t.z + cs.v.z)
   setModelViewMatrix( );
}
```

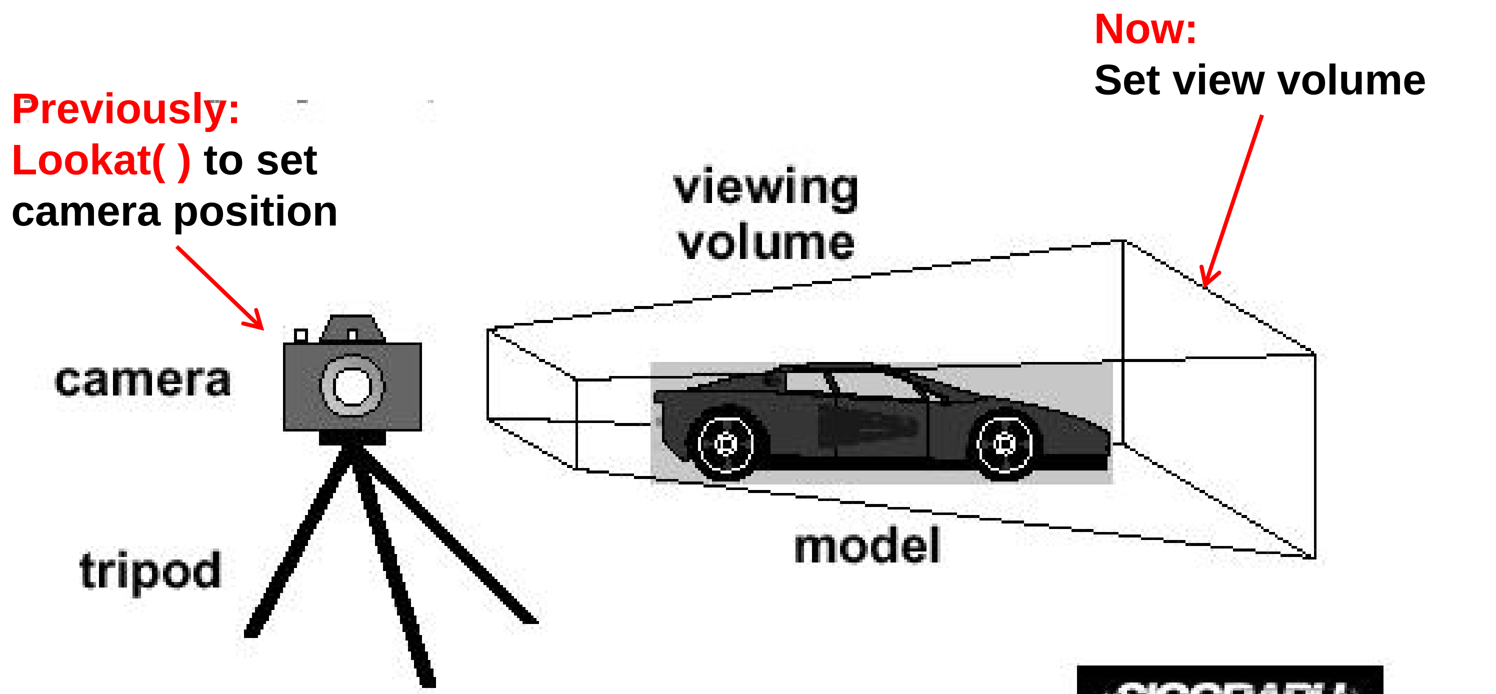
Computer Graphics (CS 4731)
Lecture 14: Projection (Part I)

Prof Emmanuel Agu

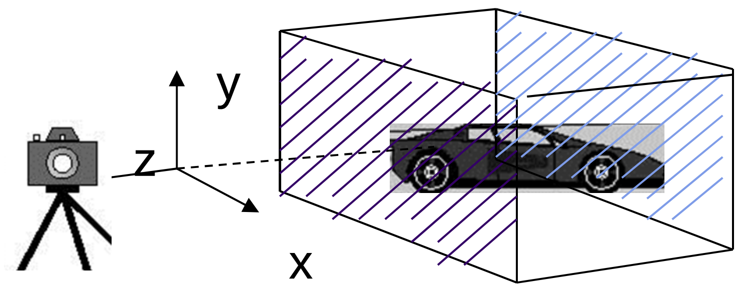
Computer Science Dept.

Worcester Polytechnic Institute (WPI)

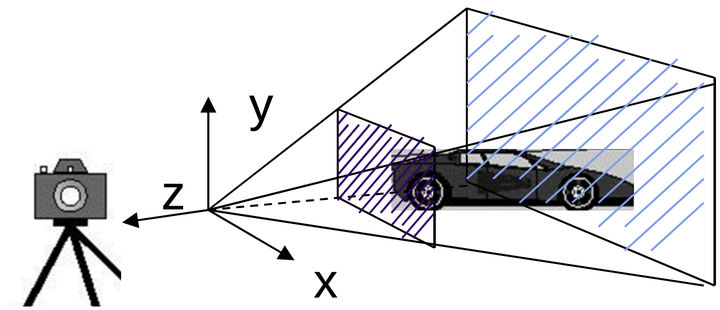
Recall: 3D Viewing and View Volume



Recall: Different View Volume Shapes



Orthogonal view volume
(no foreshortening)



Perspective view volume
(exhibits foreshortening)

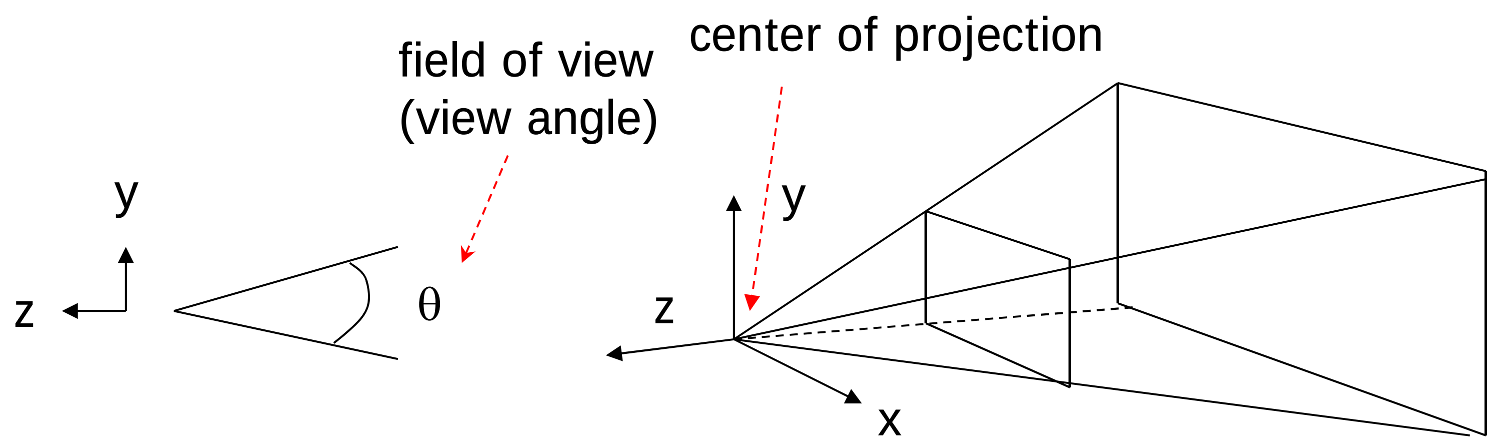
- Different view volume => different look
- **Foreshortening?** Near objects bigger

View Volume Parameters

- Need to set view volume parameters
  - **Projection type:** perspective, orthographic, etc.
  - Field of view and aspect ratio
  - Near and far clipping planes

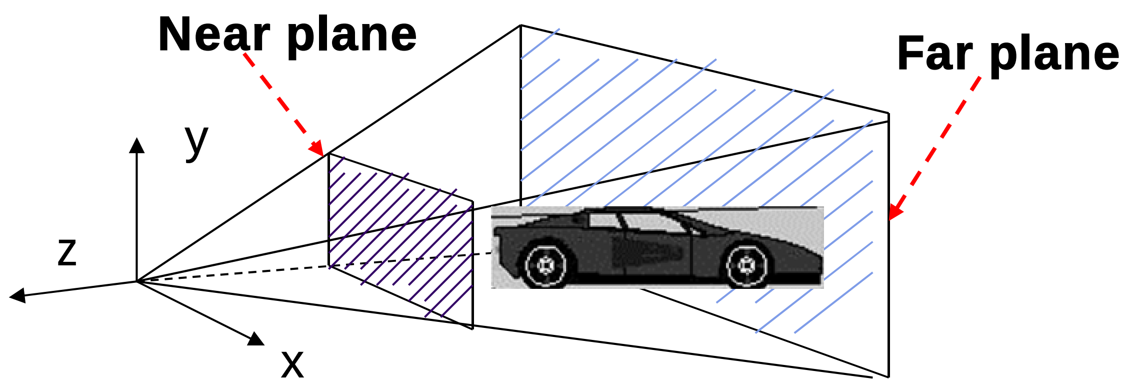
Field of View

- View volume parameter
- Determines how much of world in picture (vertically)
- Larger field of view = smaller objects drawn



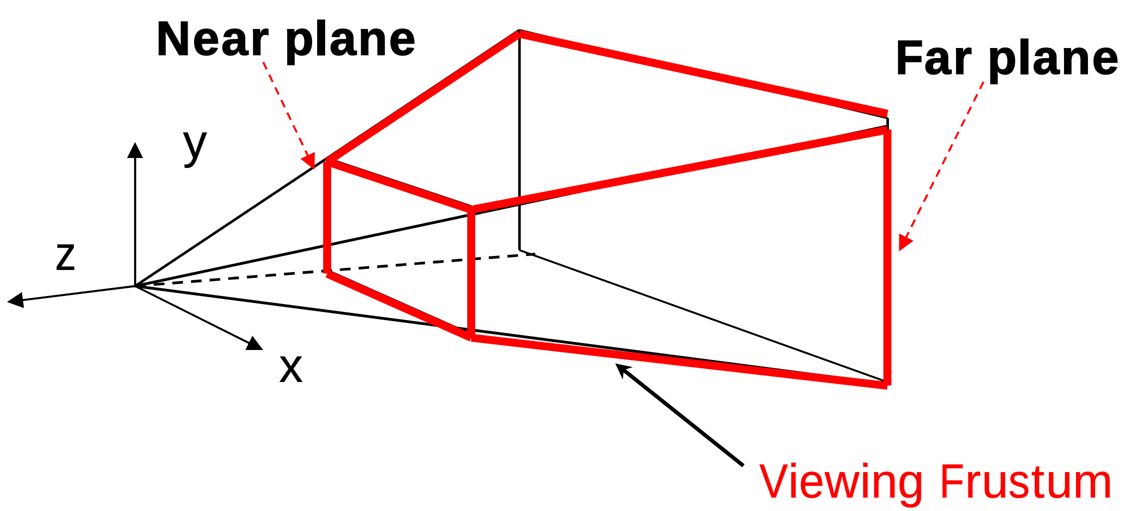
Near and Far Clipping Planes

- Only objects between near and far planes drawn



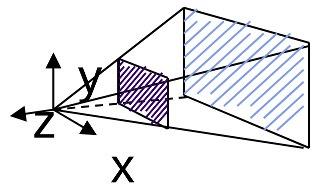
Viewing Frustrum

- Near plane + far plane + field of view = **Viewing Frustum**
- Objects outside the frustum are clipped

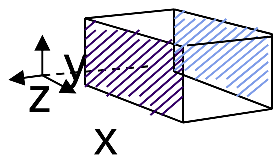


Setting up View Volume/Projection Type

- Previous OpenGL projection commands **deprecated**!!
  - Perspective view volume/projection:
    - **gluPerspective**(fovy, aspect, near, far) **or**
    - **glFrustum**(left, right, bottom, top, near, far)



  - Orthographic:
    - **glOrtho**(left, right, bottom, top, near, far)

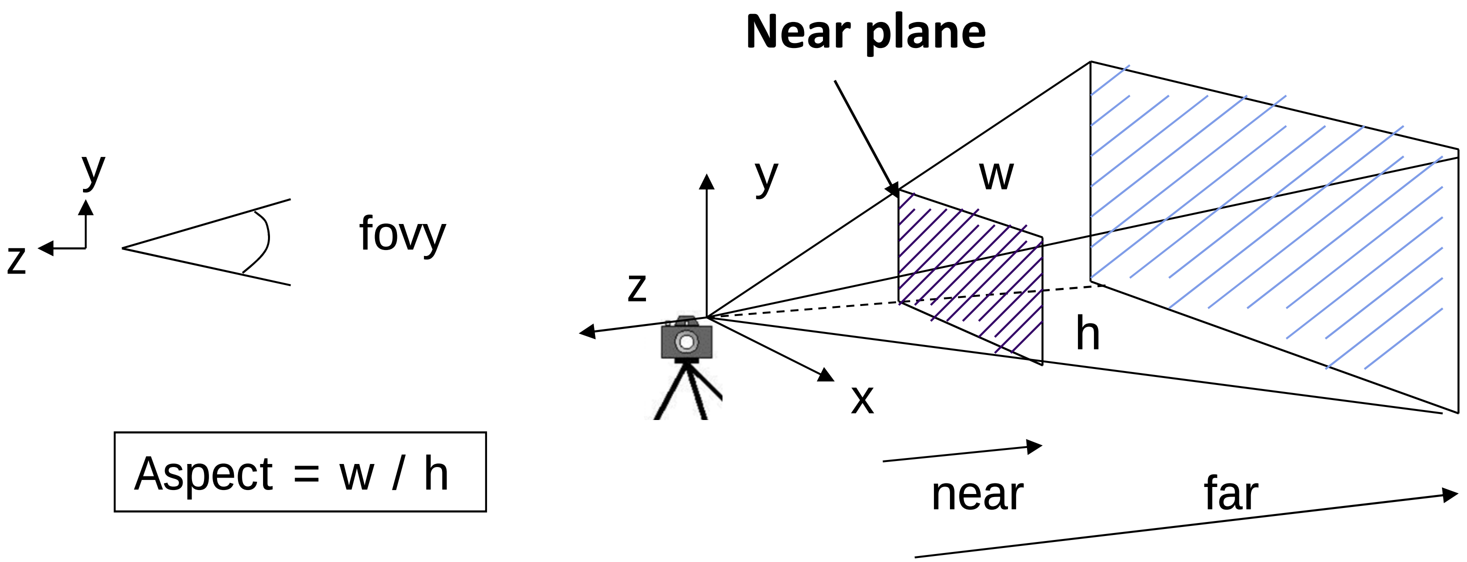


- Useful functions, so we implement similar in `mat.h`:
    - **Perspective**(fovy, aspect, near, far) **or**
    - **Frustum**(left, right, bottom, top, near, far)
    - **Ortho**(left, right, bottom, top, near, far)

What are these arguments? Next!

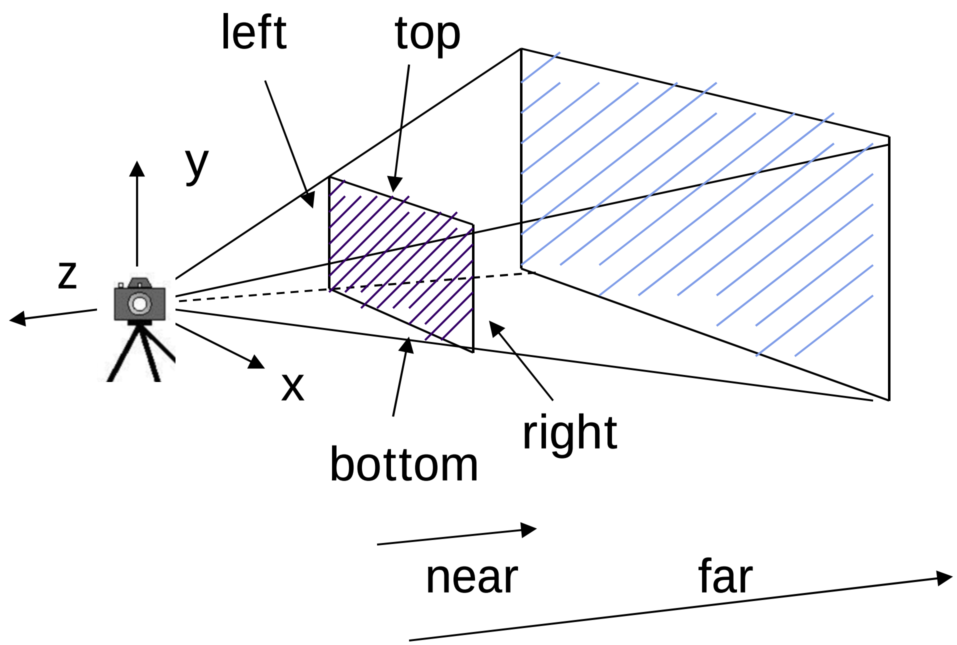
Perspective(fovy, aspect, near, far)

- Aspect ratio used to calculate window width



Frustum(left, right, bottom, top, near, far)

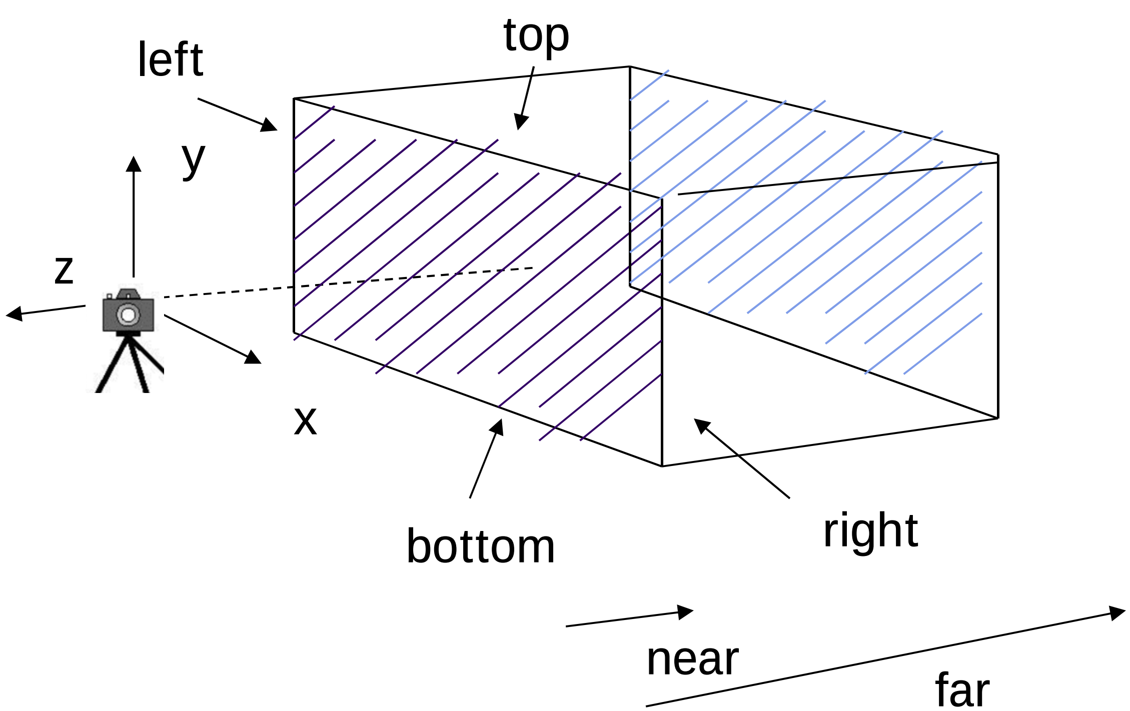
- Can use **Frustrum( )** in place of **Perspective**()
- Same view volume **shape**, different **arguments**



near and **far** measured from camera

Ortho(left, right, bottom, top, near, far)

- For orthographic projection



near and **far** measured from camera

Example Usage:
Setting View Volume/Projection Type

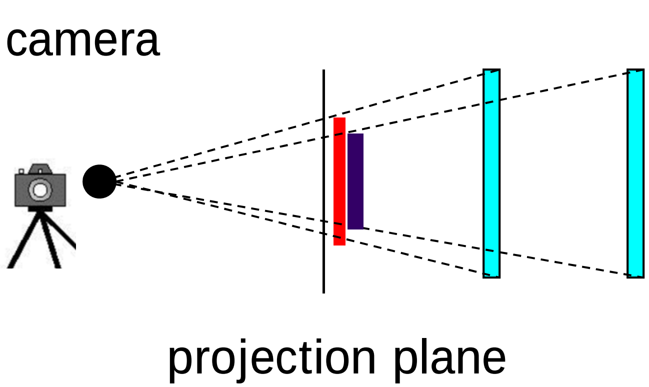
```
void display()
{     // clear screen
      glClear(GL_COLOR_BUFFER_BIT);
      ……….
      // Set up camera position
      LookAt(0,0,1,0,0,0,0,1,0);

      ……….
      // set up perspective transformation
      Perspective(fovy, aspect, near, far);

       ……….
      // draw something
      display_all();    // your display routine
}
```

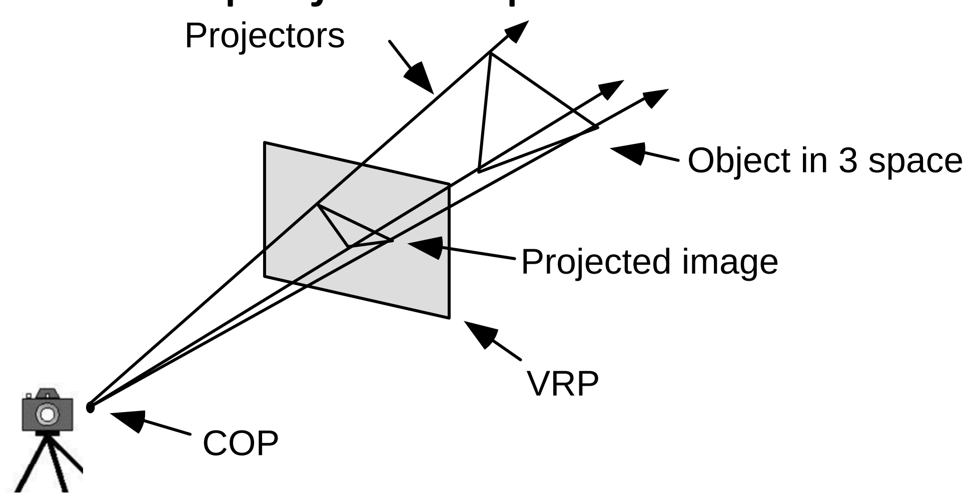
Demo

- Nate Robbins demo on projection

Perspective Projection

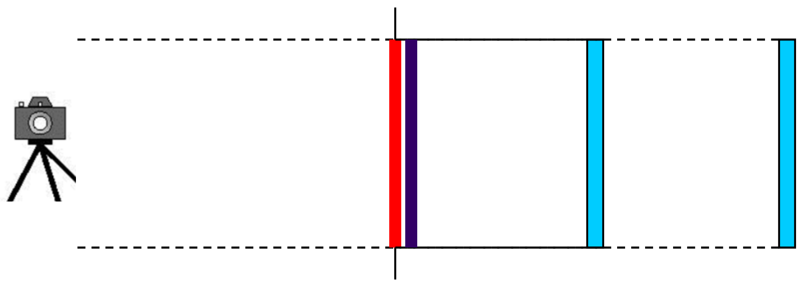
- After setting view volume, then projection transformation
- Projection?
  - **Classic:** Converts 3D object to corresponding 2D on screen
  - How? Draw line from object to projection center
  - Calculate where each intersects projection plane

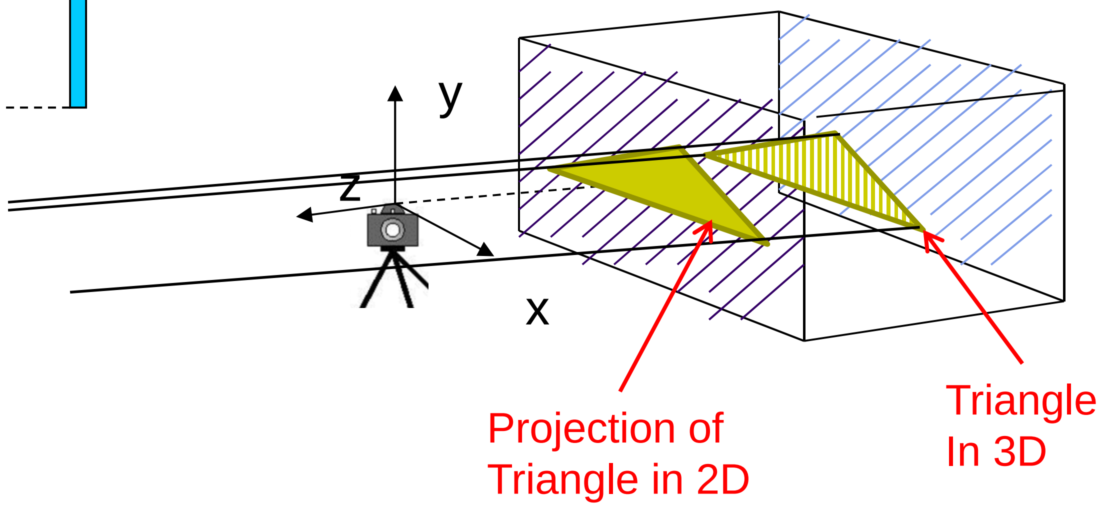




Orthographic Projection

- How? Draw parallel lines from each object vertex
- The projection center is at infinite
- In short, use (x,y) coordinates, just drop z coordinates





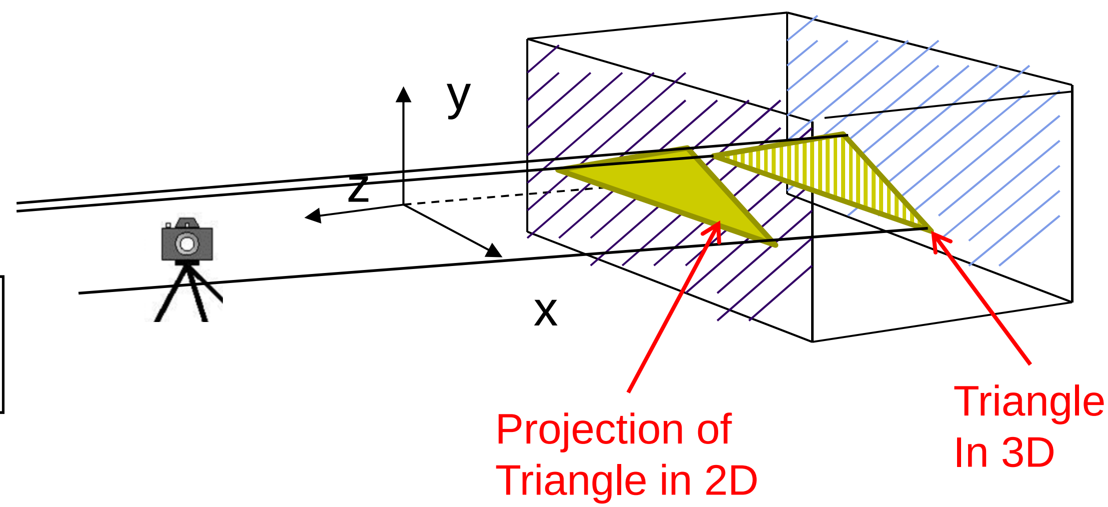
Default View Volume/Projection?

- What if you user does not set up projection?
- Default OpenGL projection is orthogonal (Ortho( ));
- To project points within default view volume

$$x_p = x$$
$$y_p = y$$
$$z_p = 0$$

Vertices **before** Projection

Vertices **after** Projection



Homogeneous Coordinate Representation

default orthographic projection

$$x_p = x$$
$$y_p = y$$
$$z_p = 0$$
$$w_p = 1$$

Vertices **before** Projection **(3D)**

Vertices **after** Projection **(2D)**

$$\mathbf{p}_p = \mathbf{M}\mathbf{p}$$

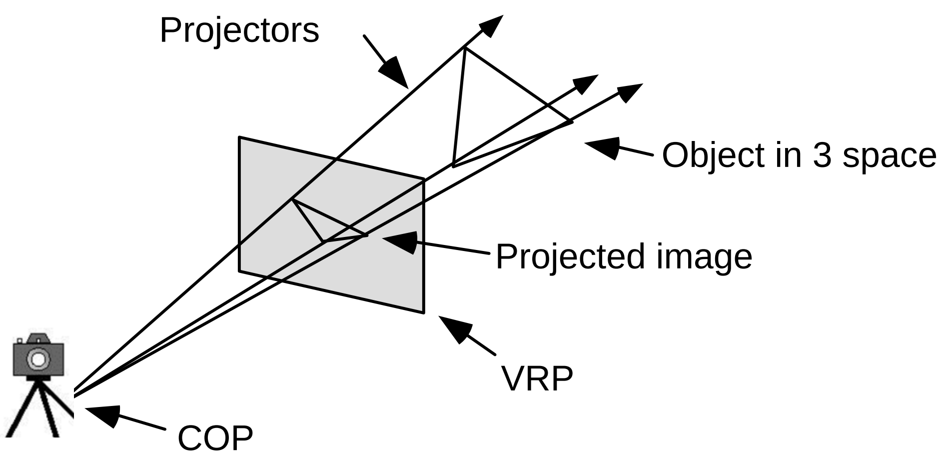
$$\mathbf{M} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

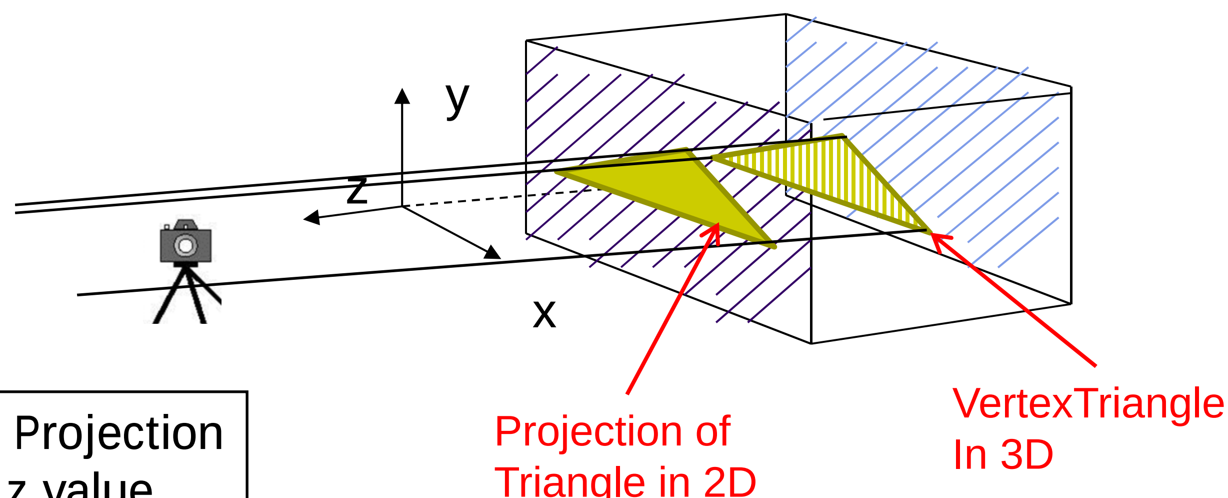
Default Projection Matrix

In practice, can let **M = I,** set the *z* term to zero later

The Problem with Classic Projection

- Keeps (x,y) coordintates for drawing, drops z
- We may need z. Why?



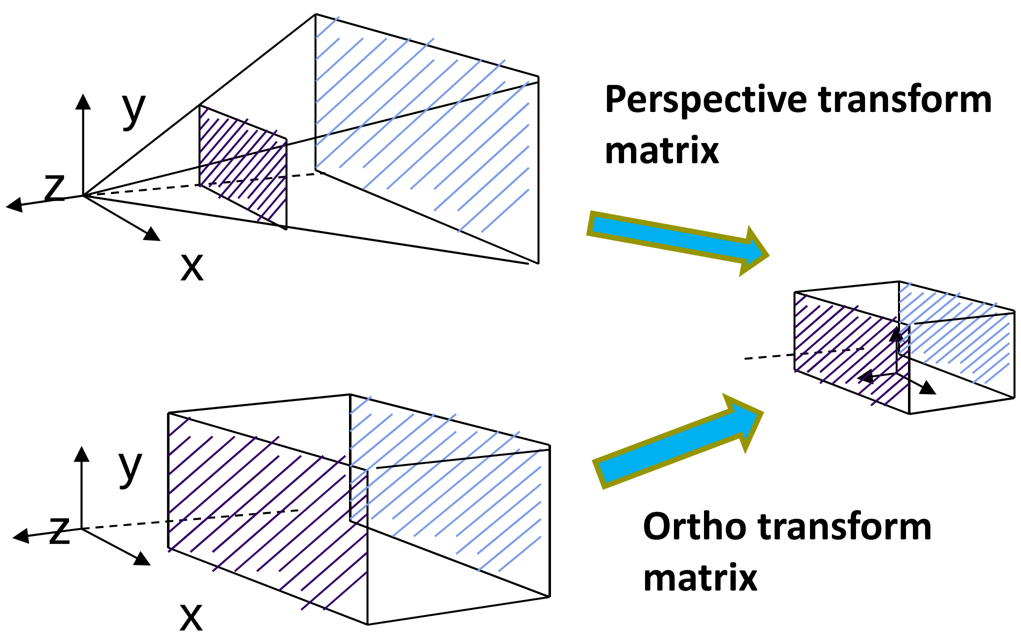


$$x_p = x$$
$$y_p = y$$
$$z_p = 0$$

Classic Projection
Loses z value

Normalization: Keeps z Value

- Most graphics systems use *view normalization*
- **Normalization:** convert all other projection types to orthogonal projections with the ***default view volume***



Default view volume
Clipping against it

References

- Interactive Computer Graphics (6th edition), Angel and Shreiner
- Computer Graphics using OpenGL (3rd edition), Hill and Kelley