3D Viewing

Canonical View Volume
Orthographic Projection
Perspective Projection

Shirley Chapter 7

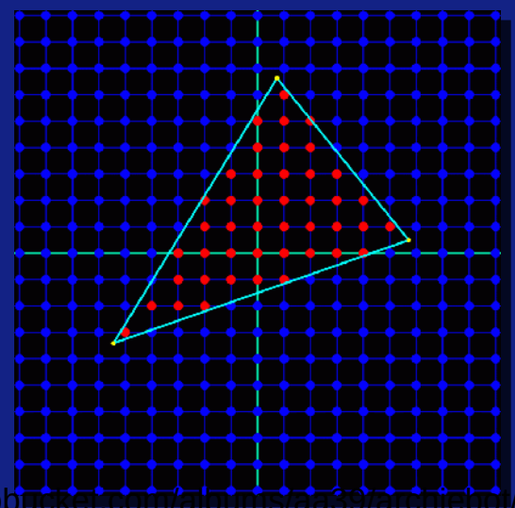
Viewing and Projection

- Our eyes collapse 3-D world to 2-D retinal image (brain then has to reconstruct 3D)
- In CG, this process occurs by *projection*
- Projection has two parts:
  - *Viewing transformations:* camera position and direction
  - *Perspective/orthographic transformation:* reduces 3-D to 2-D
- Use homogeneous transformations (of course…)

Getting Geometry on the Screen

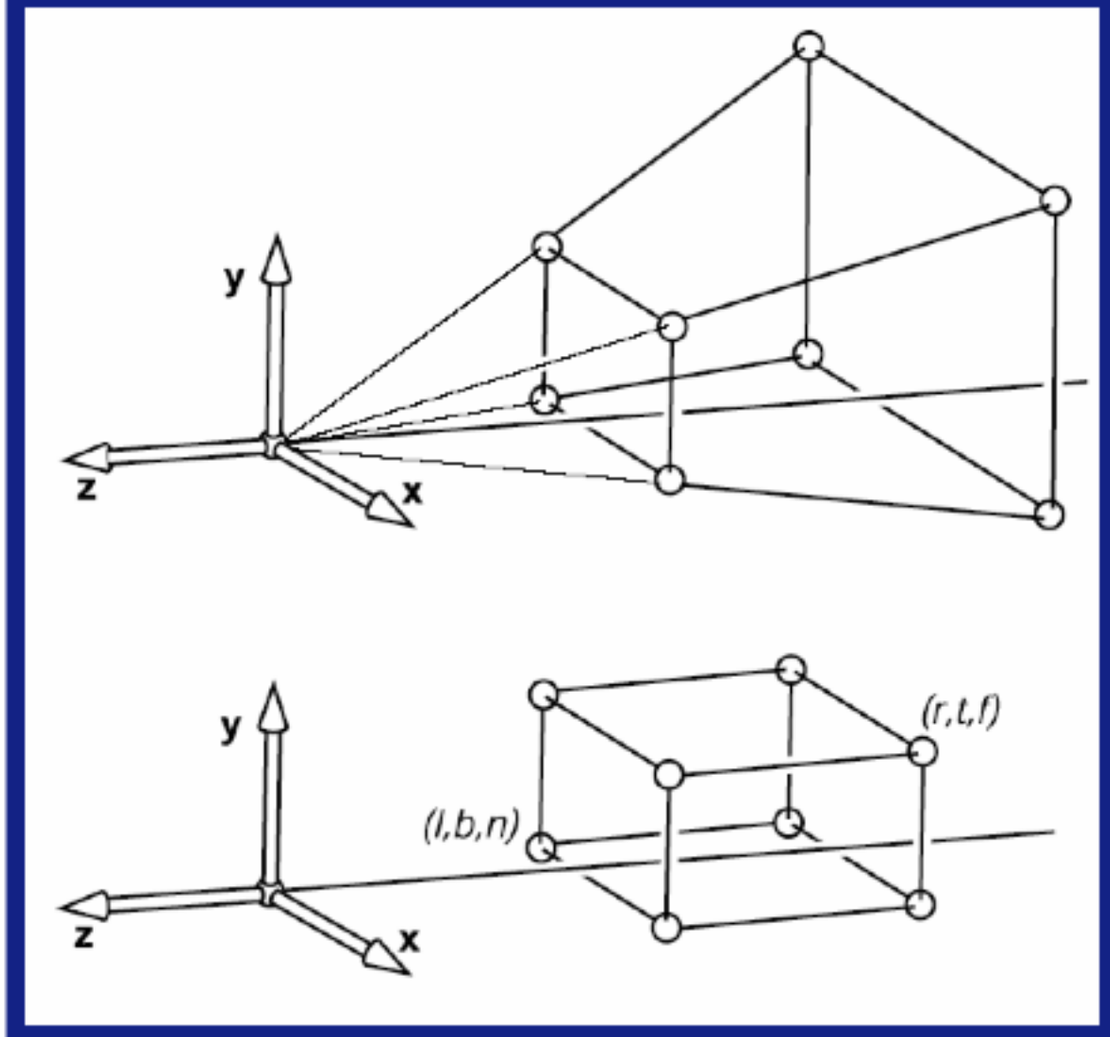
Given geometry positioned in the world coordinate system, how do we get it onto the display?

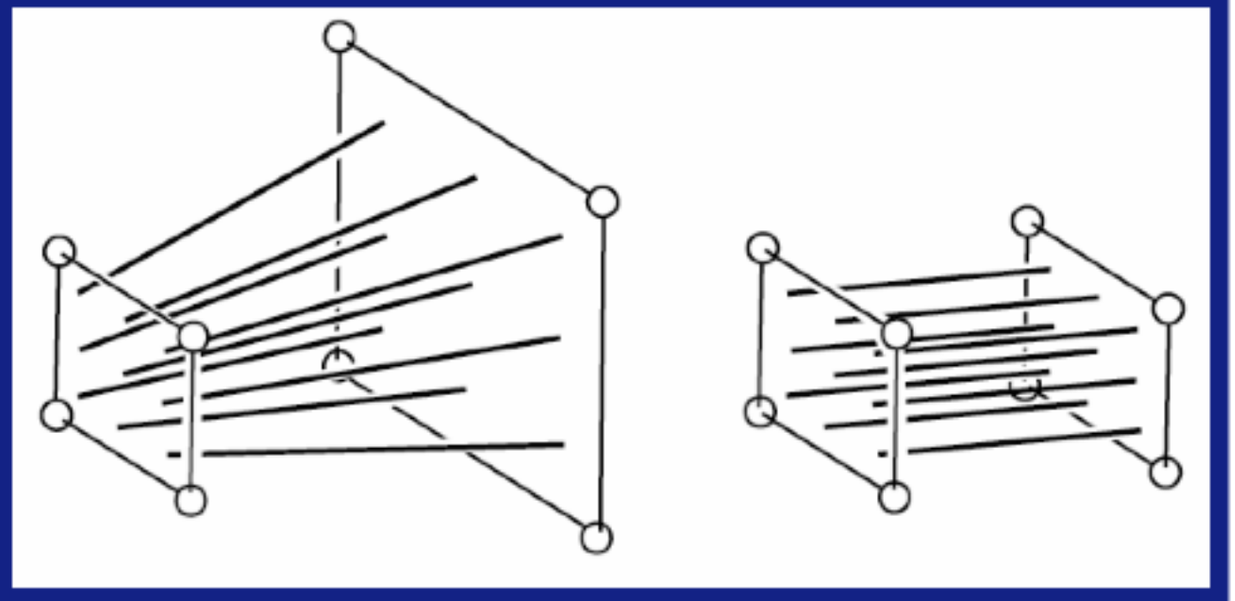
- Transform to camera coordinate system
- Transform (warp) into canonical view volume
- Clip
- Project to display coordinates
- Rasterize



http://i200.photobucket.com/albums/aa39/archiebot/rasterization.png

Perspective and Orthographic Projection



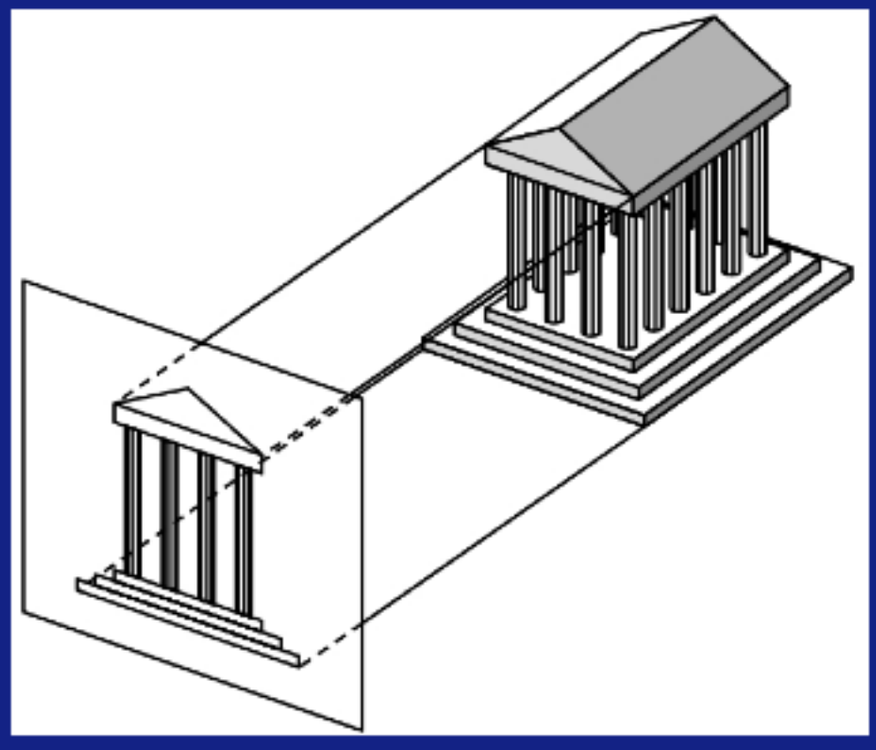


Orthographic Projection

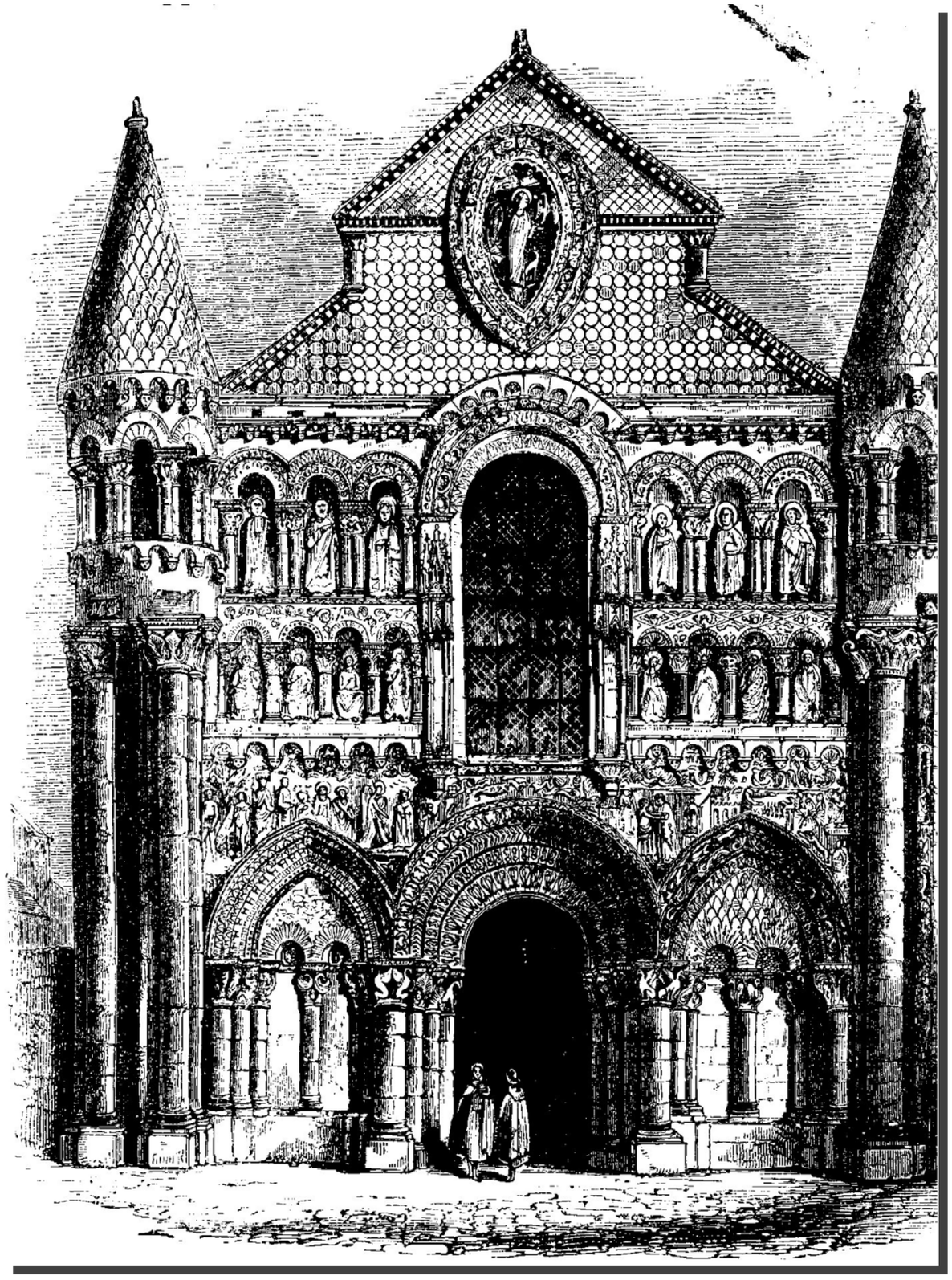
the focal point is at infinity, the rays are parallel, and orthogonal to the image plane

good model for telephoto lens. No perspective effects.

when *xy*-plane is the image plane (x,y,z) -> (x,y,0)
front orthographic view



Orthographic Projection



Telephoto Lenses and Fashion Photography

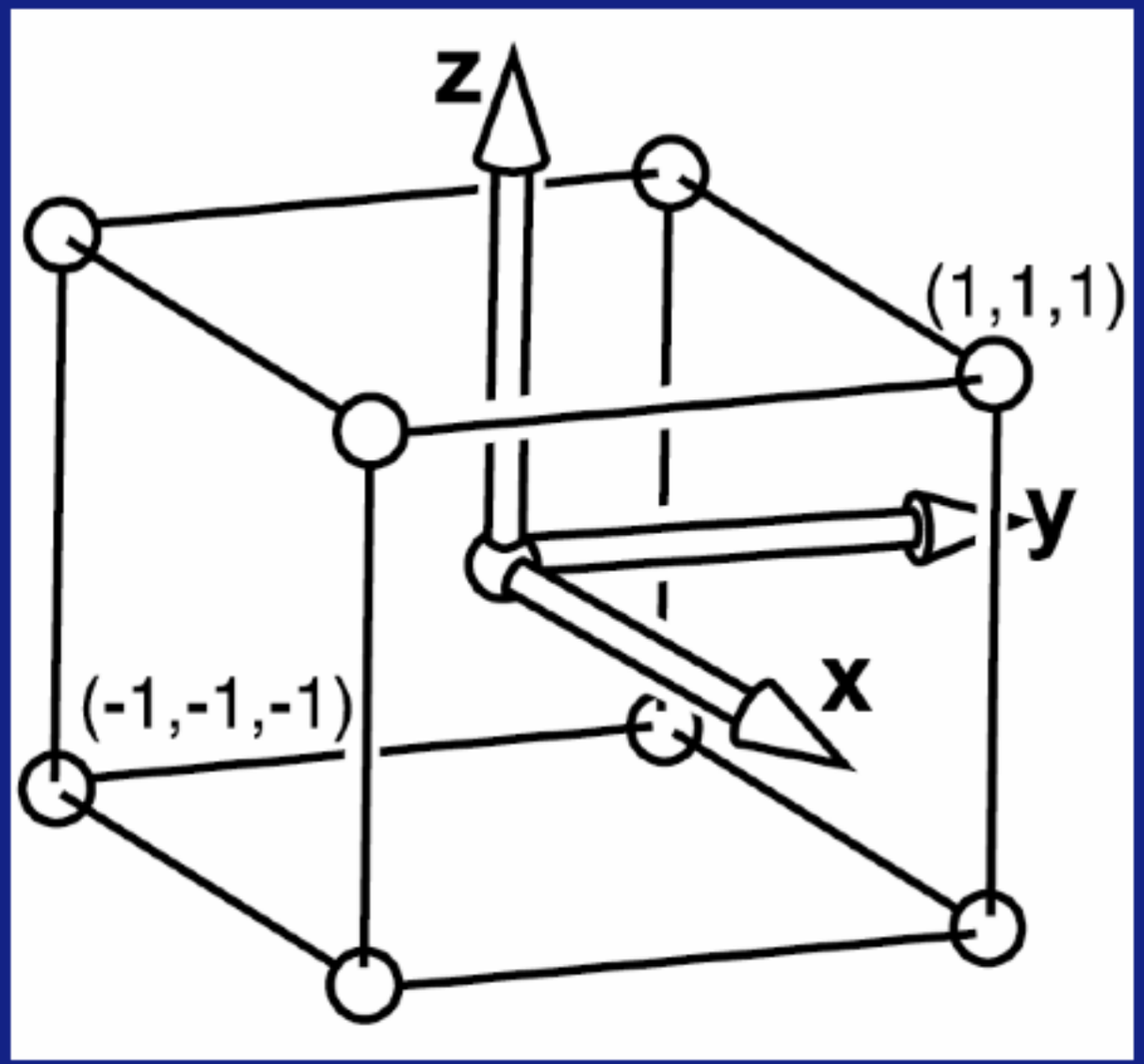
http://farm4.static.flickr.com/3057/2555706112_20a3015ddb.jpg

Viewing and Projection

Build this up in stages

- Canonical view volume to screen
- Orthographic projection to canonical view volume
- Perspective projection to orthographic space

Canonical View Volume

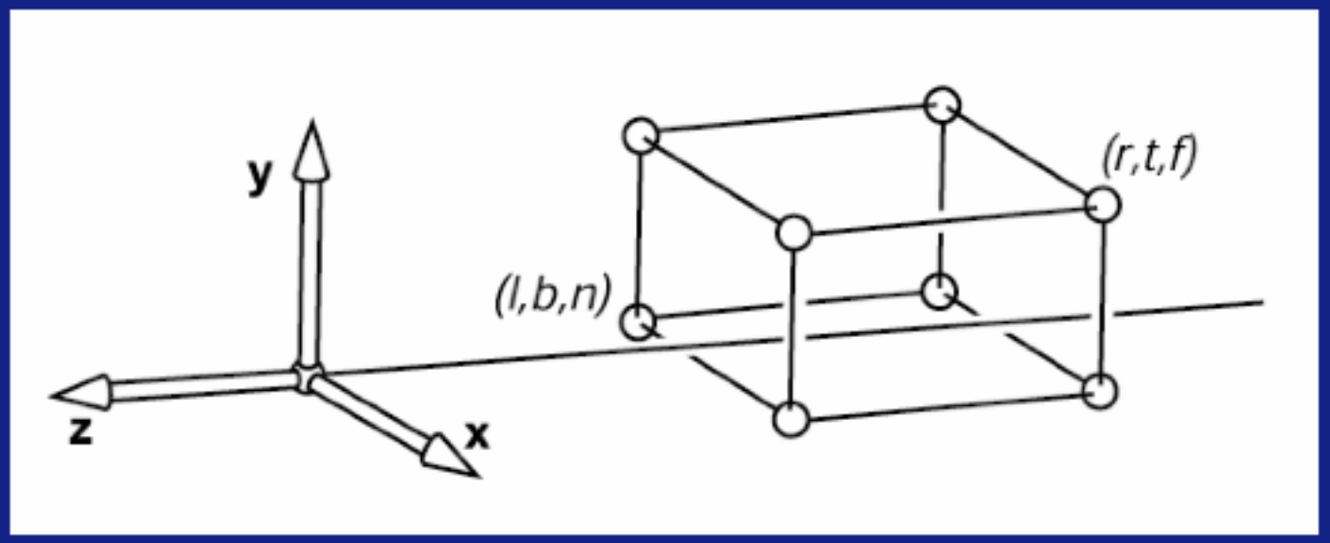


Why this shape?

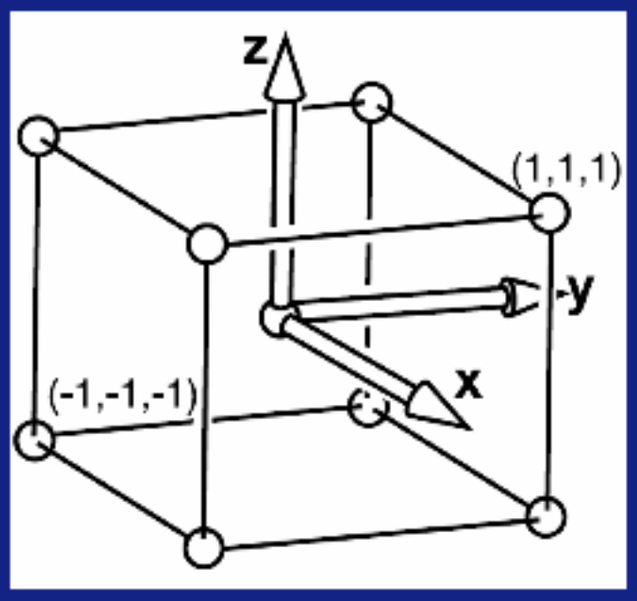
- Easy to clip to
- Trivial to project from 3D to 2D image plane

chalkboard

Orthographic Projection



X=l left plane
X=r right plane
Y=b bottom plane
Y=t top plane
Z=n near plane
Z=f far plane



Why near plane? Prevent points behind the camera being seen
Why far plane? Allows *z* to be scaled to a limited fixed-point value (*z*-buffering)

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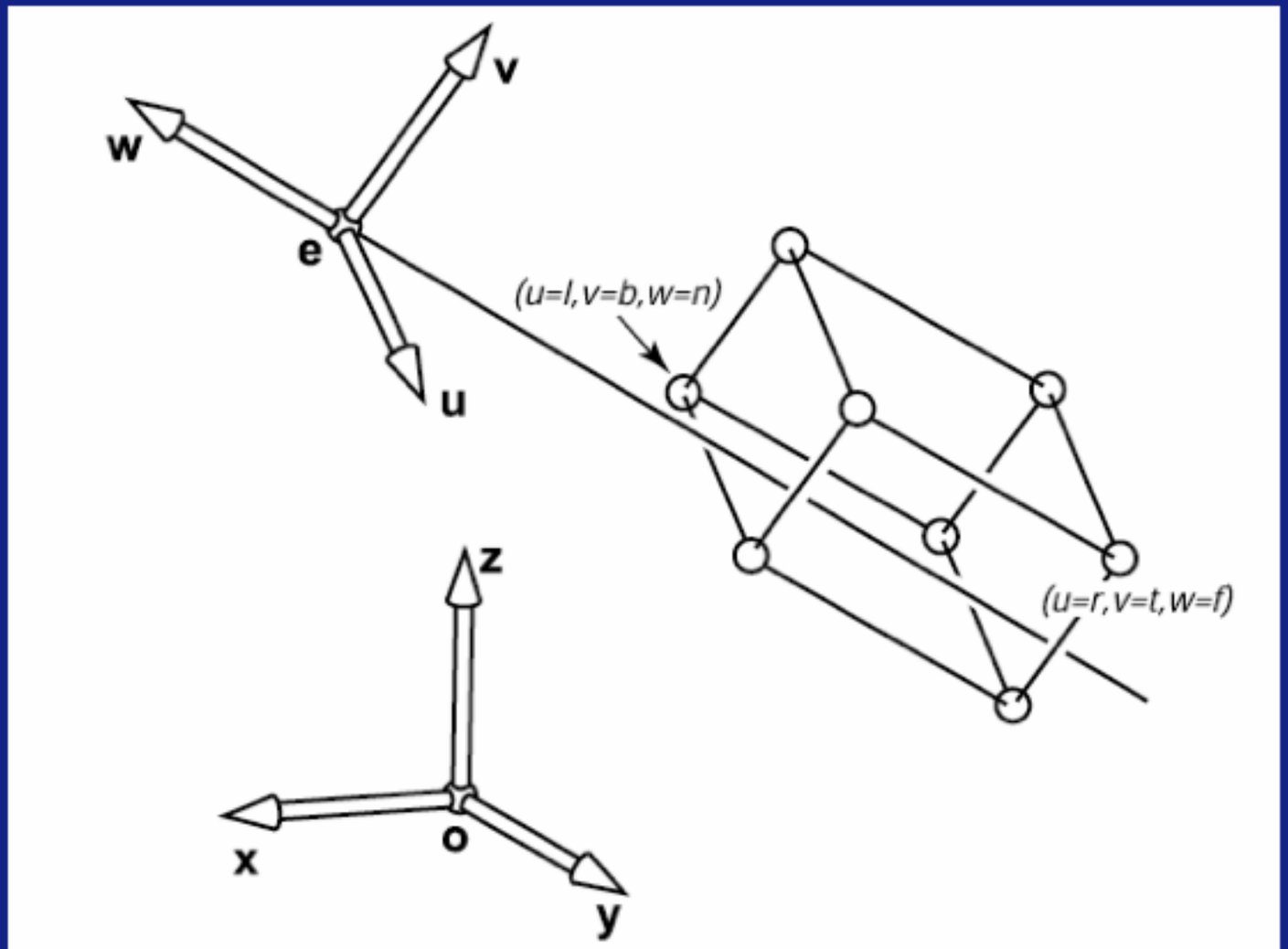
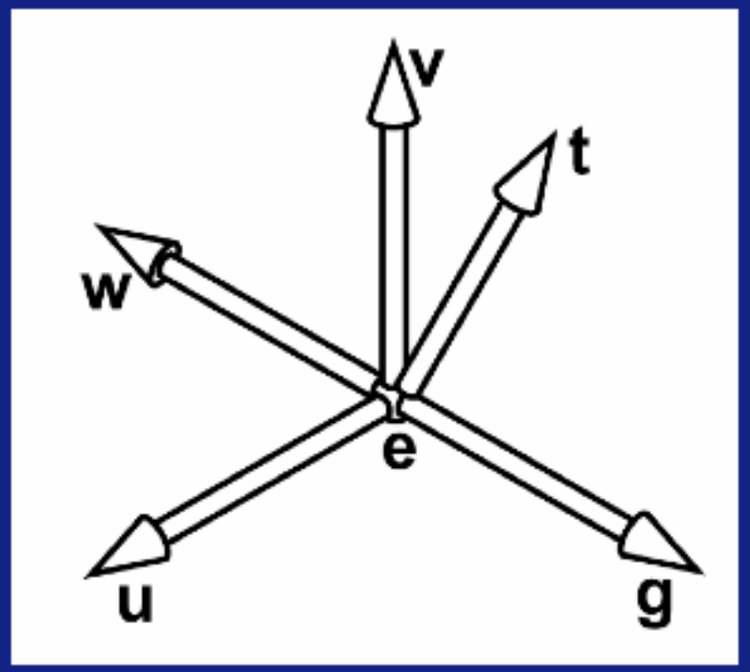
Arbitrary View Positions





Eye position: e
Gaze direction: g
view-up vector: t

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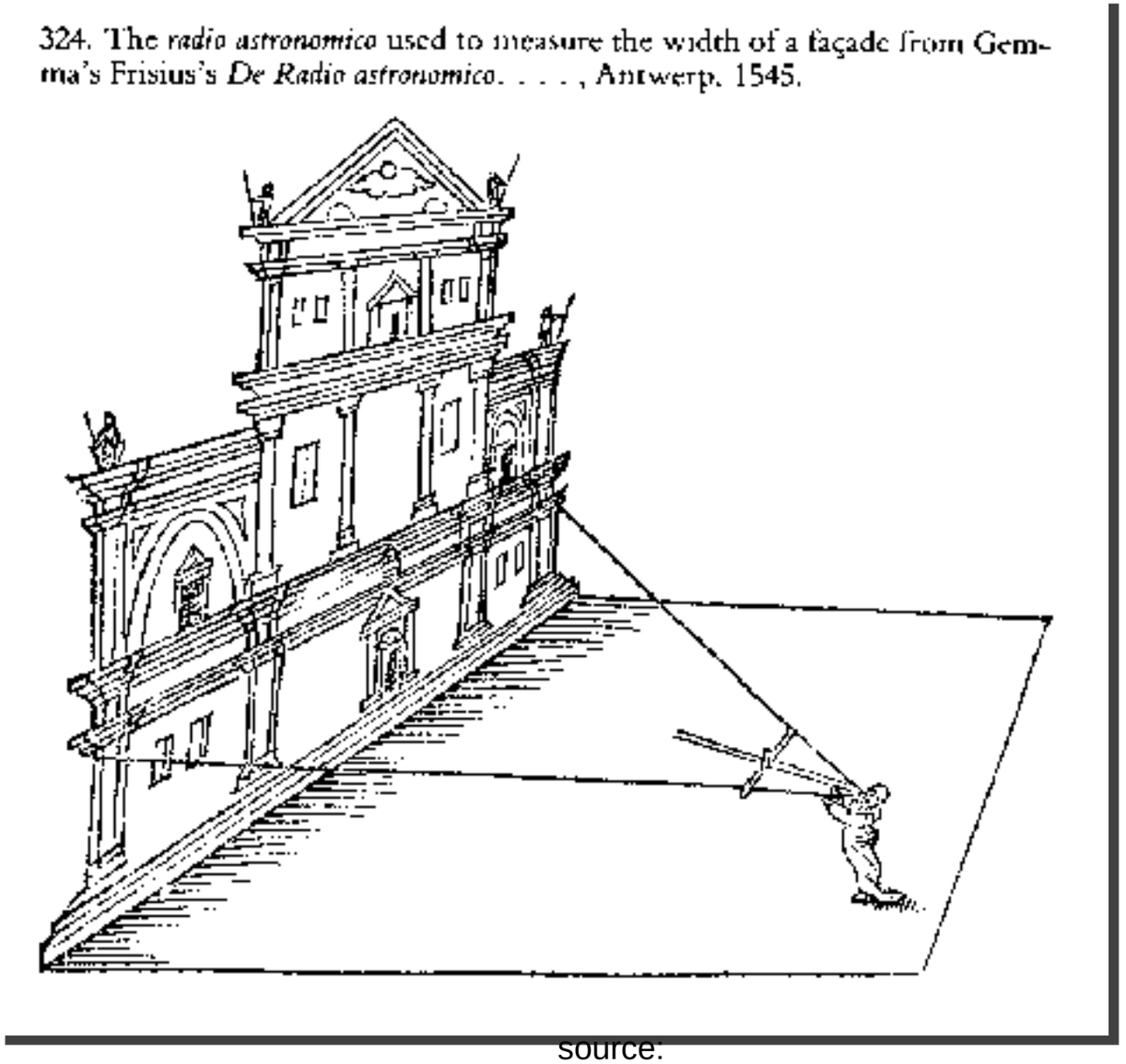
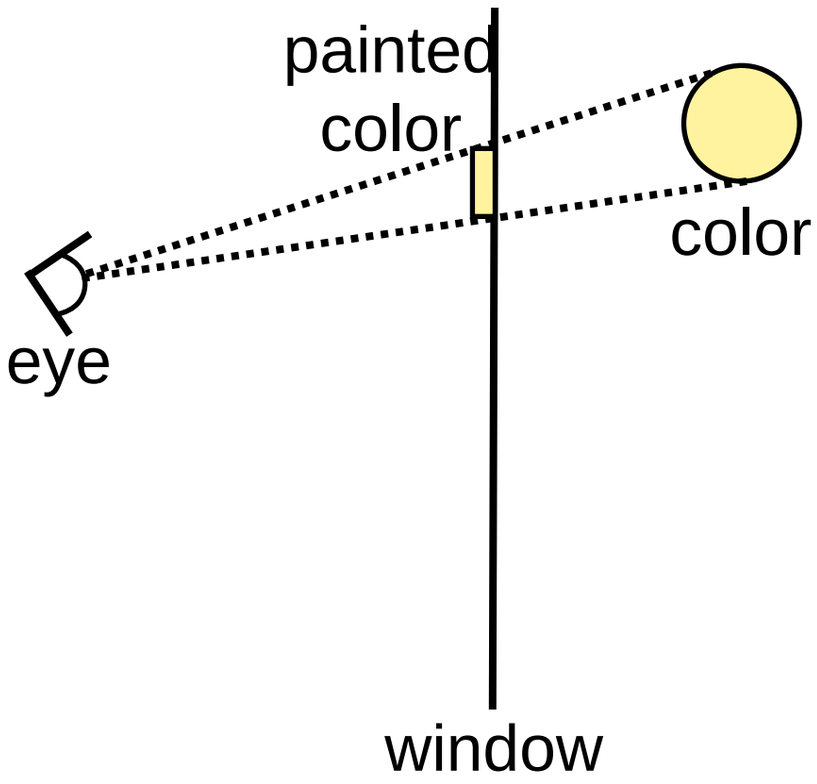
Perspective Projection



324. The *radio astronomico* used to measure the width of a façade from Gemma's Frisius's *De Radio astronomico*. . . . , Antwerp, 1545.

source:
http://www.dartmouth.edu/~matc/math5.geometry/unit15/Frisius.gif

The simplest way to look at perspective projection is as painting on a window....



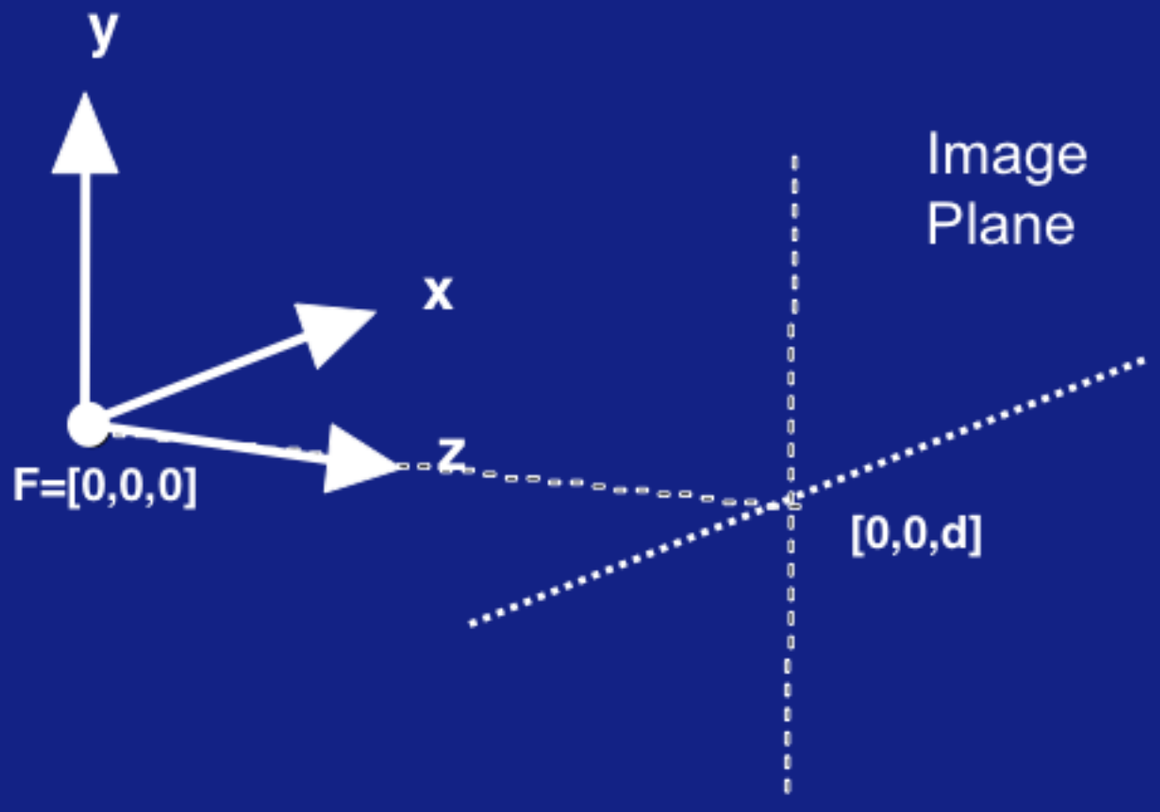
Paint on the window whatever color you see there.

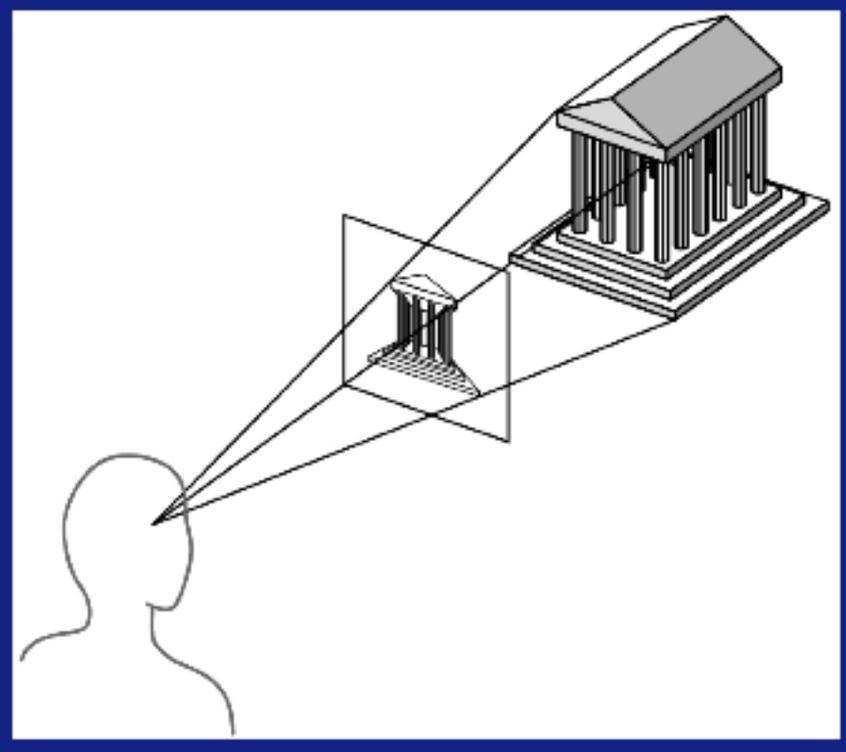
source:
http://blog.mlive.com/flintjournal/newsnow/2007/11/WINDOW_PAINTING_02.jpg

Simple Perspective Camera

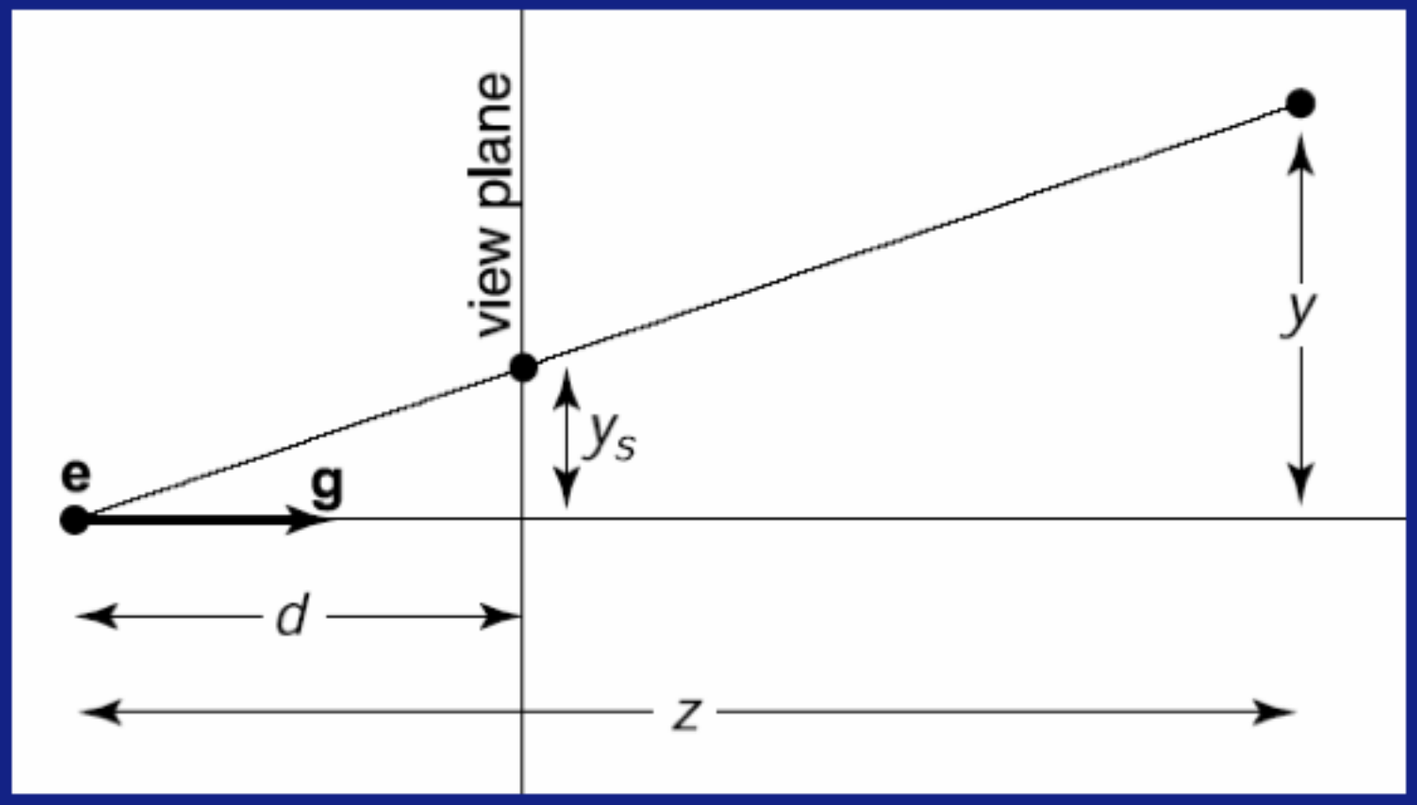
Canonical case:

- camera looks along the *z*-axis
- focal point is the origin
- image plane is parallel to the *xy*-plane at distance *d*
- (We call d the focal length, mainly for historical reasons)





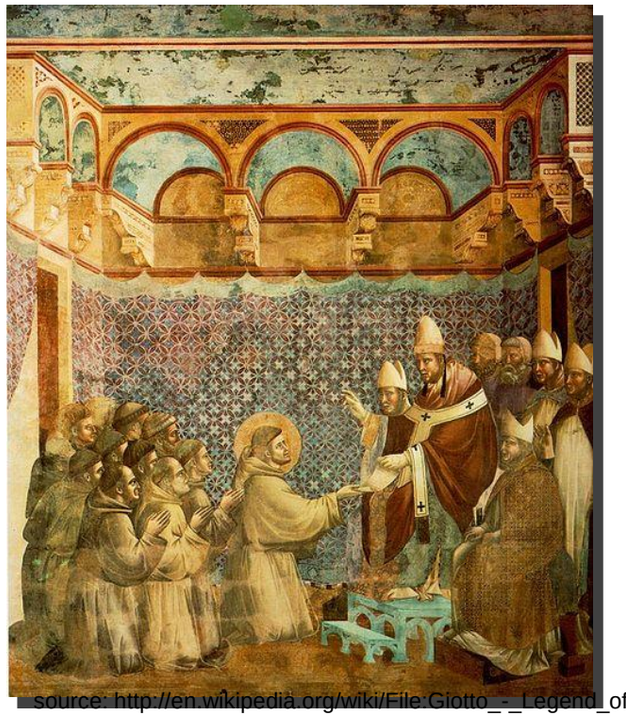
Perspective Projection of a Point



$$y_s = d\frac{y}{z}$$

History of Perspective Projection

source: http://en.wikipedia.org/wiki/File:Reconstruction_of_the_temple_of_Jerusalem.jpg



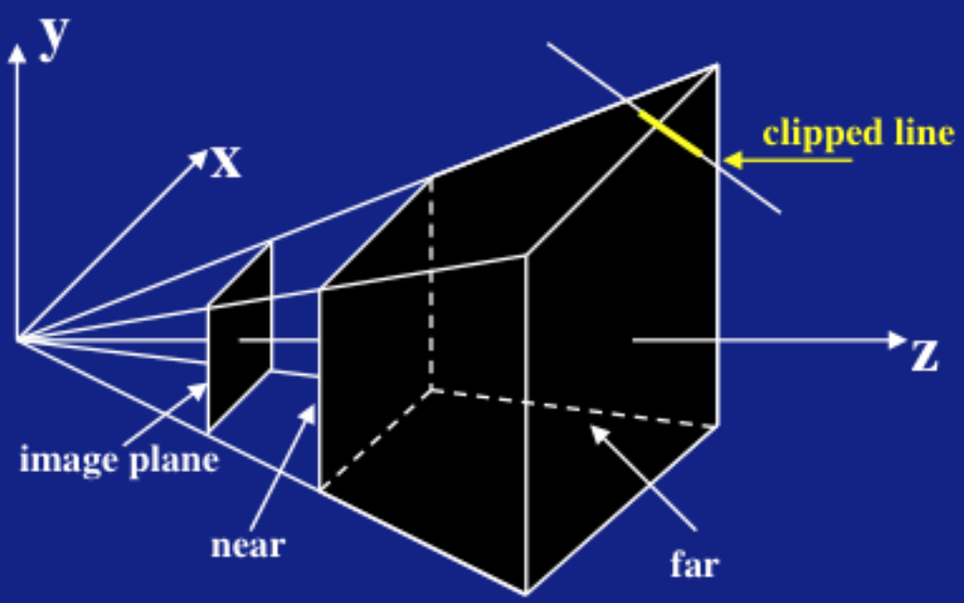
source: http://en.wikipedia.org/wiki/File:Giotto_-_Legend_of_St_Francis_-_07-_-_Confirmation_of_the_Rule.jpg

source: http://en.wikipedia.org/wiki/File:Perugino_Keys.jpg

Clipping

Something is missing between projection and viewing...

Before projecting, we need to eliminate the portion of scene that is outside the viewing frustum

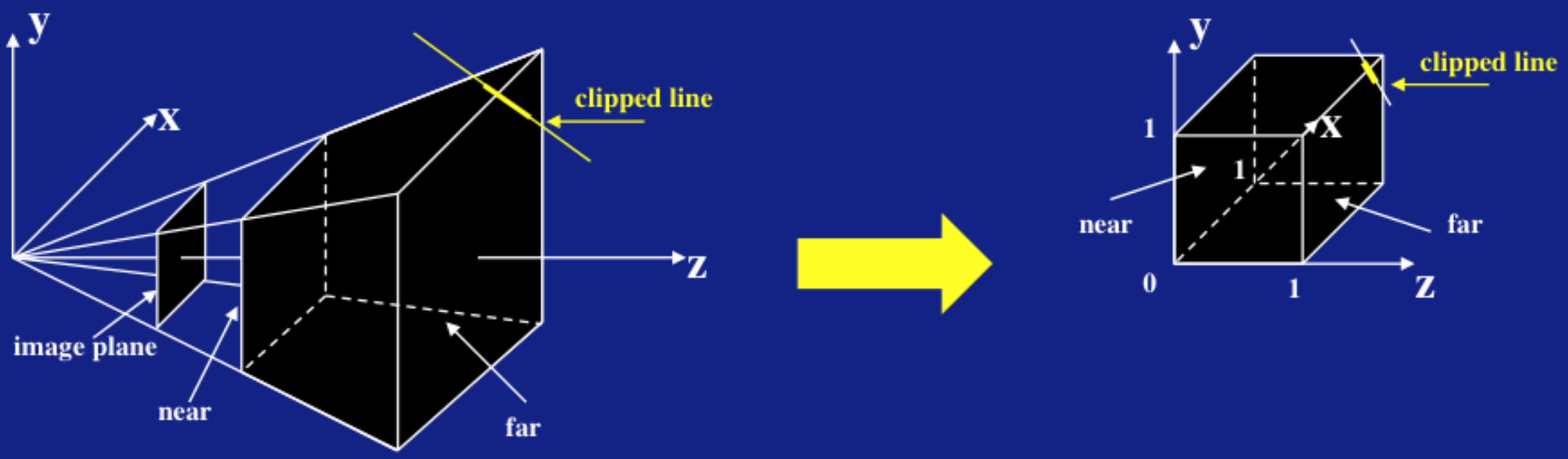


Need to clip objects to the frustum (truncated pyramid)

Now in a canonical position but it still seems kind of tricky...

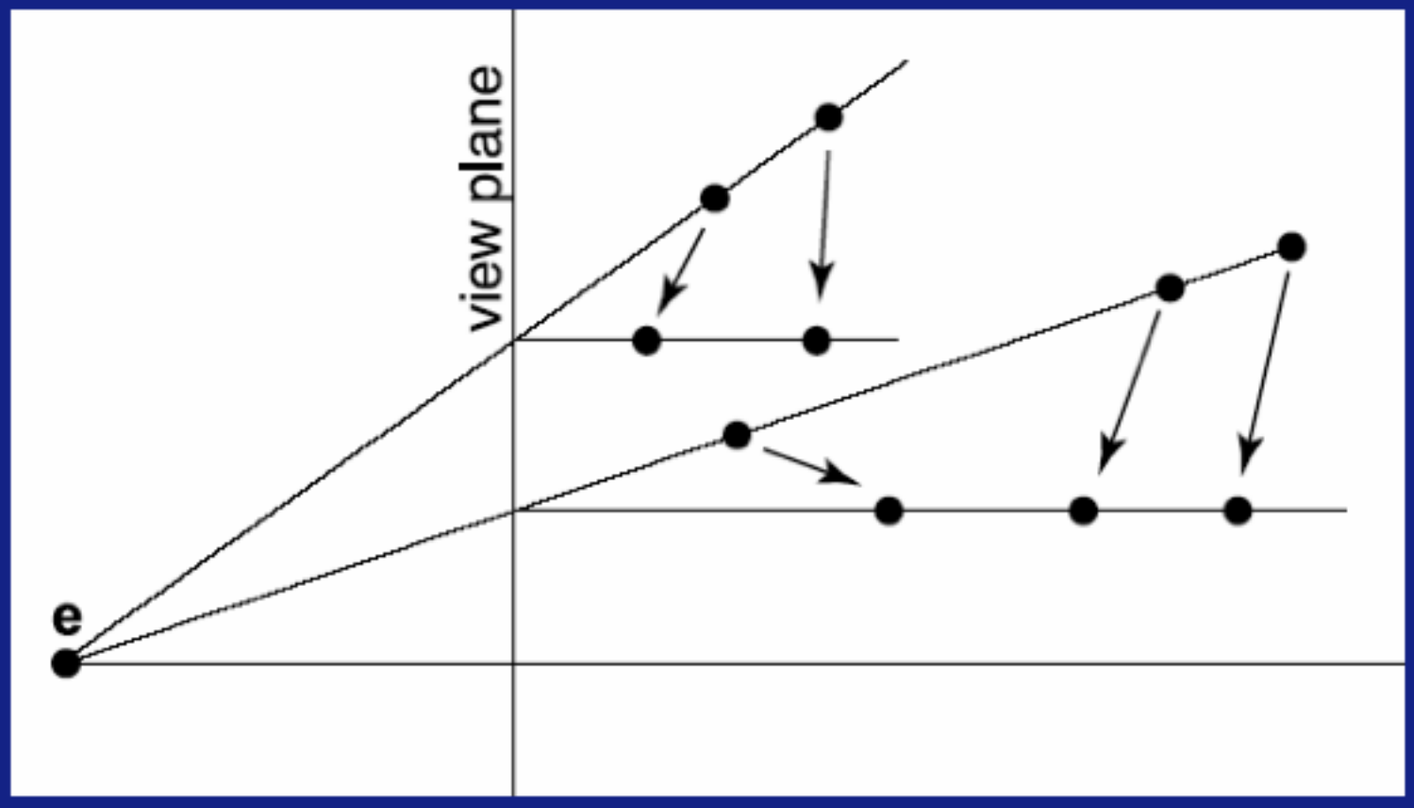
Normalizing the Viewing Frustum

Solution: transform frustum to a cube before clipping



Converts perspective frustum to orthographic frustum
Yet another homogeneous transform!

Perspective Projection



chalkboard

Warping a perspective projection into and orthographic one

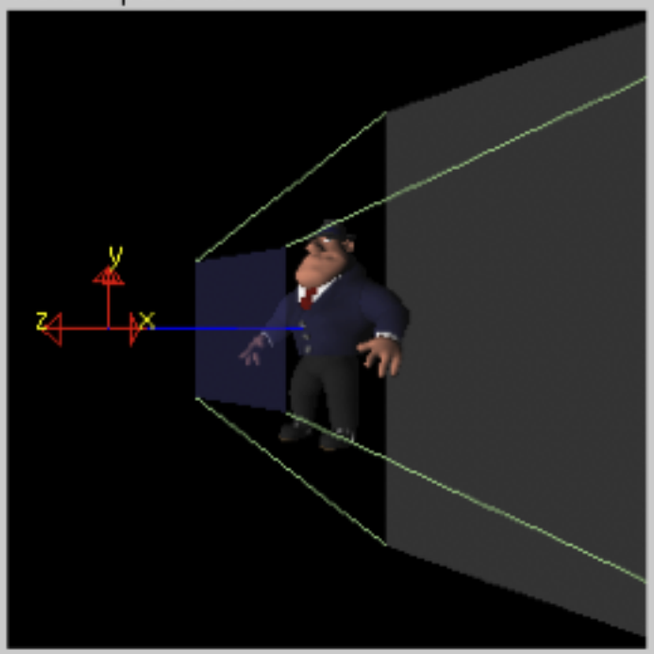
Lines for the two projections intersect at the view plane

How can we put this in matrix form?

Need to divide by z—haven't seen a divide in our matrices so far…

Requires our w from last time (or h in the book)

World-space view



Screen-space view

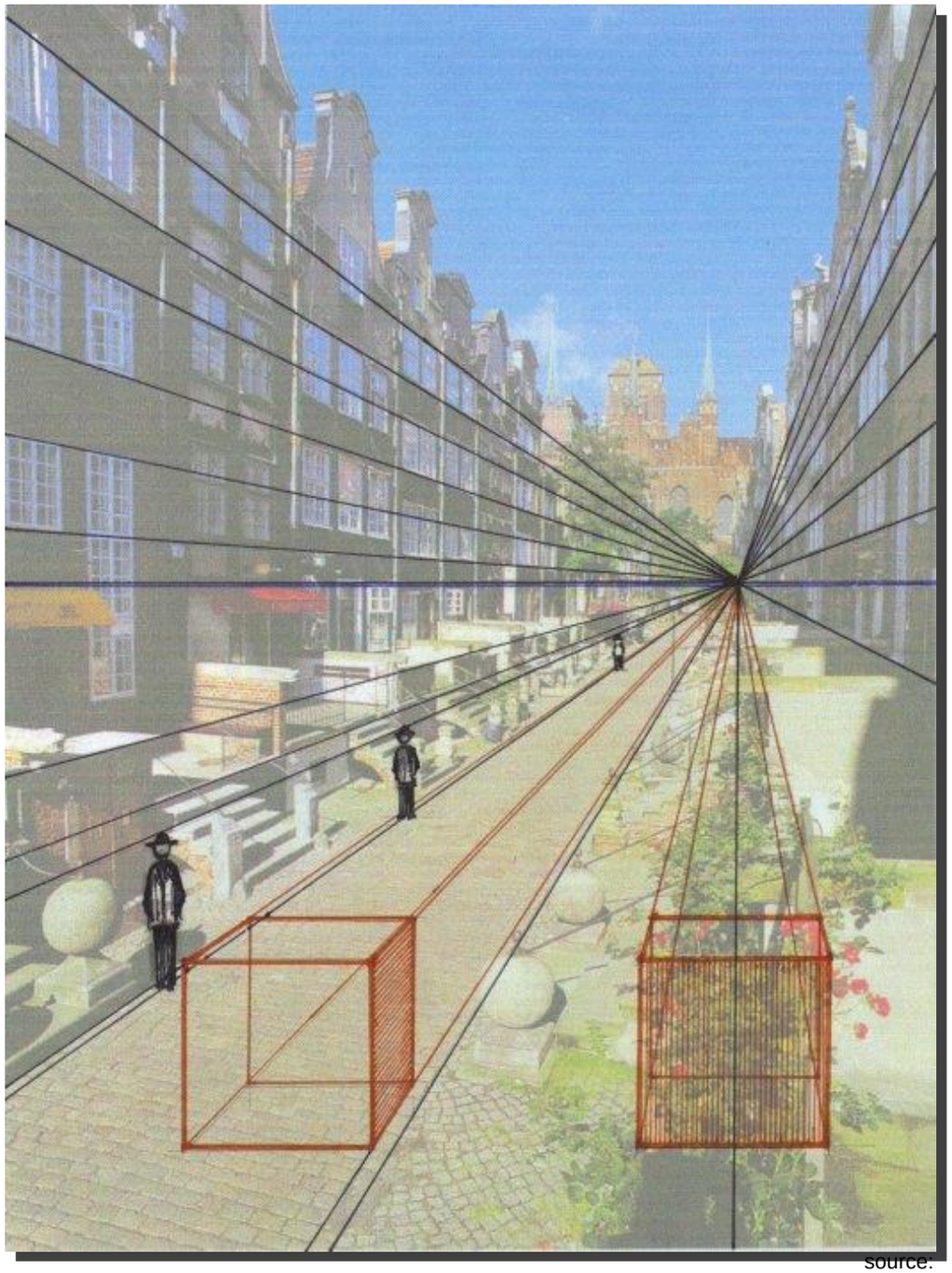
Command manipulation window

```
                    fovy  aspect  zNear  zFar
gluPerspective(  60.0  , 1.00  , 1.0   , 10.0  );
    gluLookAt(  0.00  , 0.00  , 2.00  ,    <- eye
                0.00  , 0.00  , 0.00  ,    <- center
                0.00  , 1.00  , 0.00  );   <- up
```

Click on the arguments and move the mouse to modify values.

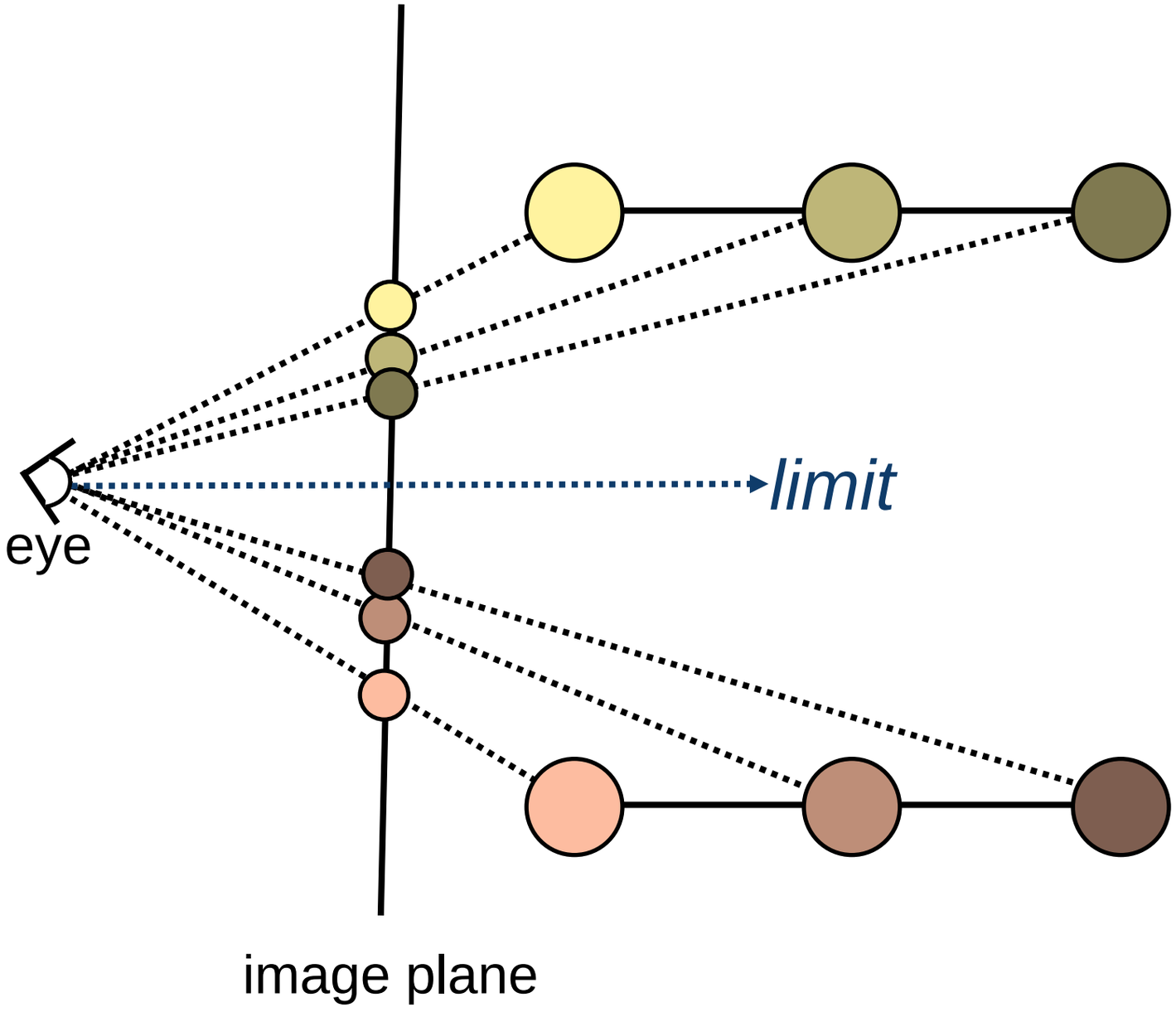
Vanishing Points

source: http://stevewebel.com/photographer/wp-content/uploads/2008/04/vanishing-point.jpg

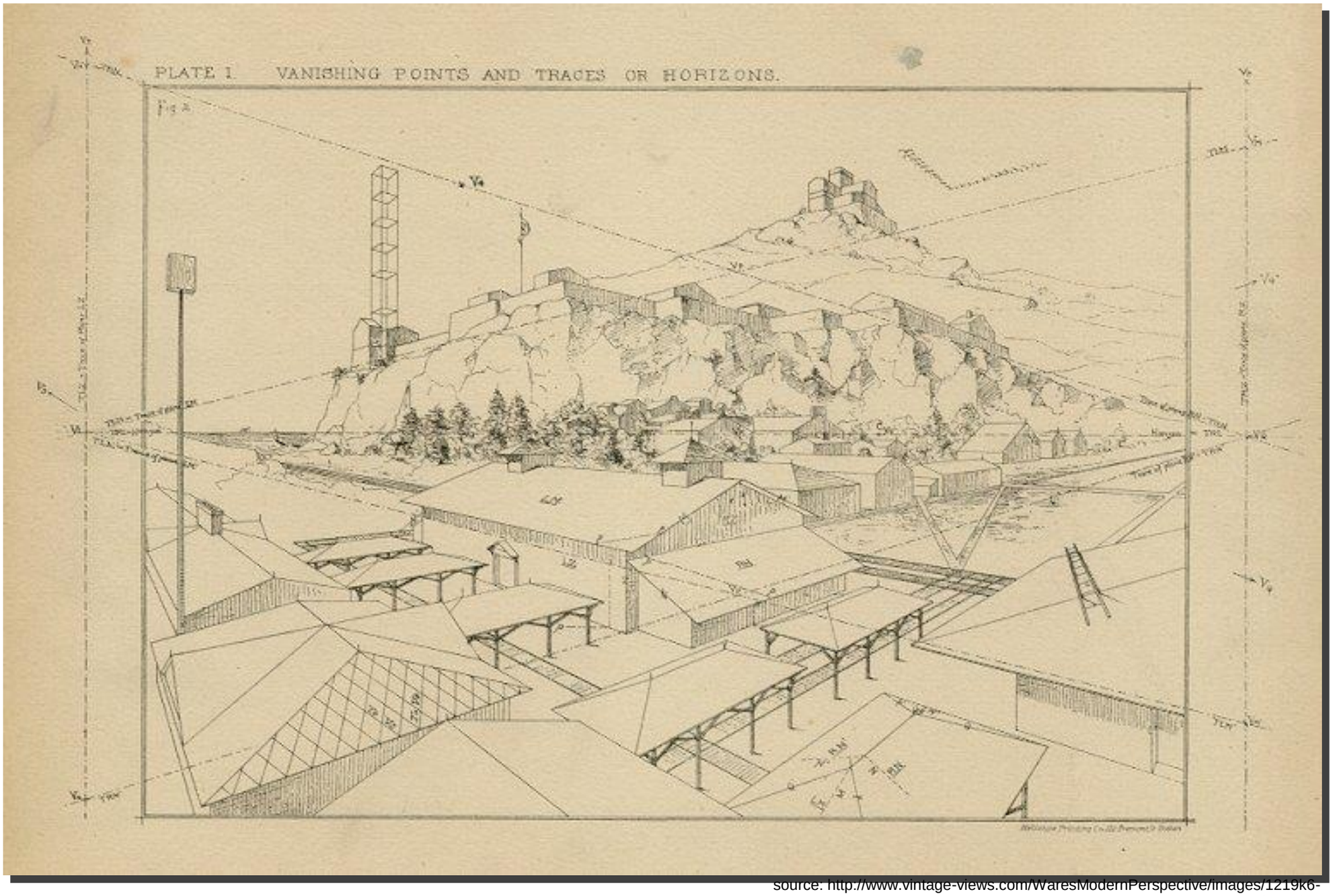


source: http://cavespirit.com/CaveWall/5/vanishing_point_high_horizon.jpg

What Causes Vanishing Points?


limit
eye
image plane

2 Vanishing Points



source: http://www.vintage-views.com/WaresModernPerspective/images/1219k6-Plate1.jpg

How many vanishing points can an image have?

Practice Problems

Suppose you define a camera to have the “eye” or lookfrom point at $[0\ 10\ 0]^T$, the lookat point at $[0\ 0\ 0]^T$, and the “up” vector at $[1\ 0\ 0]^T$. In other words, the camera is above the scene looking straight down, with its “up” vector in the x-axis direction. Derive the matrix to transform points from the world coordinate frame into the camera coordinate frame. Show your work, and plug in some examples to test your derived matrix.

Hints. Let the camera frame be specified as uvw. We want to convert a point in xyz coordinates into uvw coordinates. Recall that the v-direction of the camera frame is specified by the camera’s “up” vector. Recall that the camera’s w-direction points in the direction **opposite** the lookat vector.

Practice Problems

Review the full sequence of matrices that are needed to achieve perspective projection, i.e., to go from a definition of a view frustum to a point on the computer screen.

See if you can derive the perspective projection matrix from first principles (the law of similar triangles).