Perspective

COMP 557

Paul Kry

History of Projection

Let's look at examples in art…

15th century illustration from the Old French translation of William of Tyre's Histoire d'Outremer

Pietro Perugino, fresco at the Sistine Chapel (1481–82)

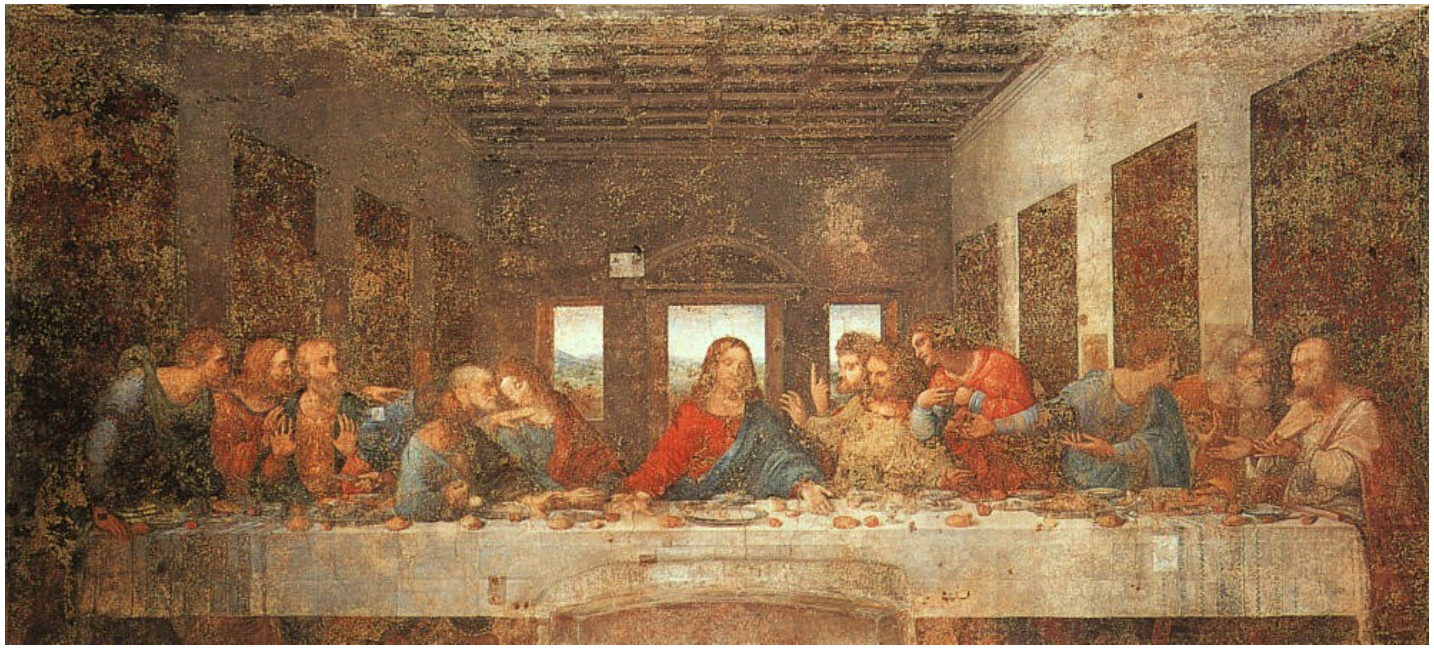
History of projection

- Ancient times: Greeks wrote about laws of perspective
- Renaissance: perspective is adopted by artists

Duccio c. 1308

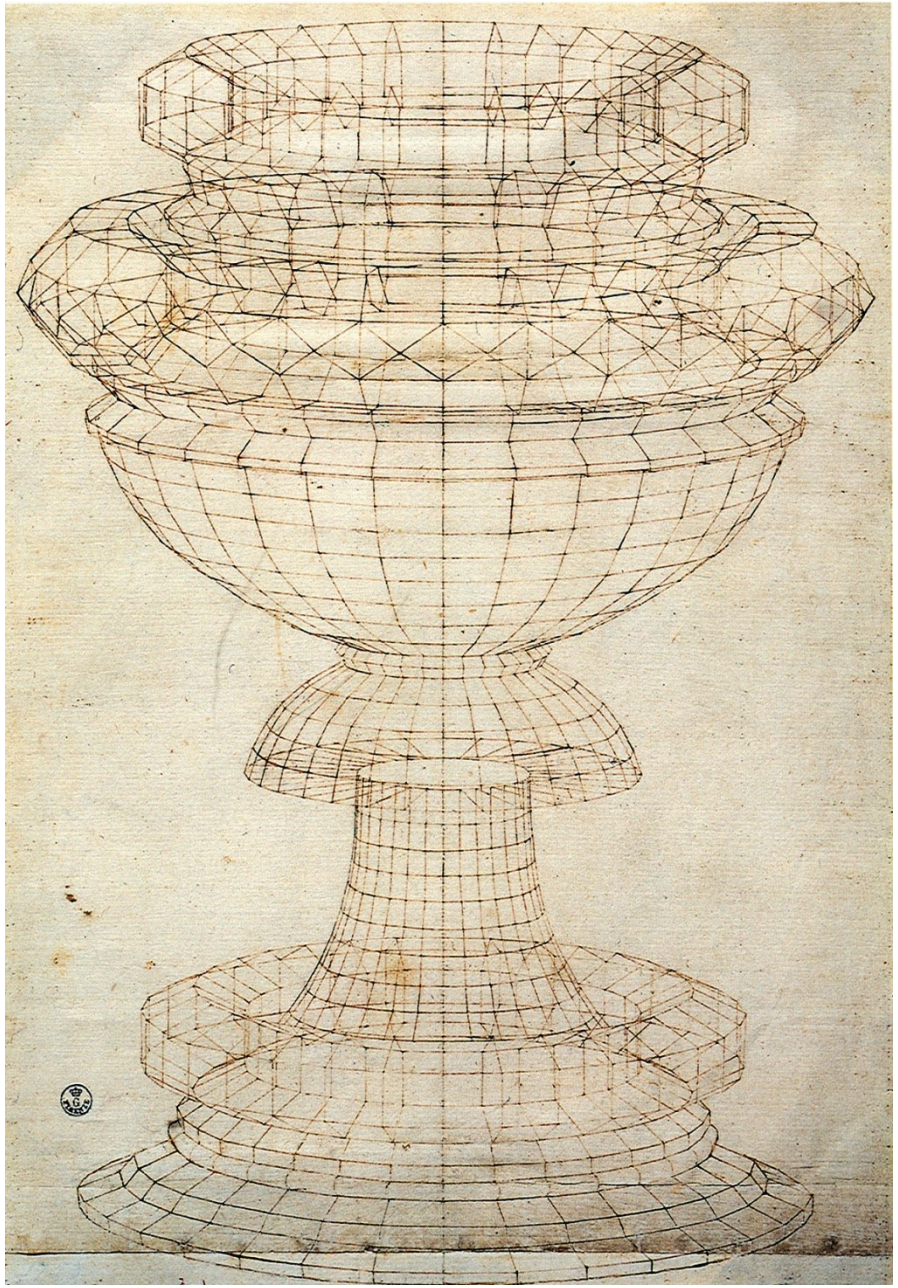
History of projection

- Later Renaissance: perspective formalized precisely



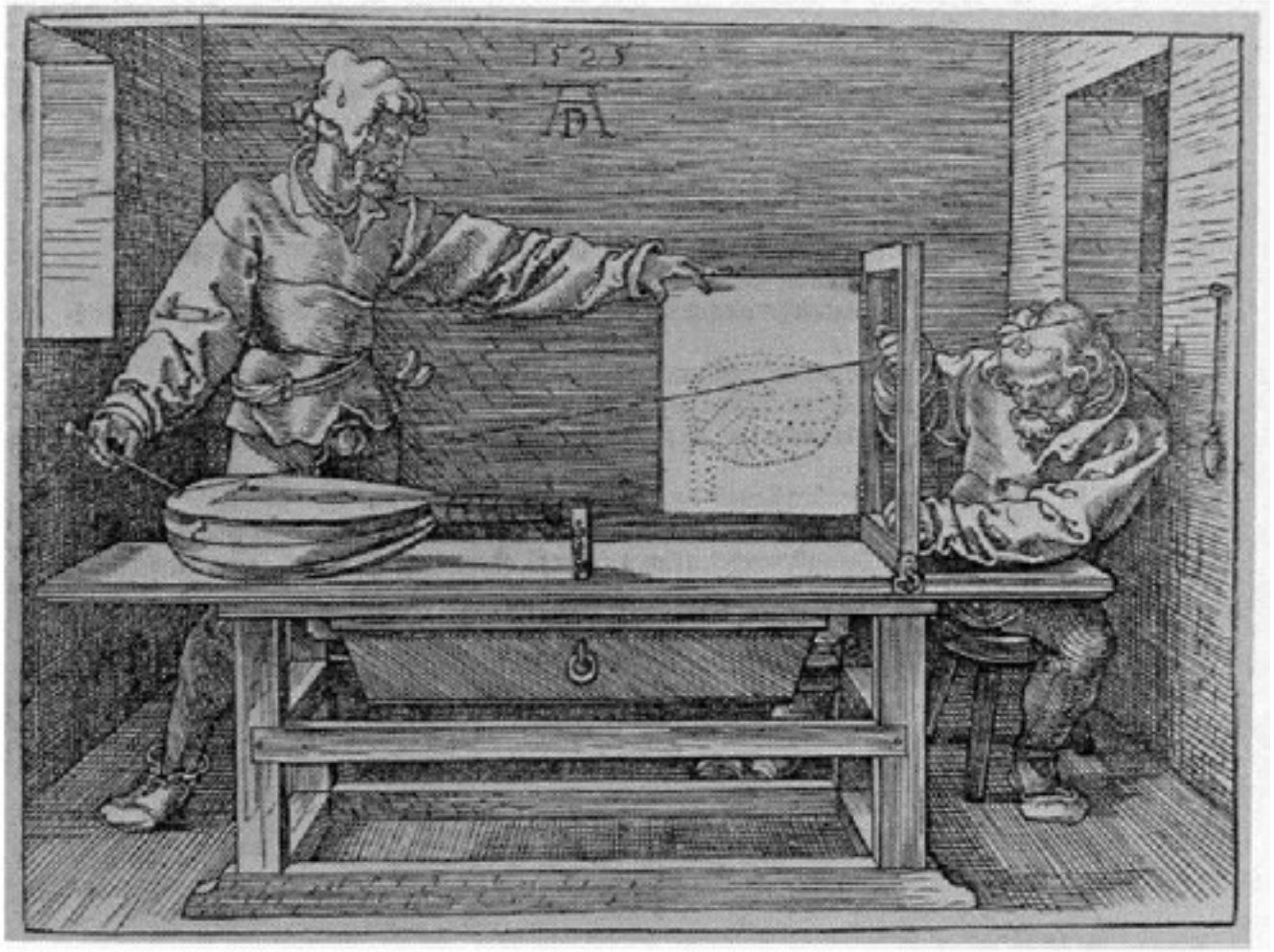
da Vinci c. 1498

Paolo Uccello (1397-1475)



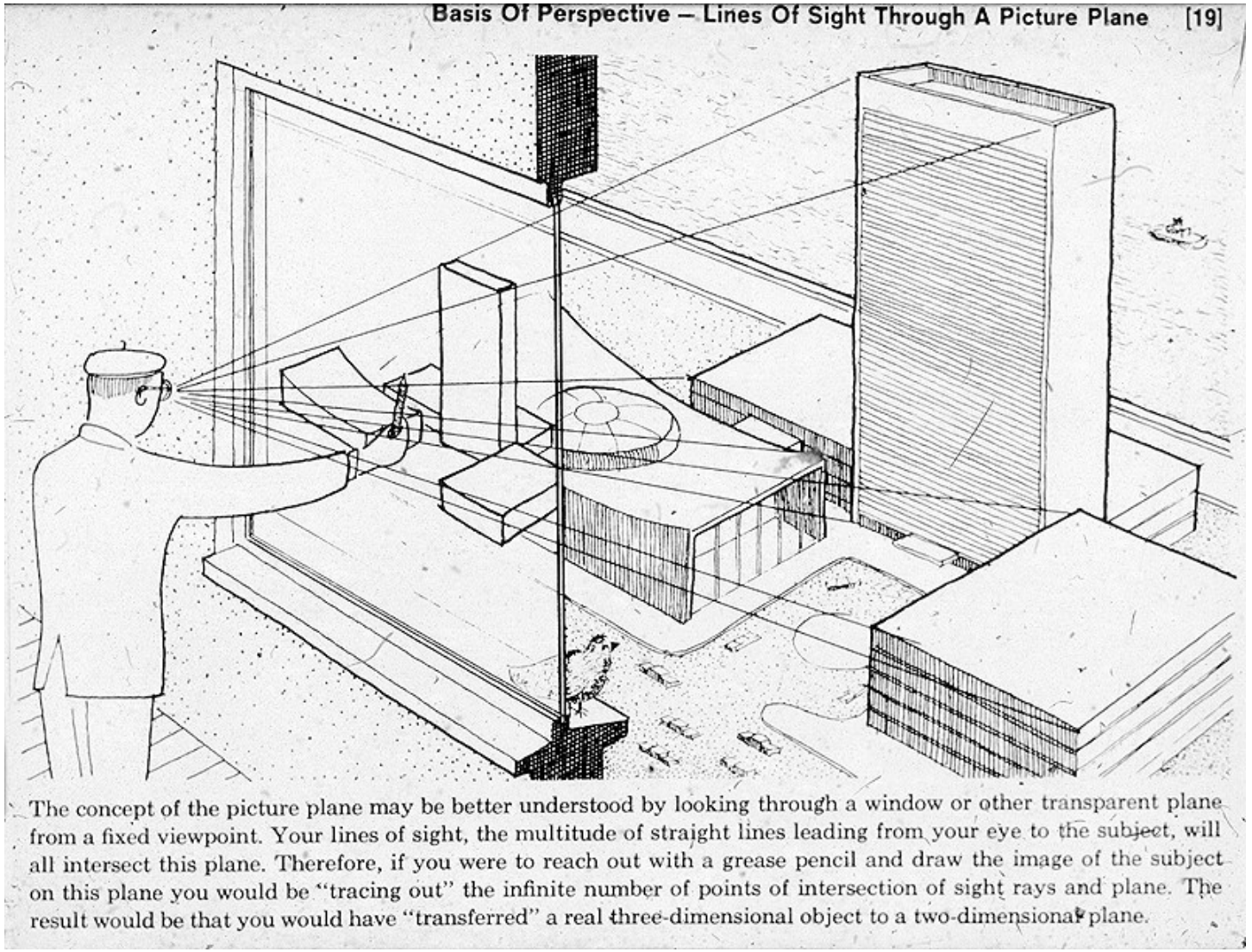
Plane projection in drawing

Artist Drawing a Lute, woodcut from Unterweysung der Messung mit dem Zyrkel und Rychtscheyd, 1525



[Carlbom & Paciorek 78 http://doi.acm.org/10.1145/356744.356750]

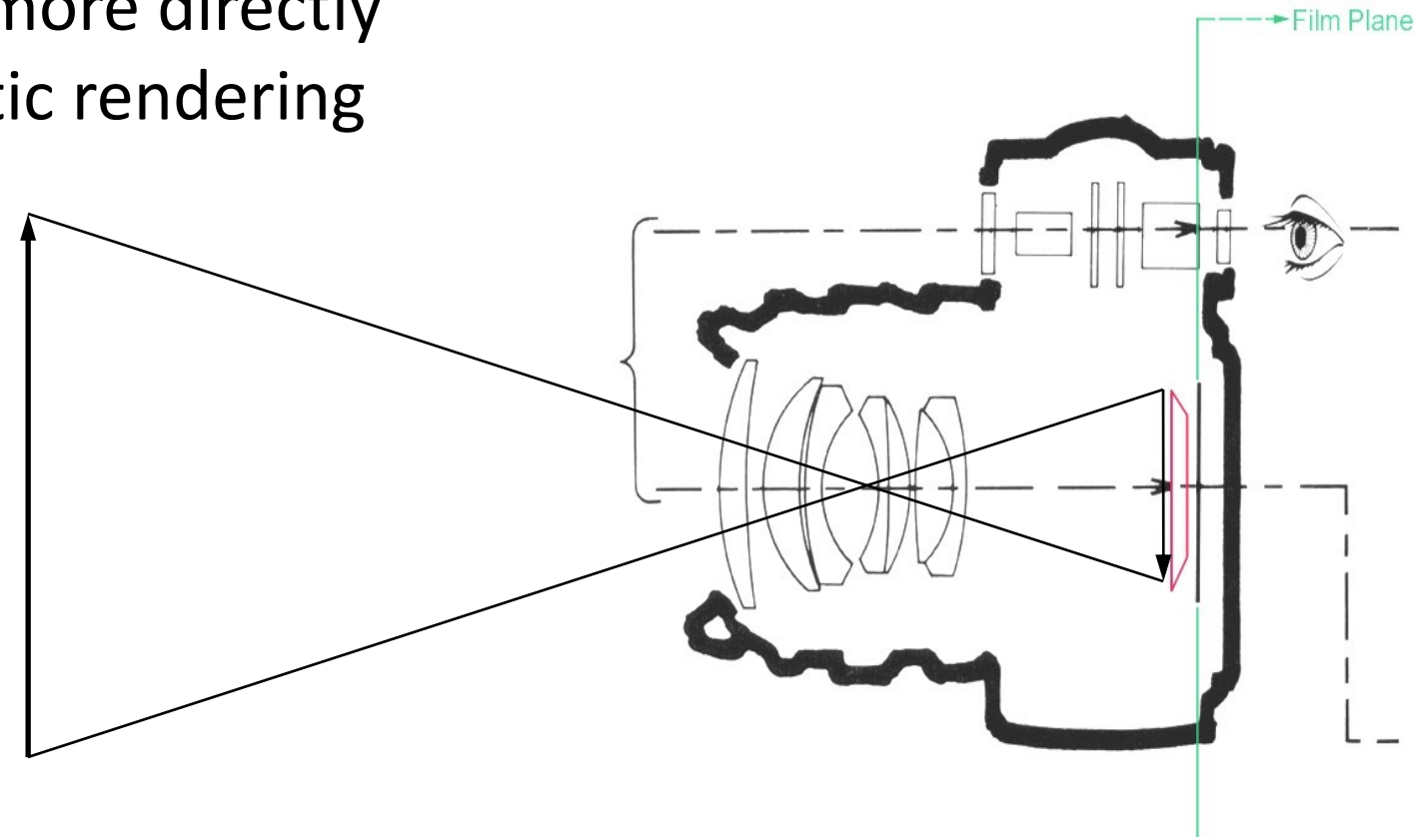
Plane projection in drawing



[Cornell CS 417 Spring 2002]

Plane projection in photography

- This is another model for what we are doing
  - applies more directly in realistic rendering

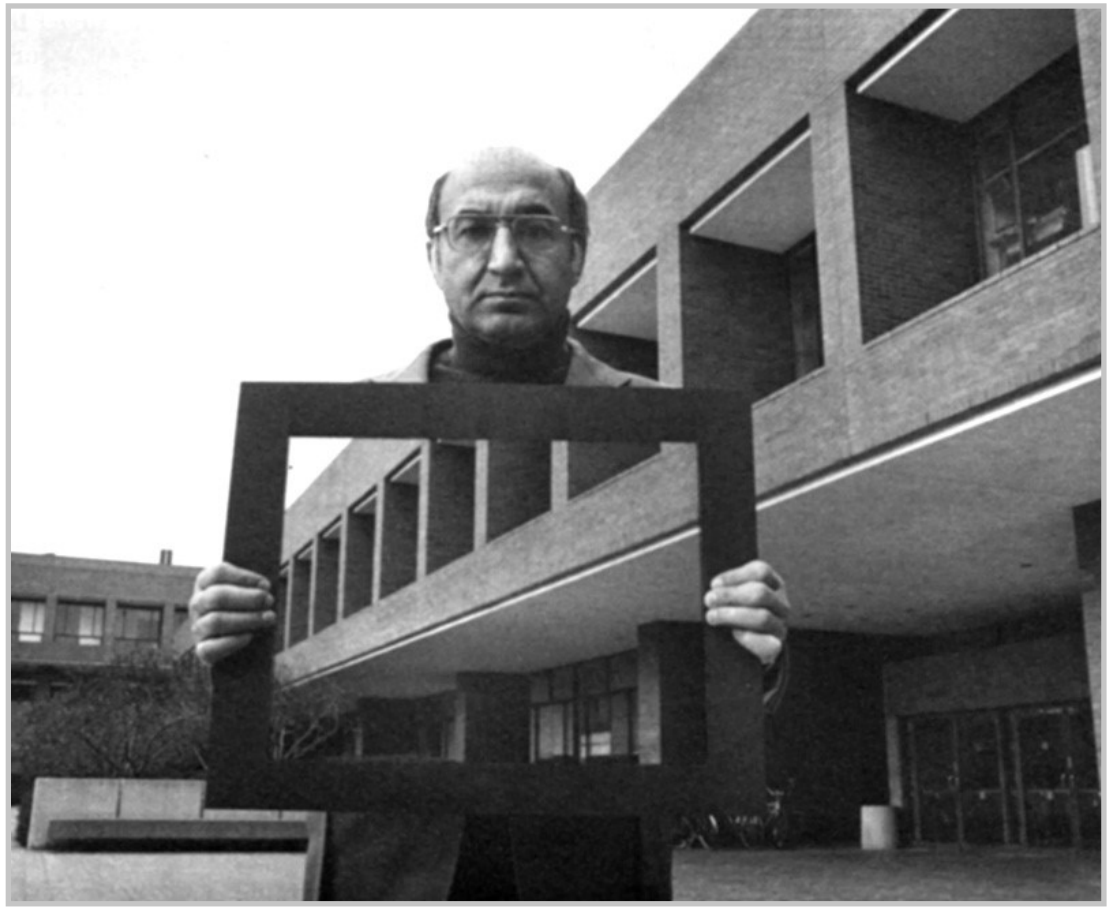


[Source unknown]

Based on slides by Steve Marschner

Plane projection in photography

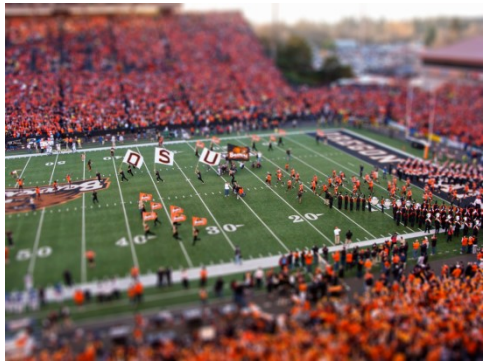
Questions: How was this picture made? What influences our perception of depth?



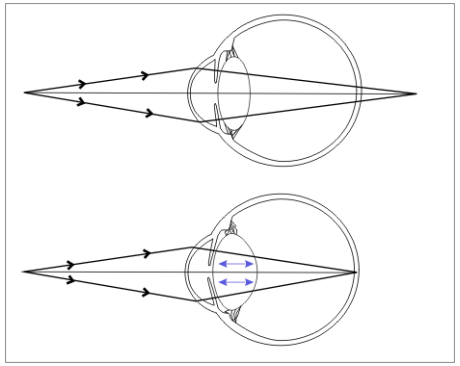
[Richard Zakia]

Tilt Shift Photography

How many depth perception cues can you think of?



defocus



accommodation

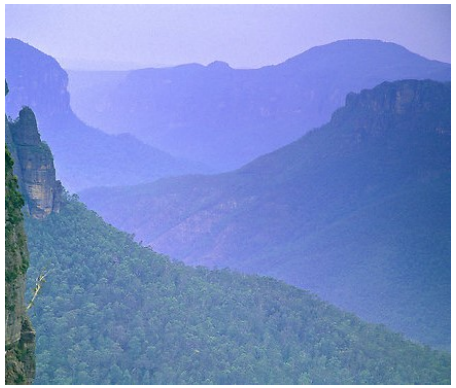
vergence

stereopsis

shading

reflection

shadows

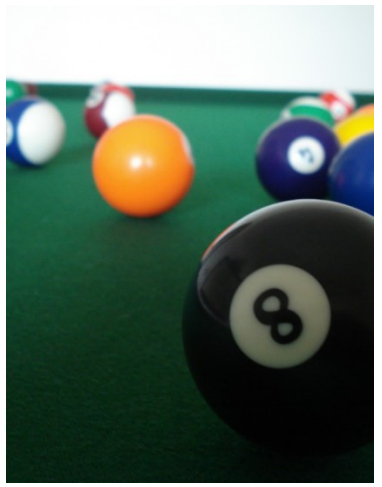


fog / atmospheric

occlusion

texture gradient

perspective

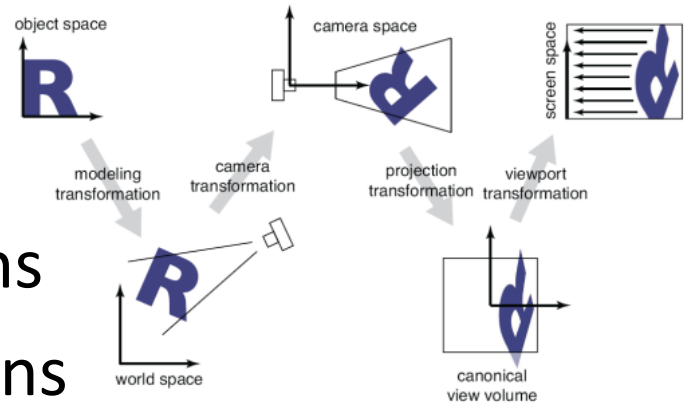


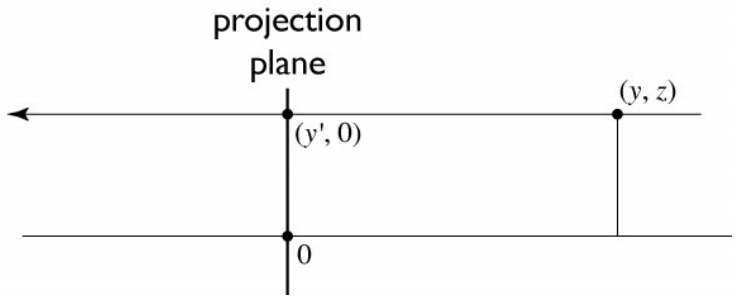
height in image

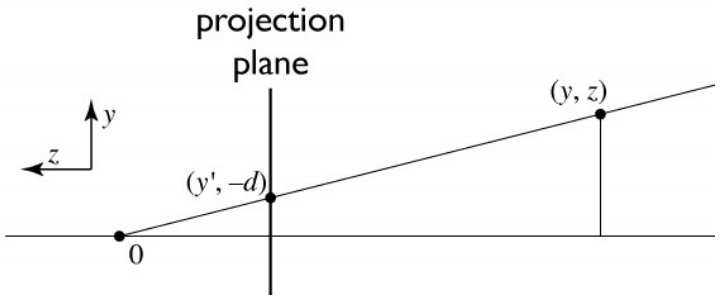
size familiarity

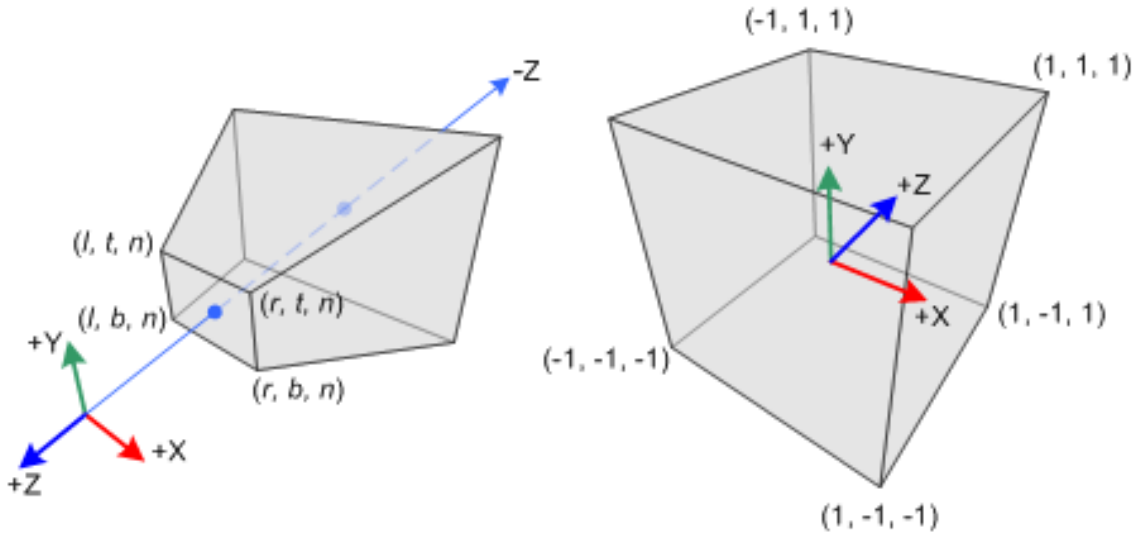
Review

- Pipeline of transformations
- Windowing transformations
- Orthographic projection matrix
- Perspective projection matrix
- Canonical view volume, Normalized Device Coordinates
- What goes where after perspective projection?

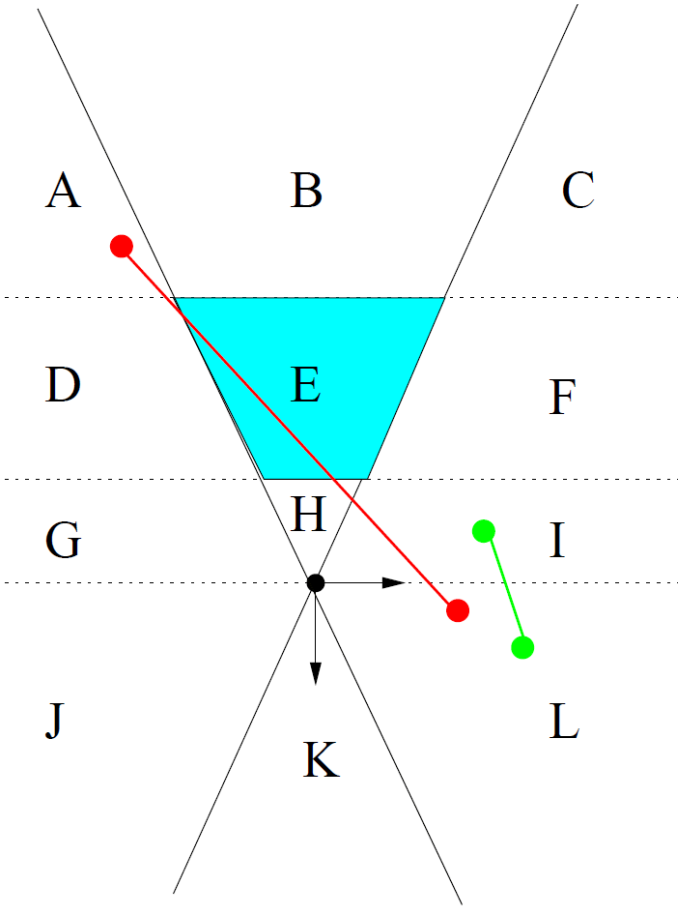








What goes where?



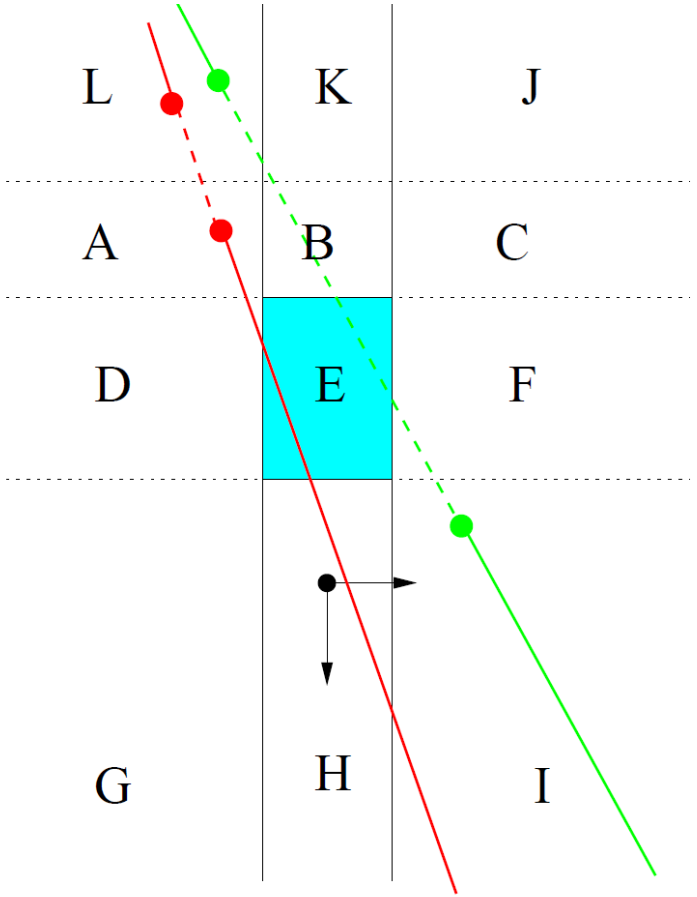
Camera coordinates

z = f0 + f1

z = f1

z = f0

z = 0



(non-normalized) projection coordinate

Notice implications for clipping (i.e., discarding) geometry!

Recall: Perspective transformation chain

- Transform into world coords (modeling transform, M_m)
- Transform into eye coords (camera xf., $M_{\text{cam}} = F_c^{-1}$)
- Perspective matrix, P
- Orthographic projection, M_{orth}
- Viewport transform, M_{vp}

$$\mathbf{p}_s = \mathbf{M}_{\text{vp}}\mathbf{M}_{\text{orth}}\mathbf{P}\mathbf{M}_{\text{cam}}\mathbf{M}_{\text{m}}\mathbf{p}_o$$

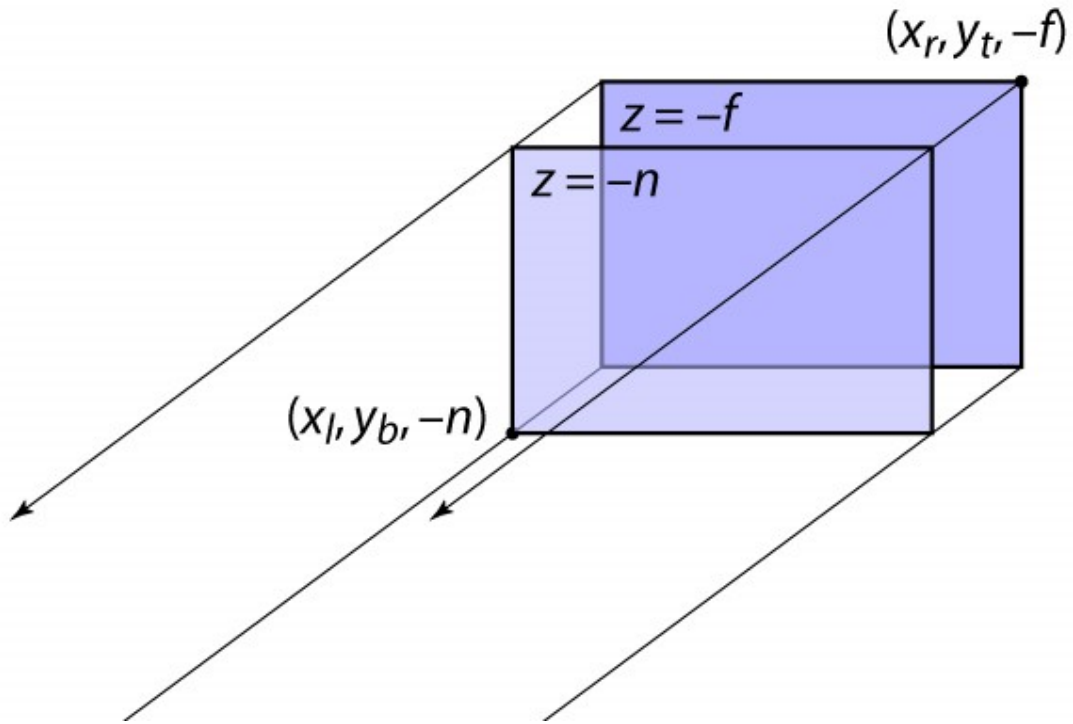
$$\begin{bmatrix} x_s \\ y_s \\ z_c \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{n_x}{2} & 0 & 0 & \frac{n_x-1}{2} \\ 0 & \frac{n_y}{2} & 0 & \frac{n_y-1}{2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} \frac{2}{r-l} & 0 & 0 & -\frac{r+l}{r-l} \\ 0 & \frac{2}{t-b} & 0 & -\frac{t+b}{t-b} \\ 0 & 0 & \frac{2}{n-f} & \frac{f+n}{n-f} \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} n & 0 & 0 & 0 \\ 0 & n & 0 & 0 \\ 0 & 0 & n+f & nf \\ 0 & 0 & -1 & 0 \end{pmatrix} \mathbf{M}_{\text{cam}}\mathbf{M}_{\text{m}} \begin{bmatrix} x_o \\ y_o \\ z_o \\ 1 \end{bmatrix}$$

OpenGL set with glViewport

Projection matrix

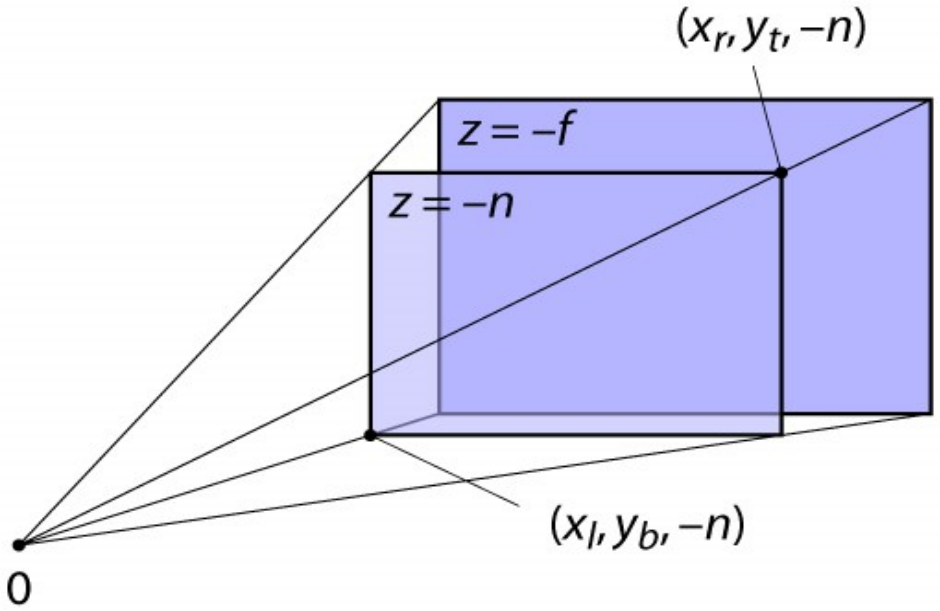
Viewing and Modeling Matrices

OpenGL view frustum: orthographic



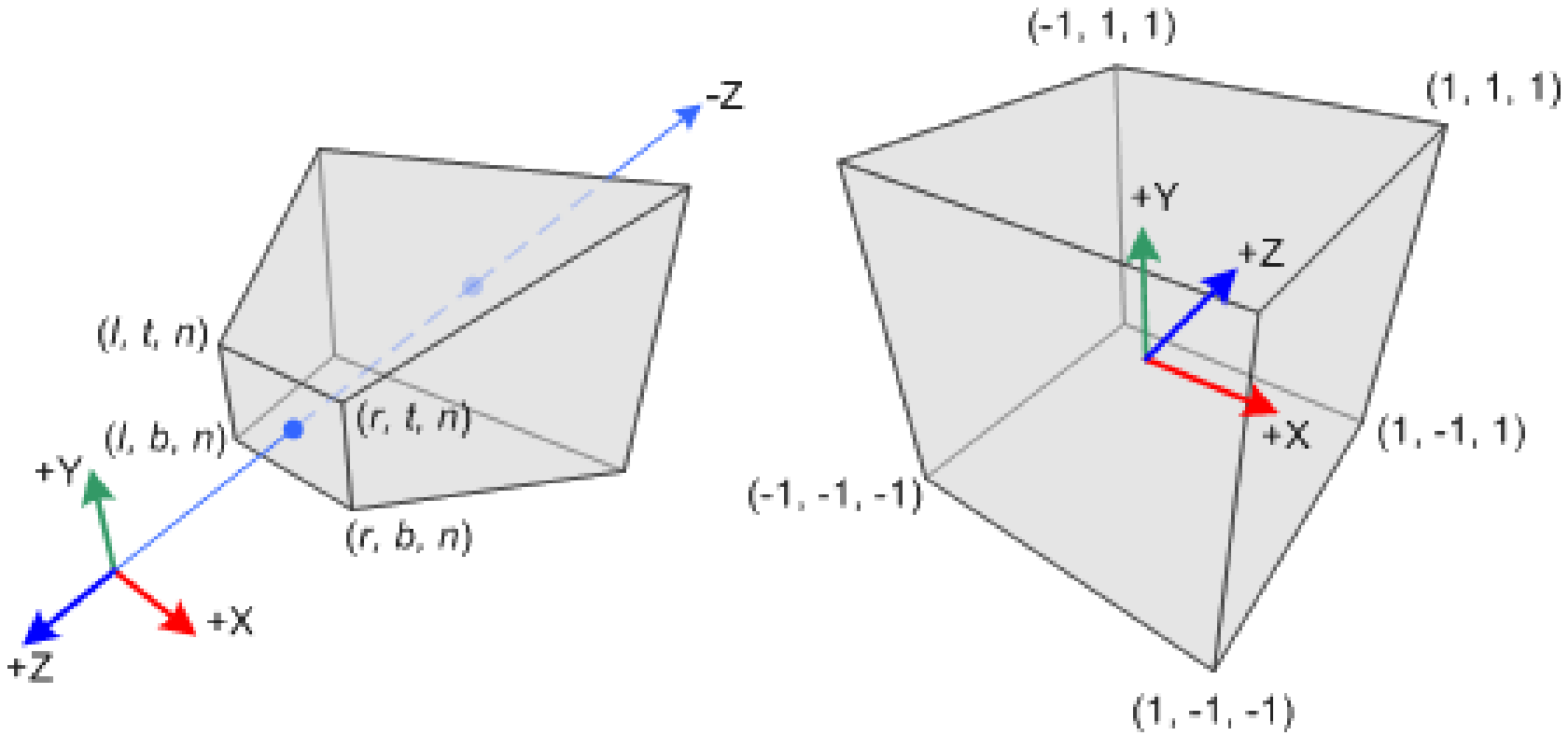
Note OpenGL puts the near and far planes at $-n$ and $-f$
so that the user can give positive numbers

OpenGL view frustum: perspective



Note we typically put the near and far planes at $-n$ and $-f$
so that the user can give positive numbers and think about distances

Frustum to Normalized Device Coordinates (NDC)



Note switch to left handed coordinates! (i.e., distance in z)

Frustum applications (explained on blackboard)

- Tiled rendering
  - Render very high resolutions
- 3D viewing
  - Left eye right eye
- Depth of field
  - Accumulating multiple render passes
- Shifted perspective