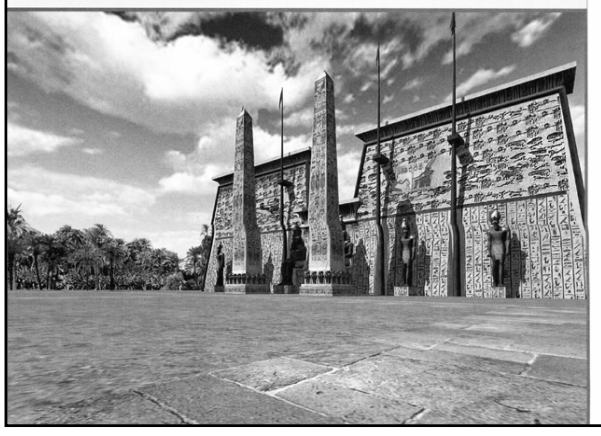
CHAPTER 7

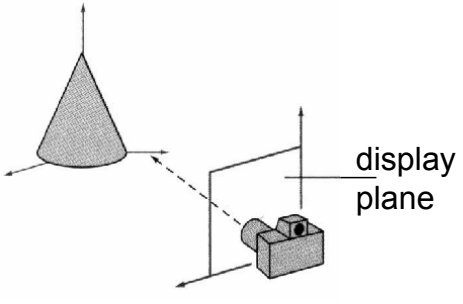
Three-Dimensional Viewing



Three-Dimensional Viewing

- overview of 3D viewing concepts
- 3D viewing pipeline
- 3D viewing-coordinate parameters
- transformation world → viewing coordinates
- projection transformations
  - orthogonal and parallel projections
  - perspective projections
- viewport transformation & 3D screen coord.

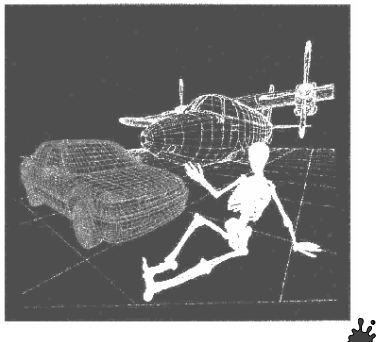
3D Display Methods



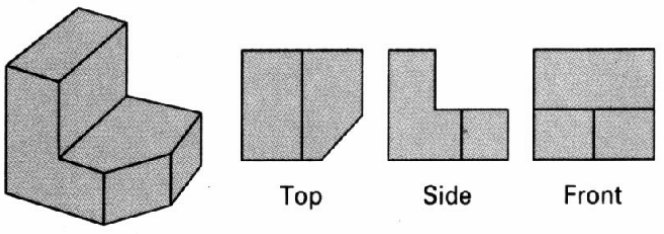
coordinate reference for obtaining a selected view of a 3D scene

3D Display: Wireframe Display

wireframe display of 3 objects, with back lines removed, from a commercial database of object shapes. Each object in the database is defined as a grid of coordinate points, which can then be viewed in wireframe form or in a surface-rendered form

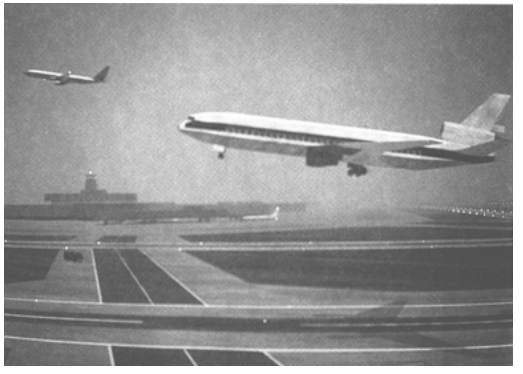


3D Display: Parallel Projection

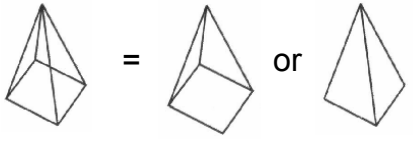


3 parallel-projection views of an object, showing relative proportions from different viewing positions

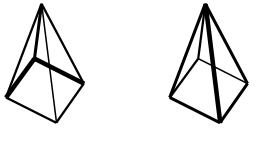
3D Display: Perspective Projection



3D Display: Depth Cueing

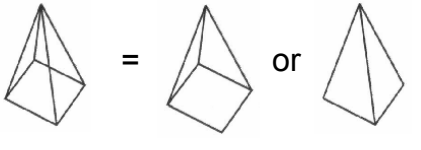


intensity decreases with increasing distance



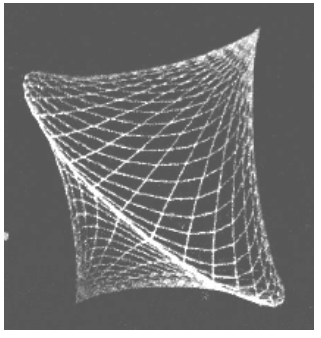
3D Display: Visibility

- visible line and surface identification



3D Display: Depth Cueing + Visibility

- only visible lines
- intensity decreases with increasing distance



3D Display: Surface Rendering

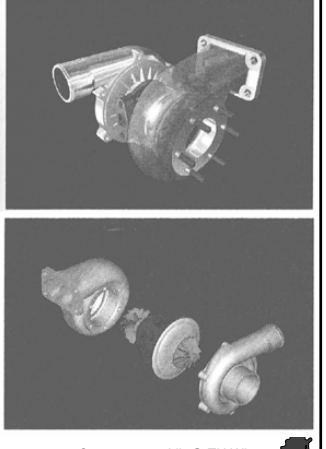
realistic room display achieved with stochastic ray-tracing methods that apply

- perspective projection
- surface-texture mapping
- illumination models

Other 3D Display Methods

- exploded and cutaway views

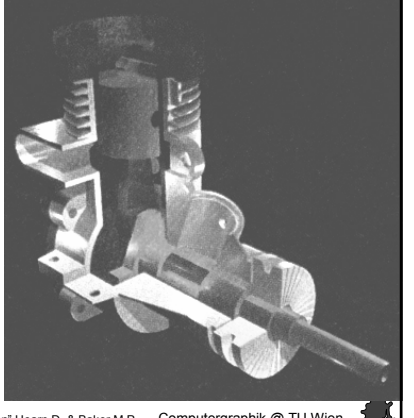
a fully rendered turbine can also be viewed as a surface-rendered exploded display



Other 3D Display Methods

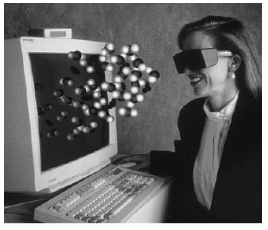
- exploded and cutaway views

color-coded cutaway view of a lawn mower engine showing the structure and relationship of internal components

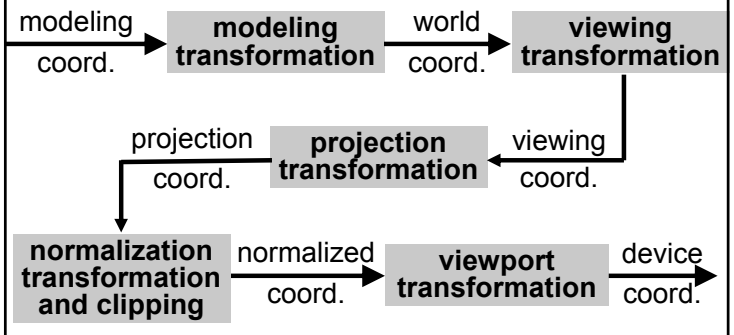


3D Display: Stereoscopic Views

- two views (one for the left, one for the right eye)
- head mounted displays (hmd)
- raster monitor with (shutter) glasses



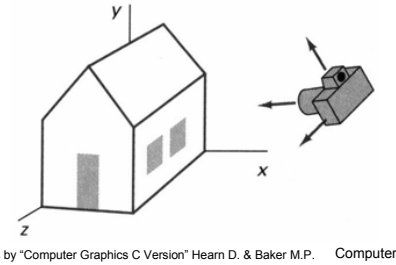
3D Viewing Pipeline



general 3-dim. transformation pipeline, from modeling coordinates to final device coordinates

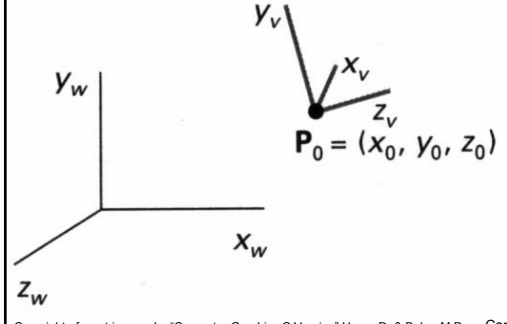
3D Viewing: Camera Definition

- similar to taking a photograph
- involves selection of
  - camera position
  - camera orientation
  - "window" (aperture) of camera



3D Viewing Coordinates (1)

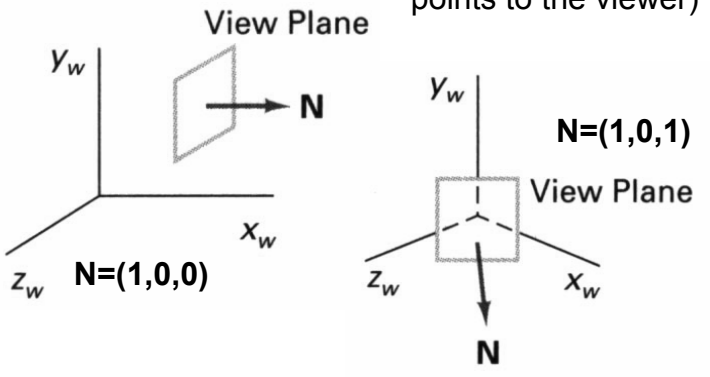
- view reference point
  - origin of viewing-coordinate system
  - camera position or look-at point



right-handed viewing-coord. system, with axes x_0, y_0, z_0, relative to world-coord. scene

3D Viewing Coordinates (2)

view-plane normal vector N (= positive z_v-axis, points to the viewer)



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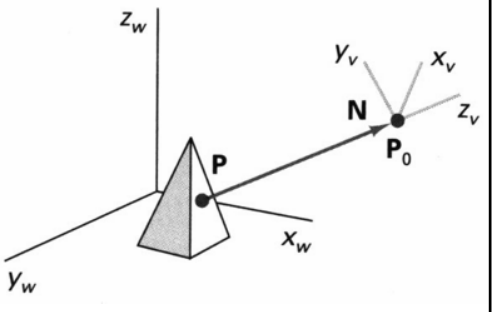
3D Viewing Coordinates (3)

view-plane normal vector N (positive z_v-axis)

orientation of the view plane for a specified look-at point P, relative to the viewing-coordinate origin P_0



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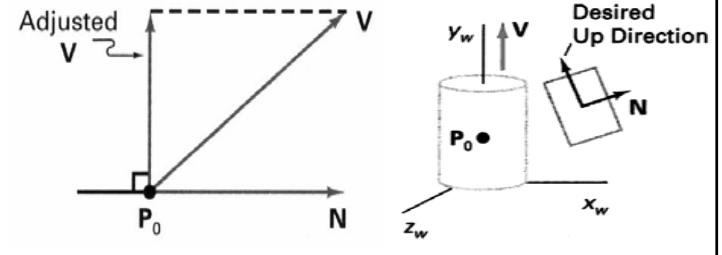
3D Viewing Coordinates (4)

choosing the view-up vector V (positive y_v-axis)



choose arbitrary up-vector and adjust it perpendicular to normal vector N

often: choose V along the y_w axis ⇒ desired direction

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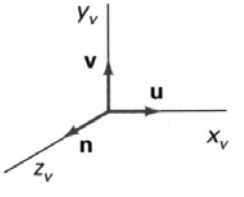
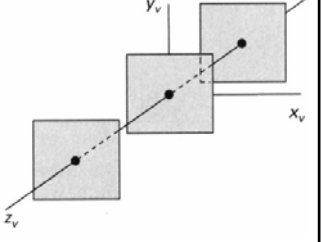
3D Viewing Coordinates (5)

- viewing-coordinate system
  - u = v x n (positive x_v-axis)
  - view-plane distance



a right-handed viewing system defined with unit vectors u, v, and n



view-plane positioning along the z_v axis

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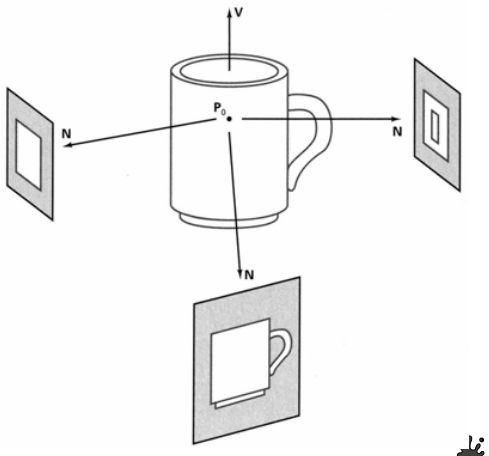
3D Viewing Coordinates (6)

viewing a scene from different directions with a **fixed view-reference point**



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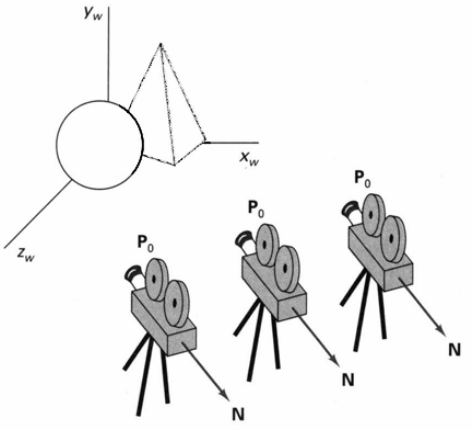
3D Viewing Coordinates (7)



moving around in a scene by **changing** the position of the **view reference point**

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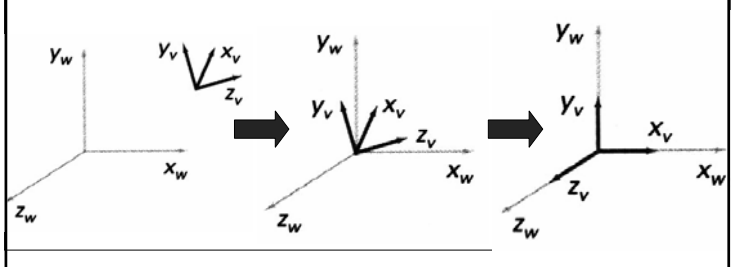
3D Viewing Coordinates (8)



$$\mathbf{M}_{WC,VC} = \mathbf{R}_z \cdot \mathbf{R}_y \cdot \mathbf{R}_x \cdot \mathbf{T}$$

aligning viewing system with world-coordinate axes using translate-rotate transformations

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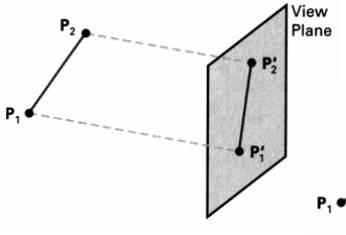
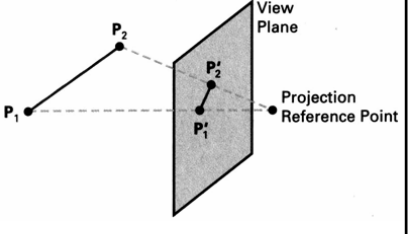
Projections



parallel projection: parallel lines, preserves relative proportions



perspective projection: center of projection, realistic views

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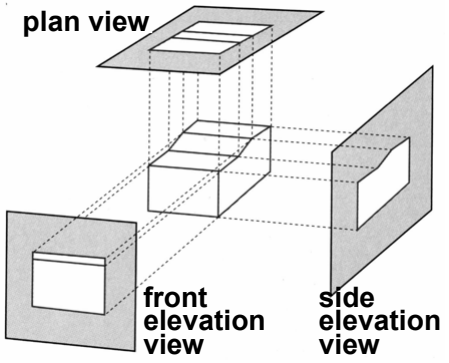
Parallel Projection (1)

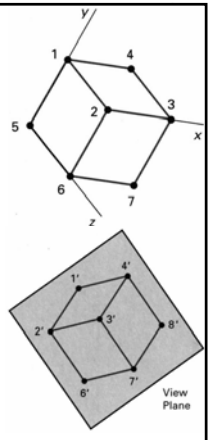
orthographic projection

oblique projection

orientation of the projection vector V_p

Parallel Projection (2)

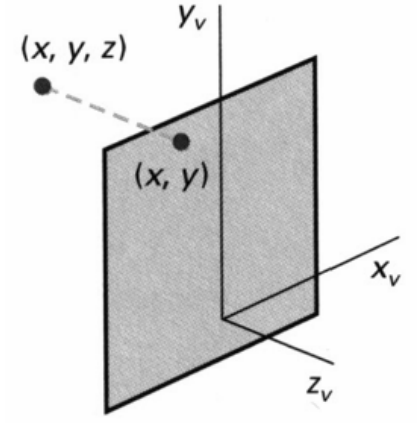




orthographic projections of an object

isometric projection for a cube

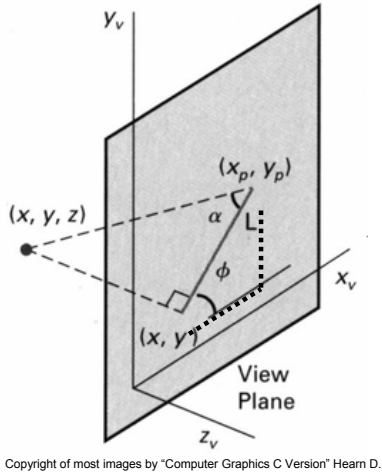
Orthographic Parallel Projection



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

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

Oblique Parallel Projection

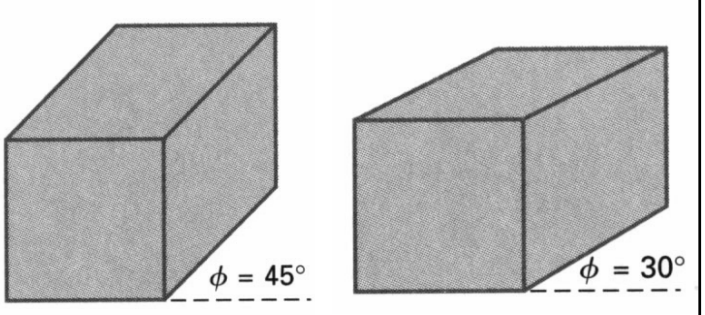


$$\tan\alpha = z/L$$
$$L = z/\tan\alpha$$

$$x_p = x + L\cos\phi$$
$$y_p = y + L\sin\phi$$

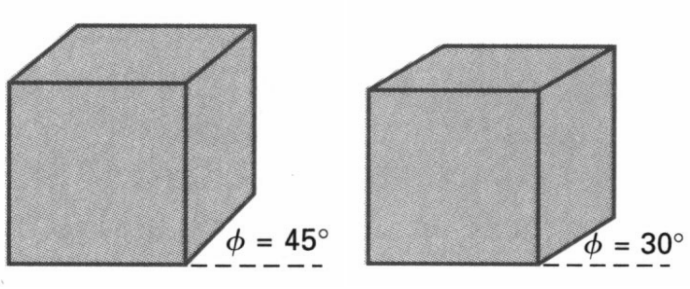
$$\mathbf{M}_{parallel} = \begin{bmatrix} 1 & 0 & \frac{\cos\phi}{\tan\alpha} & 0 \\ 0 & 1 & \frac{\sin\phi}{\tan\alpha} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Parallel Proj.: Cavalier Projection



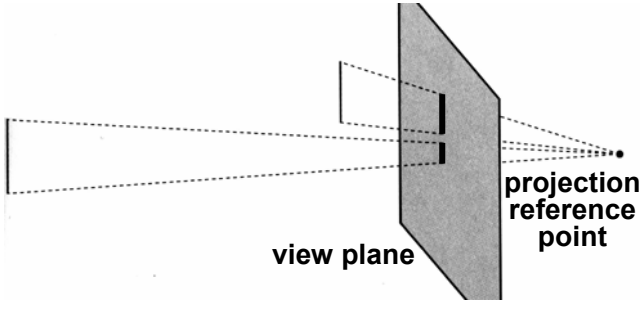
depth of the cube is projected
equal to the width and the height

Parallel Proj.: Cabinet Projection



depth of the cube is projected as
one-half that of the width and height

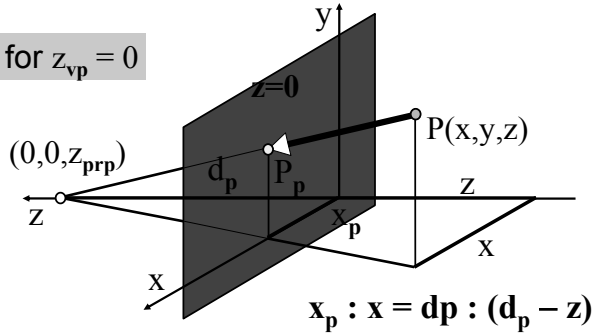
Perspective Projection



perspective projection of equal-sized objects
at different distances from the view plane

1st Derivation of Perspective (1)

1. for $z_{vp} = 0$

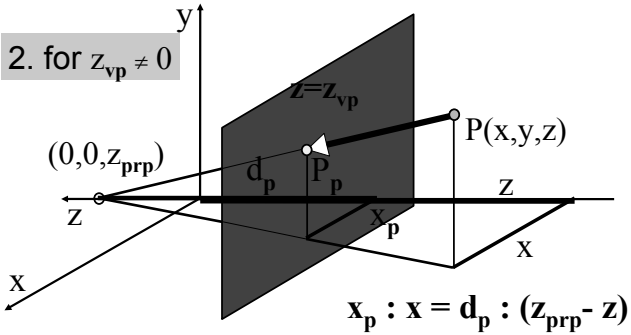


$$x_p : x = dp : (d_p - z)$$

$$x_p = \frac{x \cdot d_p}{d_p - z} \qquad y_p = \frac{y \cdot d_p}{d_p - z} \qquad z_p = 0$$

1st Derivation of Perspective (2)

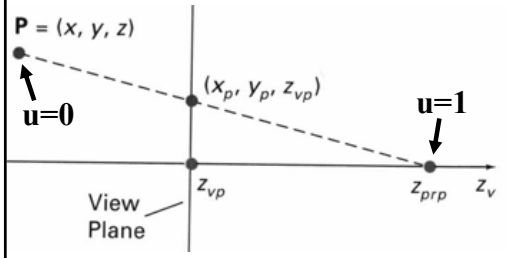
2. for $z_{vp} \neq 0$



$$x_p : x = d_p : (z_{prp} - z)$$

$$x_p = \frac{x \cdot d_p}{z_{prp} - z} \qquad y_p = \frac{y \cdot d_p}{z_{prp} - z} \qquad z_p = z_{vp}$$

2nd Derivation of Perspective (1)



perspective projection of a point P (x,y,z) to position (x_p, y_p, z_p) on the view plane

$x' = x - xu$ (x',y',z') any point on line for $\underline{0 \leq u \leq 1}$

$y' = y - yu$

$z' = z - (z - z_{prp})u \qquad z' = z_{vp} \Rightarrow u = \frac{z_{vp} - z}{z_{prp} - z}$

2nd Derivation of Perspective (2)

$$x_p = x - xu = x\,(1 - u)$$

$$u = \frac{z_{vp} - z}{z_{prp} - z}$$

$$x_p = x\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right) = x\left(\frac{d_p}{z_{prp} - z}\right)$$

$$d_p = z_{prp} - z_{vp}$$

$$y_p = y\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right) = y\left(\frac{d_p}{z_{prp} - z}\right)$$

2nd Derivation of Perspective (3)

$$\begin{bmatrix} x_h \\ y_h \\ z_h \\ h \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -z_{vp}/d_p & z_{vp}(z_{prp}/d_p) \\ 0 & 0 & -1/d_p & z_{prp}/d_p \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$h = \frac{z_{prp} - z}{d_p}$$

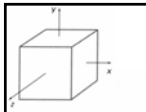
$$x_p = x_h / h$$

$$y_p = y_h / h$$

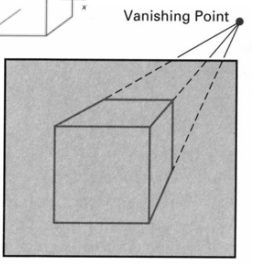
$h \neq 1$!!!

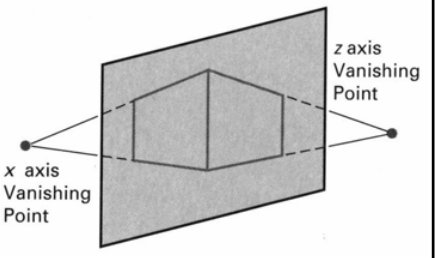
Perspective Projection Properties

- special cases: $z_{vp}=0$ or $z_{prp}=0$
- parallel lines parallel to view plane $\Rightarrow$ parallel lines
- parallel lines not parallel to view plane $\Rightarrow$ converging lines (vanishing point)
- lines parallel to coordinate axis $\Rightarrow$ principal vanishing point (one, two or three)



Vanishing Points





1-point persp. proj. 2-point persp. proj.

perspective views & **principle vanishing points** of a cube for various orientations of the view plane relative to the principle axes of the object