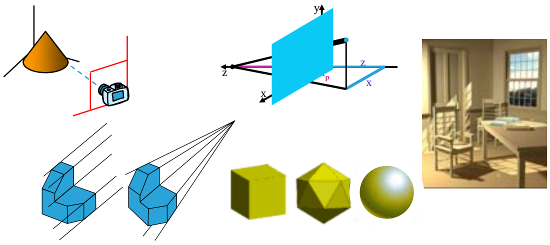
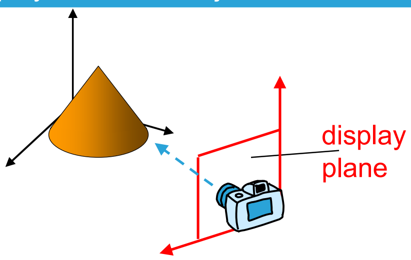
3D Viewing



Three-Dimensional Viewing

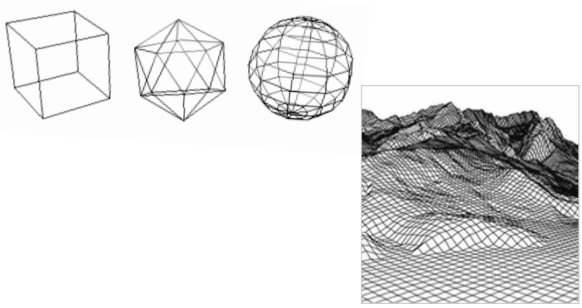
- overview of 3D viewing concepts
- 3D viewing pipeline
- 3D viewing-coordinate parameters
- transformation world → viewing coordinates
- projection transformations
  - orthogonal and parallel projections
  - perspective projections

3D Display Methods: Projection Plane

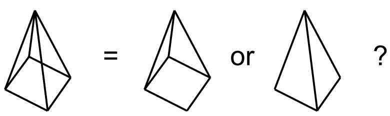


coordinate reference for obtaining a selected view of a 3D scene

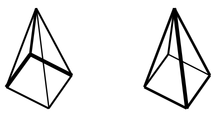
3D Display: Wireframe Display



3D Display: Depth Cueing

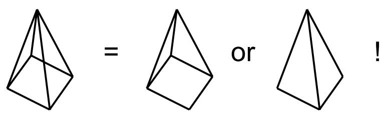


intensity decreases with increasing distance



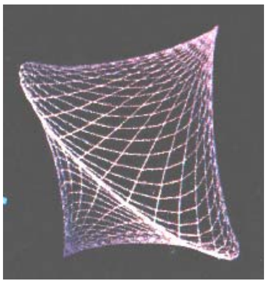
3D Display: Visibility

- visible line and surface identification

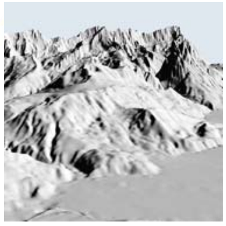


3D Display: Depth Cueing + Visibility

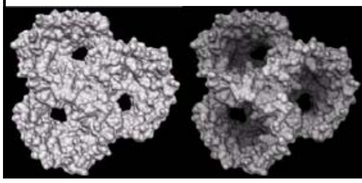
- only visible lines
- intensity decreases with increasing distance



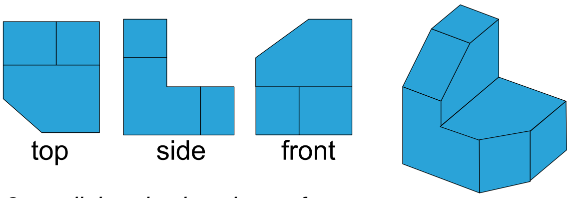
3D Display: Shaded Display



shading + depth cueing:

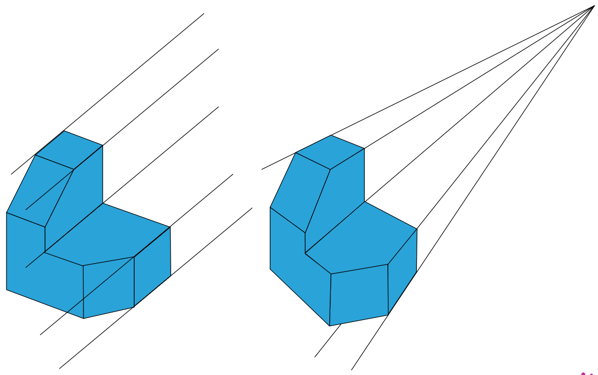


3D Display: Parallel Projection



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

3D Display: Perspective Projection



3D Display: Illumination and Shadows

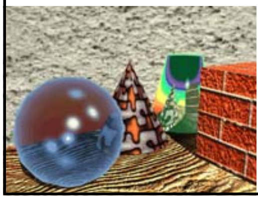
- perspective projection
- local and global illumination models
- shadow generation

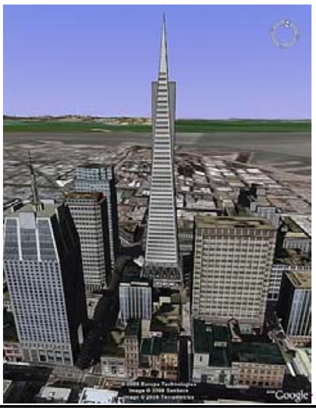
3D Display: Reflection and Transparency

- perspective projection
- local and global illumination models
- reflectivity
- transparency
- shadows

3D Display: Surface Rendering

- perspective projection
- simple illumination model
- surface textures

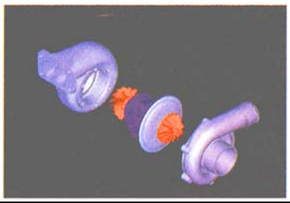




Other 3D Display Methods

- exploded and cutaway views

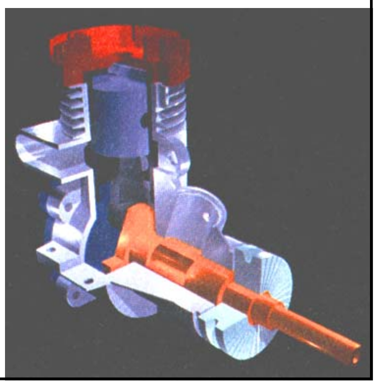
a fully rendered turbine can also be viewed as a surface-rendered exploded display



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

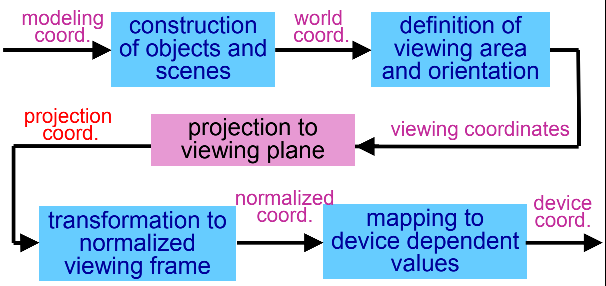


3D Display: Stereoscopic Views

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

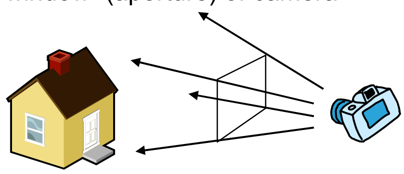
~~2-dim.~~ Viewing-Transformation Pipeline

3-dim.



3D Viewing: Camera Definition

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



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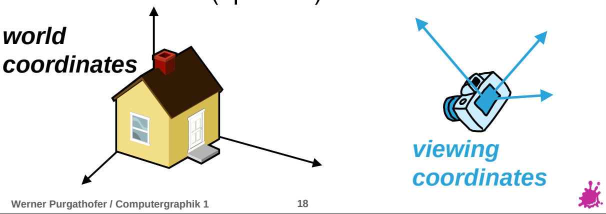
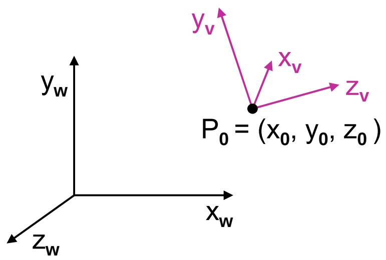


3D Viewing Coordinates (1)

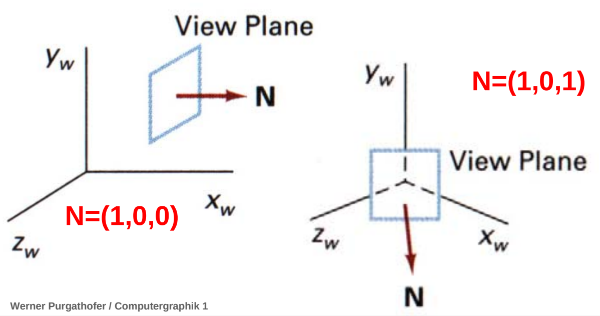
- view reference point
  - origin of viewing-coordinate system
  - camera position or look-at point



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

3D Viewing Coordinates (2)

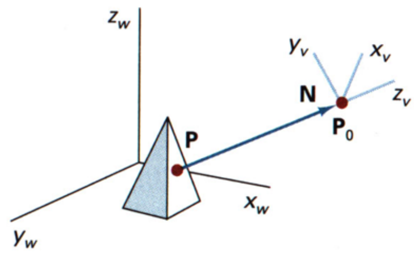
view-plane normal vector N (= positive z_v-axis, points to the viewer)



3D Viewing Coordinates (3)

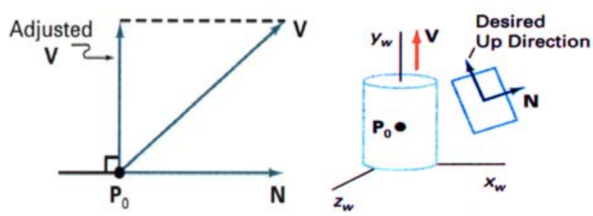
view-plane normal vector N (positive z_v-axis)

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



3D Viewing Coordinates (4)

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

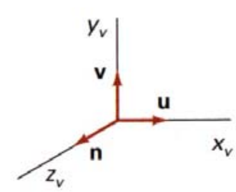


choose arbitrary up-vector and adjust it perpendicular to normal vector N

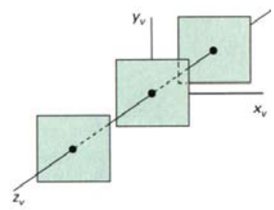
often: choose V along the y_w axis $\Rightarrow$ desired direction

3D Viewing Coordinates (5)

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

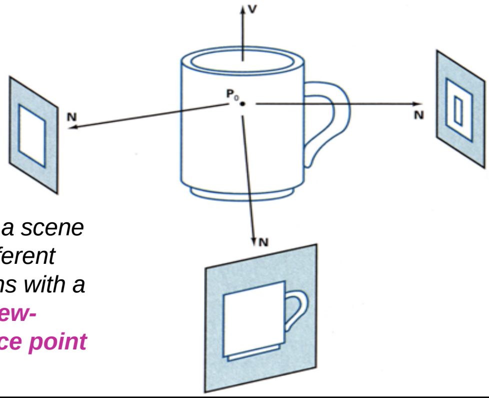


a right-handed viewing system defined with unit vectors u, v, and n



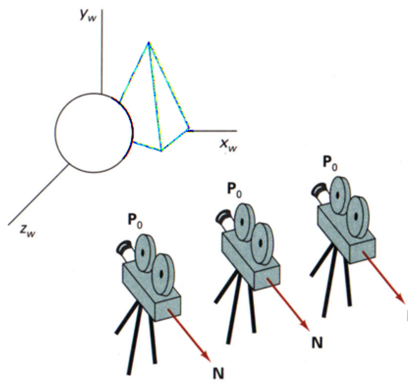
view-plane positioning along the z_v axis

3D Viewing Coordinates (6)



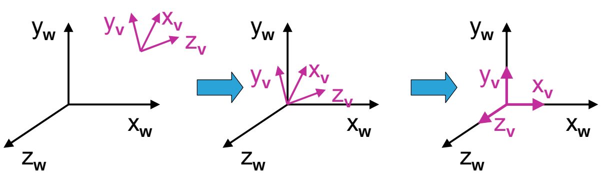
viewing a scene from different directions with a ***fixed view-reference point***

3D Viewing Coordinates (7)



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

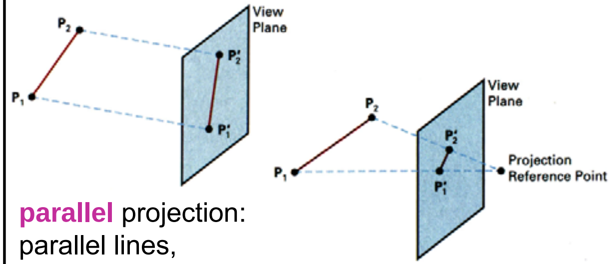
3D Viewing Coordinates (8)



$$M_{WC,VC} = R_z \cdot R_y \cdot R_x \cdot T$$

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

Projections



parallel projection: parallel lines, preserves relative proportions

perspective projection: center of projection, realistic views

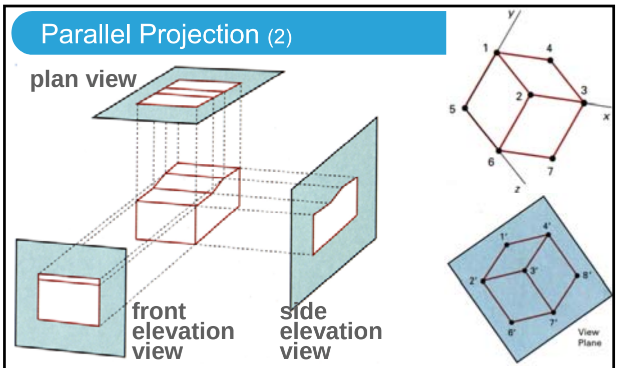
Parallel Projection (1)

orthographic projection

oblique projection

orientation of the projection vector V_p

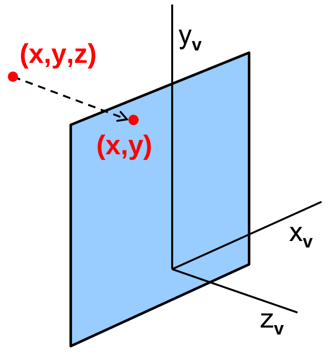
Parallel Projection (2)



orthographic projections of an object

isometric projection for a cube

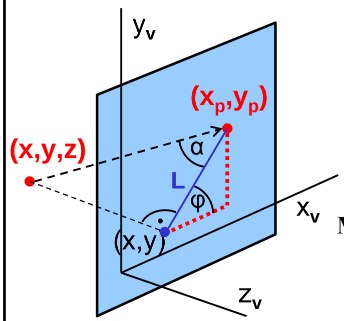
Orthographic Parallel Projection



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

$$M_{parallel} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Oblique Parallel Projection

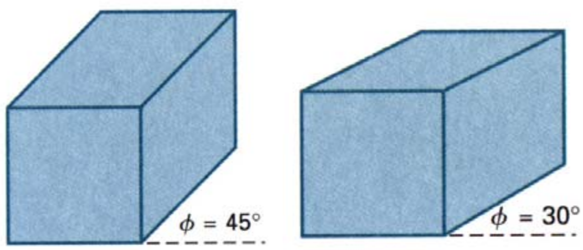


$$\tan\alpha = z / L \qquad L = z / \tan\alpha$$

$$x_p = x + L\cos\varphi \qquad y_p = y + L\sin\varphi$$

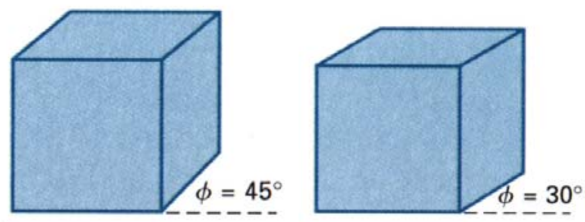
$$M_{parallel} = \begin{bmatrix} 1 & 0 & \frac{\cos\varphi}{\tan\alpha} & 0 \\ 0 & 1 & \frac{\sin\varphi}{\tan\alpha} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Parallel Projections: Cavalier Projection



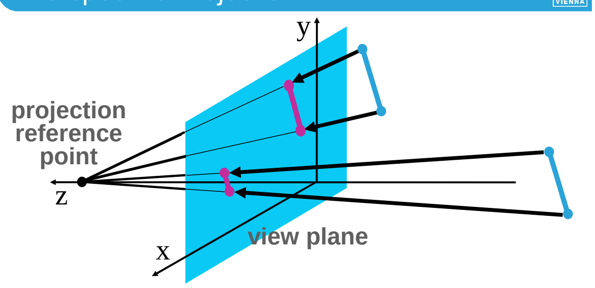
depth of the cube is projected equal to the width and the height

Parallel Projections: Cabinet Projection



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

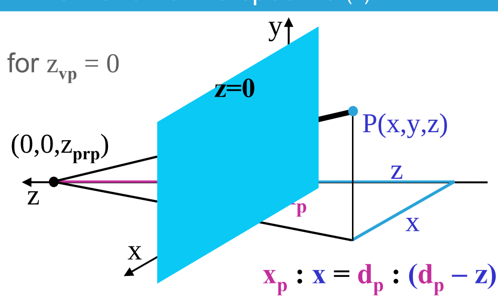
Perspective Projection



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

1st Derivation of Perspective (1)

1. for $z_{vp} = 0$

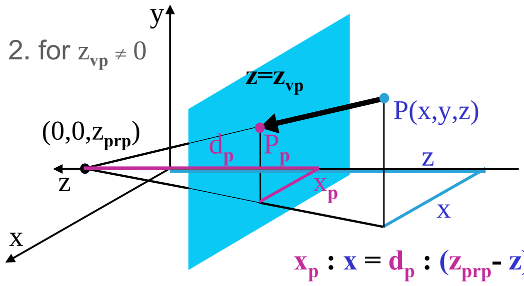


$$x_p : x = d_p : (d_p - z)$$

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

1st Derivation of Perspective (2)

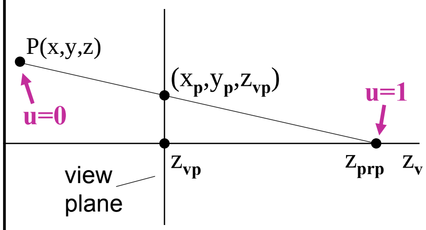
2. for $z_{vp} \neq 0$



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

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

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

$x' = x - xu$

$y' = y - yu$

$z' = z - (z - z_{prp})u$

(x',y',z') any point on line for $0 \leq u \leq 1$

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

2nd Derivation of Perspective (2)

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

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

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

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

$$x_p = x_h / h$$

$$y_p = y_h / h$$

Perspective Projection Properties

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

Principle Vanishing Points