

Three-Dimensional Viewing

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

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3D Display Methods: Projection Plane

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

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3D Display: Wireframe Display

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3D Display: Depth Cueing

intensity decreases with increasing distance

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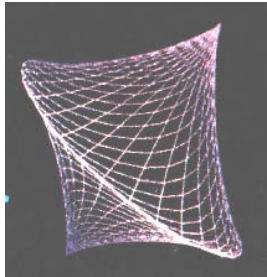
3D Display: Visibility

- visible line and surface identification

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3D Display: Depth Cueing + Visibility

- only visible lines
- intensity decreases with increasing distance

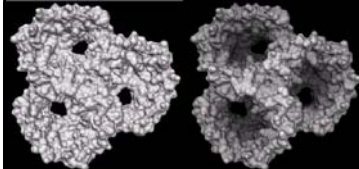
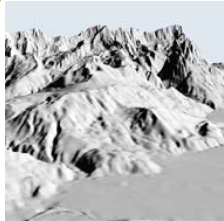


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3D Display: Shaded Display

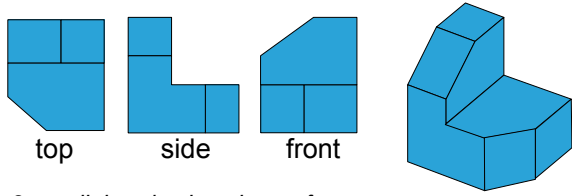


shading + depth cueing:

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3D Display: Parallel Projection

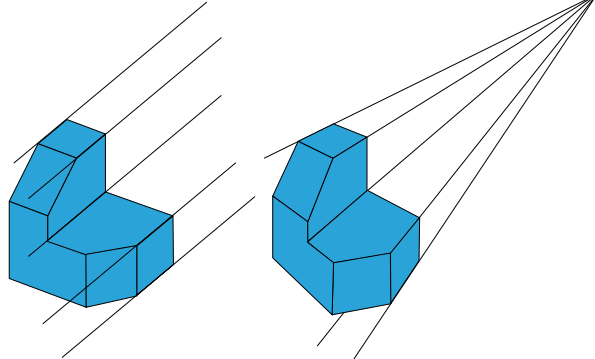


top side front

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

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3D Display: Perspective Projection



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3D Display: Illumination and Shadows


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



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3D Display: Reflection and Transparency


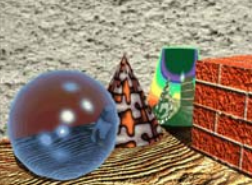
- perspective projection
- local and global illumination models
- reflectivity
- transparency
- shadows



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3D Display: Surface Rendering

- perspective projection
- simple illumination model
- surface textures

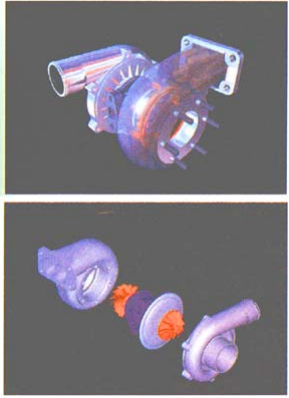



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Other 3D Display Methods

- exploded and cutaway views

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

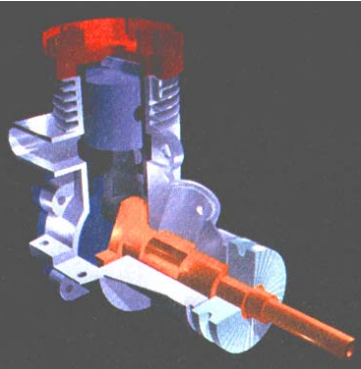


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Other 3D Display Methods

- exploded and cutaway views


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



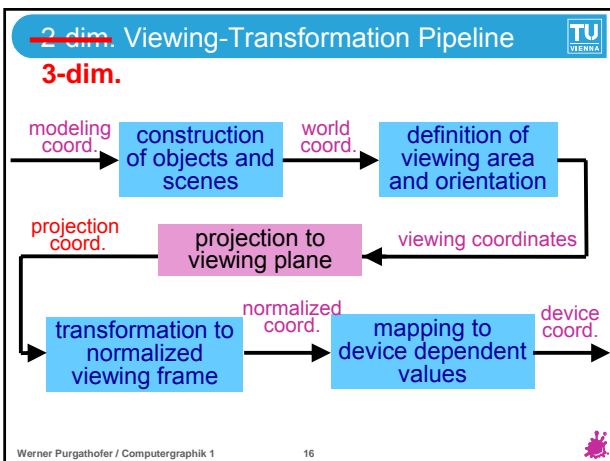
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3D Display: Stereoscopic Views

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

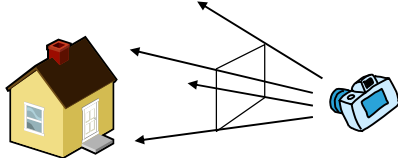


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3D Viewing: Camera Definition

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



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3D Viewing: Camera Definition

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The diagram shows a yellow house in a 3D coordinate system labeled "world coordinates". To the right, a camera is shown in a coordinate system labeled "viewing coordinates".

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3D Viewing Coordinates (1)

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

The diagram shows a 3D coordinate system with axes x_w , y_w , and z_w . A viewing-coordinate system is defined with axes x_v , y_v , and z_v . The origin of the viewing system is $P_0 = (x_0, y_0, z_0)$. The text states: "right-handed viewing-coord. system, with axes x_0, y_0, z_0 , relative to world-coord. scene".

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3D Viewing Coordinates (2)

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

The diagram shows two views of a view plane. In the first, the normal vector N points along the positive x_w axis, labeled $N=(1,0,0)$. In the second, N points along the positive z_w axis, labeled $N=(1,0,1)$.

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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

The diagram shows a view plane with normal vector N pointing towards the viewer. A look-at point P is shown, and the viewing-coordinate origin is P_0 . The viewing-coordinate axes x_v, y_v, z_v are also shown.

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3D Viewing Coordinates (4)

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

The diagram shows a view-up vector V being adjusted to be perpendicular to the normal vector N . The origin is P_0 . The text says: "choose arbitrary up-vector and adjust it perpendicular to normal vector N ".

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

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3D Viewing Coordinates (5)

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

The diagram shows the definition of the viewing-coordinate system with unit vectors u, v, n . The text says: "a right-handed viewing system defined with unit vectors u, v, n ".

The second diagram shows the 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)

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

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

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Parallel Projection (2)

orthographic projections of an object

isometric projection for a cube

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Orthographic Parallel Projection

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

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

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Oblique Parallel Projection

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

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

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

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Parallel Projections: Cavalier Projection

$\phi = 45^\circ$ $\phi = 30^\circ$

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

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Parallel Projections: Cabinet Projection

$\phi = 45^\circ$ $\phi = 30^\circ$

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

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Perspective Projection

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

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1st Derivation of Perspective (1)

1. for $z_{vp} = 0$

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

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

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1st Derivation of Perspective (2)

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

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

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

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

$$x' = x - xu$$

$$y' = y - yu$$

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

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2nd Derivation of Perspective (2)

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

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

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

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

$$x_p = x_h / h$$

$$y_p = y_h / h$$

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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)

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Principle Vanishing Points

1-point perspective projection

2-point persp. proj.

3-point persp. proj.

vanishing point

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