THREE-DIMENSIONAL CONCEPTS
(Chapter 9 in *Computer Graphics*)

- **Three-dimensional Concepts**
  - three-dimensional coordinate systems
  - three-dimensional display techniques
  - three-dimensional graphics packages

POLYGON SURFACES
(Section 10-1 in *Computer Graphics*)

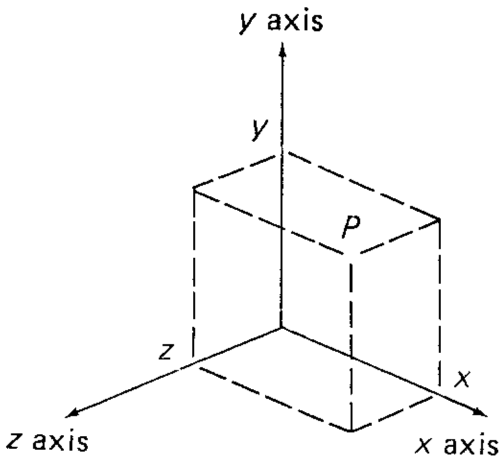
- **Polygon Surfaces**
  - polygon tables
  - polygon equations

introduction

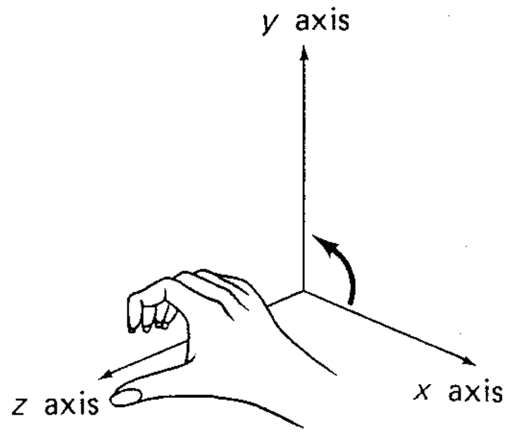
- two varieties of graphics applications
  - analytic:
    achieve approximate descriptions of existing objects using
    - straight line segments
    - flat surfaces
    - curved lines segments
    - curved surfaces
    - quad trees
    - octrees
  - synthetic:
    create new objects by constructing and manipulating patterns
- objects are defined in three dimensions and presented in two dimensions

three-dimensional coordinate systems

three-dimensional right-handed system

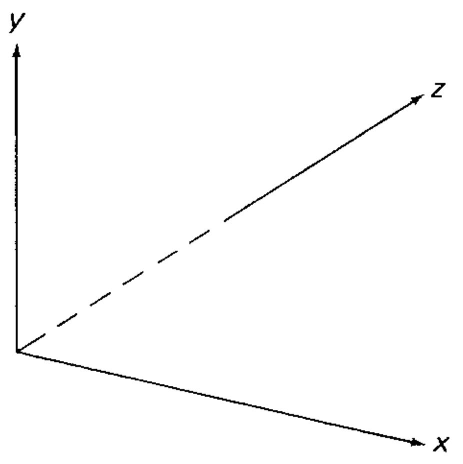


(a)

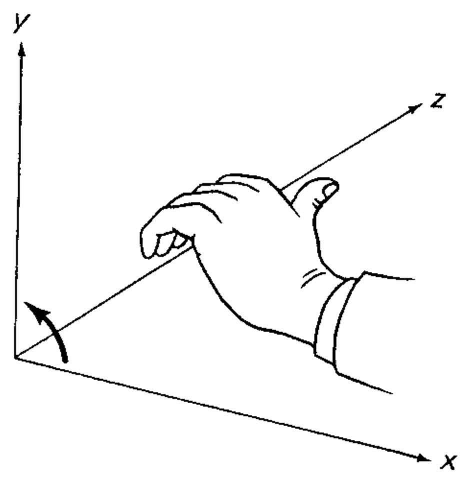


(b)

three-dimensional left-handed system



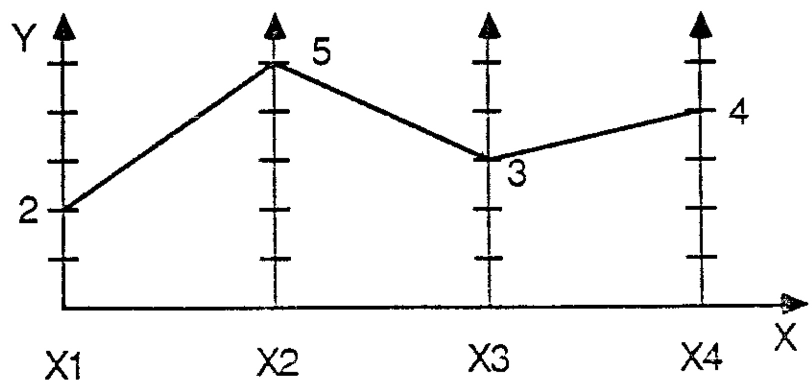
(a)



(b)

other coordinate systems

- spherical coordinates
- cylindrical coordinates
- parallel axes



P = (2, 5, 3, 4)

displaying three-dimensions

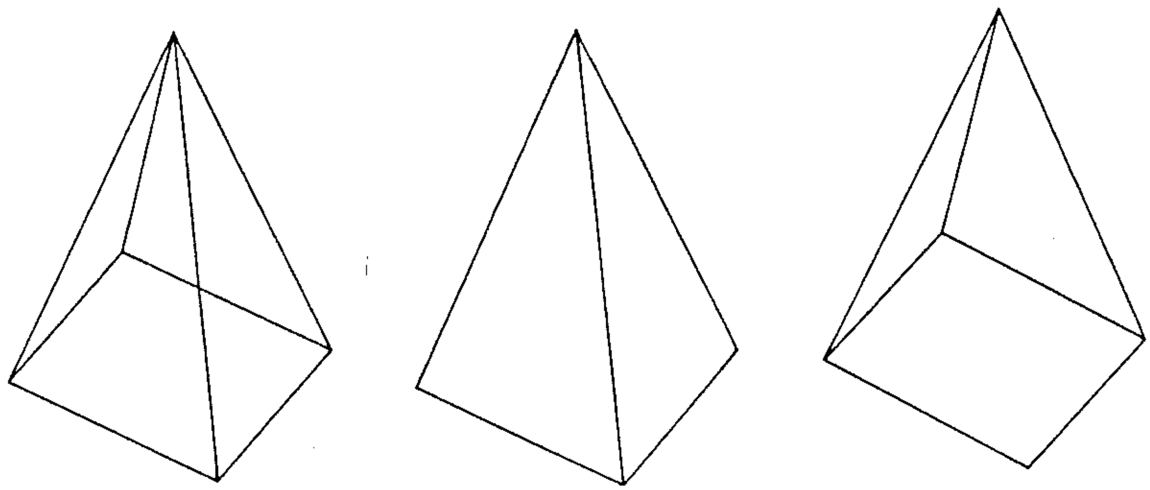
- three-dimensional world-coordinate descriptions must be converted to normalized device coordinates
- a three-dimensional world can be viewed in many ways

three-dimensional display techniques

- parallel projection
- perspective projection
- intensity cuing
- hidden-line removal
- hidden-surface removal and shading
- exploded and cutaway views
- three-dimensional and stereoscopic views

three-dimensional display techniques

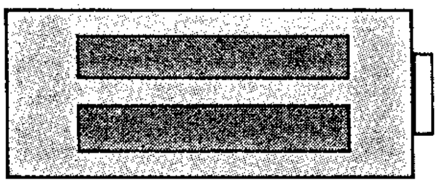
- are intended to restore depth information



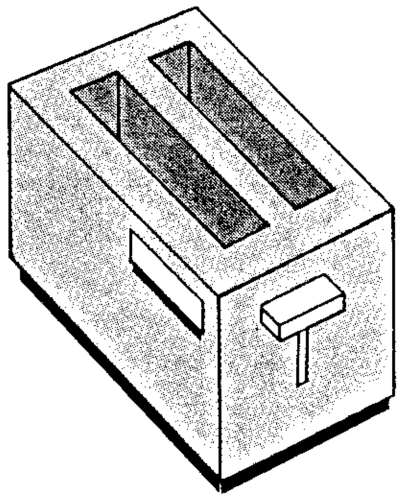
(a) (b) (c)

parallel projection

- project along parallel lines to a plane viewing surface
- parallel lines on the object project to parallel lines on the viewing surface
- relative proportions are maintained



(a)



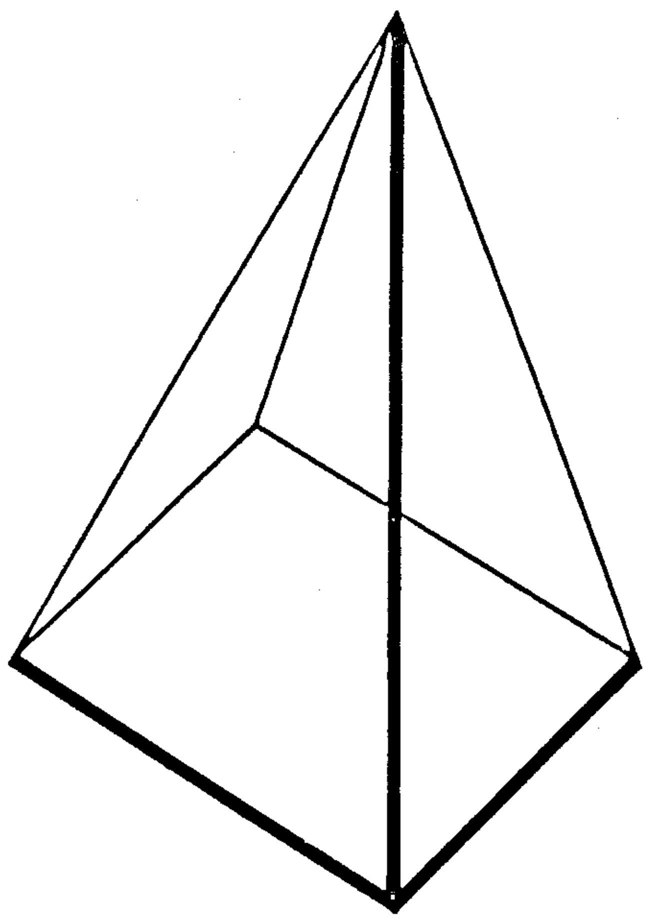
(b)

perspective projection

- far away objects appear smaller than near objects
- parallel lines on the object tend to converge on the viewing surface
- the eye and a camera lens produce perspective projections
- see figure 9-7 on page 184

intensity cuing

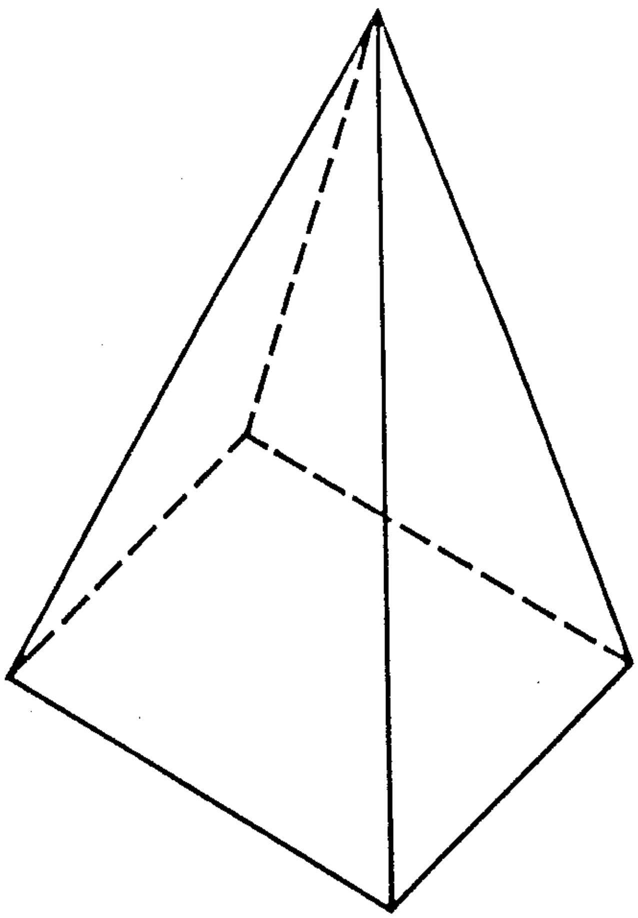
- vary the intensity of lines according to their distance from the viewing position



- extreme intensity cuing effectively performs hidden-line elimination

hidden-line removal

- useful for line-drawn images
- hidden lines may be removed entirely
  - see figure 9-2 on page 182
- alternatively, hidden lines may be replaced by lines of a different color or texture



hidden-surface removal and shading

- used to remove back surfaces hidden by front surfaces
  - see figure 9-1 on page 182
- adds to realism, especially when accompanied by
  - perspective projection
  - shadows
  - surface texture
- see figure 9-10 on page 185

exploded and cutaway views

- exploded views show the structure of component parts
  - see figure 9-11 on page 186
- cutaway views remove external surfaces to show internal structure
  - see figure 9-12 on page 187

three-dimensional and stereoscopic views

- video monitors can be adapted to present three-dimensional and stereoscopic views
  - varifocal mirrors
  - two simultaneous displays

three-dimensional graphics packages

- much in common with two-dimensional graphics packages
  - world coordinate input/output routines
    - polyline_3 (n, x, y, z)
    - fill_area _3 (n, x, y, z)
    - text_3 (x, y, z, string)
    - get_locator_3 (x, y, z)
  - attribute functions
    - colors
    - line styles
    - marker attributes
    - text fonts
  - segments

three-dimensional graphics packages, --continued

- some enhanced aspects
  - transformation of three-dimensional objects
  - adapting input devices to three-dimensions
  - functions for orienting character strings
- some new aspects
  - mapping three-dimensional descriptions onto two-dimensional display surfaces
  - modeling solid objects
  - removing hidden lines and hidden surfaces
  - orientation of the fill-area plane and the pattern plane

Polygon Surfaces

- introduction to three-dimensional representations
- polygon surfaces
- polygon tables
- plane equations

introduction to three-dimensional representations

- several alternatives
  - precise description
    - cube
    - cylinder
    - sphere
  - polygonal approximation
  - parametric curves
  - fractal representations
  - construction methods (building from simpler shapes)
    - sweeping a two-dimensional pattern through space
    - combining basic objects

polygon surfaces

- sometimes exact
- sometimes an approximation
  - see figure 10-1 on page 190
- line or fill_area commands specify vertices which define polygons
- vertices can be specified interactively

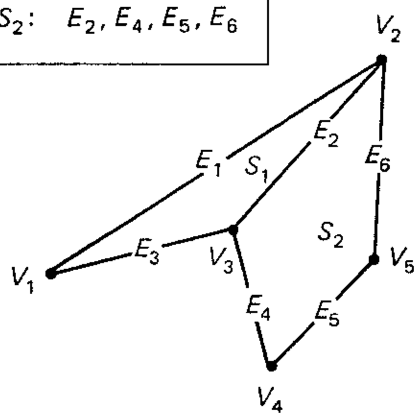
polygon tables

- the graphics package organizes the polygon surface data into tables
- the table may contain geometric, topological and attribute properties
- the tables are organized to facilitate processing

VERTEX TABLE	
V_1:	x_1, y_1, z_1
V_2:	x_2, y_2, z_2
V_3:	x_3, y_3, z_3
V_4:	x_4, y_4, z_4
V_5:	x_5, y_5, z_5

EDGE TABLE	
E_1:	V_1, V_2
E_2:	V_2, V_3
E_3:	V_3, V_1
E_4:	V_3, V_4
E_5:	V_4, V_5
E_6:	V_5, V_2

POLYGON-SURFACE TABLE	
S_1:	E_1, E_2, E_3
S_2:	E_2, E_4, E_5, E_6



- the vertex table prevents redundant storing and transformation of vertices
- the edge table prevents redundant storage and drawing of common edges
- the surface table prevents redundant storage and drawing of common surfaces

plane equations

- used in
  - viewing transformations
  - shading models
  - hidden-line and hidden-surface algorithms
- parameters are obtained from the coordinates of vertices defining each polygon
- planar equations are of the form
  Ax + By + Cz + D = 0

$$A = \begin{vmatrix} 1 & y_1 & z_1 \\ 1 & y_2 & z_2 \\ 1 & y_3 & z_3 \end{vmatrix} \qquad C = \begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{vmatrix}$$

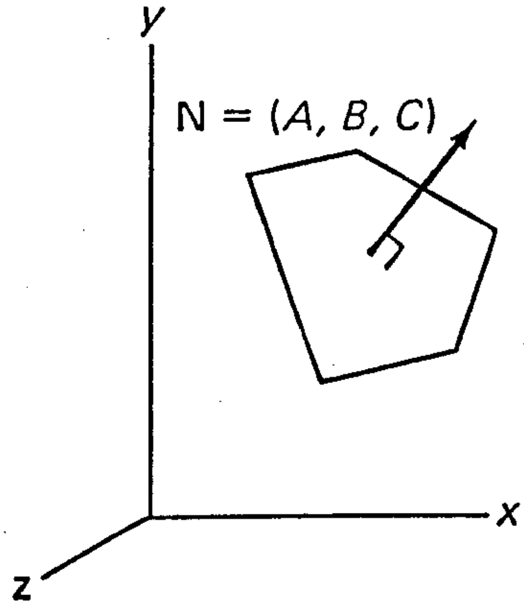
$$B = \begin{vmatrix} x_1 & 1 & z_1 \\ x_2 & 1 & z_2 \\ x_3 & 1 & z_3 \end{vmatrix} \qquad D = -\begin{vmatrix} x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \\ x_3 & y_3 & z_3 \end{vmatrix}$$

or, expanding

$$A = y_1\,(z_2 - z_3) + y_2\,(z_3 - z_1) + y_3\,(z_1 - z_2)$$
$$B = z_1\,(x_2 - x_3) + z_2\,(x_3 - x_1) + z_3\,(x_1 - x_2)$$
$$C = x_1\,(y_2 - y_3) + x_2\,(y_3 - y_1) + x_3\,(y_1 - y_2)$$
$$D = -x_1\,(y_2\,z_3 - y_3\,z_2) - x_2\,(y_3\,z_1 - y_1\,z_3) - x_3\,(y_1\,z_2 - y_2\,z_1)$$

plane equations, continued

- the orientation of a planar surface is specified by a normal vector



- planes have two sides
  - the side facing the object is the "inside"
  - the side facing away from the object is the "outside"

- if vertices are specified in a counterclockwise fashion (looking at the plane from the outside), the normal vector points out
  - points outside a plane satisfy
    $Ax + By + Cz + D > 0$
  - points inside a plane satisfy
    $Ax + By + Cz + D < 0$
  - points on a plane satisfy
    $Ax + By + Cz + D = 0$

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