Chapter 6

Surface Modeling

Introduction

- Graphics scenes ***can contain many different kinds of objects***: trees , flowers, clouds, rocks, water, bricks, wood paneling, rubber, paper, marble, steel, glass, plastic, and cloth, just to mention a few.
- ***No single method can use to describe objects*** that will include all characteristics of these different materials.
- And to produce realistic displays of scenes, we need to use representations that accurately model object characteristics.

Polygon and quadric surfaces provide precise descriptions for simple Euclidean objects ***such as polyhedrons and ellipsoids***;

Spline surfaces are useful for ***designing aircraft wings, gears, and other engineering*** structures with curved surfaces;

Procedural methods, such as fractal constructions and particle systems, allow us to give accurate representations ***for clouds, clumps of grass, and other natural objects;***

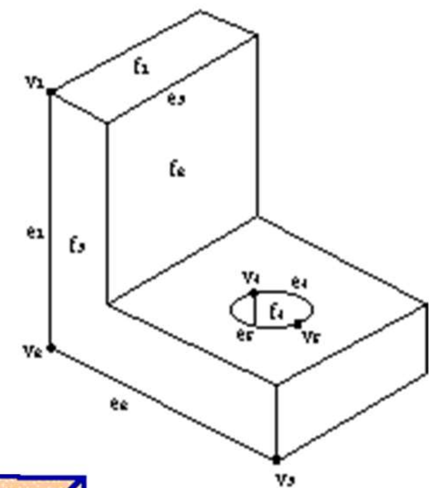
Physically based modeling methods using systems of interacting forces can be used to describe the nonrigid ***behavior of a piece of cloth;***

Octree encodings are used to represent internal features of objects, such as those obtained from ***medical CT images***;

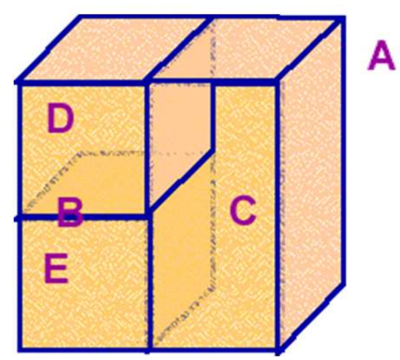
Polygon Surfaces

Objects are represented as a collection of surfaces. 3D object representation is divided into two categories.

- **Boundary Representations (B−reps)** − It describes a 3D object as a set of surfaces that separates the object interior from the environment.

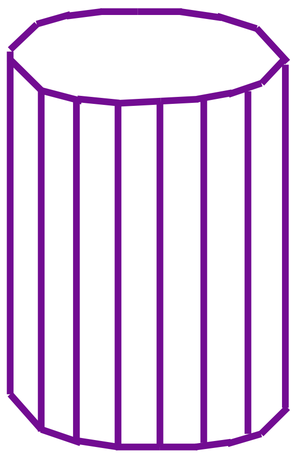


- **Space–partitioning representations** − It is used to describe interior properties, by partitioning the spatial region containing an object into a set of small, non-overlapping, contiguous solids usually cubes



Polygon Surfaces

- The most commonly used ***boundary representation for a 3D graphics object*** is a set of surface polygons that enclose the object interior. ▪Many graphics systems store all object descriptions ***as sets of surface polygons.***
- This ***simplifies and speeds up the surface rendering*** and display of objects, since all surfaces ***are described with linear equations***.
- Realistic ***renderings are produced by interpolating shading patterns*** across the polygon surfaces ***to eliminate or reduce the presence of polygon edge boundaries.***
- Polygon descriptions are often referred to as "***standard graphics objects."***

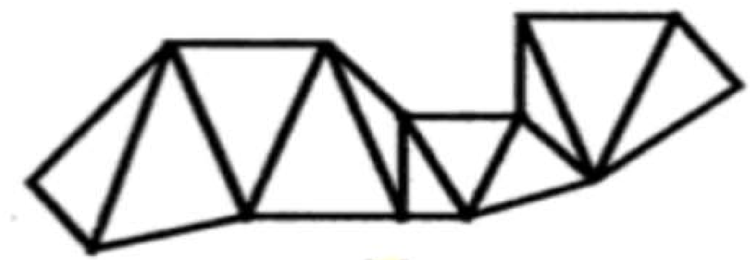


Polygon Mesh

- A polygon mesh is ***collection of edges, vertices and polygons*** connected ***such that each edge is shared by at most two polygons***.
- An edge connects two vertices and a polygon is a closed sequence of edges. An edge can be ***shared by two polygons*** and a ***vertex is shared by at least two edges.***
- ***High-quality graphics systems*** typically model objects with polygon meshes and ***set up a database of geometric and attribute information*** to facilitate processing of the polygon facets.
- The ***<u>quadrilateral mesh</u> ,*** which generates a ***mesh of (n -1) by (m - 1)*** quadrilaterals, given the coordinates ***for an n by m array of vertices***.
- **A** quadrilateral mesh ***containing 12 quadrilaterals*** constructed ***from a 5 by 4 input vertex*** array.

Polygon Mesh

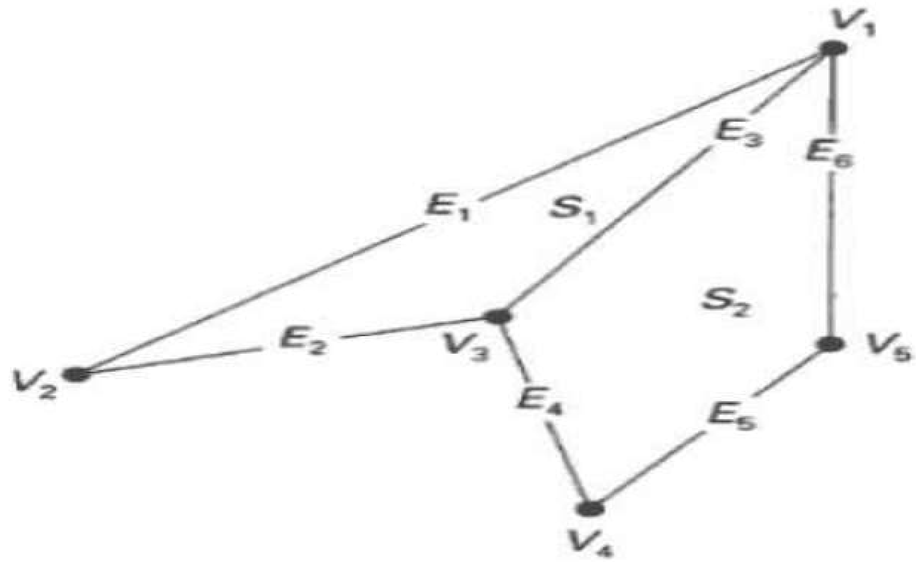
- ***Advantages***
  - It can be used to model almost any object.
  - They are easy to represent as a collection of vertices.
  - They are easy to transform.
  - They are easy to draw on computer screen.
- ***Disadvantages***
  - Curved surfaces can only be approximately described.
  - It is difficult to simulate some type of objects like hair or liquid.
- Other type of polygon mesh ***is the triangle strip***. This function ***produces n - 2 connected triangles*** , given the coordinates ***for n vertices.***
- ***Example:*** A triangle strip formed with 11 triangles connecting 13 vertices



Polygon Data Tables

- ***Polygon data tables*** stores information for each polygon (set of vertex coordinates and associated attribute parameters.) in the subsequent processing, display, and manipulation of the objects in a scene.
- Polygon data tables can ***be organized into two groups:***
    - ***Geometric data tables:*** It contains vertex coordinates and parameters to identify the spatial orientation of the polygon surfaces.
    - ***Attribute data table:*** it includes parameters specifying the degree of transparency of the object and its surface reflectivity and texture characteristics.
- A geometric data further ***divided into three lists:*** *a vertex table, an edge table, and a polygon table.*
    - ***Vertex table:*** it contains coordinate values for each vertex in the object.
    - ***Edge table:*** it contains pointers back into the vertex table to identify the vertices for each polygon edge.
    - ***Polygon table:*** it contains pointers back into the edge table to identify the edges for each polygon

Polygon Data Tables



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_1

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

Polygon Data Tables

- Guidelines ***to generate Error Free tables:***

    1) Every vertex is listed as an endpoint for at least two edges,
    2) Every edge is part of at least one polygon,
    3) Every polygon is closed,
    4) Each polygon has at least one shared edge, and
    5) If the edge table contains pointers to polygons, every edge referenced by a polygon pointer has a reciprocal pointer back to the polygon.

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Plane Equation

- Plane equation method is another method for representation the polygon surface for 3D object. The information about the spatial orientation of object is described by its individual surface, which is obtained by the vertex co-ordinates and the equation of each surface.
- The ***equation for a plane surface*** can be expressed in the form: $Ax + By + Cz + D = 0$

  Where (x, y, *z) is any point on* the plane, and the *coefficients A, B, C, and D* are constants describing, spatial properties of the plane.

- The values of ***A, B, C, D can be obtained by solving*** a set of ***three plane equations*** using co-ordinate values of 3 non collinear points on the plane.
- Let ***(x1, y1, z1), (x2, y3, z2) and (x3, y3, z3) are three such points on the plane***, then,
- ***Plane Equation***

$$Ax1 + By1 + Cz1 + D = 0$$

$$Ax2 + By2 + Cz2 + D = 0$$

$$Ax3 + By3 + Cz3 + D = 0$$

Plane Equation

- The solution of these equations can be obtained ***in determinant from using Cramer's rule as:***

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

- For any points (x, y, z)

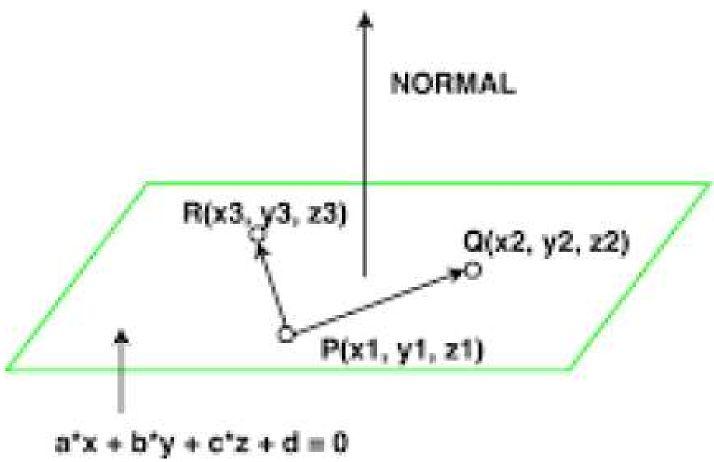
  If $Ax + By + Cz + D \neq 0$, then (x, y, z) is not on the plane.

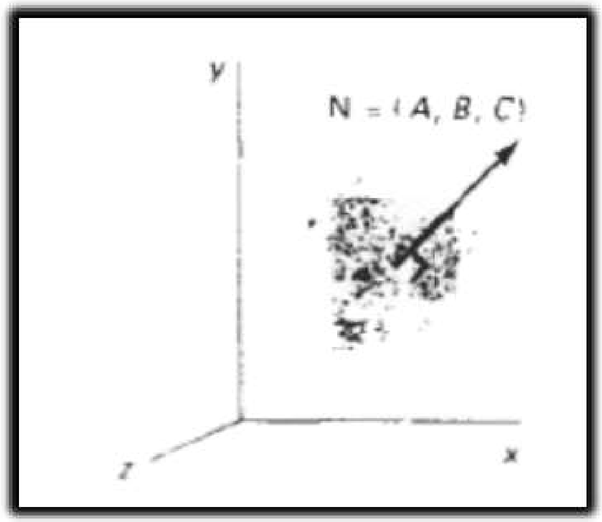
  If $Ax + By + Cz + D < 0$, then (x, y, z) is inside the plane i. e. invisible side

  If $Ax + By + Cz + D > 0$, then (x, y, z) is lies outside the plane

Normal Vector of a Plane

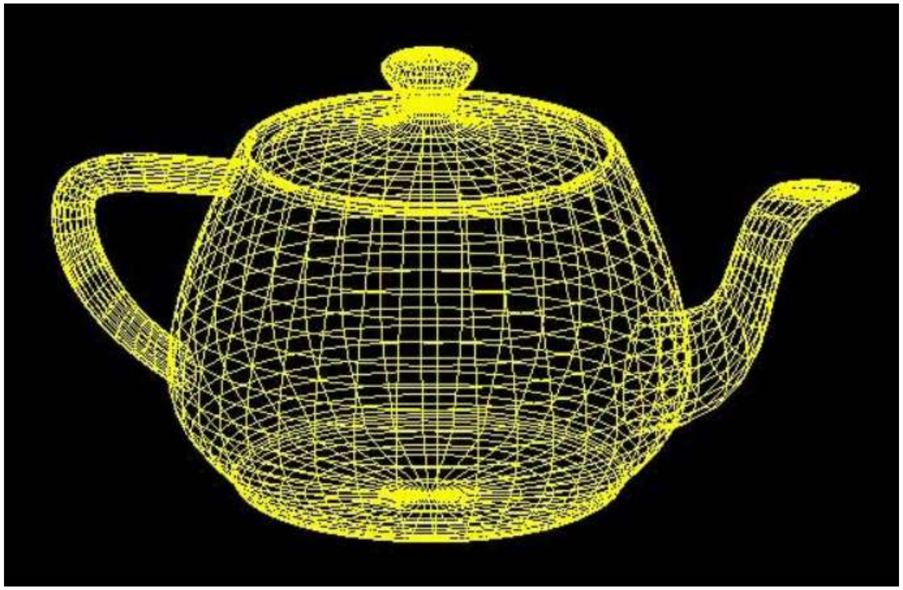
- Orientation of a plane surface in space can be described with the normal vector to the plane
- This surface normal vector has Cartesian components ***(A, B,*** C), where parameters ***A, B,*** and ***C*** are the plane coefficients.





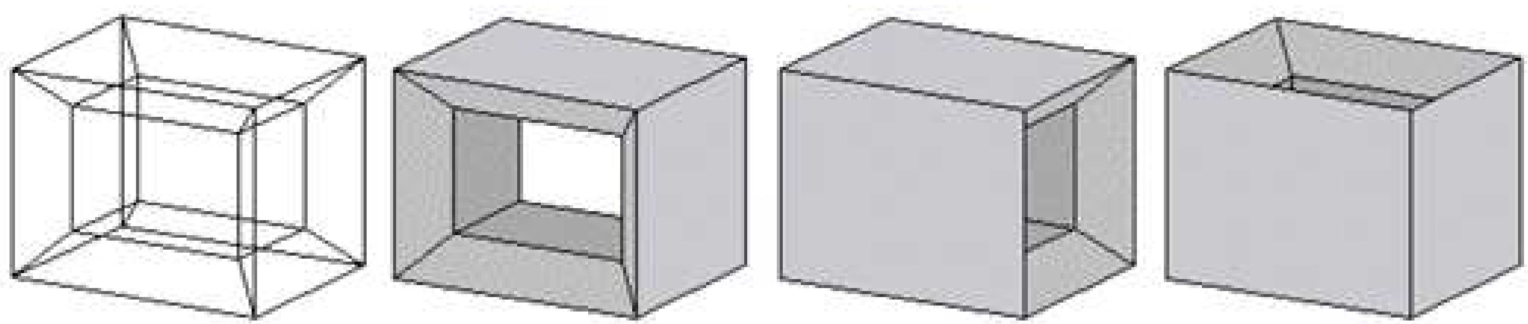
Wireframe Representation

- A **wire-frame model**, is a visual representation of a three dimensional (3D) physical object used in 3D computer graphics.
- It is created ***by specifying each edge of the physical object*** where two mathematically continuous smooth surfaces meet, or by connecting an object's constituent vertices ***using (straight) lines or curves.***
- A wireframe representation is a 3-D ***line drawing of an object showing only the edges*** without any side surface in between. A frame constructed from thin wires ***representing the edges and projected lines and curves***.



Wireframe Representation

- Furthermore, the wire-frame representation is an ambiguous technique for representing an object, as it does not define explicitly the enclosed surfaces.
- Usually, there may be more than one possible interpretation of the same wireframe. Wire frames can often be interpreted as different solid objects or as different orientations of the same object.



Solid Modeling

- ▪ A ***wireframe representation*** of an object is done ***using edges (lines curves) and vertices.*** Surface representation then is the logical evolution using faces (surfaces), edges and vertices.
- ▪ In this sequence of developments, ***the solid modeling uses topological information in addition to the geometrical information*** to represent the object unambiguously and completely.
- Solid modeling is based on *complete, valid and unambiguous* geometric representation of physical object.
    - ***Complete:*** points in space can be classified.(inside/ outside)
    - ***Valid:*** vertices, edges, faces are connected properly.
    - ***Unambiguous:*** there can only be one interpretation of object
- Solid model consist of ***geometric and topological data***.
    - ***Geometry:*** The graphical information of dimension, length, angle, area and transformations.
    - ***Topology:*** The invisible information about the connectivity, neighborhood, associatively etc.
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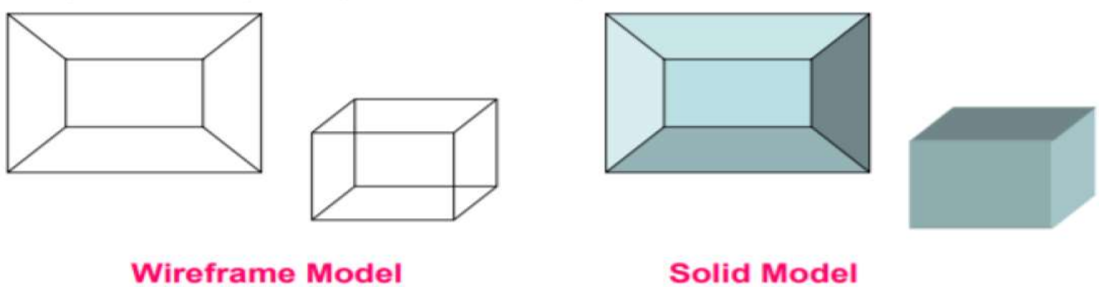

6. Represent the following surfaces by polygon table method and find the normal of surface S1. [2+5]