UNIT 5: 3D Objects Representation(7Hrs)

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Introduction

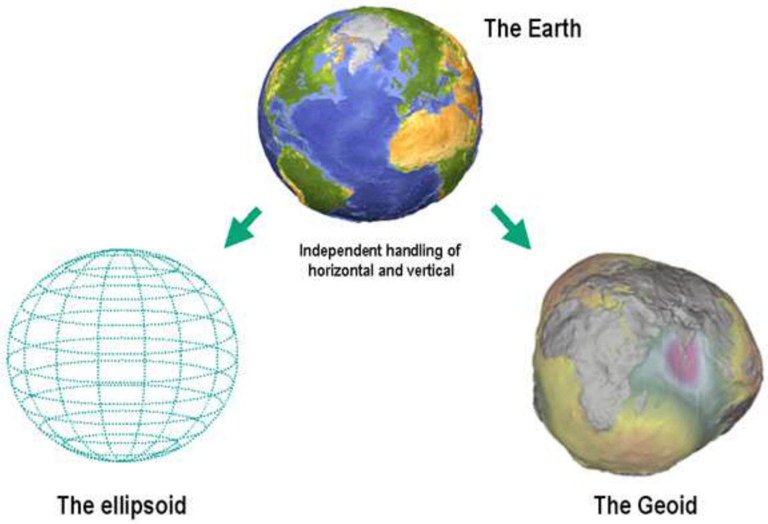
- Graphics scenes ***can contain many different kinds of objects***: trees , flowers, clouds, rocks, water, bricks, wood paneling, rubber, paper, marble, steel, glass, plastic, and cloth, just to mention a few.
- ***No single method can use to describe objects*** that will include all characteristics 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;

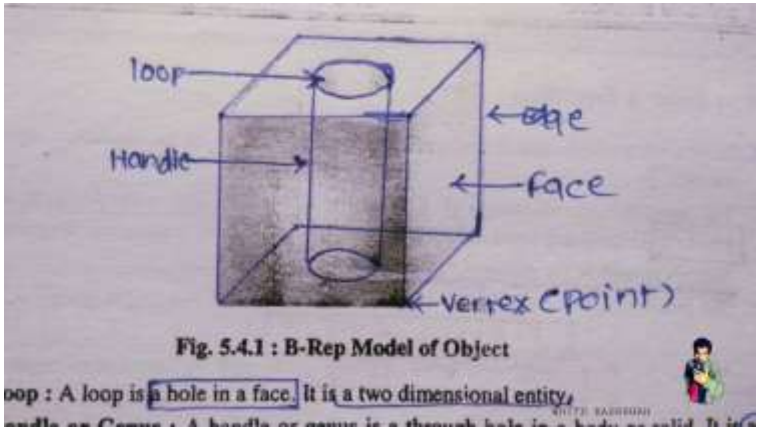
Introduction

- Representation schemes for solid objects are often divided into two broad categories:
  - ***Boundary representations (B-reps)***
  - ***Space-partitioning representations***
- B-reps describe a three-dimensional object as a ***set of surfaces*** that ***separate the object interior from the environment***. Typical examples of boundary representations are polygon facets and spline patches.
- Space-partitioning representations are used to describe interior properties, ***by partitioning the spatial region containing an object into a set of small, nonoverlapping, contiguous solids*** (usually **cubes).**

Boundary Representation

- Boundary representation (B-rep) is a fundamental technique in computer graphics for modeling 3D objects. It defines the shape of an object by describing its outer surfaces, including the vertices, edges, and faces that make up its boundary.
- The solids are described by its boundary surface. Uses the description by vertices, edges and faces. - The most common representation is the boundary polygons.
- E.g. Polyhedron, ellipsoid, aircraft, medical images etc.

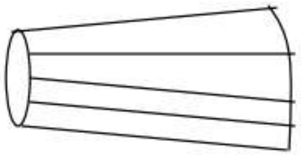




Boundary Representation

- Each 3D object is supposed to be formed its surface by collection of polygon facets and spline patches. Some of the boundary representation methods for 3D surface are:

1. **Polygon Surfaces:** It is the most common representation for 3D graphics object. In this representations, a 3D object is represented by a set of surfaces that enclose the object interior. Many graphics system use this method. Set of polygons are stored for object description. This simplifies and speeds up the surface rendering and display of object since all surfaces can be described with linear equations.



A 3D object represented by polygons

The polygon surface are common in design and solid-modeling applications, since wire frame display can be done quickly to give general indication of surface structure. Then realistic scenes are produced by interpolating shading patterns across polygon surface to illuminate.
**There are three way to represent polygon surface: Polygon Table, Plane Equations, & Polygon Meshes.

Polygon Surfaces

- **Polygon Table:** A polygon surface is specified with a set of vertex co-ordinates and associated attribute parameters. A convenient organization for storing geometric data is to create 3 lists:
- A vertex table
- An edge table
- A polygon surface table.

– Vertex table stores co-ordinates of each vertex in the object.

– The edge table stores the Edge information of each edge of polygon facets.

– The polygon surface table stores the surface information for each surface i.e. each surface is represented by edge lists of polygon.

-Are used to create video games, films, and virtual reality environments

**attribute tables store information about objects, while geometric tables store information about the shape of objects.

Polygon Surfaces

Attribute tables:

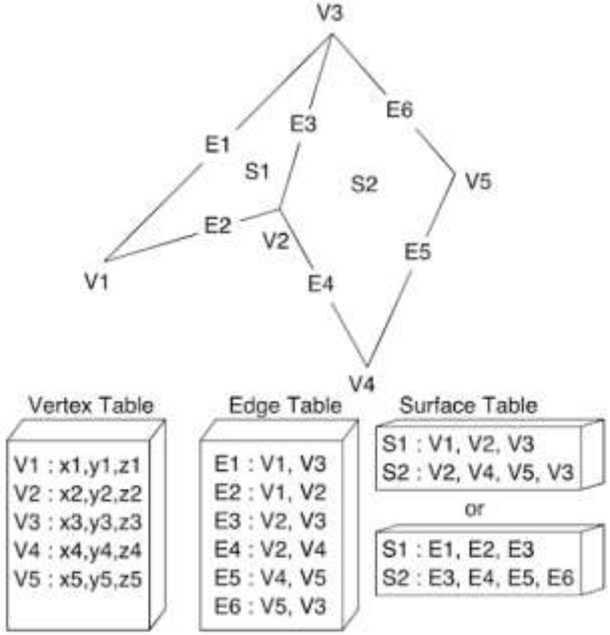
- ontain information about an object, such as its transparency, reflectivity, and texture
- Are organized into rows and columns, with each row representing a feature and each column representing an attribute
- Can be used to store information about geographic features, such as cities, with attributes like name, population, and postal code.
- Attribute tables are used to store information about objects in GIS

Polygon Surfaces

- 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.

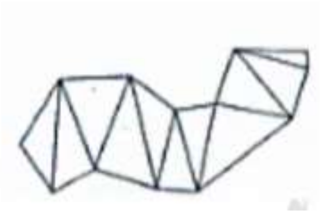
Polygon Surfaces

- Consider the surface contains polygonal facets as shown in figure (only two polygon are taken here)
- S1 and S2 are two polygon surface that represent the boundary of some 3D object. Foe storing geometric data, we can use following three table.
- The object can be displayed efficiently by using data from tables and processing them for surface rendering and visible surface determinatior



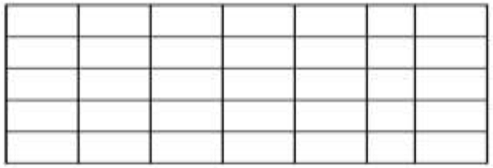
Polygon Surfaces

- **Polygon Meshes:** 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. When object surface is to be tiled, it is more convenient to specify the surface facets with a mesh function. One type of polygon mesh is triangle strip. This function produce n-2 connected triangles.



Triangular Mesh

Another similar function is the quadrilateral mesh, which generates a mesh of (n-1) by (m-1) quadrilaterals, given the co-ordinates for an n by m array of vertices



6 by 8 vertices array , 35 element quadrilateral mesh

- If the surface of 3D object is planer, it is comfortable to represent surface with meshes.

Polygon Meshes

Explicit Representation:

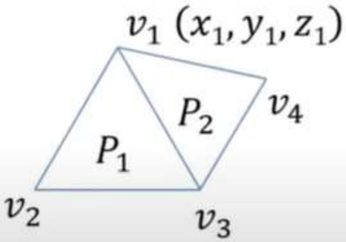
In explicit representation each polygon stores all the vertices in order in the memory as,

$$P = (((x1, y1, z1), (x2, y2, z2)), \ldots , ((xm, ym, zm), (xn, yn, zn)))$$

The mesh is represented by a list of vertex coordinates.

It process fast but requires more memory for storing.

- Example:



$$P_1 = \begin{pmatrix} ((x_1, y_1, z_1), (x_2, y_2, z_2)), ((x_2, y_2, z_2), (x_3, y_3, z_3)), \\ ((x_3, y_3, z_3), (x_1, y_1, z_1)) \end{pmatrix}$$

Pointer to Vertex List-Polygon Meshes

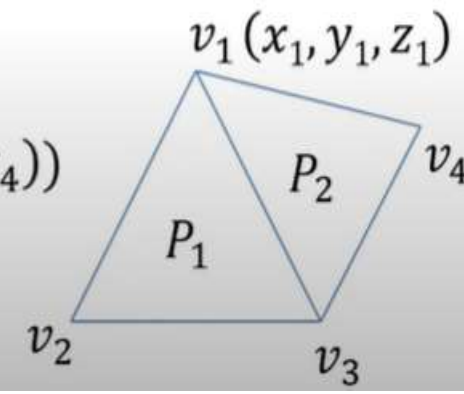
- In this method, each vertex stores in vertex list and then polygon contains pointer to the required vertex.

$$V = ((x_1, y_1, z_1), (x_2, y_2, z_2), \ldots, (x_n, y_n, z_n))$$

- Now polygon of vertices 3, 4, 5 is represented as:

$$P = ((v_3, v_4), (v_4, v_5), (v_5, v_3))$$

- It is considerably space saving but for finding common edges we require extra work.
- Example:
- $V = ((x_1, y_1, z_1), (x_2, y_2, z_2), \ldots, (x_4, y_4, z_4))$
- $P_1 = ((v_1, v_2), (v_2, v_3), (v_3, v_1))$
- $P_2 = ((v_1, v_3), (v_3, v_4), (v_4, v_1))$

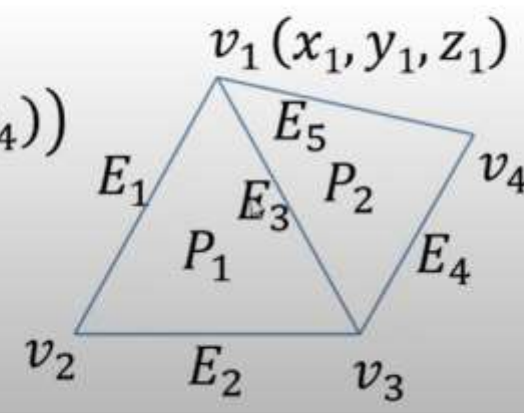


Pointer to Edge List-Polygon Meshes

- In this method, polygon have pointers to the edge list and edge list have pointer to vertex list for each edge two vertex pointer is required which points in vertex list.

$$V = ((x_1, y_1, z_1), (x_2, y_2, z_2), \dots, (x_n, y_n, z_n))$$
$$E = ((v_1, v_2), (v_2, v_3), \dots, (v_m, v_n))$$
$$P = (E_1, E_2, \dots, E_k)$$

- This approach is more memory efficient and easy to find common edges. For example,
- $V = ((x_1, y_1, z_1), (x_2, y_2, z_2), \dots, (x_4, y_4, z_4))$
- $E = ((v_1, v_2), (v_2, v_3), \dots, (v_4, v_1))$
- $P_1 = (E_1, E_2, E_3)$



Plane Equation Method

Plane Equation Method:

Plane equation method is another method for representing 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-ordinate values and the equation of each plane gives the description 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 A, B, C, D are constants describing the 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 $(x_1, y_1, z_1), (x_2, y_2, z_2)$ and (x_3, y_3, z_3) are three such points on the points on the plane. Then

$$Ax_1 + By_1 + Cz_1 + D = 0 \quad \text{———} \quad (1)$$

$$Ax_2 + By_2 + Cz_2 + D = 0 \quad \text{———} \quad (2)$$

$$Ax_3 + By_3 + Cz_3 + D = 0 \quad \text{———} \quad (3)$$

The solution of these equations can be obtained in determinant form using Cramer's rule as.

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

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

For any point (x, y, z)

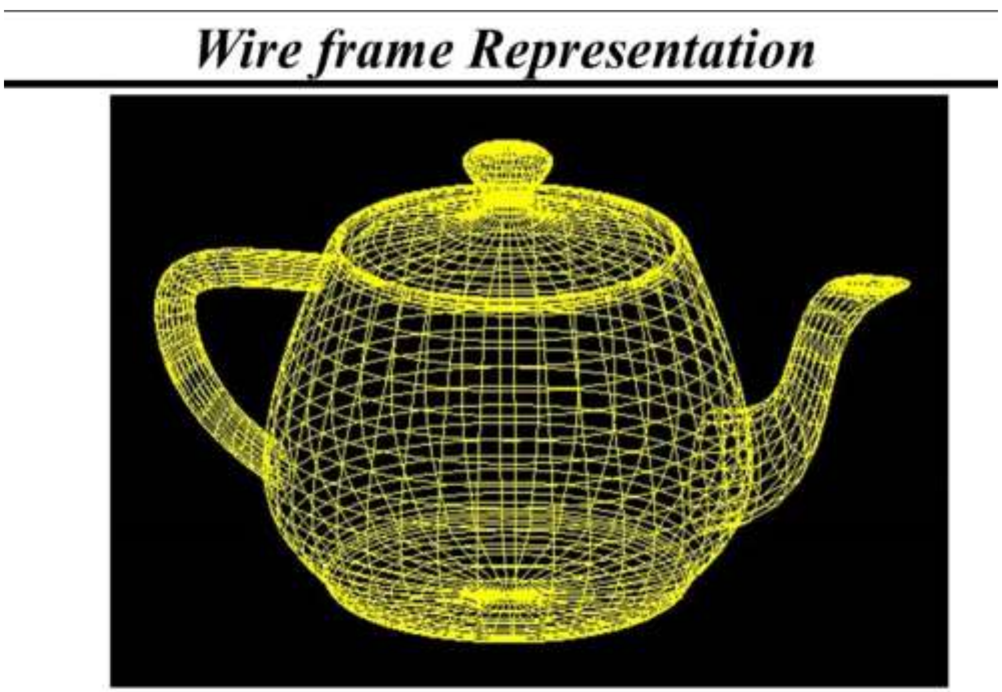
if $Ax + By + Cz + D \neq 0$ then (x, y, z) is not on the plane

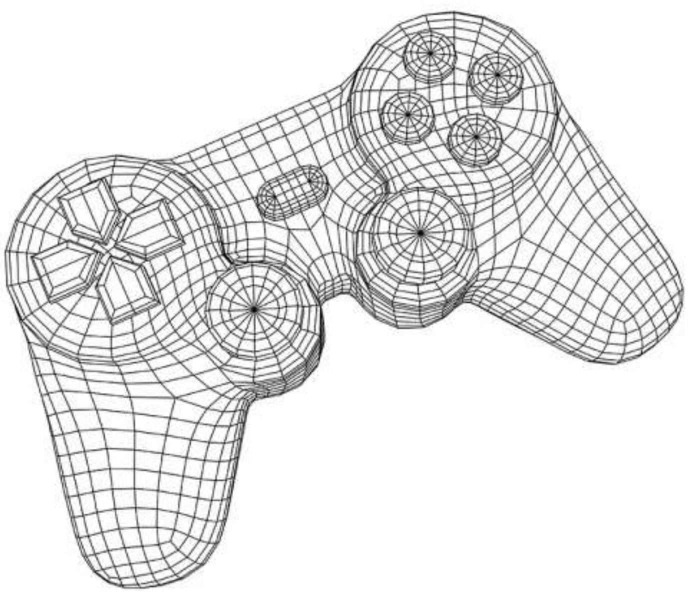
if $Ax + By + Cz + D < 0$, the point (x, y, z) is inside plane i.e. invisible side

if $Ax + By + Cz + D > 0$ the point lies outside the surface.

Wireframe Representation:

In this method 3D objects is represented as a list of straight lines, each of which is represented by its two end points (x1,y1,z1) and (x2,y2,z2). This method only shows the skeletal structure of the objects. It is simple and can see through the object and fast method. But independent line data structure is very inefficient i.e. don’t know what is connected to what. In this method the scenes represented are not realistic.





Wireframe Representation:

- **Advantages of Wire Frame Model :-**

1. It is simple methods and requires less memory space.
2. It forms the basis for surface and solid modeling.
3. Manipulations in the model can be done easily and quickl.

Wireframe Representation:

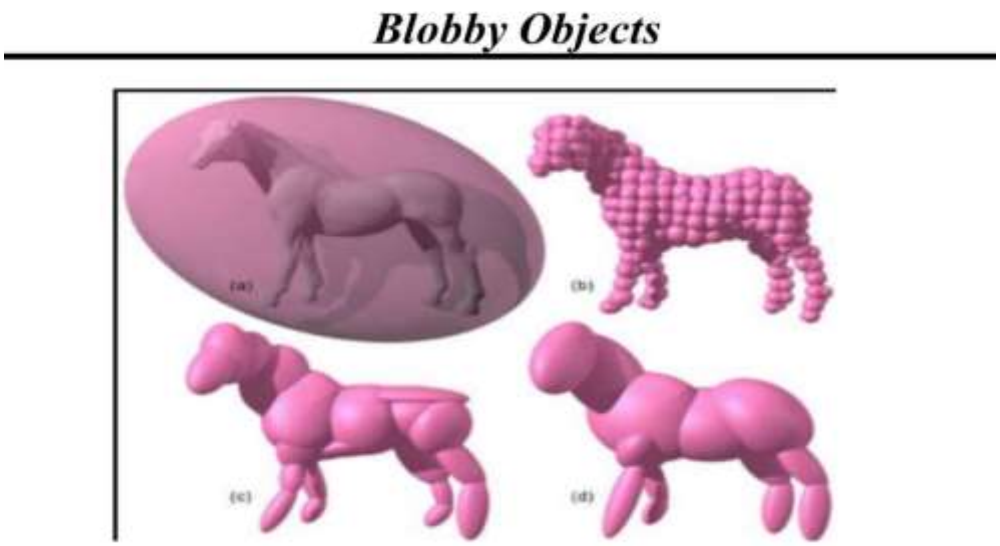
Disadvantages :-

1. One of the serious limitation in the ambiguity of orientation and viewing plane
2. Cannot model complex curve surfaces
3. Does not represent an actual solid (no surface and volume)
4. Physical properties such as mass, surface area, volume, center of gravity etc. are not possible to calculate
5. Wireframe models has no knowledge of surface faces, therefore it will not detect interface between two matting components and this is serious drawback especially in component assembly, kinematic analysis, NC tool and robot arm simulation.

Polygon Surfaces

Blobby Objects: Some objects don't maintain a fixed shape but change their surface characteristics in certain motions or when proximity to another objects e.g molecular structures, water droplets, other liquid effects, melting objects, muscle shaped in human body etc. These objects can be described as exhibiting "blobbiness" and are referred as blobby objects. Several models have been developed for representing blobby objects as distribution functions over a region of space.

- One way is to use Gaussian density function or bumps.
- A surface function is defined as:



Polygon Surfaces

f(x,y,z) = $\sum_k b_{k0} e^{-a_k r_k^2} - T = 0$

Where $r_k = \sqrt{x_k^2 + y_k^2 + z_k^2}$, T = Threshold and a and b are used to adjust amount of blobbness.

Other method for generating for generating blobby objects uses quadratic density function as:

$$f(x) = \begin{cases} b(1 - \frac{3r^3}{d^2}) \\ \frac{3}{2} b(1 - \frac{r}{d})^2 \\ 0 \end{cases}$$

Advantages

- Can represent organic, blooby or liquid line structures
- Suitable for modeling natural phenomena like water, human body
- Surface properties cam be easily derived from mathematical equations.

Disadvantages:

- Requires expensive computation
- Requires special rendering engine
- Not supported by most graphics hardware