

# UNIT-3

## 3D Object Representations

### Methods:

- Polygon and Quadric surfaces: For simple Euclidean objects
- Spline surfaces and construction: For curved surfaces
- Procedural methods: Eg. Fractals, Particle systems
- Physically based modeling methods
- Octree Encoding
- Isosurface displays, Volume rendering, etc.

### Classification:

Boundary Representations (B-reps) eg. Polygon facets and spline patches  
 Space-partitioning representations eg. Octree Representation

Objects may also associate with other properties such as mass, volume, so as to determine their response to stress and temperature etc.

### Polygon Surfaces

This method simplifies and speeds up the surface rendering and display of objects.

For other 3D objection representations, they are often converted into polygon surfaces before rendering.

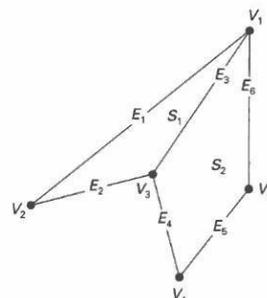
### Polygon Mesh

- Using a set of connected polygonally bounded planar surfaces to represent an object, which may have curved surfaces or curved edges.
- The wireframe display of such object can be displayed quickly to give general indication of the surface structure.
- Realistic renderings can be produced by interpolating shading patterns across the polygon surfaces to eliminate or reduce the presence of polygon edge boundaries.

### Polygon Tables

This is the specification of polygon surfaces using vertex coordinates and other attributes:

1. Geometric data table: vertices, edges, and polygon surfaces.
2. Attribute table: eg. Degree of transparency and surface reflectivity etc.



Some consistency checks of the geometric data table:

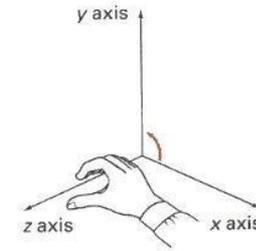
VERTEX TABLE	EDGE TABLE	POLYGON-SURFACE TABLE
$V_1: x_1, y_1, z_1$	$E_1: V_1, V_2$	$S_1: E_1, E_2, E_3$ $S_2: E_3, E_4, E_5, E_6$
$V_2: x_2, y_2, z_2$	$E_2: V_2, V_3$	
$V_3: x_3, y_3, z_3$	$E_3: V_3, V_1$	
$V_4: x_4, y_4, z_4$	$E_4: V_3, V_4$	
$V_5: x_5, y_5, z_5$	$E_5: V_4, V_5$	

- Every vertex is listed as an endpoint for at least 2 edges
- Every edge is part of at least one polygon
- Every polygon is closed

## Plane equation and visible points

Consider a cube, each of the 6 planes has 2 sides: inside face and outside face.

For each plane (in a right-handed coordinate system), if we look at its surface and take 3 points in counter-clockwise direction:  $(x_1, y_1)$ ,  $(x_2, y_2)$ , and  $(x_3, y_3)$ , we can compute 4 values: A,B,C,D as



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

Then, the plane equation at the form:  $Ax+By+Cz+D=0$  has the property that:

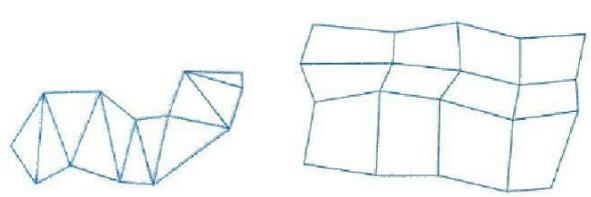
If we substitute any arbitrary point  $(x,y)$  into this equation, then,

$Ax + By + Cz + D < 0$  implies that the point  $(x,y)$  is inside the surface, and

$Ax + By + Cz + D > 0$  implies that the point  $(x,y)$  is outside the surface.

## Polygon Meshes

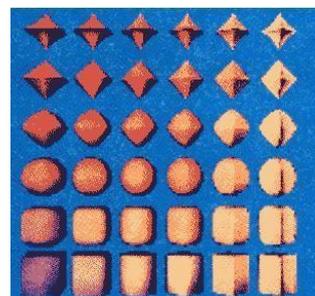
Common types of polygon meshes are triangle strip and quadrilateral mesh.



Fast hardware-implemented polygon renderers are capable of displaying up to 1,000,000 or more shaded triangles per second, including the application of surface texture and special lighting effects.

## Curved Surfaces

1. Regular curved surfaces can be generated as
  - Quadric Surfaces, eg. Sphere, Ellipsoid, or
  - Superquadrics, eg. Superellipsoids

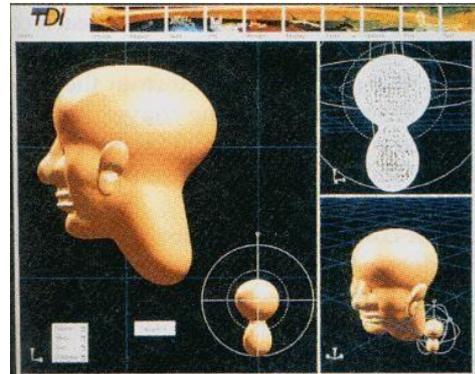


These surfaces can be represented by some simple parametric equations, eg, for ellipsoid:

$$\begin{aligned} x &= r_x \cos^s \phi \cos^s \theta, & -\pi/2 \leq \phi \leq \pi/2 \\ y &= r_y \cos^s \phi \sin^s \theta, & -\pi \leq \theta \leq \pi \\ z &= r_z \sin^s \phi \end{aligned}$$

Where  $s_1$ ,  $r_x$ ,  $r_y$ , and  $r_x$  are constants. By varying the values of  $\phi$  and  $\theta$ , points on the surface can be computed.

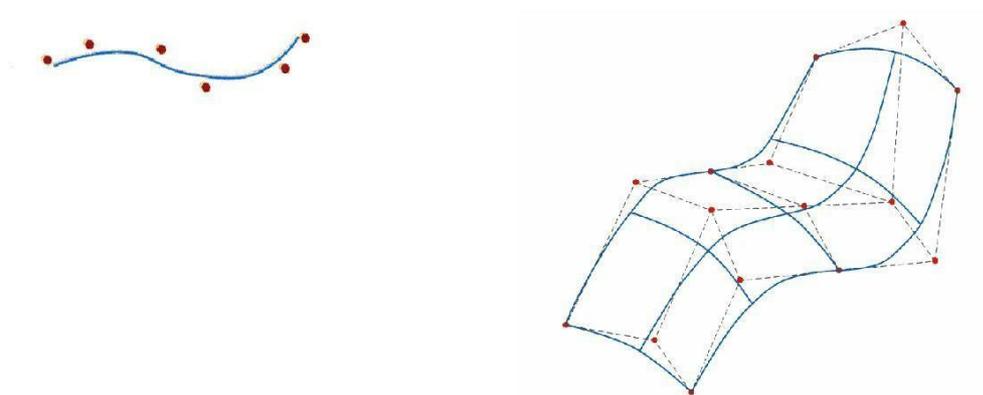
2. Irregular surfaces can also be generated using some special formulating approach, to form a kind of **blobby objects** -- The shapes showing a certain degree of fluidity.



## Spline Representations

Spline means a flexible strip used to produce a smooth curve through a designated set of points. Several small weights are distributed along the length of the strip to hold it in position on the drafting table as the curve is drawn.

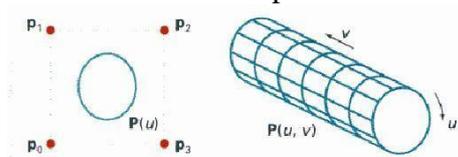
We can mathematically describe such a curve with a piecewise cubic polynomial function => spline curves. Then a spline surface can be described with 2 sets of orthogonal spline curves.



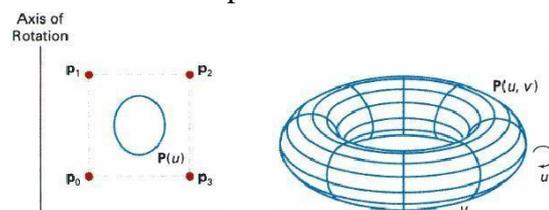
## Sweep Representations

Sweep representations mean sweeping a 2D surface in 3D space to create an object. However, the objects created by this method are usually converted into polygon meshes and/or parametric surfaces before storing.

A Translational Sweep:



A Rotational Sweep:



Other variations:

- We can specify special path for the sweep as some curve function.
- We can vary the shape or size of the cross section along the sweep path.

- We can also vary the orientation of the cross section relative to the sweep path.