IV/IV B. Tech (Regular) DEGREE EXAMINATION-November 2019

CAD/CAM (14ME704)

Seventh Semester

(MECHANICAL ENGINEERING)

Scheme of Evaluation

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1. Answer all questions **(1X12 = 12 Marks)**

(a) What is a Pixel?

It is a picture element, which is the smallest addressable area on the screen. A pixel is the smallest unit of a digital image or graphic that can be displayed and represented on a digital display device.

(b) Define random scan approach.

In random scan, graphics can be generated by drawing vectors or line segments on the screen in a random order which is controlled by the user input and the software. The word 'random' indicates that the screen is not scanned in a particular order.

(c) What is meant by concatenation?

The process of combining the individual transformation matrices by multiplying the respective transformation matrices is called the concatenation of matrices. The order of the multiplication must be as shown below.

$[P^*]= [T_n][T_n-1] [T_n-2] [T_n-3]......[T_3] [T_2] [T_1]$

(d) What is shading?

Shading is the process of altering the color of an object/surface/polygon in the 3D scene, based on its angle to lights and its distance from lights to create a photorealistic effect. Shading is performed during the rendering process.

(Or) shading defines to describe depth perception in three dimensioning models by different levels of darkness.

(e) Expand CSG

Constructive solid geometry

(f) List any two techniques for visual realism.

1. parallel projections
2. perspective projection
3. Hidden line removal
4. Hidden surface removal
5. Hidden solid removal

(g) List the interpolation methods.

1. Linear interpolation
2. Circular interpolation
3. Helical interpolation

4. Parabolic interpolation
5. Cubic interpolation

(h) List any four NC codes

1. G00-Rapid Traverse
2. G01-Linear interpolation movement
3. G02-Circular interpolation clockwise
4. G03-Circular interpolations counter clockwise.

(i) What is DNC machine?

Direct numerical control: single computer controls number of machine tools through direct connection and in real time. In operation, the computer called the required part program from bulk memory and sent it (one block at a time) to the designated machine tool.

Distributed numerical control: in this central computer is connected to MCUs, which are themselves computers. This permits complete part programs to be sent to the machine tools, rather than one block at a time.

(j) What is the part family?

Similar parts are arranged into groups which are called part families, where each part family possesses similar design and/ or manufacturing characteristics.

(k) What do you understand by OPITZ coding system?

The OPITZ coding scheme uses the following digit sequence

12345 6789 ABCD

First five digits 12345 are called the form code. It describes the primary design attributes of the part such as external shape, and machined **features (holes,** threads, gear teeth etc.).

The next four digits 6789 are called the form code. It describes the primary design attributes of the part, such as external shape and machined features.

The extra four digits ABCD are referred to as the secondary code and are intended to identify production operation type and sequence.

(l) What is a cellular layout?

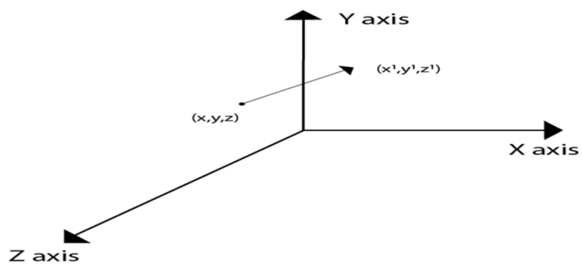
Cellular layout is one in which dissimilar machines or processes have been aggregated into cells, each of which is dedicated to the production of a part or part family or a limited group of families.

UNIT I

2. **(a) Explore the 3D transformations in computer graphics.** **4M**

Methods for geometric transformations and object modelling in three dimensions are extended from two-dimensional methods by including considerations for the Z-coordinate.

TRANSLATION: In a three dimensional homogeneous coordinate representation, a point is translated from position P=(x, y, z) to position P'= (x', y', z') with matrix operation:



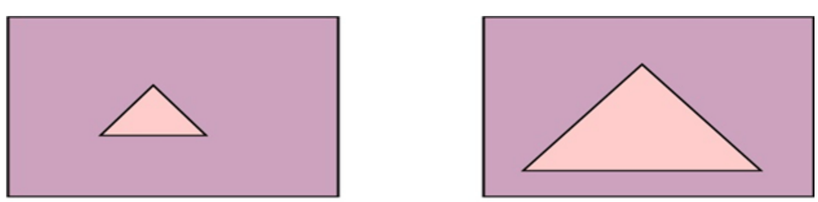
$x^1 = x + T_x$
$y^1 = y + T_y$
$z^1 = z + T_z$

Point shown in fig is (x, y, z). It becomes (x^1, y1, z1) after translation. T_x T_y T_z is translation vector.

$$\begin{pmatrix} x^1 \\ y^1 \\ z^1 \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & T_x \\ 0 & 1 & 0 & T_y \\ 0 & 0 & 1 & T_z \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$

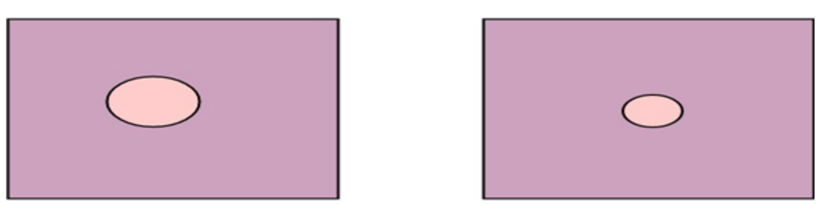
Scaling:Scaling is used to change the size of an object. The size can be increased or decreased. The scaling three factors are required S_x S_y and S_z.

S_x=Scaling factor in x- direction
S_y=Scaling factor in y-direction
S_z=Scaling factor in z-direction



Original
(a)

Enlarged
(b)



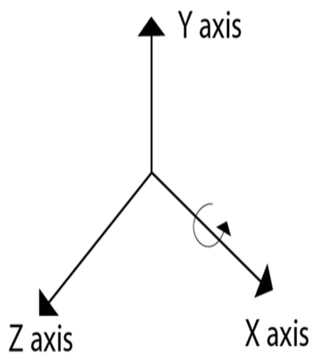
Original
(a)

Reduced
(b)

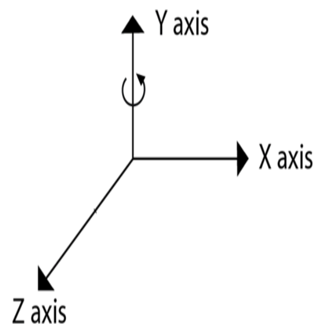
Matrix for Scaling:

$$\begin{Bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{Bmatrix}$$

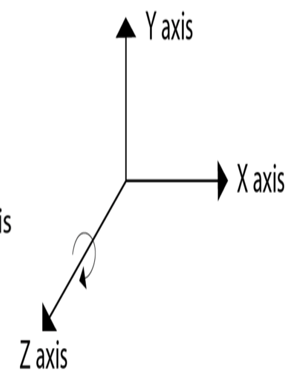
<u>Rotation:</u>It is moving of an object about an angle. Movement can be anticlockwise or clockwise. 3D rotation is complex as compared to the 2D rotation. For 2D we describe the angle of rotation, but for a 3D angle of rotation and axis of rotation are required. The axis can be either x or y or z.



rotation object X axis anticlockwise



rotation object Y axis anticlockwise



rotation about Z axis clockwise

Matrix for representing three-dimensional rotations about the Z axis

$$\begin{pmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Matrix for representing three-dimensional rotations about the X axis

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Matrix for representing three-dimensional rotations about the Y axis

$$\begin{pmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

(b) Develop the Brasenham's algorithm for generation of a Line and highlight its Advantages. 8M

Bresenham Line Drawing Algorithm-Procedure-

Given-

- Starting coordinates = (X_0, Y_0)
- Ending coordinates = (X_n, Y_n)

The points generation using Bresenham Line Drawing Algorithm involves the following steps-

Step-01:

Calculate ΔX and ΔY from the given input.

These parameters are calculated as-

- $\Delta X = X_n - X_0$
- $\Delta Y = Y_n - Y_0$

Step-02:

Calculate the decision parameter P_k.

It is calculated as-

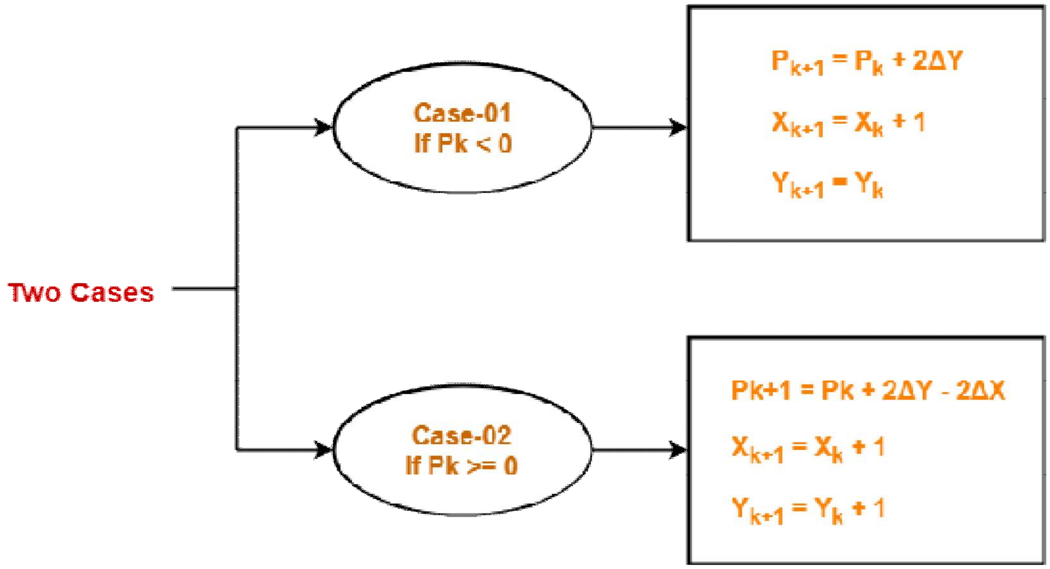
$P_k = 2\Delta Y - \Delta X$

Step-03:

Suppose the current point is (X_k, Y_k) and the next point is (X_{k+1}, Y_{k+1}).

Find the next point depending on the value of decision parameter P_k.

Follow the below two cases-



Step-04:

Keep repeating Step-03 until the end point is reached or number of iterations equals to (ΔX-1) times.

Advantages:

- It is easy to implement.
- It is fast and incremental.
- It executes fast but less faster than DDA Algorithm.
- The points generated by this algorithm are more accurate than DDA Algorithm.
- It uses fixed points only.

(OR)

3. **(a) Explain briefly about various CAD display devices and discuss its merits and de-merits.** **6M**

Different CAD display devices available are:

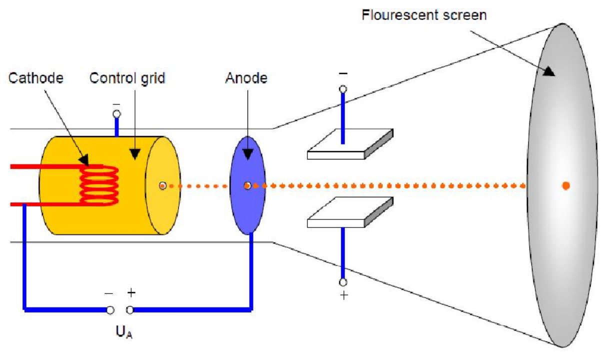
- Cathode ray tube (CRT)
- Direct view storage tube(DVST)
- LCD
- LED

CRT**:** The Cathode Ray Tube is today used in computer monitors, TV set s and oscilloscope tubes. The path of the electrons in the tube filled with a low-pressure rare gas can be observed in a darkened room as a trace of light. Electron beam deflection can be effected by means of either an electrical or a magnetic field.

Working Principle: The source of the electron beam is the electron gun, which produces a stream of electrons through thermionic emission at the heated cathode and focuses it into a thin beam by the control grid

• A strong electric field between cathode and anode accelerates the electrons, before they leave the electron gun through a small hole in the anode.

• The electron beam can be deflected by a capacitor or coils in a way which causes it to display an image on the screen. The image may represent electrical waveforms (oscilloscope), pictures(television, computer monitor), echoes of aircraft detected by radar etc.



•When electrons strike the fluorescent screen, light is emitted.

• The whole configuration is placed in a vacuum tube to avoid collisions between electrons and gas molecules of the air, which would attenuate the beam.

Advantages:

(a) They operate at any resolution, geometry and aspect ratio without the need for rescaling the image.

b) CRTs run at the highest pixel resolutions generally available.

c) Produce a very dark black and the highest contrast levels normally available. Suitable for use even in dimly lit or dark environments.

d) CRTs produce the very best color and gray-scale and are the reference standard for all professional calibrations. They have a perfectly smooth gray-scale with an infinite number of intensity levels. Other display technologies are expected to reproduce the natural power-law Gamma curve of a CRT, but can only do so approximately.

e) CRTs have fast response times and no motion artifacts. Best for rapidly moving or changing images.

f) CRTs are less expensive than comparable displays using other display technologies.

Disadvantages:

a) The CRT's Gaussian beam profile produces images with softer edges that are not as sharp as an LCD at its native resolution. Imperfect focus and color registration also reduce sharpness. Generally sharper than LCDs at other than native resolutions.

b) All color CRTs produce annoying Moiré patterns. Many monitors include Moiré reduction, which normally doesn't eliminate the Moiré interference patterns entirely.

c) Subject to geometric distortion and screen regulation problems. Also affected by magnetic fields from other equipment including other CRTs.

d) Relatively bright but not as bright as LCDs. Not suitable for very brightly lit environments.

e) Some CRTs have a rounded spherical or cylindrical shape screen. Newer CRTs are flat.

f) CRTs give off electric, magnetic and electromagnetic fields. There is considerable controversy as to whether any of these pose a health hazard, particularly magnetic fields. The most authoritative scientific studies conclude that they are not harmful but some people remain unconvinced.

g) They are large, heavy, and bulky. They consume a lot of electricity and produce a lot of heat.

(b) Generate the homogeneous combined transformation matrix for transforming a point, A (2, 2, 3), which is applying the following successive sequence transformations and the coordinates new point, A.

1. **Rotation 45^0 about z-axis in CW direction.**
2. **Translation of (2,-3, 4)**
3. **Rotation 30^0 about y-axis CCW direction.** **6M**

Given Sequence of Transformations are

(1) Rotation of 45° about z-axis in cw direction

for This matrix form is

$$R_1 = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos 45 & \sin 45 & 0 & 0 \\ -\sin 45 & \cos 45 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(2) Translation of (2, -3, 4)

in the Matrix form

$$T_1 = \begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(3) Rotation of 30° about Y-axis ccw direction

$$R_2 = \begin{bmatrix} \cos 30 & 0 & \sin 30 & 0 \\ 0 & 1 & 0 & 0 \\ -\sin 30 & 0 & \cos 30 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

Resultant Transformation Matrix

$$T_R = R_2\, T_1\, R_1$$

$$= \begin{bmatrix} 0.866 & 0 & 0.5 & 0 \\ 0 & 1 & 0 & 0 \\ -0.5 & 0 & 0.866 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 0.707 & 0.707 & 0 & 0 \\ -0.707 & 0.707 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.6122 & 0.6122 & 0.5 & 3.732 \\ -0.707 & 0.707 & 0 & -3 \\ -0.3535 & -0.3535 & 0.866 & 2.464 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For Coordinates of New point

$$\text{New point} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = [T_R] \times \begin{bmatrix} 2 \\ 2 \\ 3 \\ 1 \end{bmatrix}$$

$$= \begin{pmatrix} 7.681 \\ -3 \\ 3.648 \\ 1 \end{pmatrix}$$

UNIT II

4. **(a)** **Generate the parametric equation for 'Cubic spline' and highlight its applications.** **8M**

Cubic splines use cubic polynomials. A cubic polynomial has four coefficients and thus requires four conditions to evaluate. These conditions could be a combination of points and tangent vectors. A cubic spline uses four data points.

The Hermite cubic spline uses two data points at its ends and two tangent vectors at these points.

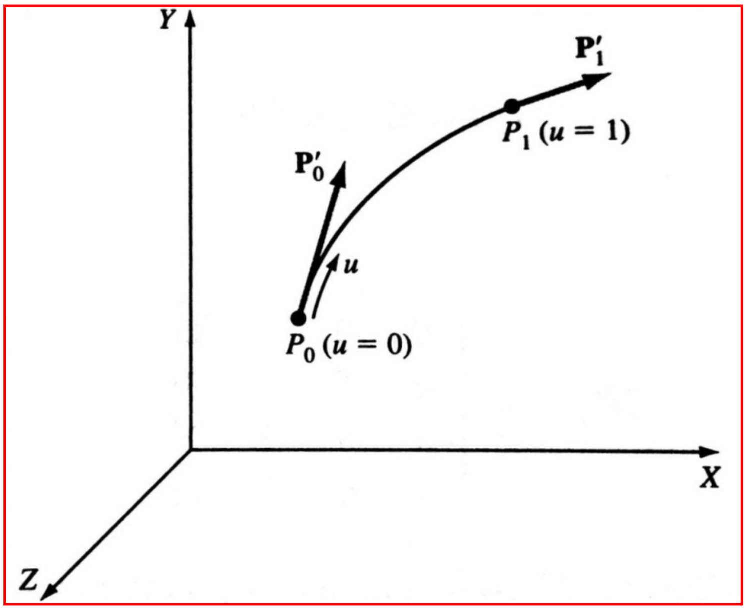


Figure 2.5 Hermite cubic spline curve

The parametric equation of a cubic spline segment is given by:

$P(u) = \sum_{i=0}^{3} C_i u^i$, $0 \leq u \leq 1$ -------------------------------------- (1)

Where, u is the parameter and C_i are the polynomial (also called algebraic) coefficients.

In scalar form, this equation is written as:

$$x(u) = C_{3x}u^3 + C_{2x}u^2 + C_{1x}u + C_{0x}$$

$$y(u) = C_{3y}u^3 + C_{2y}u^2 + C_{1y}u + C_{0y}$$

$$z(u) = C_{3z}u^3 + C_{2z}u^2 + C_{1z}u + C_{0z}$$ -------------------------------- (2)

In an expanded vector form equation (1) can be written as:

$P(u) = C_3u^3 + C_2u^2 + C_1u + C_0$ -------------------------------- (3)

The above equation can also be written in matrix form as

$P(u) = U^TC$ ------------------------------ (4)

Where
$U = [u^3 \quad u^2 \quad u \quad 1]^T$ $and\ C =$
$[C_3 \quad C_2 \quad C_1 \quad C_0]^T$, $C\ is\ called\ the\ coefficient\ vector.$

The tangent vector to the curve at any point is given by differentiating equation (1) with respect to u to give:

$P'(u) = \sum_{i=0}^{3} C_i i u^{i-1}$, $0 \le u \le 1$ --------------------------- (5)

In order to find the coefficients C_i , consider the cubic spline segment with the two end points $P_0\ and\ P_1$ shown in figure 2.5.

Applying the boundary conditions ($P_0, P_o' at\ u = 0\ and\ P_1, P_1'\ at\ u = 1$) equations (1) and (5) give

$$P_0 = C_0$$

$$P_0' = C_1$$

$$P_1 = C_3 + C_2 + C_1 + C_0$$

$P_1' = 3C_3 + 2C_2 + C_1$ ------------- (6)

Solving the above four equations simultaneously for the coefficients gives,

$$C_0 = P_0$$

$$C_1 = P_0'$$

$$C_2 = 3(P_1 - P_0) - 2P_0' - P_1'$$

$C_3 = 2(P_0 - P_1) + P_0' + P_1'$ -------------------------- (7)

Substituting equations (7) into equation (3) and rearranging gives:

$P(u) = (2u^3 - 3u^2 + 1)P_0 + (-2u^3 + 3u^2)P_1 + (u^3 - 2u^2 + u)P_0' + (u^3 - u^2)P_1',$
$0 \le u \le 1$ ---------------(*)

$$P_0, P_1, P_0', and\ P_1'\ are\ called\ geometric\ coefficients.$$

The tangent vector becomes

$P'(u) = (6u^2 - 6u)P_0 + (-6u^2 + 6u)P_1 + (3u^2 - 4u + 1)P_0' + (3u^2 - 2u)P_1',\ 0 \le$
$u \le 1$ ----------- (8)

The functions of u in equations (7) and (8) are called blending functions.

The first two functions blend P_0 and P_1 and the second two blend P_0' and P_1'

Equation (7) can be rewritten in a matrix form as

$P(u) = U^T[M_H]V, \quad 0 \le u \le 1$------------------- (9)

Where $[M_H]$ is the Hermite matrix and V is the geometry (or boundary conditions) matrix. Both are given by:

$$[M_H] = \begin{bmatrix} 2 & -2 & 1 & 1 \\ -3 & 3 & -2 & -1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \text{-------------------- (10)}$$

$$V = \begin{bmatrix} P_0 & P_1 & P_0' & P_1' \end{bmatrix}^T \text{---------------------------- (11)}$$

Comparing equations (4) and (9) show that $C = [M_H]V \ or \quad V = [M_H]^{-1}C$

$$\text{Where, } [M_H]^{-1} = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 \\ 3 & 2 & 1 & 0 \end{bmatrix} \text{--------------------- (12)}$$

Similarly equation (8) can be written as

$P'(u) = U^T[M_H]^u\, V$ ------------------------------ (13)

Where, $[M_H]^u$ *is given by*

$$[M_H]^u = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 6 & -6 & 3 & 3 \\ -6 & 6 & -4 & -2 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

(b) Generate the parametric equation for 'Bezier' curve. 4M

A Bezier curve is defined by a set of data points. The curve may interpolate or extrapolate the data points. In both cases, the data points are used to control the shape of the resulting curves.

The main characteristics of Bezier curves are:

1. The shape of the Bezier curve is controlled by its defining points. Tangent vectors are not used in the curve development as in the case of cubic spline. This

allows the designer a much better feel for the relationship between input (points) and output (curve).

2. The order of the Bezier curve is variable and is related to the number of points defining it. $n + 1$ points define an n^{th} degree curve, which permits higher-order continuity. This is not the case for cubic splines, where the degree is always cubic for a spline segment.

The data points of a Bezier curve are called control points. They form the vertices of control polygon or characteristic polygon, which uniquely defines the curve shape as shown in figure

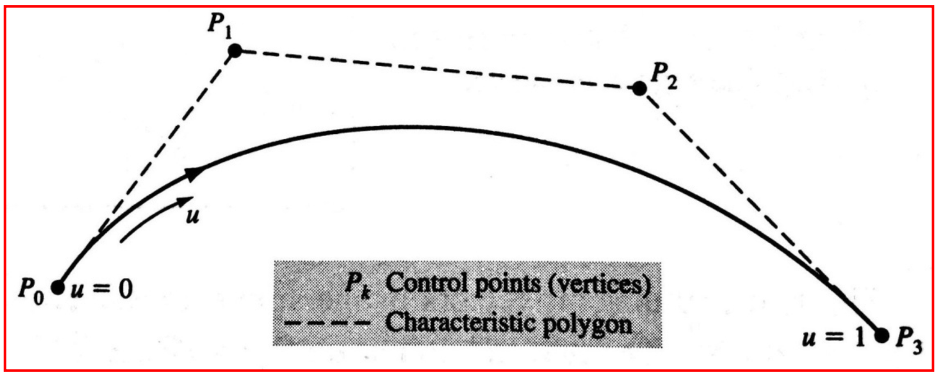


Figure 2.7 Cubic Bezier Curve

Only the first and the last control points or vertices of the polygon actually lie on the curve. The other vertices define the order, derivatives, and shape of the curve. The curve is also always tangent to the first and last polygon segments. In addition, the curve shape tends to follow the polygon shape.

Figure 2.8 illustrates the form of Bezier curve for various control points. It shows that the order of defining the control points changes the polygon definition, which changes the resulting curve shape. The arrow shown on each curve shows its parameterization direction.

Mathematically, for $n + 1$ control points, the Bezier curve is defined by the following polynomial of degree n:

$P(u) = \sum_{i=0}^{n} P_i B_{i,n}(u), \quad 0 \leq u \leq 1$--------------------- (2.14)

Where, $P(u)$ is a point on the curve and P_i is a control point. $B_{i,n}$ are the Bernstein polynomials. Thus, the Bezier curve has a Bernstein basis. The Bernstein polynomial serves as the blending or basis function for the Bezier curve and is given by

$B_{i,n}(u) = C(n, i)u^i(1 - u)^{n-i}$ -------------------- (2.15)

Where, $C(n, i)$ is the binomial coefficient.

$C(n,i) = \frac{n!}{i!(n-i)!}$ ------------------------------------ (2.16)

Utilizing equations 2.15 and 2.16 and observing that $C(n,0) = C(n,n) = 1$, equation 2.14 can be expanded to give:

$$P(u) = P_0(1-u)^n + P_1C(n,1)u(1-u)^{n-1} + P_2C(n,2)u^2(1-u)^{n-2} + \cdots\ldots$$

$$+P_{n-1}C(n,n-1)u^{n-1}(1-u) + P_nu^n, \quad 0 \le u \le 1$$ ---------------- (2.17)

For the Bezier cubic polynomial, referring to figure 2.7, we can write

$$P_0' = 3(P_1 - P_0)$$

$$P_3' = 3(P_3 - P_2)$$

Substituting these in to equation 2.17 yields,

$$P = P(u) = P_0(1 - 3u + 3u^2 - u^3) + P_1(3u - 6u^2 + 3u^3) + P_2(3u^2 - 3u^3) + P_3(u^3)$$

This may be expressed in matrix form as:

$$P = P(u) = \begin{bmatrix}1 & u & u^2 & u^3\end{bmatrix}\begin{bmatrix}1 & 0 & 0 & 0\\ -3 & 3 & 0 & 0\\ 3 & -6 & 3 & 0\\ -1 & 3 & -3 & 1\end{bmatrix}\begin{bmatrix}P_0\\ P_1\\ P_2\\ P_3\end{bmatrix}$$

(OR)

5. **(a) Discuss the techniques for hidden line removal in CAD modelling. 6M**

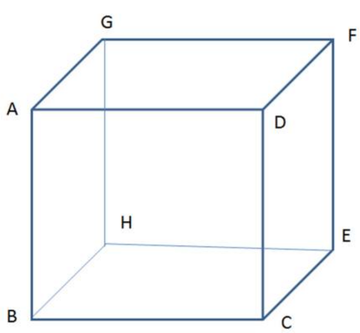
Hidden line removal (HLR) is the method of computing which edges are not hidden by the faces of parts for a specified view and the display of parts in the projection of a model into a 2D plane. Hidden line removal is utilized by a CAD to display the visual lines. It is considered that information openly exists to define a 2D wireframe model as well as the 3D topological information. Typically, the best algorithm is required for viewing this information from an available part representation.

3D parts are simply manufactured and frequently happen in a CAD design of such a part. In addition, the degrees of freedom are adequate to show the majority of models and are not overwhelming in the number of constraints to be forced. Also, almost all the surface-surface intersections and shadow computations can be calculated analytically which results in significant savings in the number of computations over numerical methods

Hidden line removal techniques are:

- MINIMAX TEST
- CONTAINMENT TEST
- SURFACE TEST
- COMPUTING SILHOUETTES
- EDGE INTERSECTION
- SEGMENT COMPARISONS
- HOMOGENITY TEST
- PRIORITY ALGORITHM

Priority algorithm: Priority algorithm is basis on organization all the polygons in the view according to the biggest Z-coordinate value of each. If a face intersects more than one face, other visibility tests besides the Z- depth required to solve any issue. This step comprises purposes of wrapper.Imagines that objects are modeled with lines and lines are generated where surfaces join. If only the visible surfaces are created, then the invisible lines are automatically removed.



Face	Priority
ABCE	1
ADFG	1
DCEF	1
ABHG	2
EFGH	2
BCFH	2

ABCD, ADFG, DCEF are given higher priority-1. Hence, all lines in this face are visible, that is, AB, BC, CD, DA, AD, DF, FG, AG, DC, CE, EF and DF are visible.
AGHB, EFGH, BCEH are given lower priority-2. Hence, all lines in this face other than priority-1 are invisible, that is BH, EH and GH. These lines must be eliminated.

(b) Explain the 'Boundary representation' in volume modelling. 6M

A boundary model or b-rep model is based on the topological notion that a physical object is bounded by a set of faces. These faces are regions or subsets of closed and orientable surfaces. The geometry of the object can be described by its boundaries, namely vertices, edges and surfaces. A closed surface is one that is continuous without breaks. An orientable surface is one in where it is possible to distinguish two sides by using the direction of the surface normal to point inside or outside the solid model. Each face is bounded by edges and each edge is bounded by vertices.

A **b-rep (boundary) model** of an object consists of faces, edges, vertices, loops, and handles. A **face** is a closed, orientable, and bounded (by edges) surface. An **edge** is a bounded (by two vertices) curve. A v**ertex** is a point in E^3. A **loop** is a hole in a face. A **handle** is a through hole in a solid (body). Think of a loop as a 2D hole and of a handle as 3D through hole. Figure 2.17 shows the b-rep model of a box with a hole.

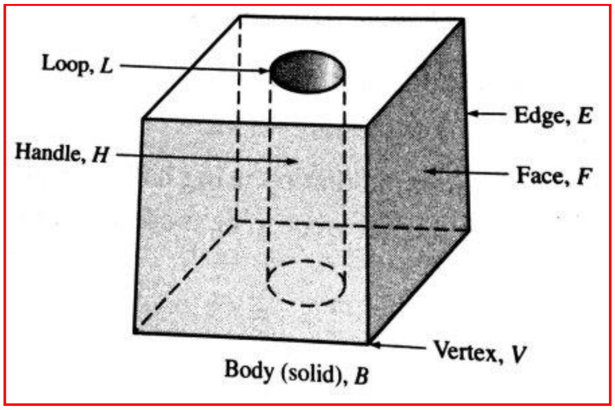


Figure 2.17 B-rep model of a solid

The database of a boundary model contains both its topology and geometry. Topology is created by performing Euler operations and geometry is created by performing Euclidian calculations. Euler operations are used to create, manipulate, and edit the faces, edges, and vertices of a boundary model. Euler operators, as Boolean operators, ensure the validity (closeness, no dangling faces or edges, and so forth) of boundary models. Geometry includes coordinates of vertices and rigid motion and transformation.

Topology and geometry are interrelated and cannot be separated entirely from each other; Figure 2.18 shows a square which, after dividing its top edges by introducing a new vertex, is still valid topologically but produces a nonsense object depending on the geometry of the new vertex.

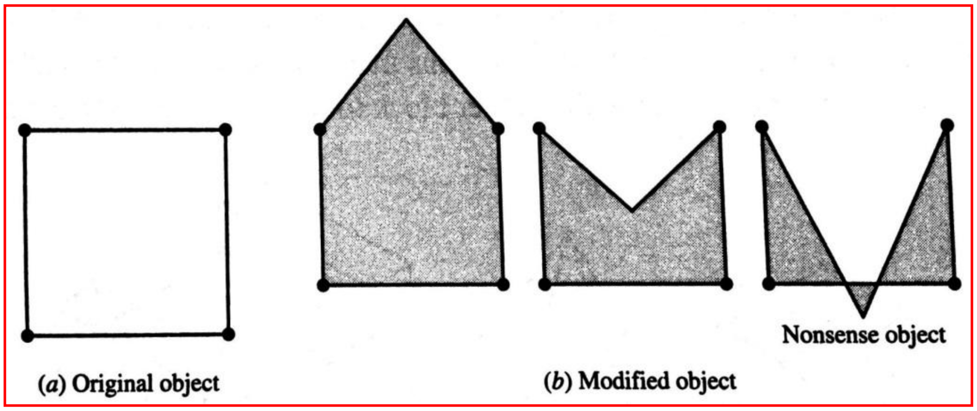


Figure 2.18 Effect of topology and geometry on boundary models

Basic Elements

Objects that are often encountered in engineering applications can be classified as either polyhedral or curved objects. A polyhedral object (plane-faced polyhedron) consists of planar faces (or sides) connected at straight (linear) edges which, in turn are connected at vertices. Example is a cube or a tetrahedron.

A curved object (curved polyhedron) is similar to a polyhedral object but with curved faces and edges.

The basic elements of a B-rep are faces, edges, vertices, loops, handles, and bodies (solids themselves). Figure 2.18 shows Polyhedral objects which can be simple or complex. They are classified in to four classes.

The first class Figure 2.18a, is the simple polyhedral. These do not have holes, and each face is bounded by a single set of connected edges.

The second class Figure 2.18b is similar to the first with the exception that a face may have loops.

The third class, Figure 2.18c, includes objects with holes that do not go through the entire object. For this class, a hole may have a face coincident with the object boundary; in this case we call it as a boundary hole, or if it is an interior hole (as a void or crack inside the object), it has no faces on the boundary.

The fourth class figure 2.18d, includes objects that have holes that go through the entire object. Topologically, these through holes are called handles. The topological name for the number of handles in an object is genus.

There exist topological constraints on the B-rep elements to ensure model validity. A vertex is always a unique point in space. An edge is a nonself-intersecting, directed space curve bounded by two vertices that are not necessarily distinct (as in the case of closed edge). A face is a finite connected, nonself-intersecting region of a closed oriented surface bounded by edges. A loop defines a nonself-intersecting, piecewise, closed space curve. The body (sometimes called a shell) is the solid itself. A minimum body is a point.

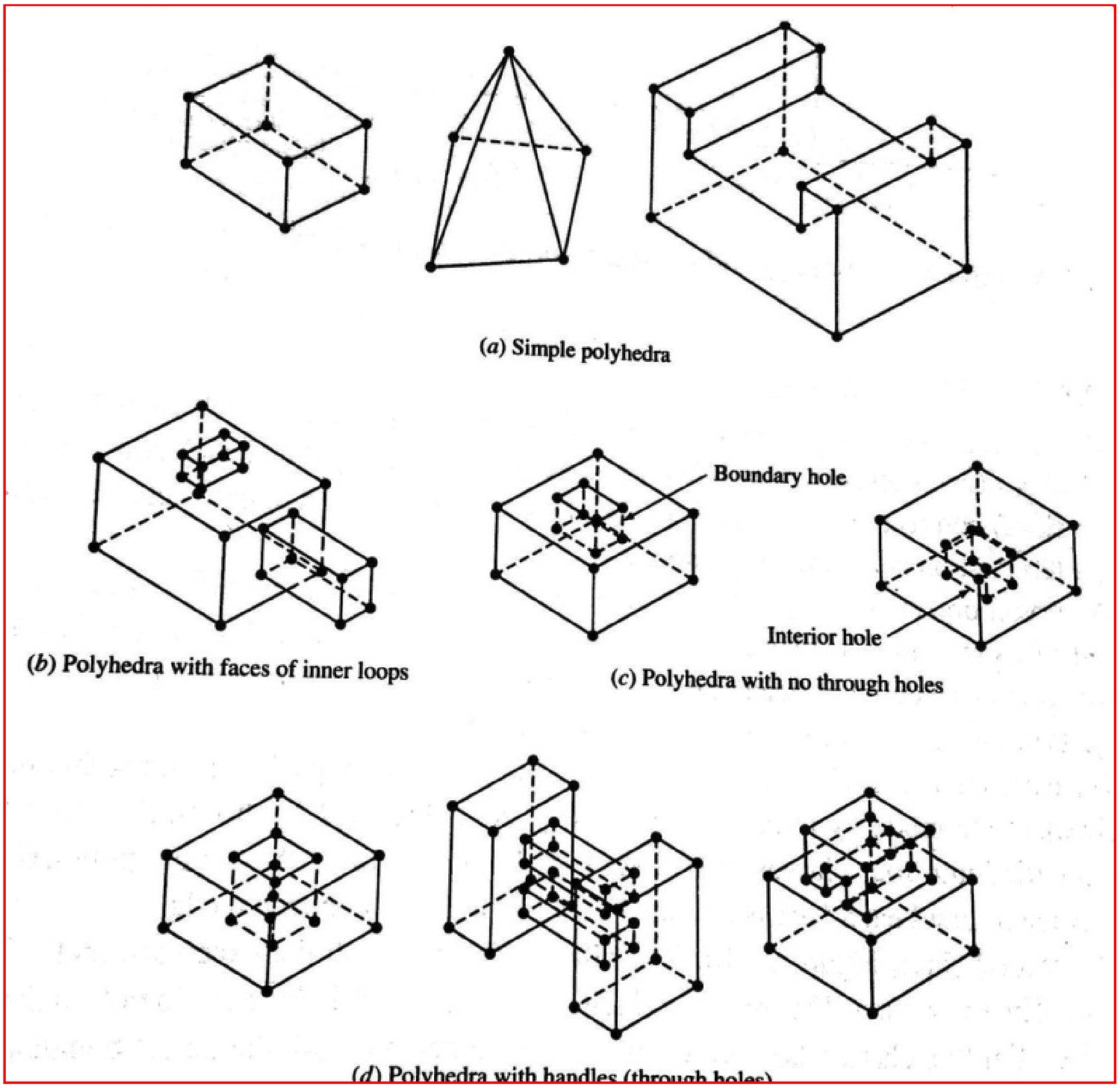


Figure 2.198 types of polyhedral objects

B-rep models are validated by Euler equations.

$$F - E + V - L = 2(B - G)$$

Where, F, E, V, L, B and G are the number of faces, edges, vertices, face's inner loops, bodies, and genus. The above equation is known as Euler or Euler-Poincare law.

Table 2.2 verifying the validity of the solids shown in figure 2.18

Solid number	F	E	V	L	B	G
1	6	12	8	0	1	0
2	5	8	5	0	1	0
3	10	24	16	0	1	0
4	16	36	24	2	1	0
5	11	24	16	1	1	0
6	12	24	16	0	2	0
7	10	24	16	2	1	1
8	20	48	32	4	1	1
9	14	36	34	2	1	1

Euler's law given by above equation applies to closed polyhedral objects only. These are the valid 3D solid models. However, for open polyhedral objects the following Euler's law is applied.

$$F - E + V - L = B - G$$

Figure 2.20 shows some examples of open objects. In the above equation B refers to an open body which can be a wire, an area, or a volume. Note that all the objects in figure 2.20 have one body, and only the two bodies of figure 2.20 c have one genus each.

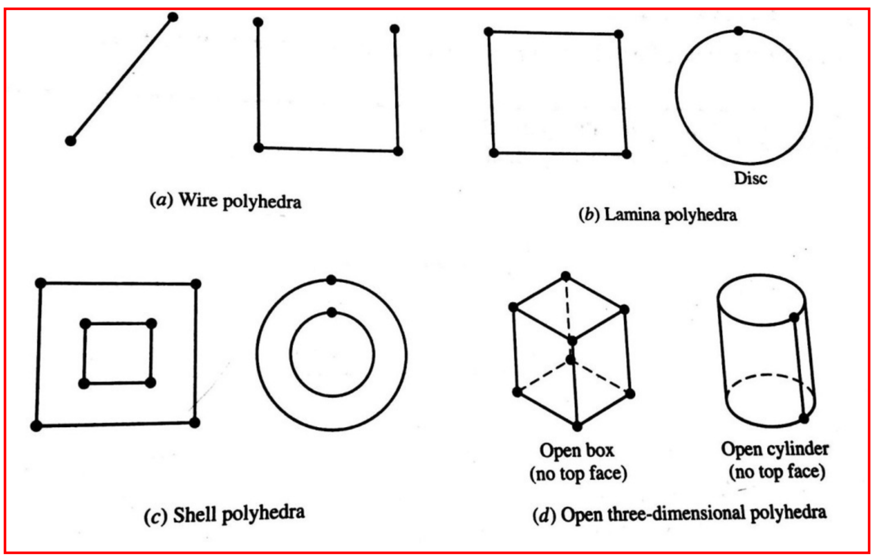


Figure 2.20 open polyhedral objects

2.3 verifying the validity of the open polyhedral objects shown in figure 2.19

Solid number	*F*	*E*	*V*	*L*	*B*	*G*
1	0	1	2	0	1	0
2	0	3	4	0	1	0
3	1	4	4	0	1	0
4	1	1	1	0	1	0
5	1	8	8	1	1	1
6	1	2	2	1	1	1
7	5	12	8	0	1	0
8	2	3	2	0	1	0

UNIT III

6. **(a)** **Explore the merits and de-merits of NC machines with highlighting the Applications.** **6M**

Advantages of NC

- Non productive time is reduced
- Greater accuracy and repeatability
- Lower scrap rates
- Inspection requirements are reduced
- More complex part geometries are possible
- Engineering changes can be accommodated more gracefully
- Simpler fixtures are needed
- Shorter manufacturing lead times
- Reduced parts inventory
- Less floor space required
- Operator skill level requirements are reduced
- Improved quality control

Disadvantages of NC

- Higher investment costs
- Higher maintenance effort
- Part programming
- Higher utilization of NC equipment
- Finding and training NC personnel

Applications of NC

- Batch production
- Repeat orders
- Complex part geometry
- Much metal needs to be removed from the work part
- Many separate machining operations on the part
- The part is expensive
- Engineering design changes are likely
- Close tolerances must be held on the work part
- The parts require 100% inspection

(b) Illuminate the basic components of the CNC machine and write about functional Operation. 6M

Components of CNC

1) **PART PROGRAM**
These are coded instruction in a series which are a requirement to produce parts. This part program is able to control the movement of the tool and an on and off control for functions like coolant and spindle rotation. These instructions which are coded consist of symbols, numerical and letters.

2) **MACHINE CONTROL UNIT(MCU)**
This MCU is the most important part of CNC machining. Made of electronics components, this is able to interpret after reading the program instructions, after which, this is able to convert them in to the mechanical actions of the specific machine tools. The control unit, thus, is the required link between the machine tool and the program. This operates the machine in accordance to the given instructions. The functions are,

   - Reading the instructions which are coded
   - Decoding these instructions.
   - Implementing interpolations (helical, circular, linear) generating commands for motion of the axis.
   - Feeding these axis commands to the amplifier circuits to enable driving of the mechanisms of the axis.

- Receiving the signals of the feedback of the speed and position for every drive axis.
- Implementing the controls of the auxiliary functions like tool change, spindle on and off and coolant.

3) MACHINE TOOL

The actual operations for machining are carried out by the machine tool. This can be any tool like drilling machine, milling machine, lathe or any other. This is the part which is controlled in the CNC. These machines also have the control console or the control panel that contains the switches and dials which the operator uses to run the machine. You also have displays where the required information is displayed.

4) PROGRAM INPUT DEVICE

This is for entering the part program in the CNC machine. The three common input devices used are magnetic tape reader, punch tape reader and computer via the RS-232-C communication.

5) DRIVE SYSTEM

This system consists of drive motors, ball lead-screws and amplifier circuits. The MCU feeds the signals for control of the position and speed of every axis to the circuits of the amplifier. These signals are then augmented to drive the motors which turn the ball lead-screws in order to position the table of the machine.

6) FEED BACK SYSTEM

The measuring system is the feedback system. Making use of transducers of speed and position, this can monitor constantly the position of the tool which is cutting, at any instant. Using the difference between the feed back signals and reference signals, the MCU is able to generate the signals for controlling and correction any errors in the speed and position.

(OR)

7. **Develop the APT program to perform the milling operation with an end mill cutter diameter of 20 mm and thickness of the plate is 10 mm, as in fig.1.** **12M**

MACHI

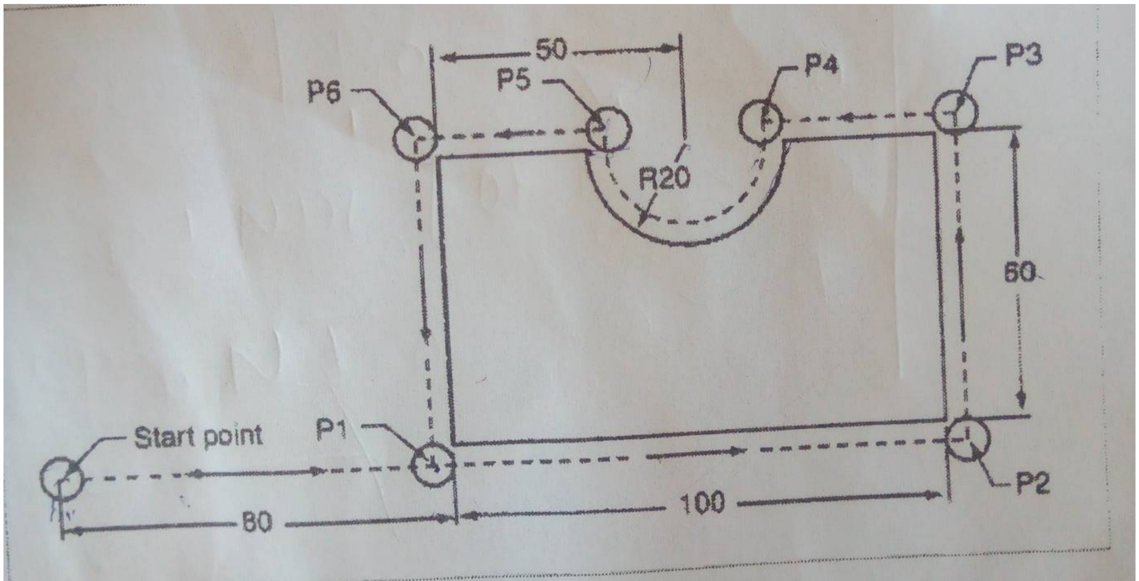


Fig. 1

MACHIN/MILL,01

CLPRNT

UNITS/MM

CUTTER/20.0

P=POINT/0,0,0

P_1=POINT/80,0,0

P2=POINT/180,0,0

P3=POINT/180,60,0

P4=POINT/150,60,0

P5=POINT/110,60,0

P6=POINT/80,60,0

L1=LINE/P1,P2

L2=LINE/P2,P3

L3=LINE/P3,P4

```
L4=LINE/P5,P6
L5=LINE/P6,P1
C1=CIRCLE/RADIUS,20,CENTER,130,60,0
PL1=PLANE/P1,P2,P3
PL2=PLANE/0,0,-12,2,4,-12,4,5,-12
FROM/P0
SPINDL/1000,CLW
FEDRAT/50,IPM
GO/TO,P1
GOFWD/L1,PAST,L2
GOLFT/L2,PAST,L3
GOLFT/L3,PAST,C1
GOFWD/C1,PAST,L4
GOFWD/L4,PAST,L5
GOLFT/L5,PAST,L1
RAPID
GOTO/P0
SPINDL/OFF
FINI
```

UNIT IV

8. **(a) Develop the concept of Machine cell design and highlight its applications. 6M**

Design of the machine cell is critical in cellular manufacturing. The cell design determines to a great degree the performance of the cell. In this subsection, we discuss types of machine cells, cell layouts, and the key machine concept.

Types *of Machine Cells and Layouts:*

GT manufacturing cells can be classified according to the number of machines and the degree to which the material flow is mechanized between machines. Here we identify four common GT cell configurations.

1) **single machine cell**

   As its name indicates, the *single machine cell* consists of one machine plus supporting fixtures and tooling. This type of cell can be applied to work-parts whose attributes allow them to be made on one basic type of process, such as turning or milling. *For* example, the composite part of Figure 15.10 could be produced on a conventional turret lathe, with the possible exception of the cylindrical grinding operation

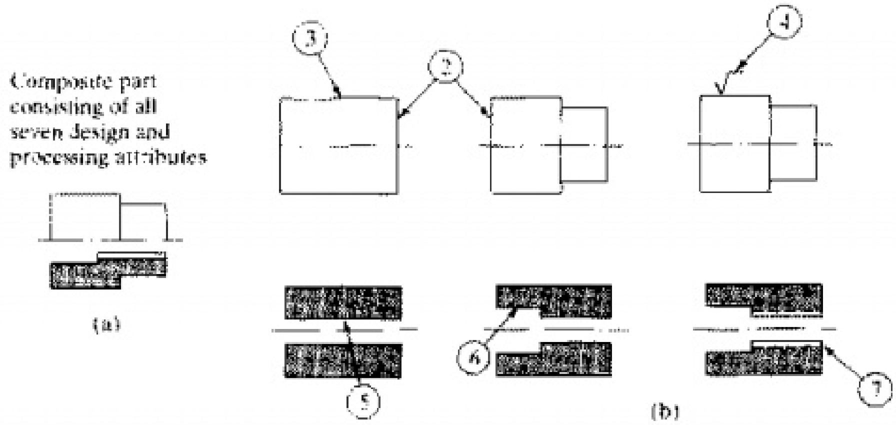


Figure 15.10 Composite part concept: (a) the composite part for a family of machined rotational parts and (b) the individual features of the composite part. See Table 15.6 for key to individual features and corresponding manufacturing operations.

TABLE 15.6 Design Features of the Composite Part in Figure 15.10 and the Manufacturing Operations Required to Shape Those Features

Label	*Design Feature*	*Corresponding Manufacturing Operation*
1	External cylinder	Turning
2	Cylinder face	Facing
3	Cylindrical step	Turning
4	Smooth surface	External cylindrical grinding
5	Axial hole	Drilling
6	Counterbore	Counterboring
7	Internal threads	Tapping

2) group machine cell with manual handling

The *group machine cell with manual handling* is an arrangement of more than one machine used collectively to produce one or more part families. There is no provision for mechanized parts movement between the machines in the cell. Instead, the human operators who run the cell perform the material handling function. The cell is often organized into a U shaped layout, as shown in Figure 15.12. This layout is considered appropriate when there is variation in the work flow among the parts made in the cell. It also allows the multifunctional workers in the cell to move easily between machines

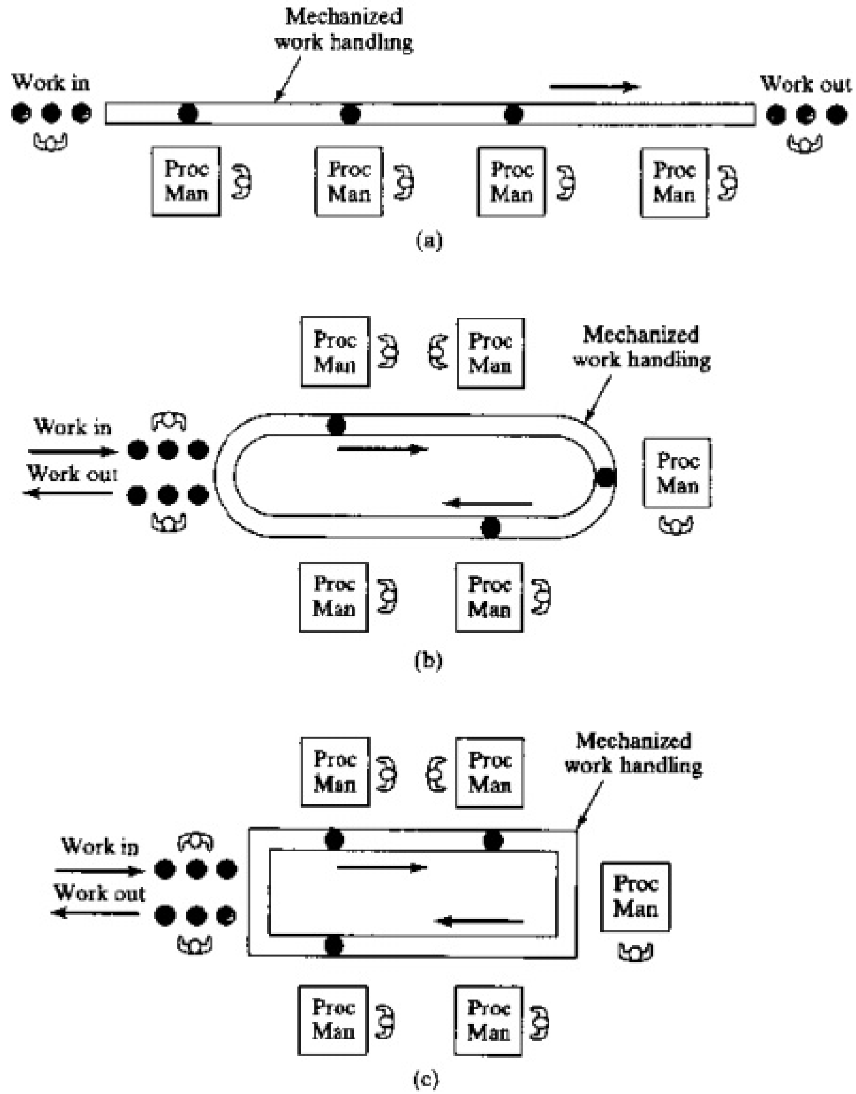


Figure 15.12 Machine cells with semi-integrated handling: (a) in-line layout, (b) loop layout, and (c) rectangular layout. (Key: "Proc" = processing operation (e.g., mill, turn, etc.), "Man" = manual operation; arrows indicate work flow.)

3) group machine cell with semi integrated handling

The *group machine cell with semi integrated handling* uses a mechanized handling system, such as a conveyor, to move parts between machines in the cell

4) flexible manufacturing cell or flexible manufacturing system

The flexible manufacturing system (FMS) combines a fully integrated material handling system with automated processing stations. The FMS is the most highly automated of the group technology machine cells.

APPLICATIONS:

1) product design benefits
   It is estimated that 10% reduction in the number of drawings can be expected through standardization with GT.
2) Tooling and setups
   It is estimated that the use of GT can result a 69% reduction in a setup time.
3) Material handling
   Reduction in the work part move and waiting time can be achieved with GT.
4) Production and inventory control:
   It is estimated that
   70% reduction in production times
   62% reduction in work-in- process inventories
   82% reduction in overdue orders
5) Employee satisfaction
   Workers are able visualize their contribution to the firm clearly.
6) Process planning procedures
   The time and cost of process planning function can be reduced through standardization associated with GT.

TABLE 15.7 Benefits of Cellular Manufacturing Reported by Companies in Survey

Rank	*Reason for Installing Manufacturing Cells*	*Average Improvement* (%)
1	Reduce throughput time (Manufacturing lead time)	61
2	Reduce work-in-process	48
3	Improve part and/or product quality	28
4	Reduce response time for customer orders	50
5	Reduce move distances	61
6	Increase manufacturing flexibility	
7	Reduce unit costs	16
8	Simplify production planning and control	
9	Facilitate employee involvement	
10	Reduce setup times	44
11	Reduce finished goods inventory	39

Source: Wemmerlov and Johnson [38].

(b) List the benefits of CAPP. **6M**

1) Process rationalization and standardization
2) Increased productivity of process planners
3) Reduced lead time for process planning

4) Improved legibility
5) Incorporation of other application programs

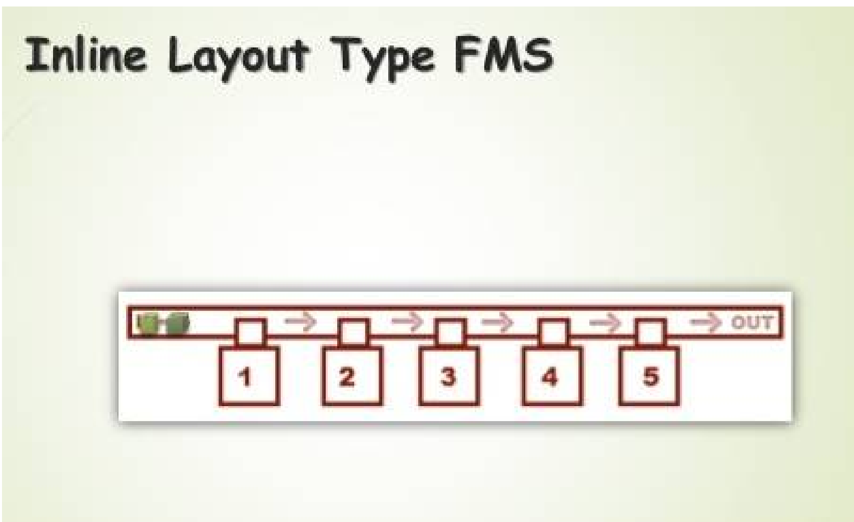
(OR)

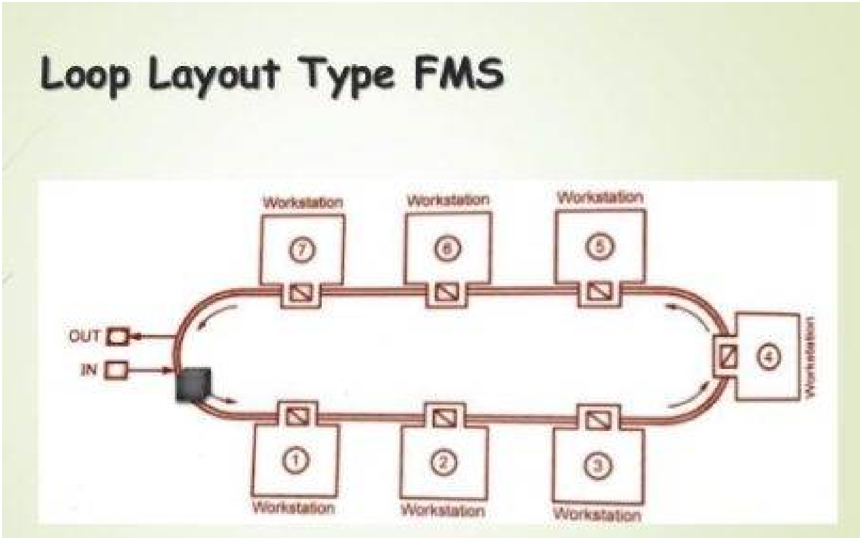
9. **(a) Generate FMS layout configurations and highlight its applications.** **6M**

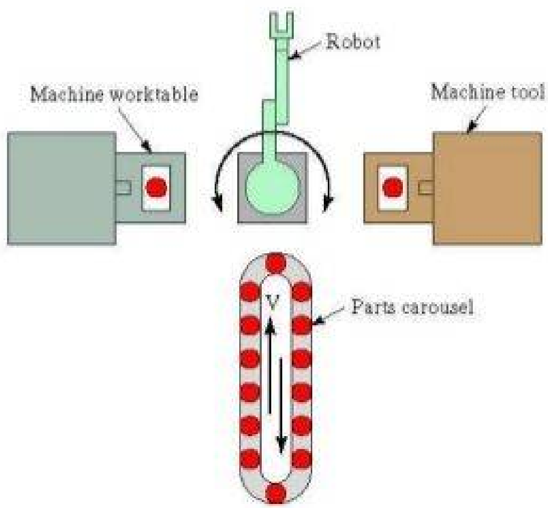
Basic layout of the FMS. Five layout types can be distinguished.

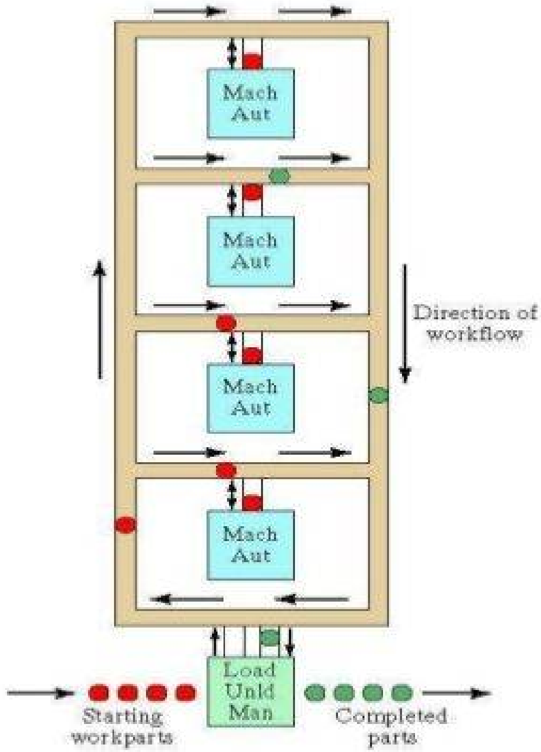
- in-line
- loop
- ladder
- open field
- robot-cantered cell

All these basic layouts are shown below in same order.



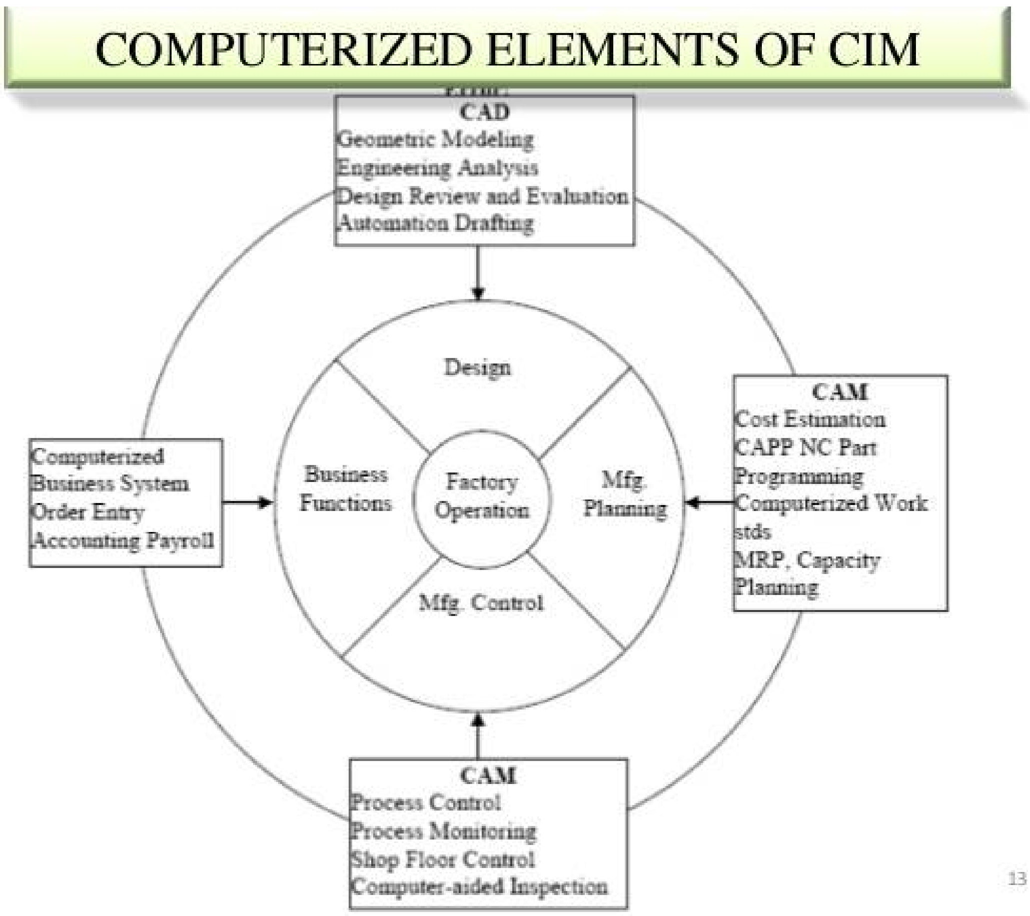

Loop Layout Type FMS
Workstation
7
Workstation
6
Workstation
5
OUT
IN
4
Workstation
1
Workstation
2
Workstation
3
Workstation


Robot
Machine worktable
Machine tool
V
Parts carousel



The **in-line layout** uses a linear transfer system to move parts between processing stations and load/unload station(s). The in-line transfer system is usually capable of two-directional movement; if not, then the FMS operates much like a transfer line, and the different part styles made on the system must follow the same basic processing sequence due to the one-direction flow. The **loop Layout** consists of a conveyor loop with workstations located around its periphery. This configuration permits any processing sequence, because any station is accessible from any other station. This is also true for the **ladder layout**, in which workstations are located on the rungs of the ladder. The **open field layout** is the most complex FMS configuration, and consists of several loops tied together. Finally, **the robot-cantered cell** consists of a robot whose work volume includes the load/unload positions of the machines in the cell.

(b) **Write a brief note on 'Computer Integrated manufacturing'.** **6M**



Computer integrated manufacturing includes all of the engineering functions of CAD/CAM, but it also includes the firm's business functions that are related to manufacturing.

The scope of CIM, compared with the scope of CAD/CAM is depicted in the figure

The CIM concept is that, all of the firms operations related to production are incorporated in an integrated computer system to assist, augment, and automate the operation. The computer system is pervasive throughout the firm, touching all activities that support manufacturing. In this integrated computer system output of one activity serves as the input to the next activity. Through the chain of events that starts with the sales order and culminates with shipment of the product.

Customer orders are initially entered by the company's sales force or directly by the customer into computerized order entry system. The orders contain the specifications describing the product. The specification serves as the input to the product design department. New products are designed on a CAD system. The components that comprise the product are the bill of materials is compiled, and assembly drawings are prepared.

The output of the design department serves as the input to manufacturing engineering where the process planning, tool design and similar activities are accomplished to prepare for production. Process planning is performed using CAPP. Tool and fixture design is done on a CAD system, like this it goes. Through each step in the manufacturing cycle.