

Sparks Academy



CAD/CAM/CIM

CAD/CAM

Fundamentals of Computer Graphics

Geometric Modeling

Visual Realism

Assembly of Parts

CAD Standards

CIM

Fundamentals of CIM

Production Planning and Control and Computerized Process Planning

Cellular Manufacturing

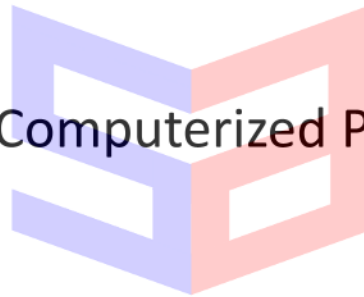
Flexible Manufacturing System

Automated Guided Vehicle System

Industrial Robotics

Additive manufacturing

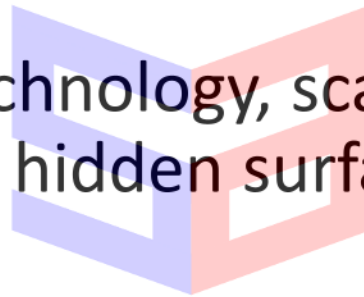
- Just in Time(JIT)
- lean manufacturing



1. Fundamentals of Computer Graphics

❖ The display of the drawing or the geometric model of the component in CAD uses the technology of computer graphics.

❖ The techniques of raster technology, scan conversion, clipping, removal of hidden lines and hidden surfaces, color, shading and texture



❑ Modern computer graphics displays are simple in construction. They consist of basically three components.

i. Monitor

ii. Digital Memory or Frame Buffer

iii. Display Controller

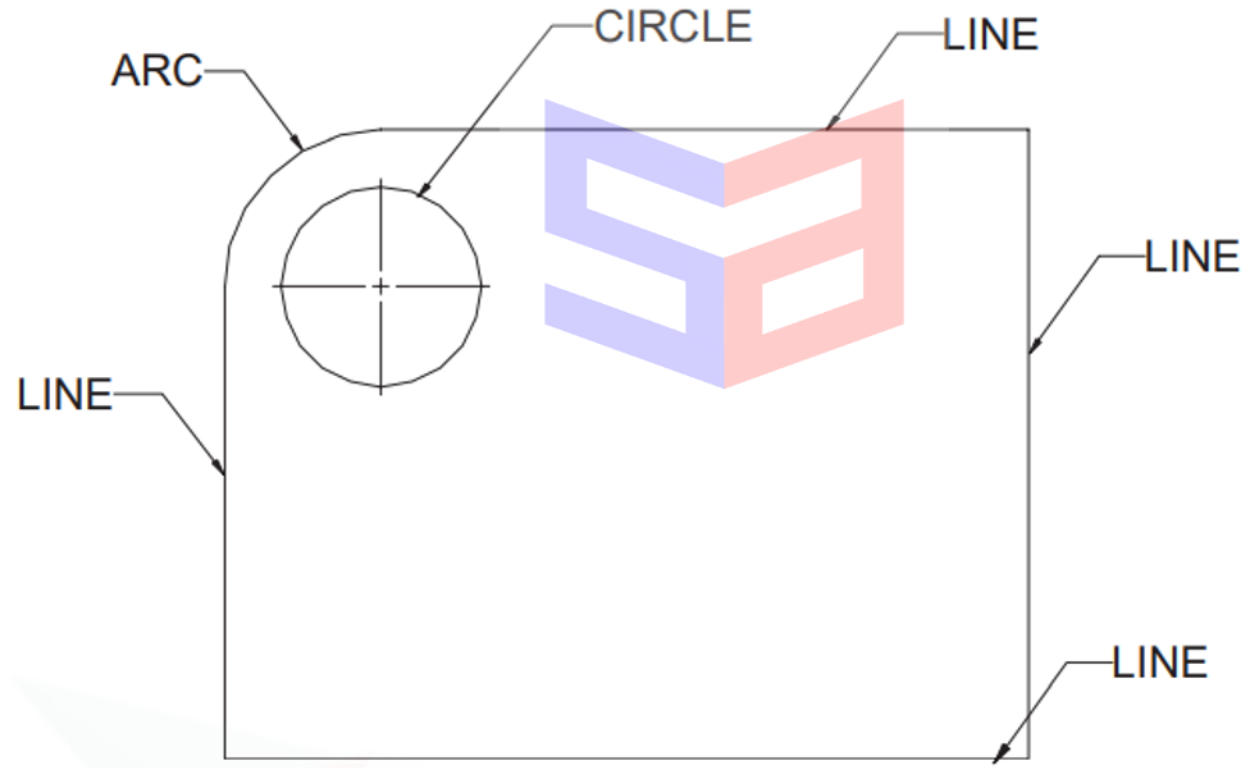
❑ Most of the computer graphics displays use **raster CRT (cathode-ray tube)** which is a matrix of discrete cells each of which can be made bright.

❑ A graphic entity like line or circle is represented as a series of “points or dots” on the screen. Therefore, it is called as a **point plotting device**.

❑ The video display screen is divided into very small rectangular elements called a picture element or pixel. This happens to be the smallest addressable screen element.

GRAPHIC PRIMITIVES

A drawing is created by an assembly of points, lines, arcs, circles. For example, drawing shown in Fig. consists of several entities. In computer graphics also drawings are created in a similar manner.



Drawing of lines:

1. digital differential analyzer (DDA)

The DDA is therefore initialized by adding 0.5 in each of the fractional parts to achieve true rounding.

To draw a straight line from connecting two points (2, 7) and (15, 10)

$$X1 = 2, X2 = 15$$

$$\text{abs}(X2 - X1) = 13$$

$$Y1 = 7, Y2 = 10$$

$$\text{abs}(Y2 - Y1) = 3$$

$$\text{Length} = 13$$

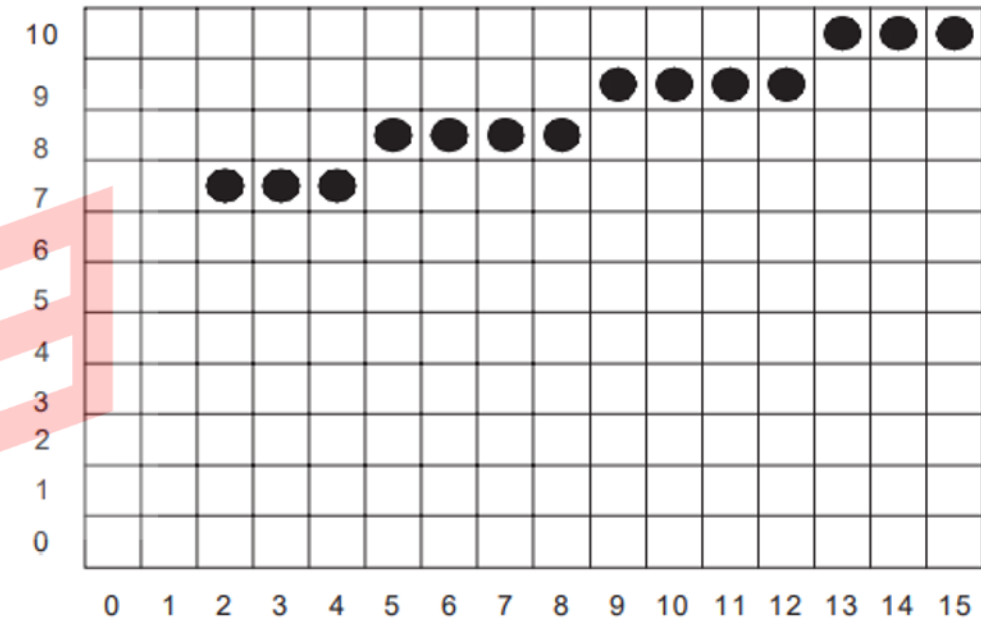
$$X \text{ incr} = X2 - X1 / \text{Length} = 13 / 13 = 1$$

$$Y \text{ incr} = Y2 - Y1 / \text{Length} = 3 / 13 = 0.23$$

Initial values of X and Y are $X = 2.5$ $Y = 7.5$



<i>X</i>	<i>Y</i>	<i>trunc (X)</i>	<i>trunc (Y)</i>
2.5	7.50	2	7
3.5	7.73	3	7
4.5	7.96	4	7
5.5	8.19	5	8
6.5	8.42	6	8
7.5	8.65	7	8
8.5	8.88	8	8
9.5	9.11	9	9
10.5	9.34	10	9
11.5	9.57	11	9
12.5	9.80	12	9
13.5	10.23	13	10
14.5	10.46	14	10
15.5	10.69	15	10



2. Bresenham's line-drawing algorithm

In this algorithm either pixels along X or Y directions are incremented by one unit depending upon the slope of the line.

DRAWING OF CIRCLES

1. BRESENHAM'S CIRCLE ALGORITHM

- ❖ An efficient algorithm for generating a circle has been developed by J. Bresenham.
- ❖ Values of a circle centred at the origin are computed in the sector $X = 0$ to $Y = R$ where R is the radius of the circle.
- ❖ The symmetry of the circle is used to obtain the pixels corresponding to other sectors



2-D TRANSFORMATIONS in graphics

- In computer graphics, drawings are created by a series of primitives which are represented by the co-ordinates of their end points. Certain changes in these drawings can be made by performing some mathematical operations on these co-ordinates.
- The basic transformations are **scaling, translation and rotation**.

1. SCALING

- Changing the dimensions of window and view port, it is possible to alter the size of drawings.
- In general, this can be done by multiplying the co-ordinates of the drawing by an enlargement or reduction factor called **scaling factor**, and the operation is called scaling.



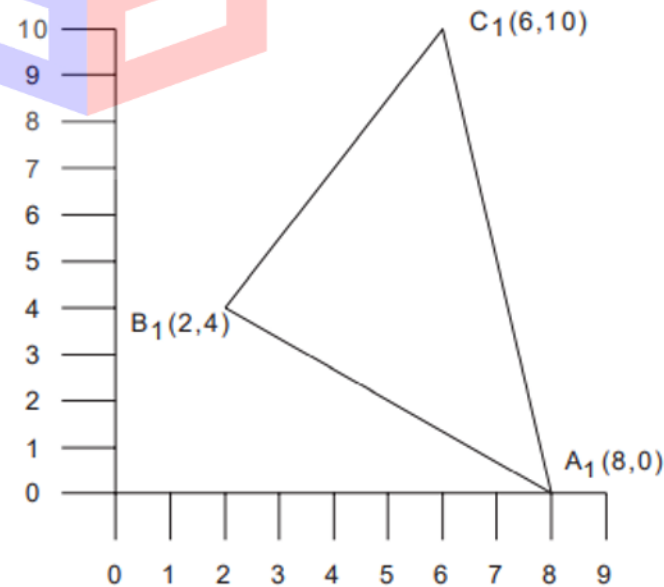
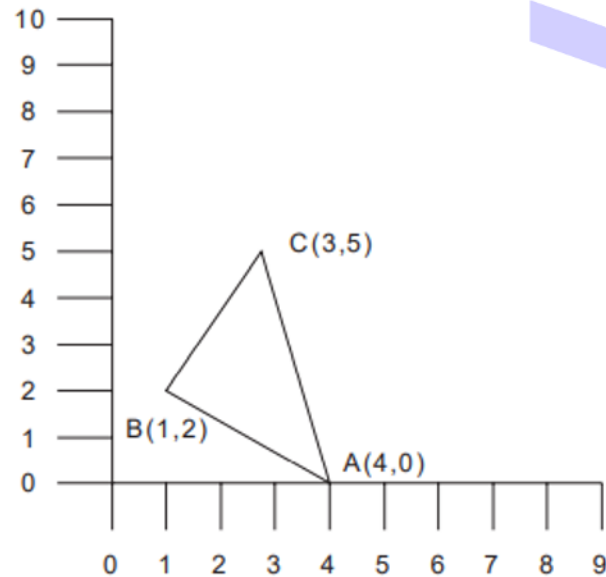
$$P1 = [30, 20]$$

If we multiply this by a matrix

$$\begin{bmatrix} 2 & 0 \\ 0 & 3 \end{bmatrix}$$

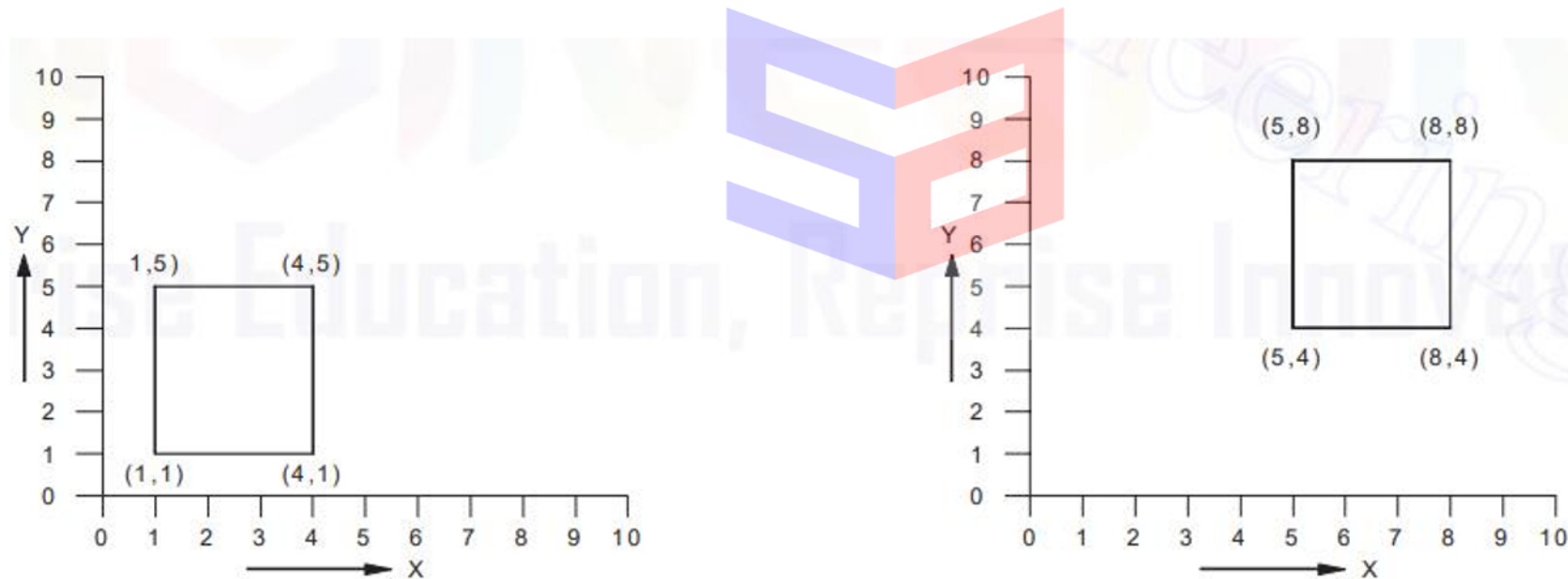
we get a new point P2 (60, 60). The matrix is called the scaling matrix. In general, the scaling matrix can be represented as:

$$\begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix}$$



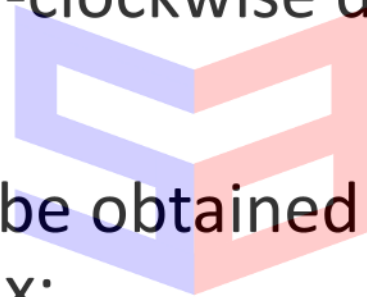
2. TRANSLATION

- Moving drawing or model across the screen is called translation. This is done by adding to the co-ordinates of each corner point the distance through which the drawing is to be moved (translated).
- a rectangle being moved to a new position by adding 40 units to X co-ordinate values and 30 units to Y coordinate values.



3. ROTATION

- ❖ Rotation Another useful transformation is the rotation of a drawing about a pivot point.
- ❖ Point P1 (40, 20) can be seen being rotated about the origin through an angle, $\theta = 45^\circ$, in the anti-clockwise direction to position P2.
- ❖ The co-ordinates of P2 can be obtained by multiplying the co-ordinates of P1 by the matrix:



$$\begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix}$$

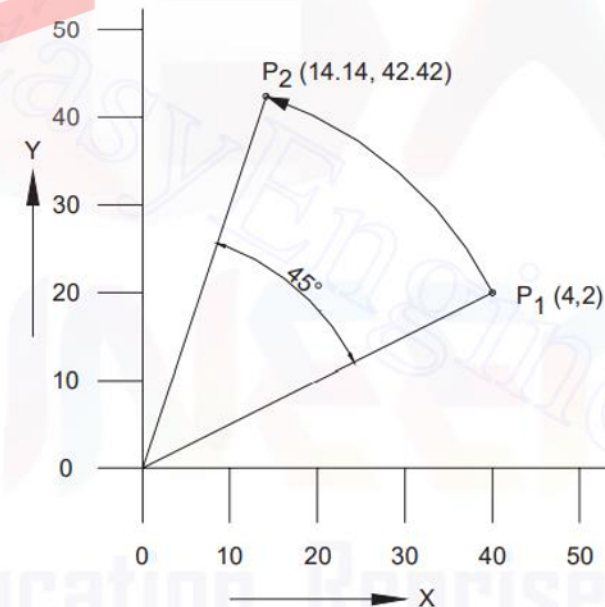
The new co-ordinates are

$$= [40 \quad 20] \begin{bmatrix} \cos 45^\circ & \sin 45^\circ \\ -\sin 45^\circ & \cos 45^\circ \end{bmatrix}$$

$$= [40 \quad 20] \begin{bmatrix} 0.707 & 0.707 \\ -0.707 & 0.707 \end{bmatrix}$$

$$= [14.14 \quad 42.42]$$

For rotating drawings in anticlockwise direction positive angles are used.



Translation:

$$[X_1 \ Y_1 \ 1] = [X \ Y \ 1] \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ T_x & T_y & 1 \end{bmatrix}$$

X-shear

Rotation

$$[X_1 \ Y_1 \ 1] = [X \ Y \ 1] \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[X_1 \ Y_1 \ 1] = [X \ Y \ 1] \begin{bmatrix} 1 & 0 & 0 \\ Sh_x & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Y-shear

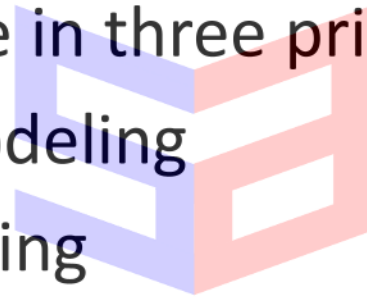
Scaling

$$[X_1 \ Y_1 \ 1] = [X \ Y \ 1] \begin{bmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[X_1 \ Y_1 \ 1] = [X \ Y \ 1] \begin{bmatrix} 1 & Sh_y & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

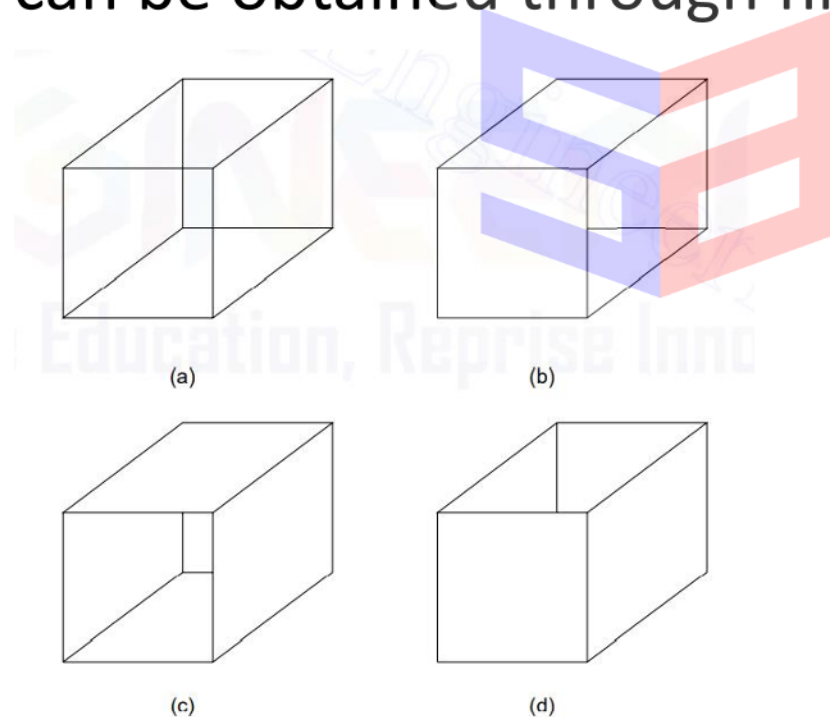
2. GEOMETRIC MODELING

- Computer representation of the geometry of a component using software is called a geometric model.
- Geometric modeling is done in three principal ways.
 - i. Wire frame modeling
 - ii. Surface modeling
 - iii. Solid modeling



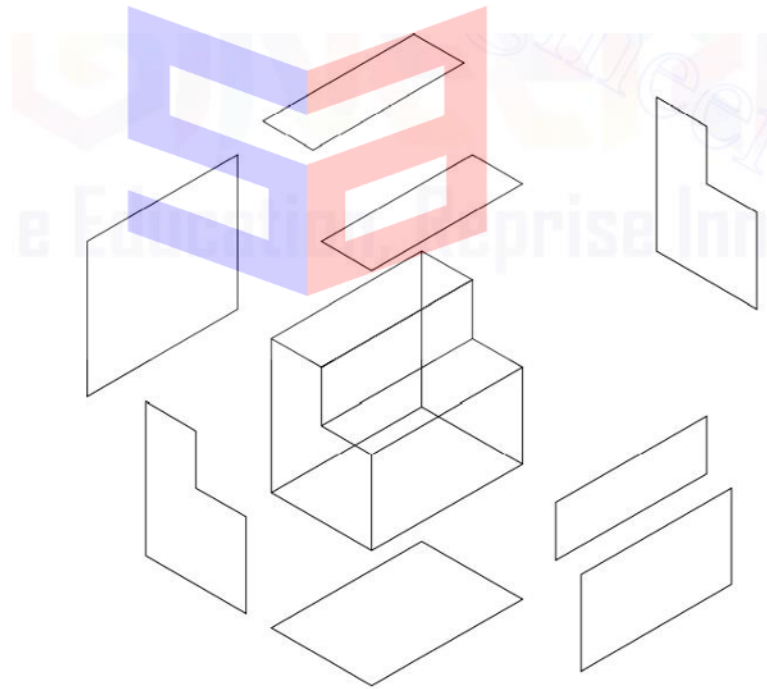
1. WIRE FRAME MODELING

- In wire frame modeling the object is represented by its edges.
- three objects which can have the same wire frame model of the box. Thus in the case of complex parts wire frame models can be confusing.
- Some clarity can be obtained through hidden line elimination.



2. SURFACE MODELING

- in this approach, a component is represented by its surfaces which in turn are represented by their vertices and edges. For example, eight surfaces are put together to create a box,
- Surface modeling has been very popular in aerospace product design and automotive design.



- Apart from standard surface types available for surface modeling (box, pyramid, wedge, dome, sphere, cone, torus, dish and mesh) techniques are available for interactive modeling and editing of curved surface geometry.
- Surfaces can be created through an assembly of polygonal meshes or using advanced curve and surface modeling techniques like B-splines or NURBS (Non-Uniform Rational B-splines).
- Standard primitives used in a typical surface modeling software (Tabulated surfaces, ruled surfaces and edge surfaces and revolved are simple ways in which curved geometry could be created and edited.)

A surface can be created in several ways:

- i. Creating a plane surface by the linear sweep of a line or series of lines.
- ii. Revolving a straight line about an axis. (Cylindrical, conical surfaces etc. can be generated by this technique).
- iii. Revolving a curve about an axis.
- iv. Combination of plane surfaces.
- v. **Analytic surfaces:** Planes, cylinders, cones, ellipsoid, parabolic hyperboloid etc can be defined by mathematical equations in terms of X, Y and Z co-ordinates.
- vi. **Sculptured surfaces:** These are created by spline curves in one or both directions in a 3-D space.

(These surfaces are used in the manufacture of car body panels, aircraft structures, mixed flow impellers, telephone instruments, plastic containers and several consumer and engineering products.)

REPRESENTATION OF CURVES AND SURFACES

1. CUBIC SPLINES

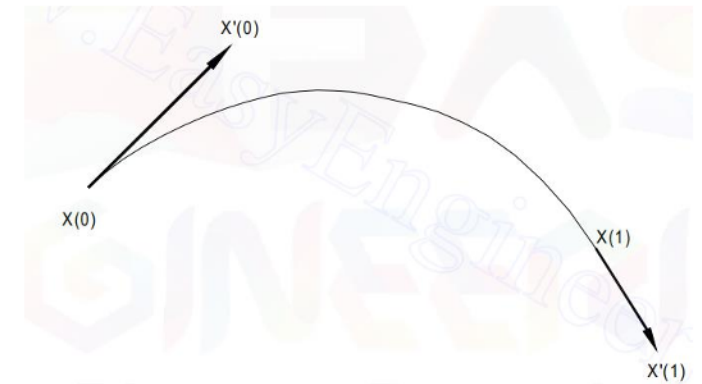
- Splines are functions that are used for fitting a curve through a number of data points.
- A cubic spline has the property that the three co-ordinate functions $x(u)$, $y(u)$, and $z(u)$ are each cubic polynomials in the variable u

$$x(u) = a u^3 + b u^2 + c u + d$$

$$y(u) = e u^3 + f u^2 + g u + h$$

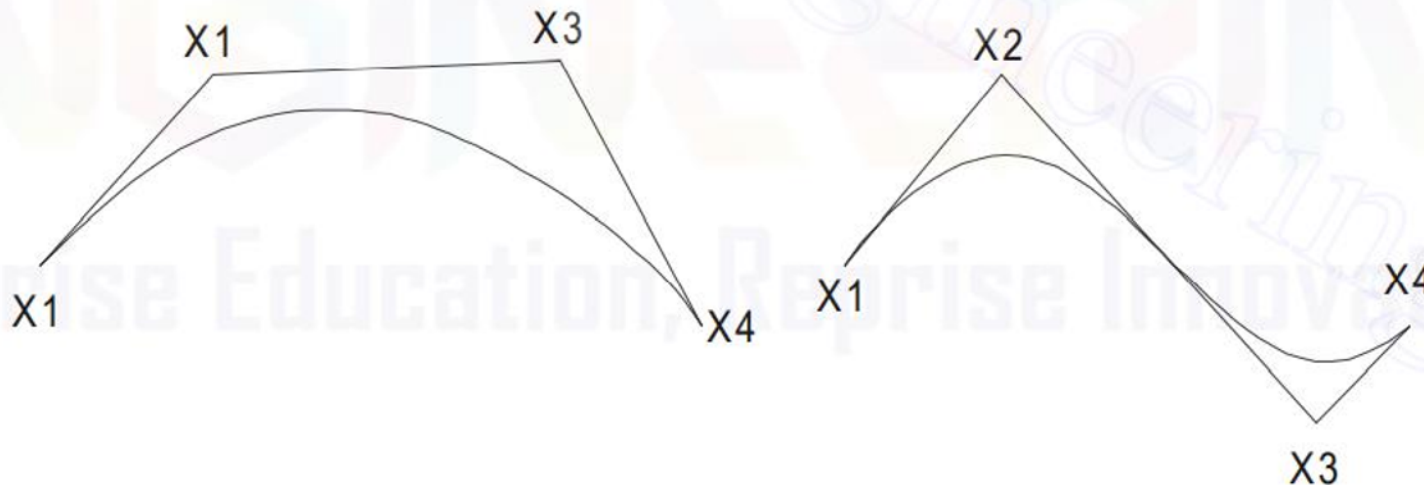
$$z(u) = j u^3 + k u^2 + l u + m$$

- cubic spline connecting four points.
- Ferguson used cubic polynomials for curve and surface design in aircrafts.
- However, these methods generally suffer from the fact that they do not allow the user to change the smoothness of the curve



2. BEZIER CURVES

- A Bezier curve is blended at the joints and is completely defined by four consecutive points (X_0, Y_0) , (X_1, Y_1) , (X_2, Y_2) , (X_3, Y_3) .
- The curve passes only through the first and fourth point.
- The two intermediate points are used to define the slope of the curve at the end points.
- The advantages of Bezier curve over cubic spline is that the direction of the curve at the joints can be defined and changed simply by specifying the position of the second and third data points.



Cubic Bezier curve is usually defined as:

$$\mathbf{B}(t) = (1 - t)^3 \mathbf{P}_0 + 3(1 - t)^2 t \mathbf{P}_1 + 3(1 - t) t^2 \mathbf{P}_2 + t^3 \mathbf{P}_3, 0 \leq t \leq 1.$$

When you expand and rearrange the term you will get:

$$(-\mathbf{P}_0 + 3\mathbf{P}_1 - 3\mathbf{P}_2 + \mathbf{P}_3)t^3 + (3\mathbf{P}_0 - 6\mathbf{P}_1 + 3\mathbf{P}_2)t^2 + (-3\mathbf{P}_0 + 3\mathbf{P}_1)t + \mathbf{P}_0$$

Which is a polynomial in t of degree 3. In general, the "degree" of a Bezier curve is the highest exponent of t if written as polynomial.

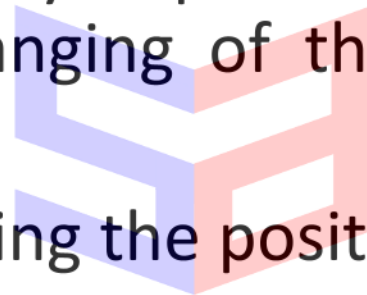
If you stare at the first equation, you will notice there are four terms near the four points, each with raising power of t (i.e., t^0, t^1, t^2, t^3). Counting from zero, there are four points for degree 3. In general, one needs degree + 1 points to define the curve.

Properties of bezier curves

1. They always pass through the first and last control points.
2. They are contained in the convex hull of their defining control points.
3. The degree of the polynomial defining the curve segment is one less than the number of defining polygon point. Therefore, for 4 control points, the degree of the polynomial is 3, i.e. cubic polynomial.
4. A Bezier curve generally follows the shape of the defining polygon
5. The direction of the tangent vector at the endpoints is the same as that of the vector determined by the first and last segments.
6. Bezier curves exhibit global control means moving a control point alters the shape of the whole curve

3. B-Spline Curve in Computer Graphics

- Concept of B-spline curve came to resolve the disadvantages having by Bezier curve, as we all know that both curves are parametric in nature.
- In Bezier curve we face a problem, when we change any of the control point respective location the whole curve shape gets change.
- But here in B-spline curve, the only a specific segment of the curve-shape gets changes or affected by the changing of the corresponding location of the control points.

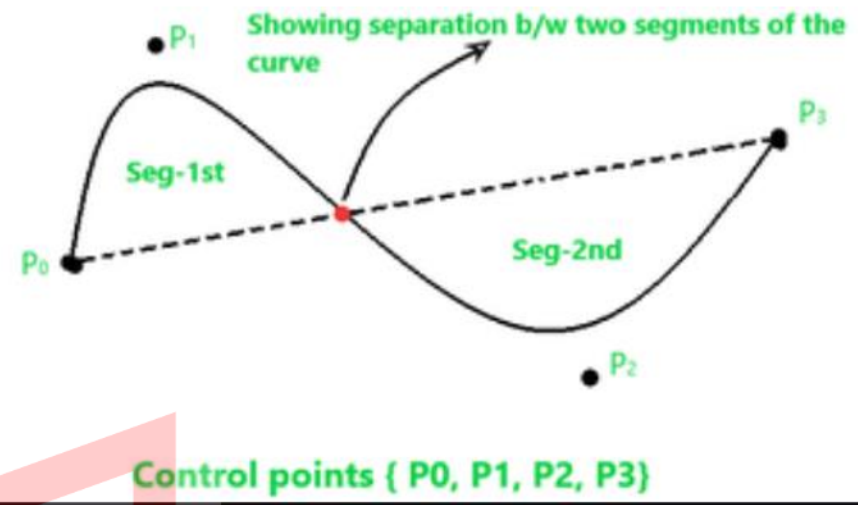


B-spline curve shape before changing the position of control point P1

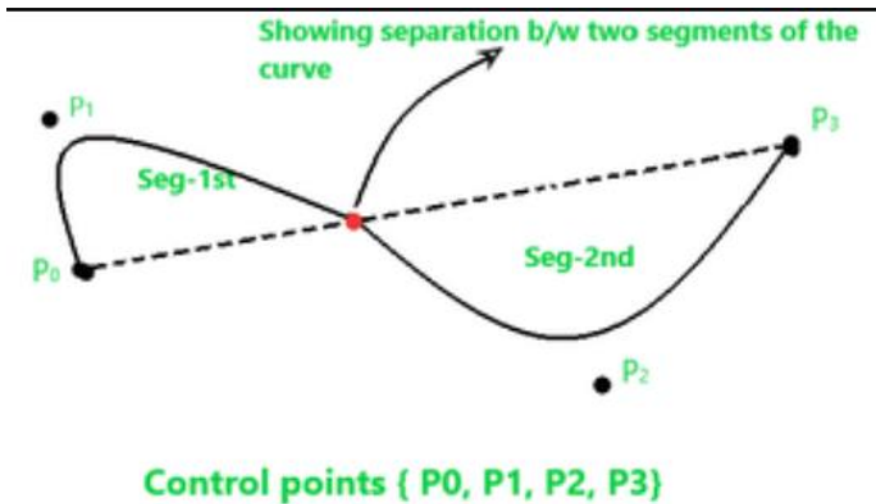
B-spline curve shape after changing the position of control point P1

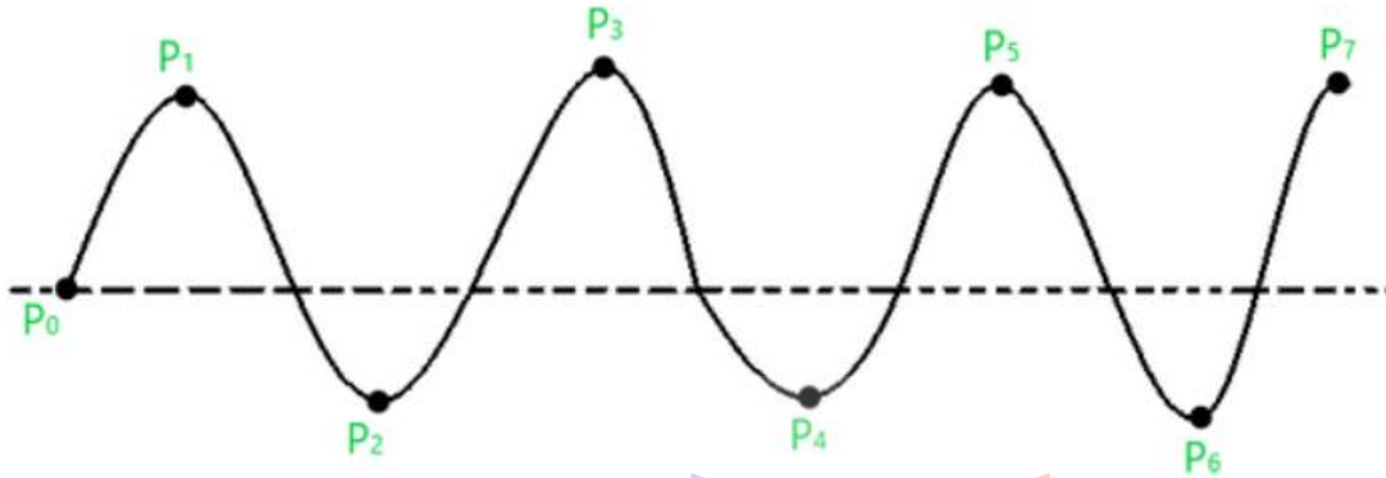
- You can see in the above figure that only the segment-1st shape as we have only changed the control point P , and the shape of segment-2nd remains intact.

B-spline curve shape before changing the position of control point P1



B-spline curve shape after changing the position of control point P1





- Control points term is generally used in the computer-aided geometric design system where these are a set of points used to determine the shape of a spline curve
- In term B-spline curve designation "B" stands for Basis, so the full name of this approach to curve and surface design is the basis spline curve.
- quadratic B-spline curve, we know that to design a quadratic curve in CAD we need to fix 4 control points.
- Two points need to be fixed at the endpoints of the curve section. But there can be an infinite number of curves passing through those two points by rotating the axis of the parabola.
- Then we need to fix two more points to arrest this rotation.
- "Number of minimum control points required to generate a straight line".
- one point is not fixing the straight line, there can be still infinite many straight lines passing through the same point. So, we need to fix one more control point so as to fix the straight line. Hence there the minimum number of control points will be 2 for a straight line.

- We have “n+1” control points in the above, so, n+1=8, so n=7.
- Let’s assume that the order of this curve is ‘k’, so the curve that we get will be of a polynomial degree of “k-1”.
Conventionally it’s said that the value of ‘k’ must be in the range: $2 \leq k \leq n+1$. So, let us assume k=4, so the curve degree will be $k-1 = 3$.
- The total number of segments for this curve will be calculated through the following formula –
Total no. of seg = $n - k + 2 = 7 - 4 + 2 = 5$.

Segments	Control points	Parameter
S_0	P_0, P_1, P_2, P_3	$0 \leq t \leq 2$
S_1	P_1, P_2, P_3, P_4	$2 \leq t \leq 3$
S_2	P_2, P_3, P_4, P_5	$3 \leq t \leq 4$
S_3	P_3, P_4, P_5, P_6	$4 \leq t \leq 5$
S_4	P_4, P_5, P_6, P_7	$5 \leq t \leq 6$



B-spline Curve Equation : The equation of the spline-curve is as follows –

$$Q(t) = \sum_{i=0}^n P_i * N_{i,k}(t)$$

Where $N_{i,k}$ is Basis function of B-spline curve.

Where P_i , k , t correspondingly represents the control points, degree, parameter of the curve.

$$N_{i,k}(t) = \frac{(t-x_i)*N_{i,k-1}(t)}{x_{i+k-1}-x_i} + \frac{(x_{i+k}-t)*N_{i+1,k-1}(t)}{x_{i+k}-x_{i+1}}$$

And following are some conditions for x_i are as follows –

$$\begin{aligned} x_i &= 0; \text{ if } i < k; \\ x_i &= i - k + 1; \text{ if } k \leq i \leq n; \\ x_i &= 1; \text{ if } i = n+1. \end{aligned}$$

Some cases of Basis function :

$$N_{i,k}(t) = \begin{cases} 1; & \text{if } x_i \leq t \leq x_{i+1} \\ 0; & \text{else} \end{cases}$$

where $t_{\min} \leq t \leq t_{\max}$.

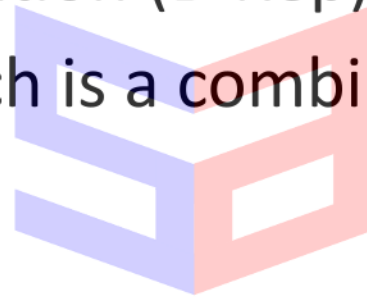


Properties of B-spline Curve :

- Each basis function has 0 or +ve value for all parameters.
- Each basis function has one maximum value except for $k=1$.
- The degree of B-spline curve polynomial does not depend on the number of control points which makes it more reliable to use than Bezier curve.
- B-spline curve provides the local control through control points over each segment of the curve.
- The sum of basis functions for a given parameter is one.

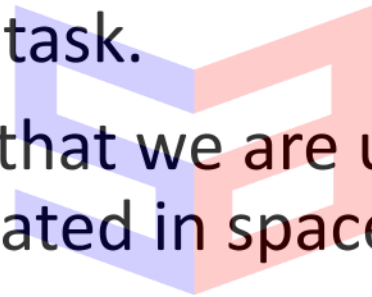
3. SOLID MODELING

- In most of the modeling packages, the approach used for modeling uses any one of the following three techniques:
 - i. Constructive solid geometry (CSG or C-Rep)
 - ii. Boundary representation (B-Rep)
 - iii. Hybrid method which is a combination of B-Rep and CSG.

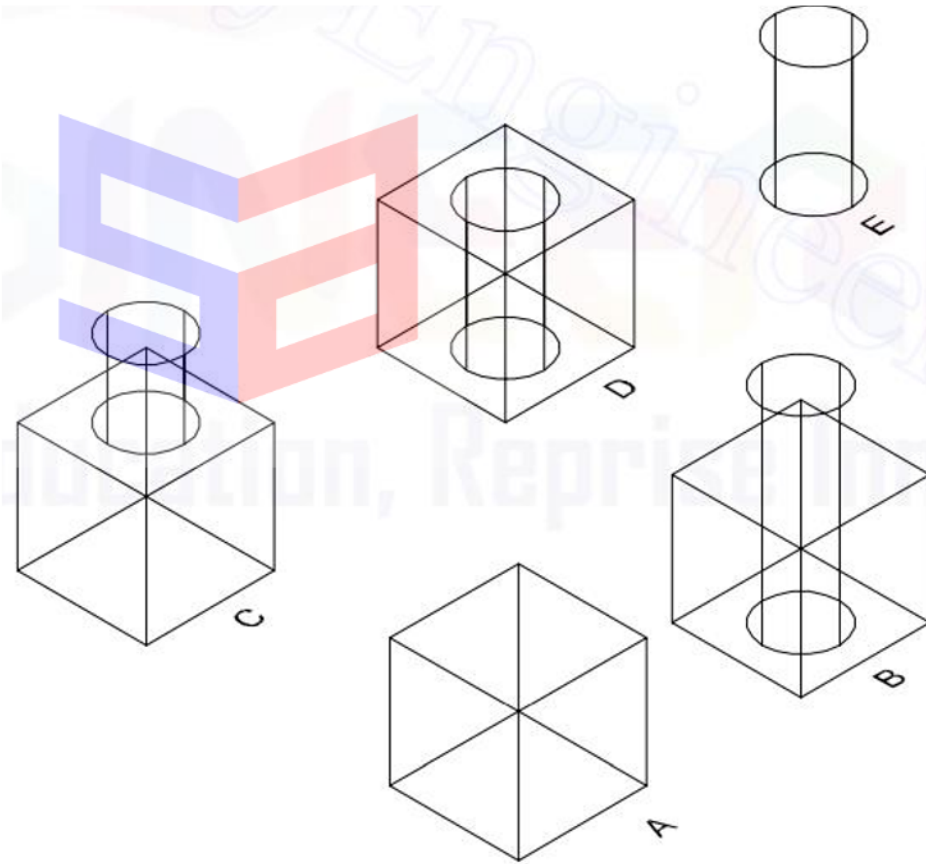


i. Constructive solid geometry (CSG or C-Rep)

- Constructive Solid Geometry (CSG) In a CSG model, physical objects are created by combining basic elementary shapes known as primitives like blocks, cylinders, cones, pyramids and spheres.
- The Boolean operations like union ($\cup$), difference ($-$) and intersection $\cap$ are used to carry out this task.
- For example, let us assume that we are using two primitives, a block and a cylinder which are located in space.

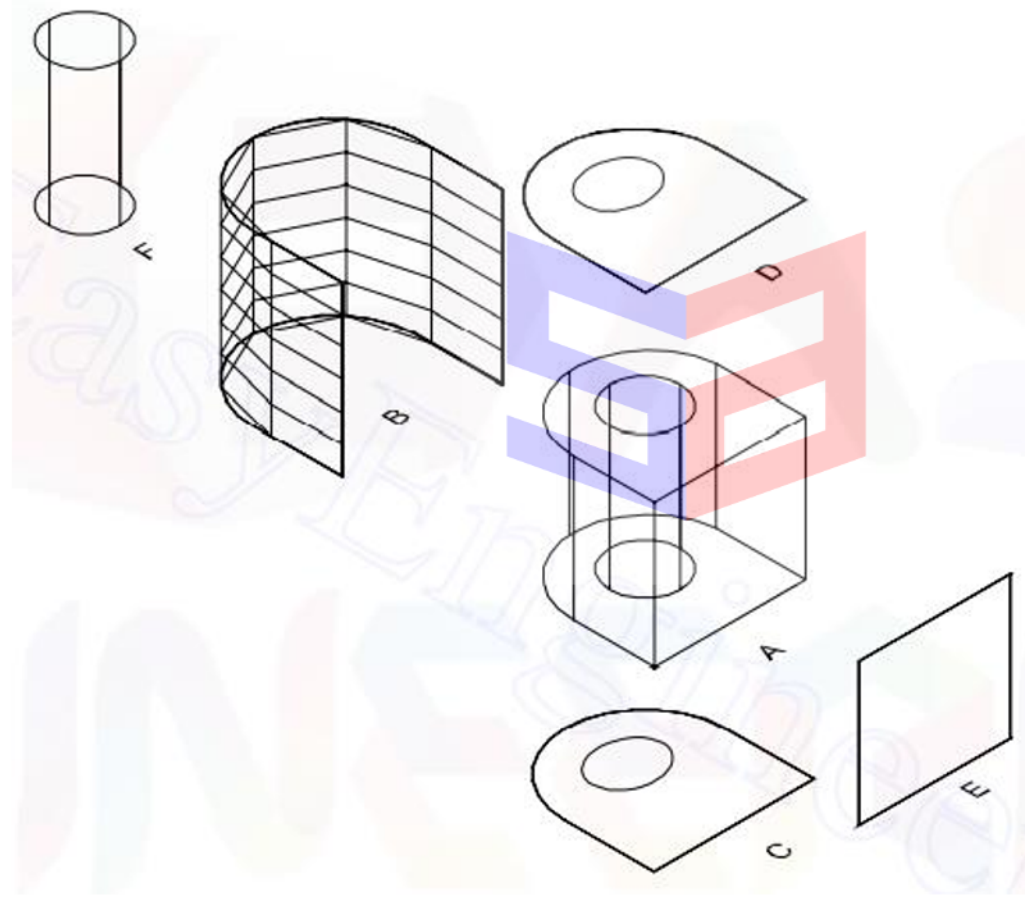


- A “union” operation ($A \cup B$) will combine the two to convert them into a new solid.(Fig. (c))
- The difference operation ($A - B$) will create a block with a hole (Fig. (D)).
- An intersection operation ($A \cap B$) will yield the portion common to the two primitives. (Fig.(E)).



2. Boundary Representation

- Boundary representation is built on the concept that a physical object is enclosed by a set of faces which themselves are closed and orientable surfaces.



1. In comparison to the number of control points, the degree of Beziar curve is

(A). one-more

(B) one less

(C) two less

(D) three more

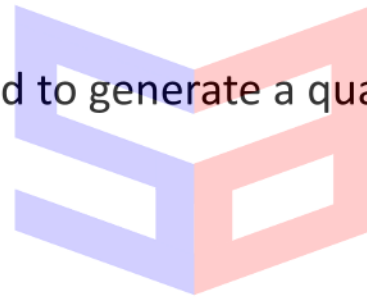
2. Number of minimum control points required to generate a quadratic B-spline curve

(A) 1

(B) 2

(C) 3

(D) 4



VISUAL REALISM

Visual Realism is a method for interpreting picture data fed into a computer and for creating pictures from difficult multidimensional data sets.

Existing visualization methods are:

- Parallel projections
- Perspective projection.
- Hidden line removal
- Hidden surface removal
- Hidden solid removal
- Shaded models



1. Hidden line removal

a. Priority algorithm

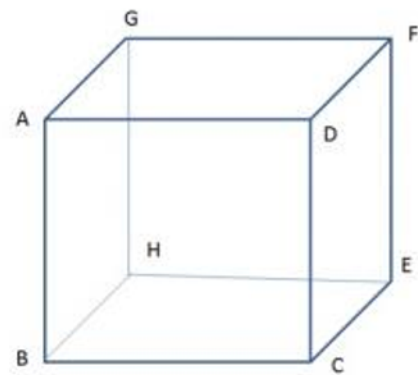


Fig.3.2. Priority algorithm

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

Face Priority

ABCE 1

ADFG 1

DCEF 1

ABHG 2

EFGH 2

BCEH 2

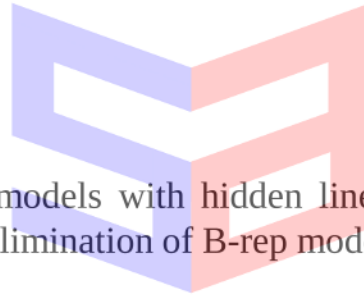
ABCD, ADFG, DCEF are given higher priority-1. Hence, all lines in this faces are visible, that is, AB, BC, CD, DA, AD, DF, FG, AG, DC, CE, EF and DF are visible.

AGHB, EFGH, BCEH are given lower priority-2. Hence, all lines in this faces other than priority-1 are invisible, that is BH, EH and GH. These lines must be eliminated.

Hidden surface removal

1. Z - buffer algorithm
2. Painter's algorithm
3. Warnock algorithm

Hidden Solid Removal



The hidden solid removal issue involves the view of solid models with hidden line or surface eliminated. Available hidden line algorithm and hidden surface algorithms are useable to hidden solid elimination of B-rep models.

The following techniques to display CSG models:

1. Transfer the CSG model into a boundary model.
2. Use a spatial subdivision strategy.
3. Based on ray sorting.

1. Ray-Tracing algorithm

PARTS ASSEMBLY

Exploded view



Assembly view



Bottom-up assembly approach -:

- Allows the designer to use part drawings that already exist (off the shelf)
- Provides the designer with more control over individual parts
- Multiple copies (instances) of parts can be inserted into the assembly

Top-down assembly approach -:

- The approach is ideal for large assemblies consisting of thousands of parts.
- The approach is used to deal with large designs including multiple design teams.
- It lends itself well to the conceptual design phase
- E.g. :
 - Piping and fittings
 - Welds
 - Lock pins

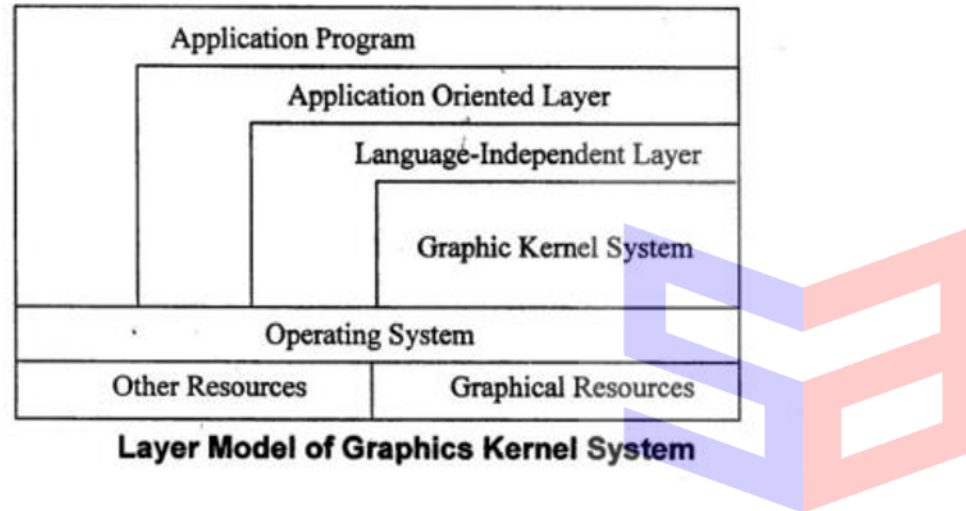
Bottom up Assembly design:

Bottom-up design is the traditional method. You first design and model parts, then insert them into an assembly and use mates to position the parts. To change the parts, you must edit them individually. These changes are then seen in the assembly and use the mating conditions to locate and orient them in the assembly as required by the assembly design.



CAD STANDARDS

1. GRAPHICAL KERNEL SYSTEM (GKS)



2. STEP (Standard for the Exchange of Product model Data)

- Uses a formal model for data exchange

STEP Architecture



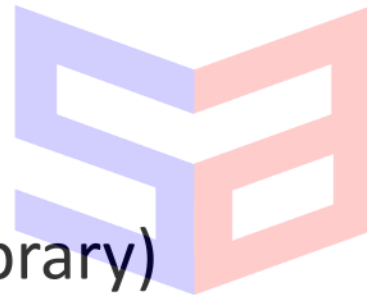
3. Continuous Acquisition and Life -cycle Support (CALS)

- Developed by US Department of Defense
- Prescribes formats for storage and exchange of technical data
- Technical publications an important focus Important CALS Standards

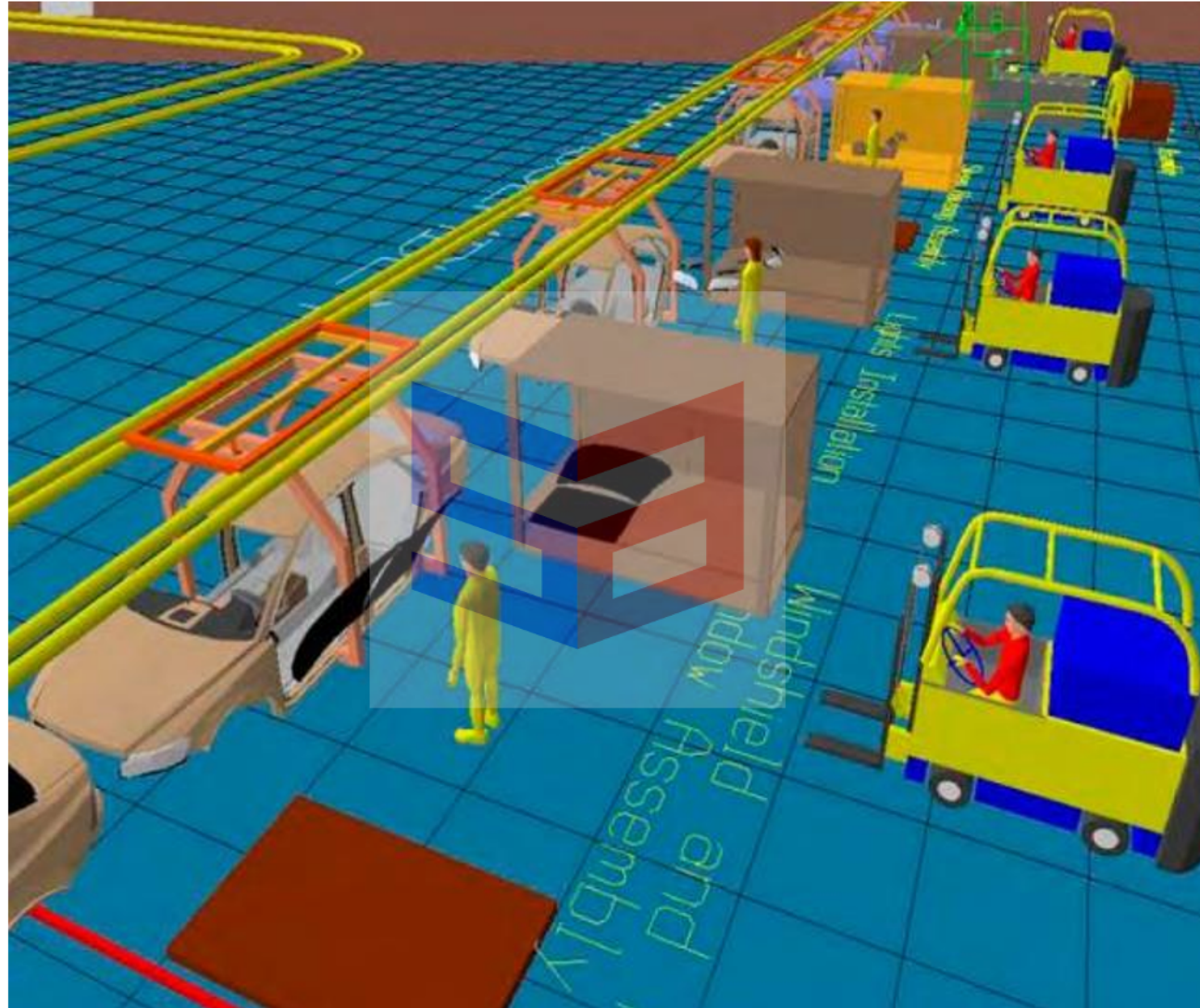
4. Standard Generalized Markup Language (SGML)

- developed in 1960s IBM
- HTML is based on SGML

5. OpenGL (Open Graphics Library)

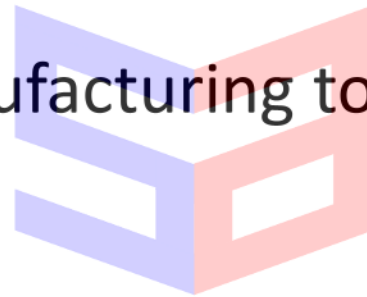


COMPUTER INTEGRATED MANUFACTURING(CIM)



Manufacturing engineers are required to achieve the following objectives to be competitive in a global context.

1. Reduction in inventory
2. Lower the cost of the product
3. Reduce waste
4. Improve quality
5. Increase flexibility in manufacturing to achieve immediate and rapid response to:
 1. Product changes
 2. Production changes
 3. Process change
 4. Equipment change



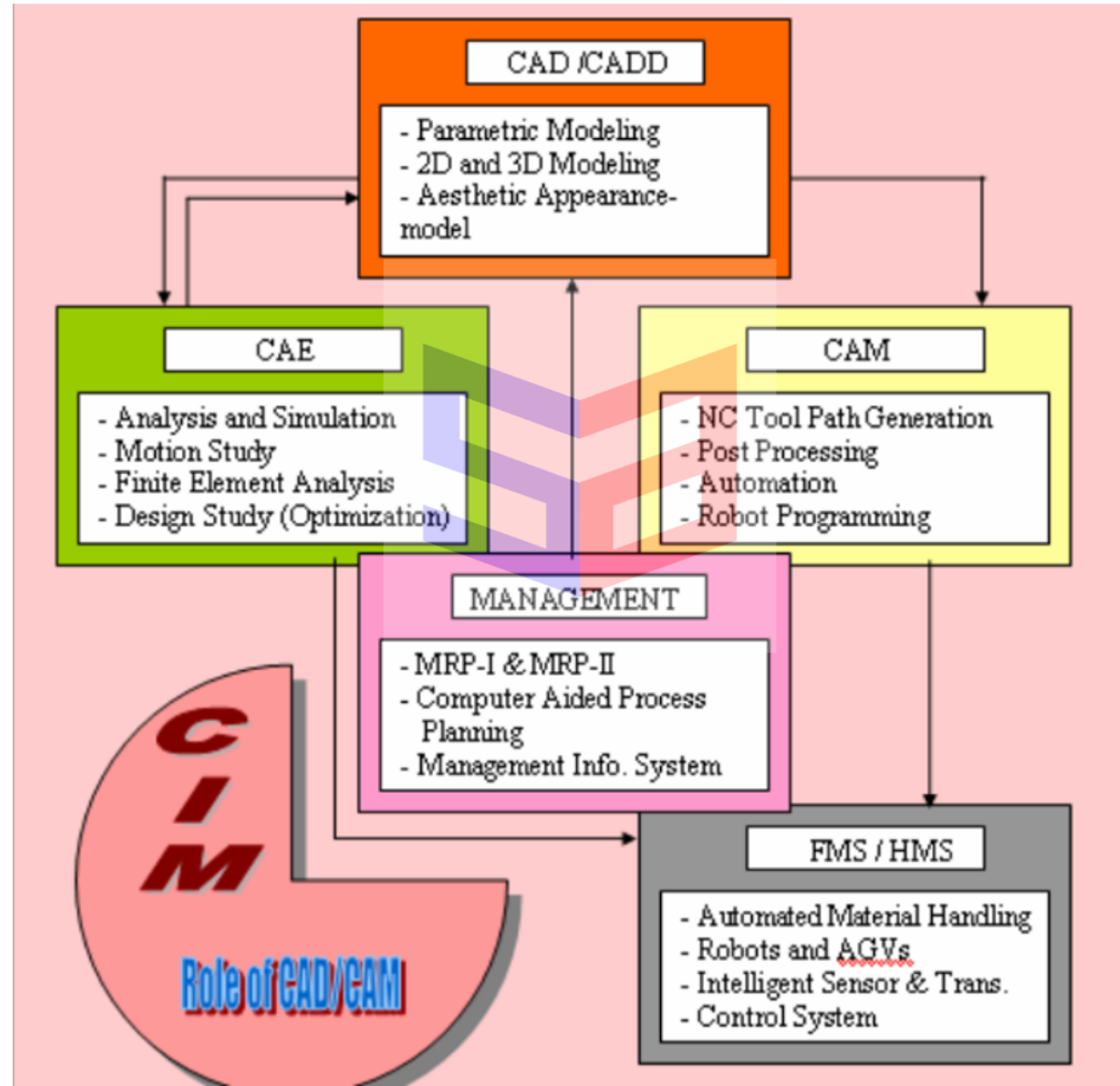
CIM technology is an enabling technology to meet the above challenges to the manufacturing.

CIM

- CIM is the technique of using computers to control an entire production process.
- It's commonly used by factories to automate functions such as analysis, cost accounting, design, distribution, inventory control, planning and purchasing.



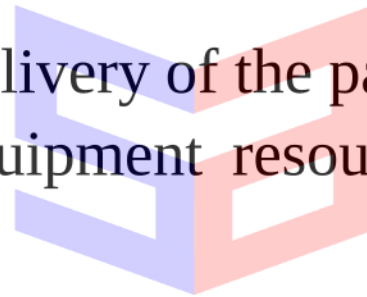
Role of CAD/CAM in CIM



Production Planning and Control

Production planning:

- ✓ Production Planning may be defined as the determination, acquisition and arrangement of all facilities necessary for future production of products.
- ✓ It is concerned with
 - a) Deciding which products to make, how many of each, and when they should be completed
 - b) Scheduling the production and delivery of the parts and products
 - c) Planning the manpower and equipment resources needed to accomplish the product plan.



Activities of production planning:

1. Aggregated production planning
2. Master production planning
3. Material Requirement Planning
4. Capacity Planning.

1. Aggregate production planning

- ✓ Planning the production output levels for major product lines.
(Must be coordinated with product design, production, marketing, and sales.)
- ✓ It is concerned with determining the quantity and timing of production for the intermediate future ahead, **setting employment, inventory and sub contracting**
- ✓ It is a strategy provides the data to plan the variable resources – total labor hours per period, number of sub contractor.



2. Master production planning

- ✓ Master production schedule is a detailed plan that states how many end items (i.e final product to be sold to customer) will be available for sale/distribution during specific periods.
- ✓ Aggregate production plan must be converted into master production schedule
- ✓ It is a listing of the products to be manufactured when they are to be delivered
- ✓ It list the production quantities of major product line.

	Month				
	Jan.	Feb.	Mar.	Apr.	May
Planned output (Number of units of product)	1400	1750	1700	2250	2750

(a) Aggregate production plan

Product line models	Month				
	Jan.	Feb.	Mar.	Apr.	May
Model M1	475	500	500	600	625
Model M2	150	400	425	450	650
Model M3	450	500	475	600	675
Model M4	175	150	125	275	425
Model M5	150	200	175	250	300

(b) Master production schedule

3. Material requirements planning (MRP)

- ✓ Detailed schedule of raw materials and parts production for models in master schedule.
- ✓ It translates the master production schedule (MPS) of end products

Information need for MRP:

- Demand for all products.
- Lead time for all finished goods, components, parts and raw materials.
- Lot sizing policies for all parts.
- Opening inventory levels.
- Safety stock requirements.
- Any order previously placed but which have not arrived yet.



Inputs to MRP:

1. Master production schedule
2. Bill of materials file
3. Inventory record file.

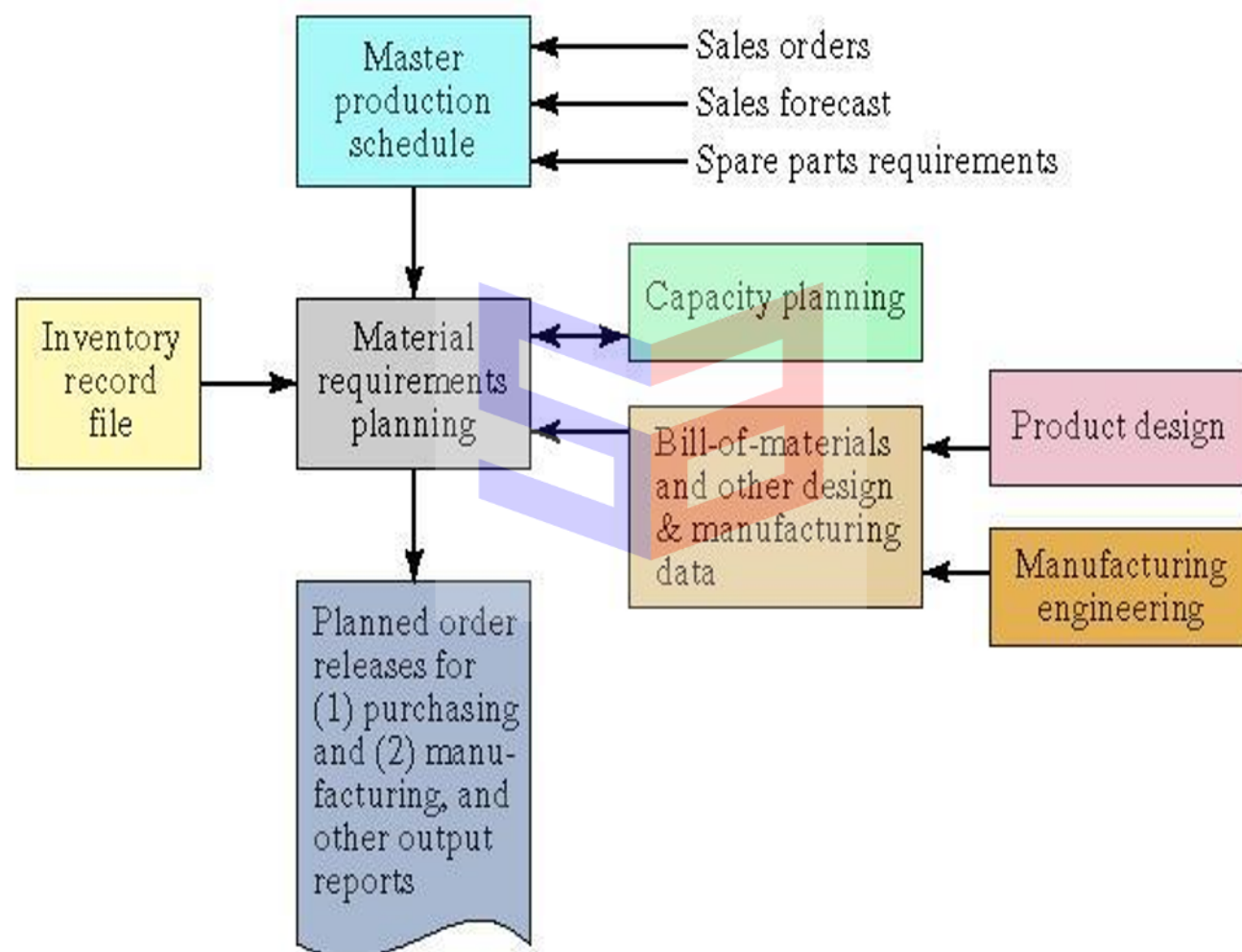
Bill of materials (BOM) file

- The bill of material designated what items and how many of each are used to make up a specified final product.
- Product structure and list of component parts in each product.

Inventory record file

- ✓ Item master data – part number, order quantities, lead times.
- ✓ Inventory status – time-phased record of inventory status.
- ✓ Subsidiary data – purchase orders, engineering changes.

STRUCTURE OF MRP SYSTEM



MRP Outputs:

1. Planned order releases

- ✓ Purchase orders – to buy raw materials and parts
- ✓ Work orders – to make parts and products

2. Report of planned order releases in future periods

3. Rescheduling notices- To indicate the changes in due dates for open order

4. Cancellation notices- To indicate the cancellation of open order because of changes in the master schedule.

5. Inventory status reports - To indicate the current status of the inventory

6. Performance reports - To indicate costs, item usage etc.

7. Exception reports- To show deviations from schedule, order that are overdue, scrap and so on.

8. Inventory forecasts - To indicate the projected level in future periods.

4. CAPACITY PLANNING

- ✓ It is used to decide the manpower (labour) and (plant) machine capacity required to meet the Master production schedule

Capacity adjustments

1. short term adjustments
2. long-term adjustments.

Capacity adjustments for the short term include

- ❖ Employment levels
- ❖ Temporary workers
- ❖ Number of work shifts
- ❖ Labor hour
- ❖ Inventory stockpiling
- ❖ Order backlogs
- ❖ Subcontracting

Capacity planning adjustments for the long term

- ❖ New equipment Investments:
- ❖ New plant construction
- ❖ *Purchase of existing plants*

PRODUCTION CONTROL

Production control is concerned with determining whether the necessary resources to implement the production plan have been provided or not.

Activities of Production control

- Shop floor control
- Inventory control
- Manufacturing resource planning-II

1. Shop floor control

A shop floor control system is defined as a system for utilizing data from the shop floor as well as data processing files to maintain and communicates status information on shop orders and work centre.

Concerned with:

- The release of production orders to the factory
- Monitoring and controlling the progress orders through the various work centres.
- Acquiring information on the status of the orders.

2. Inventory control

It is the scientific method of determining what to order, when to order and how much to order and how much to stock so that cost associated with buying and storing are optimal without interrupting production and sales.

Inventory control is concerned with:

- Minimizing the cost of holding inventory
- Maximizing service to customers.

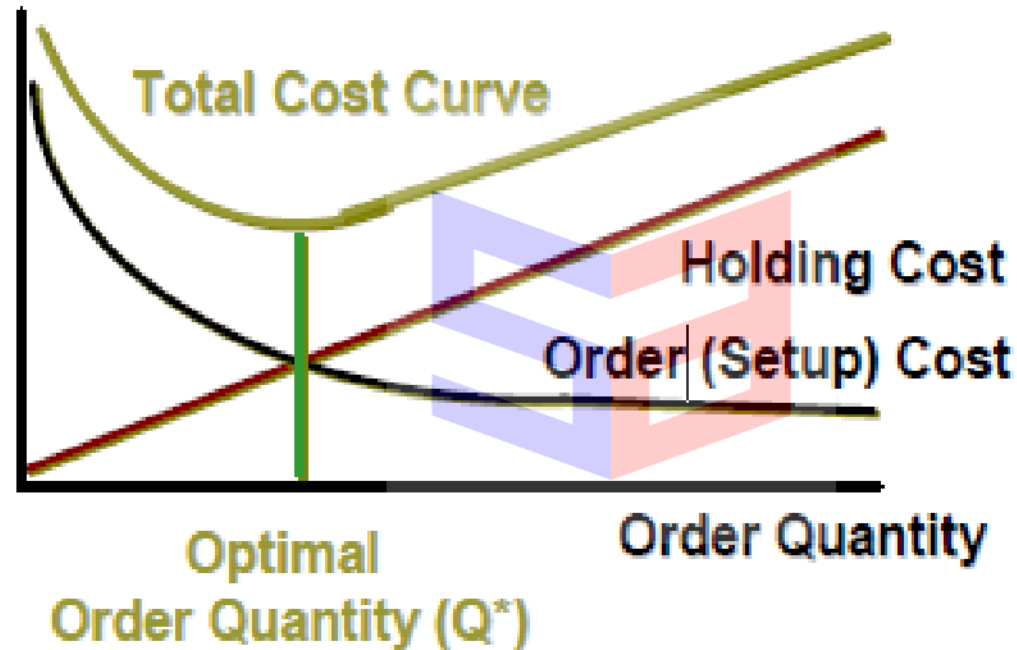
Costs Associated with inventory:

1. Ordering cost
2. Carrying cost(holding)
3. Shortage cost(stock out)
4. Purchase cost



Economic Order Quantity (EOQ)

Economic ordering quantity is that size of order which minimizes the total costs of carrying inventory and ordering.



TC = Total annual cost,
D = Demand
C=Cost per
Q=Order quantity
EOQ=Economic order quantity

S=Setup cost or ordering cost per order

H=Annual holding cost per unit of average inventory

H=iC, i=Percent carrying cost

N=number of orders per annum.

Total annual cost = Annual ordering cost + Annual carrying cost + Annual purchase cost

$$\text{Annual Holding Cost} = \frac{Q}{2} H$$

$$\text{Annual Carrying Cost} = \frac{D}{Q} S$$

$$\text{Annual Purchase cost} = D.C$$

$$\text{Total annual Inventory Cost} = \frac{Q}{2} H + \frac{D}{Q} S + D.C \text{ ----- (i)}$$

To determine EOQ , differentiate the above equation with respect to the order quantity Q.

In above fig, the total cost is minimum at the EOQ where the slope of the curve is zero.

$$\frac{d(TC)}{dQ} = \left(\frac{-D.S}{Q^2} \right) + \frac{H}{2} + 0$$

$$Q_{opt} = EOQ = \sqrt{\frac{2D.S}{H}}$$

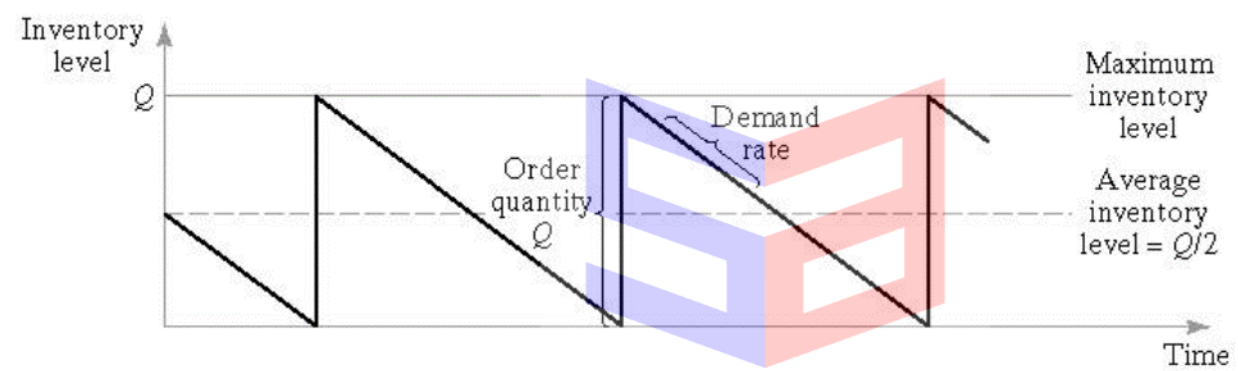
Types of Inventory Systems

1. Fixed order quantity models (Q-models)
2. Fixed-time period models (P-models)

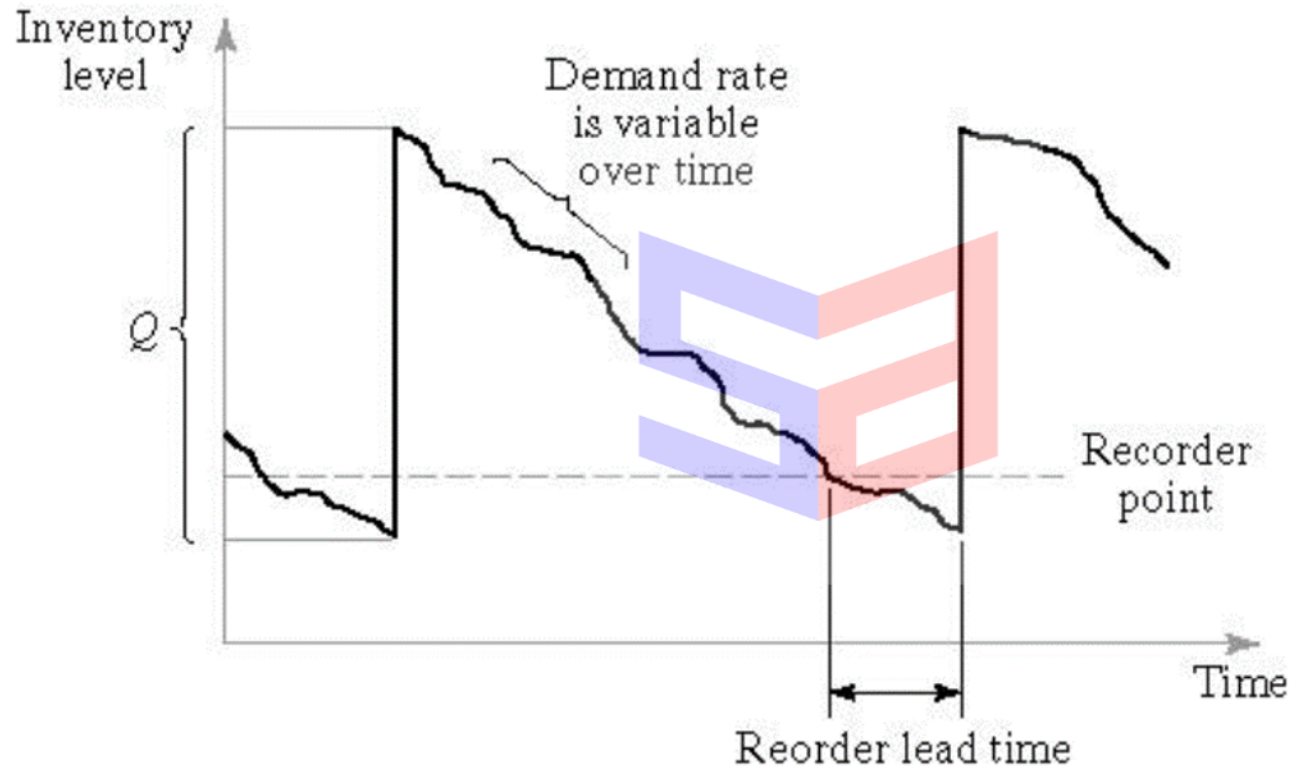
1. Fixed order quantity models (Q-models)

- ✓ Fixed order quantity model, the size of the order (i.e order quantity) is predetermined and fixed, but the time of its placement (i.e ordering time) is allowed to vary depending upon the fluctuation of demand.
- ✓ This model also known as the economic order quantity (**EOQ**) model, **Q model**, **re-orders point inventory system**, and **perpetual inventory system**.
- ✓ **Re order quantity (i.e how much to order?):**
In Q model, Q is fixed, and it is usually equal to EOQ.
- ✓ **Reorder level (i.e when to order?):**
Re-order level = Safety stock + Lead time consumption

$$= \text{Safety stock} + (\text{Lead time} \times \text{Consumption rate})$$



Fixed time period models:



- The annual demand for a certain item made-to-stock = 15,000 pc/yr. One unit of the item costs \$20.00. and the holding cost rate = 18%/yr. Setup time to produce a batch = 5 hr. The cost of equipment downtime plus labor = \$150/hr, Determine the economic order quantity and the total inventory cost for this case.

$$Q_{opt} = EOQ = \sqrt{\frac{2D.S}{H}}$$
$$EOQ = \sqrt{\frac{2 \times 15000 \times 750}{3.60}} = \mathbf{2500 \text{ units}}$$

Total inventory cost is given by the TIC equation:

$$TIC = (0.5 \times 3.60 \times 2500) + (750 \times 15000 / 2500) = \mathbf{\$9000}$$

Including the actual production costs in the annual total,

$$TC = 15000 (20) + 9000 = \mathbf{\$309000}$$

3. Manufacturing resource planning (MRP II)

Manufacturing resource planning (MRP II) is a computer based system for planning, scheduling and controlling the materials, resources and supporting activities to meet master production schedule.

Functions of MRP II system:

- i) Management planning
- iii) Operations planning
- v) Financial functions



- ii) Customer service
- iv) Operations execution

Computerized Process Planning (CAPP)

CAPP refers to computer aided process planning. CAPP used to overcome the drawbacks of manual process planning. With the use of computers, one can reduce the routine clerical work of manufacturing engineers. It provides the opportunity to generate rational, consistent and optimal plans.

- **Benefits of CAPP**

- ✓ Process rationalization and standardization
- ✓ Productivity improvement
- ✓ Product cost reduction
- ✓ Elimination of human error
- ✓ Reduction in time
- ✓ Reduced clerical effort and paper work
- ✓ Improved legibility
- ✓ Faster response to engineering changes
- ✓ Incorporation of other application programs



Retrieval CAPP system

- A process plan for a new part is created by recalling, identifying and retrieving an Existing plan for a similar part and making the necessary modifications for the new part.

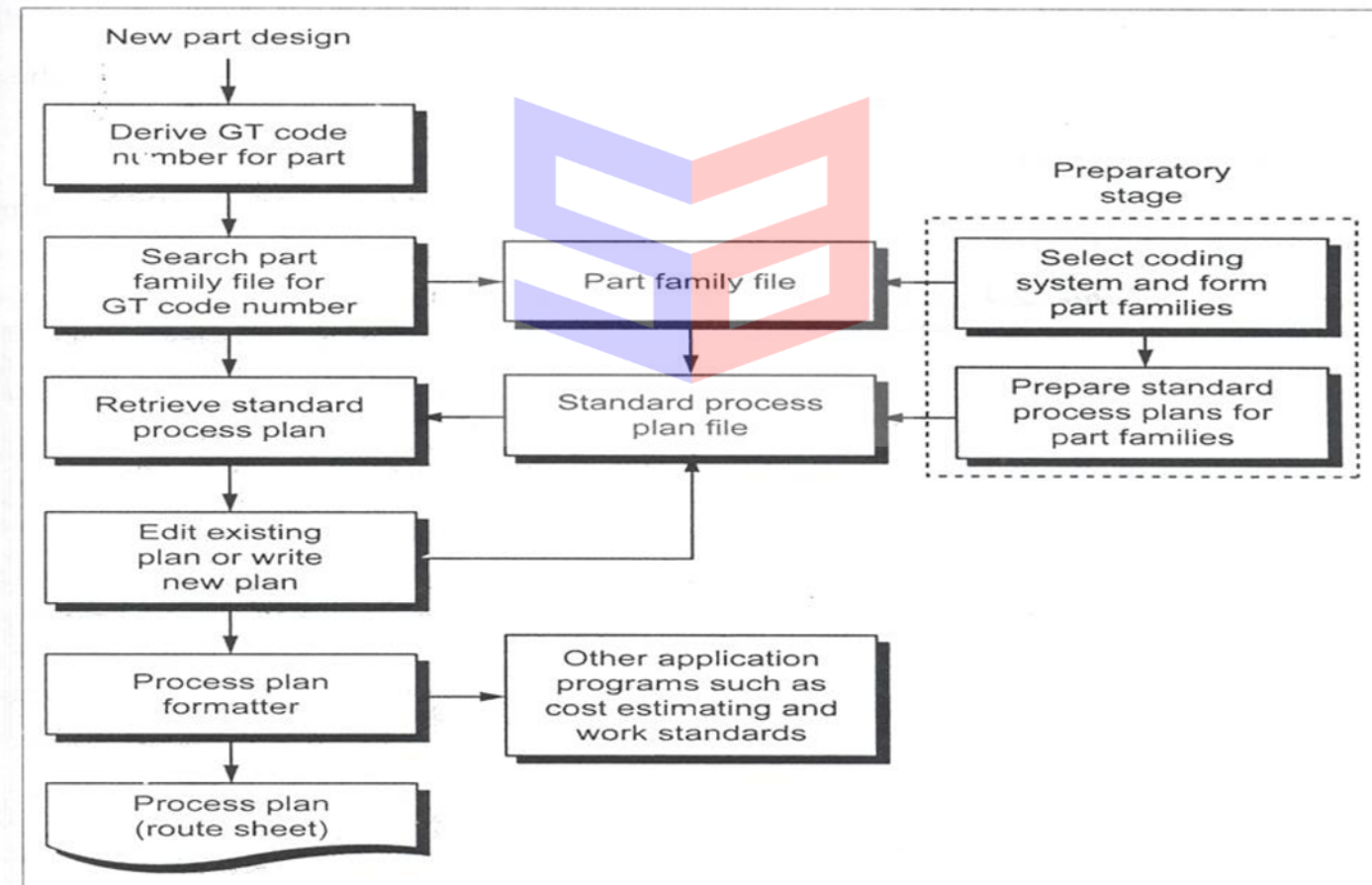


Fig. 2.25. Retrieval CAPP system procedure

Generative CAPP

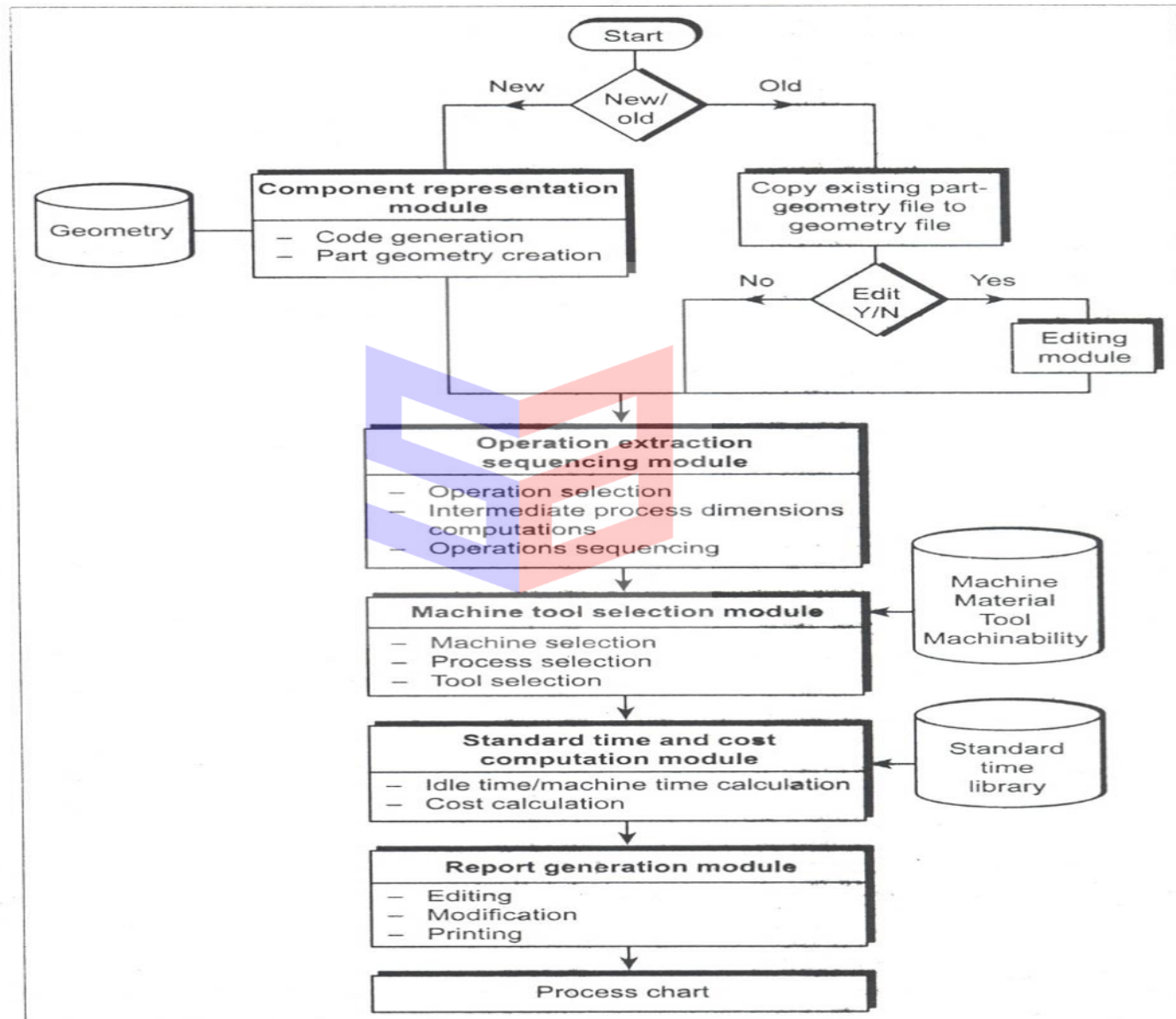


Fig. 2.26. Structure of a generative CAPP system

Cellular Manufacturing (OR) Group Technology

GT is a manufacturing concept in which similar parts are grouped together in parts

Role of GT in CAD/CAM integration

1. Identifying the part families.
2. Rearranging production machines into machine cells

Part Families Concept:

- **A part family** is a collection of parts which are similar either because of geometric shape and size or because similar processing steps are required in their manufacturing.
- The parts which are similar in their design characteristics (i.e shape and geometry) are grouped in a family referred to as a design part family.
- The parts which are similar in their manufacturing characteristics are grouped in a family referred to as a manufacturing part family.
- The characteristics used in classifying parts are referred to as “attributes”

METHODS FOR PART FAMILY FORMATION

1. ***Visual inspection*** - using best judgment to group parts into appropriate families, based on the parts or photos of the parts
2. ***Production flow analysis*** - using information contained on route sheets to classify parts
3. ***Parts classification and coding*** - identifying similarities and differences among parts and relating them by means of a coding scheme.

PARTS CLASSIFICATION AND CODING SYSTEM

Part Design Attributes	Part Manufacturing Attributes
▪ Major dimensions ▪ Basic external shape ▪ Basic internal shape ▪ Length/diameter ratio ▪ Material type ▪ Part function ▪ Tolerances ▪ Surface finish	▪ Major process ▪ Operation sequence ▪ Batch size ▪ Annual production ▪ Machine tools ▪ Cutting tools ▪ Material type

CODING SYSTEM

1. Opitz classification system.
2. DCLASS system.
3. MCLASS system.

1. Opitz classification system:

- **The Opitz Classification System** (Developed by the Technical University of Aachen): the code number has a maximum of 13 positions. Each position may assume 10 different values (attributes).

- Basic structure of the Opitz system

- 1 2 3 4 5

- Form Code

6 7 8 9

Supplementary code

A B C D

Secondary Code

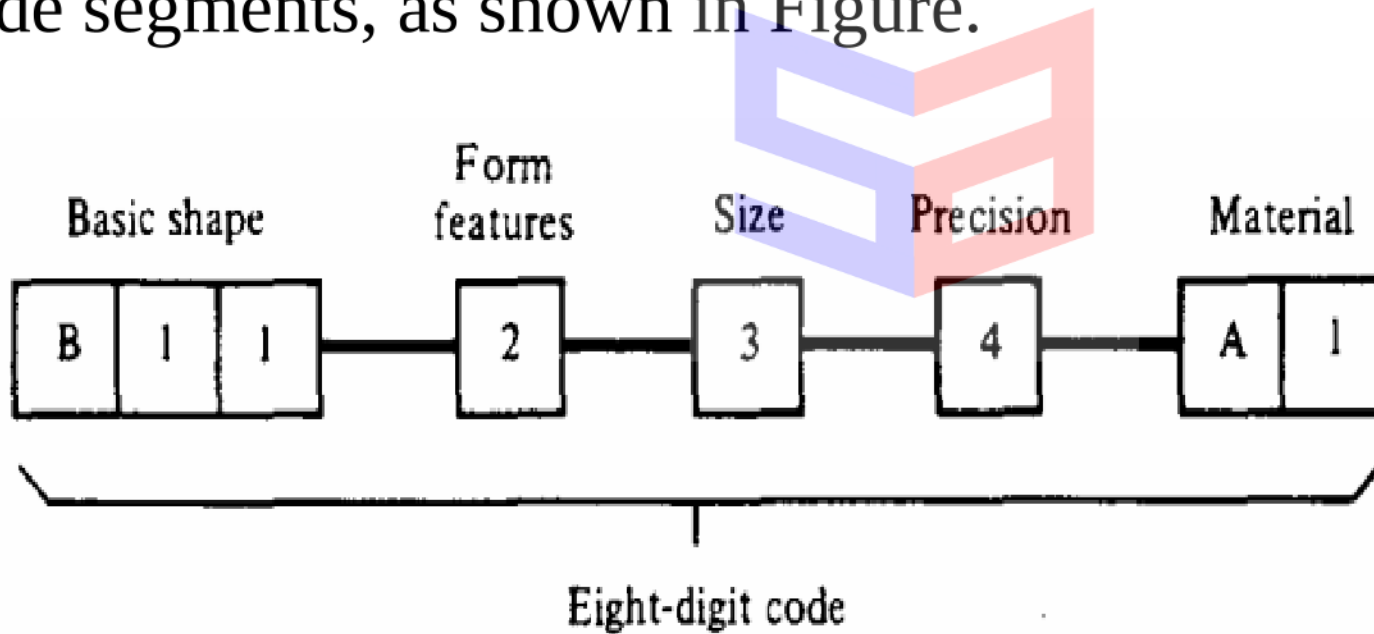


- The first five digits (12345) code the major design attributes of a part and are called the “form code”.
- The next four digits (6789) are for coding manufacturing – related attributes and are called the “supplementary code”.
- The letters (ABCD) code the production operation and sequence and are referred to as the “secondary code”.

Digit	Description
1	Part shape class: rotation versus nonrotational (Figure 22.1). Rotational parts are classified by length-to-diameter ratio. Nonrotational parts by length, width, and thickness.
2	External shape features; various types are distinguished.
3	Rotational machining. This digit applies to internal shape features (e.g., holes, threads) on rotational parts, and general rotational shape features for nonrotational parts.
4	Plane machined surfaces (e.g., flats, slots).
5	Auxiliary holes, gear teeth, and other features.
6	Dimensions—overall size.
7	Work material (e.g., steel, cast iron, aluminum).
8	Original shape of raw material.
9	Accuracy requirements.

2. DCLASS system.

- DCLASS (Design and Classification Information System) was developed at Brigham Young University.
- The DCLASS part family code is comprised of eight digits partitioned into five code segments, as shown in Figure.



3. MICLASS System (Developed in the Netherlands):

the abbreviation is derived from the name Metal Institute Classification System. Developed to help automate & standardize a number of design, production and management function. These include:

➤ MICLASS system is also known referred as Multiclass system.

➤ The System consists of 30 digits (maximum)

1 2 3 4 12

Universal Code

(for any part)

13 14 15 30

Special Code

(for any company or industry including lot size,
cost data, time, operation sequence, etc.)

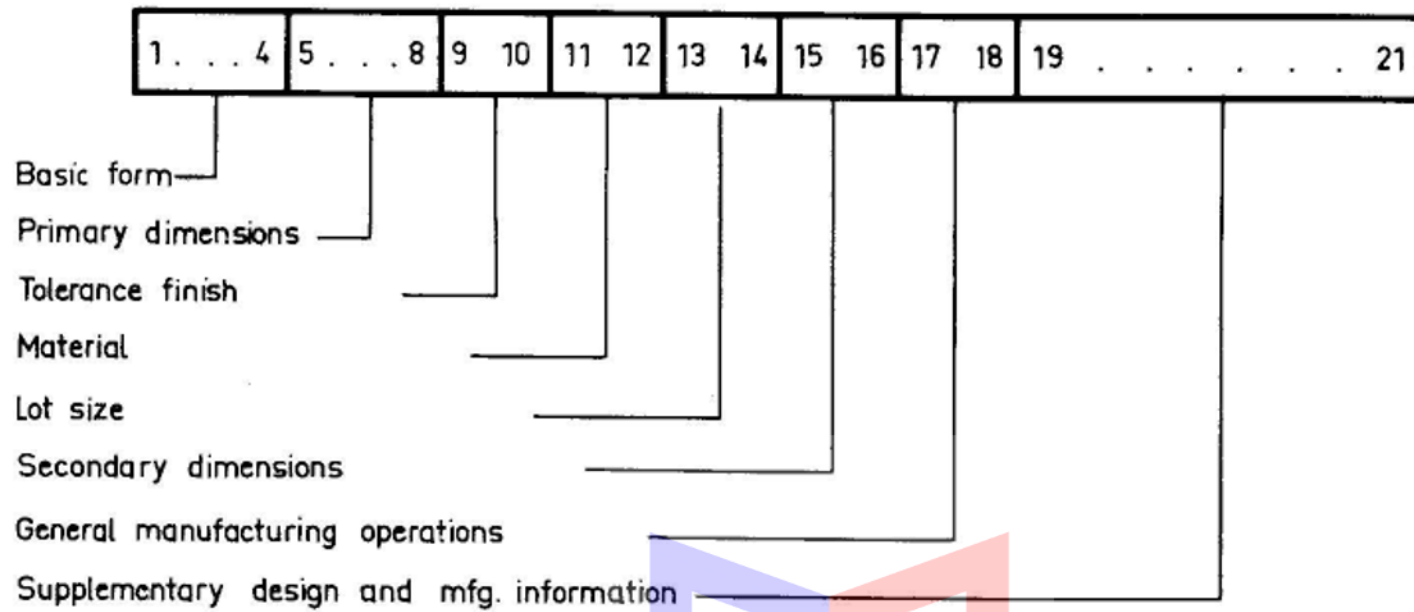
➤ MICLASS classification number can range from 12 to 30 digits.

➤ The first 12 digits are universal codes that can be applied to any part.

➤ The next 18 digits are called supplementary digits.

➤ The first 12 digits are mandatory and are used to classify the engineering and manufacturing characteristics of a part.

➤ The next 18 digits, called supplementary digits, are optional. These 18 additional digits can be used to code data that are specific to the particular company or industry.



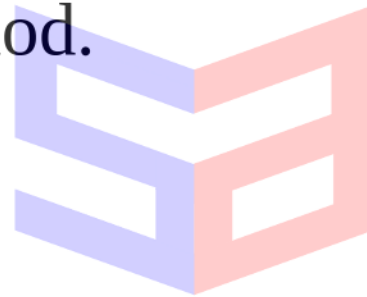
Digits	Attributes
1	Main shape
2&3	Shape Element
4	Position of shape element
5&6	Main Dimension
7	Dimension ratio
8	Auxiliary dimension
9&10	Tolerance codes
11&12	Material codes

PRODUCTION FLOW ANALYSIS (PFA)

- Production flow analysis (PFA), is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather on part drawings.
- This method based on the route sheet information, it is sometimes referred as the route sheet inspection method.

Steps involved in PFA

1. Data collection
2. Sortation of process routings
3. Preparation of PFA chart
4. Cluster analysis



Step 1: data collection

- ✓ The step in the PFA procedure is to collect the necessary data.
- ✓ The route sheets of all the components to be manufactured in the shop are prepared. The route sheet should contain the part number and operation sequences.
- ✓ Other data that can be collected/obtained from route sheet/operation sheet include lot size, time standards and annual demand.

Step 2: sortation of process routes

- ✓ The second step in the PFA is to arrange the parts into groups according to the similarity of their process routings.
- ✓ A typical card format is required for organizing the data such as the part number, sequence of code, and lot size.

Step 3: PFA chart

MACHINES	PARTS								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
M1	1	1		1				1	
M2					1				1
M3			1		1				1
M4		1		1		1			
M5	1							1	
M6			1						1
M7		1				1	1		

Step 4: cluster analysis

- ✓ From the PFA chart, related grouping are identified and rearranged into a new pattern that brings together packs with similar machine sequences. The table shows one possible rearrangement of the original PFA chart.

MACHINES	PARTS								
	P1	P8	P2	P4	P6	P7	P9	P3	P5
M1	1	1	1	1					
M5	1	1							
M4			1	1	1				
M7			1		1	1			
M3							1	1	1
M6							1	1	
M2							1		1

Flexible Manufacturing System

- Flexible Manufacturing System (FMS) is an integrated approach to automating a production system with a view to accommodate fast response to product changes.
- The primary nature of an FMS is that it is a computer-controlled manufacturing system that ties together storage, manufacturing machines, inspection, tooling and materials handling equipment.
- The FMS is designed to be flexible so that it can manufacture a variety of products at relatively low volumes, with minimum lead time between product changes.

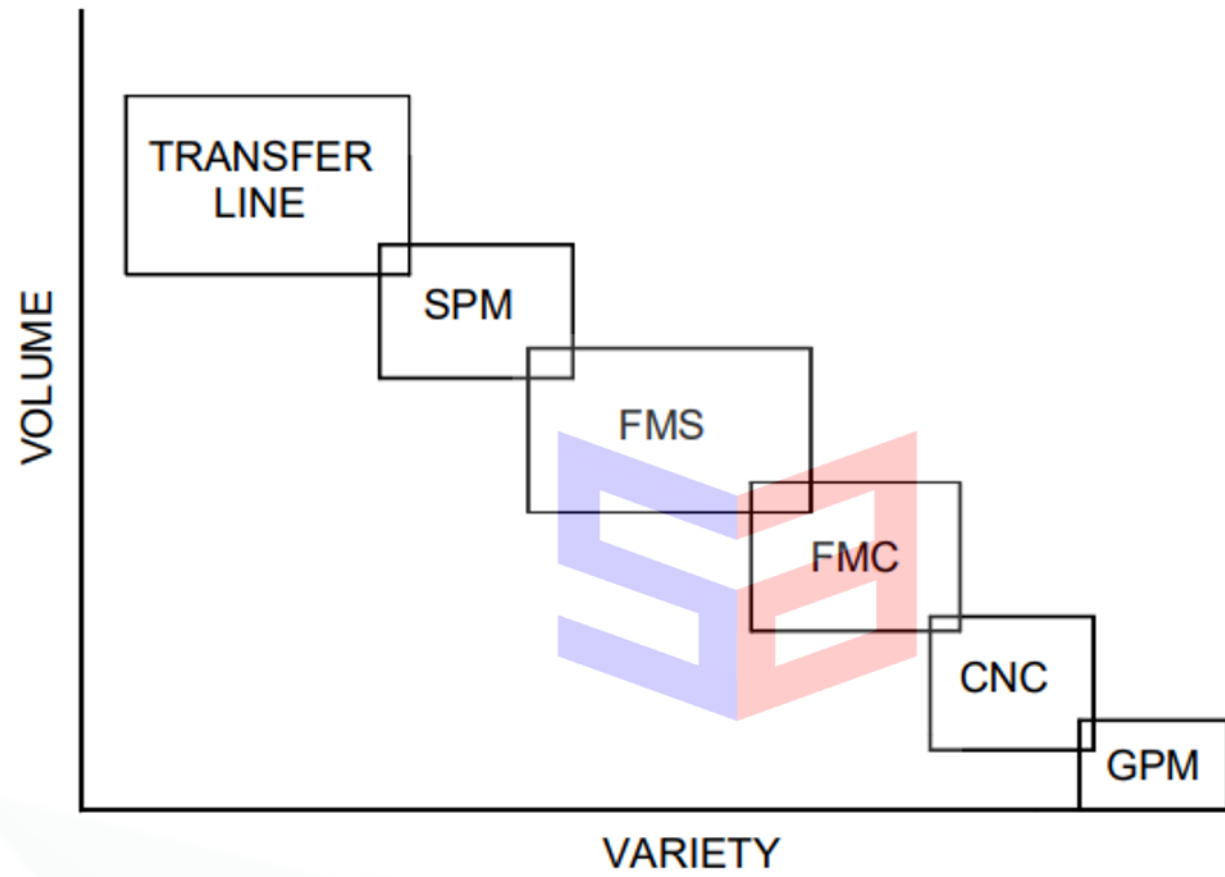


Fig. 19.1 Types of Production Systems

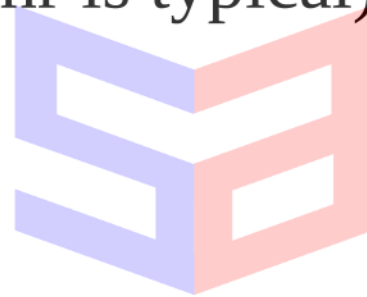


AUTOMATED GUIDED VEHICLE SYSTEMS (AGVS)

- An automated guided vehicle system (AGVS) is a material handling system that uses independently operated, self-propelled vehicles guided along defined pathways. The vehicles are powered by on-board batteries that allow many hours of operation (8-16 hr is typical) between recharging.

- **Types of Vehicles**

- (1) driverless trains
 - (2) pallet trucks and
 - (3) unit load carriers



Vehicle Guidance Technology

The guidance system is the method by which AGVS pathways are defined and vehicles are controlled to follow the pathways.

- (1) Imbedded guide wires,
- (2) Paint strips, and
- (3) Self-guided vehicles.



Advantages of using AGV systems in FMS

i) Flexibility:

- ❖ The route of the AGV's can be easily altered, expanded and modified, simply by changing the guide path of the vehicles.
- ❖ This is more cost effective than modifying fixed conveyor lines or rail guided vehicles.
- ❖ It provides direct access materials handling system for loading and unloading FMS cells and accessing the automated storage and retrieval system.



i) Real time monitoring and control:

- ❖ Because of computer control, AGV's can be monitored in real time. If the FMS control system decides to change the schedule, the vehicles can be re-routed and urgent requests can be served.
- ❖ AGV's are usually controlled through wires implanted on the factory floor. The control is effected using a variable frequency approach

INDUSTRIAL ROBOTICS

- Robots in manufacturing plants has helped to integrate materials handling and several manufacturing operations.
- In general robots can be defined as “Programmable and Automatic Manipulators”. It is a special type of computer-controlled machine that can perform a wide variety of tasks.

Components of the robot manipulator:

- (a) A manipulator (the base and arm assembly)
- (b) End-of-arm tooling, such as a gripper or end effector
- (c) Actuators (motors or drives that move the links of the robot) and associated equipment
- (d) Transmission elements like belts, pulleys, ball screws, gearing and other mechanical components.

Need For Using Robots

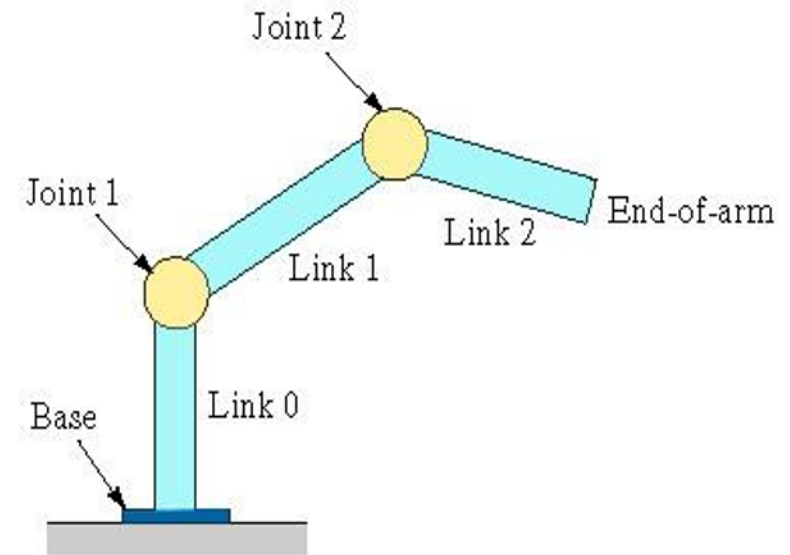
- i. Robots can be built with performance capabilities superior to those of human beings in terms of strength, size, speed, accuracy and repeatability.
- ii. Robots are better than humans to perform simple and repetitive tasks with better quality and consistency.
- iii. Robots can replace humans in performing tasks that are difficult and hazardous because of factors such as size, weight, reach, precision or environment (e.g., heat (as in pressure die casting), dust (as in foundries), chemicals (detection of mines), nuclear radiation, and pollution).
- iv. Robots do not have the limitations and negative attributes of human workers, such as fatigue, need for rest, diversion of attention, absenteeism, need for refreshments etc.

Robot Anatomy

The manipulator of an industrial robot is constructed of a series of joints and links. Robot anatomy is concerned with the types and sizes of these joints and links and other aspects of the manipulator's physical construction.

✚ Manipulator consists of joints and links

- Joints provide relative motion
- Links are rigid members between joints
- Various joint types: linear and rotary
- Each joint provides a “degree-of-freedom”
- Most robots possess five or six degrees-of-freedom



Types of Manipulator Joints

- Translational motion
 - Linear joint (type L)
 - Orthogonal joint (type O)
- Rotary motion
 - Rotational joint (type R)
 - Twisting joint (type T)
 - Revolving joint (type V)



CLASSIFICATION OF ROBOTS

(1) Robot Body-and-Arm Configurations

(2) Wrist Configurations

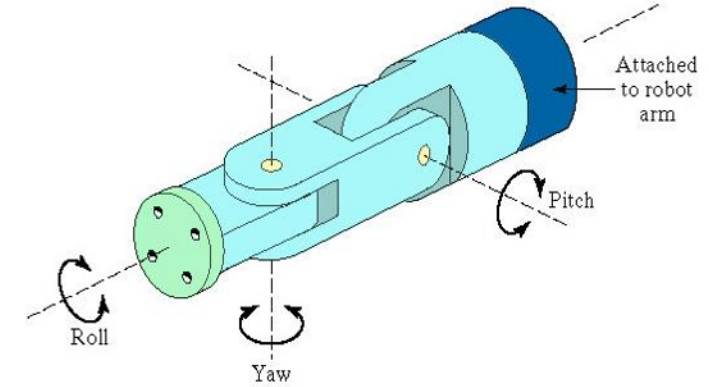
- **Robot Body-and-Arm Configurations**

- Five common body-and-arm configurations for industrial robots:

1. Polar coordinate body-and-arm assembly
2. Cylindrical body-and-arm assembly
3. Cartesian coordinate body-and-arm assembly
4. Jointed-arm body-and-arm assembly
5. Selective Compliance Assembly Robot Arm (SCARA)

Wrist Configurations

- Wrist assembly is attached to end-of-arm
- End effector is attached to wrist assembly
- Function of wrist assembly is to orient end effector
 - (i) Body-and-arm determines global position of end effector
- All of the basic mechanical configurations of manipulators provide only three degrees of freedom, additional axes must be added if more flexibility in motion is required. This is normally achieved by adding wrist and hand movements with the end-of-arm tooling.
- There are three basic types of wrist motions:
 - (i) **Roll** - Rotational or swivel movement in a plane perpendicular to the end of the arm.
 - (ii) **Pitch**- Rotational or bending movement in a plane vertical to the arm.
 - (iii) **Yaw** - Rotational or twisting movement in a plane horizontal to the arm.



Just in Time(JIT)

- ✓ It is a management philosophy that strives to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. It is a **stockless production**.

Objectives of JIT:

- (i) Zero defects
- (ii) Zero setup time
- (iii) Zero inventories
- (iv) Zero handling
- (v) Zero breakdowns
- (vi) Zero lead time
- (vii) Lot size of one.



Kanban production control system:

Kanban means ‘sign’ or ‘instruction card’ in Japanese. A kanban is a card that is attached to a storage and transport container. It identifies the part number and container capacity, along with other information.

Two main types of Kanban:

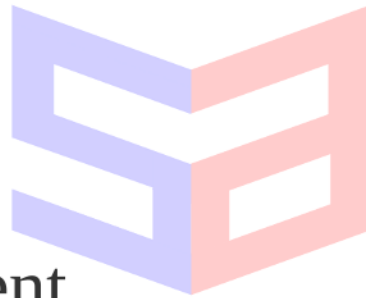
1. **Production kanban (P-Kanban):** It signals the need to produce more parts.
2. **Transport or conveyance Kanban (T- Kanban):** It signals the need to deliver more parts to the next work center. T-kanban is also called as ‘**More Kanban**’ or **withdrawal Kanban**.

Pull Vs Push system

- ✓ A kanban system is a pull system, in which the kanban is used to pull parts to the next production stage when they are needed. That is, in a pull system, production is **made-to-order**.
- ✓ A MRP system (or any schedule based system) is a push system, in which a detailed production schedule for each part is used to push parts to the next production stage when scheduled. That is, **in a push system, the production is made-to-stock**.
- ✓ The weakness of a push system over a pull system is excess inventory, longer lead time and more room for error.
- ✓ In a pull production system, product is made-to-order, Whereas in a push system, the product is made-to-stock.

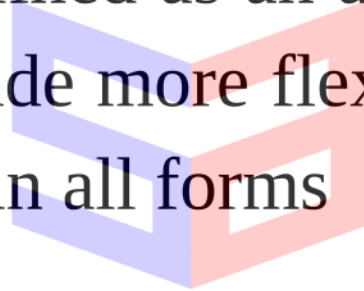
Benefits of JIT:

- i) Reducing inventory level
- ii) Reducing variability
- iii) Improving product quality
- iv) Improve profit
- v) Improve return on investment
- vi) Reduce production & lead times
- vii) Reducing machine set up cost & equipment breakdown cost



LEAN MANUFACTURING

- ✓ Lean production also known as lean manufacturing, is a set of tools and methodologies that aims for the continuous elimination of all wastes in the production process.
- ✓ Lean production can be defined as an adaption of mass production in which workers cells are made more flexible and efficient by adopting methods that reduce waste in all forms



Key principles of Lean manufacturing:

Recognition of waste : Identify the waste and eliminate the materials

Standard processes : Implementation of very detailed production guidelines called standard work

Continuous flow : Implementation of Continuous production process

Pull Production : Produce what is needed

Quality at the source : Elimination of defects with quality inspection

Continuous improvement: Striving for perfection

Lean manufacturing Concepts:

1. Value Creation and waste : The value of the product is based on what customer actually requires and is willing to pay for

(i) Value added Activities : Activities which transform materials into the exact product that the customer requires

(ii) Non – Value added : activities which are not required for transforming the materials into the product that the customer wants e.g.: Inspection and testing

(iii) Necessary Non – value added activities : activities that do not add value from the perspective of the customer but necessary to produce the product unless the existing supply of production process is radically changed

2. Main kinds of waste

- (i) **Over production**: unnecessary producing more than demanded or producing it too early before it is needed.
- (ii) **Defects** : physical defects which directly add to the cost of the goods sold, include paper work, late delivery etc
- (iii) **Inventory** : unnecessary high level of raw materials, work in process and finished products
- (iv) **Transportation** : Movement of materials that does not add value to the product . e.g. Moving materials between work stations
- (v) **Waiting** : idle time for workers and machine due to inefficient production flow
- (vi) **Motion** : unnecessary physical motions or walking which diverts them from actual process
- (vii) **Corrections** : reprocessing which is already done before to rectify the error in work. (Rework)

1. Kanban in Japanese language indicates

(A) a method of line balancing

(b) information for production and withdrawal of items

(C) priority dispatching

(D) line time employment

2. The goal of Just in Time (JIT) philosophy is

(A) The elimination of wastes .

(B) The elimination of process layout

(C) The elimination of costly machine tools

(d) The elimination of sub assemblies in the inventory

3. The JIT production is essentially .

(A) a pull production system

(B) a push production system

(C) a pull and push production system

(D) intermittent production system



4. A manufacturing system based on multi operation machine tools incorporating integrated computer control with associated support function and material handling.

(A) FMC

(B) AGV

(C) FMS

(D) CAPP

5. In inventory control, the economic order quantity is the . :

(A) highest level of inventory

(B) lot corresponding to break-even-point

(C) capacity of a plant to produce

(D) optimum lot size that will minimize the total inventory cost

6. The master schedule

(A) specifies the quantity and time of delivery the units of each product

(B) demands pending orders

(C) specifies resource availabilities and capacities

(D) specifies stock status and inventory information



7. In Retrieval CAPP systems.

(A) No standard manufacturing plans are stored

(B) A standard process plan is stored in computer files for each part code number

(C) Engineering drawing specifications are translated into computer interpretable data

(D) Manufacturing plans are prepared

8. Which Robot configuration represent a human arm?

(A) Mechanical configuration

(B) Polar configuration

(C) Cylindrical configuration.

(D) Jointed arm configuration.

