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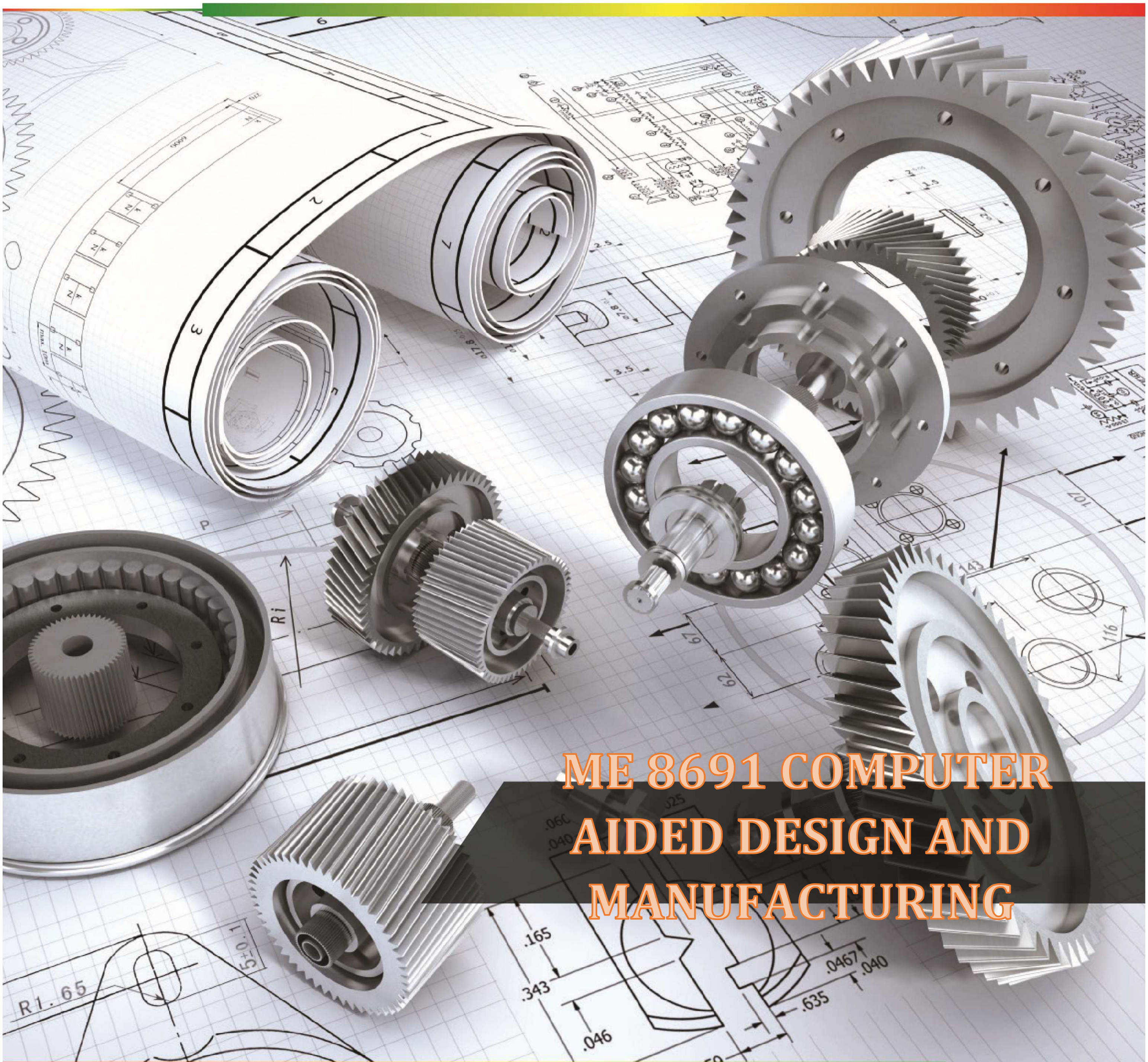


ME 8691 COMPUTER AIDED DESIGN AND MANUFACTURING

DEPARTMENT OF
MECHANICAL ENGINEERING

ROHINI COLLEGE OF ENGINEERING AND TECH NOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

ME8691 -COMPUTER AIDED DESIGN AND MANUFACTTURING

UNIT NOTES

UNIT-1

INTRODUCTION

PRODUCT LIFE CYCLE (PLC)

Every product goes through a cycle from birth, followed by an initial growth stage, a relatively stable matured period, and finally into a declining stage that eventually ends in the death of the product as shown schematically in *Figure.*

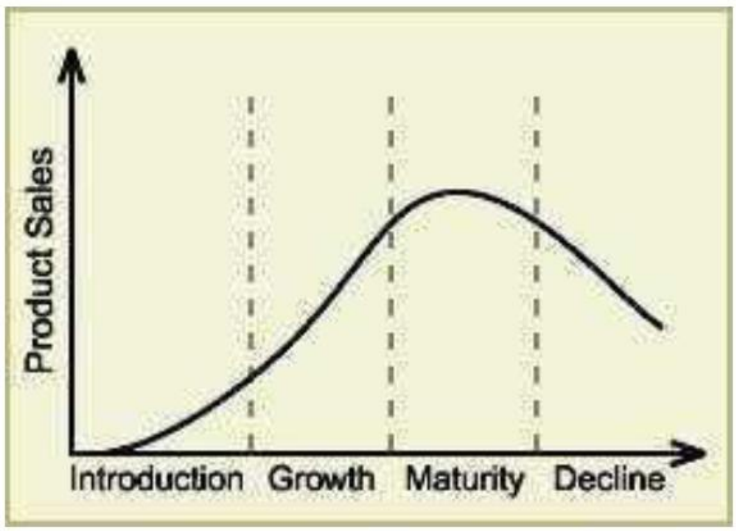
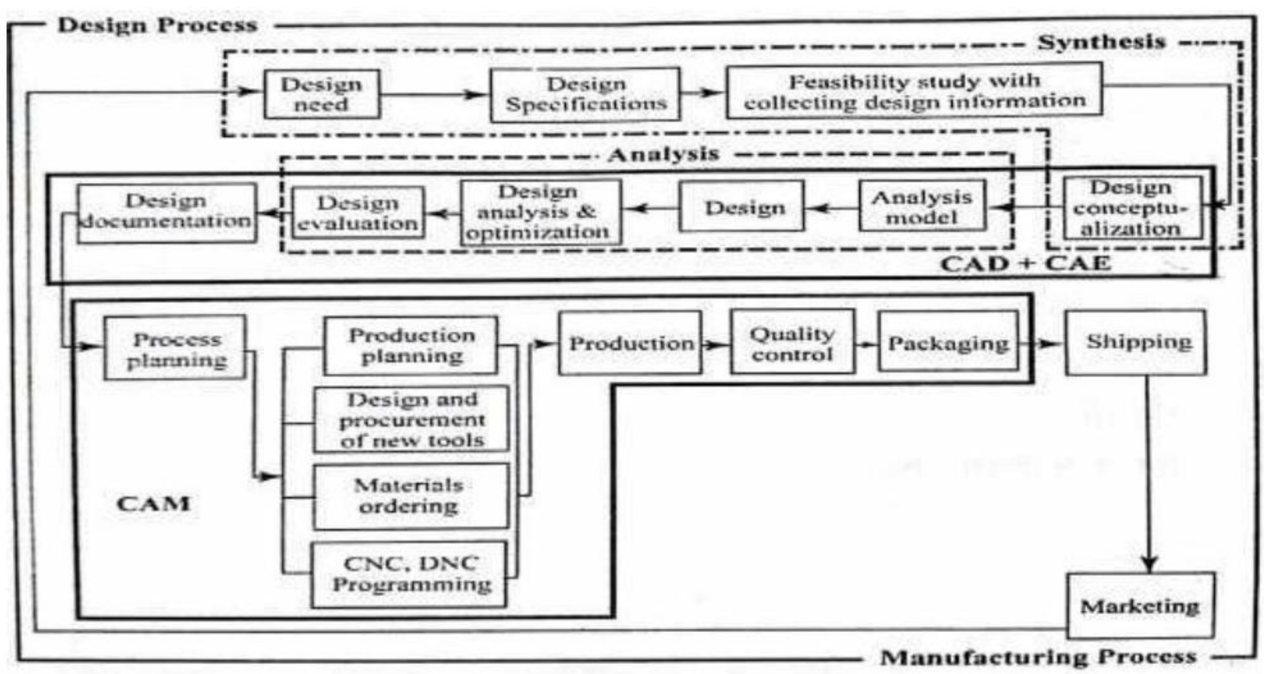


Figure.1.1. Product Life Cycle



(1) *Introduction stage*: In this stage the product is new and the customer acceptance is low and

hence the sales are low.

(2) *Growth stage*: Knowledge of the product and its capabilities reaches to a g rowing number of customers.

(3) *Maturity stage*: The product is widely acceptable and sales are now stable , and it grows with the same rate as the economy as a whole grows.

(4) *Decline stage*: At some point of time the product enters the decline st age. Its sales start decreasing because of a new and a better product has entered the market to fulfill the same customer requirements.

PRODUCT LIFE CYCLE (PLC) FOR CONTINUOUS IMPROVEMENT

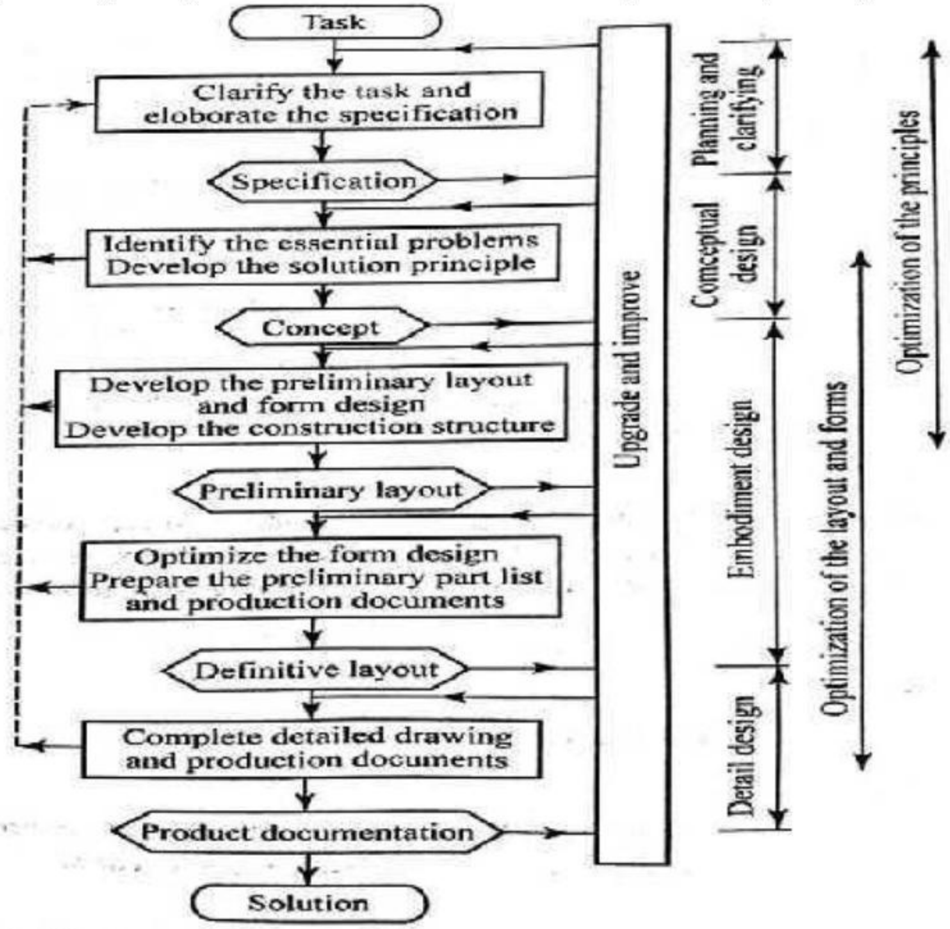
Product Life Cycle for continuous Improvement (Basic)

DESIGN PROCESS

- Design is an activity that neeeds to be well organized and should take into acccount all influences that are likely to be responsible for the success of the product under development. The following models are considered in design purpose
- Shigley
- Pahl and Beitz
- Ohsuga
- Earle

THE DESIGN PROCESS - INTRODUCTION

- The **Engineering Design Process** is the formulation of a plan to help an engineer build a

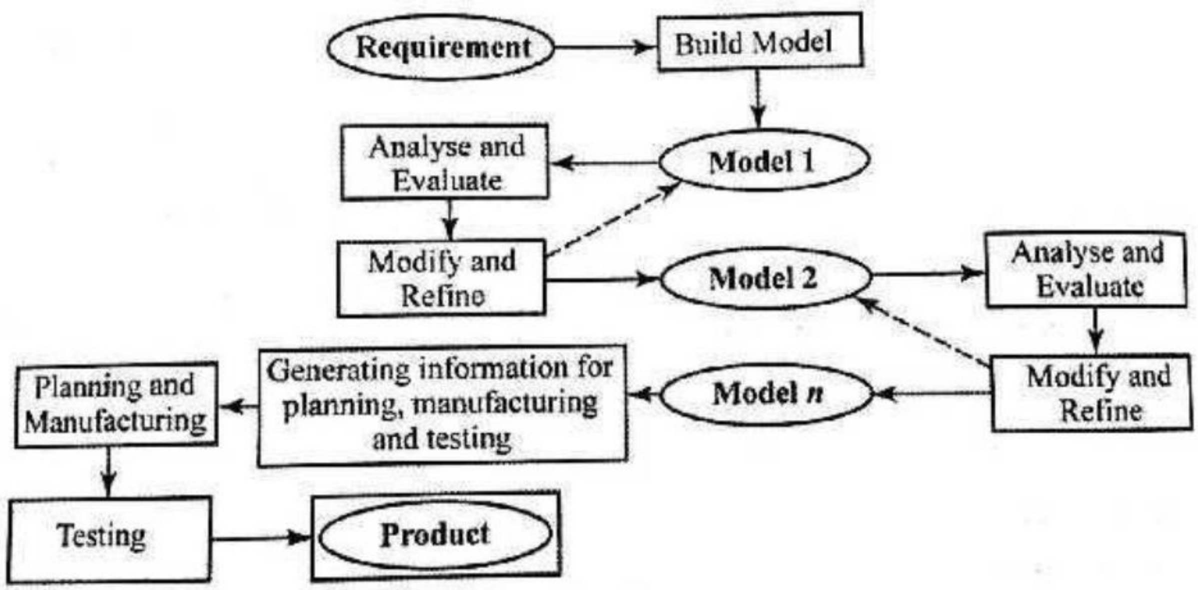


product with a specified performance goal. This process involves a number of steps, and parts of the process may need to be repeated many times before production of a final product can begin.

- It is a decision making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation.

- The Engineering Design process is a multi-step process including the research, conceptualization, feasibility assessment, establishing design requirements, preliminary design, detailed design, production planning and tool design, and finally production.

Ohsuga design Process:



Conceptual Design

It is a process in which we initiate the design and come up with a number of design concepts and then narrow down to the single best concept. This involved the following step s.

(1) *Identification of customer needs*: The mail objective of this is to completely understand the customers' needs and to communicate them to the design team

(2) *Problem definition*: The mail goal of this activity is to create a statement that describes what all needs to be accomplished to meet the needs of the customers' requirements.

(3) *Gathering Information*: In this step, we collect all the information that can be helpful for developing and translating the customers' needs into engineering design.

(4) *Conceptualization*: In this step, broad sets of concepts are generated that can potentially satisfy the problem statement

(5) *Concept selection*: The main objective of this step is to evaluate the various design concepts, modifying and evolving into a single preferred concept.

Embodiment Design

It is a process where the structured development of the design concepts takes place. It is in this phase that decisions are made on strength, material selection, size shape and spatial compatibility. Embodiment design is concerned with three major tasks – product architecture, configuration design, and parametric design.

(1) *Product architecture*: It is concerned with dividing the overall design system into small subsystems and modules. It is in this step we decide how the physical components of the design are to be arranged in order to combine them to carry out the functional duties of the

design.

(2) *Configuration design*: In this process we determine what all features are required in the various parts / components and how these features are to be arranged in space relative to each other.

(3) *Parametric design*: It starts with information from the configuration design process and aims to establish the exact dimensions and tolerances of the product. Also, final decisions on the material and manufacturing processes are done if it has not been fixed in the previous process. One of the important aspects of parametric designs is to examine if the design is robust or not.

Detail Design

It is in this phase the design is brought to a state where it has the complete engineering description of a tested and a producible product. Any missing information about the arrangement, form, material, manufacturing process, dimensions, tolerances etc of each part is added and detailed engineering drawing suitable for manufacturing are prepared.

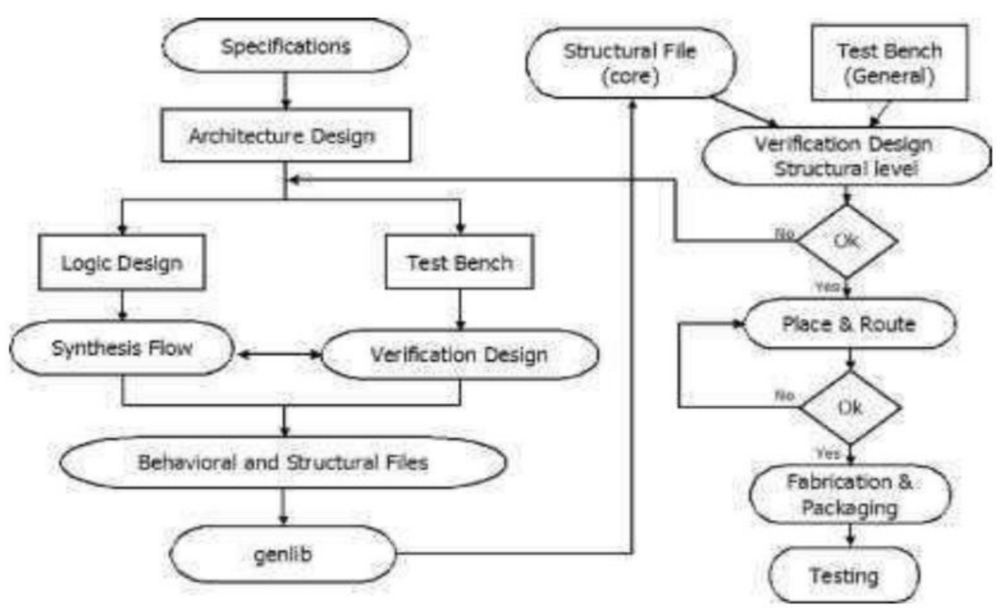
Models of the Design Process

Designers have to:

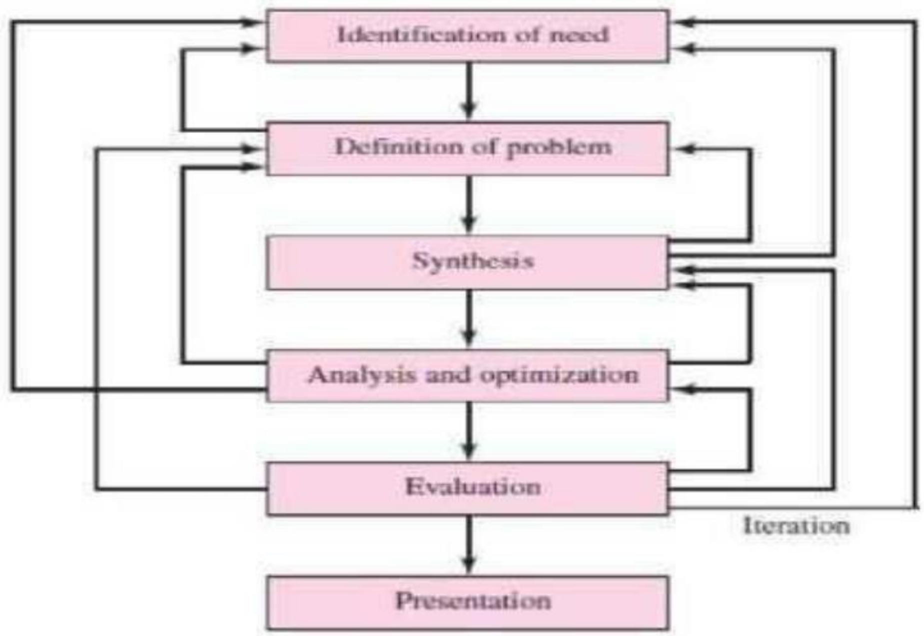
Explore - the problem territory
Generate - solution concepts
Evaluate - alternative solution concepts
Communicate - a final proposal

DESIGN PROCESS MODELS

Ohsuga Model

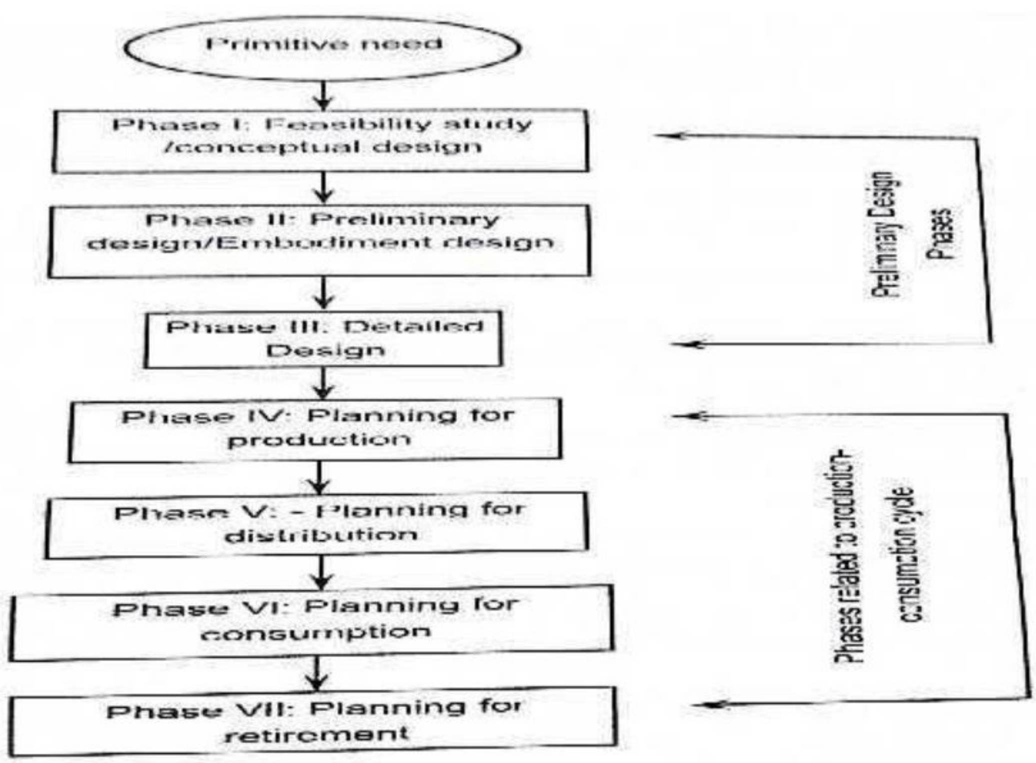


Earle Model

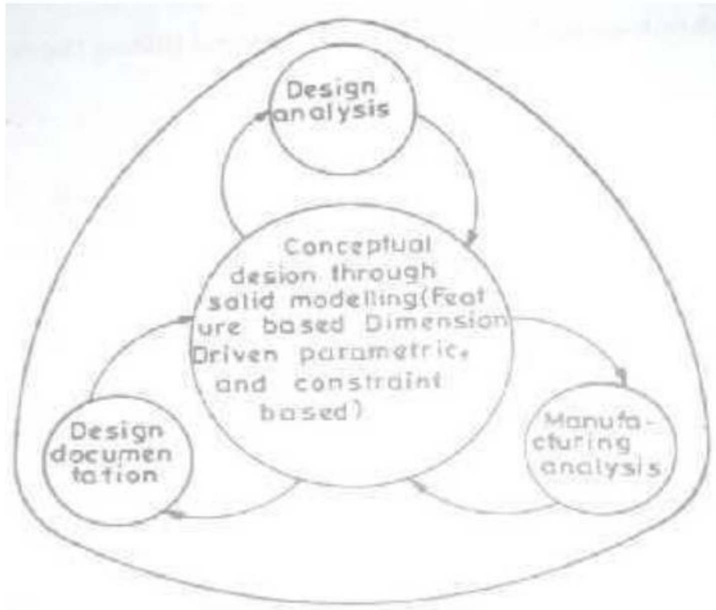


MORPHOLOGY OF DESIGN:

- Morphology design refers to the study of the chronological structure of design projects.
- It is defined by seven phases and their sub steps. Out of seven phases, the first three phases belong to the design the proposed by asimow and the remaining four phases belong to production, distribution, consumption and retirement.



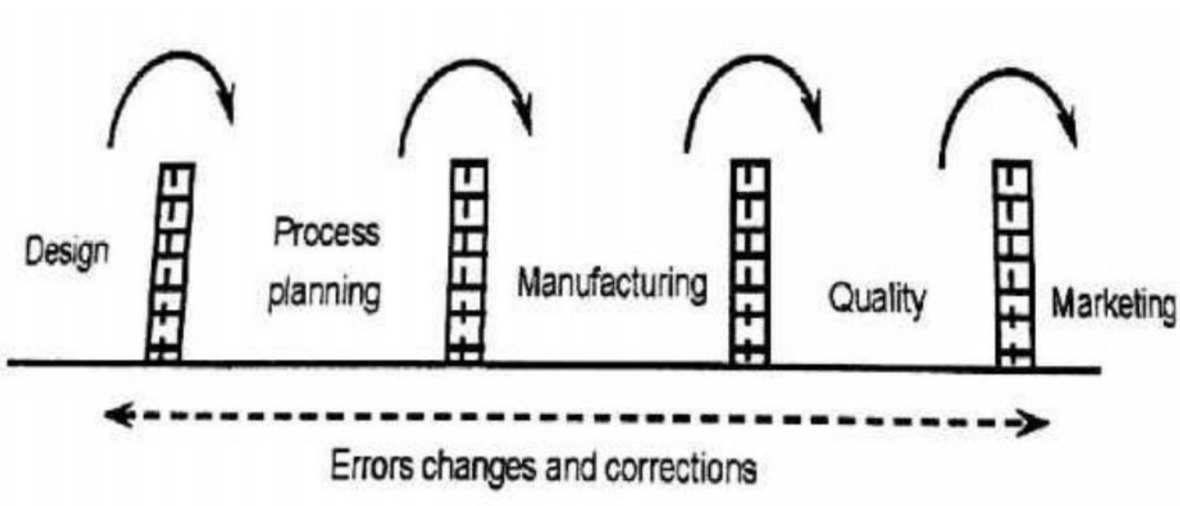
CONCURRENT ENGIN EERING DESIGN



SEQUENTIAL AND CONCURRENT ENGINEERING

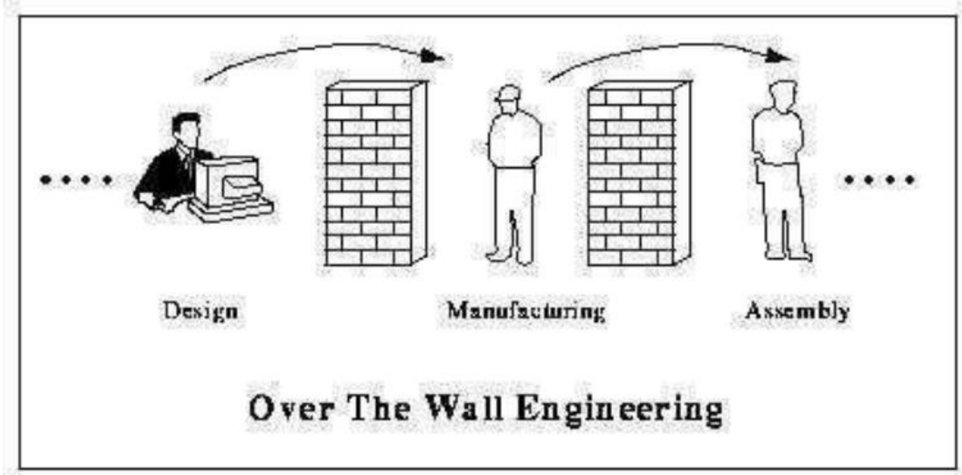
With today's marketplace becoming more and more competitive, there is an ever- increasing pressure on companies to respond quickly to market needs, be cost effective, reduce lead-times to market and deliver superior quality products.

Traditionally, design has been carried out as a sequential set of activities with d istinct non-

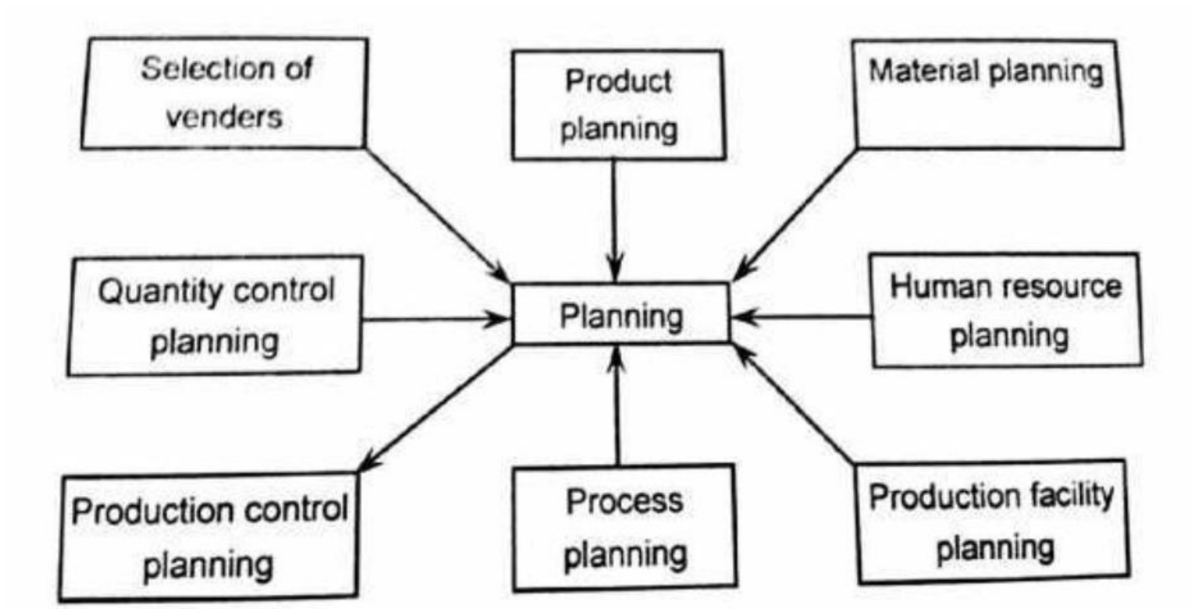


overlapping phases. In such an approach, the life-cycle of a product starts with the identification of the need for that product. These needs are converted into product requirements which are passed on to the design department. The designers design the product's form, fit, and function to meet all the requirements, and pass on the design to the manufacturing department.

After the product is manufactured it goes through the phases of assembly, testing, and installation. This type of approach to life-cycle development is also known as `over the wall' approach, because the different life-cycle phases are hidden or isolated from each other. Each phase receives the output of the preceding phase as if the output had been thrown over the wall. In such an approach, the manufacturing department, for example, does not know what it will actually be manufacturing until the detailed design of the product is over.

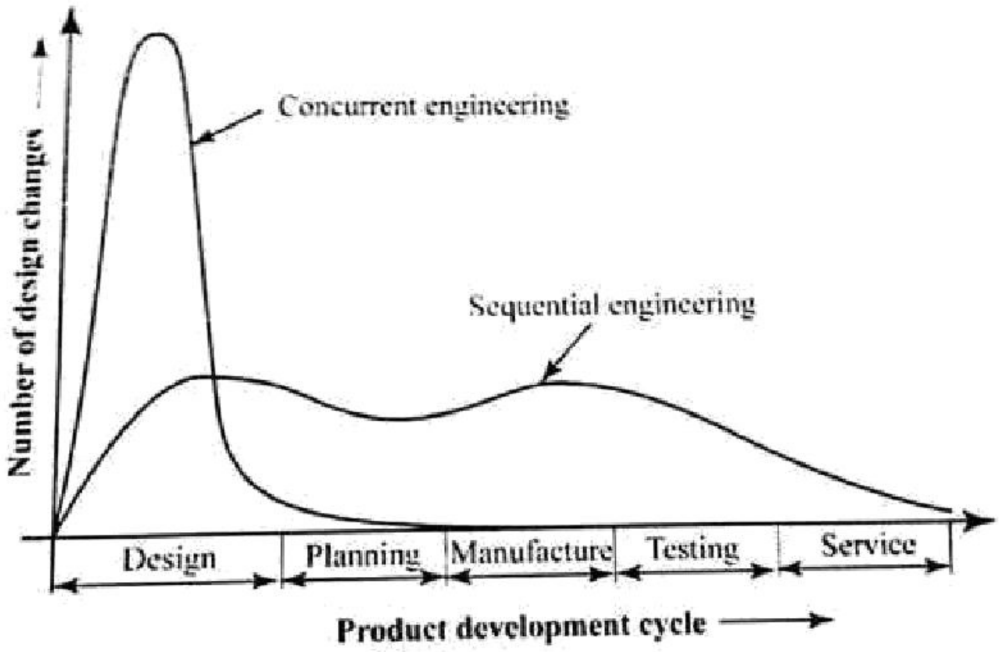


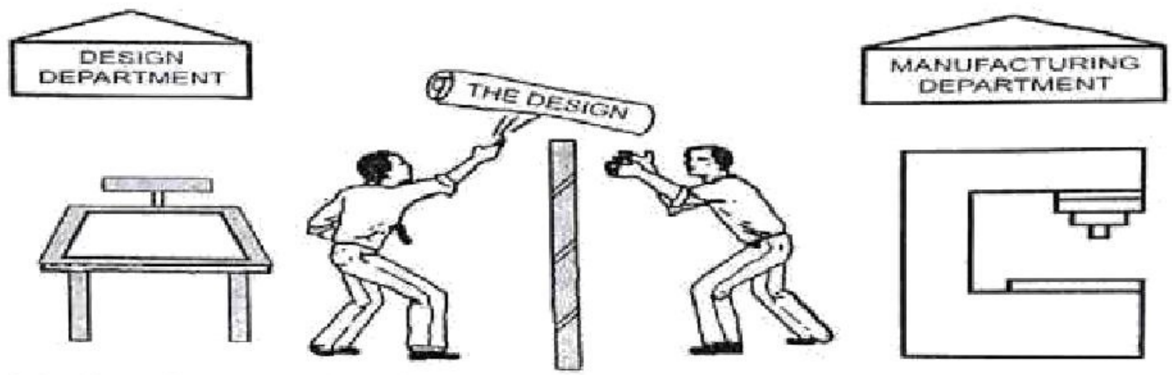
Over the Wall Engineering (Sequential Engineering)



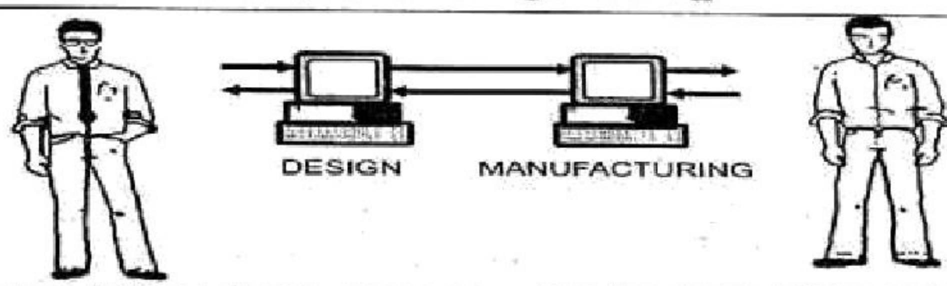
COMPARISION BETWEEN SEQUENTIAL AND CONCURRENT ENGINEERING

- ❖ Product development cost
- ❖ Number of design changes
- ❖ Lead time for product development
- ❖ Customer satisfaction
- ❖ Coordination between departments



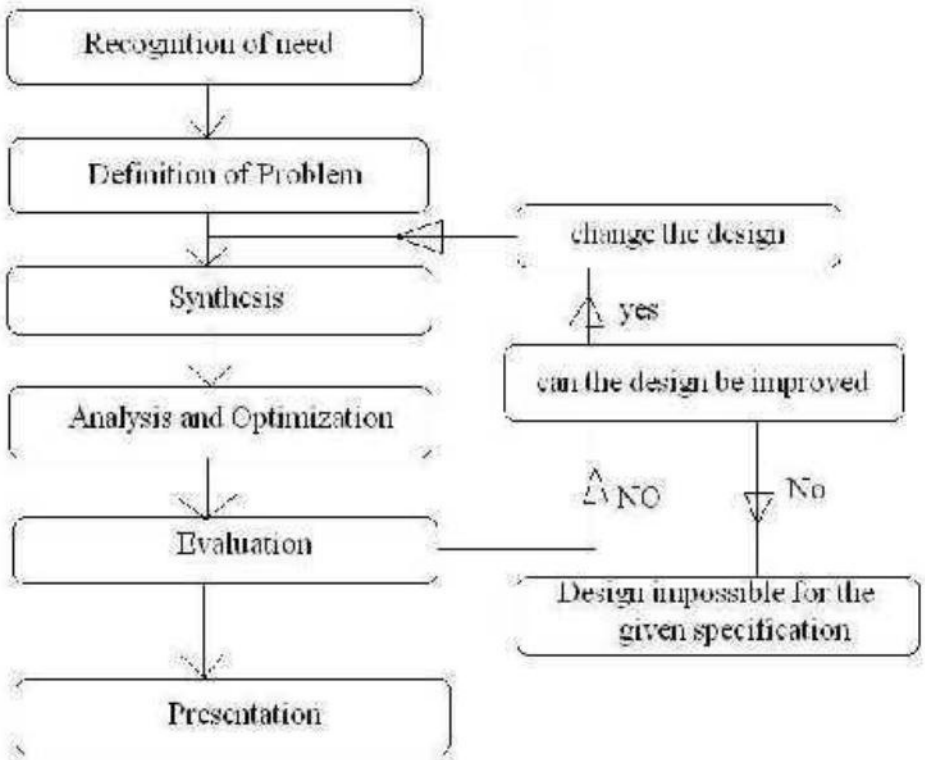


(a) Traditional design/manufacturing communication in sequential engineering

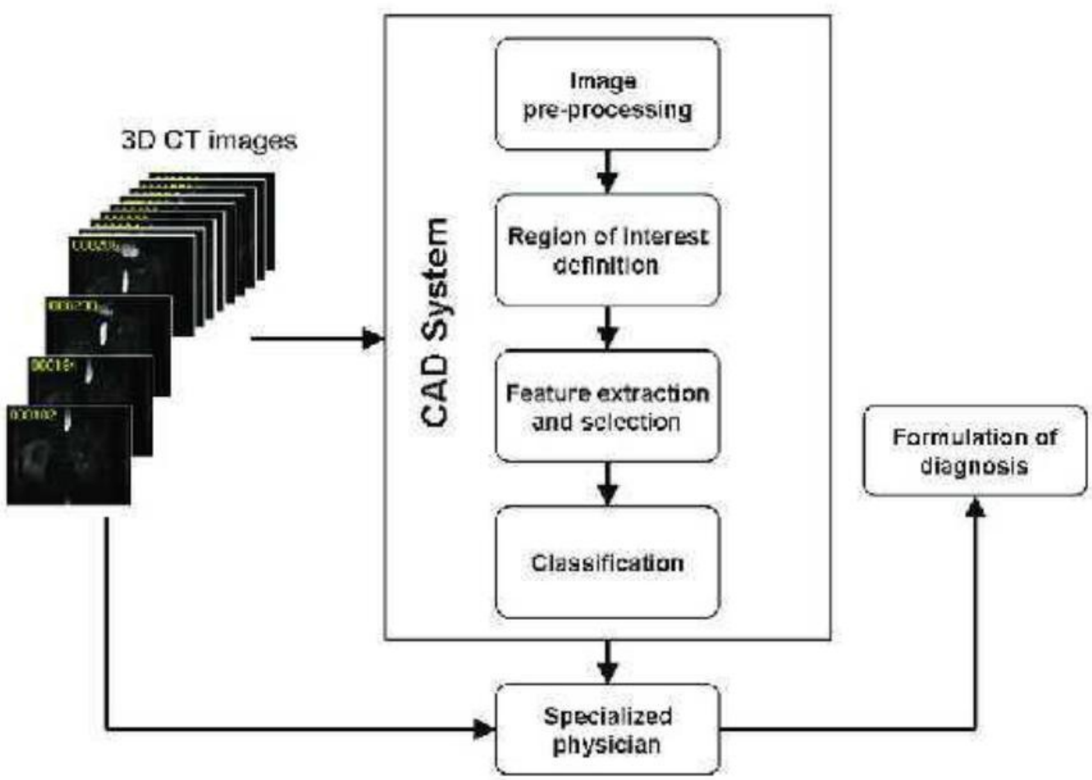


(b) Design/Manufacturing communication with CAD/CAM in concurrent engineering

ROLE OF COMPUTERS IN DESIGN

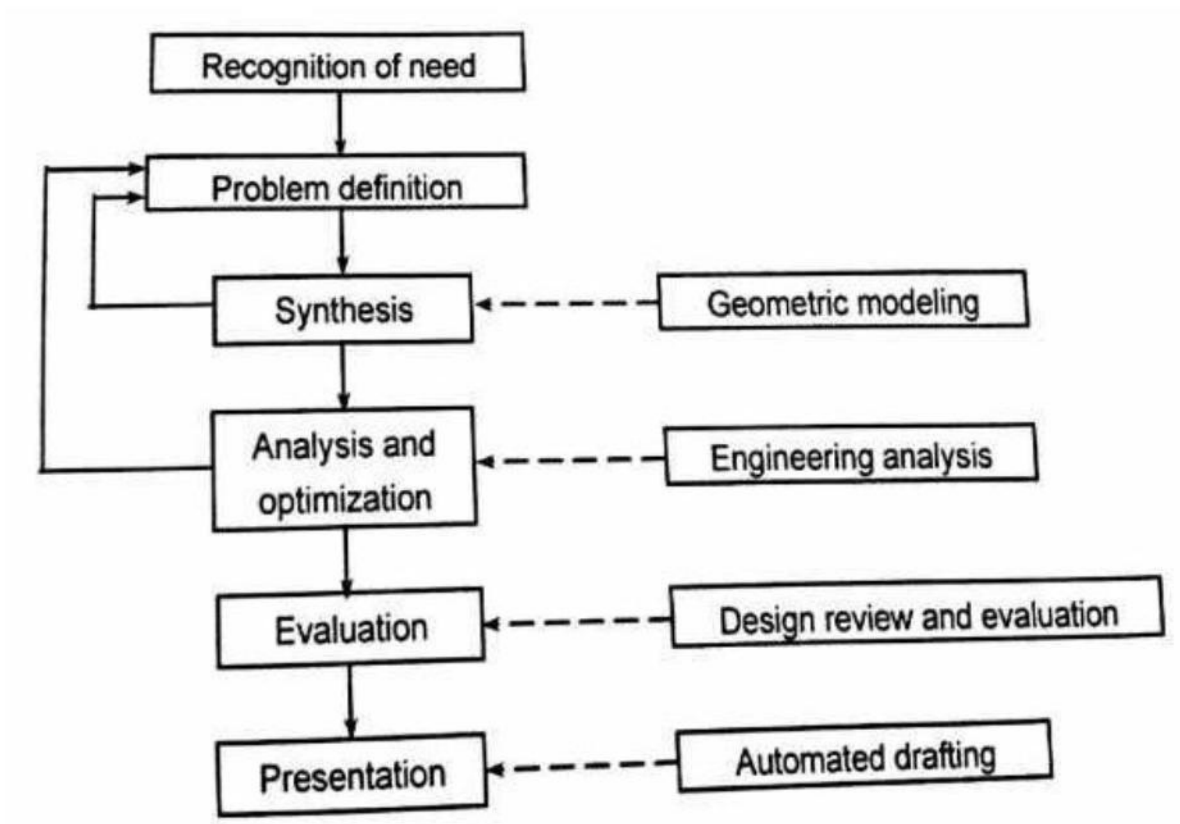


CAD SYSTEM ARCHITECTURE



Roles of CAD in Design

- Accurately generated and easily modifiable graphical representation of the product.
- User can nearly view the actual product on the screen, make any modification to it and present his ideas on screen without any prototype, especially during the early stages of the design process.
- Complex design analysis in short time. By implementing Finite Element Analysis (FEA) methods user can perform as follows
- Static, dynamic & natural frequency analysis
- Heat transfer analysis
- Fluid flow analysis
- Plastic analysis
- It records and recalls information with consistency and speed
- Use of Product Data Management (PDM) systems can store the whole design and processing history of a certain product for future reuse and upgrade.



APPLICATION OF CAD

- Mechanical engineering
- Civil engineering
- Electrical and electronics engineering
- Textile industry

ADVANTAGES OF CAD

- Easy editing
- High quality
- Compact storage
- 3D Drawing

APPLICATION OF COMPUTERS TO DESIGN

- Modeling of the Design
- Engineering design and analysis
- Evaluation of Prototype through Simulation and Testing
- Drafting and Design Documentation

BENEFITS OF CAD

1. Productivity Improvement in Design
   Depends on Complexity of drawing,
   Degree of repetitiveness of features in the designed parts, Degree of symmetry in the parts,
   Extensive use of library of user defined shapes and commonly use d entities
2. Shorter Lead Times
3. Flexibility in Design
4. Design Analysis
5. Fewer Design Error
6. Standardization of Design, Drafting and Documentation
7. Drawings are more understandable
8. Improved Procedures of Engineering Changes
9. Benefits in Manufacturing :
   a. Tool and fixture design for manufacturing
   b. Computer Aided process planning
   c. Preparation of assembly lists and bill of materials
   d. Computer aided inspection
   e. Coding and classification of components
   f. Production planning and control
   g. Preparation of numerical control programs for manufacturing the parts on CNC machines
   h. Assembly sequence planning

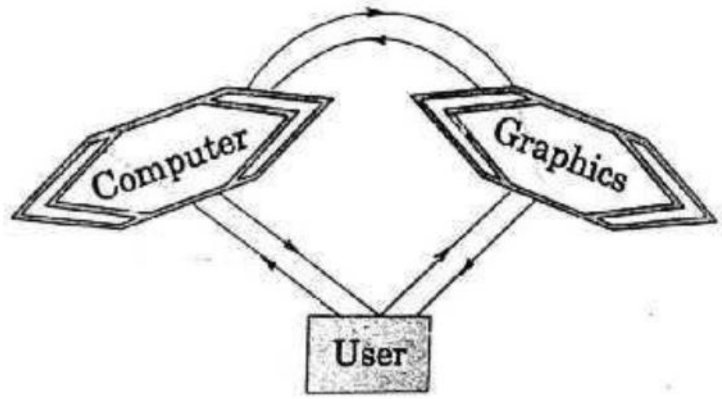
REASONS FOR IMPLEMENTING CAD

- To increase the productivity of the designer
- To improve the Quality of Design
- To improve Documentation
- To create a Database for manufacturing

COMPUTER GRAPHICS or INTERACTIVE COMPUTER GRAPHICS

- Computer Graphics is defined as creation, storage, and manipulation of pictures and drawings by means of a digital computer
- It is an extremely effective medium for communication between people and computers
- Computer graphics studies the manipulation of visual and geometric information using computational techniques

- It focuses on the mathematical and computational foundations of image generation and processing rather than purely aesthetic issues



Concept of Interactive computer Graphics

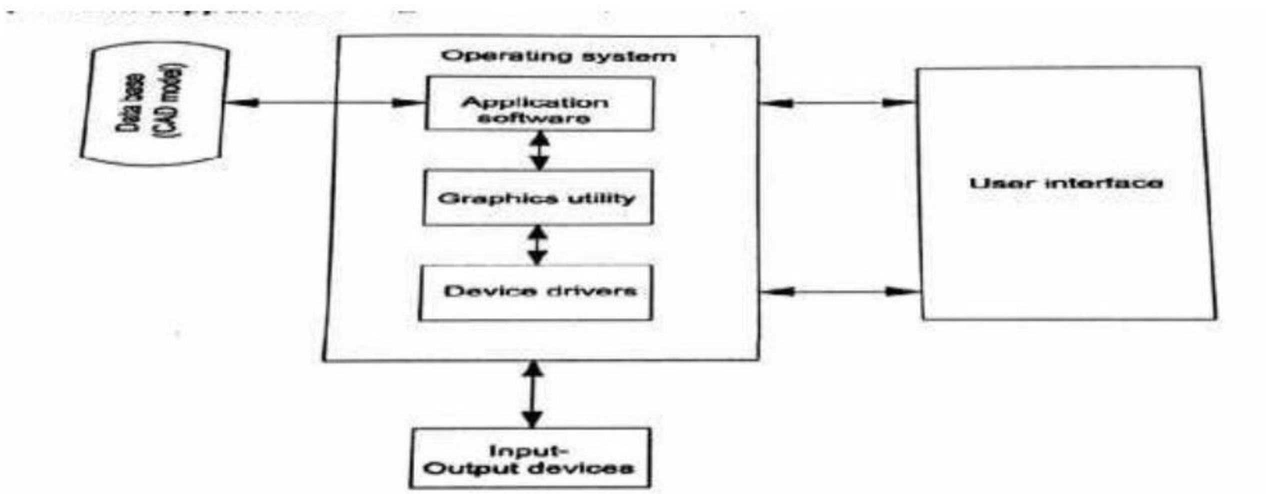
In Interactive Computer Graphics (ICG) the user interacts with the compute
and comprises the following important functions:

A coordinate system is o ne which uses one or more numbers, or coordinates, to uniquely determine the position of a point or other geometric element on a manifold such as Euclidean space.

CAD SYSTEM ARCHITECTURE

- It is an early model which was used for the basic geometry construction and modelling purpose.
- Four major components of *CAD System Architecture are*

1. Database



2. Operating system
3. Input/output devices
4. User interface

COMPUTER GRAPHICS (CG) COMPUTER GRAPHICS (CG)
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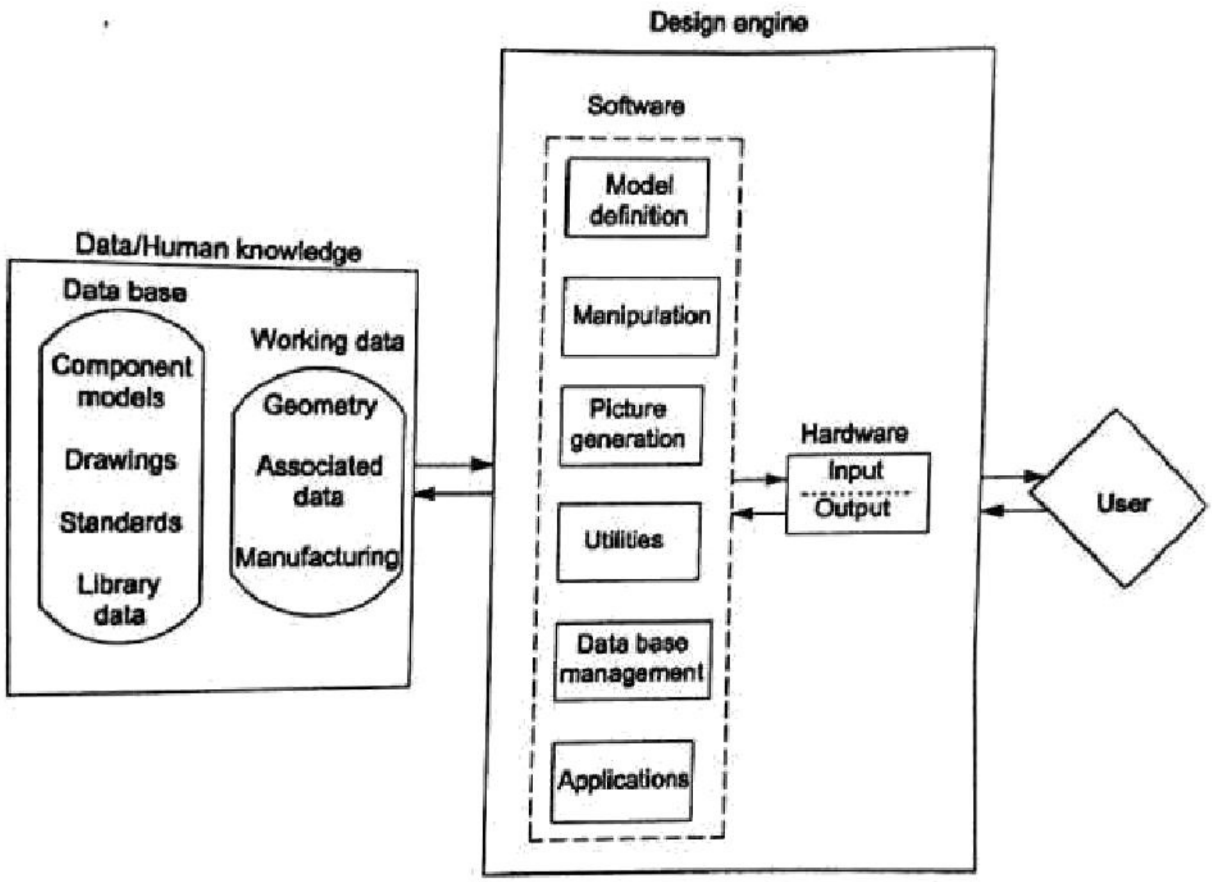
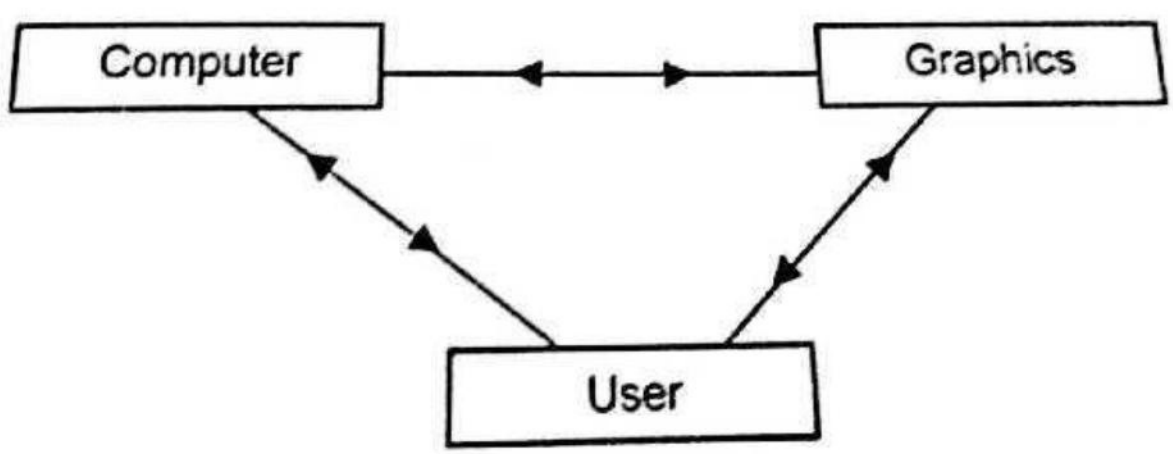


COMPUTER GRAPHICS (CG)

- ❖ Computer graphics is a technology which uses the display of the drawing or the geometric model of the component in CAD.
- ❖ CG may be defined as the process of creation, storage and manipulation of drawings and pictures with aid of a computer.
- ❖ It is an extremely effective medium for communication between users and computers.
- ❖ There are two types

  1. Passive CG



2. Interactive CG

The following functions of the ICG

- ❖ Modelling
- ❖ Storage
- ❖ Manipulation
- ❖ Viewing

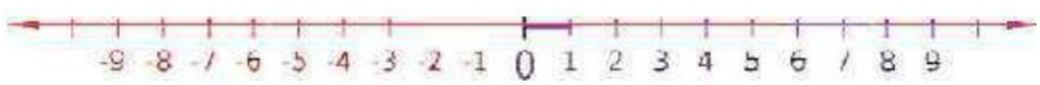
- ❖ The object drawings can be denoted by its geometric model in three dimensions. i.e. X, Y, Z coordinates.
- ❖ Accurate drawings can be made.
- ❖ Sectional drawings can be easily created.
- ❖ Modification of geometric model of objects is easy.
- ❖ It is easy storage and retrieval of drawings.

- ❖ Paint programs
- ❖ Design programs
- ❖ Presentation graphics software
- ❖ Animation software
- ❖ CAD software
- ❖ Desktop publishing
- ❖ Education and training
- ❖ Image processing

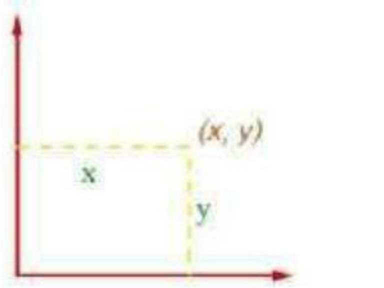
Common coordinate systems are:

Number line

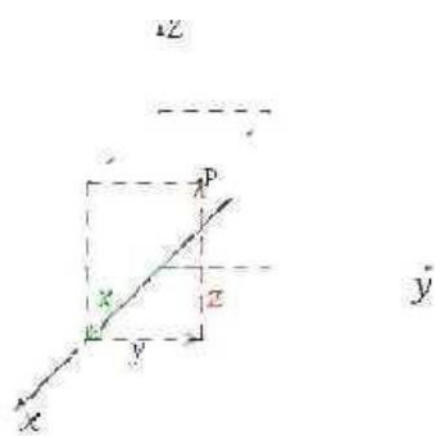
The simplest example of a coordinate system is the identification of points on a line with real numbers using the number line. In this system, an arbitrary point O (the origin) is chosen o n a given line. The coordinate of a point P is de fined as the signed distance from O to P, where the signed distance is the distance taken as positive or negative depending on which side of the line P lies. Each point is given a unique coordinate and each real number is the coordinate of a unique point



Cartesian coordinate system [(x,y) and (x,y,z)]

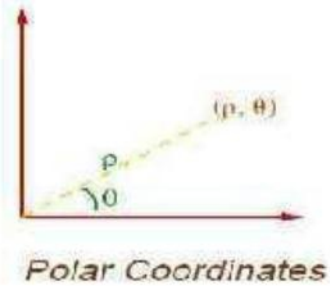


Cartesian Coordinates

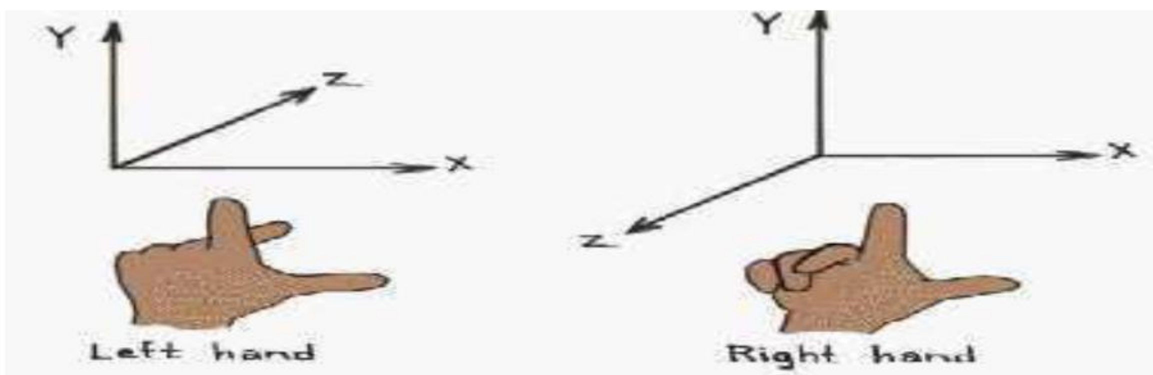


- **Polar coordinate system (ρ,θ)**

Another common coordinate system for the plane is the *polar coordinate system*. A point is chosen as the *pole* and a ray from this point is taken as the *polar axis*.

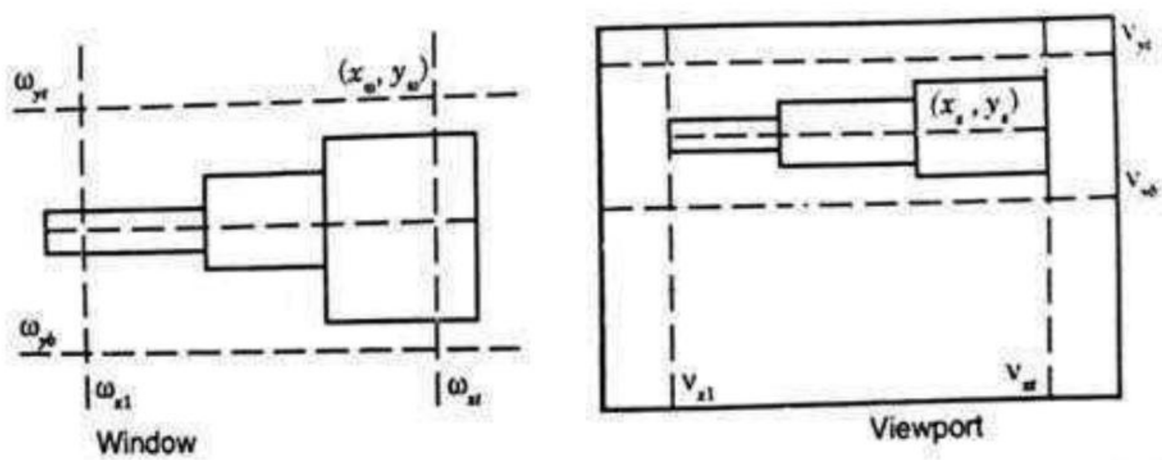


Left and right handed coordinate system



2. Windowing Transformation

$\rho = r$

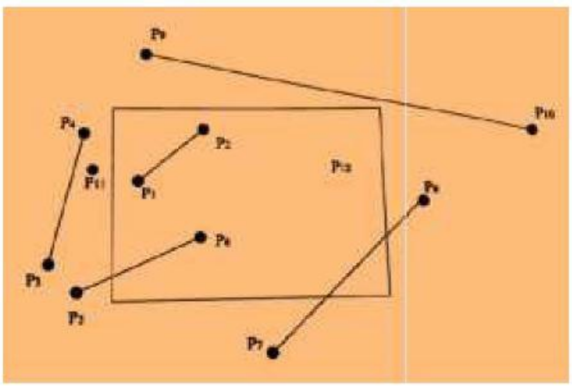


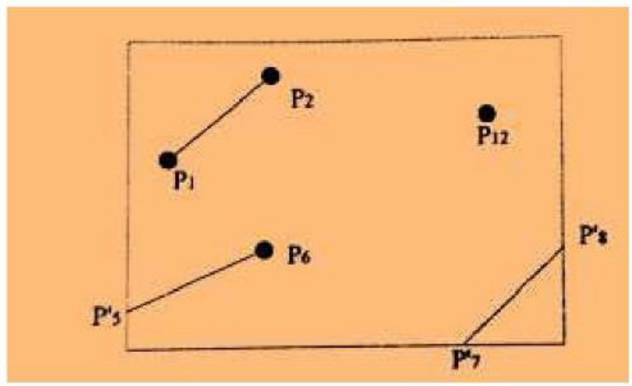
When it is necessary to examine in detail a part of a picture being displayed, a window may be placed around the desired part and the windowed area magnified to fill the whole screen and multiple views of the model may also be sho wn on the same screen.

The window is a rectangular frame or boundary through which the user looks onto the model. The viewport is the area on the screen in which the contents of the window are to be presented as an image.

Clipping Transformation

The clipping is an operation to plot part of a picture within the given window of the plotting area and to discard the rest.





2– D TRANSFORMATIONS

i. Scaling
ii. Translation
iii. Reflection with mirror
iv. Rotation

2. Scaling

Scaling is the transformation applied to change the scale of an entity. As shown in following figure, this alters the size of the entity by the scaling factor applied. For Example, in following figure, to achieve scaling, the original coordinates would be multiplied uniformly by the scaling factor.

$$P' = [X', Y'] = [S_x \times X, S_y \times dY] \qquad \text{-------(6)}$$

This equation can also be represented in a matrix form as follows.

$$[P'] = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \qquad \text{-------(7)}$$

$$[P'] = [T_s] \cdot [P] \qquad \text{-------(8)}$$

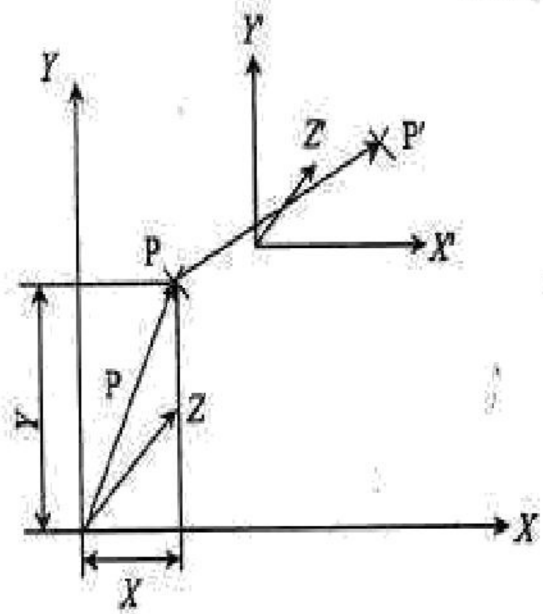
Translation

It is the most common and easily understood transformation in CAD. This moves a geometric entity in space in such a way that the new entity is parallel at all points to the old entity. A representation is shown in following figure for an object. Let us now consider a point on the object, represented by P which is translated along X and Y axes by dX and dY to a new position P'. The new coordinates after transformation are given by following equations.

$P' = [x', y']$ -------(1)

$x' = x + dX$ -------(2)

$y' = y + dY$ -------(3)



Translation of the Point

Putting equations (3) back into equations (1) we can write

$$[P'] = \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x + dX \\ y + dY \end{bmatrix}$$ -------(4)

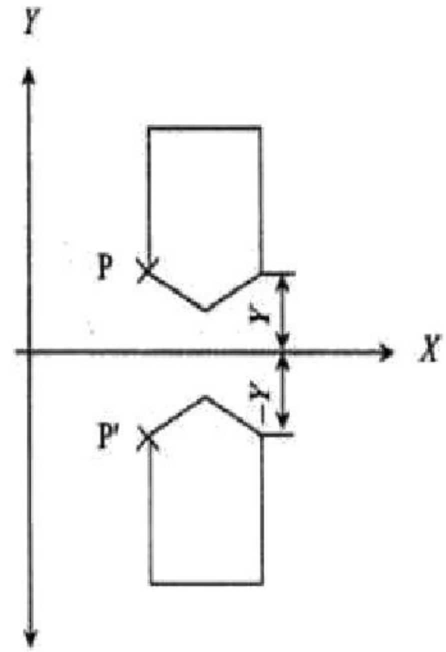
This can also be written in matrix form as follows.

$$[P'] = \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x + dX \\ y + dY \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} dX \\ dY \end{bmatrix}$$ -------(5)

this is normally the operation used in the CAD systems as MOVE command.

3. **Reflection or Mirror**

Reflection or mirror is a transformation, which allows a copy of the object to be displayed while the object is reflected about a line or a plane.



Example for Reflection Transformation

The transformation required in this case is that the axes coordinates will get negated depending upon the reflection required. For example from following figures, the new

$$P' = [X', Y'] = [X, -Y] \qquad \text{-------(10)}$$

This can be given a matrix form as

$$[P'] = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \qquad \text{-------(11)}$$

$$[P'] = [T_m] \cdot [P]$$

where

$$[T_m] = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \qquad \text{-------(12)}$$

Thus the general transformation matrix will be

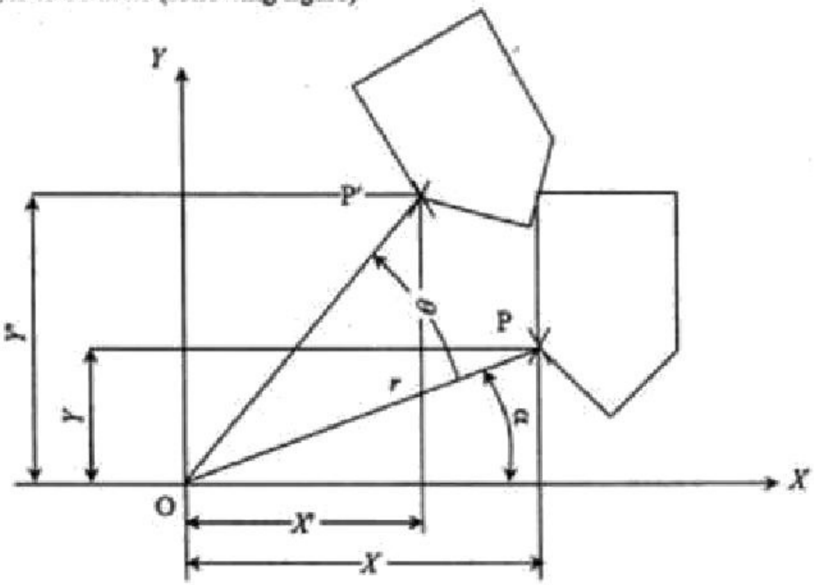
$$[M] = \begin{bmatrix} \pm 1 & 0 \\ 0 & \pm 1 \end{bmatrix} \qquad \text{-------(13)}$$

Here, –1 in the first position refers to reflection about *Y*-axis where all the *X* coordinate values get negated.

When the second term becomes –1 the reflection will be about the *X*-axis with all *Y* coordinate values getting reversed. Both the values are –1 for reflection about *X* and *Y*-axes.

4. Rotation

Rotation is another important geometric transformation. The final position and orientation of a geometric entity is decided by the angle of rotation (θ) and the base point about which the rotation, is to be done (following figure)



To develop the transformation matrix for transformation, consider a point P located in XY plane, being rotated in the counter clockwise direction to the new position, P' by an angle θ as shown in following figure, The new position P' is given by

$P' = [x', y']$

From the following figure, the original position is specified by

$x = r\cos\alpha$

$y = r\sin\alpha$

The new position, P' is specified by

$$x' = r\cos(\alpha+\theta)$$
$$= r\cos\theta\cos\alpha - r\sin\theta\sin\alpha$$
$$= x\cos\theta - y\sin\theta$$

$$y' = r\sin(\alpha+\theta)$$
$$= r\sin\theta\cos\alpha + r\cos\theta\sin\alpha$$
$$= x\sin\theta + y\cos\theta$$

This can be written in a matrix form as

$$[P'] = \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad \text{-------(14)}$$

$$[P'] = [T_R]\cdot[P]$$

$$[T_R] = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \quad \text{-------(15)}$$

HOMOGENEOUS CO-ORDINATES

Homogeneous Representation

In order to concatenate the transformation as shown in equation (16), all the transformation matrices should be multiplicative type. However, as seen earlier, the translation matrix (equation (5)) is vector additive, while all others are matrix multiplications. The following form should be used to convert the translation into a multiplication form.

$$[P'] = \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & dX \\ 0 & 1 & dY \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \qquad \text{--------(17)}$$

Hence the translation matrix in multiplication form can be given as

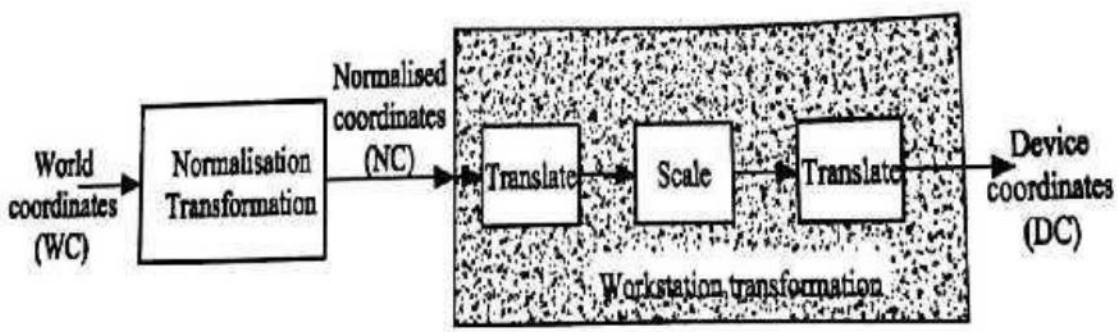
$$[MT] = \begin{bmatrix} 1 & 0 & dX \\ 0 & 1 & dY \\ 0 & 0 & 1 \end{bmatrix} \qquad \text{--------(18)}$$

This is termed as homogeneous representation. In homogeneous representation, an n-dimensional space is mapped into $(n+1)$ dimensional space. Thus a 2 dimensions point $[x \;\; y]$ is represented by 3 dimensions as $[x \;\; y \;\; 1]$.

This greatly facilities the computer graphics operations where the concatenation of multiple transformations can be easily carried out. This can be experienced in the following situations

VIEWING TRANSFORMATIONS

- Displaying an image of a picture involves in mapping the co-ordinates of the picture into the appropriate coordinates on the device where the image is to be displayed.



Elements of CAD system

Functional areas of a CAD design Process

- Geometric modelling
- Design analysis and optimization
- Design review and evaluation
- Documentation and drafting

MANUFACTURING CONTROL APPLICATIONS OF CAM

- The manufacturing control applications of CAM are concerned with developing computer systems for implementing the manufacturing control function.

The important manufacturing planning applications of CAM includes:

- Process monitoring and control
- Quality control
- Shop floor control
- Inventory control
- Just in time production systems

CIM

- CAD+CAM = CIM
- CIM is the total integration of all components involved in converting raw materials into finished products and getting the products to the market.
- CIM is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organisational and personnel efficiency.

Types of production systems

- Job shop production

  Meaning: Job or unit production involves the manufacturing of a single complete unit as per the customer's order. This is a special order type of production. Each job or product is different from others and no repetition is involved.

  Three types of job production

  A small number of pieces produced once

  A small number of pieces produced intermittently when the need arises A

  small number of pieces produced periodically at known time intervals

- Batch production

  Meaning: In this type, the products are made in small batches and in large variety. Each batch contains identical items but every batch is different from the others.

  Three types of batch production are

  A batch produced only once.

  A batch produced repeatedly at irregular intervals, when the need arises.

  A batch produced periodically at known intervals, to satisfy continuous demand.

- Mass production

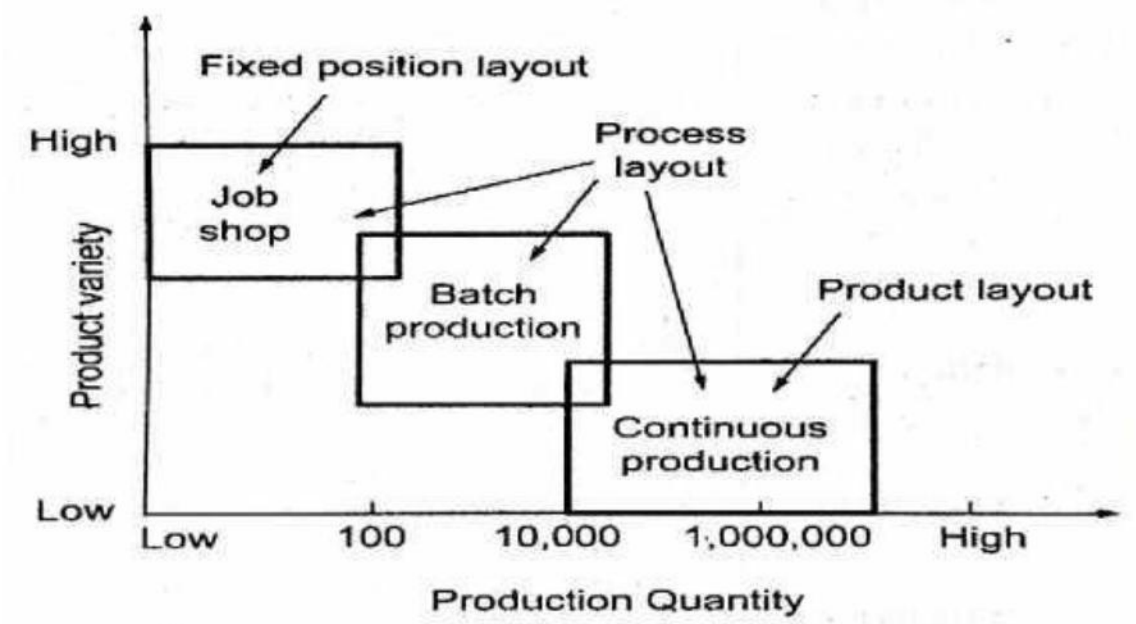
  Meaning: In this type of production, only one type of product or maximum 2 or 3 types are manufactured in large quantities. Standardisation of products, process, materials, machines and uninterrupted flow of materials are the basic features of this system. Mass production system offers economics of scale as the volume of output is large.

- Process or continuous production

  Meaning: This type of production is used for manufacture of those items whose demand is continuous and high. Here single raw material can be transformed into different kind of products at different stages of production processes. E.g., in processing of crude oil in refinery one gets kerosene, gasoline, etc., at different stage of production.

  The characteristics, merits and demerits of continuous production system are the same as that of the mass production system.

  Suitability: the industries like paper, textiles, cement, chemicals, automobiles, etc., are a few examples of continuous production industries.



Manufacturing Models and Metrics:

- Manufacturing metrics are used to quantitatively measure the performance of the production facility or a manufacturing company.
- Manufacturing metrics is a system of related measures that facilitates the quantification of some particular characteristics of production.

Why use manufacturing metrics?

- To track performance of the production system in successive periods.
- To determine the merits, and demerits of the potential new technologies and system.
- To compare alternative methods
- To make good decisions