Dr.M.Suresh M.E. Ph.D

Department of Robotics and Automation Engineering,

PSG College of Technology

COMPUTER INTEGRATED MANUFACTURING

19R046 COMPUTER INTEGRATED MANUFACTURING

THE MEANING AND SCOPE OF CIM : ***Introduction to CIM, definition of CIM, CIM wheel, evolution of CIM, benefits of CIM, Needs of CIM hardware, CIM software, Fundamentals of communications: Network topologies - the seven layers-OSI model, local area network (LAN), manufacturing automation protocol (MAP), CIM workstations.***

PRODUCT DESIGN : ***Needs of the market, design and engineering, the design process, computer-aided design (CAD), benefits of CAD, Geometric modeling: wire frame, Surface and solid modeling, Three-dimensional capabilities - principles of curve generation, representation of 3D surfaces, CAD/CAM workstations, Computer- aided engineering (CAE) - finite element technique.***

PRODUCTION PLANNING: Introduction, production planning and control –MRP I, MRP II and ERP History of Group Technology–role of G.T in CAD/CAM Integration –part families, classification and coding –DCLASS, MICLASS and OPTIZ coding systems –benefits of G.T – cellular manufacturing, Process planning - role of Process, planning in CAD/CAM Integration – approaches to computer aided process planning – variant approach and generative approaches

SHOP-FLOOR CONTROL: Automated data collection methods, Flexible Manufacturing Systems – components of FMS– types – FMS workstation – FMS layout- computer control systems – Reconfigurable manufacturing systems applications and benefits.

MANAGEMENT OF CIM : Role of management in CIM, cost justification, expert systems, participative management, Impact of CIM in industry, role of manufacturing engineers - CIM engineer and technologist, CIM technicians.

Text Books

1. Kant Vajpayee S , "Principles of Computer Integrated Manufacturing", PHI Learning Private Limited, New Delhi, 2010.
2. Mikell P Groover , "Automation, Production Systems and Computer Integrated Manufacturing", Pearson Education, 2016

References

1. Mikell P Groover and Emory ZimmersJr , "CAD/CAM", Prentice hall of India Pvt. Ltd, 1998.
2. Rao P N , "CAD/CAM Principles and Applications", Tata McGraw Hill Publications, 2007.
3. Radhakrishnan P, Subramanyam S and Raju V , "CAD/CAM/CIM", New Age International, 2008.
4. A.WilhelmScheer , "Computer Integrated Manufacturing:Towards the factory of the Future", Springer, Verlag Berlin Heidelberg, 1994.

Marks Distribution

Contact Hours			
L	**T**	**P**	**C**
3	**0**	**0**	**3**

Course assessment methods	Marks
Three monthly tests	30 marks
Assignment/Assignment Presentation/ Seminar	10 marks
Obj.test1/Mini project1 Ass.1	5 marks
Obj.test2/Mini project2 Ass.2	5 marks
Internal Assessment	**50 Marks**
End semester examination	**50 marks**

Course pre-requisites

- *Manufacturing Technology*
- *CNC Machines*
- *Automation System Design*

Expected outcome of the course

No.	Statement	PO/PSO	No. of Hours
CO1	Understand the fundamental concept of CIM	PO1, PO2, PO3, PO4, PO5, PO11, PSO1	7
CO2	Apply the geometric modeling techniques and engineering analysis for product design	PO1, PO2, PO3, PO4, PO5, PO11, PSO1	12
CO3	Plan the production process for automated industries using group technology, cellular manufacturing and process planning	PO1, PO2, PO3, PO4, PO5, PO11, PSO1	12
CO4	Apply the concept of a flexible manufacturing system for shop floor control	PO1, PO2, PO3, PO4, PO5, PO9, PO11, PSO1	7
CO5	Discover the role of management in computer integrated manufacturing	PO1, PO2, PO3, PO4, PO5, PO9, PO11, PSO1	7
		Total Hours	**45**

Course Outcome – Program Outcome Mapping

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	2	3	3	3						2		3	
CO2	2	2	3	3	3						2		3	
CO3	2	2	3	3	3						2		3	
CO4	2	2	3	3	3				2		2		3	
CO5	2	2	3	3	3				2		2		3	
19R046	**2**	**2**	**3**	**3**	**3**				**2**		**2**		**3**	

Mini project / Seminar

	Mini Project	Seminar
Activity	Group	Group
No. of students	3	2
Presentation	✓	✓
Presentation Date	Last working day	After 2nd CA
Presentation Venue	Department	Seminar hall
Report	Project report	PPT handouts
Demo	Final Product	nil

Assignment

- *Any of the topic related to CAD/CAM/CIM*
- *Written assignment submitted to course coordinator place / Softcopy of the assignment send to the course coordinator mail (msh.rae@psgtech.ac.in)*
- *Assignment may be a word file or pdf file or written document.*
- *Marks will be awarded based on the innovation, technology and involvement.*

Attendance

- *75% attendance must*
- *On duty will be accepted based on the situation and recommendation by respective tutor.*

Contact Hours

1	**Tuesday**	**04.20 – 05.10 PM**
2	**Thursday**	**10.30 – 11.20 AM**
3	**Friday**	**03.30 – 04.20 PM**

Hall: Y-202

THE MEANING AND SCOPE OF CIM

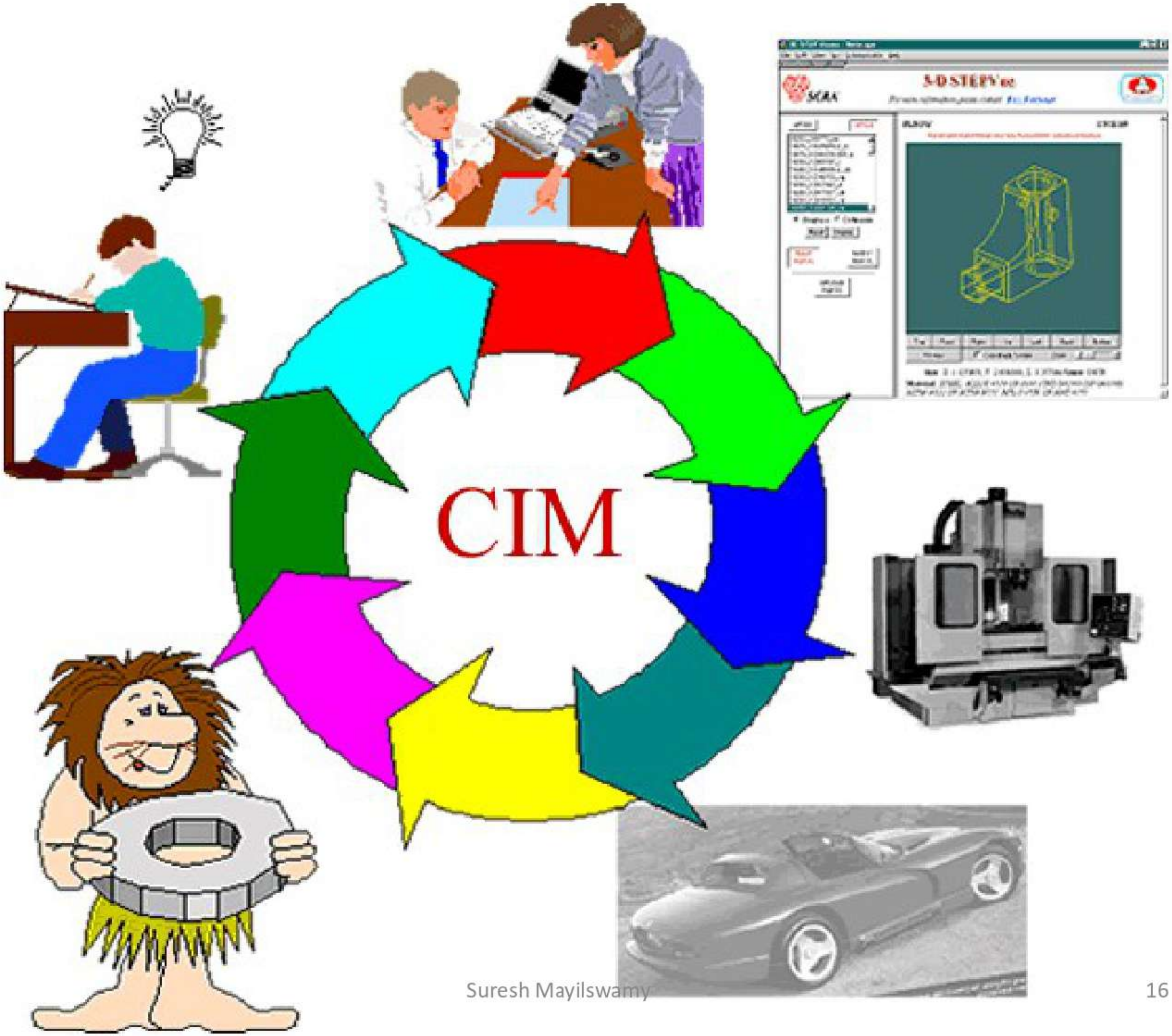
Introduction to CIM, definition of CIM, CIM wheel, evolution of CIM, benefits of CIM, Needs of CIM hardware, CIM software, Fundamentals of communications: Network topologies - the seven layers-OSI model, local area network (LAN), manufacturing automation protocol (MAP), CIM workstations.

Computer Integrated Manufacturing (CIM)

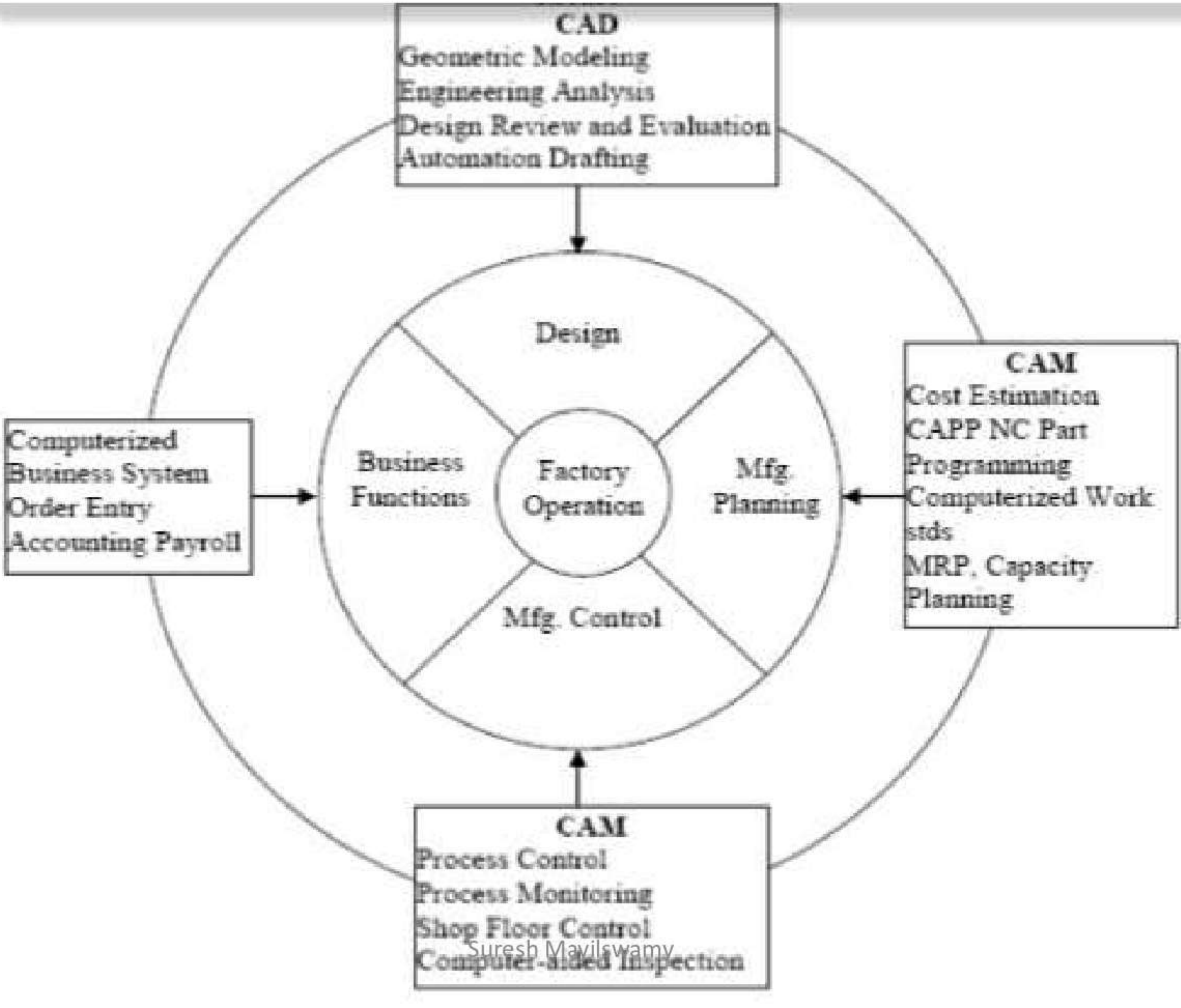
- CIM is the manufacturing approach of using computers to control the entire production process.

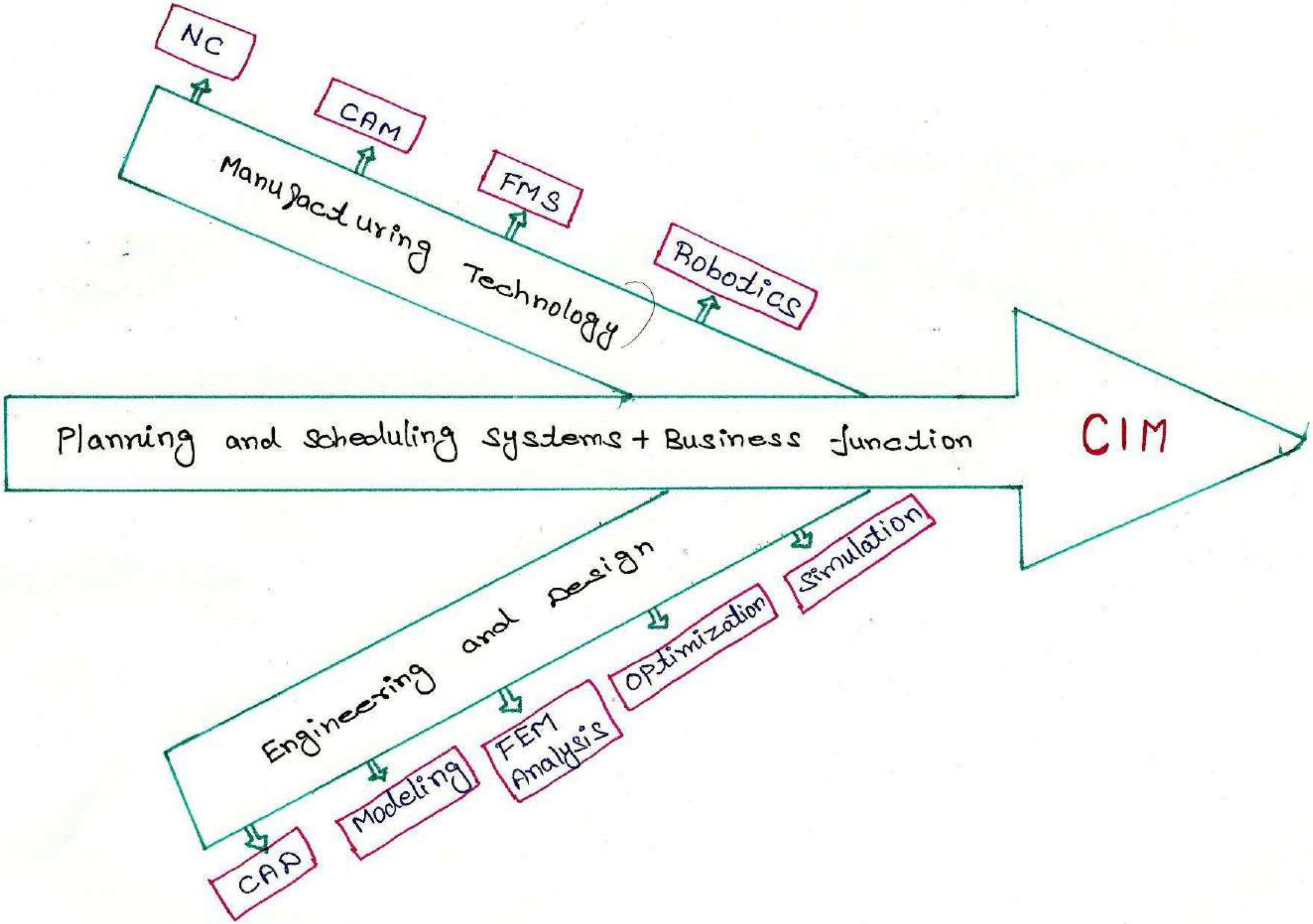
- CIM integration allows individual processes to exchange information with each other and initiate actions.

- CIM is both a method of manufacturing and the name of a computer automated system in which individual engineering, production, marketing and support functions of a manufacturing enterprise.

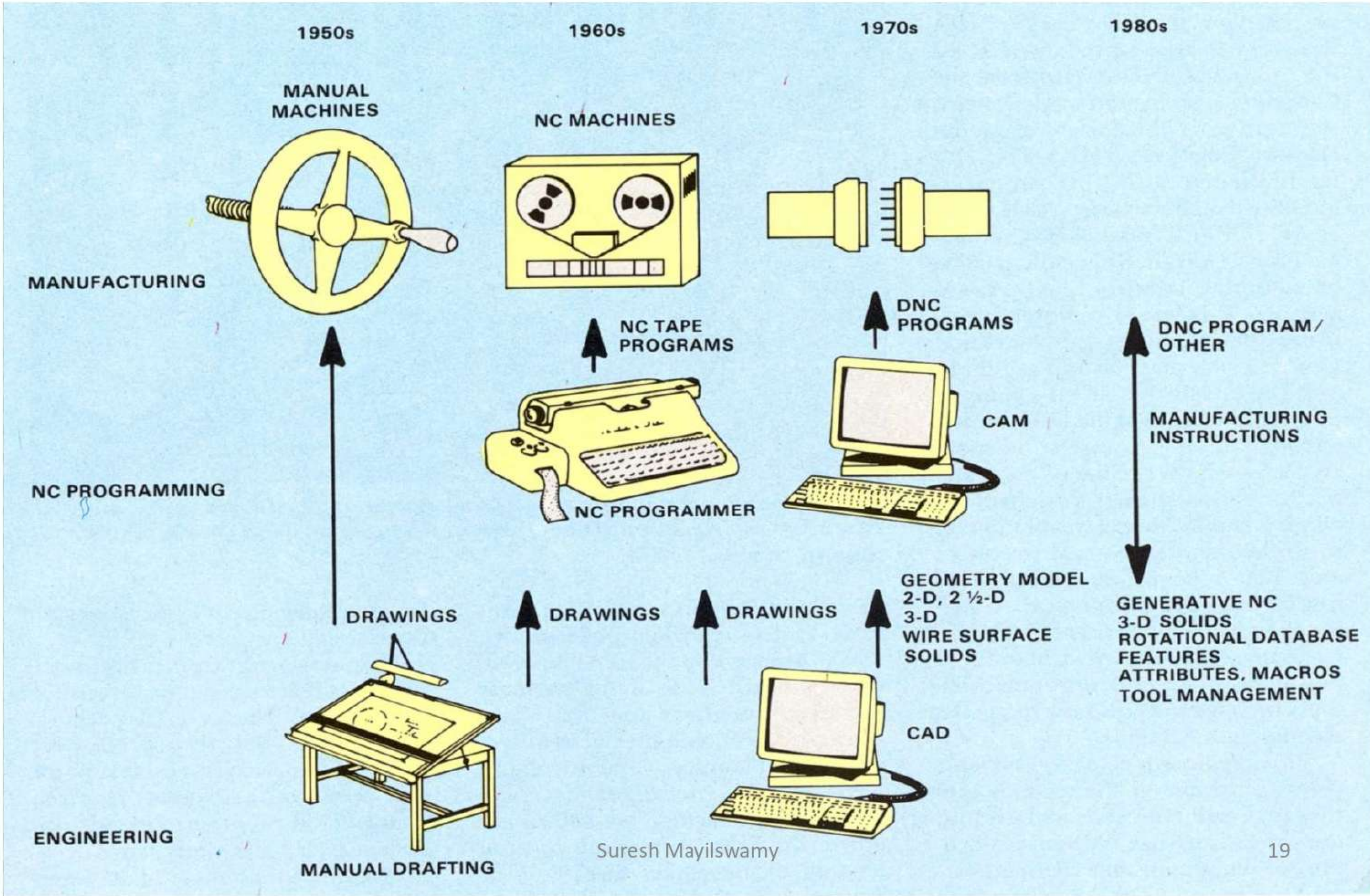

CIM

Computer Integrated Manufacturing Wheel




NC
CAM
FMS
Robotics
Manufacturing Technology
Planning and Scheduling systems + Business function
CIM
Engineering and Design
Simulation
Optimization
FEM Analysis
Modeling
CAD

Evolution of CAD/CAM and CIM



History of NC, CNC and DNC

- 1959 – MIT (Massachusetts Institute of Technology) announces Automatic Programmed Tools (APT) programming language.

- 1960 - Direct Numerical Control (DNC). This eliminates paper tape punch programs and allows programmers to send files directly to machine tools

- 1968 - Kearney & Trecker machine tool builders market first machining center

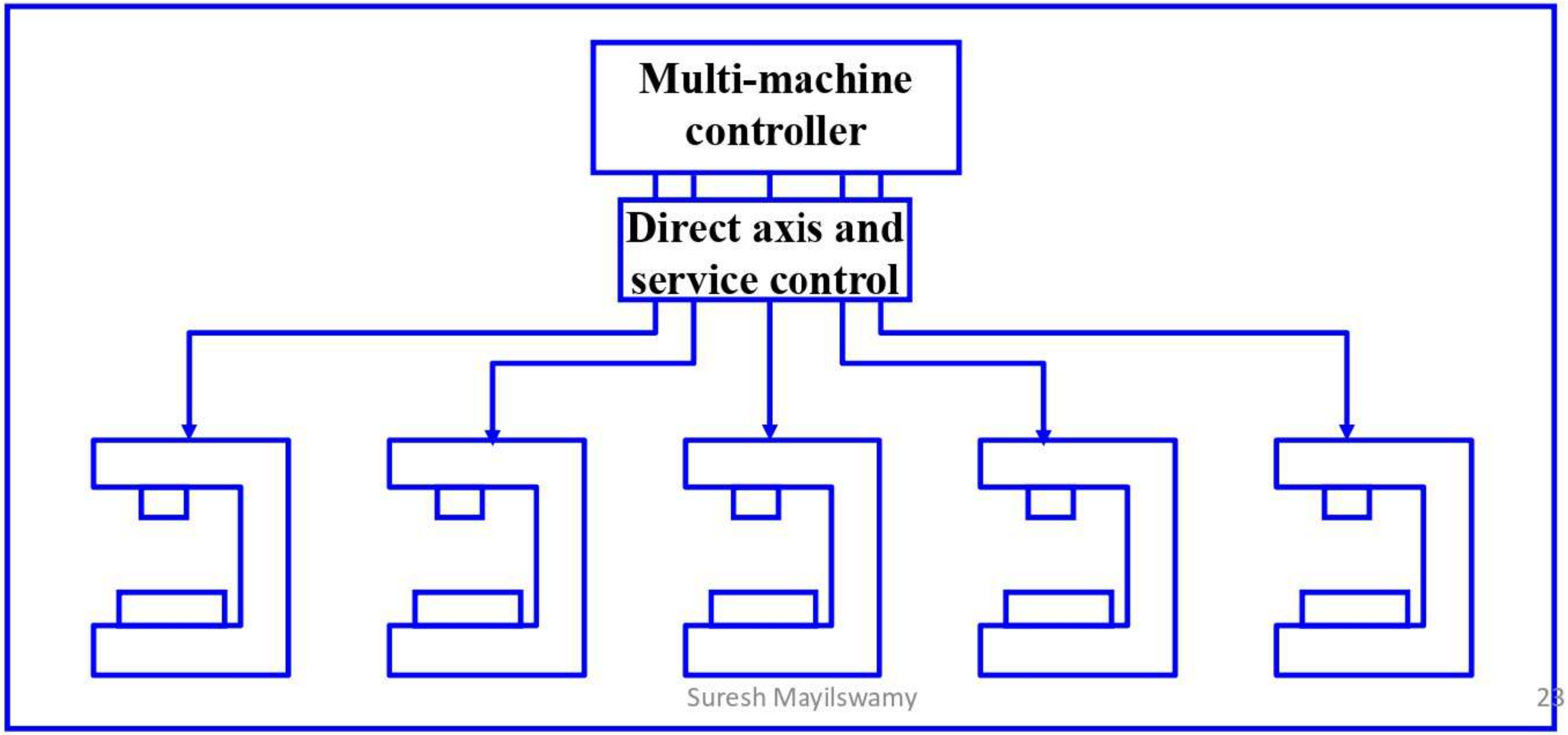
- 1970's - CNC machine tools & Distributed Numerical Control
- 1980's - Graphics based CAM systems introduced. Unix and PC based systems available.
- 1990's - Price drop in CNC technology
- 1997 - PC- Windows based "Open Modular Architecture Control (OMAC)" systems introduced.

DNC

- Direct numerical control (DNC) – control of multiple machine tools by a single (mainframe) computer through direct connection and in real time

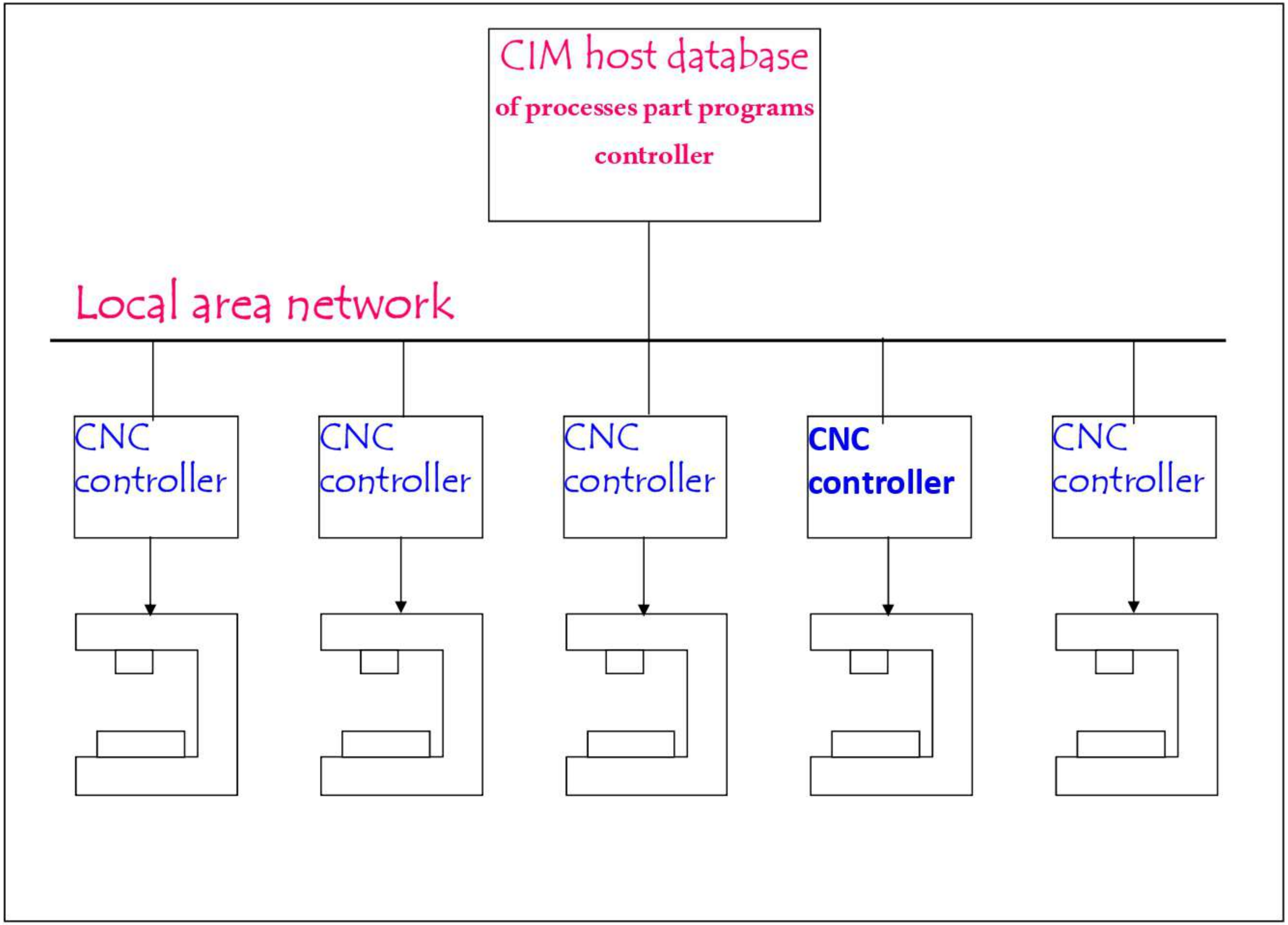
- Distributed numerical control (DNC) – network consisting of central computer connected to machine tool MCUs, which are CNC

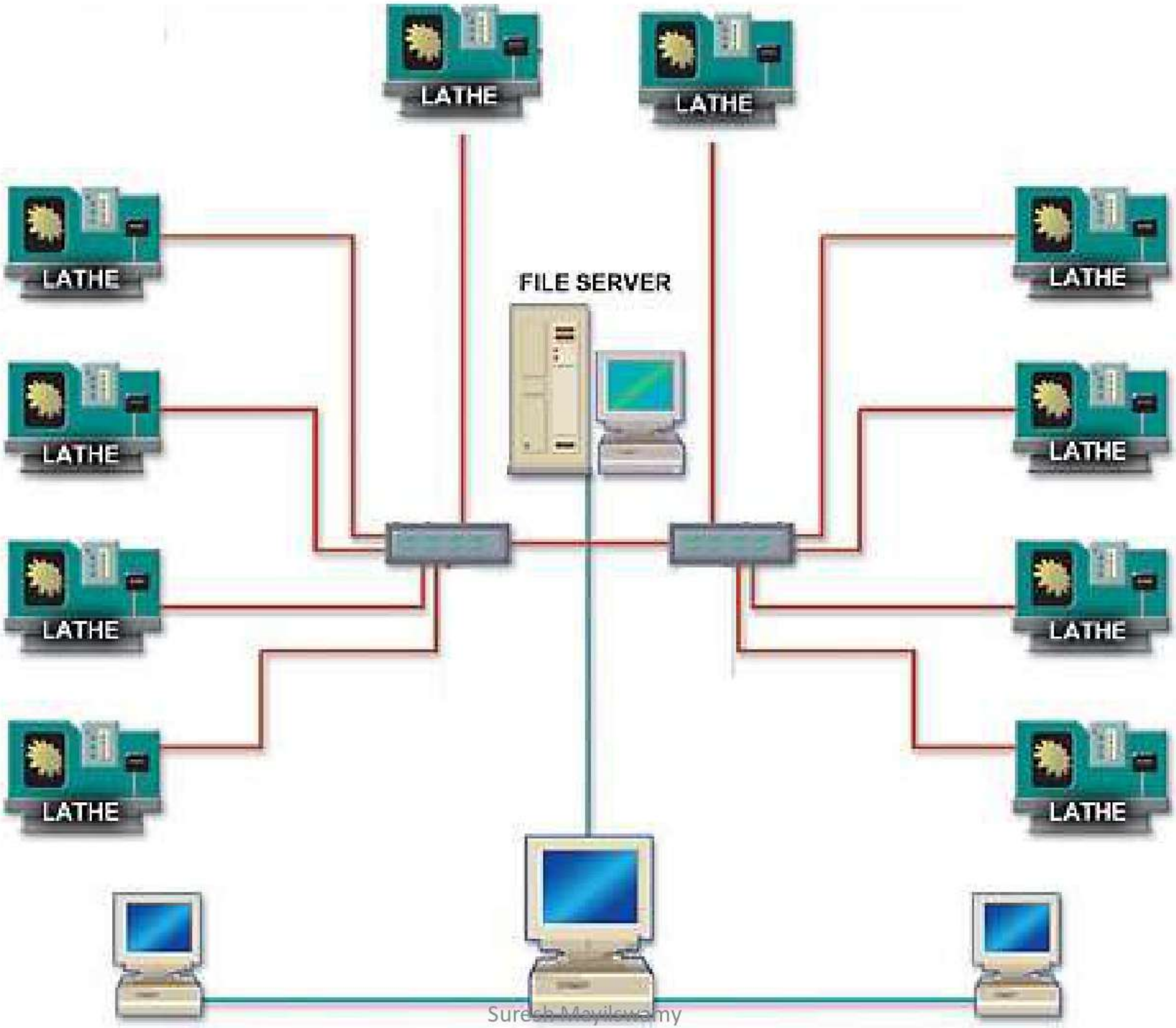
Direct Numerical control (DNC) can be defined as a set of NC machines that is connected to a main computer system to establish a direct interface between the DNC computer memory and the machine tools. The tape is not used in the DNC system; hence a central time-sharing computer is used.



Distributed Numerical Control

- Distributed NC is more advanced than DNC and is widely used in many current applications.
- The distributed NC uses a local area network but not like that in DNC.
- It has been indicated that the main difference between DNC and distributed NC is that because modern NC machines have CNC capability, they have memory and therefore computer programs can be downloaded into the memory of a CNC local computer, rather than one block at a time as in DNC systems.


CIM host database
of processes part programs
controller
Local area network
CNC controller
CNC controller
CNC controller
CNC controller
CNC controller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Manufacturing System

what is system.

A system has number of components, combined together to achieve a goal.

Manufacturing is conversion of raw material into final goods and services.

Any manufacturing organization can also be called as a Production system.

Manufacturing System

- There are 3 main components in a manufacturing system.

Components of Manufacturing System

- Production Machines
- Material Handling System
- Computer Control System
- Human Resources

Manufacturing System

- The manufacturing system can be seen as interdependent group of sub-systems.

- The sub-systems are related to its successor and predecessor to achieve a predetermined goal.

Manufacturing System

- **Internal Environment** is a combination of marketing, accounts and finance activities.

- Marketing and production have a very sensitive relationship.

- **External Environment** is formed of Customers, Competitors, Suppliers, Labor Unions, Stock holders and etc.

Conventional Manufacturing System

It is simple or Normal Production System and here the Cycle Time is Fixed

Using conventional (manual handling) machines

Under Normal Working Environment

Advanced Manufacturing System (AMS)

- **Definition**

AMS is an automated production system of people, machines and tools for planning and control of production processes, Including the procurement of raw materials, parts or components and the shipment & service of finished products.

Advanced Manufacturing System

Objectives

AMS Shows wide range of outcomes

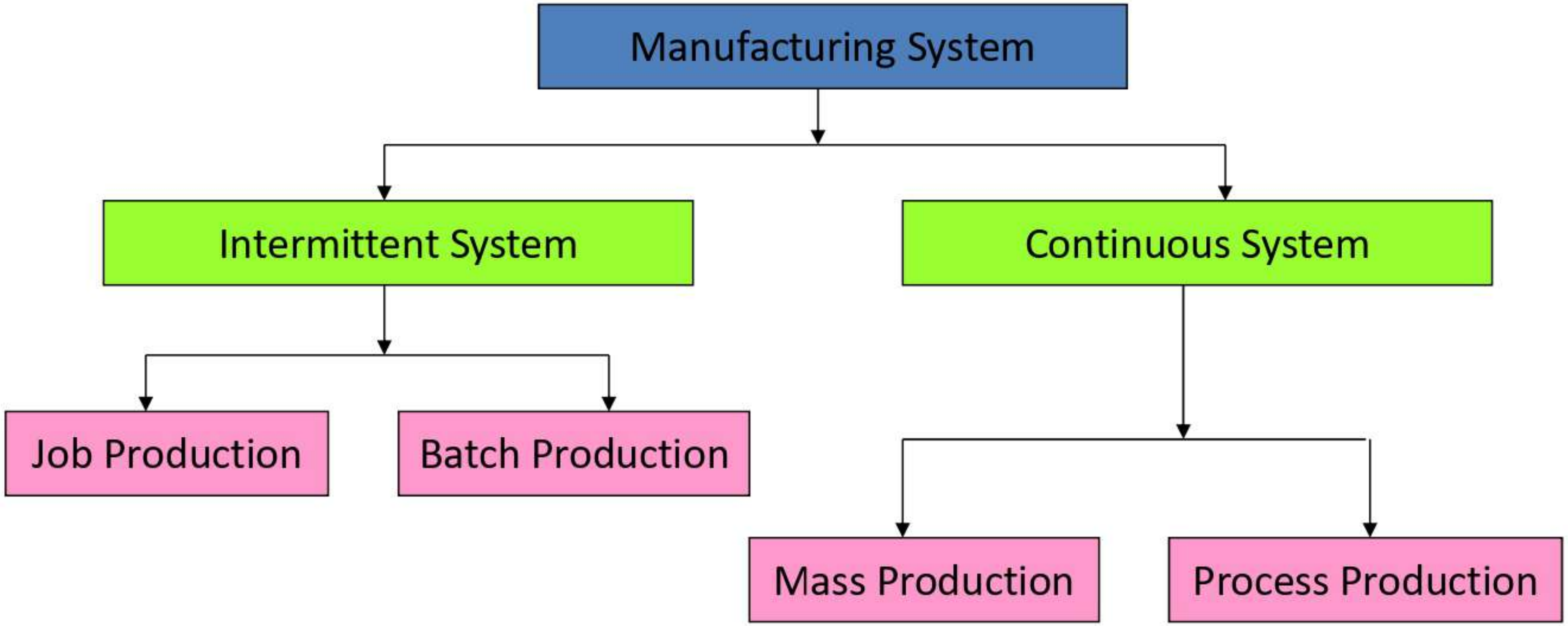
- Cope up with fragmenting Mass Market
- Shorter Production time
- Produce customized products at mass production cost

Advanced Manufacturing System

AMS refers to the Family Technologies that includes

* Computer Assisted Design and Engineering Systems
* Manufacturing Resource Planning Systems
* Automated Materials Planning Systems
* Industrial Robotics
* Computer Numerical Control Machines (CNC)
* Flexible manufacturing systems (FMS)

Types of Manufacturing System



Intermittent System

- As the name suggests, it is a non-continuous manufacturing system.
- This system requires regular adjustments.
- In this, goods are prepared to fulfill orders.
- The production facilities are flexible.
- It is basically used for manufacturing things of non-regular inputs and design of product.

Characteristics of Intermittent System

1 Items are produced for order.

2 Production process is flexible.

3 Capital investment may be moderate.

4 Change in location is easy.

5 Accuracy is low.

6 Less security of jobs.

7 Requires highly skilled staff.

JOB PRODUCTION

- It is production of one complete unit by a single or multiple operators.
- The example of job production are, bridge building, dam, ship making.
- The whole project is one operation.
- This system requires highly skilled labors and huge capital investments.
- Future demand of the same is not assured.

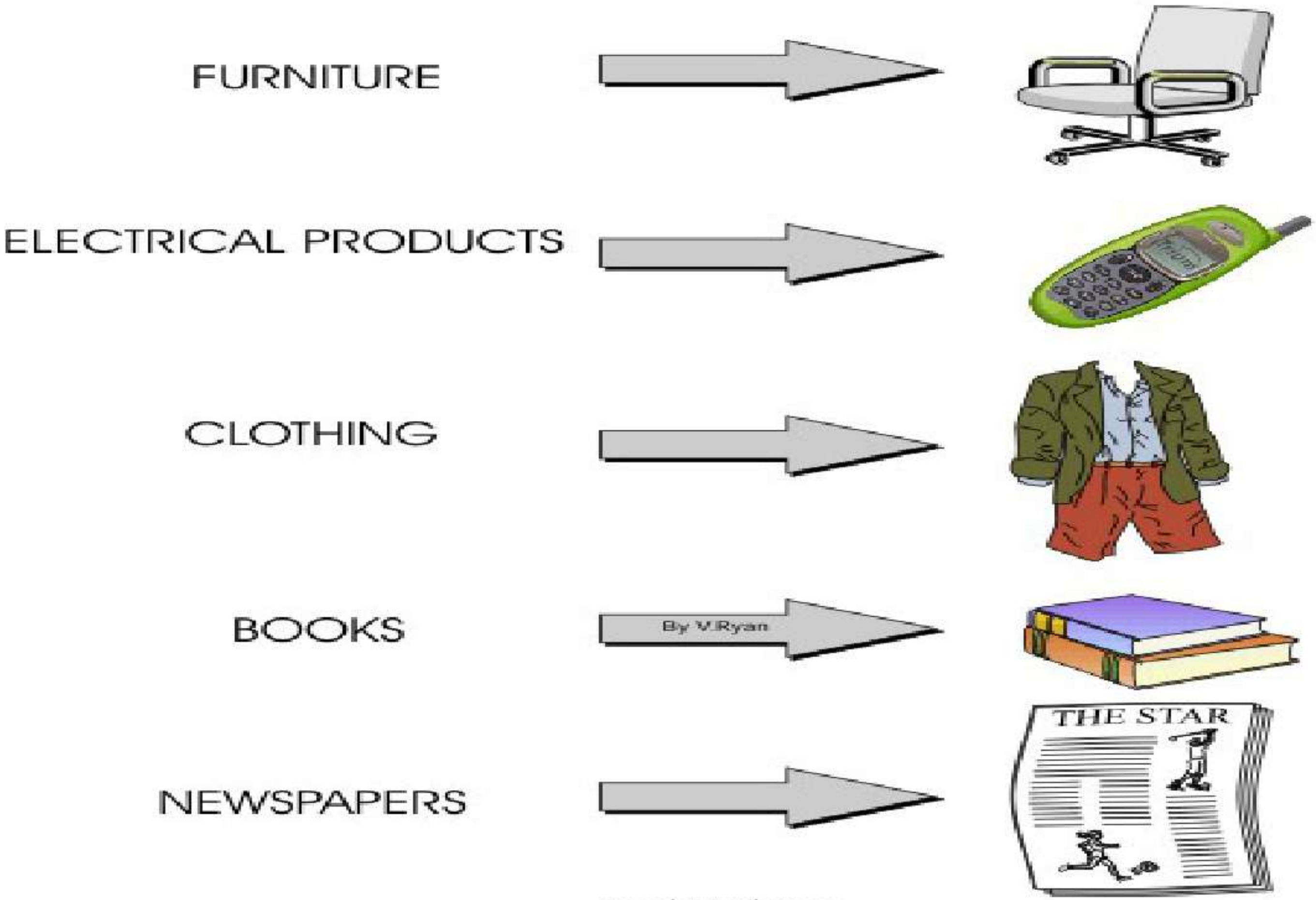
JOB PRODUCTION

- Aircraft mfg. ship mfg.

BATCH PRODUCTION

- It is an extension of Job production system.
- Here the work can be divided into number of operations and activities.
- After the work for the batch is over, the machine is ready for another batch of similar (not same) kind of manufacturing.
- This requires high amount of planning.
- Example:- Printing press, chemical products.

Batch Production



Continuous System

- The items are produced for stocks.
- A rough estimation of sales forecast is made before carrying out the production.
- Here, the inputs are of standardized nature, with set line of production.
- The production is in single flow and very low or no WIP storage is required.
- It is further divided into Mass and process system of manufacturing.

Continuous System

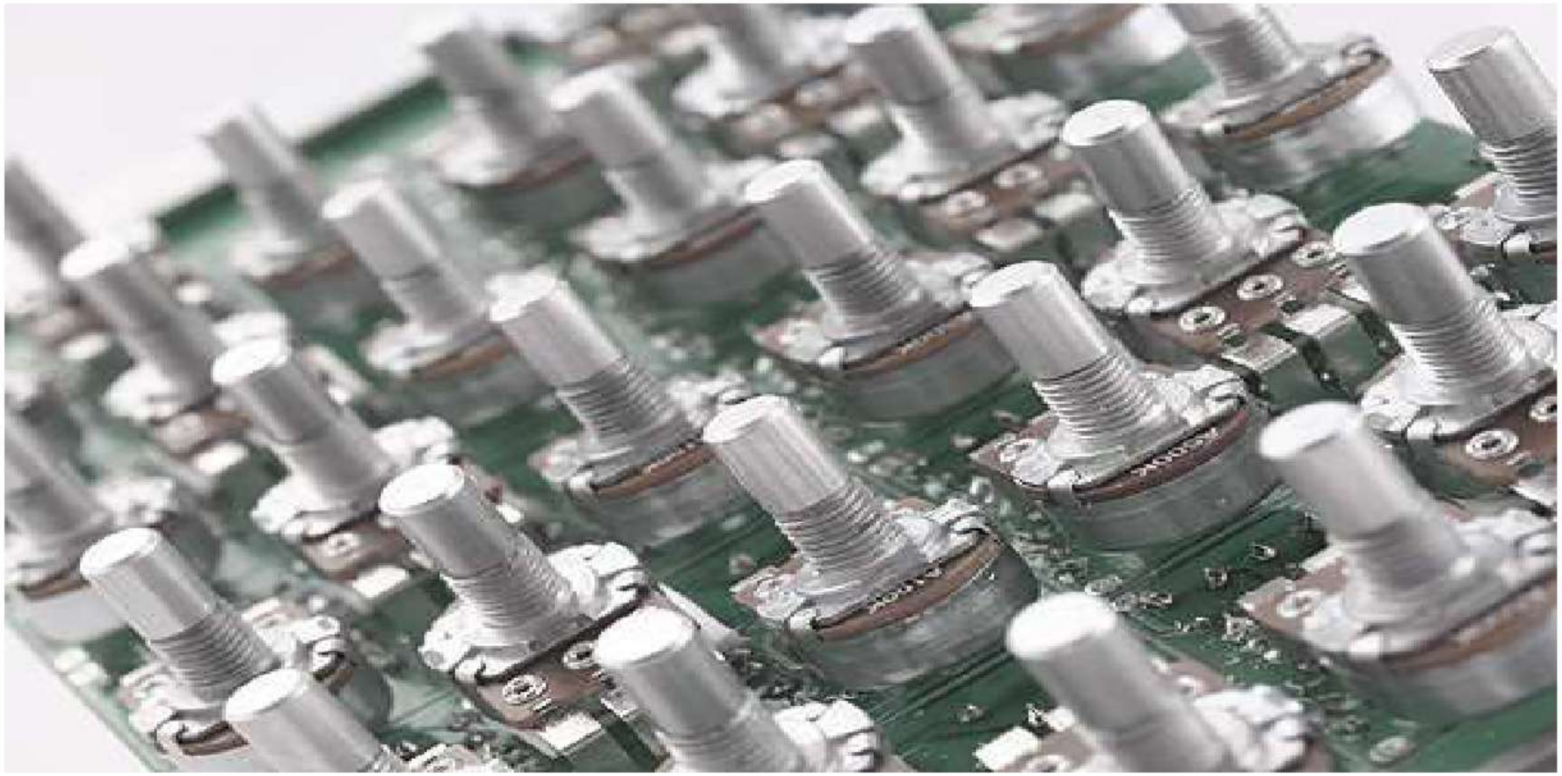
Characteristics of Continuous System

1. Same product is produced continuously.
2. Large scale of production is done.
3. Planning & Control operations are easy.
4. Per unit cost of production is low.
5. More security of Jobs.
6. Storage is required only at limited place.
7. Accuracy is high.

Mass Production

- Standard product is a basic characteristic of this manufacturing system.
- The goods are produced to stock rather than consumer orders.
- The system is made to produce only one type of a product at a time.
- It is basically used to make components and assemblies of an item.
- Example: Spark plugs.

Mass production



Process Production

- It is similar to Mass production.
- This system is used to manufacture the goods which are in continuous high demand.
- The goods can either be a raw material for many or itself a thing of high demand.
- The whole process is made to manufacture a specific product. Only a minor adjustment can be done in case of emergency.
- Ex. Oils, Petroleum products, plastics, etc.

Process Production
Petrochemical plant

Limitations of Intermittent system

1 Planning and control operations are complicated and tedious.

2 Per unit cost is high.

3 Less security of jobs.

4 Requires highly skilled staff.

5 Storage is required at each operation.

6 Accuracy is low.

7 Equipment is used for limited time.

Limitations of Continuous System

1 Only a particular type of product is produced.

2 Capital investment is high

3 Requires better co-ordination of activity

4 Change in location is difficult.

Applications

Depends on

- Type of production
- Variety of production
- Volume of production

Network Topologies

Networking

Computer network

A collection of computing devices connected in order to communicate and share resources

Connections between computing devices can be physical using wires or cables or wireless using radio waves or infrared signals.

Networking

Node (host)

Any device on a network

Data transfer rate (bandwidth)

The speed with which data is moved from one place to another on a network

Simple Physical Topologies

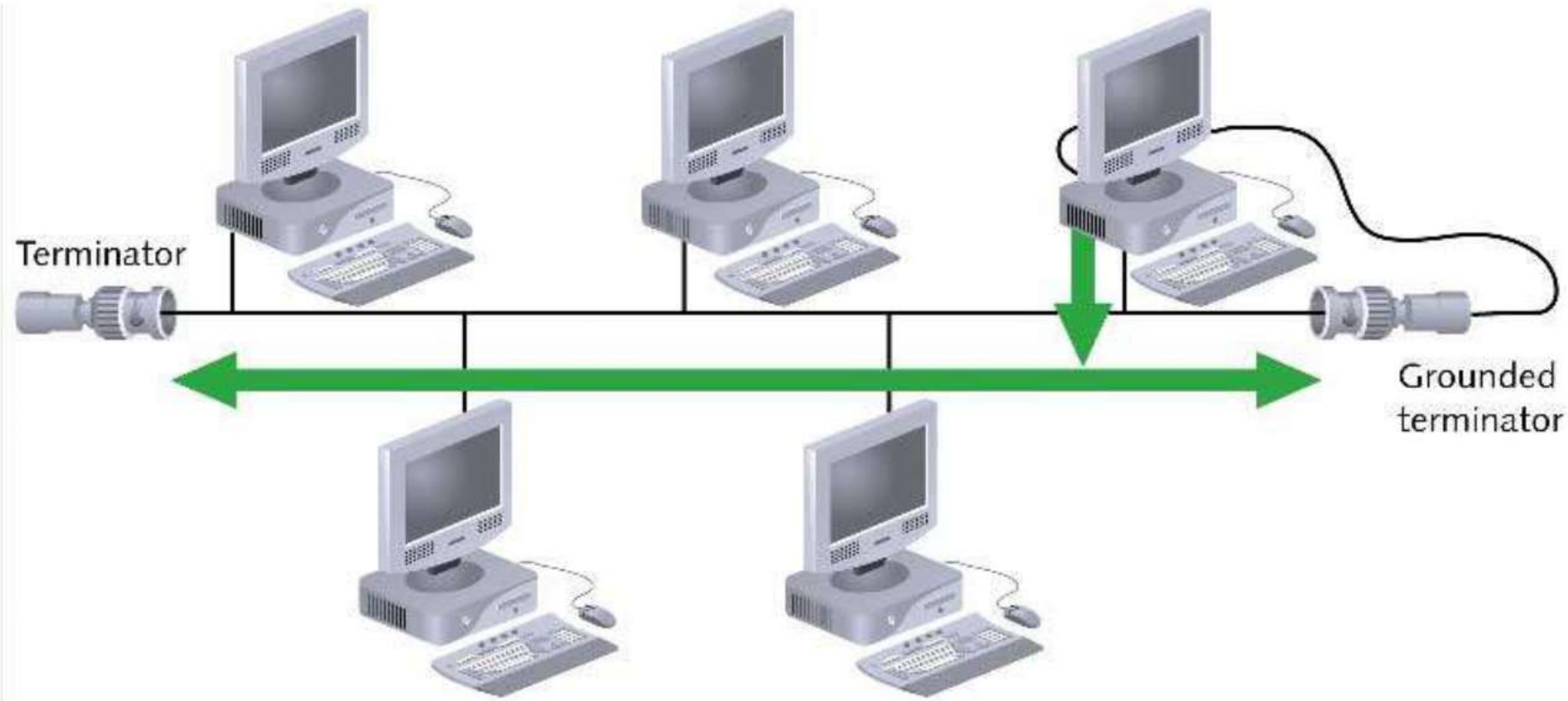
- Physical topology: physical layout of nodes on a network
- Four fundamental shapes:
  - Bus
  - Ring
  - Star
  - Mesh
- May create hybrid topologies
- Topology integral to type of network, cabling infrastructure, and transmission media used

Why we need a topology?

Choosing one topology over another can impact :

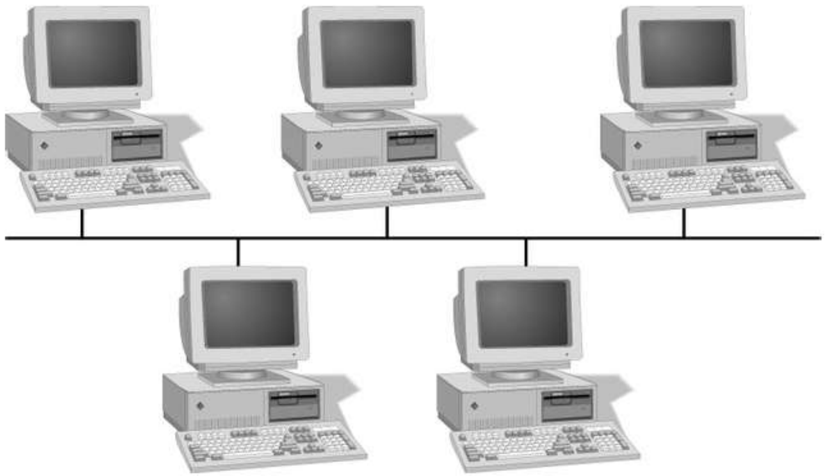
- type of equipment the network needs
- capabilities of the equipment
- network’s growth
- way a network is managed

Bus



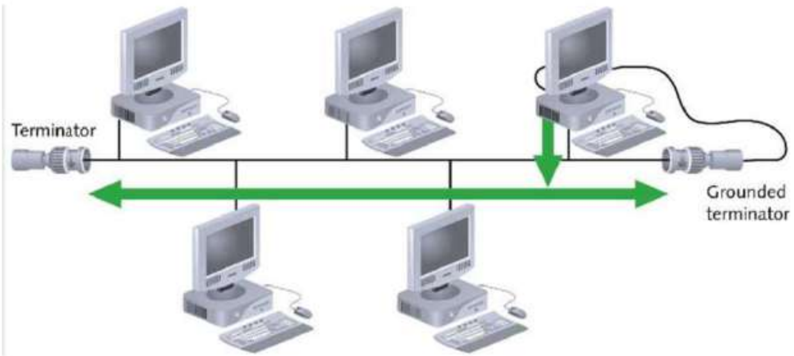
Simple Physical Topologies

- A **Bus topology** consists of a single cable—called a **backbone**— connecting all nodes on a network without intervening connectivity devices



Bus (continued)

- Devices share responsibility for getting data from one point to another
- Terminators stop signals after reaching end of wire
  - Prevent signal bounce
- Inexpensive, not very scalable
- Difficult to troubleshoot, not fault-tolerant



Bus

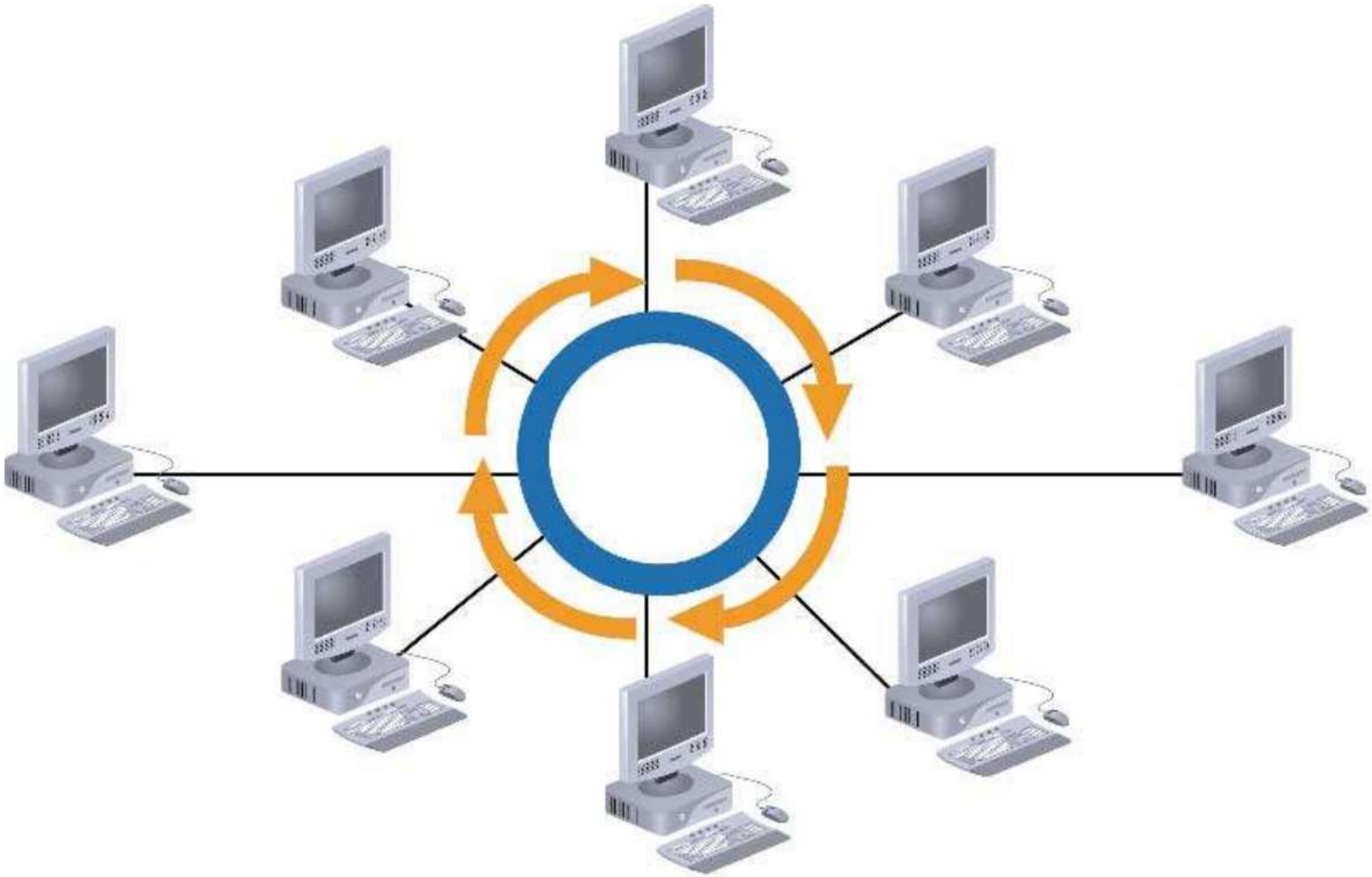
Advantages

- Works well for small networks
- Easy to install
- Relatively inexpensive to implement

Disadvantage

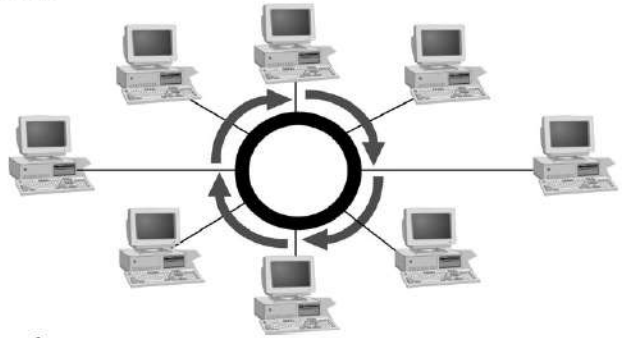
- Management costs can be high
- Network disruption when computers are added or removed
- A break in the cable will prevent all systems from accessing the network.
- Difficult to troubleshoot

Ring



Simple Physical Topologies

- Ring topology
  - Each node is connected to the two nearest nodes so the entire network forms a circle
  - One method for passing data on ring networks is **token passing**
  - Data travels around the network
  - Traffic flows in one direction
  - Slow performance
  - One workstation goes down; whole network goes down
  - Network is highly dependent



Ring

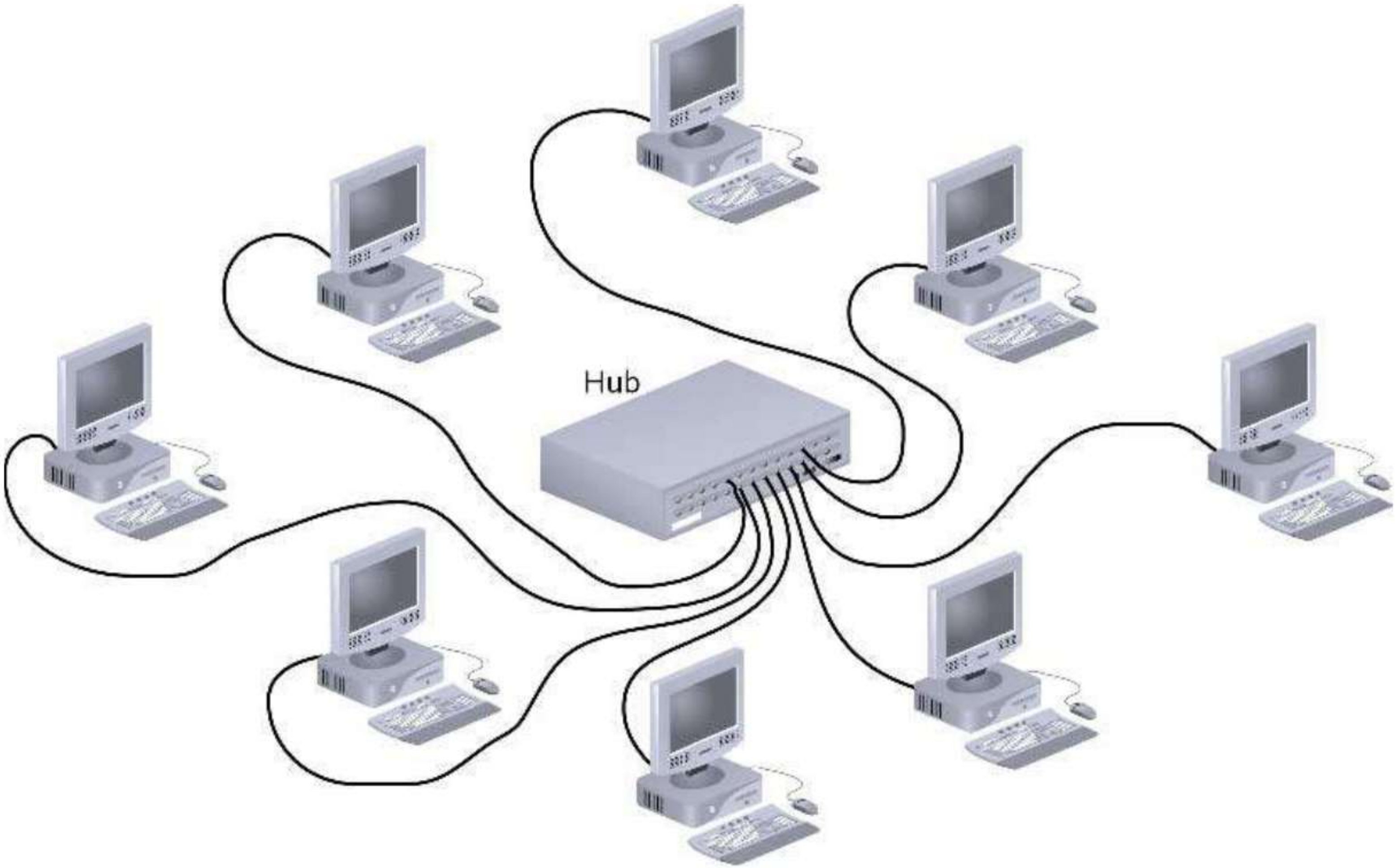
Advantages

- Cable faults are easily located, making troubleshooting easier
- Ring networks are moderately easy to install

Disadvantage

- Expensive
- Requires more cable and network equipment at the start
- Expansion to the network can cause network disruption
- A single break in the cable can disrupt the entire network

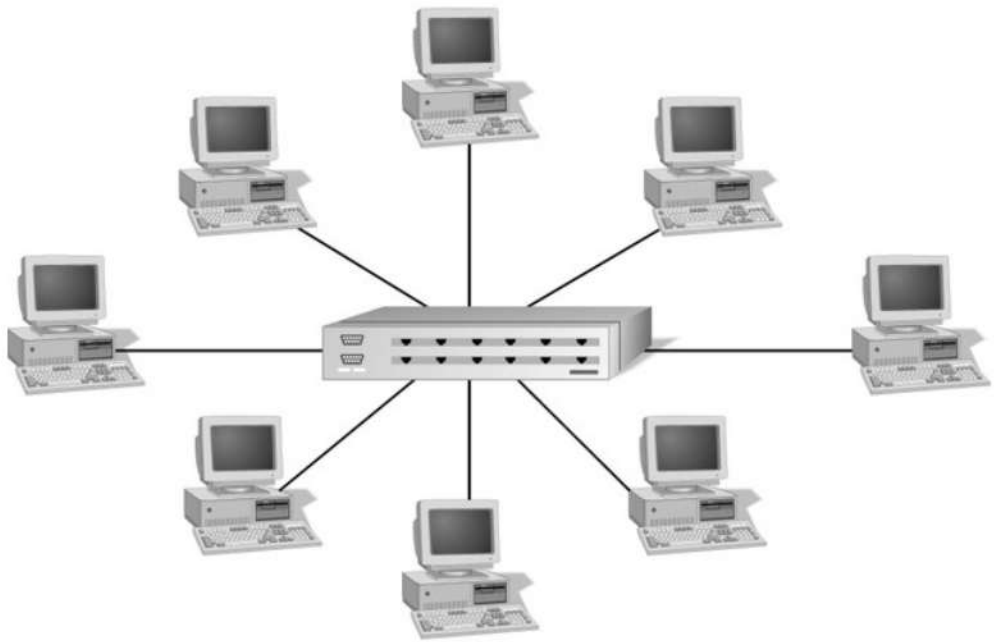
Star



Simple Physical Topologies

Star topology

– Every node on the network is connected through a central device called **hub or switch**.



Star (continued)

- Any single cable connects only two devices
  - Cabling problems affect two nodes at most
- Requires more cabling than ring or bus networks
  - More fault-tolerant
- Easily moved, isolated, or interconnected with other networks
  - Scalable
- Supports max of 1024 addressable nodes on logical network

Star

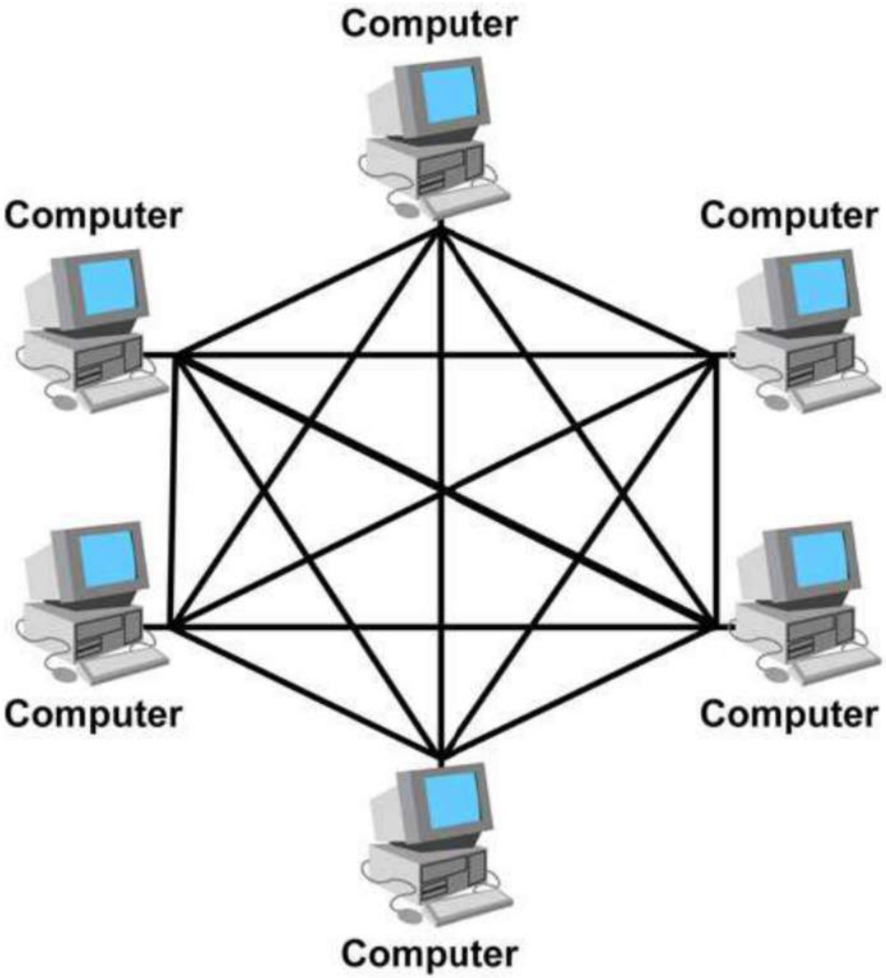
Advantages

- Good option for modern networks
- Low startup costs
- Easy to manage
- Offers opportunities for expansion
- Most popular topology in use; wide variety of equipment available

Disadvantage

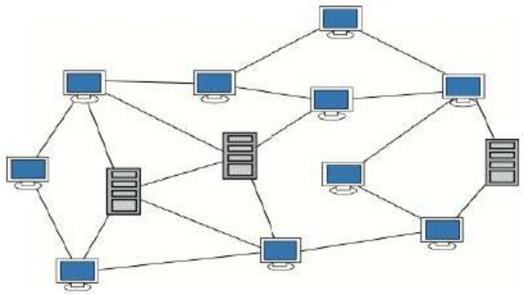
- Hub is a single point of failure
- Requires more cable than the bus

Mesh



Simple Physical Topologies

- Mesh Topology: Each computer connects to every other.
- High level of redundancy.
- Rarely used.
  - Wiring is very complicated
  - Cabling cost is high
  - Troubleshooting a failed cable is tricky
  - A variation hybrid mesh – create point to point
- connection between specific network devices, often
- seen in WAN implementation.



Mesh

Advantages

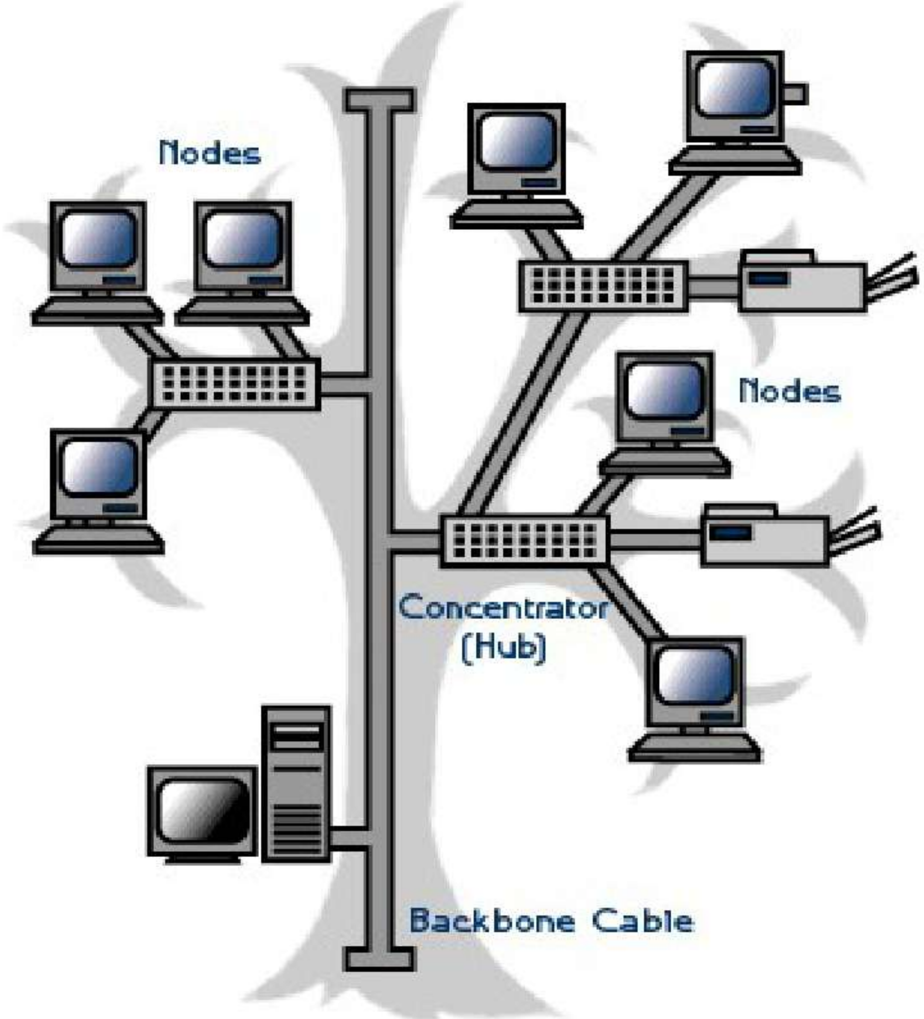
- Robust
- There is the advantage of privacy or security
- The network can be expanded without disruption to current uses
- Point to point links make fault identification and fault isolation easy

Disadvantage

- Requires more cable than the other LAN topologies
- Complicated implementation
  - Installation and reconnection are difficult.
  - Sheer bulk of wiring can be greater than the available space can accommodate
  - Expensive

Hybrid Physical Topologies

- One example of **Hybrid Topology is Tree topology**
- **Tree topology** is a combination of Bus and Star topology.
- It consists of groups of star-configured workstations connected to a linear bus backbone cable.
- If the backbone line breaks, the entire segment goes down
- An example of this network could be cable TV technology



Choosing a Topology

- **BUS**
  - network is small
  - network will not be frequently reconfigured
  - least expensive solution is required
  - network is not expected to grow much
- **STAR**
  - it must be easy to add/remove PCs
  - it must be easy to troubleshoot
  - network is large
  - network is expected to grow in the future
- **RING**
  - network must operate reasonably under heavy load
  - higher speed network is required
  - network will not be frequently reconfigured

Open Systems Interconnection (OSI) Reference Model

Packet Switching

Packet

A unit of data sent across a network

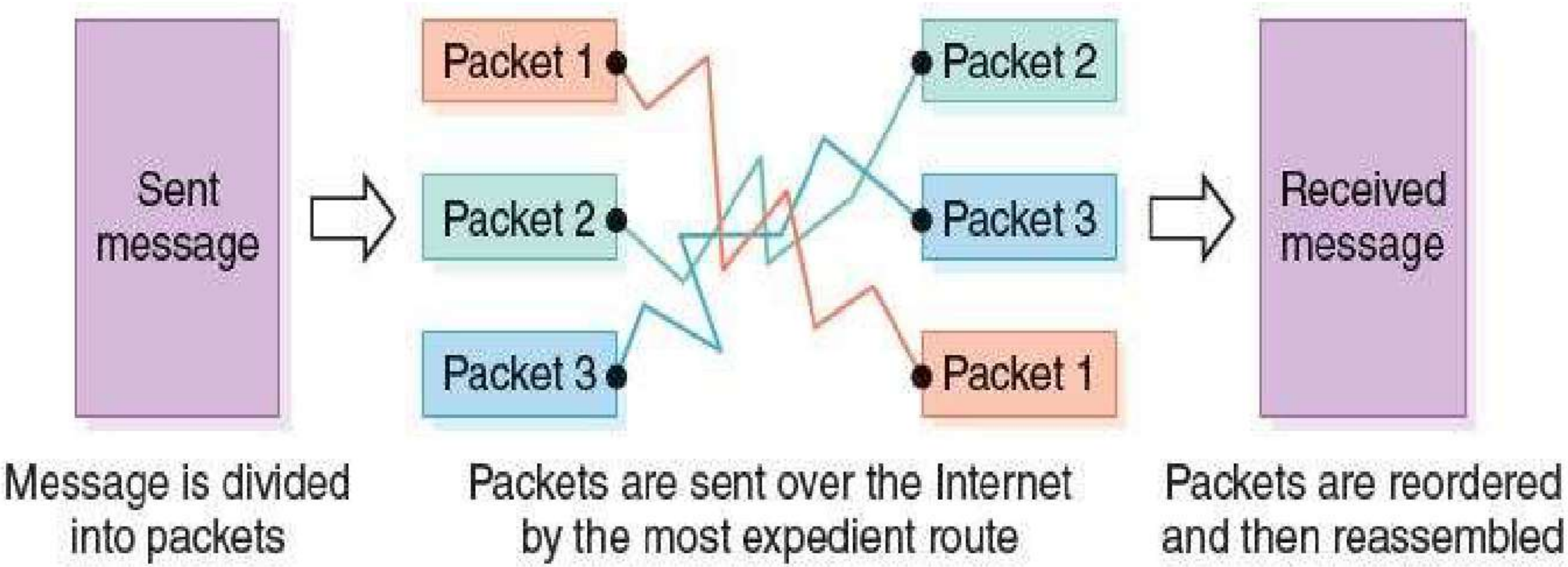
Router

A network device that directs a packet between networks toward its final destination

Packet switching

Messages are divided into fixed-sized, numbered packets; packets are individually routed to their destination, then reassembled

Packet Switching



Layered Tasks

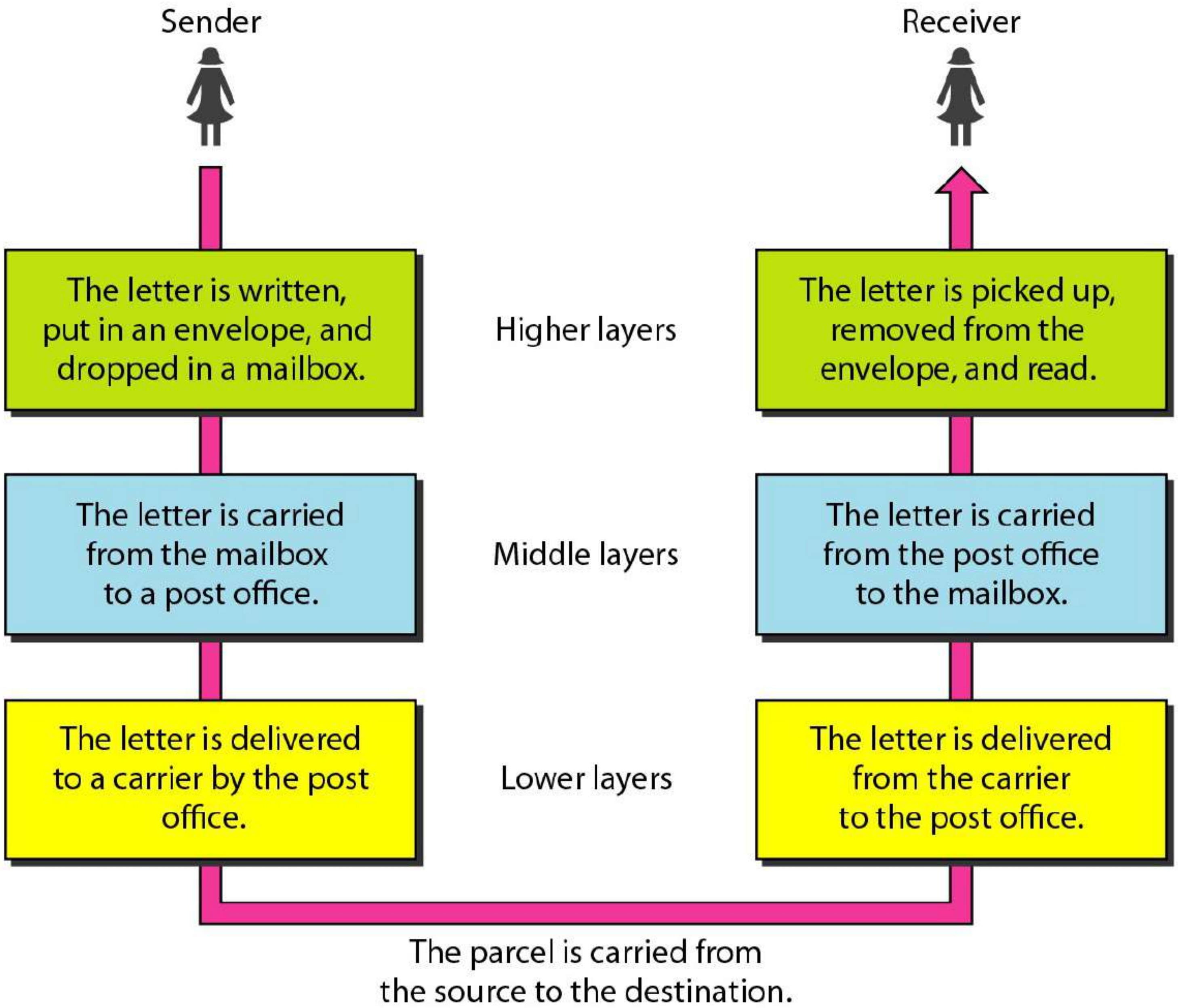
We use the concept of layers in our daily life. As an example, let us consider two friends who communicate through postal mail. The process of sending a letter to a friend would be complex if there were no services available from the post office.

Communication Requirements

Sender, Receiver, and Carrier

Hierarchy

Tasks involved in sending a letter



Open Systems

A logical progression...

Proprietary system

A system that uses technologies kept private by a particular commercial vendor

Interoperability

The ability of software and hardware on multiple machines and from multiple commercial vendors to communicate

Open systems

Systems based on a common model of network architecture and a suite of protocols used in its implementation

Open Systems – 7 Layers

Number	Layer
7	Application layer
6	Presentation layer
5	Session layer
4	Transport layer
3	Network layer
2	Data Link layer
1	Physical layer

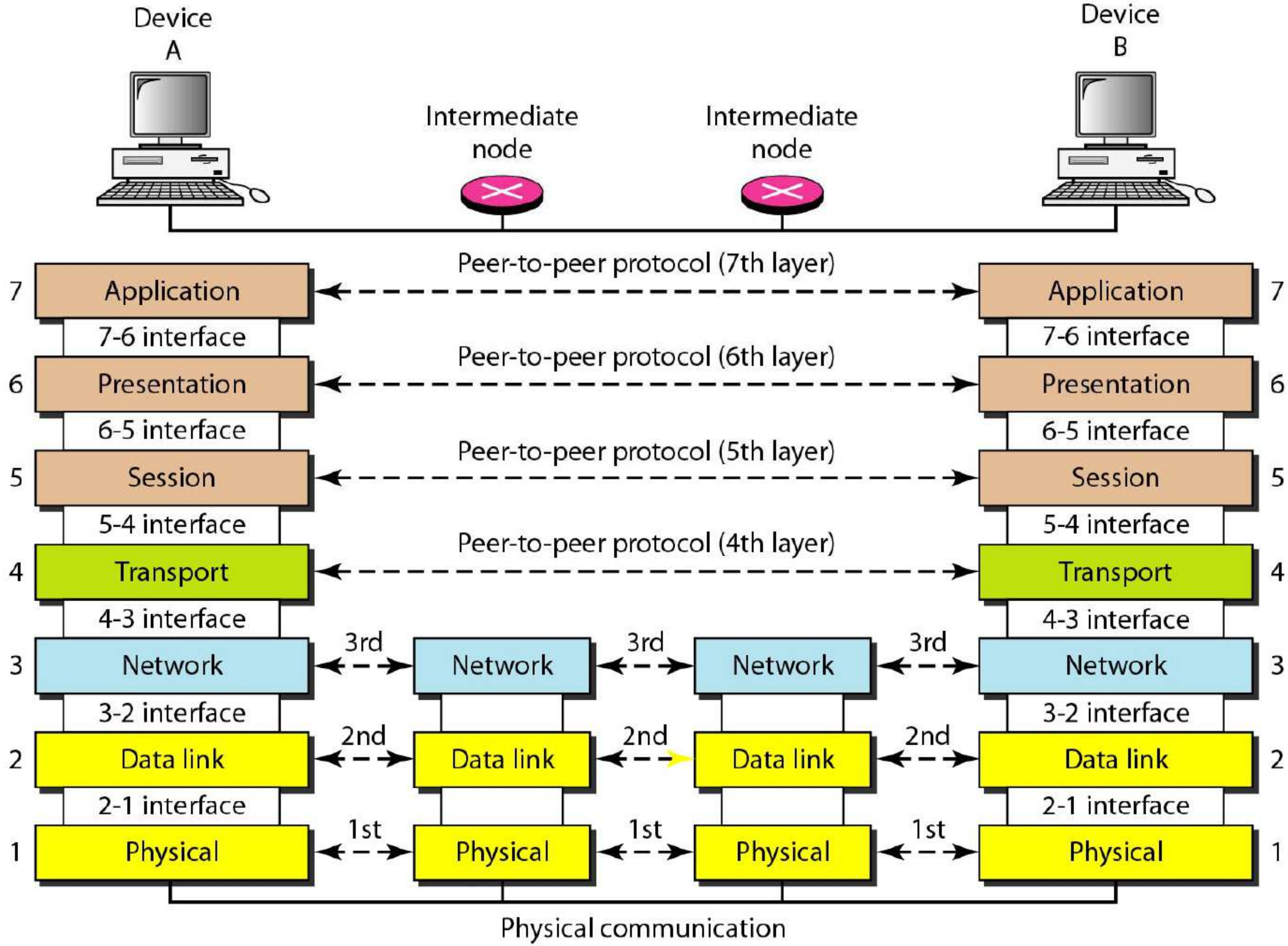
Open Systems Interconnection Reference Model

A seven-layer logical break down of network interaction to facilitate communication standards

Each layer deals with a particular aspect of network communication

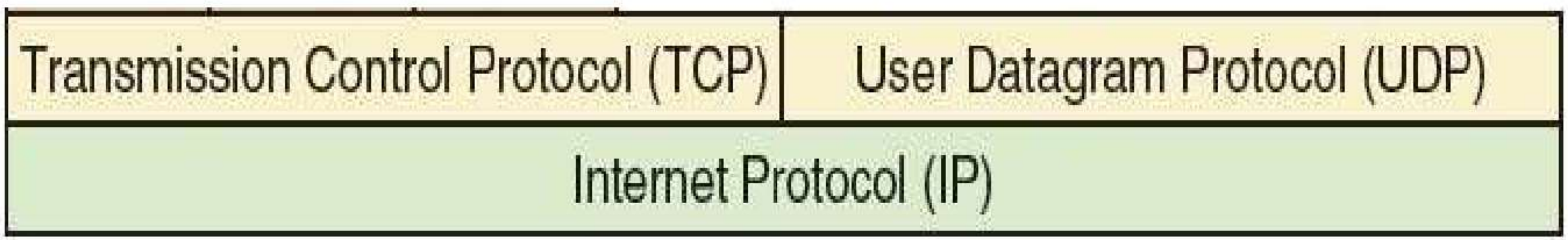
OSI Model			
	Data unit	Layer	Function
Host layers	Data	7. Application	Network process to application, data base access and email etc
		6. Presentation	Data representation, data compression, encryption and decryption
		5. Session	Interhost communication, file transfer
	Segments	4. Transport	Manages transmission packets, Reassembles in correct order to get the original message
Media layers	Packet	3. Network	Path determination, routing of data and logical addressing
	Frame	2. Data Link	Physical addressing
	Bit	1. Physical	Media, signal and binary transmission

The interaction between layers in the OSI mode



Network Protocols

- Network protocols are layered such that each one relies on the protocols that underlie it
- Sometimes referred to as a **protocol stack**



TCP/IP

Transmission Control Protocol (TCP)

Software that breaks messages into packets, hands them off to the IP software for delivery, and then orders and reassembles the packets at their destination

Internet Protocol (IP)

Software that deals with the routing of packets through the interconnected networks to their final destination

TCP/IP

User Datagram Protocol (UDP)

An alternative to TCP that is faster but less reliable

Ping

A program used to test whether a particular network computer is active and reachable

Trace route

A program that shows the route a packet takes across the Internet

Manufacturing Automation Protocol (MAP)

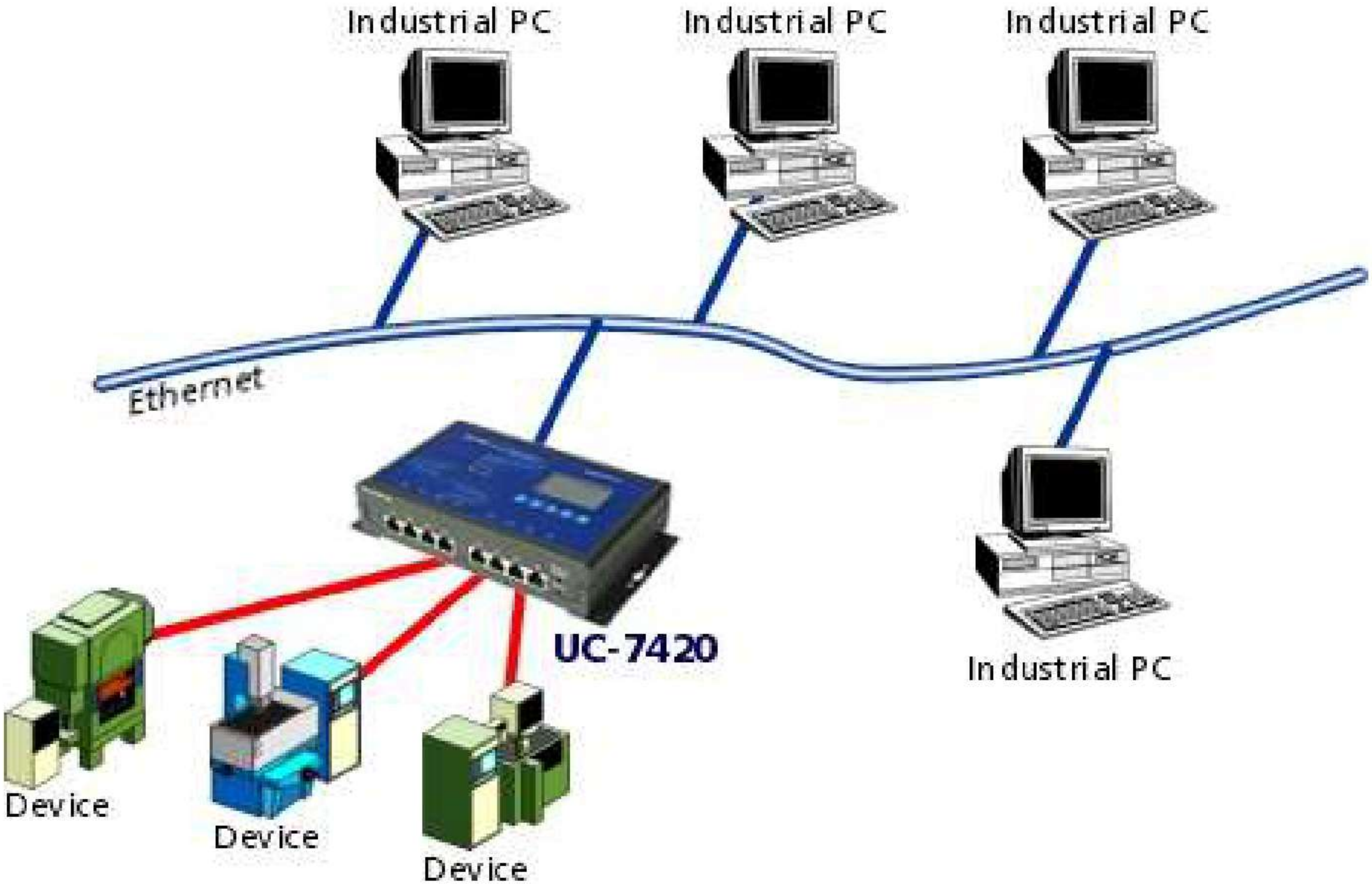
- Manufacturing Automation Protocol was a computer network standard for interconnection of devices from multiple manufacturers.
- In 1980 General Motors developed MAP. A communication network consists of a number of components such as hardware, software and media.

Manufacturing Automation Protocol

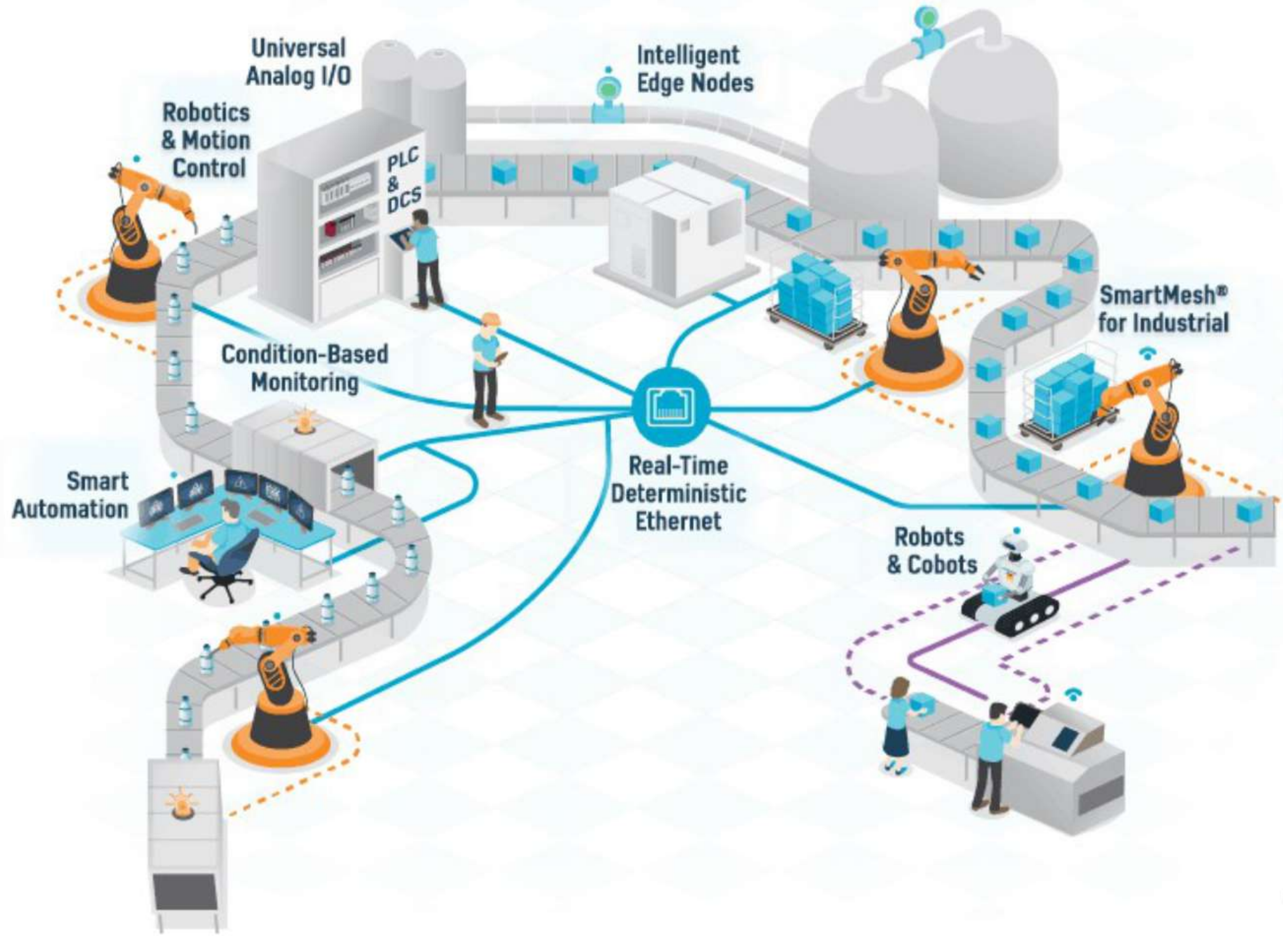
- Protocols in the network system are a set of instructions to exchange the information between two devices. A protocol specifies the message format and the rules for interpreting and reacting to message.

Manufacturing Automation Protocol

- An initiative by general Motors of US has resulted in the selection of a set of protocols, all based on ISO standards, to achieve open system interconnection with in an automated manufacturing plant. The resulting protocols are known as MAP.


Industrial PC
Industrial PC
Industrial PC
Ethernet
UC-7420
Industrial PC
Device
Device
Device

CIM Workstations



PRODUCT DESIGN

Design and engineering, design for manufacturability, computer-aided design (CAD), computer graphics, CAD hardware and software, CAD/CAM workstations. Computer-aided engineering (CAE). Data formats, CAD-CAM integration. Reverse engineering.

CAD Definition

- Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design.

Need for CAD/CAM

- To increase productivity of the designer
- To improve quality of the design
- To improve communications
- To create a manufacturing database
- To create and test tool paths and optimize them
- To help in production scheduling and MRP models
- To have effective shop floor control

Design Process

*A **design process** is a systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve or satisfy human needs or wants and to narrow down the possible solutions to one final choice.*

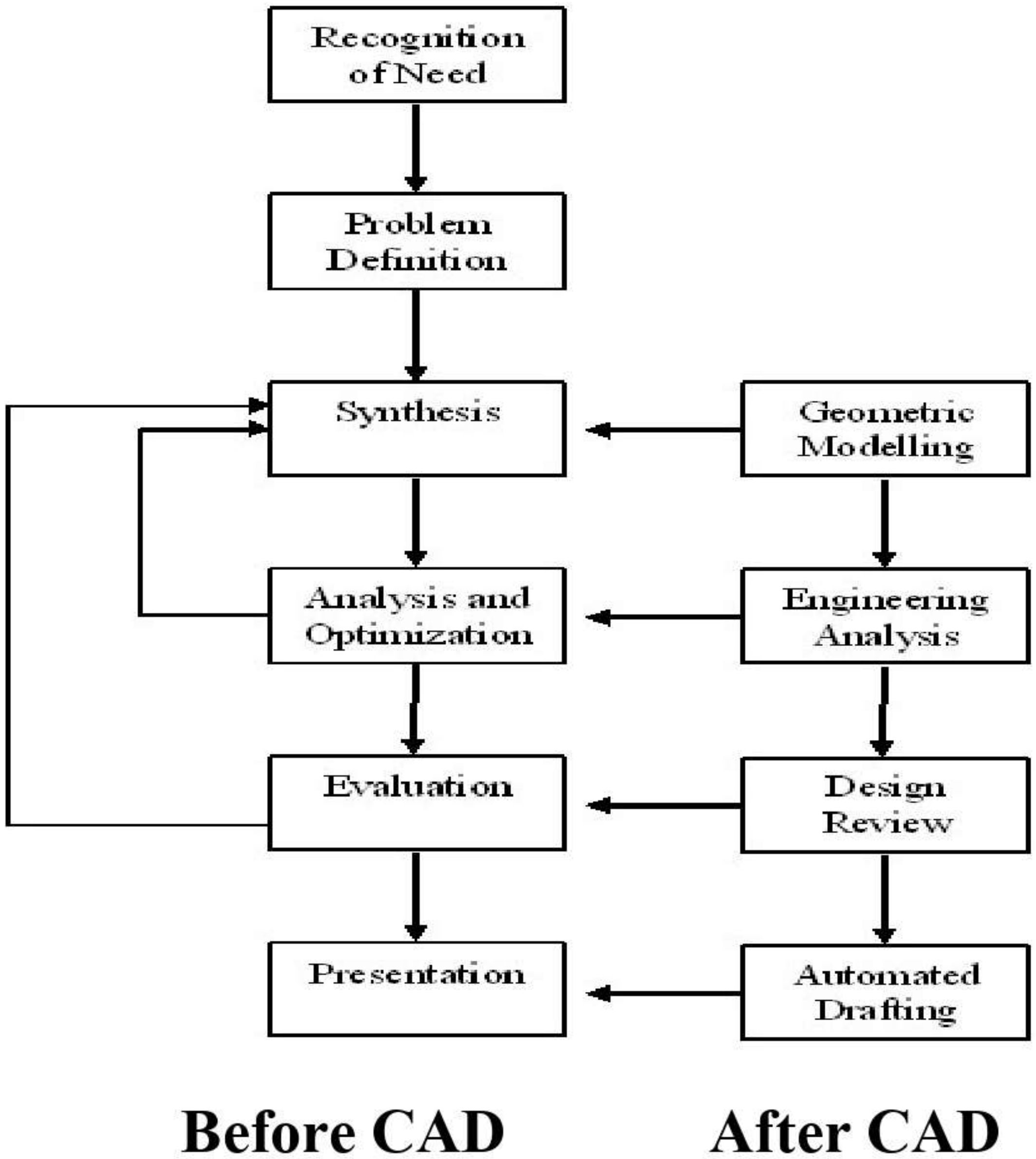
– ITEA *Standards for Technological Literacy*

Design Process

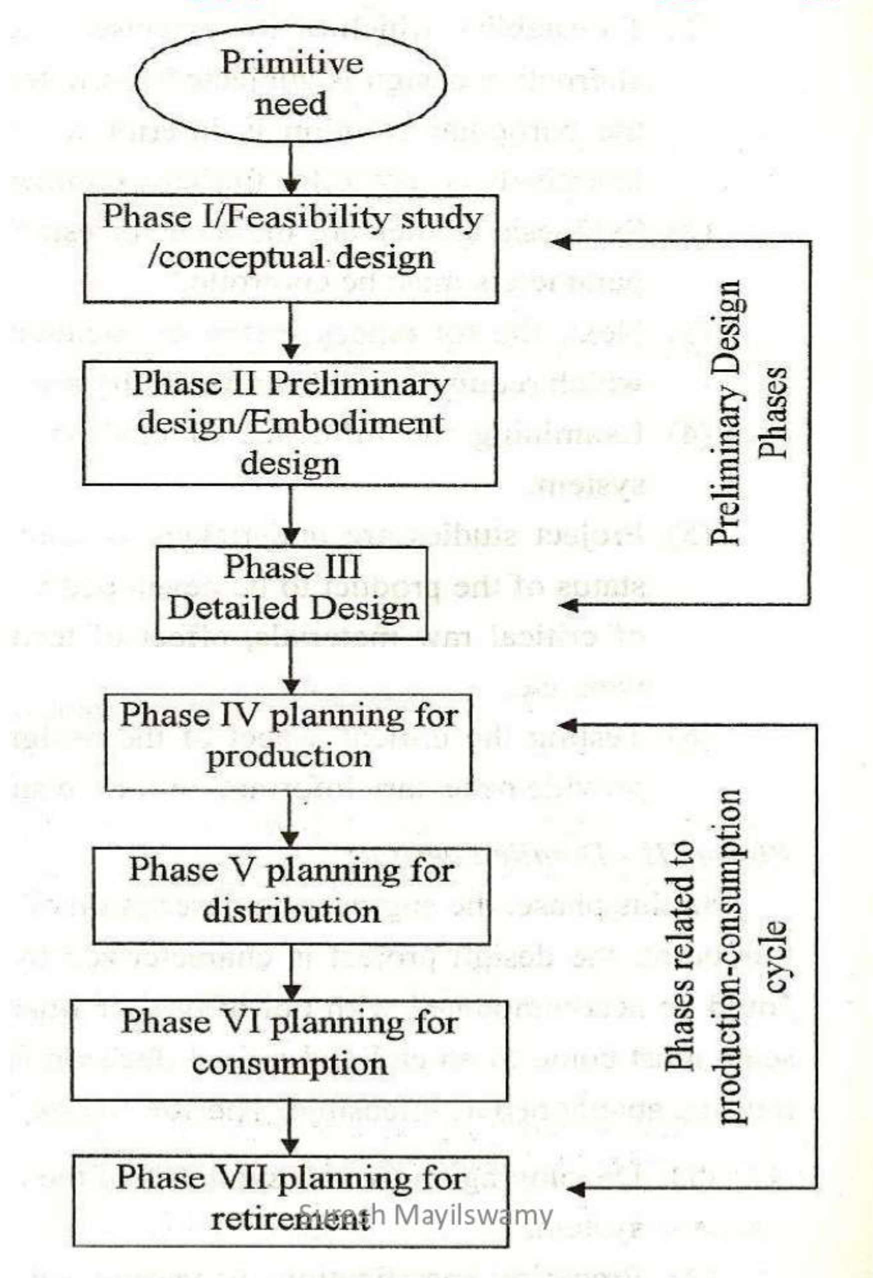
There are several design processes used in the different technical fields.

- Shighely model
- Pahl and Beitz model
- Ohsuga model
- Earle model

The Design Process : Then and Now



Morphology of design process



Phase I – Feasibility study

- To determine whether the need is original, whether it is valid.
- To explore the design problem generated by the need and to identify its elements such as working parameters, constraints and major design criteria.
- To collect a number of feasible solutions to the problem
- Sort out the potentially useful solution out of the feasible ones.

Phase II – Preliminary design

- To establish which of the proposed alternatives is the best design concept.
- Combination studies are initiated for establishing the range of major design
- The tolerances in the characteristics of major components and critical materials are investigated and properly fit into the system.
- Examining the influence of environmental, internal and external constituents on the system.
- Project studies are undertaken to study whether the design will meet customers need.
- Testing the critical aspect of the design in order to validate the design concept and to provide necessary information for the subsequent phases.

Phase III – Detailed design

- Developing an overall synthesis of the design project and preparing a major layout of the system.
- Preparing specifications of various sub systems and components on the basis of master layout.
- Deciding various dimensions of components.
- Initiating the experiment design by constructing models to check untried ideas.
- Testing the prototype and obtaining the necessary feedback information based on the redesign and improvements are carried until well proven design is accomplished.

Phase IV – Planning the production process

- Preparing the process planning sheets for every parts, subassembly and final assembly.
- Design of tool and fixture.
- Planning to acquire new production or plant facilities.
- Planning for quality control system.
- Planning for production control.
- Planning for information flow feedback system.

Phase V – Planning for distribution

- Design the packaging of the product.
- Planning the ware housing system.

Phase VI – Planning for consumption

- Design for maintenance
- Design for safety
- Design for convenience of use
- Design for aesthetic features
- Design for adequate duration of services

Phase VII – Planning for retirement

- In a design phase clearly mentioned the usage and life time of the product.
- Designing for several levels of use so that when the service life is reached, higher level of use is terminated and the product can be used less.

Benefits of CAD

- Improved engineering productivity
- Shorter lead times
- Reduced engineering component requirements
- Customer modifications are easier to make
- Faster response to requests for quotations
- Minimized human errors

Benefits of CAD

- Improved accuracy of design
- In analysis, easier recognition of component interactions
- Provides better functional analysis to reduce prototype testing
- Assistance in preparation of documentation
- Designs have more standardization

Benefits of CAD

- Better designs provided
- Improved productivity in tool design
- Better knowledge of costs provided
- Reduced training time for routine drafting tasks and NC part programming
- Fewer errors in NC part programming
- Provides the potential for using more existing parts and tooling

Benefits of CAD

- Helps ensure designs are appropriate to existing manufacturing techniques
- Saves materials and machining time by optimization algorithms
- Assistance in inspection of complicated parts
- Better communication interfaces and greater understanding among engineers, designers, drafters, management, and different project groups

Computer Graphics
Geometric Modeling

Geometric modelling refers to a set of techniques concerned mainly with developing efficient representations of geometric aspects of a design. Therefore, geometric modeling is a fundamental part of all CAD tools.

Geometric modeling is the basic of many applications such as:

- *Mechanism analysis*
- *Finite-element Analysis*
- *NC programming*

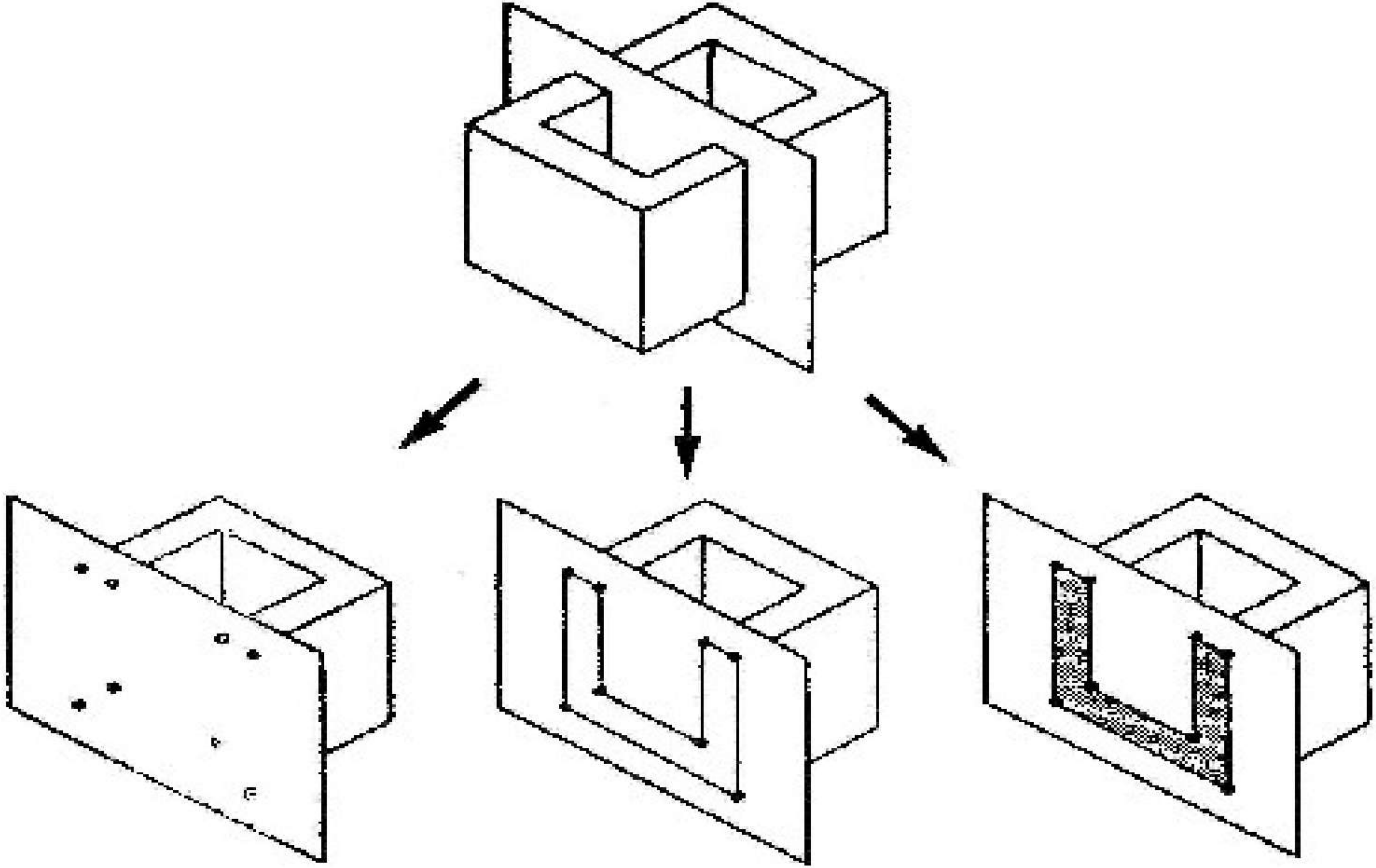
Requirements of geometric modeling include:

- Completeness of the part representation.
- The modeling method should be easy to use by designers.
- Rendering capabilities (which means how fast the entities can be accessed and displayed by the computer).

Geometric Modeling Approaches

The basic geometric modeling approaches available to designers on CAD/CAM systems are:

1. Wire-frame modeling.
2. Surface modeling.
3. Solid modeling.

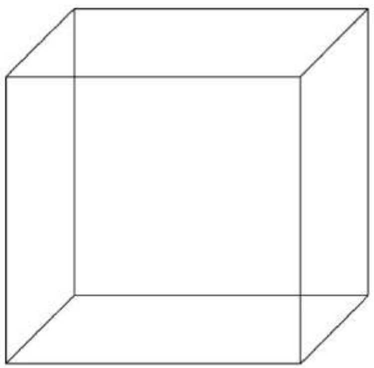


Wireframe Model Surface Model Solid Model

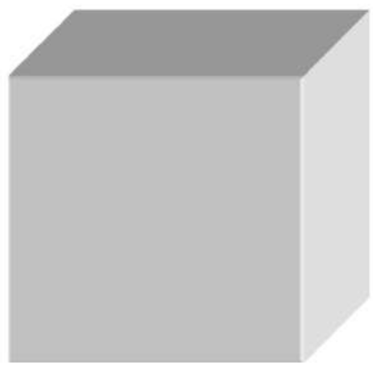
Wire-frame Modeling

Wire-frame modeling uses points and curves (i.e. lines, circles, arcs), and so forth to define objects.

The user uses edges and vertices of the part to form a 3-D object

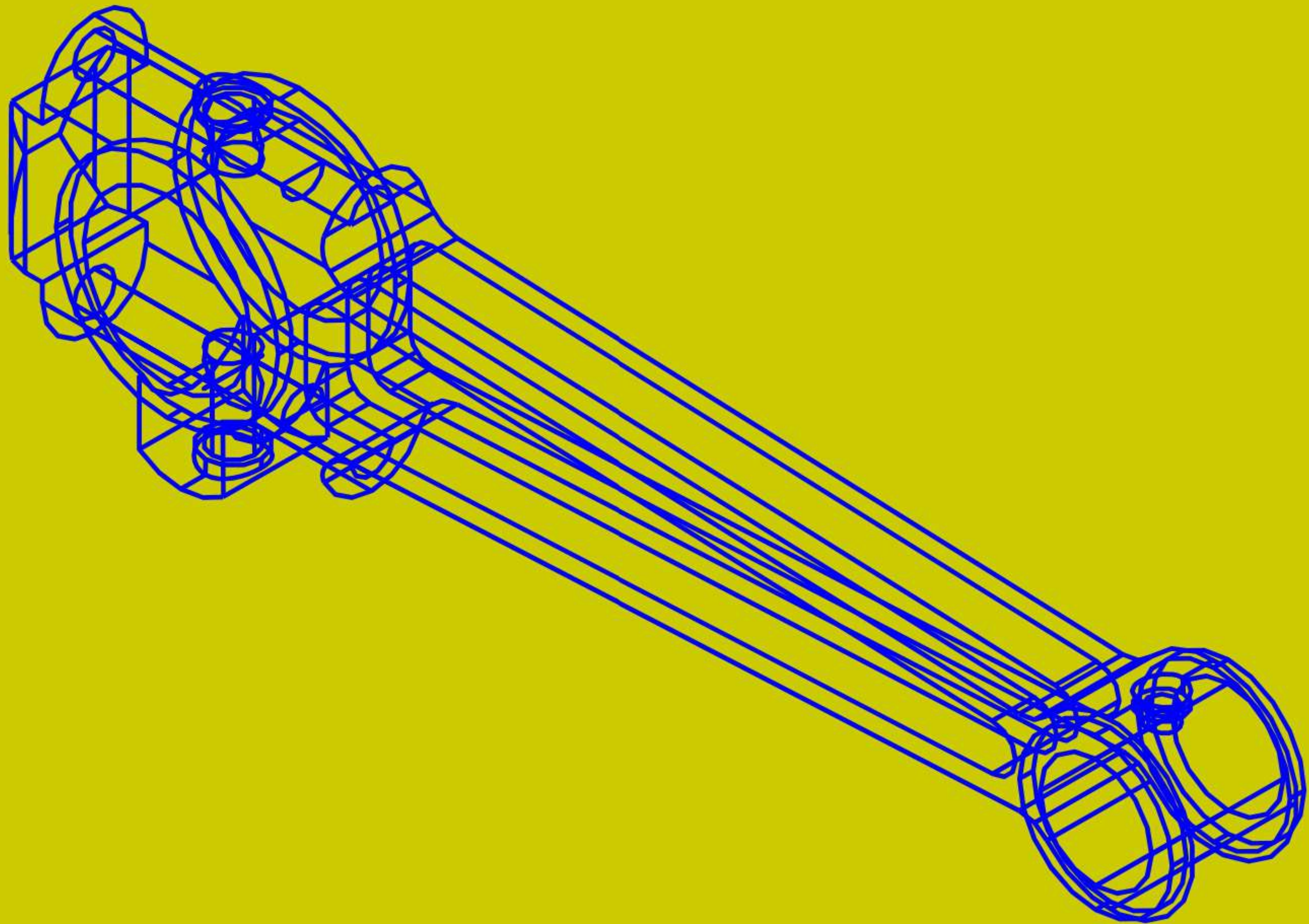


Wire-frame model



part

Example



Surface Modeling

Surface modeling is more sophisticated than wireframe modeling in that it defines not only the edges of a 3D object, but also its surfaces.

In surface modeling, objects are defined by their bounding faces.

SURFACE ENTITIES

Similar to wireframe entities, existing CAD/CAM systems provide designers with both analytic and synthetic surface entities.

Analytic entities include :

- Plane surface,
- Ruled surface,
- Surface of revolution, and
- Tabulated cylinder.

Synthetic entities include

- B-spline surface,
- Rectangular and triangular Bezier patches,
- Rectangular and triangular Coons patches, and
- Gordon surface.

Plane surface. This is the simplest surface. It requires three noncoincident points to define an infinite plane.

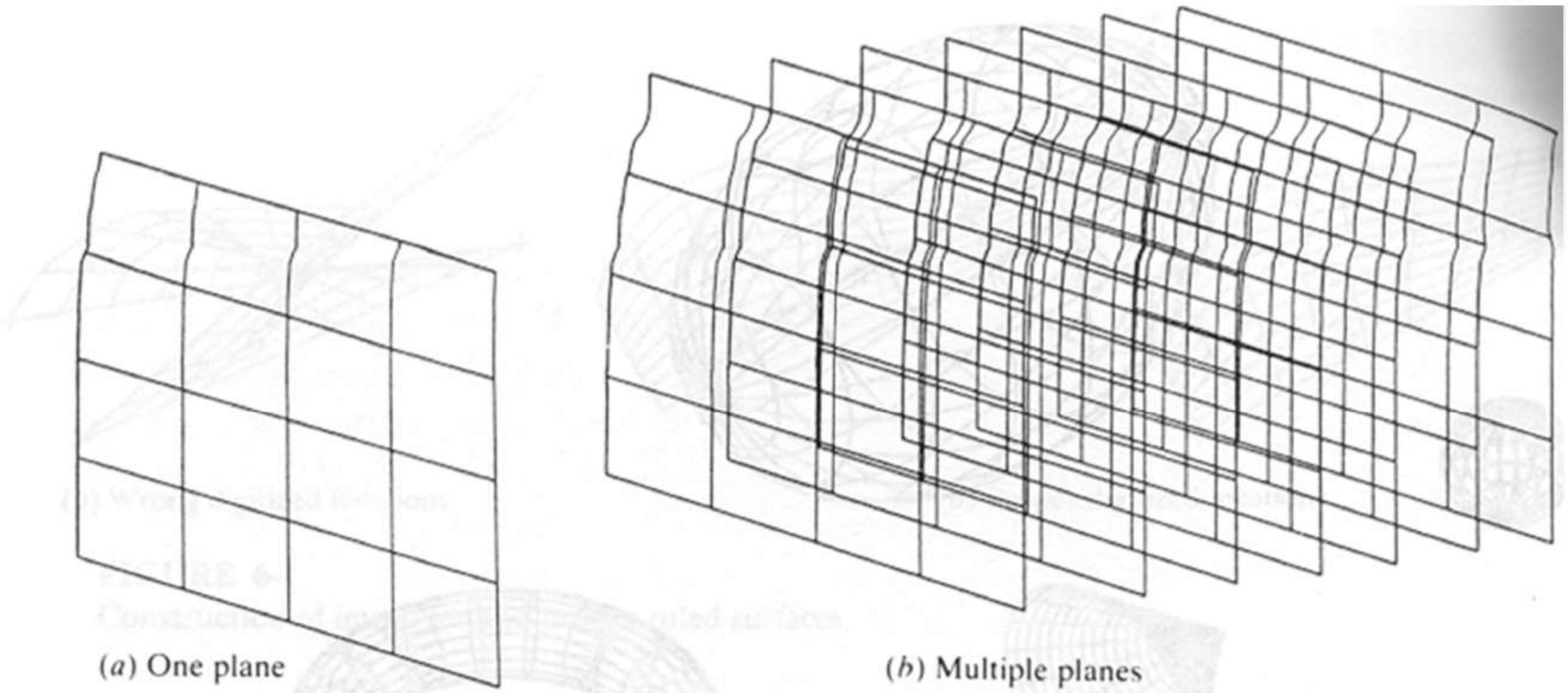
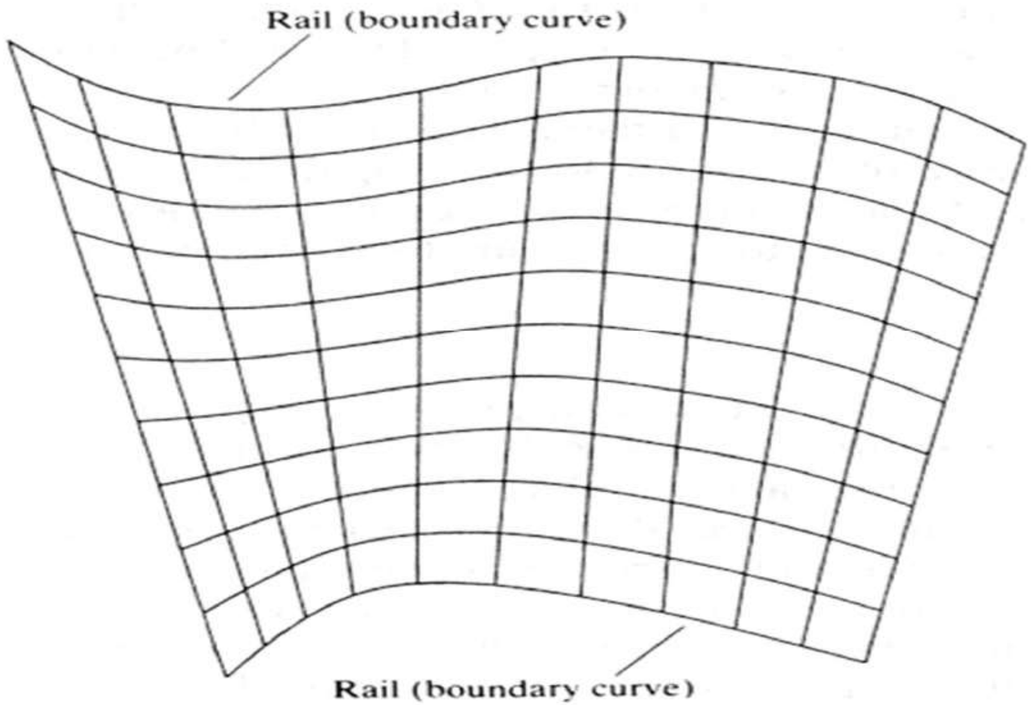


FIGURE 6-4
Plane surface.

Ruled (lofted) surface. This is a linear surface. It interpolates linearly between two boundary curves that define the surface (rails). Rails can be any wireframe entity.



Surface of revolution. This is an axisymmetric surface that can model axisymmetric objects. It is generated by rotating a planar wireframe entity in space about the axis of symmetry a certain angle.

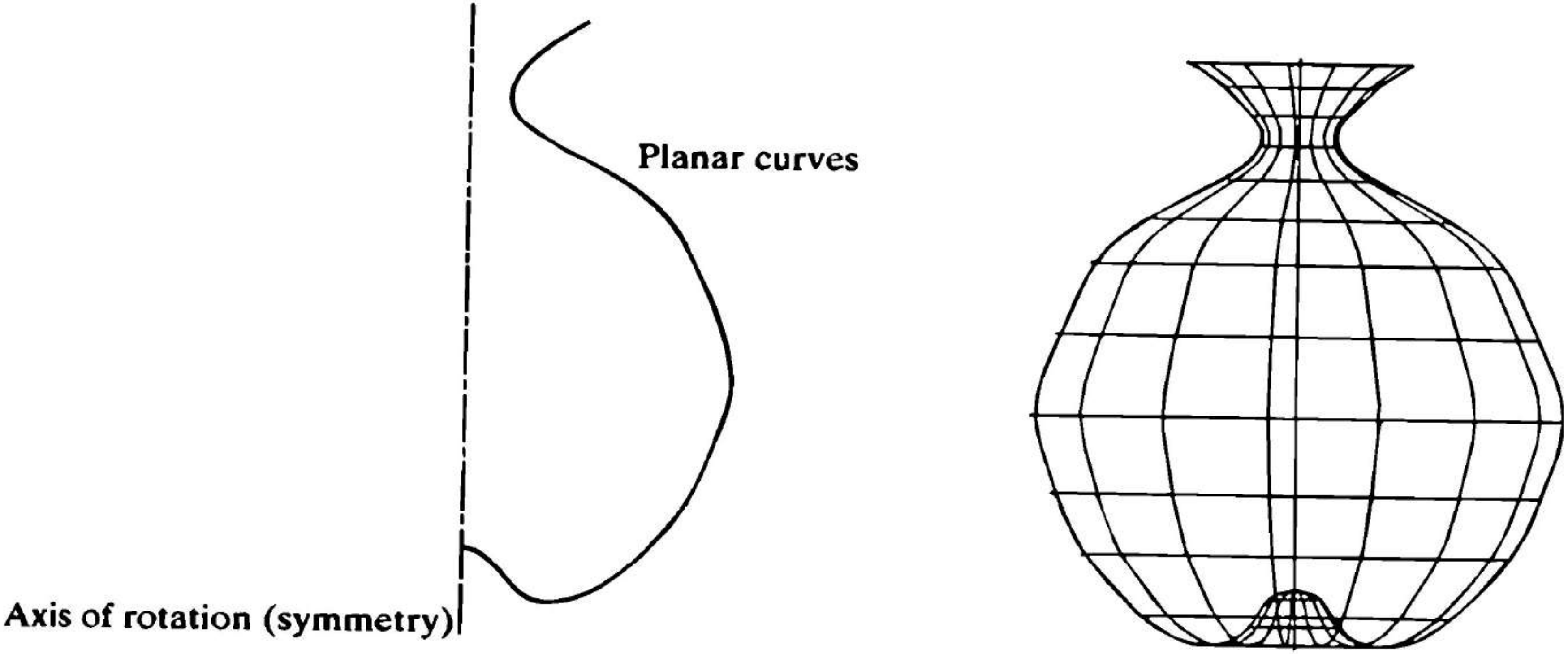


FIGURE 6-6
Surface of revolution.

Tabulated cylinder. This is a surface generated by translating a planar curve a certain distance along a specified direction (axis of the cylinder).

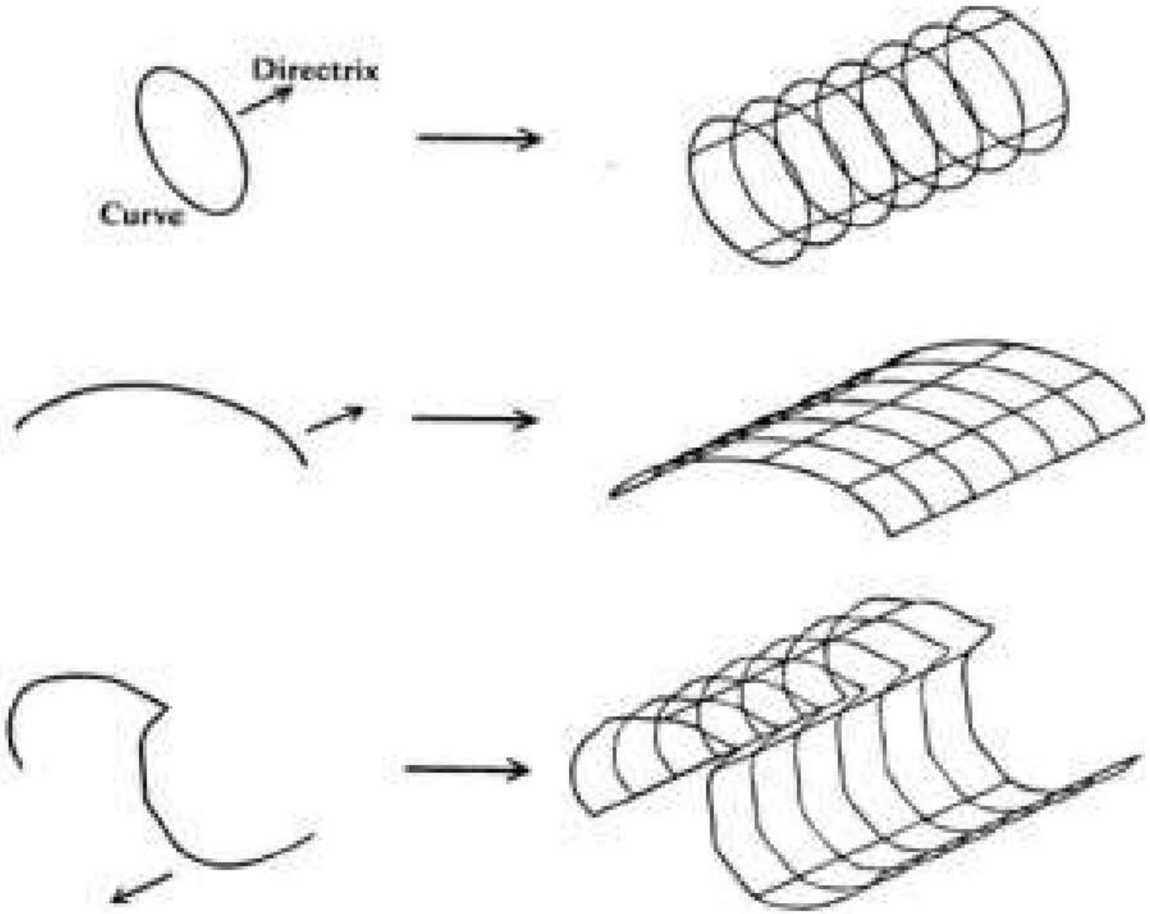


FIGURE 6-7
Tabulated cylinder.

Bezier surface. This is a surface that approximates given input data. It is different from the previous surfaces in that it is a synthetic surface. Similarly to the Bezier curve, it does not pass through all given data points. The Bezier surface allows only global control of the surface.

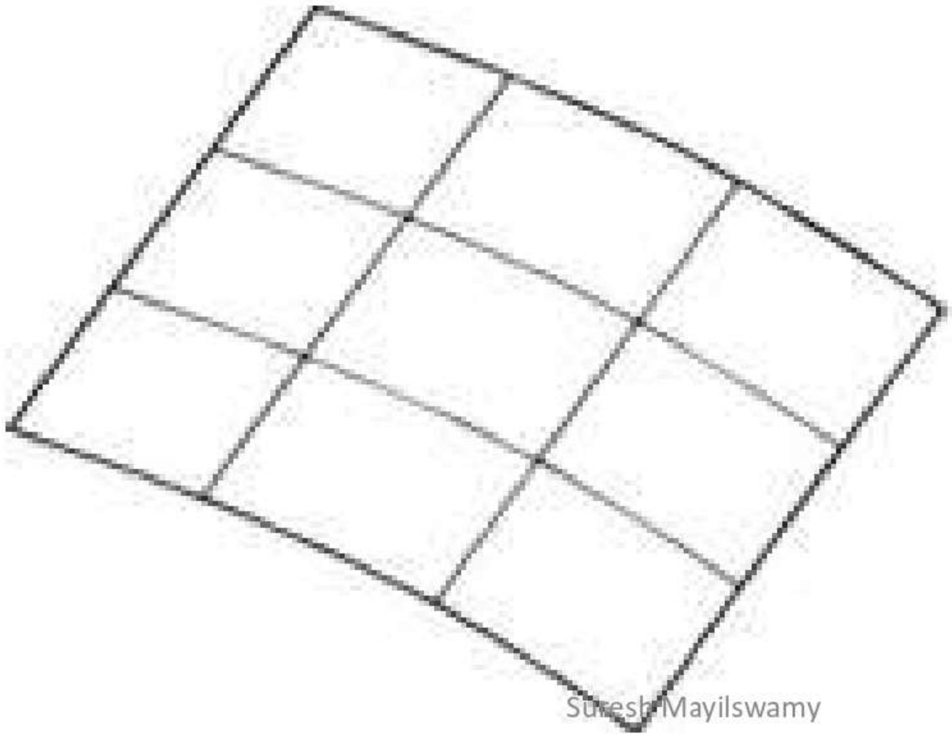
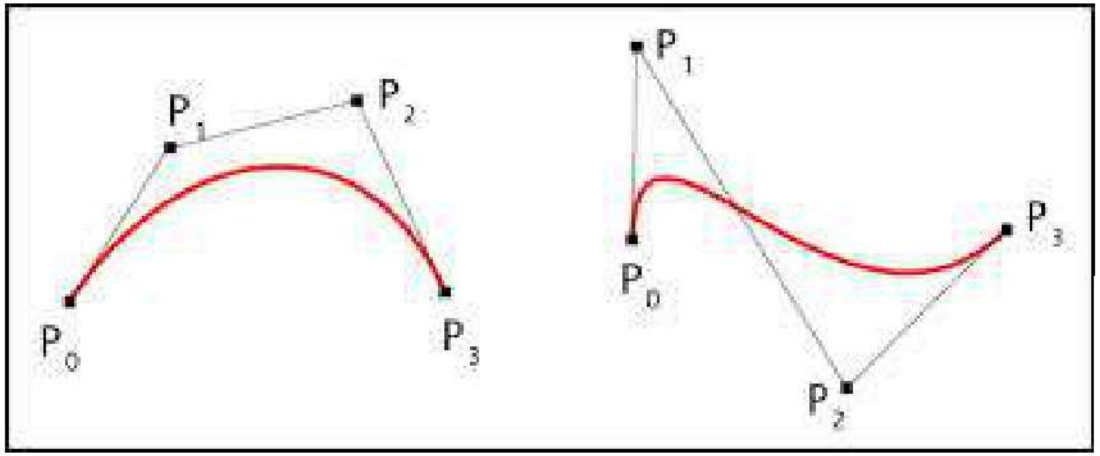
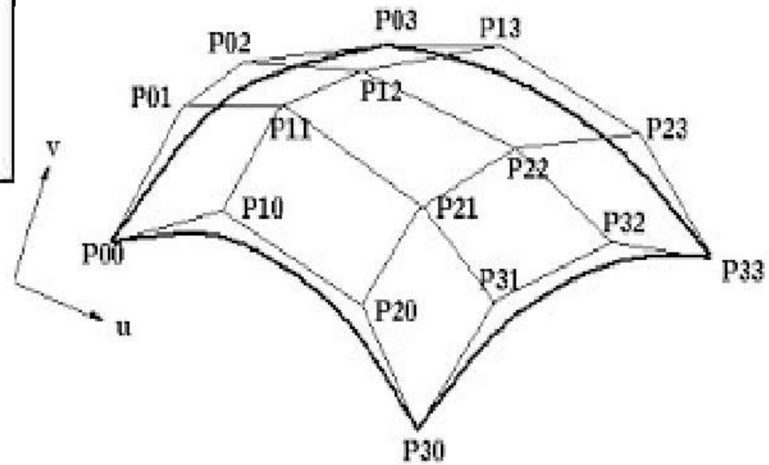
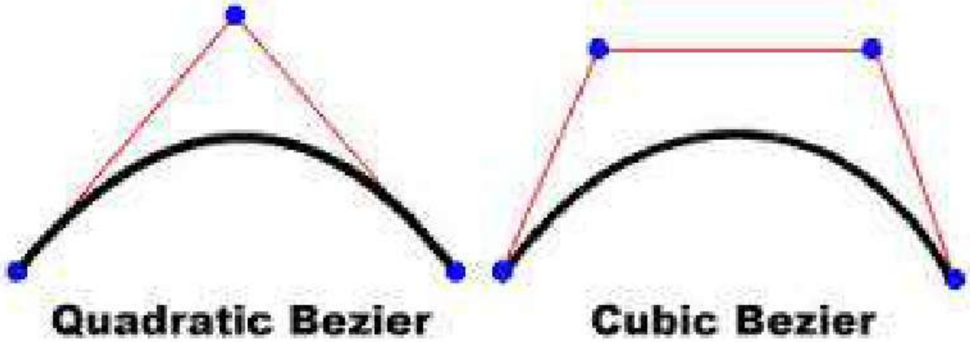


FIGURE 6-8
Bezier surface.

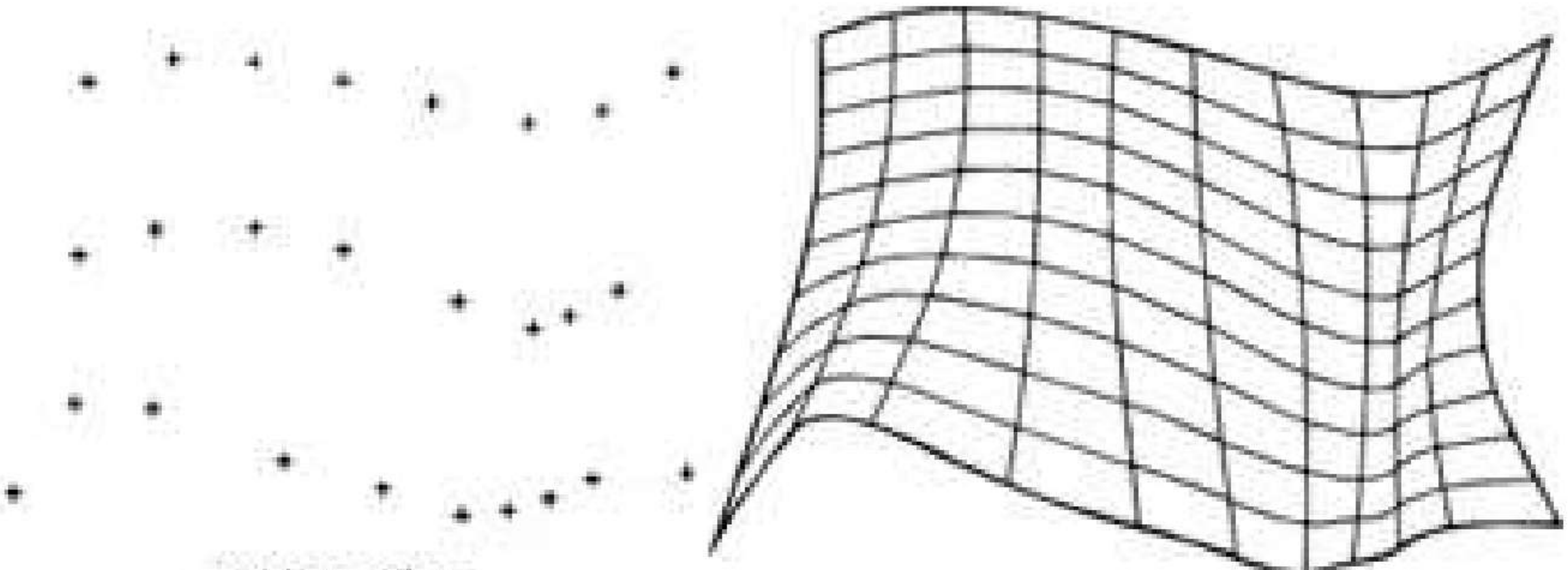
Bezier surface





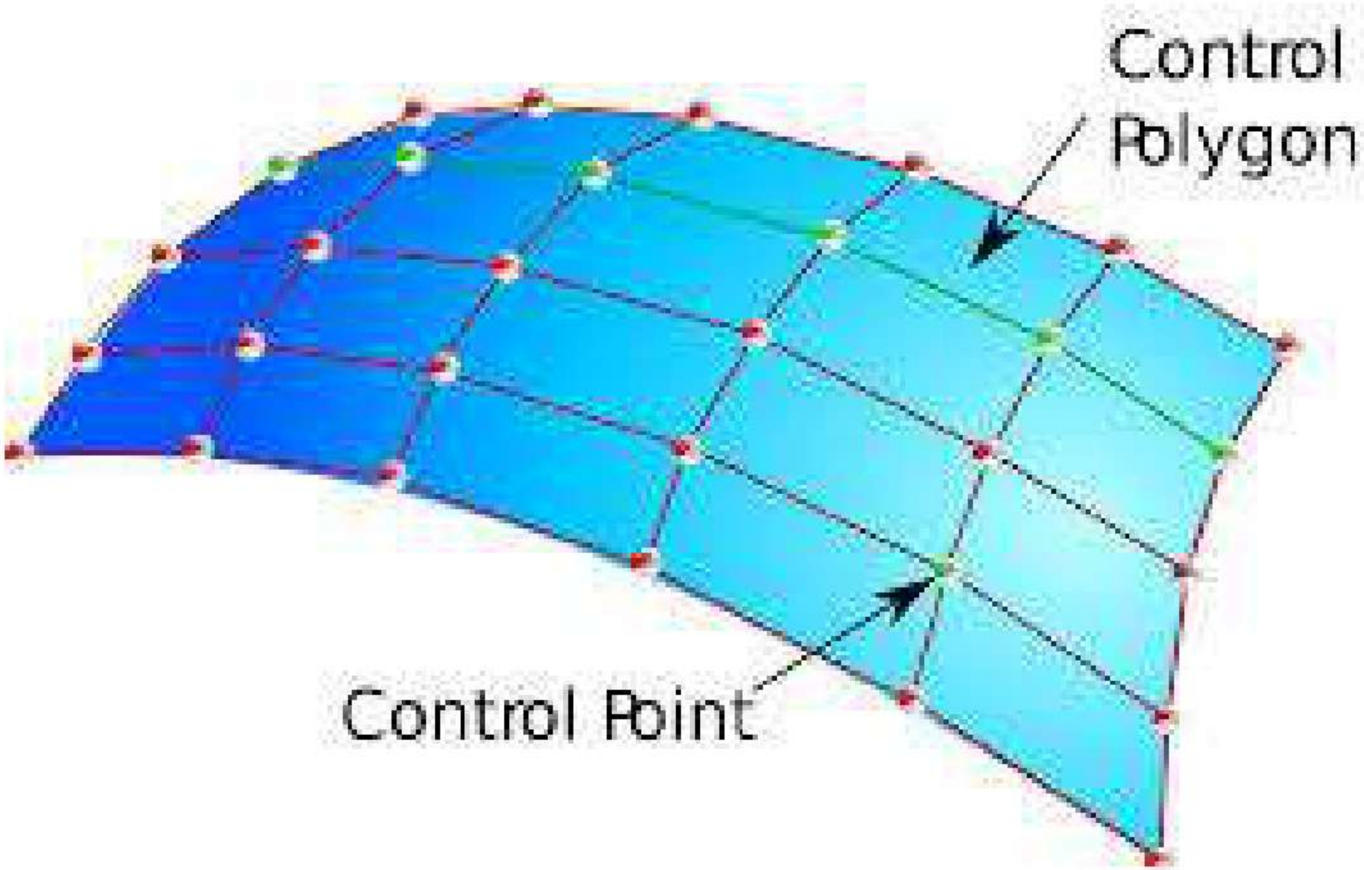


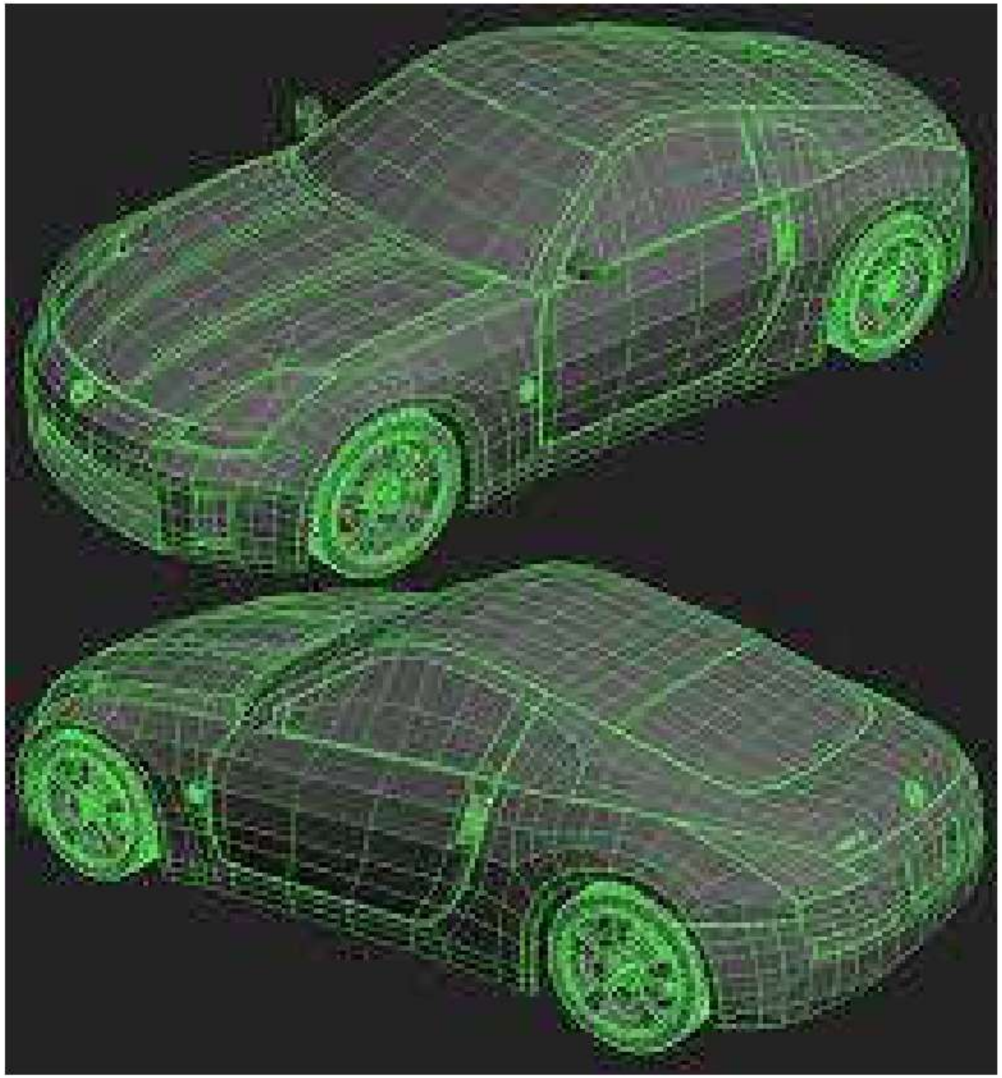
B-spline surface. This is a surface that can approximate or interpolate given input data. It is a synthetic surface. It is a general surface like the Bezier surface but with the advantage of permitting local control of the surface.



(a) Data points

B-spline surface

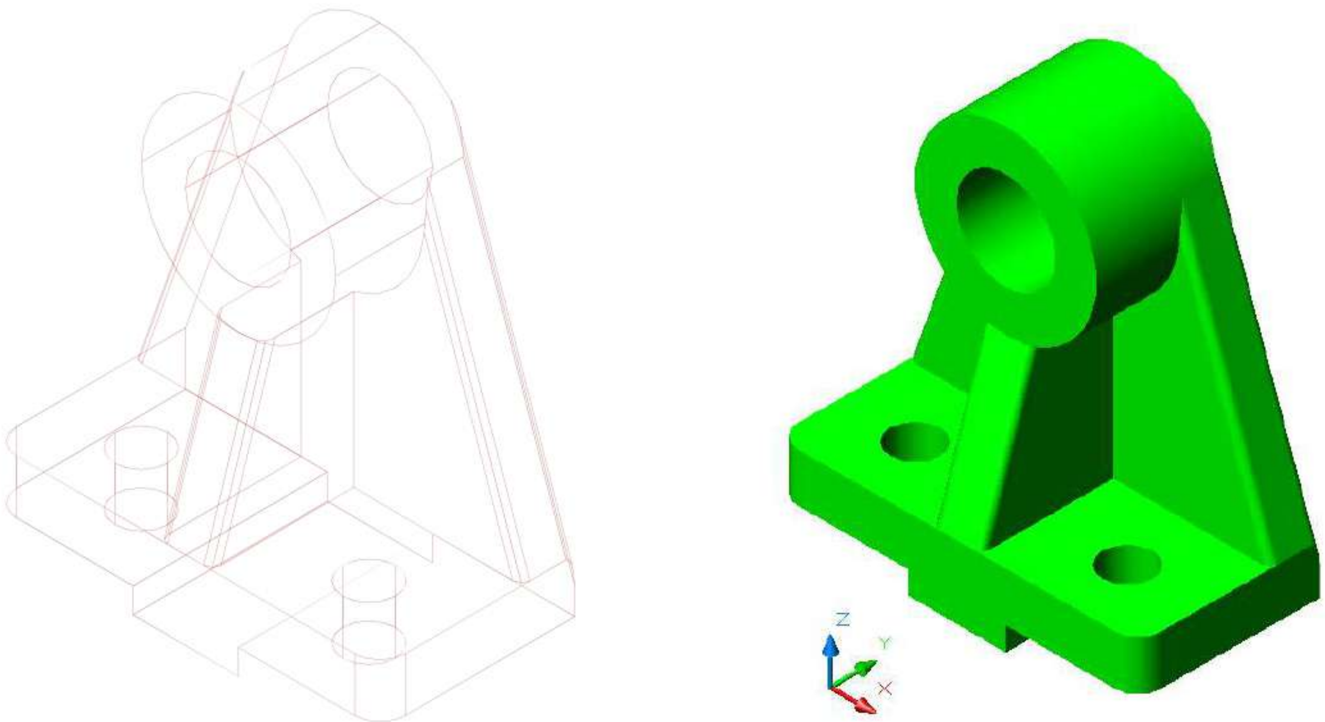




Surface Modeling

Solid Modeling

Solid models give designers a complete descriptions of constructs, shape, surface, volume, and density.

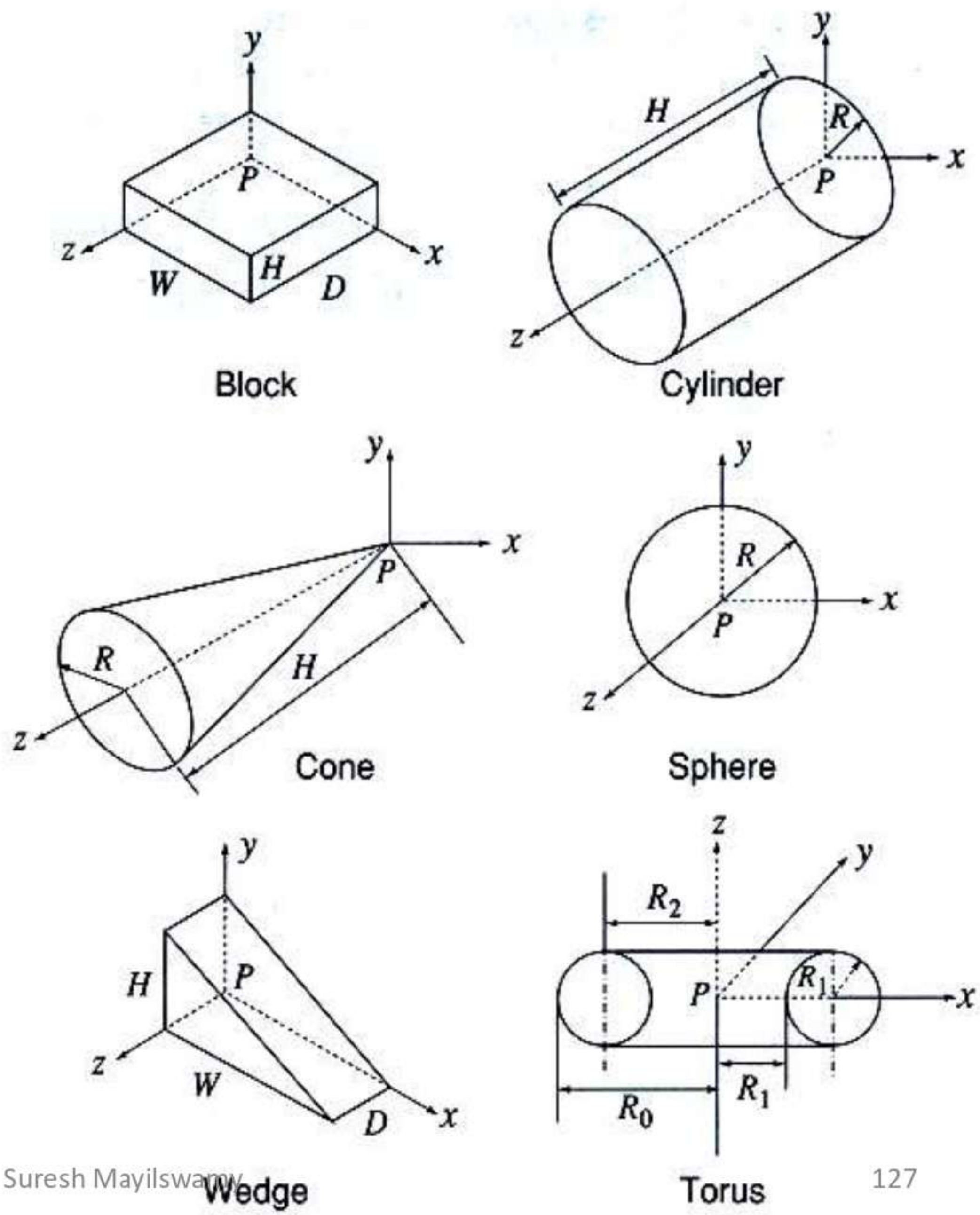


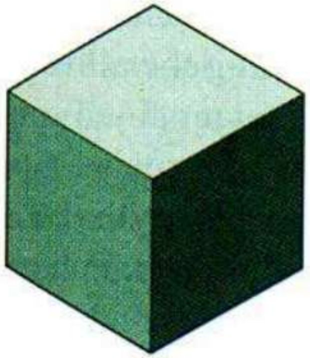
In CAD systems there are a number of representation schemes for solid modeling include:

- Primitive creation functions.
- Constructive Solid Geometry (CSG)
- Sweeping
- Boundary Representation (B-rep)

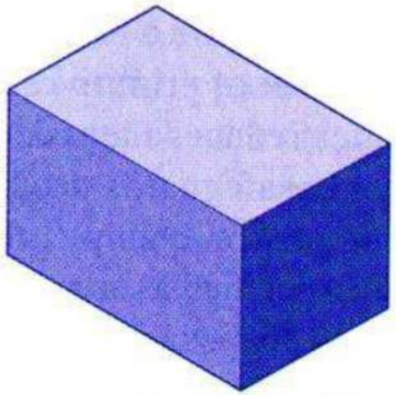
Primitive creation functions:

These functions retrieve a solid of a simple shape from among the primitive solids stored in the program in advance and create a solid of the same shape but of the size specified by the user.

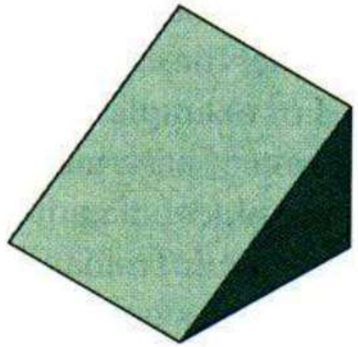




Cube



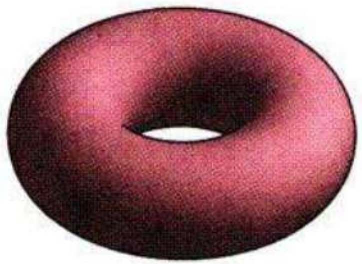
Rectangular Prism



Triangular Prism

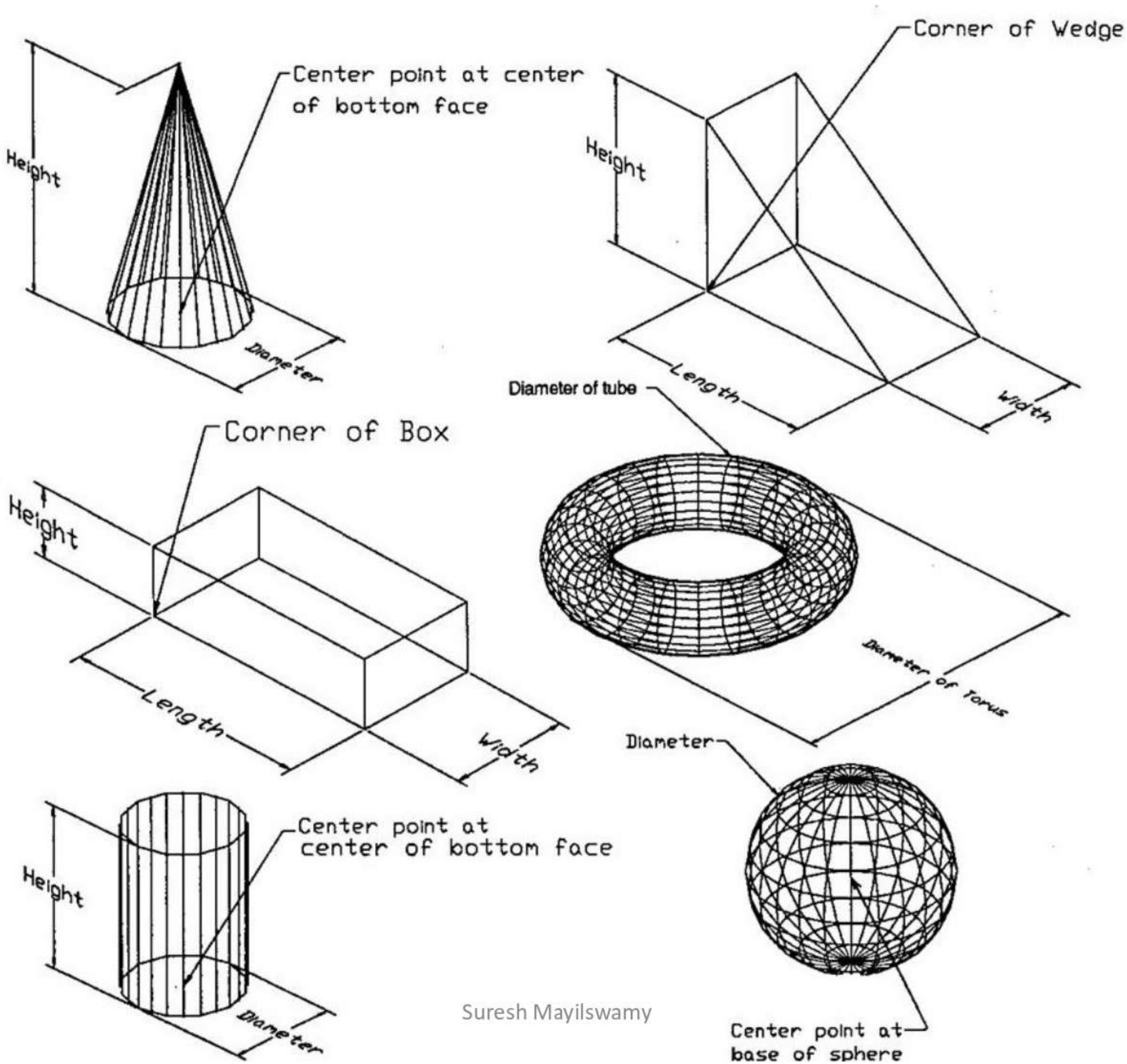
Sphere

Cone



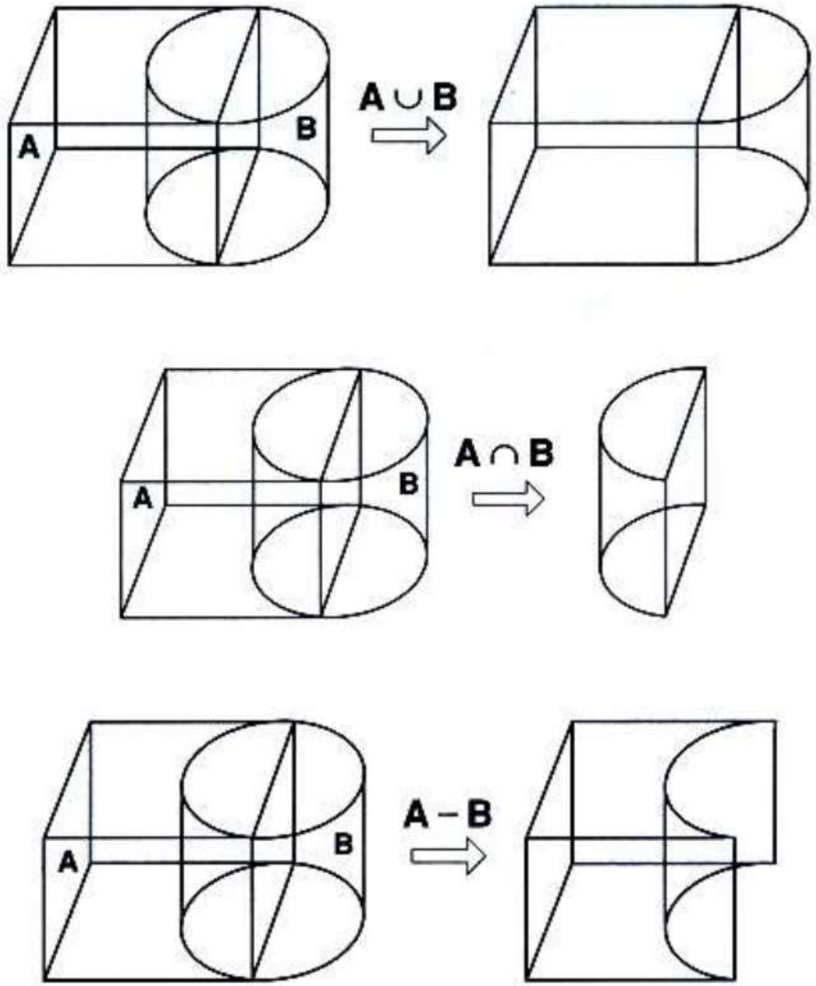
Torus

Cylinder

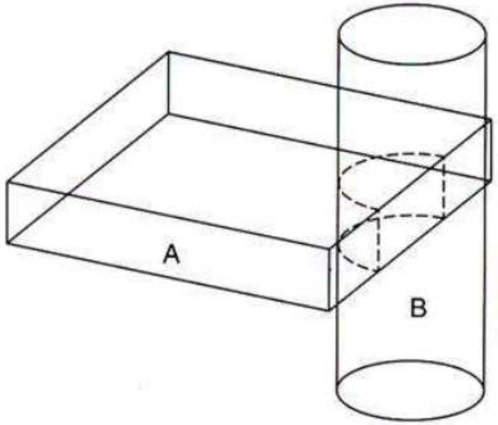

Center point at center of bottom face
Height
Diameter
Corner of Wedge
Height
Length
Width
Diameter of tube
Corner of Box
Height
Length
Width
Diameter of Torus
Diameter
Center point at center of bottom face
Height
Diameter
Center point at base of sphere

Constructive Solid Geometry (CSG)

CSG uses primitive shapes as building blocks and Boolean set operators (U union, difference, and ∩ intersection) to construct an object.

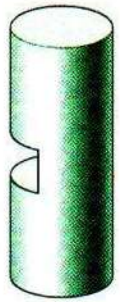


Boolean Operations

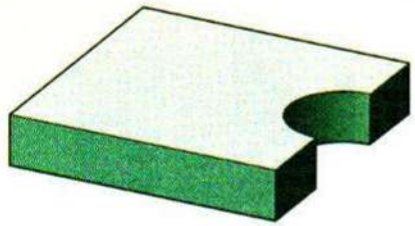


Subtract

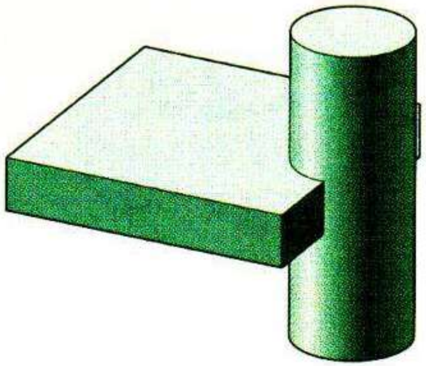
B − A



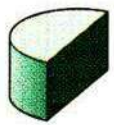
A − B



A ∪ B



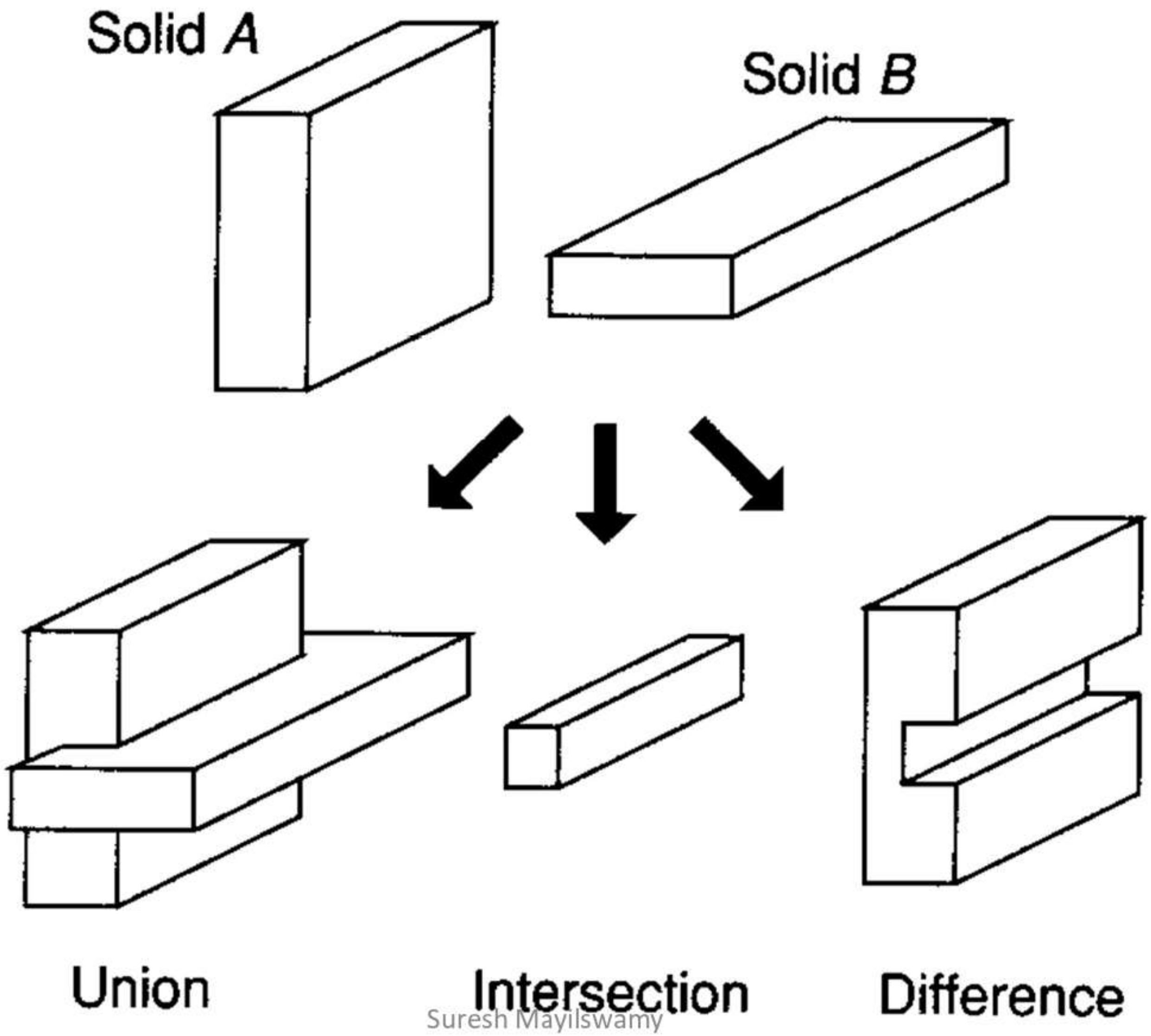
A ∩ B



Union

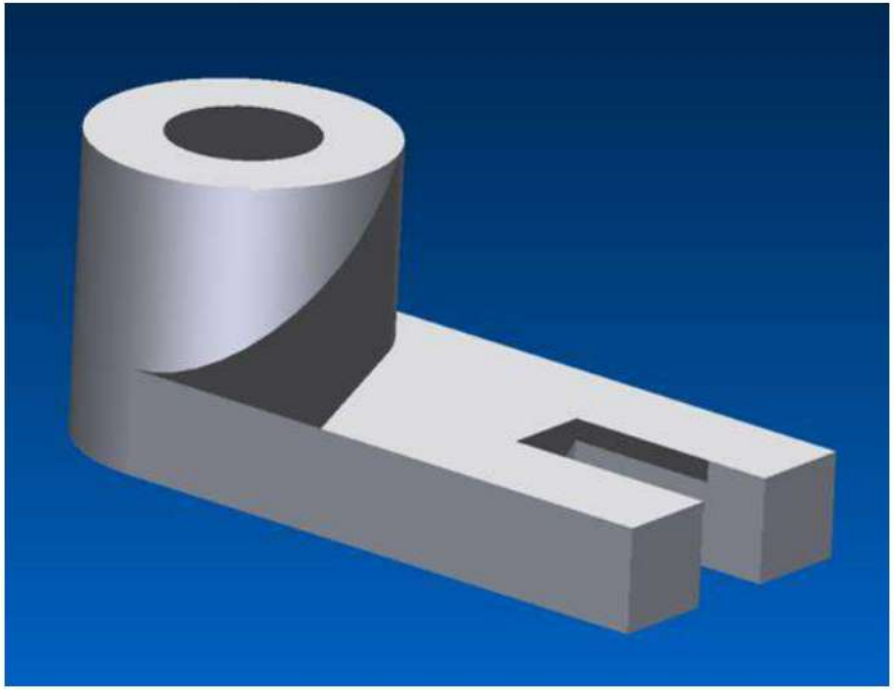
Intersection

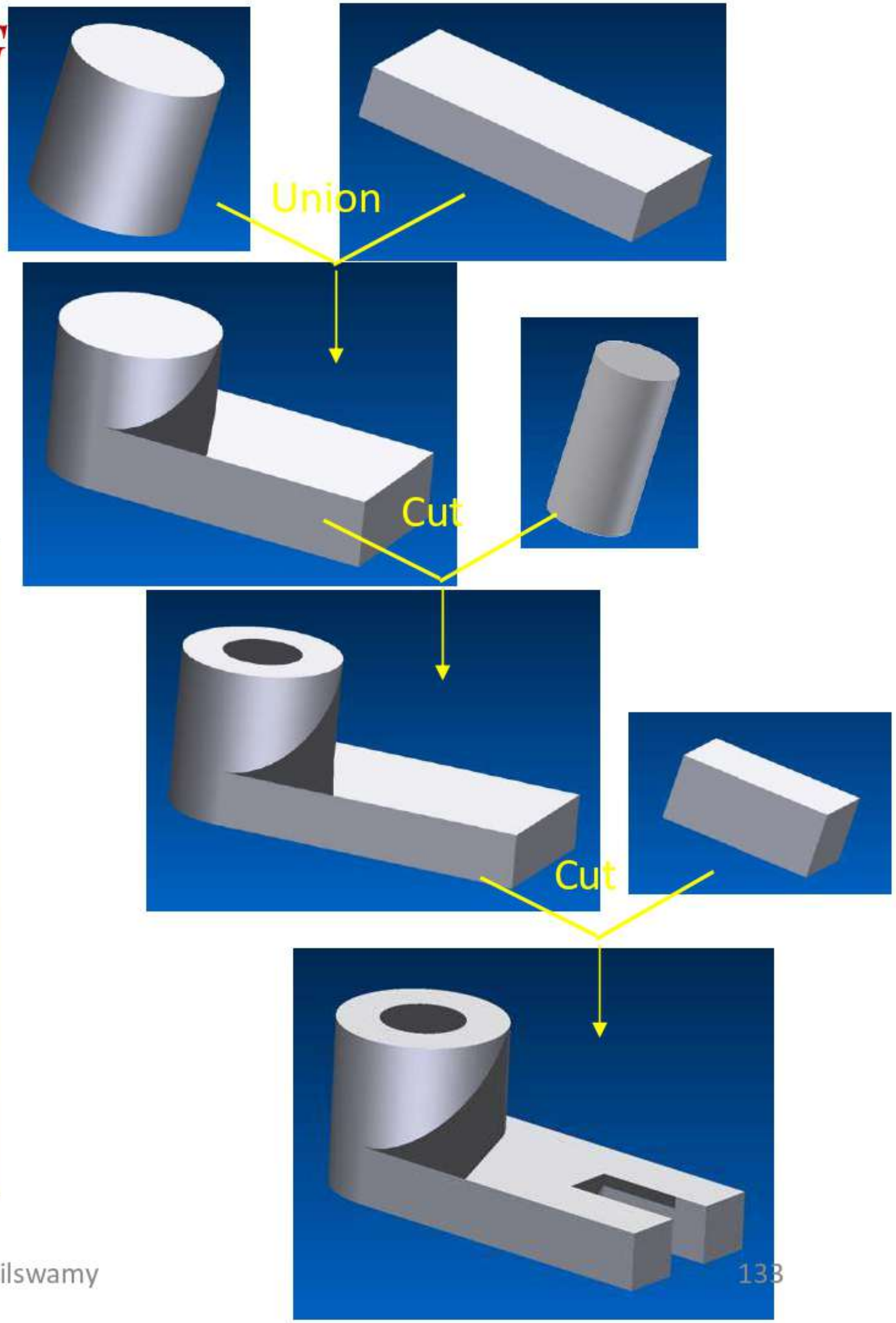
Implementing Boolean Operation



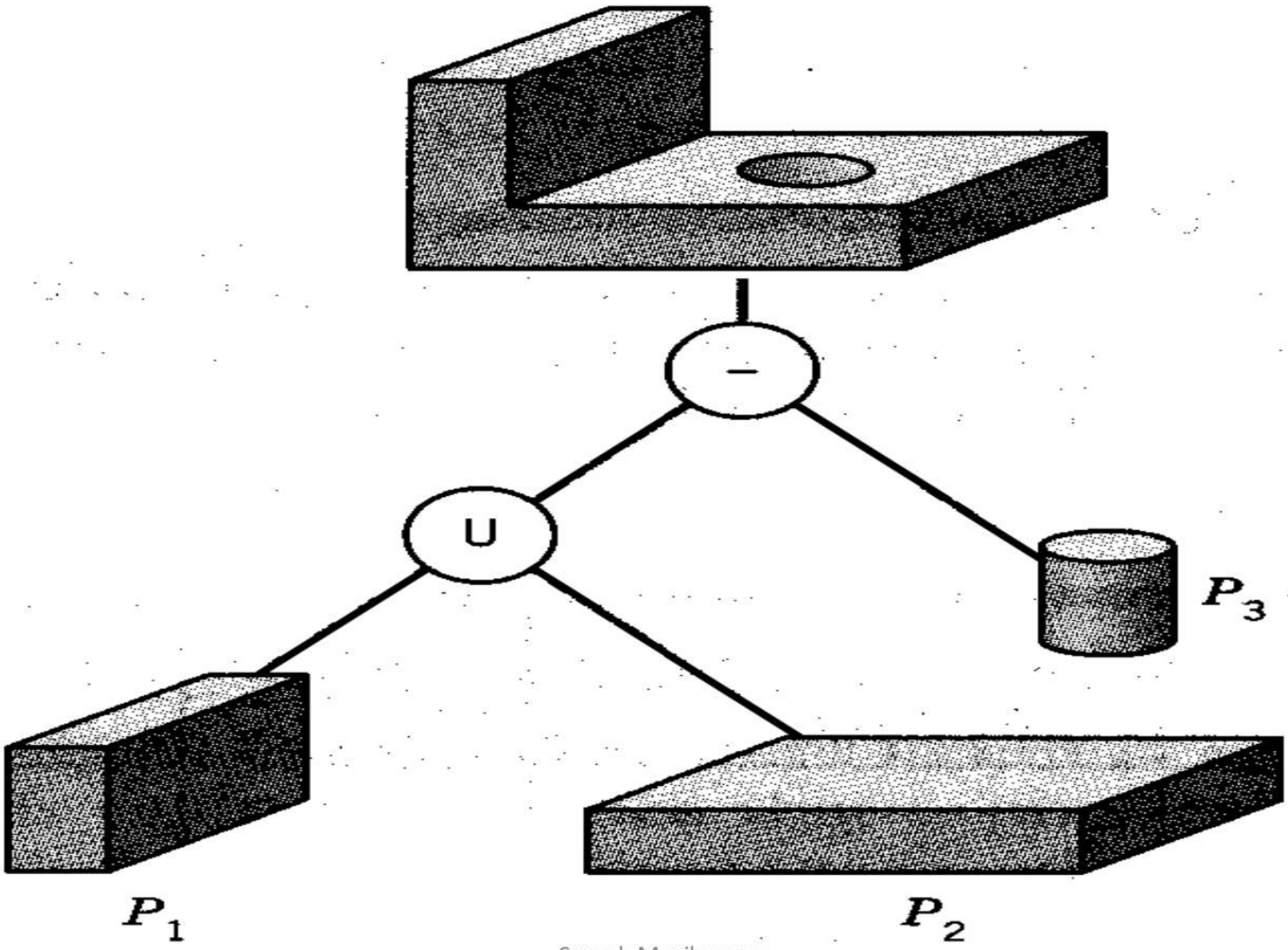
Solid Modeling Example Using CSG

Plan your modeling strategy before you start creating the solid model





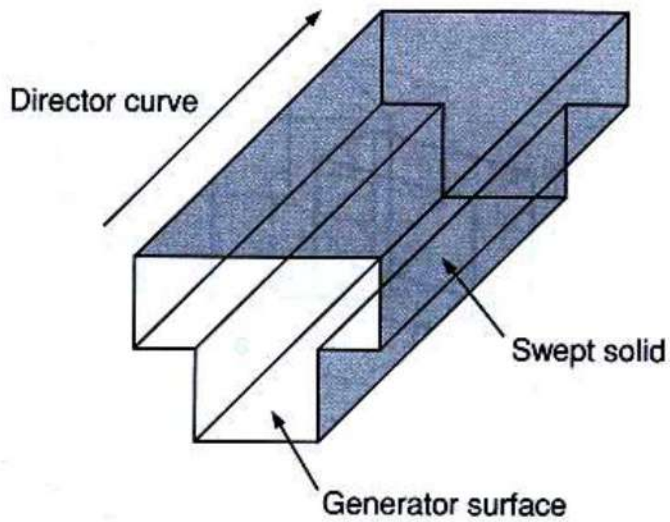
CSG Tree

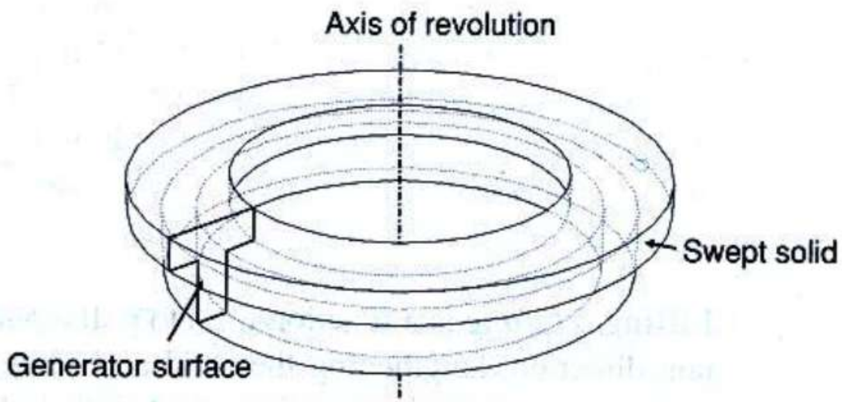


CSG Tree

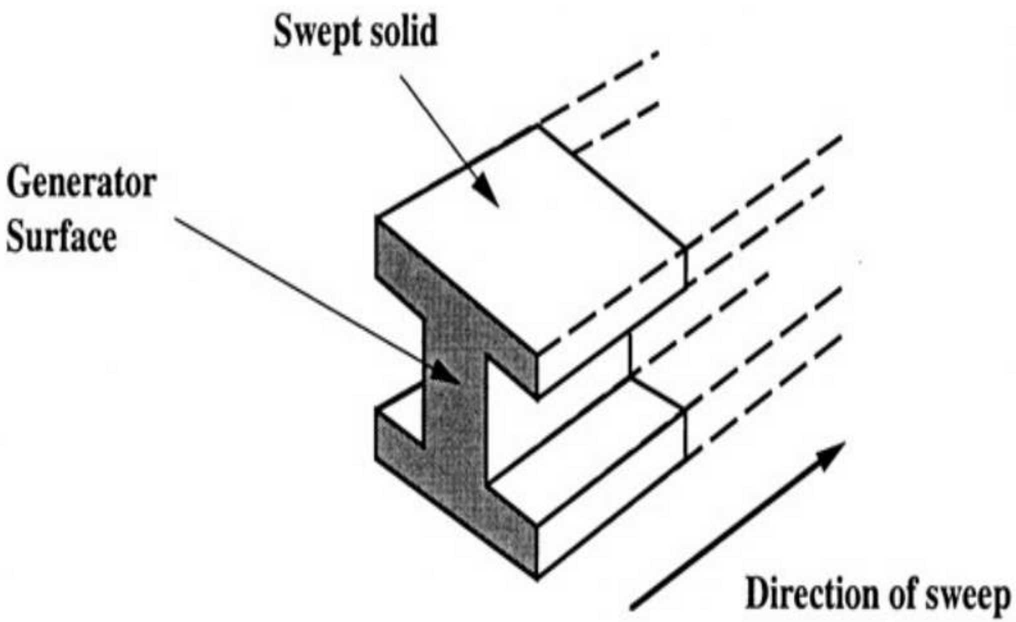
Sweeping

Sweeping is a modeling function in which a planar closed domain is translated or revolved to form a solid. When the planar domain is translated, the modeling activity is called *translational sweeping;* when the planar region is revolved, it is called *swinging, or rotational sweeping.*

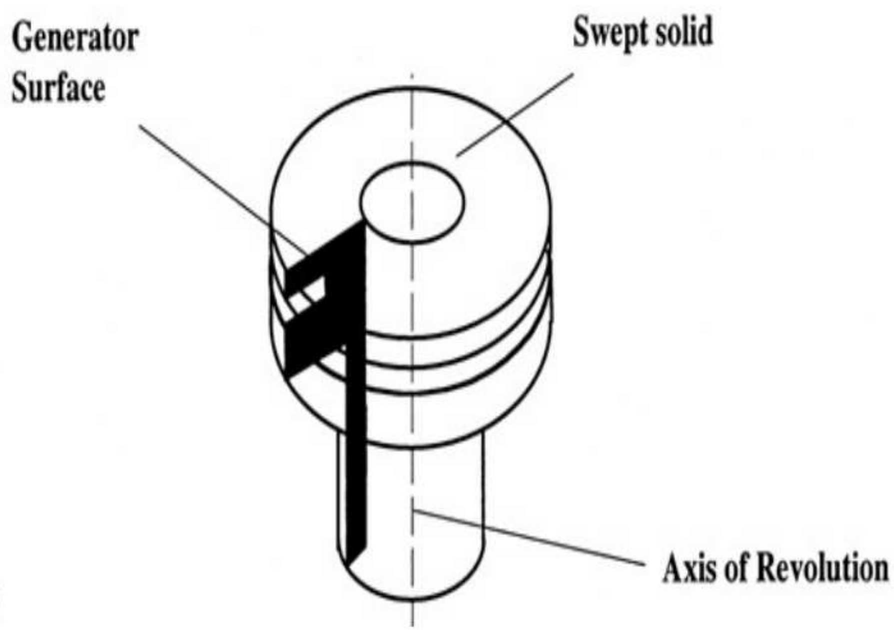


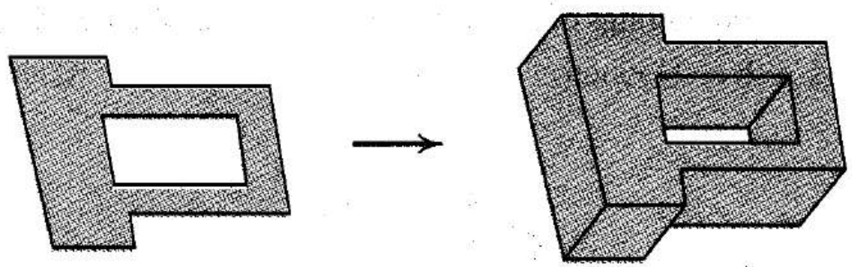


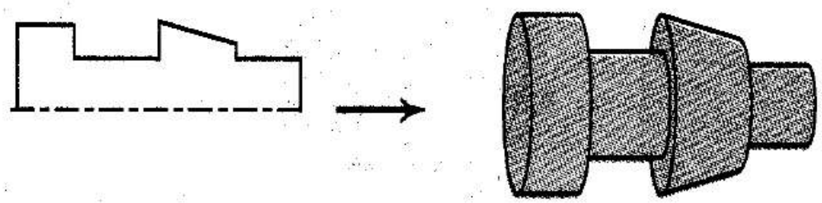
Extrusion



Revolution

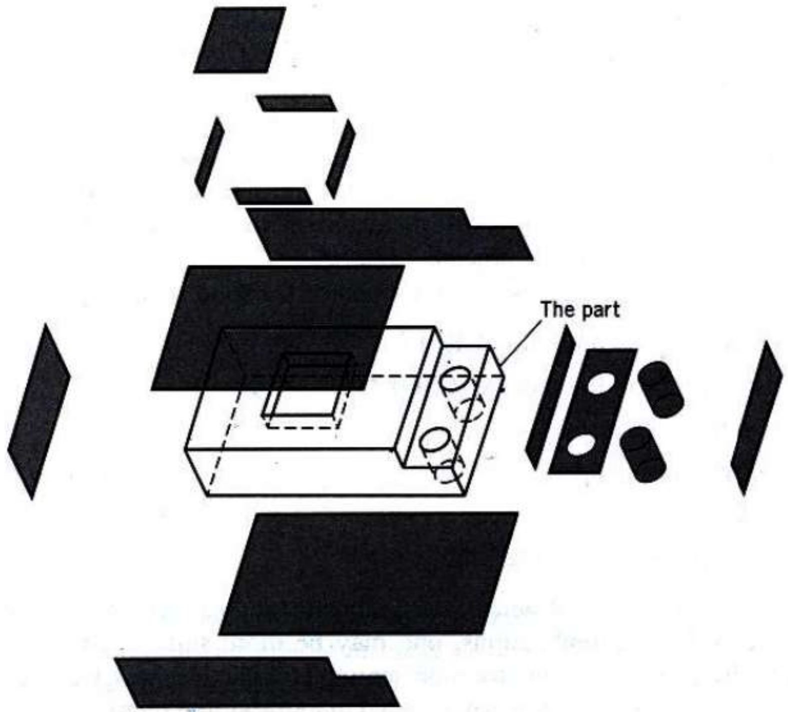


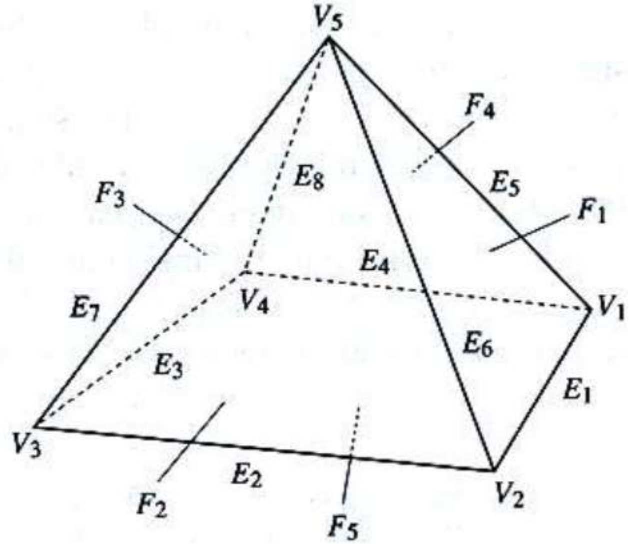




Boundary Representation

Objects are represented by their bounded faces.





B-Rep Data Structure

Three tables for storing B-Rep

Face Table

Face	*Edges*
F_1	E_1, E_5, E_6
F_2	E_2, E_6, E_7
F_3	E_3, E_7, E_8
F_4	E_4, E_8, E_5
F_5	E_1, E_2, E_3, E_4

Edge Table

Edge	*Vertices*
E_1	V_1, V_2
E_2	V_2, V_3
E_3	V_3, V_4
E_4	V_4, V_1
E_5	V_1, V_5
E_6	V_2, V_5
E_7	V_3, V_5
E_8	V_4, V_5

Vertex Table

Vertex	*Coordinates*
V_1	x_1, y_1, z_1
V_2	x_2, y_2, z_2
V_3	x_3, y_3, z_3
V_4	x_4, y_4, z_4
V_5	x_5, y_5, z_5
V_6	x_6, y_6, z_6

Euler's Rule

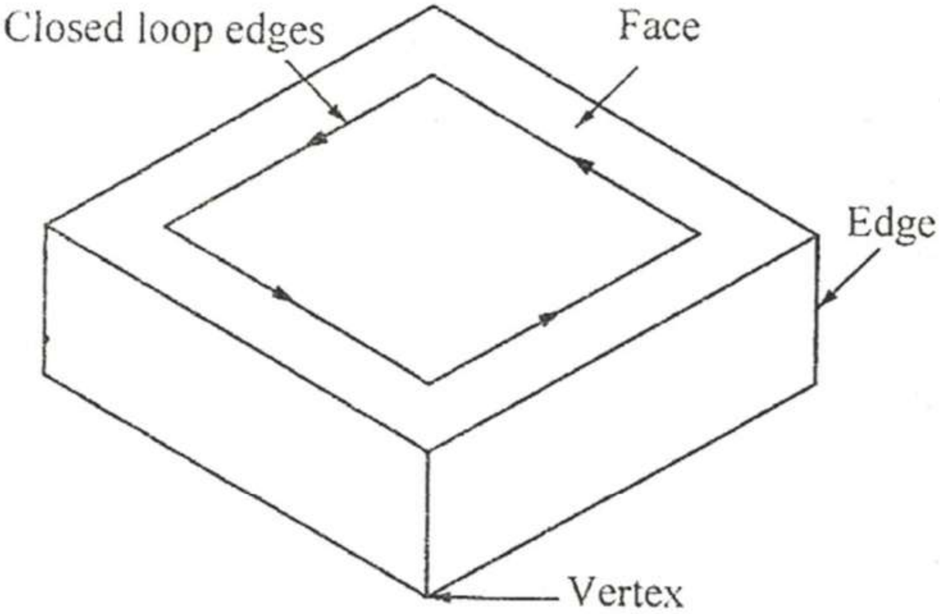


Fig 3.21. Elements of topology

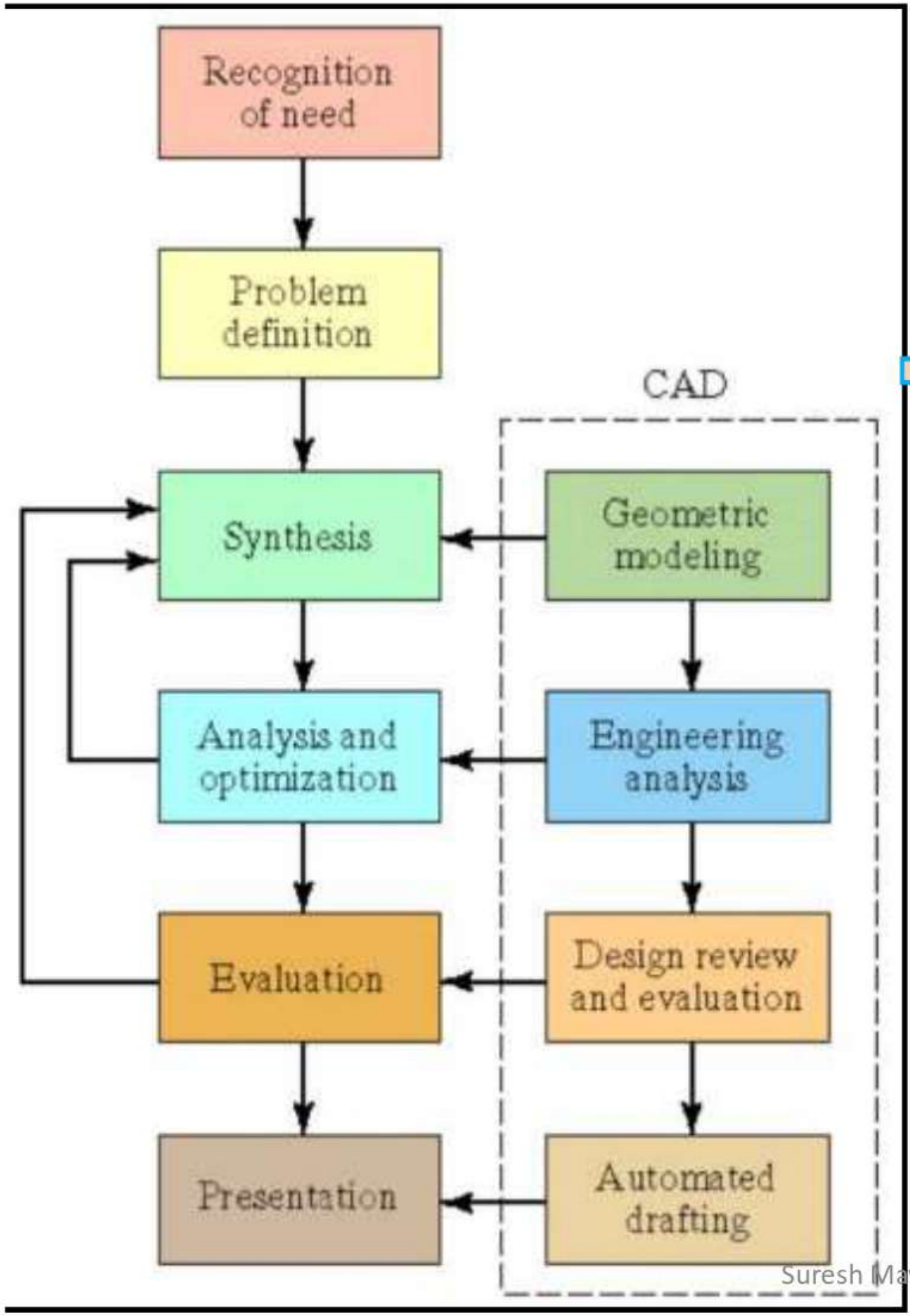
For bodies without holes should satisfy Euler's rule.

i.e. $V - E + F = 2$.

where, V = Number of vertices

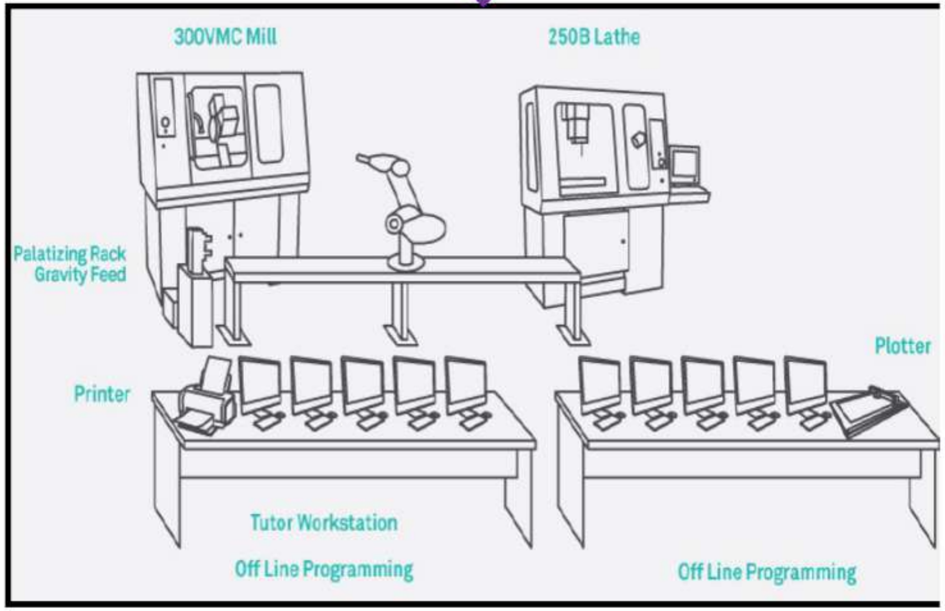
E = Number of edges

F = Number of faces

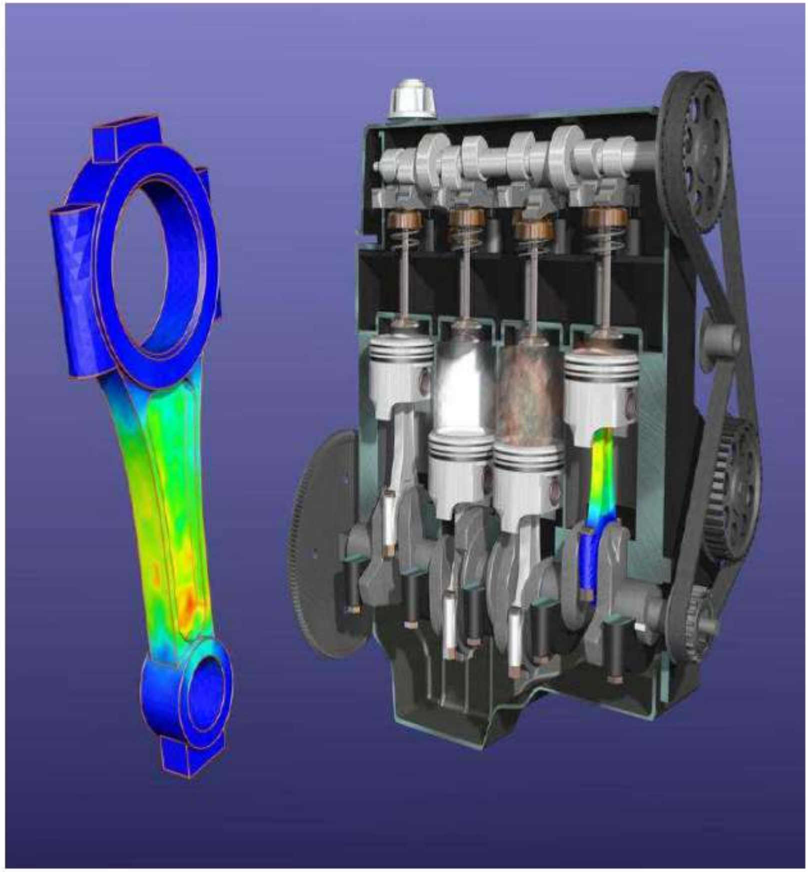


CAD/CAM Workstations

Process Plan



Computer-Aided Engineering (CAE)

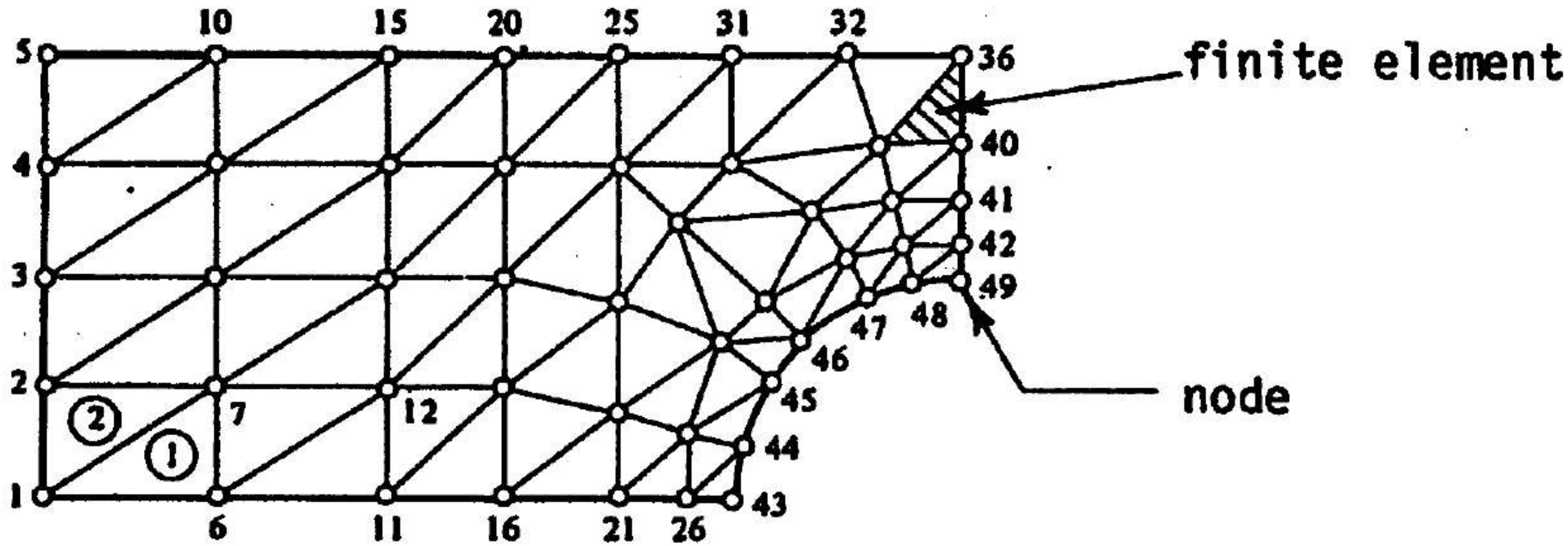


- Use of computer systems to analyze CAD geometry
- Allows designer to simulate and study how the product will behave, allowing for optimization
- Finite-element method (FEM)
  - Divides model into interconnected elements
  - Solves continuous field problems

Introduction to Finite Element Methods

- **The finite element method is a computational scheme to solve field problems in engineering and science.**
- **The technique has very wide application, and has been used on problems involving stress analysis, fluid mechanics, heat transfer, diffusion, vibrations, electrical and magnetic fields, etc.**
- **The fundamental concept involves dividing the body under study into a finite number of pieces (sub domains) called elements.**

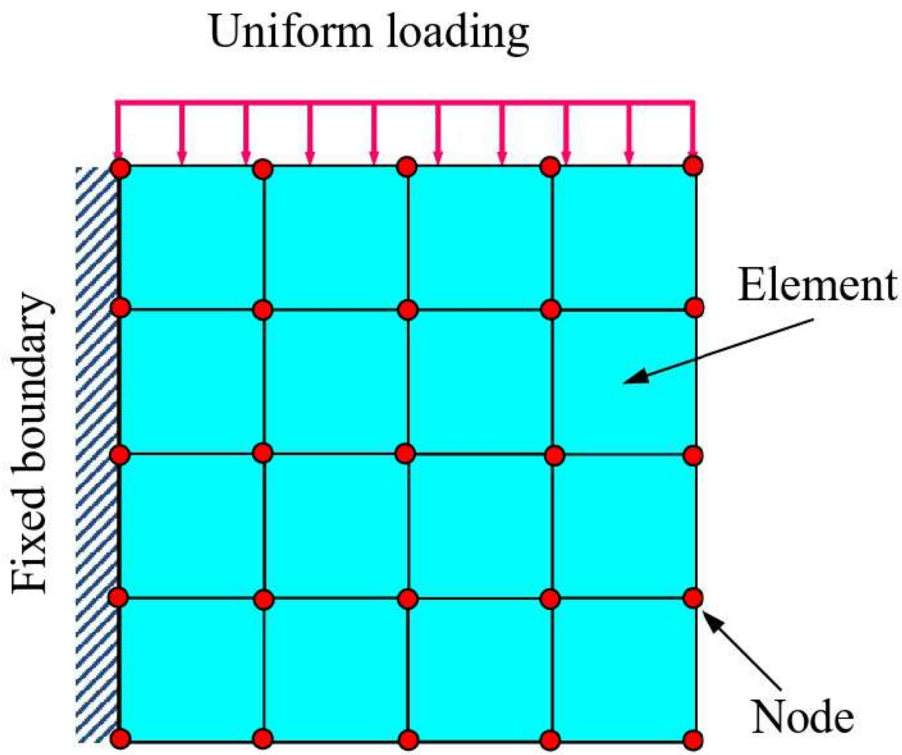
- **Particular assumptions are then made on the variation of the unknown dependent variable(s) across each element using so-called interpolation or approximation functions.**
- **This approximated variation is quantified in terms of solution values at special element locations called nodes.**



- **Through this discretization process, the method sets up an algebraic system of equations for unknown nodal values which approximate the continuous solution.**

- **Because element size, shape and approximating scheme can be varied to suit the problem, the method can accurately simulate solutions to problems of complex geometry and loading and thus this technique has become a very useful and practical tool.**

Finite Element Model

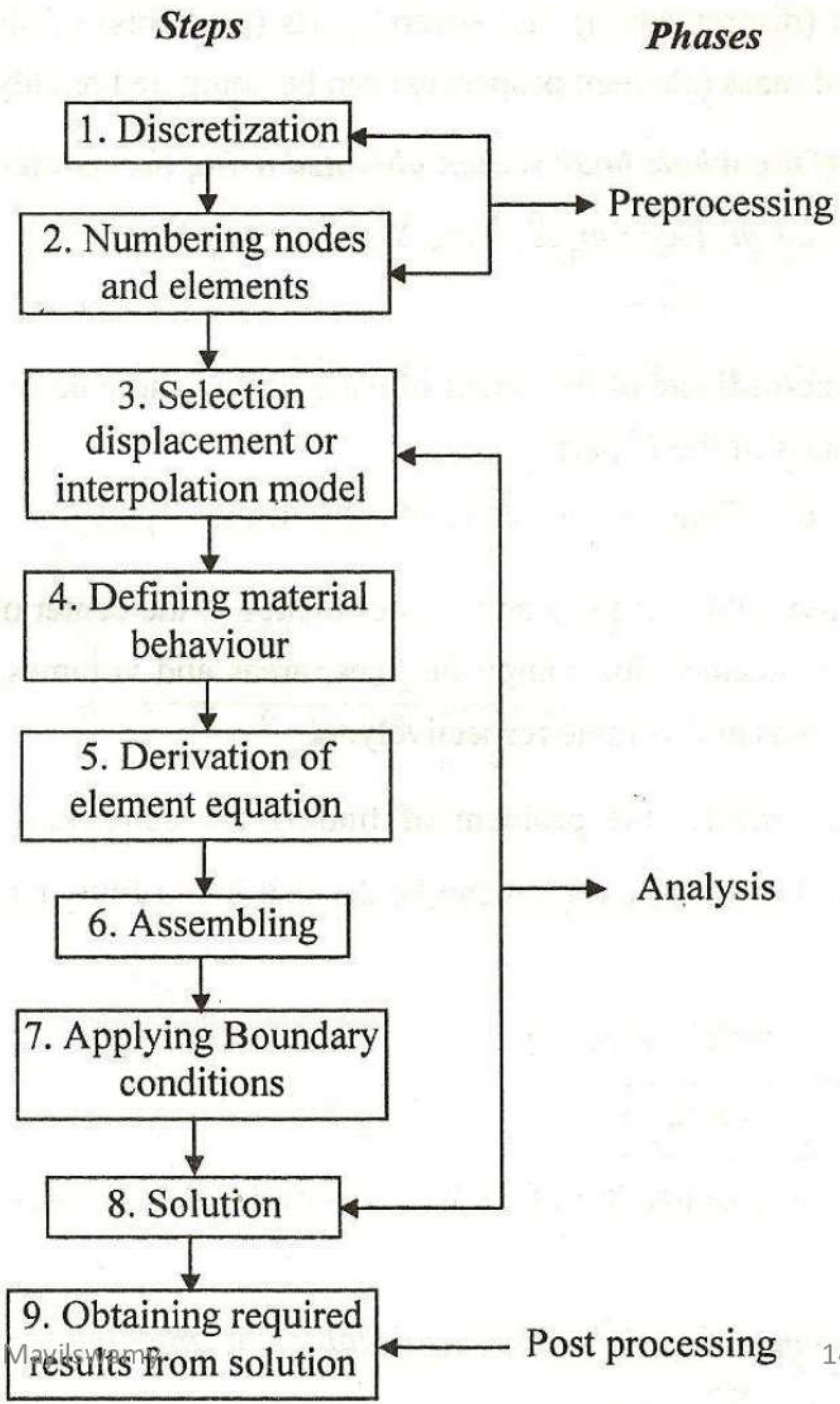


Problem: Obtain the stresses/strains in the plate

- Approximate method
- Geometric model
- Node
- Element
- Mesh
- Discretization

Procedure of Finite Element Analysis (FEA)

Procedure of FEA



Discretization of Domain

- Discretization is the process in which the given body or domain is subdivided into numbers and elements.

- 1D – Line/bar elements
- 2D – Triangular and quadrilateral elements
- 3D – Tetrahedral/brick elements

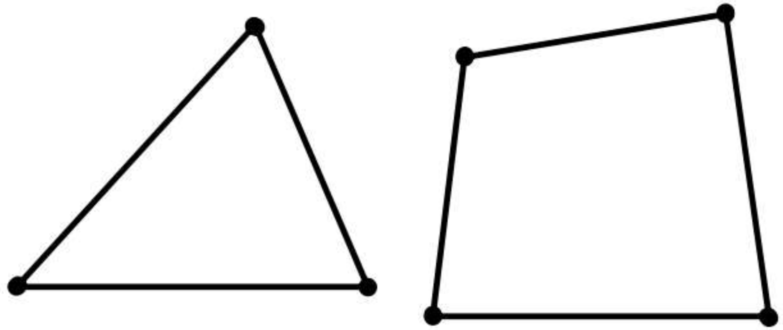
- The size of elements and number of elements will have effect on accuracy and convergence of solution.

- If the size of elements is small, the solution will be more accurate with increase in cost of computation

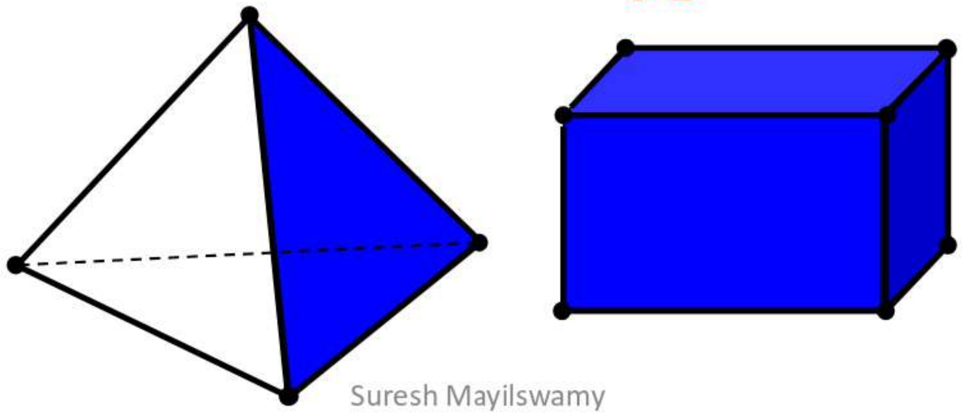
Common Types of Elements

Two-Dimensional Elements
Triangular, Quadrilateral
Plates, Shells, 2-D

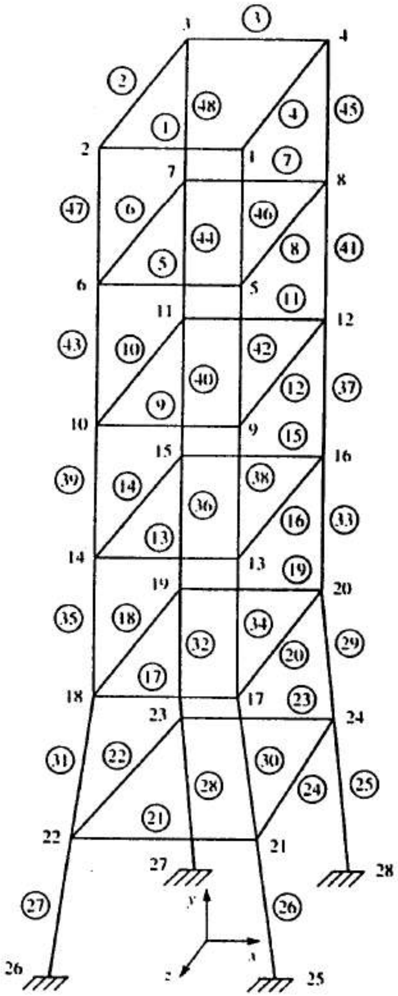
One-Dimensional Elements
Line
Rods, Beams, Trusses, Frames



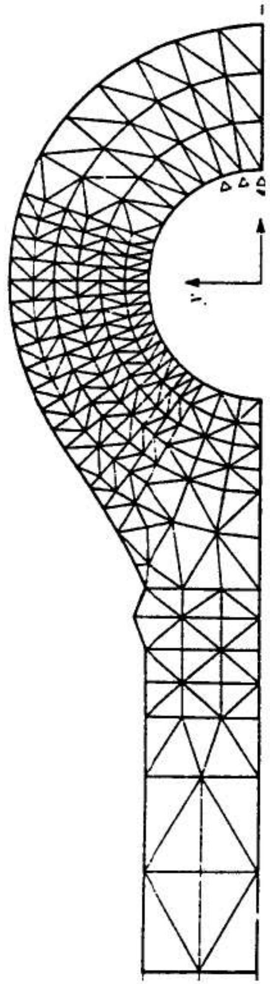
Three-Dimensional Elements
Tetrahedral, Rectangular Prism (Brick)
3-D



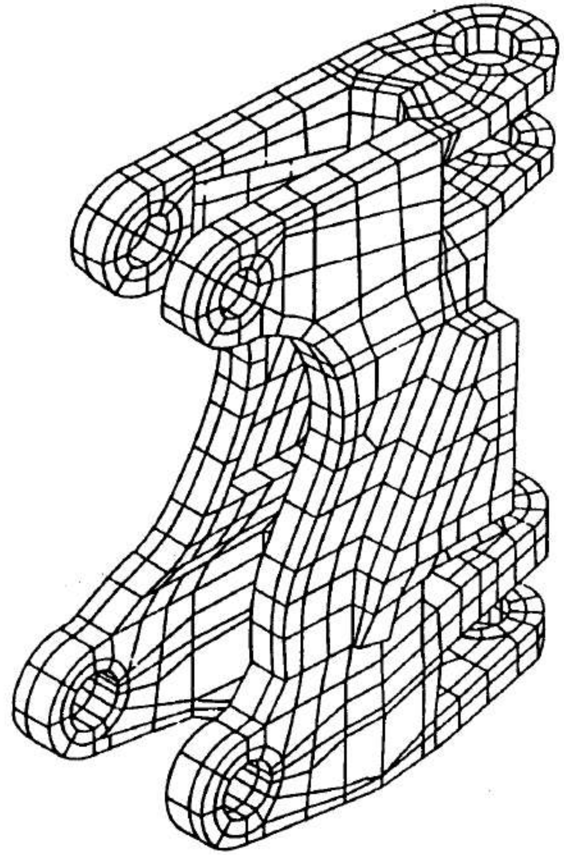
Discretization Examples



One-Dimensional Frame Elements

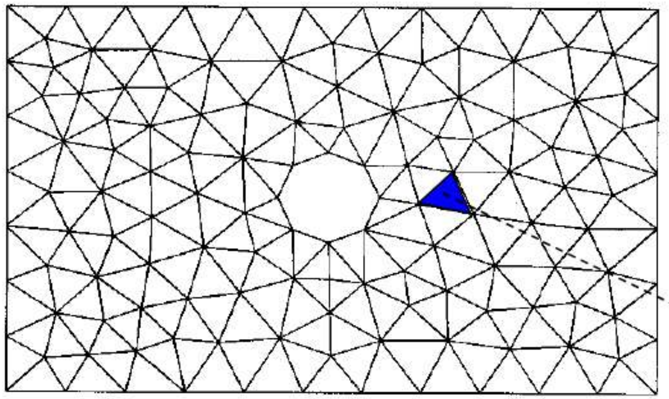


Two-Dimensional Triangular Elements

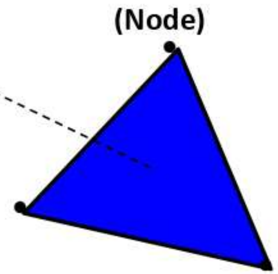


Three-Dimensional Brick Elements

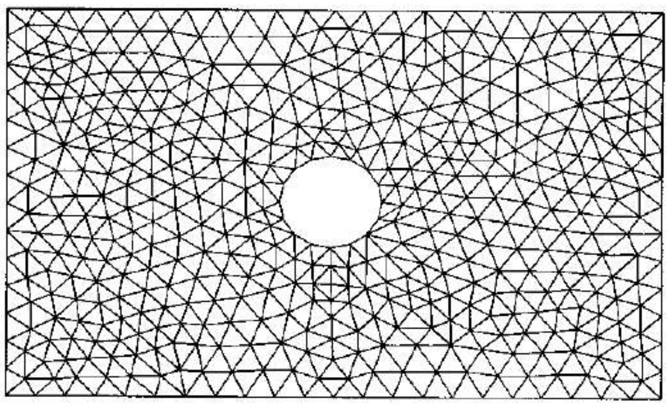
Two-Dimensional Discretization Refinement



(Discretization with 228 Elements)



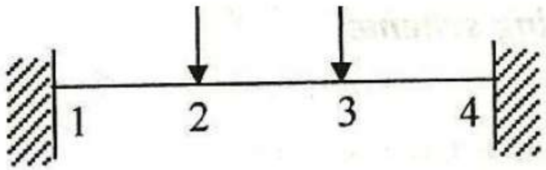
(Triangular Element)



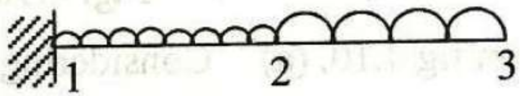
(Discretization with 912 Elements)

Numbering of Nodes and Elements

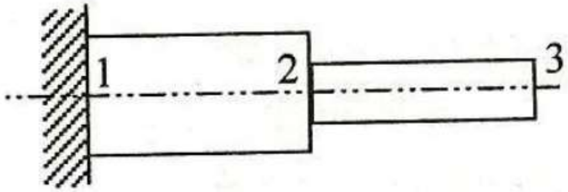
- After discretization the nodes and elements are to be numbered.



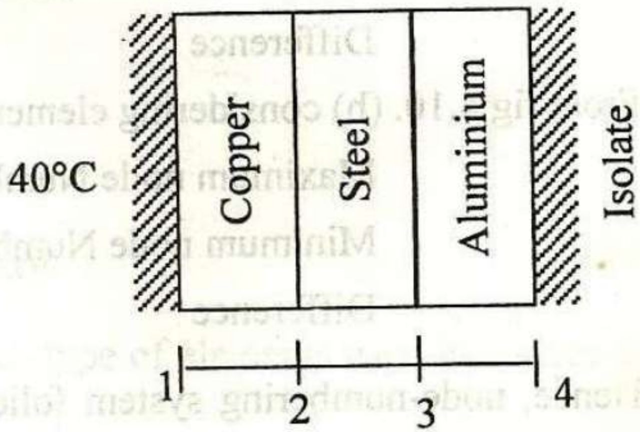
(a). Concentrated loads on a beam



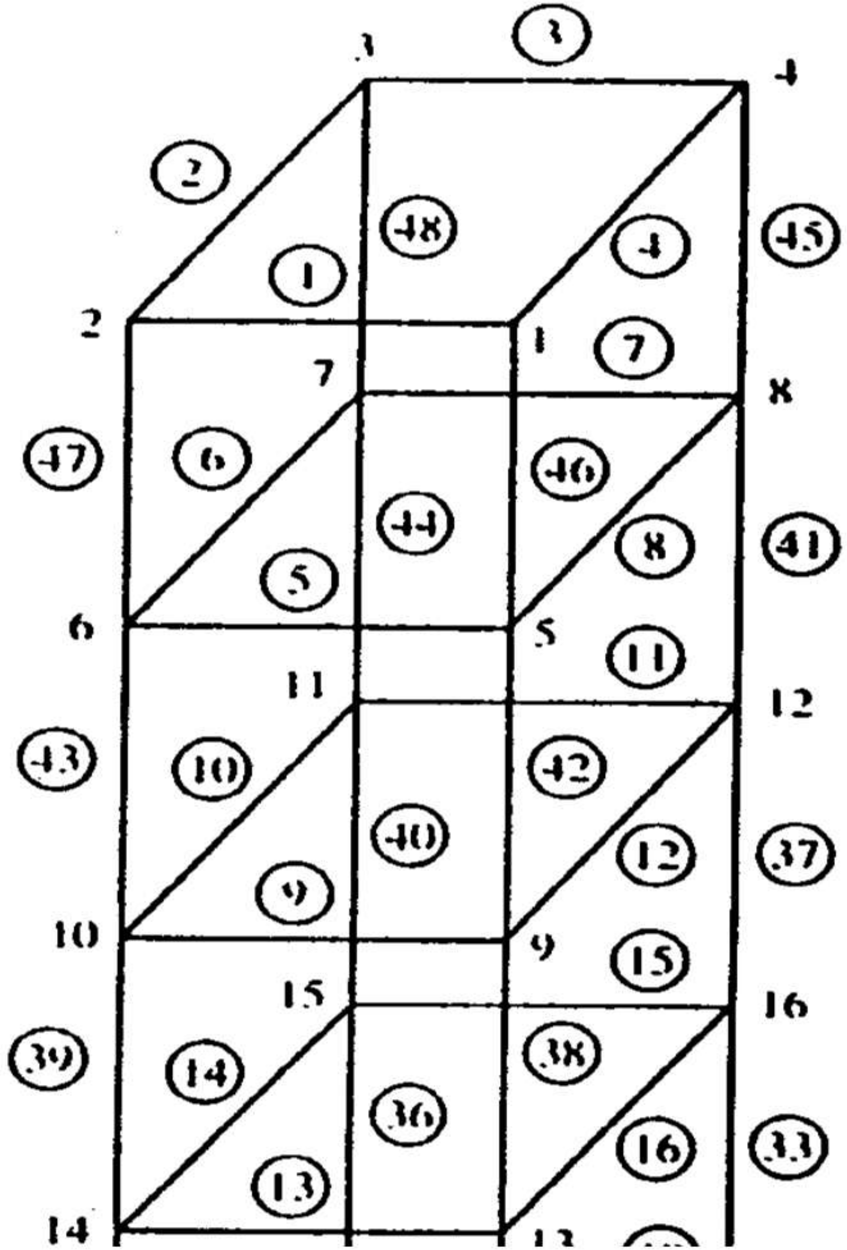
(b). Abrupt change in loads



(c). Change in cross section



(d). Composite wall different material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Selection of a displacement function

- In Finite Element Analysis assumed the solution function used to represent the behaviour of field variables in each element are called "Displacement Function" or "Interpolation Function".

Defining the Material Behaviour

- The results from FEA mainly depend on how well the material behaviour is accurately modeled.
- The material behaviour model is defined by stress-strain relationship and strain displacement relationship.

Derivation of element equation

- The following methods are used to derive the element equation.

$$\{f\} = \{d\}[K]$$

  - ➢ Variational method
  - ➢ Weight residual method (Thermal analysis)
  - ➢ Virtual displacement method (Stress analysis)
  - ➢ Energy method (Stress analysis)

Assembling

- The individual element stiffness matrices are then assembled to obtain the global stiffness matrix ($\{f\} = \{d\}[K]$) of the whole component being analyzed.

Applying the boundary conditions

- The known degrees of freedom at the boundary nodes of a physical domain are applied to global equation before solving for global displacement vector. Hence the number of unknown field variable to be solved will be reduced.

Solution

- After applying the boundary conditions, the resulting simultaneous equations are solved by using Gauss-elimination method or any other method.
- By solving, the global displacement vector is determined.

Obtaining the required results from the solution

- From the solution of displacement vector stress and strain values can be obtained.
- Similarly the required results are obtained from the displacement vector and they are represented either tabular form or graphical form.
- It is very difficult to understand the displacement pattern, stress distribution etc from the tabulated results.
- To over come these difficulties, the results are usually represented in the graphical form, animated views, contour plots, graphs etc.

Advantages of FEA

- Irregular geometries can be modeled more accurately and easily
- Implementation of any type of boundary conditions is very easy.
- Any type of loading can be handled.
- The element sizes can be varied throughout the model. Wherever it is necessary, we can use fine meshes.
- Whether the problem is linear or non linear, the basics of FEA remain same.
- Altering the element model with different loads, boundary conditions and other changes on the model can be done easily.

Disadvantages of FEA

- FEA software's are costlier.
- Output result will vary considerably, when the body is modeled with fine mesh when compared to body modeled with course mesh.
- Even though the FEA softwares are user friendly but they are not relatively easier for use.

Evolution of CAD/CAM and CIM