Introduction to Robotics

A common view : Robots as Humanoids

We will be studying Industrial manipulator type Robots.

Agenda

- Introduction to Robotics
- Classification of Robots
- Robot accessories
- Robot coordinates
- Work volumes and Reference Frames
- Robot Programming
- Robot Applications in Lean Mfg.

Robotics Timeline

- **1922 Czech author Karel Capek wrote a story called Rossum's Universal Robots and introduced the word "Rabota"(meaning worker)**
- **1954 George Devol developed the first programmable Robot.**
- **1955 Denavit and Hartenberg developed the homogenous transformation matrices**
- **1962 Unimation was formed, first industrial Robots appeared.**
- **1973 Cincinnati Milacron introduced the T3 model robot, which became very popular in industry.**
- **1990 Cincinnati Milacron was acquired by ABB**

Robot Classification

The following is the classification of Robots according to the Robotics Institute of America

- Variable-Sequence Robot : A device that performs the successive stages of a task according to a predetermined method easy to modify
- Playback Robot :A human operator performs the task manually by leading the Robot
- Numerical Control Robot : The operator supplies the movement program rather than teaching it the task manually.
- Intelligent Robot : A robot with the means to understand its environment and the ability to successfully complete a task despite changes to the environment.

ROBOT

- Defined by Robotics Industry Association (RIA) as
  - a re-programmable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motion for a variety of tasks
- possess certain anthropomorphic characteristics
  - mechanical arm
  - sensors to respond to input
  - Intelligence to make decisions

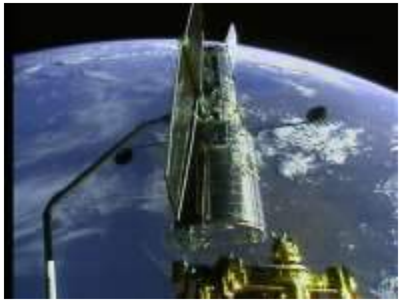
Robot Accessories

A Robot is a system, consists of the following elements, which are integrated to form a whole:

- **Manipulator / Rover : This is the main body of the Robot and consists of links, joints and structural elements of the Robot.**

- **End Effector : This is the part that generally handles objects, makes connection to other machines, or performs the required tasks.**

It can vary in size and complexity from a endeffector on the space shuttle to a small gripper



Accessories

- **Acutators : Actuators are the muscles of the manipulators. Common types of actuators are servomotors, stepper motors, pneumatic cylinders etc.**

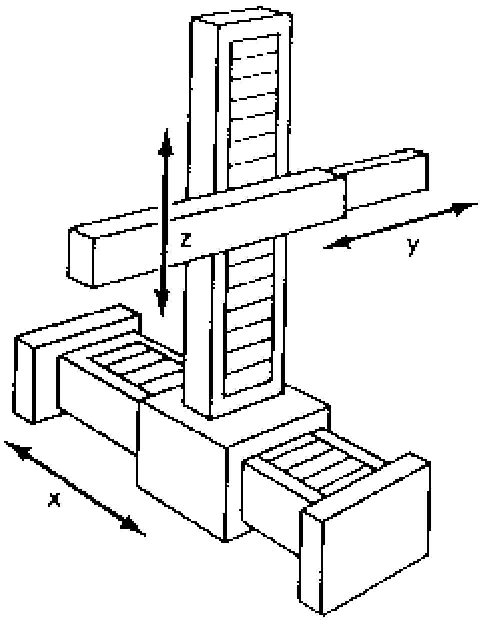
- **Sensors : Sensors are used to collect information about the internal state of the robot or to communicate with the outside environment. Robots are often equipped with external sensory devices such as a vision system, touch and tactile sensors etc which help to communicate with the environment**

- **Controller : The controller receives data from the computer, controls the motions of the actuator and coordinates these motions with the sensory feedback information.**

Robot Configurations

Some of the commonly used configurations in Robotics are

- **Cartesian/Rectangular Gantry(3P) :** These Robots are made of 3 Linear joints that orient the end effector, which are usually followed by additional revolute joints.



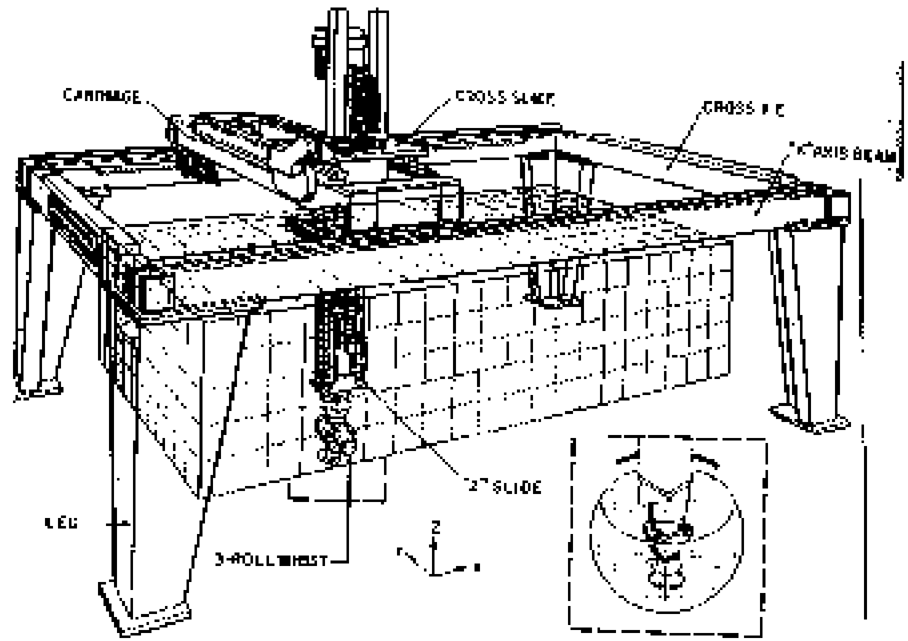
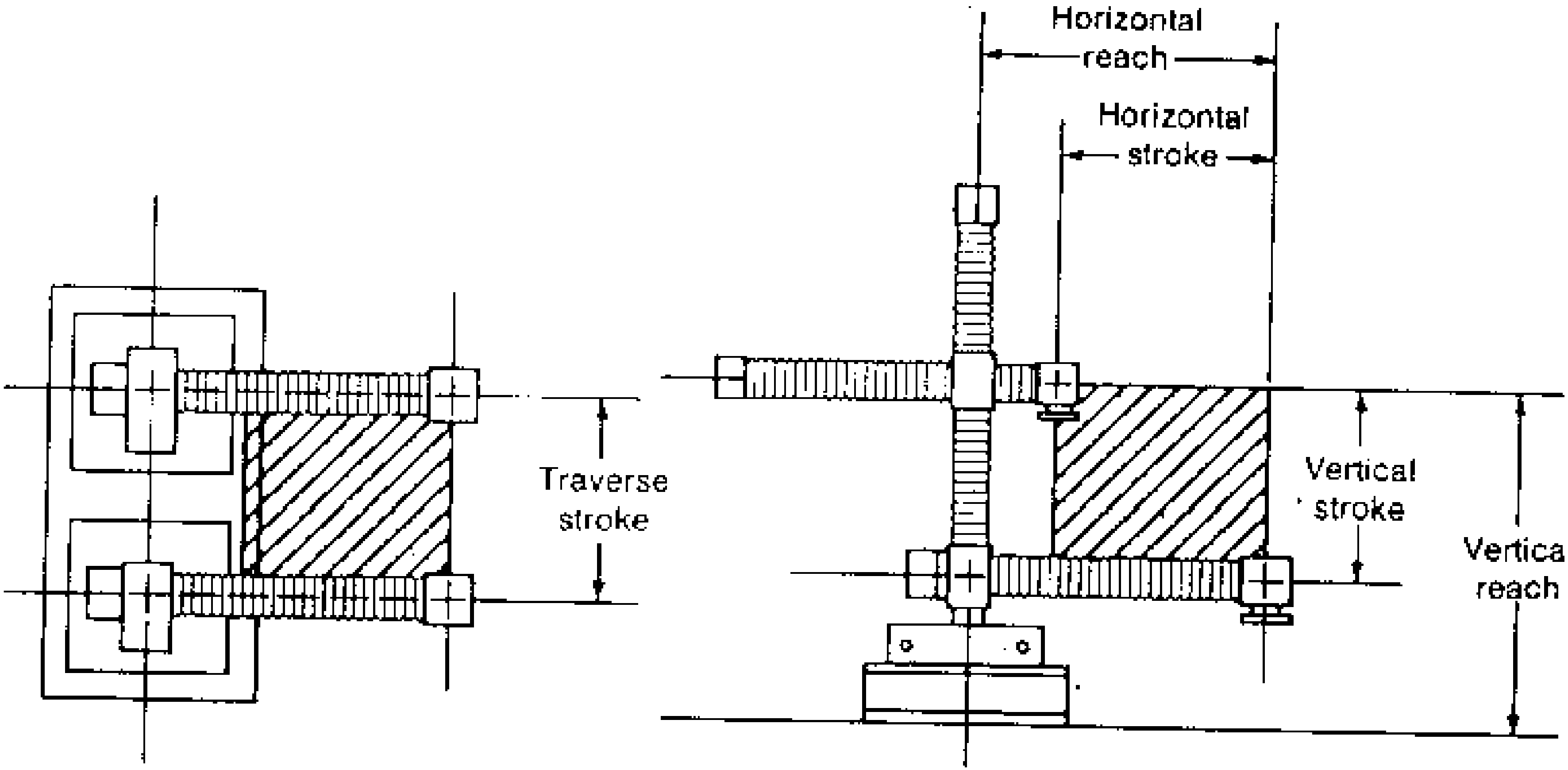


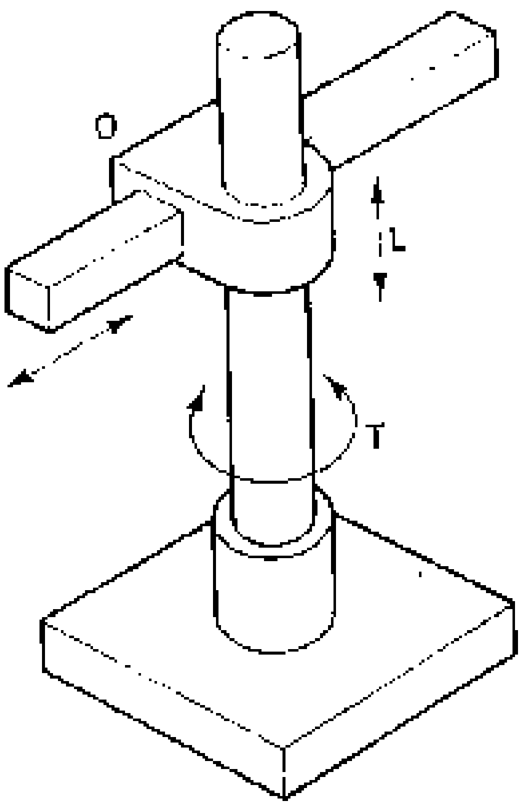
Figure 9.3. Gantry configuration robot. (Courtesy of Cincinnati Milacron.)

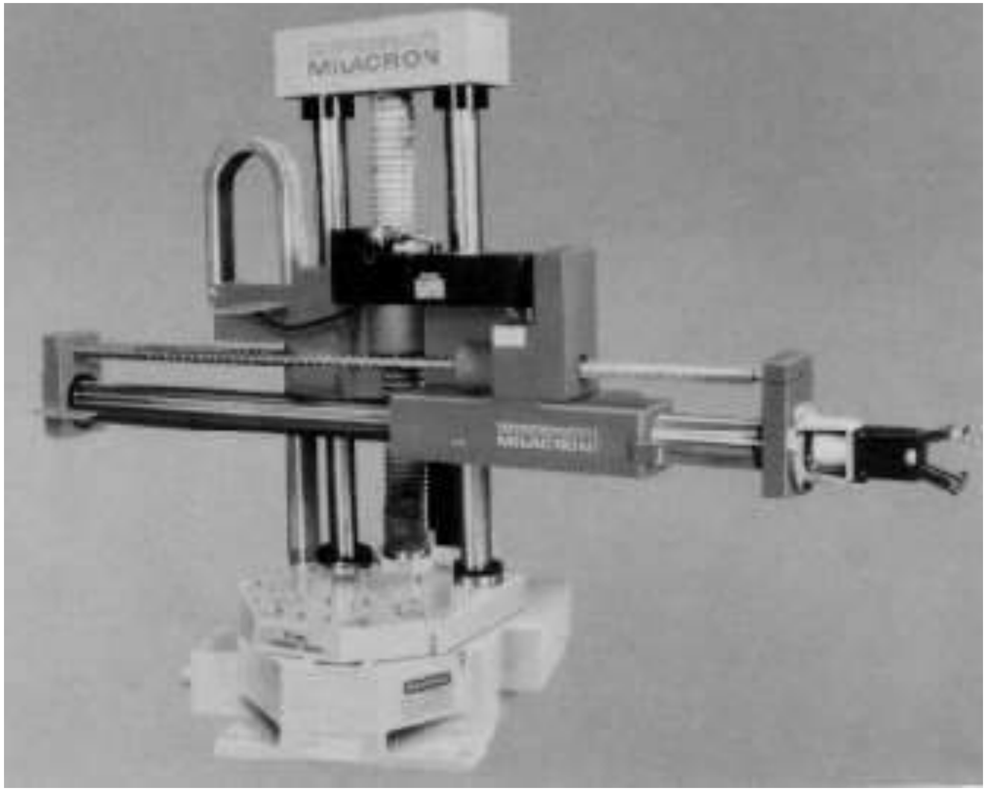
Cartesian Robot - Work Envelope



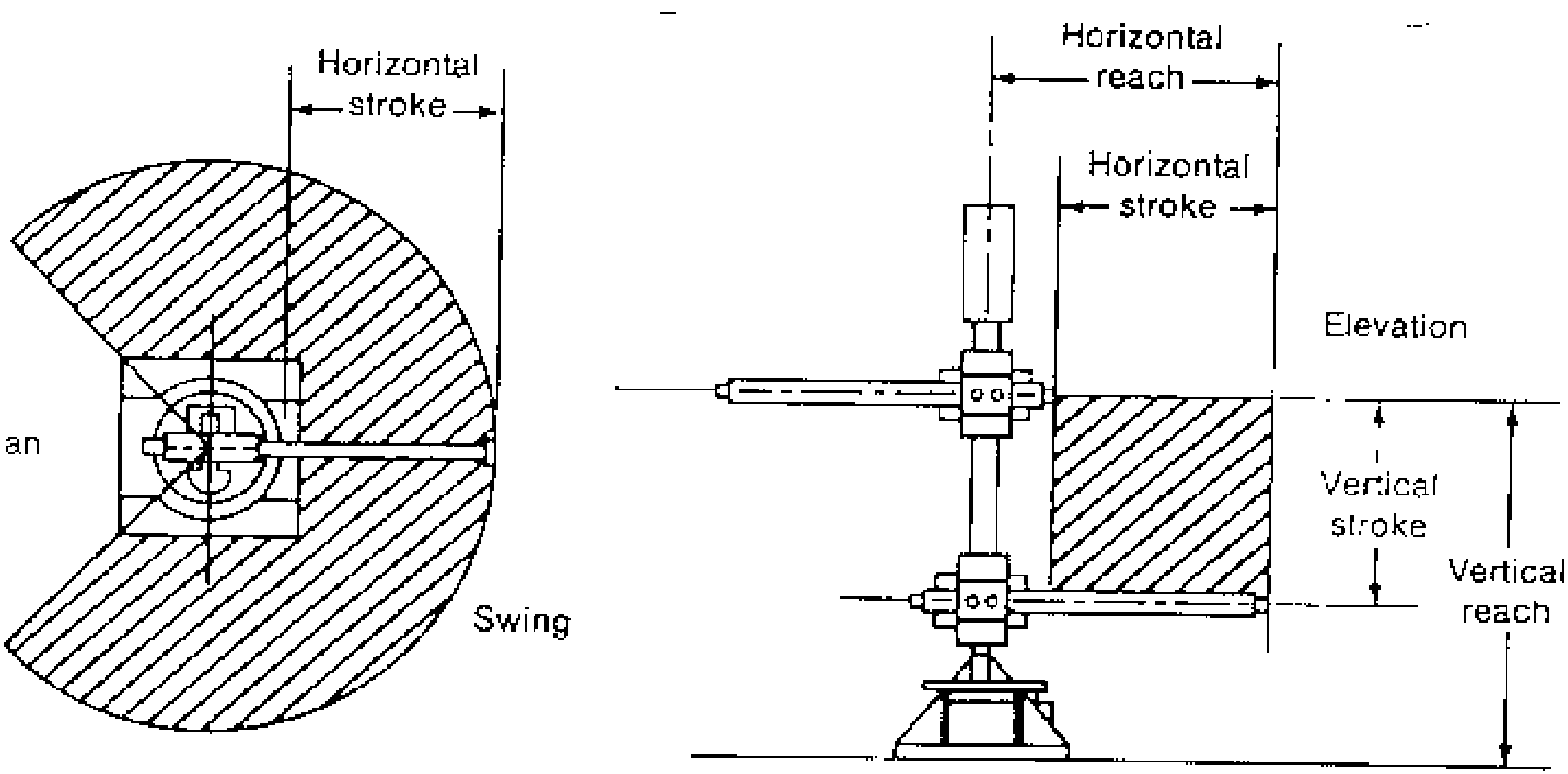
Robot Configurations (cont'd)

- **Cylindrical (R2P):** Cylindrical coordinate Robots have 2 prismatic joints and one revolute joint.



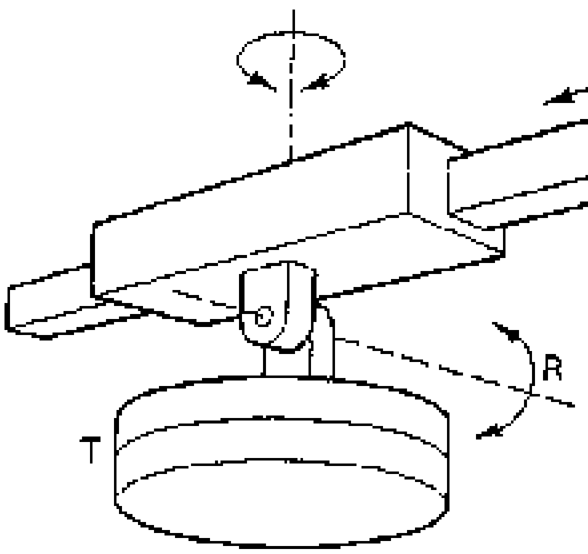


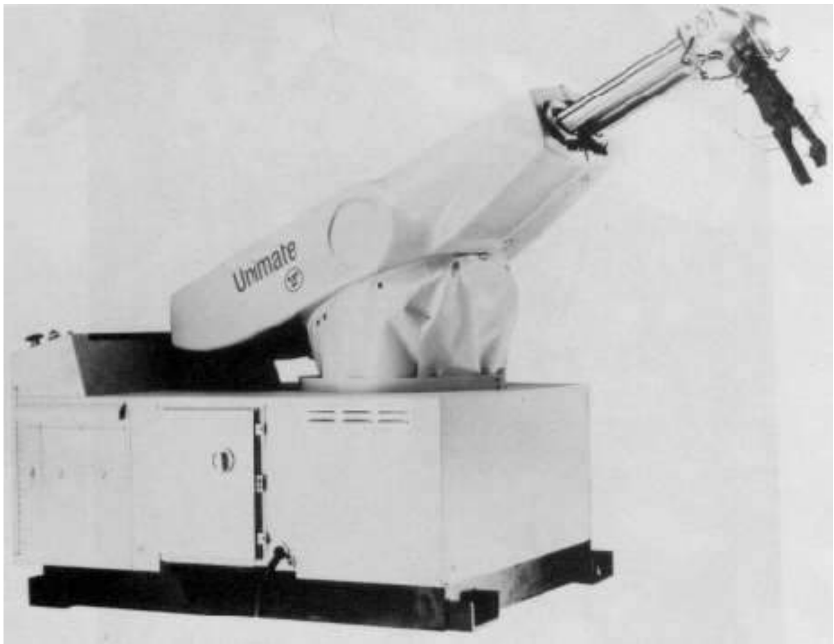
Cylindrical Robot - Work Envelope



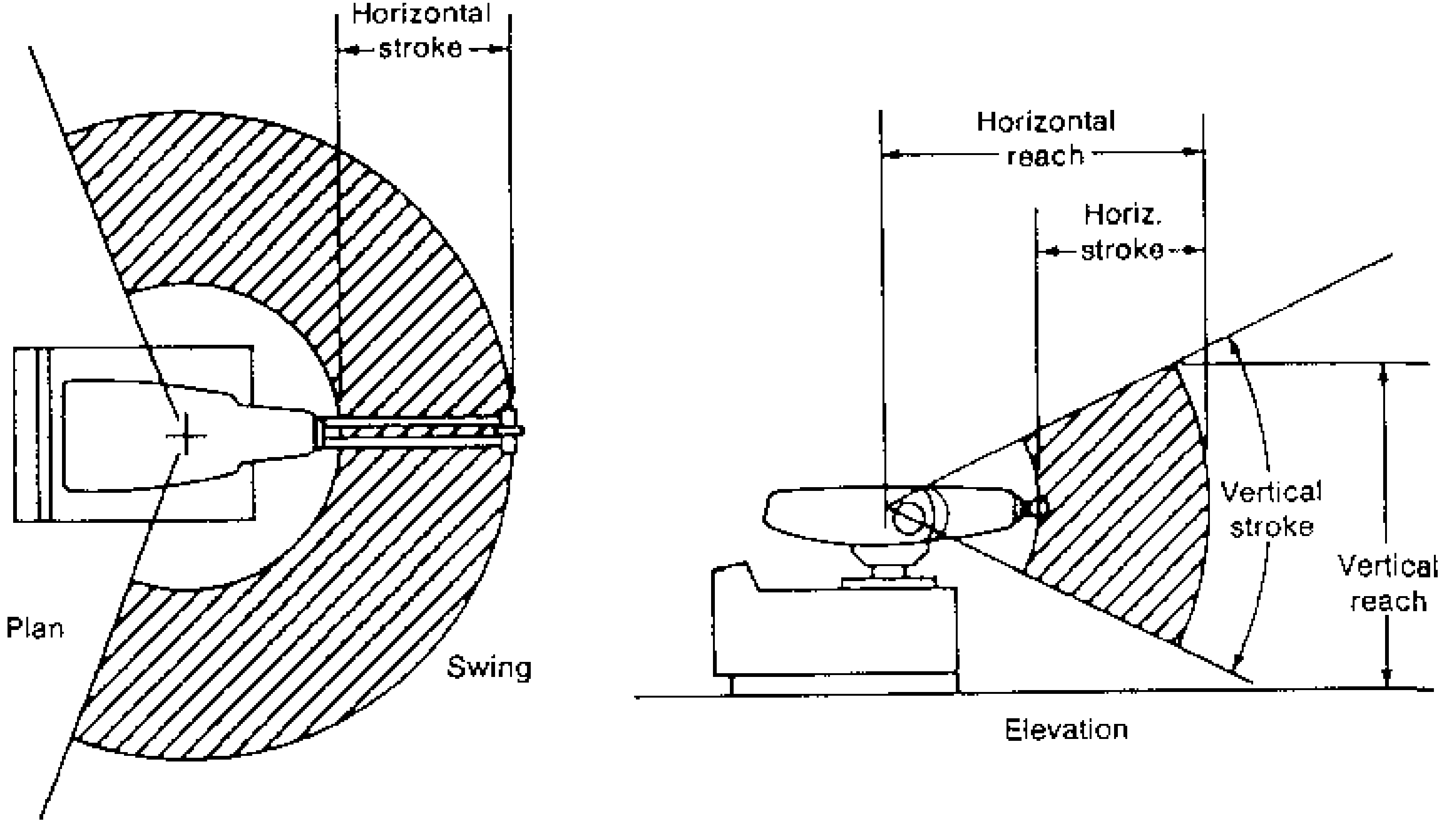
Robot Configurations (cont'd)

- **Spherical joint (2RP):** They follow a spherical coordinate system, which has one



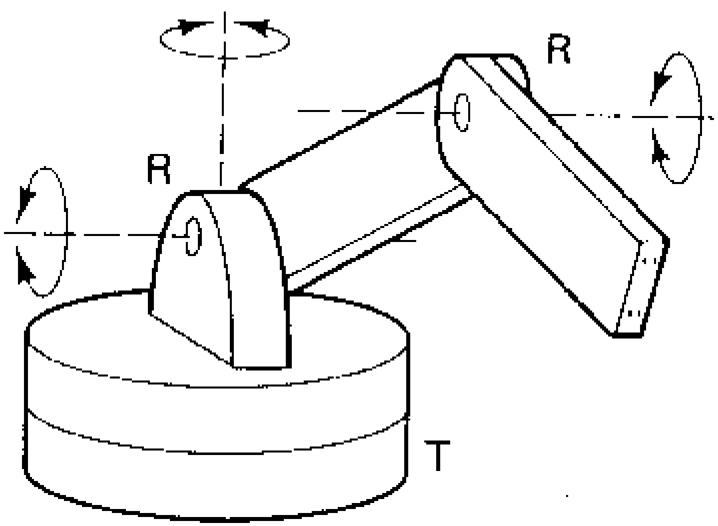


Spherical Robot - Work Envelope



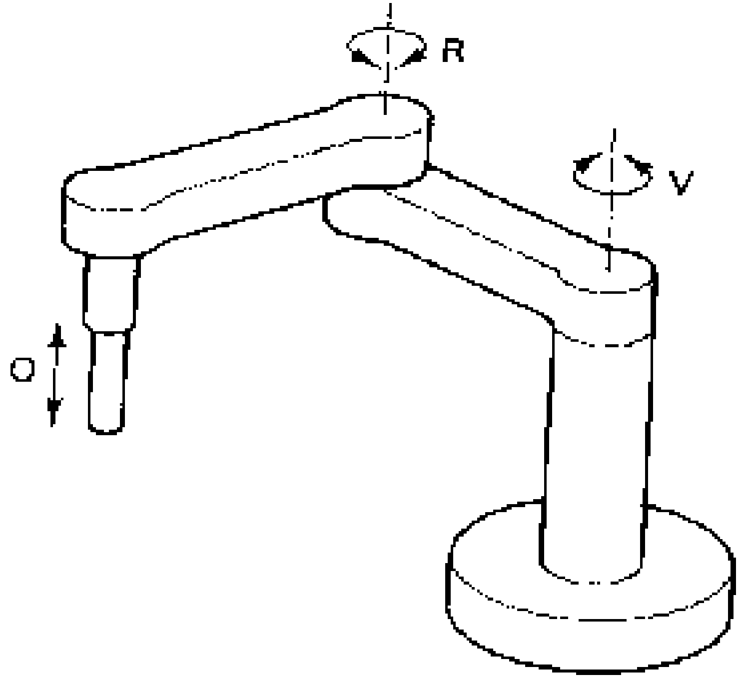
Robot Configurations (cont’d)

- **Articulated/anthropomorphic(3R) :**An articulated robot’s joints are all revolute, similar to a human’s arm.

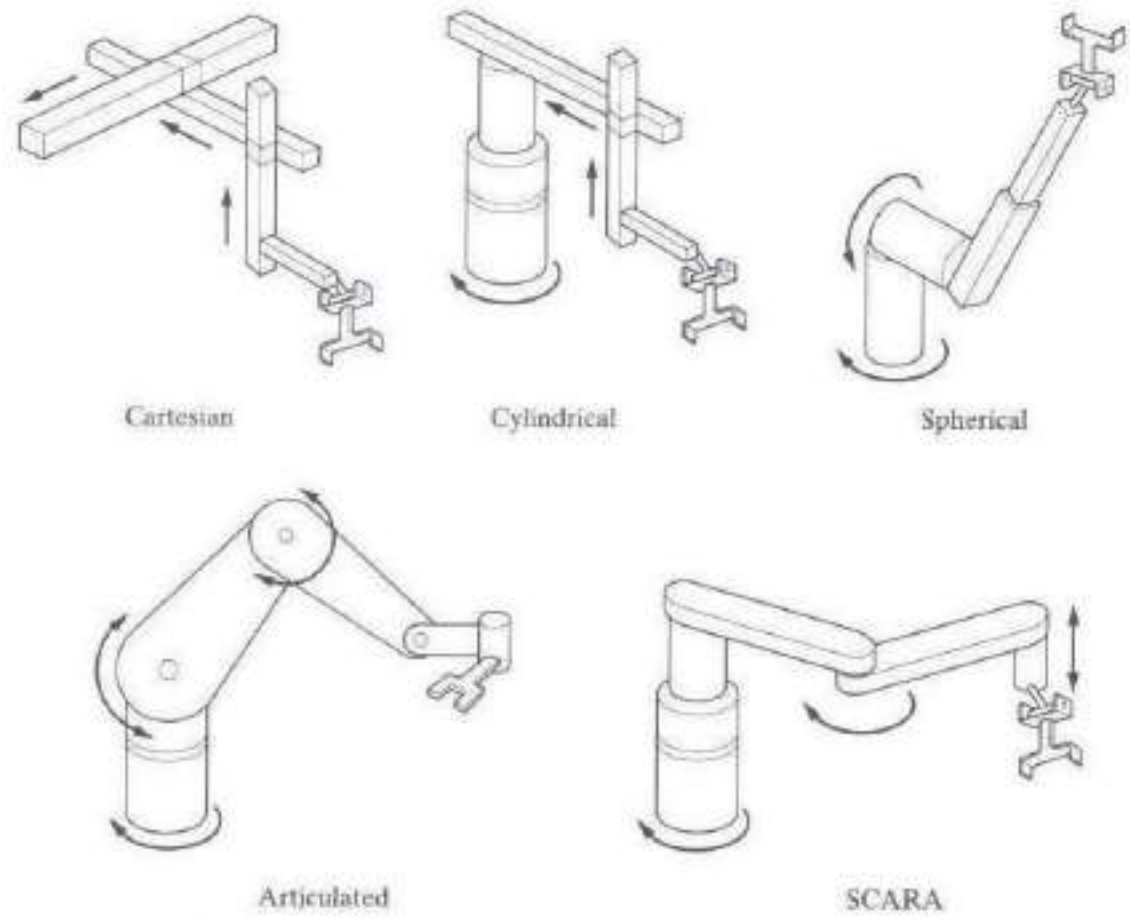


Robot Configurations (cont'd)

- **Selective Compliance Assembly Robot Arm (SCARA) (2R1P):** They have two revolute joints that are parallel and allow the Robot to move in a horizontal plane, plus an additional prismatic joint that moves vertically



Robot Configurations



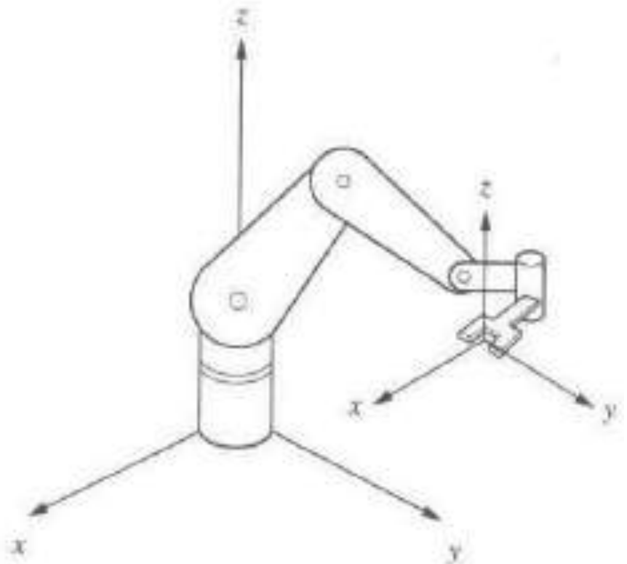
Reference Frames

- World Reference Frame which is a universal coordinate frame, as defined by the x-y-z axes. In this case the joints of the robot move simultaneously so as to create motions along the three major axes.

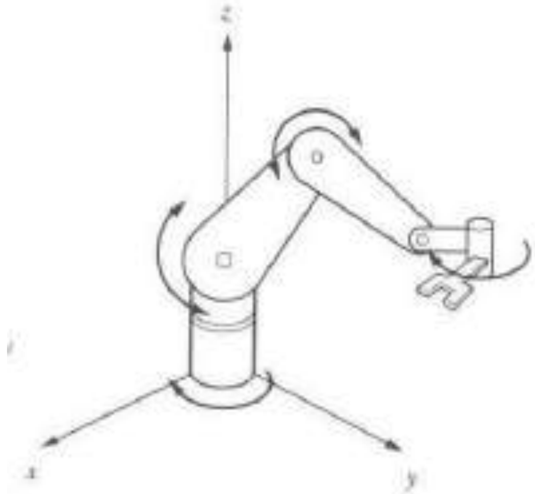
- Joint Reference Frame which is used to specify movements of each individual joint of the Robot. In this case each joint may be accessed individually and thus only one joint moves at a time.

- Tool Reference Frame which specifies the movements of the Robots hand relative to the frame attached to the hand. The x',y'and z' axes attached to the hand define the motions of the hand relative to this local frame. All joints of the Robot move simultaneously to create coordinated motions about the Tool frame.

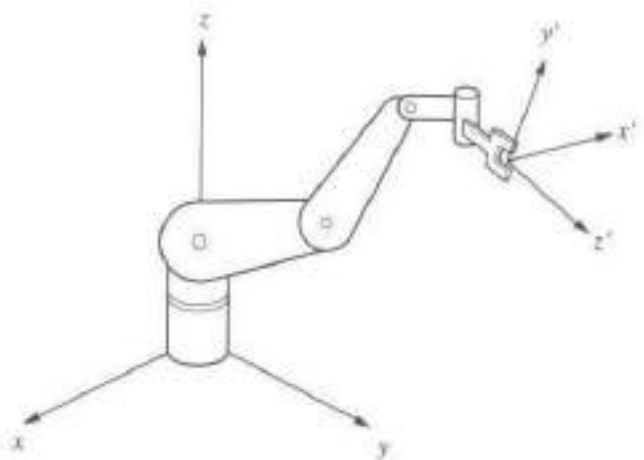
Robot Reference Frames



World reference frame



Joint reference frame



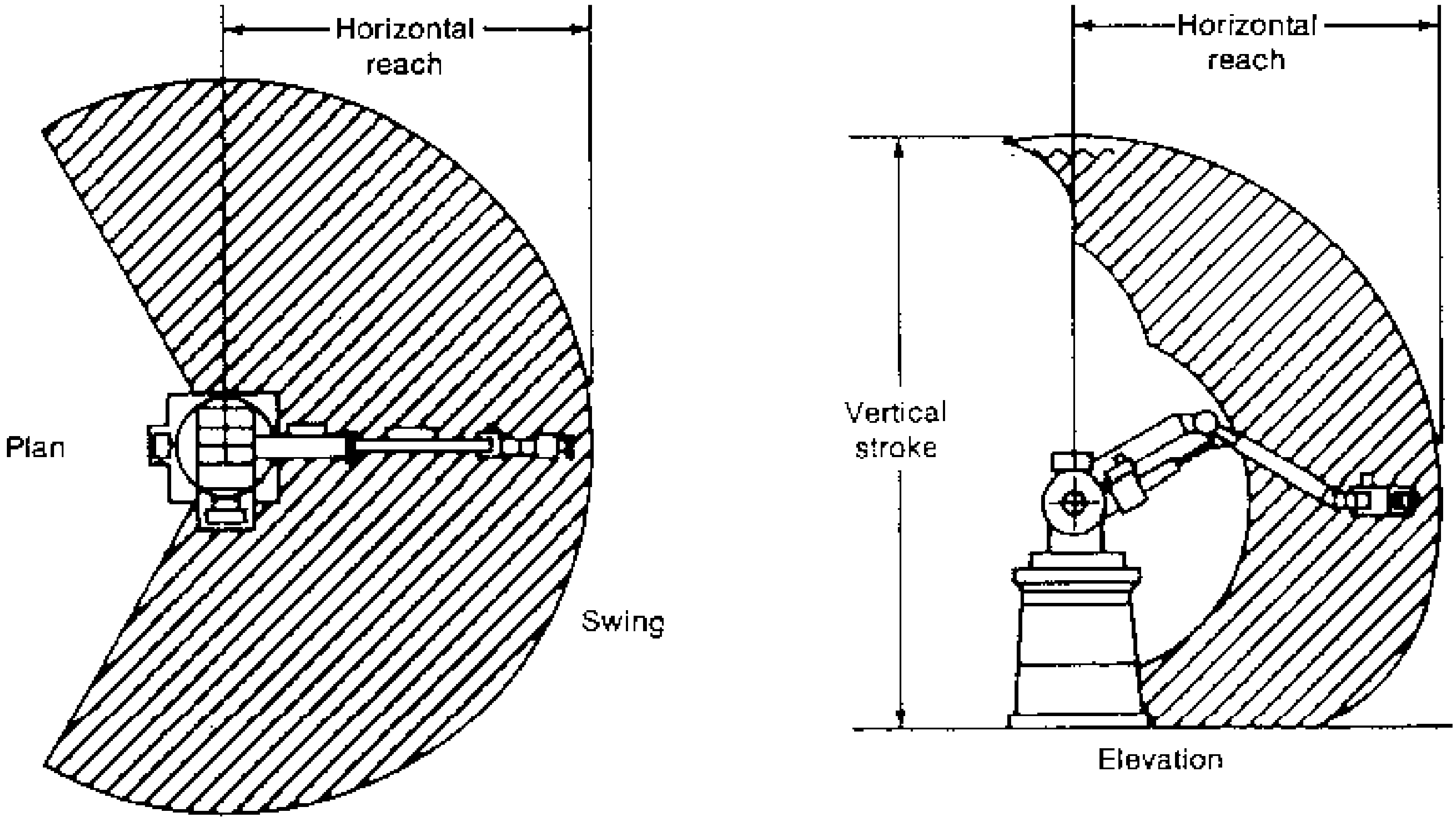
Tool reference frame

Work Envelope concept

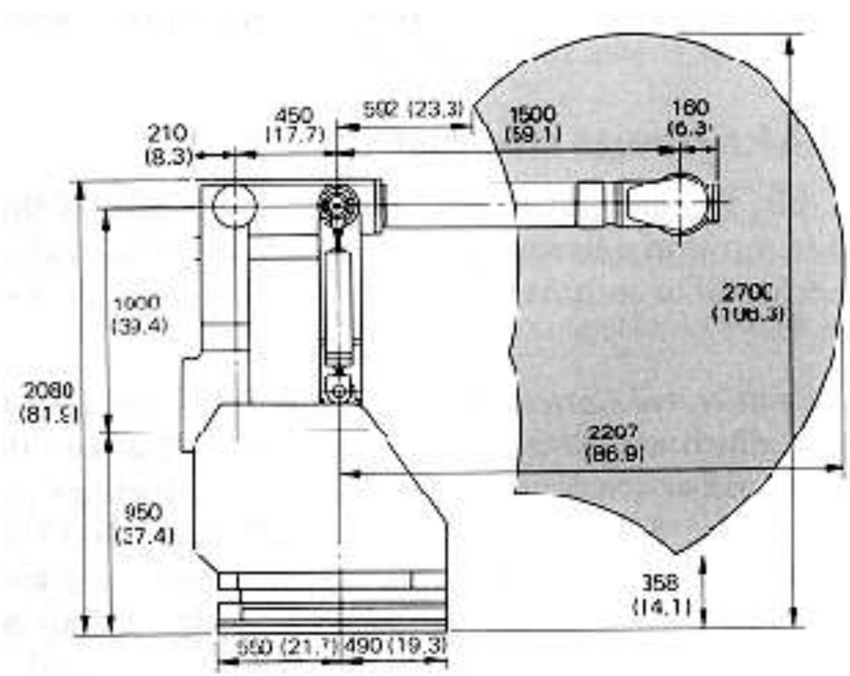
- Depending on the configuration and size of the links and wrist joints, robots can reach a collection of points called a **Workspace**.

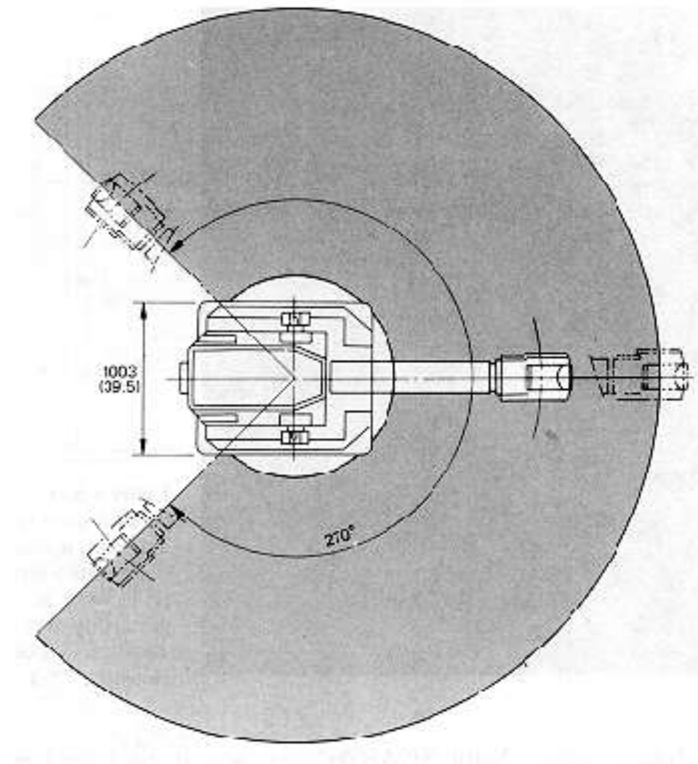
- Alternately Workspace may be found empirically, by moving each joint through its range of motions and combining all space it can reach and subtracting what space it cannot reach

Pure Spherical Jointed Arm - Work envelope



2) Parallelogram Jointed





Exercise

Readiness Assessment Test A.K.A. RAT

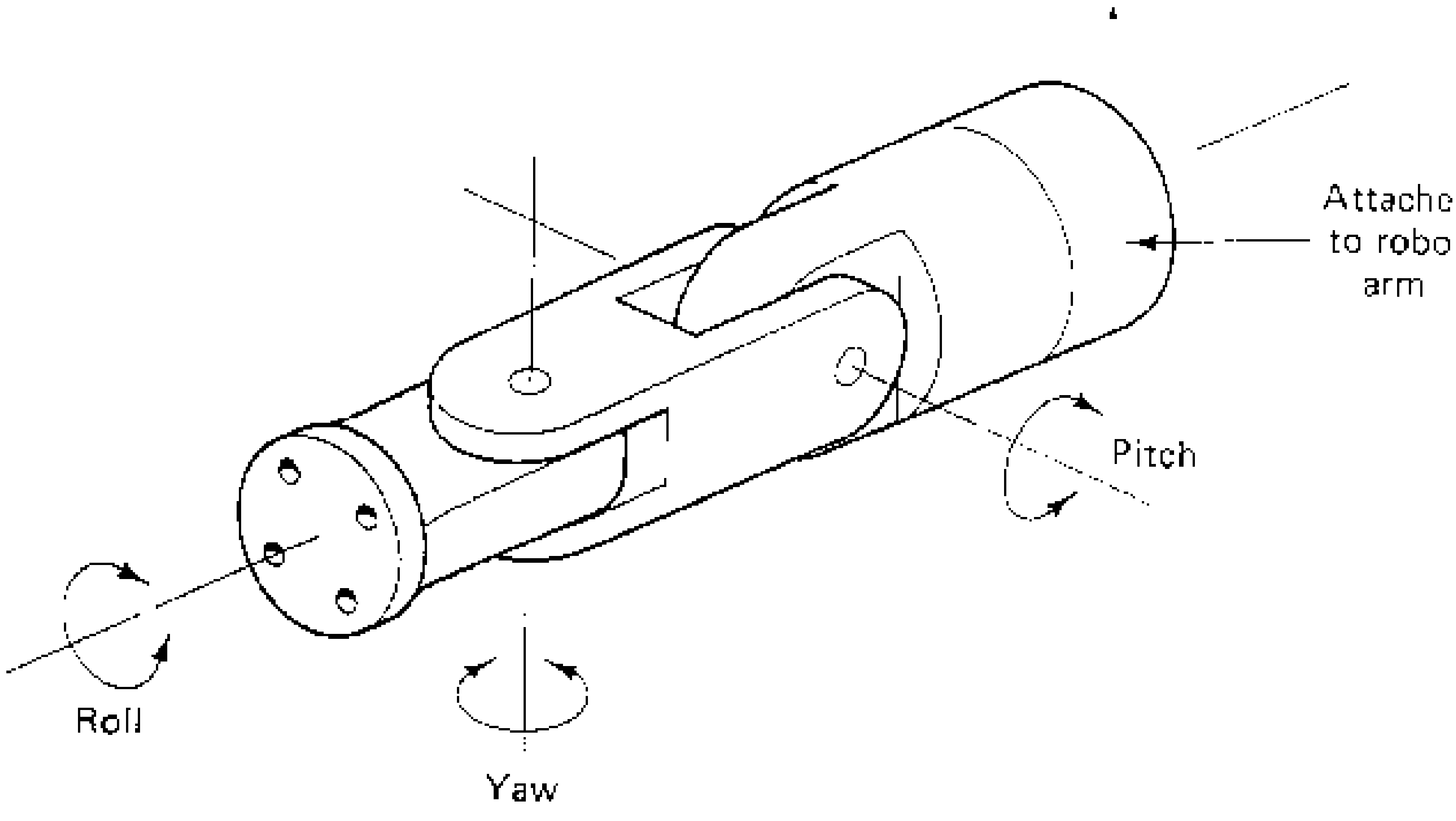
AS A INDIVIDUAL, prepare a detailed response for the following Readiness Assessment test

What type of Robot Configuration does the ABB 140 Robot have?
Can you find out its Work Space?

WRIST

- typically has 3 degrees of freedom
  - ***Roll*** involves rotating the wrist about the arm axis
  - ***Pitch*** up-down rotation of the wrist
  - ***Yaw*** left-right rotation of the wrist
- End effector is mounted on the wrist

WRIST MOTIONS



CONTROL METHODS

- ***Non Servo Control***
  - implemented by setting limits or mechanical stops for each joint and sequencing the actuation of each joint to accomplish the cycle
  - end point robot, limited sequence robot, bang-bang robot
  - No control over the motion at the intermediate points, only end points are known

- Programming accomplished by
  - setting desired sequence of moves
  - adjusting end stops for each axis accordingly
  - the sequence of moves is controlled by a “squencer”, which uses feedback received from the end stops to index to next step in the program
- Low cost and easy to maintain, reliable
- relatively high speed
- repeatability of up to 0.01 inch
- limited flexibility
- typically hydraulic, pneumatic drives

- ***Servo Control***
  - Point to point Control
  - Continuous Path Control
- Closed Loop control used to monitor position, velocity (other variables) of each joint

Point-to-Point Control

- Only the end points are programmed, the path used to connect the end points are computed by the controller
- user can control velocity, and may permit linear or piece wise linear motion
- Feedback control is used during motion to ascertain that individual joints have achieved desired location

- Often used hydraulic drives, recent trend towards servomotors
- loads up to 500lb and large reach
- Applications
  - pick and place type operations
  - palletizing
  - machine loading

Continuous Path Controlled

- in addition to the control over the endpoints, the path taken by the end effector can be controlled
- Path is controlled by manipulating the joints throughout the entire motion, via closed loop control
- Applications:
  - spray painting, polishing, grinding, arc welding

ROBOT PROGRAMMING

- Typically performed using one of the following
  - On line
    - teach pendant
    - lead through programming
  - Off line
    - robot programming languages
    - task level programming

Use of Teach Pendant

- hand held device with switches used to control the robot motions
- End points are recorded in controller memory
- sequentially played back to execute robot actions
- trajectory determined by robot controller
- suited for point to point control applications

- Easy to use, no special programming skills required
- Useful when programming robots for wide range of repetitive tasks for long production runs
- RAPID

Lead Through Programming

- lead the robot physically through the required sequence of motions
- trajectory and endpoints are recorded, using a sampling routine which records points at 60-80 times a second
- when played back results in a smooth continuous motion
- large memory requirements

Programming Languages

- Motivation
  - need to interface robot control system to external sensors, to provide “real time” changes based on sensory equipment
  - computing based on geometry of environment
  - ability to interface with CAD/CAM systems
  - meaningful task descriptions
  - off-line programming capability

- Large number of robot languages available
  - AML, VAL, AL, RAIL, RobotStudio, etc. (200+)
- Each robot manufacturer has their own robot programming language
- No standards exist
- Portability of programs virtually non-existent

In-class Exercise

- As a group, discuss an activity that you think could be automated by using a robot.
- Define the tasks that the robot will perform.
- What kind of special tooling is required? Sketch if you will use any.
- Can the activity be justified economically? Show your development – do not simply say yes or no.

UNIT V OPEN SYSTEM AND DATABASE FOR CIM

Open systems-open system inter connection -manufacturing automations protocol and technical office protocol (MAP (145-156)/TOP).

Development of databases -database terminology(171-190)

architecture of database systems-

data modelling and data associations –

relational data bases –
database operators –

advantages of data base and relational database

Manufacturing Automation Protocol (MAP)

was **a computer network standard released in 1982 for interconnection of devices from multiple manufacturers**. ... Difficulties included changing protocol specifications, the expense of MAP interface links, and the speed penalty of a token-passing network.

. Ø55 mm

Data
Information

Database
DBMS
Classification of DATA
Physical data : storage devices
Logical data: Conceptulization meaning full relation to the namely / vaule
Data independence: DBMS

Why are protocols needed?

- Protocols are needed for communication between any two devices.
  - In what **format** will the messages be transmitted?
  - At what **speed** should messages be transmitted?
  - What to do if **errors** take place?
  - What to do if parts of a message are **lost**?

Need For Protocol Architecture

- E.g. File transfer
  - Source must activate comms. Path or inform network of destination
  - Source must check destination is prepared to receive
  - File transfer application on source must check destination file management system will accept and store file for his user
  - May need file format translation
- Task broken into subtasks
- Implemented separately in layers in stack
- Functions needed in both systems
- Peer layers communicate

WHAT IS MAP ?

Manufacturing Automation Protocol (MAP) was **a computer network standard released in 1982 for interconnection of devices from multiple manufacturers**. ... Difficulties included changing protocol specifications, the expense of MAP interface links, and the speed penalty of a token-passing network.

What is technical office protocol TOP

It s **a set of rules or procedures for transmitting data between electronic devices, such as computers**. In order for computers to exchange information, there must be a preexisting agreement as to how the information will be structured and how each side will send and receive it.

Open Systems Interconnection (OSI) Model

- International standard organization (ISO) established a committee in 1977 to develop an architecture for computer communication.
- Open Systems Interconnection (OSI) reference model is the result of this effort.
- In 1984, the Open Systems Interconnection (OSI) reference model was approved as an international standard for communications architecture.
- Term "open" denotes the ability to connect any two systems which conform to the reference model and associated standards.
- The OSI model describes how information or data makes its way from application programmes (such as spreadsheets) through a network medium (such as wire) to another application programme located on another network.

Open System Interconnection

- It is a process of communication between the two end points in the telecommunication network .

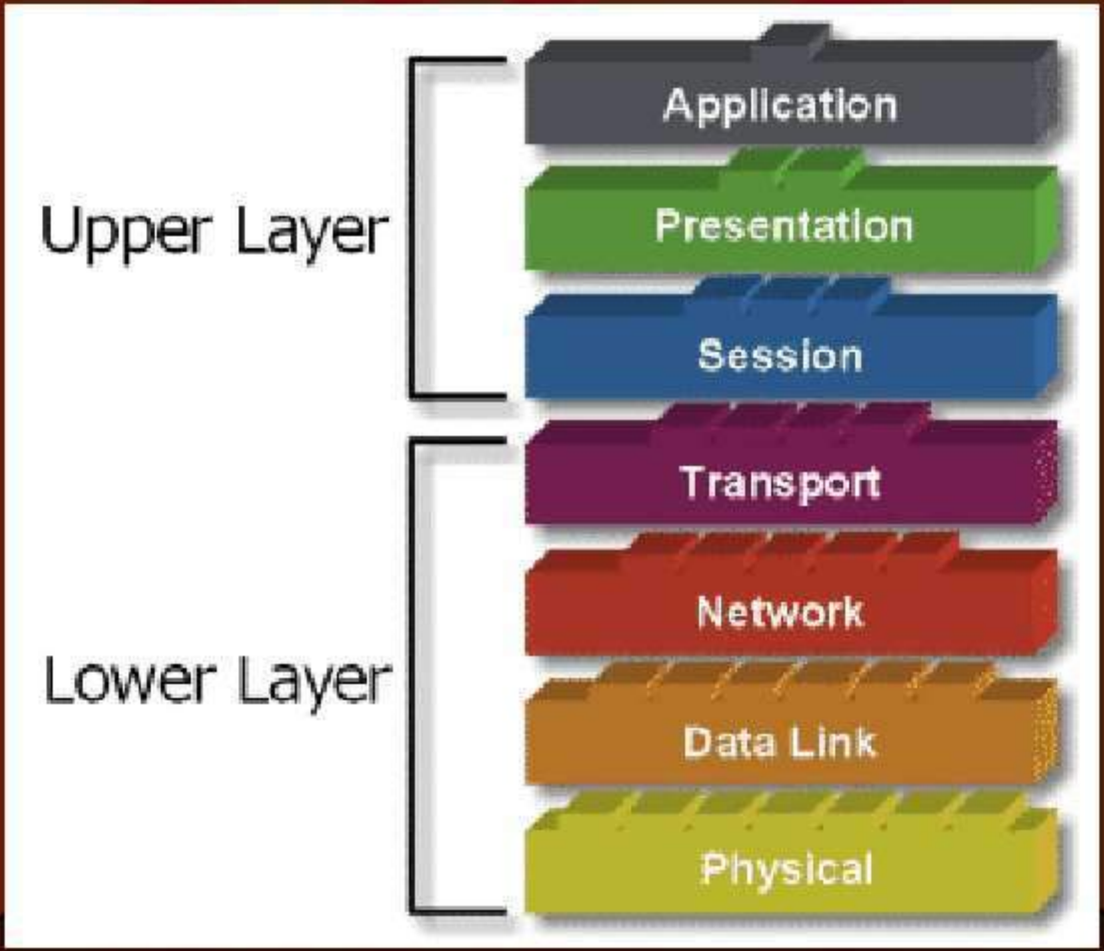
- OSI is divided into seven layers .

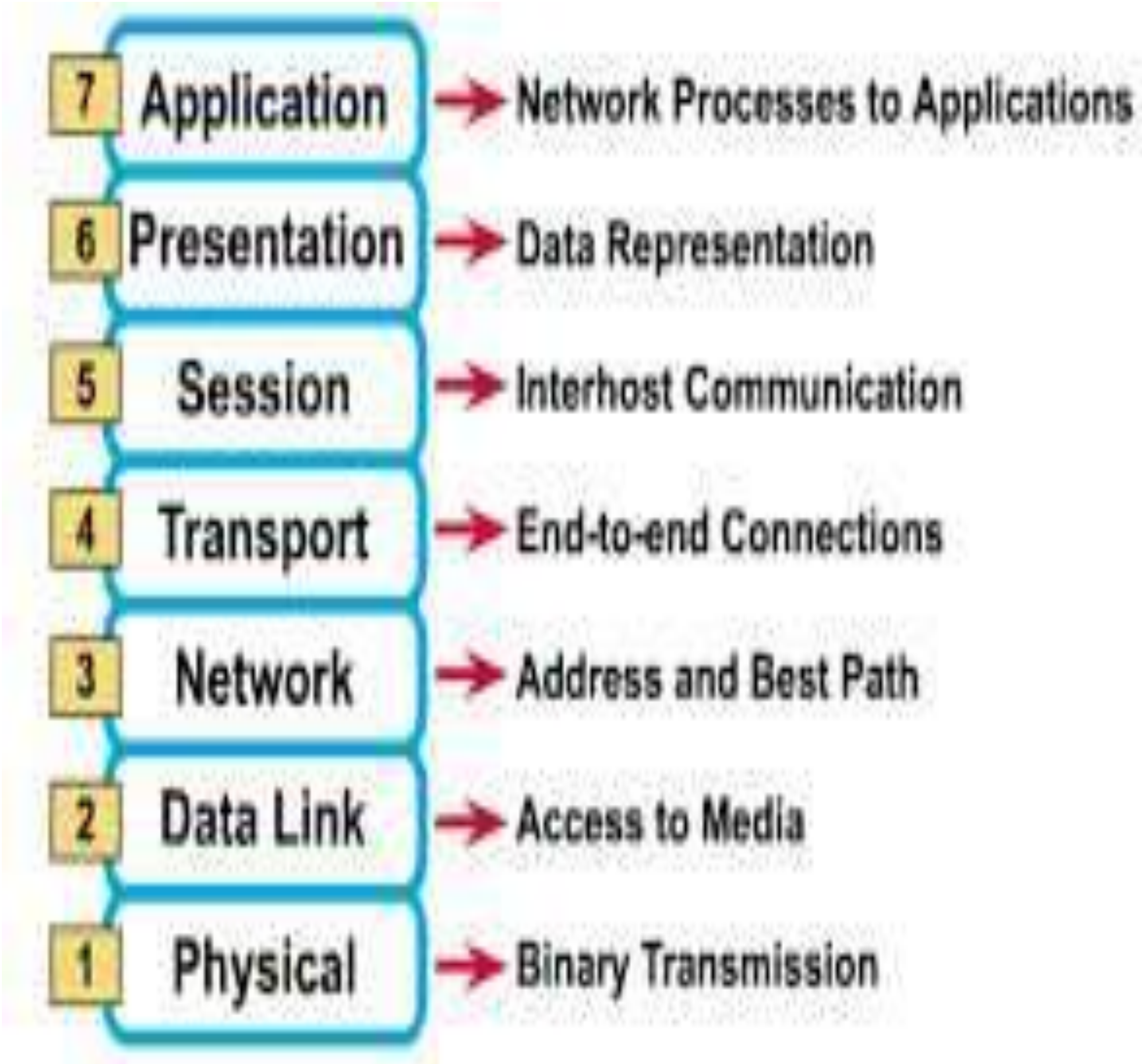
- **It has two groups** :

➢ The upper four layers are used whenever a messages passes through the user.

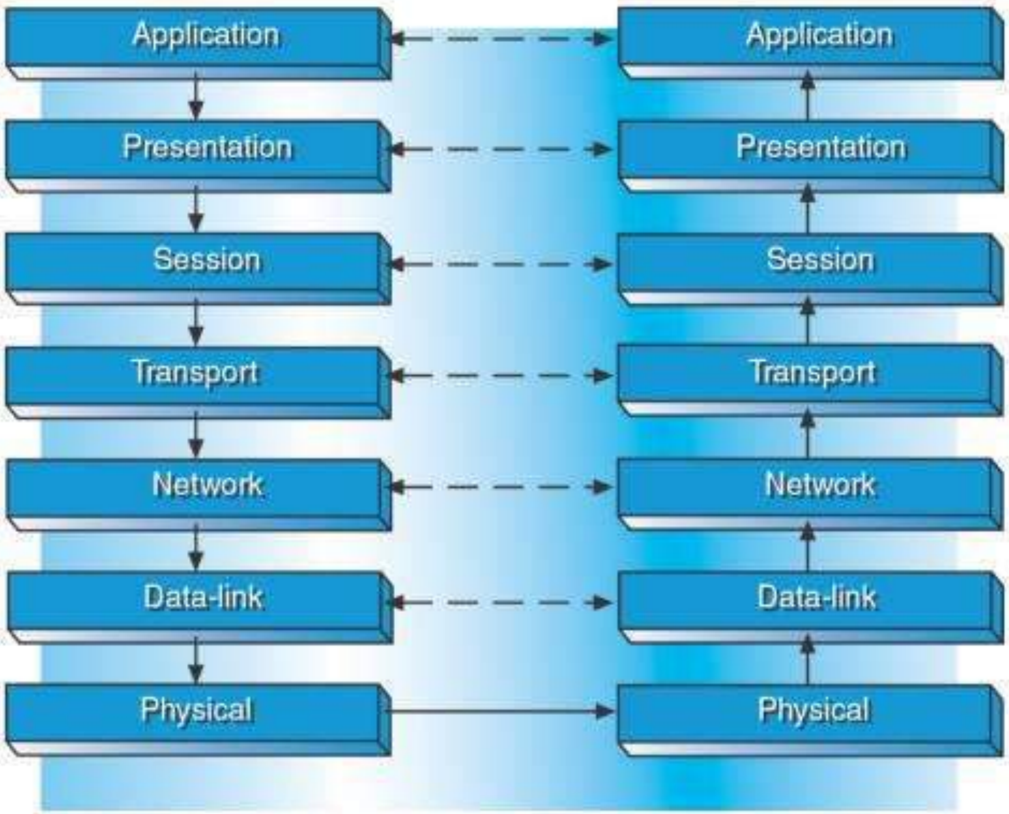
➢ The lower three layers are whenever a message passes through the host computer

OSI Model Layers




7 Application
Network Processes to Applications
6 Presentation
Data Representation
5 Session
Interhost Communication
4 Transport
End-to-end Connections
3 Network
Address and Best Path
2 Data Link
Access to Media
1 Physical
Binary Transmission

Protocol Interaction (ISO's Open Systems Interconnection (OSI model))



Open Systems Interconnect (OSI) Model

Host	Data	Layer 7 Application	Interacts with software requiring network communications; identifies partners, resources and synchronization
		Layer 6 Presentation	Formats and encrypts data; unifies syntax and semantics
		Layer 5 Session	Establishes, manages, and terminates connections between computers
	Segment/ Datagram	Layer 4 Transport	Provides transparent transfer of data between hosts; end-to-end error recovery and flow control
Media	Packet	Layer 3 Network	Provides switching, routing, addressing, error handling, congestion control, and packet fragmentation and sequencing
	Frame	Layer 2 Data Link	Encodes/decodes data packets into bits Logical Link Control: handles error in physical layer, flow control and frame synchronization Media Access Control: defines transmission protocol and management
	Bit	Layer 1 Physical	Carries bit stream; defines physical characteristics such as voltage/light levels and frequencies

LAYER 7 – The APPLICATION Layer

- The top layer of the OSI model
- Provides a set of interfaces for sending and receiving applications and to use network services, such as: message handling and database query processing
- Responsibility: The application layer is responsible for providing services to the user.

LAYER 6 – The PRESENTATION Layer

- Manages data-format information for networked communications (the network's translator)
- For outgoing messages, it converts data into a generic format for network transmission; for incoming messages, it converts data from the generic network format to a format that the receiving application can understand
- This layer is also responsible for certain protocol conversions, data encryption/decryption, or data compression/decompression
- A special software facility called a "*redirector*" operates at this layer to determine if a request is network related on not and forward network-related requests to an appropriate network resource

LAYER 5 – The SESSION Layer

- Enables two networked resources to hold ongoing communications (called a session) across a network
- Applications on either end of the session are able to ex hange data for the duration of the session

This layer is:

- Responsible for initiating, maintaining and terminating sessions
- Responsible for security and access control to session information (via session participant identification)
- Responsible for synchronization services, and for checkpoint services

LAYER 4 – The TRANSPORT Layer

- Manages the transmission of data across a network
- Manages the flow of data between parties by segmenting long data streams into smaller data chunks (based on allowed "packet" size for a given transmission medium)
- Reassembles chunks into their original sequence at the receiving end
- Provides acknowledgements of successful transmissions and requests resends for packets which arrive with errors
- The transport layer is responsible for the delivery of a message from one process to another.

LAYER 3 – The NETWORK Layer

- Handles addressing messages for delivery, as well as translating logical network addresses and names into their physical counterparts
- Responsible for deciding how to route transmissions between computers
- This layer also handles the decisions needed to get data from one point to the next point along a network path
- This layer also handles packet switching and network congestion control

LAYER 2 – The DATA LINK Layer

- Handles special data frames (packets) between the Network layer and the Physical layer
- At the receiving end, this layer packages raw data from the physical layer into data frames for delivery to the Network layer
- At the sending end this layer handles conversion of data into raw formats that can be handled by the Physical Layer

LAYER 1 – The PHYSICAL Layer

- Converts bits into electronic signals for outgoing messages
- Converts electronic signals into bits for incoming messages
- This layer manages the interface between the the computer and the network medium (coax, twisted pair, etc.)
- This layer tells the driver software for the MAU (media attachment unit, ex. network interface cards (NICs, modems, etc.)) what needs to be sent across the medium
- The bottom layer of the OSI model
- The physical layer is responsible for movements of
- individual bits from one hop (node) to the next.

MAP

- based on Open Systems Interconnection (OSI)
- seven layer broadband token-bus communication spec
- MAP and TOP always connected, differ in applications
- GM has 8 plants running MAP with 25 (1990)
- GM installing MAP as they overhaul plant
- tests on ethernet
- Lotus 1-2-3 "Factory" has MAP protocols

TOP

- exchange of info in electronic mail,
- word processing,
- file transfer,
- graphics,
- database management,
- business analysis tools

Communication Networks

A communication network is the backbone of an enterprise integration. Networks help to unify a company by linking together all the computerized devices irrespective of their physical location.

Through networks the whole enterprise can be integrated, including suppliers and customers.

Types of Communication Networks

There 2 main types of communication networks:

1) Telecommunication Networks;

2) Computer communication Networks.

Types of Communication Networks

Telecommunication network is mainly used for voice communication.

Computer communication network is a system of interconnected computers and other devices capable exchanging information.

Types of Communication Networks

Network Architectures & Protocols

A communication network consists of a number components such as hardware, software and media.

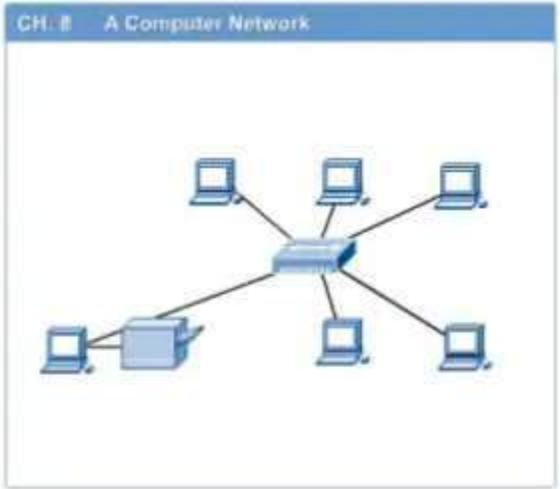
A network architecture describes the components, the functions performed, and the interfaces between the components of a network.

It encompasses hardware, software, standards, data link controls, topologies and protocols.

COMPUTER NETWORKS

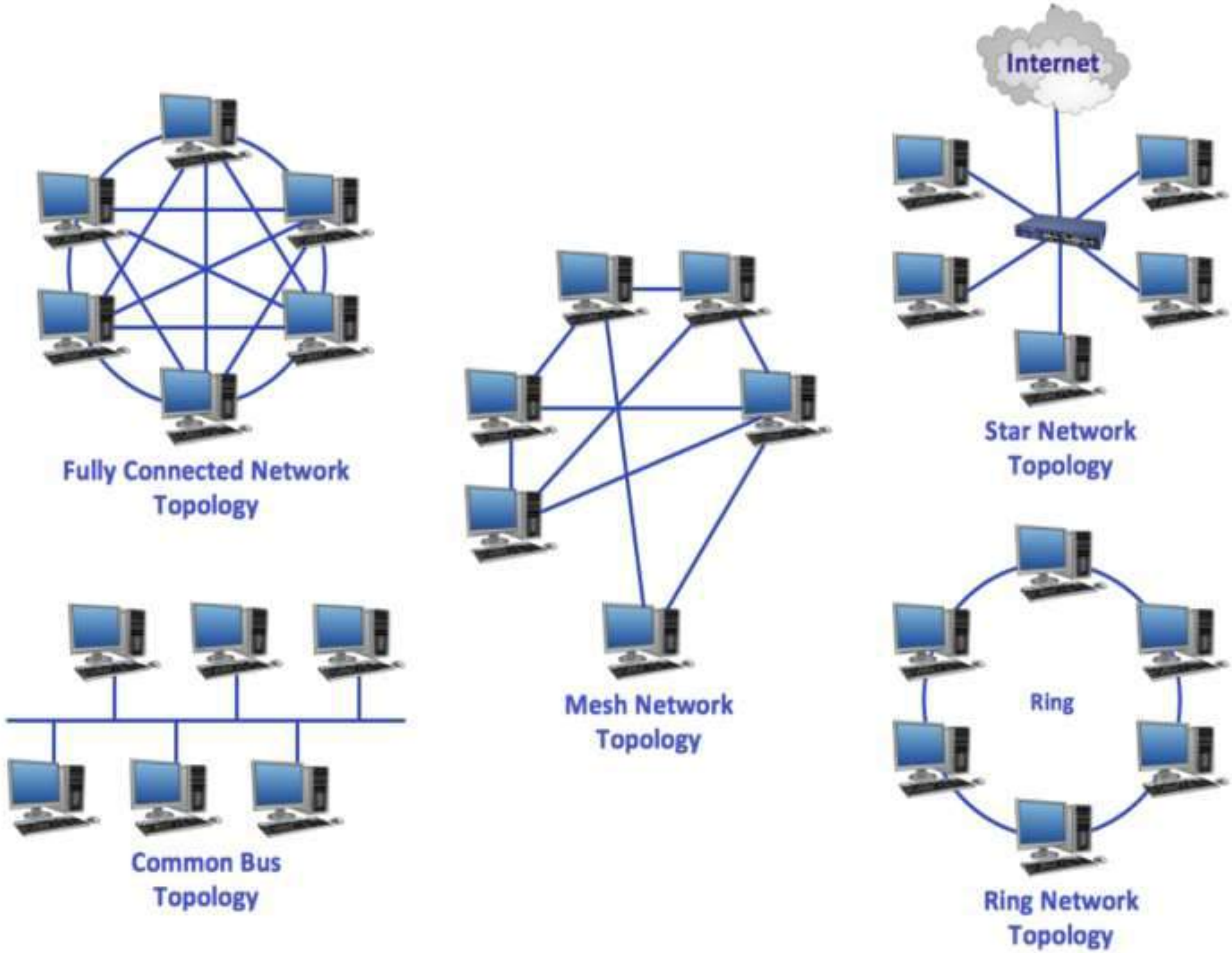
Computer network connects two or more autonomous computers.

The computers can be geographically located anywhere.



APPLICATIONS OF NETWORKS

- **Resource Sharing**
  - Hardware (computing resources, disks, printers)
  - Software (application software)
- **Information Sharing**
  - Easy accessibility from anywhere (files, databases)
  - Search Capability (WWW)
- **Communication**
  - Email, Message broadcast
- **Remote computing**
- **Distributed processing (GRID Computing)**


Fully Connected Network Topology
Internet
Star Network Topology
Mesh Network Topology
Common Bus Topology
Ring
Ring Network Topology

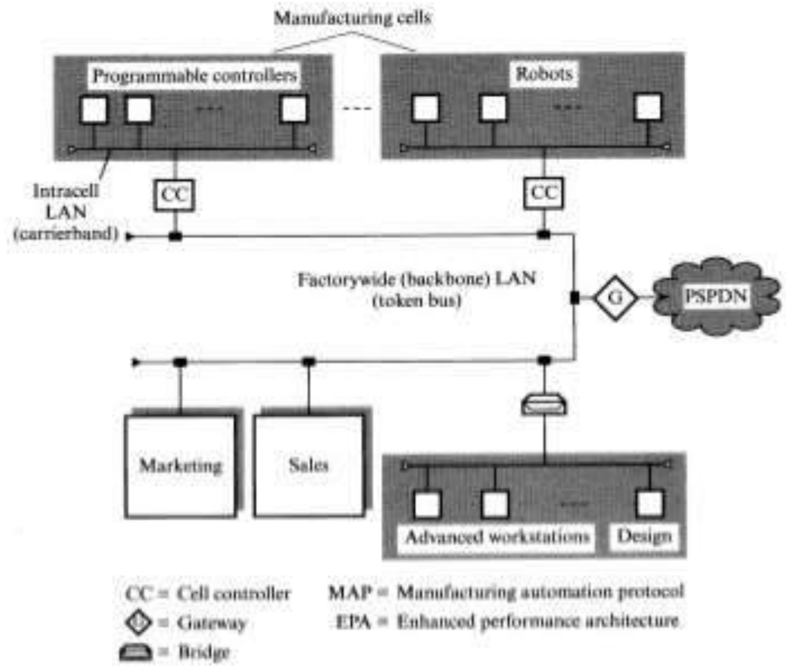
MANUFACTURING

MAP

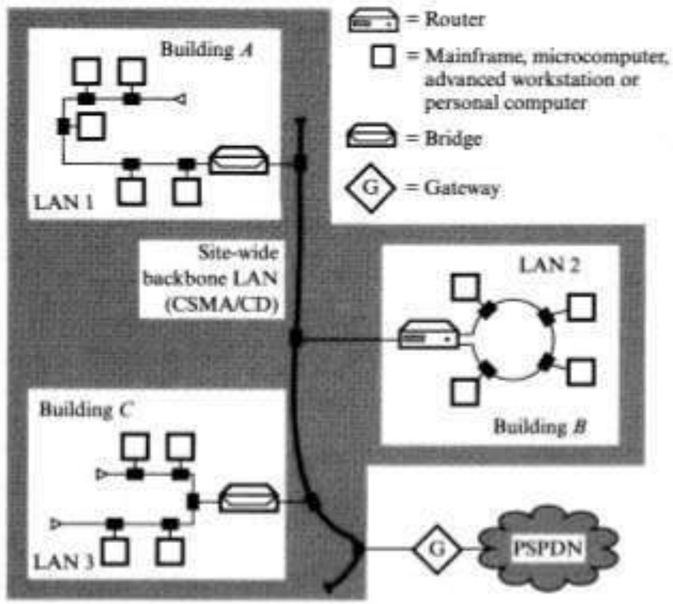
An initiative by General Motors of The United States has resulted in the selection of a set of protocols, all based on ISO standards, to achieve open system interconnection within an automated manufacturing plant.

The resulting protocols are knows as *manufacturing automation protocols (MAPs)*.

MANUFACTURING



MANUFACTURING



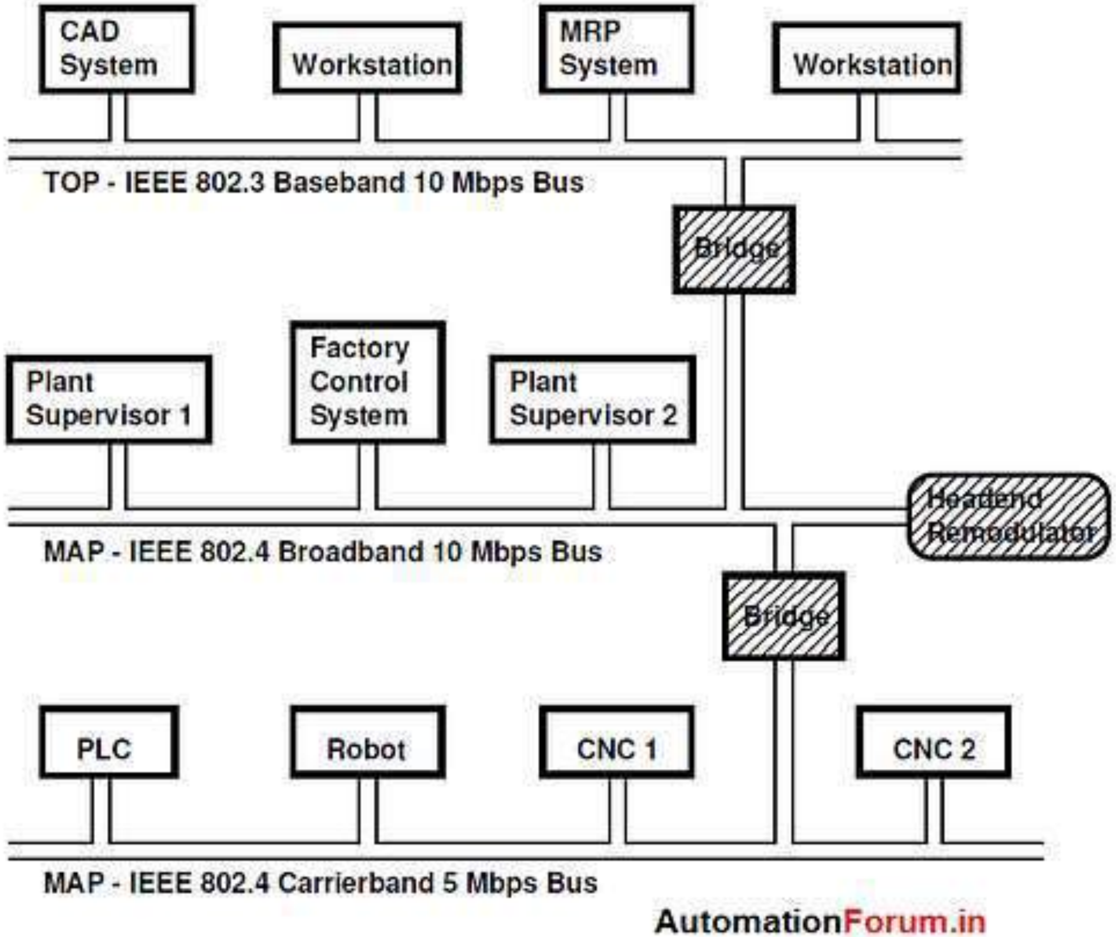
MANUFACTURING

TOP

In a similar way, an initiative by the Boeing Corporation (USA) has resulted in the selection of a set of ISO standards to achieve open system interconnection in a technical and office environment.

The selected protocols are known as *technical and office protocols (TOPs).*

MAP/TOP architecture:



DIFFERENCE BETWEEN MAP AND TOP

- **The MAP network, having its main position on the factory ground, is focused on the deterministic token passing bus scheme (IEEE 802.4).**

- **The TOP network is focused on the small price CSMA / CD card ISO 8802.3 2 (IEEE 802.3), but can be operated on a token bus or card ring network.**

- **The other significant distinction between MAP and TOP is the services supplied by the implementation layer to end-user programs.**

- **The main goal of contemporary plant communication is to allow the communication between pcs, CNC machines, system controllers, PLCs and robots.**

The manufacturing automation protocol (MAP) was developed by General Motors to meet its manufacturing integration needs. Sometimes the networks for different products of the same vendors are not always compatible. To connect these products directly in a communication network becomes a seemingly impossible task. On the other hand, to implement a computer-integrated system,

it is required to have communication between different factory devices such as NC machines, robots, cell controllers, and area controllers. MAP supports application-layer protocols such as manufacturing messaging specifications (MMS), intended for real time communication between such devices.

The different layered approach of MAP, allows new technology to be incorporated when it becomes available. It uses the ISO reference model and coordinates with the Technical and Office Protocol (TOP) developed by Boeing Company for office communications, and other standards. TOP and MAP share

DAAT BASE In CIM

CIMS DATA FILES

- Part Programming files
- Routing files
- Part production files
- Pallet Reference files
- Station tool files
- Tool life files

DATABASE

It is a unified computer based collection of data shared by authorized user's.

Key features

- To define data
- To Access data
- To manipulate data
- To present data

Computer Integrated Manufacturing integrates all the functions related to the manufacture. The following are the major functions among them:

i. Computer aided engineering covering design, analysis, simulation and optimization.

ii. Computer aided manufacturing

iii. Operations Management

iv. Logistics, Supply Chain Management, Warehousing and other functions.

database comprises basically four classes of data:

i. Product Data: Data about parts to be manufactured. It includes text and geometry data.

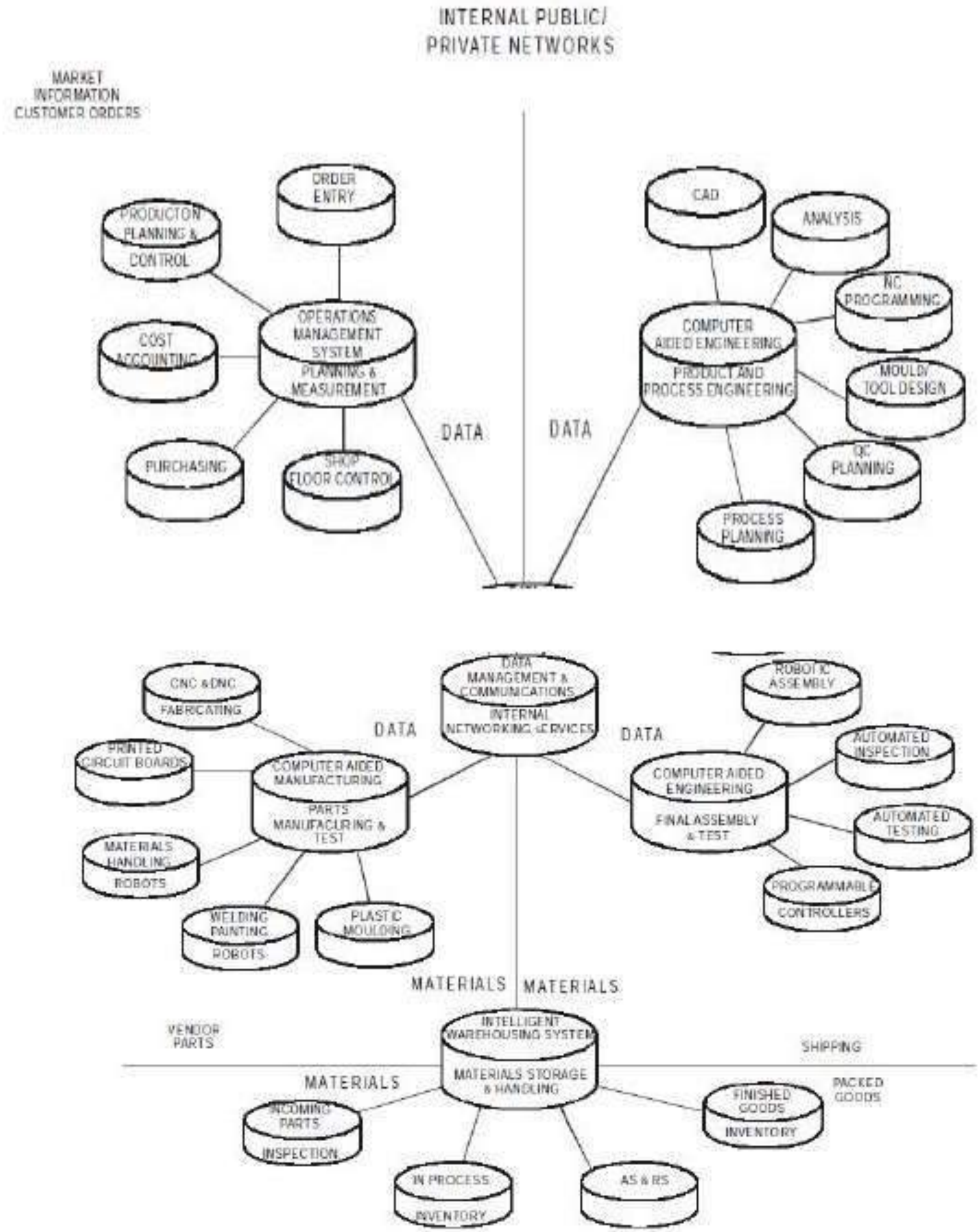
ii. Manufacturing Data: The information as to how the parts are to be manufactured is available in production data.

iii. Operational Data: Closely related to manufacturing data but describes the things specific to production, such as lot size, schedule, assembly sequence, qualification scheme etc.

iv. Resource Data: This is closely related to operational data but describes the resources involved in operations, such as materials, machines, human resources and money.

Database Elements

- Product Data
- Manufacturing Data
- Operational Data
- Resource Data



CIM Data Base

Database Requirements of CIM

A major challenge facing the implementation of CIM is to establish the type of data needed to bridge the mechanical design and manufacturing functions. Following is the list of varied tasks one might expect to accomplish in a CIM environment.

STEP and IGES are used to exchange of graphic information

i. Designing assemblies and performing tolerance analysis on those assemblies.

ii. Preparing production drawings of assemblies, individual parts, tooling, fixtures and other manufacturing facilities.

iii. Creating analytical models of parts for structural, kinematical and thermal analysis (FEM, MeM etc).

iv. Calculating weights, volumes, centres of gravity and other mass properties and costs of manufacturing (cost estimation).

v. Classifying existing parts according to shape, function, and the process by which they are manufactured and retrieving these parts from the parts library on demand (Group technology and coding).

vi. Preparing part lists and bill of materials (BOM).

vii. Preparing process plans for individual part manufacture and assembly (Variant or Generative).

Reduce/ Eliminate redundant data

- Integrate existing data

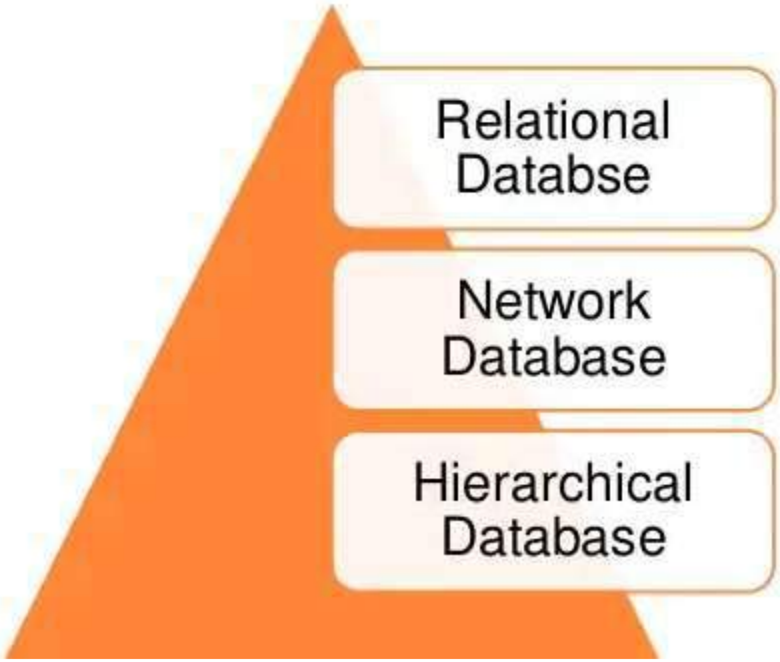
Provide Security

- Share data amongst Users

Incorporate changes quickly.

- Simplify & improve accuracy of data

DATABASE MODELS



DBMS (Data base management system)

A database management system consists of a collection of interrelated data and a set of programs to access that data.

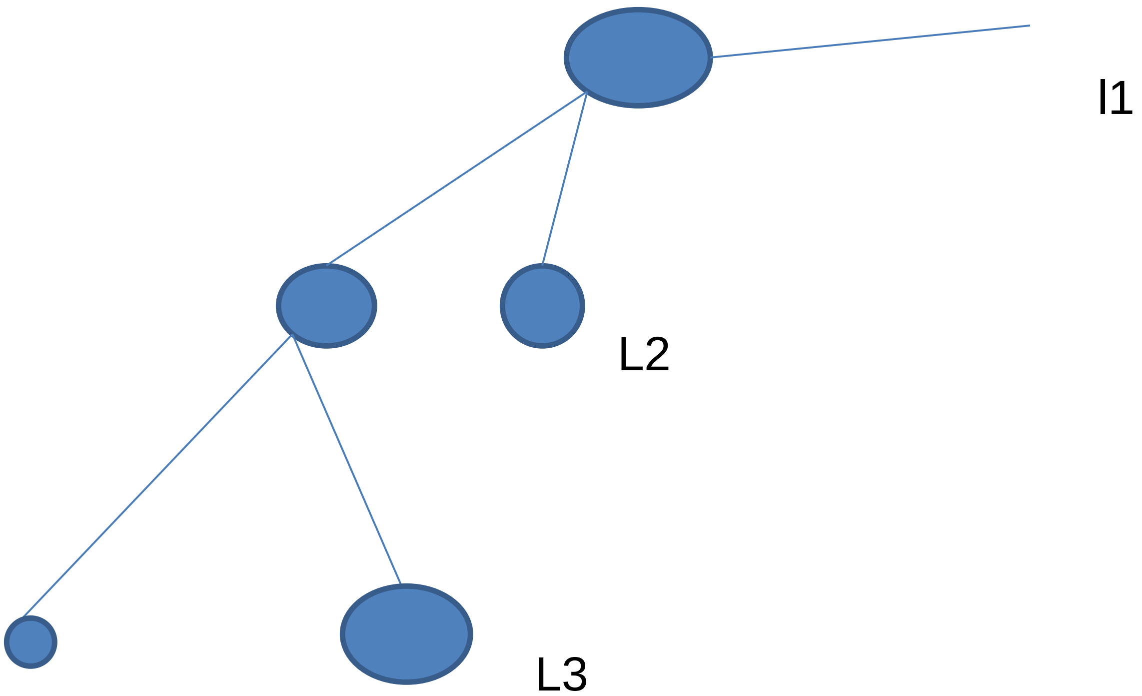
It consists of a collection of interrelated data and a set of programs to access that data.

Some well known DBMS are MYSQL, Microsoft SQL, ORACLE, SAP & IBM DB2.

Typical Issues

- High Investment
- Necessity to have highly trained man-power
- Redundancy under eventualities like crash of data base server
- Need to ensure reliability of data

- ***Manufacturing database & its management is a topic of concern for CIM, a problem has been that of distributing information amongst different computer based systems.***


l1
L2
L3