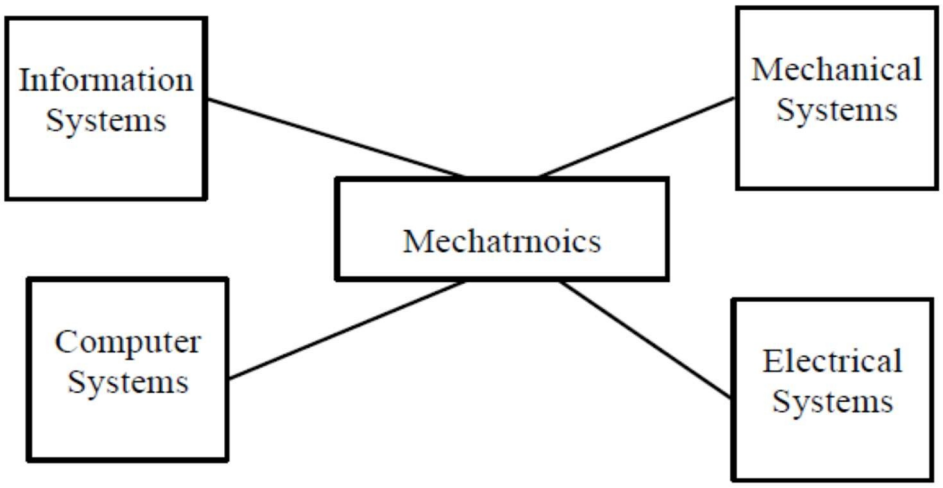
INTRODUCTION TO MECHATRONICS

What is MECHATRONICS?

Defined as the complete integration of mechanical system with electrical, electronic and computer system into single system.



Mechatronics comprises of

- Motion control
- Actuators and Sensors
- Micro devices and optoelectronics
- Robotics
- Automotive systems
- Modeling and Design
- System Integration
- Manufacturing
- Vibration and noise control

Advantages of Mechatronics:

1. The products produced are cost effective and very good quality.
2. High degree of flexibility
3. Greater extent of machine utilization
4. Greater productivity
5. High life expected by proper maintenance.
6. The integration of sensor and control system in a complex system reduces capital expenses.

Disadvantages of Mechatronics:

1. Higher initial cost of the system.
2.Important to have Knowledge of different engineering fields for design and implementation.
3. Is expenses to incorporate Mechatronics approaches to existing/old systems.
4.Specific problem of various systems will have to be addressed separately and properly.

Characteristics of Mechatronic system:

1. High quality product.
2. Safe.
3. Low cost.
4. Portable produced quickly
5. Serviceability, maintainability and upgradeability.

Applications of Mechatronic systems:

1. Automotive machines.
2. Fax and photocopier mechanics
3. Dishwashers.
4. Automatic washing machine
5. Air conditioners, elevator controls.
6. Documents scanners
7. IC manufacturing systems.
8. Robotics employed in welding, nuclear inspection, painting etc.,
9. VCRs (Videocassette recorder) and CD Players.

Definition of Control system:

A group of devices/elements which maintains the required output based on the predefined value by controlling the parameter responsible for output.

Classification of control system:

1.Open loop control system (NO FEEDBACK control system).
2.Closed loop control system (WITH FEEDBACK control system).

1. Open loop control system (NO FEEDBACK control system):

In which the output is dependent on the input, but input is independent of output is called open loop control system.

Example 1: ON/OFF of an electric lamp: electric lamps are used for lighting the lamp. ON/OFF control is carried out with the help of a switch and the switch is generally operated by an operator depending on the amount of light that exist in that area. If the switch is ON, the lamp is glow. If the person operating the switch does not put OFF of then switch, the lamp remains ON until he switched OFF. So, it is called open loop control system.

Example 2: Control the temperature of the room with room heater: the amount of heat generated by a room heater depends on the amount of input power controlled by a regulator.
If the power is switch ON, the power supplied to the heater continues and temperature of the room goes on increasing immaterial of whether heat is required in the room or not. Here person is to go and OFF the power supply switch and there by cooling the temperature of the room is decreasing.

Advantages of open loop control system

1. Less costly.
2. Relatively simple.
3. Good reliability.
4. Easy maintenance.
5. Inherently stable.

Disadvantages of open loop control system:

1. Inaccurate since there is no correction of error.
2. Relatively slow in response to change in demand.

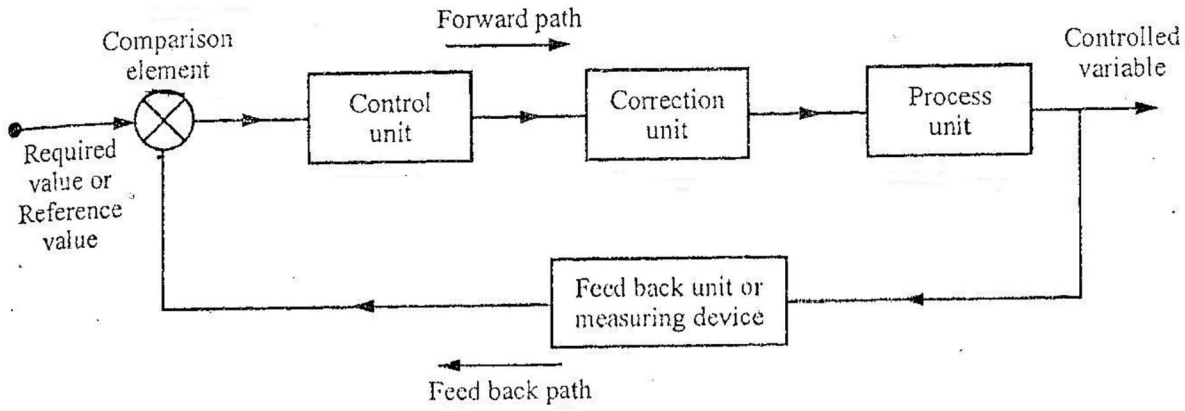
3. The control depends on the human judgment.

4. Often leads to waste.

5. Any change in system component not to be taken care automatically.

2. Closed loop control system (WITH FEEDBACK control system):

In which input is depend on the output. i.e., variation in the output influences the input by some means of controlling on the input is called a closed loop system.



Elements of closed loop control system:

The basic elements of a closed loop control system are:

1. Comparison element.

2. Control unit.

3. Correction unit.

4. Process unit.

5. Feedback unit.

Functions of each element of a closed loop system:

Comparison element: this unit compares the reference value with feedback value and produces an error signal.

Error = reference value – feedback value

Control unit: Control unit analyses the error signal and decides what action is to be taken.

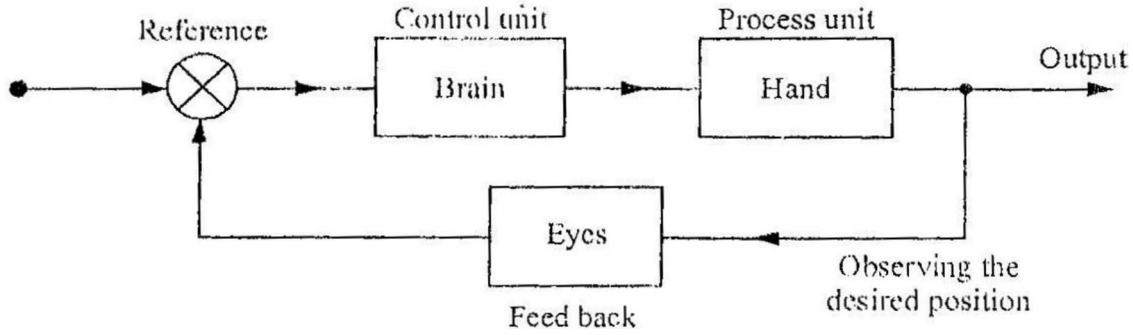
Correction unit: the modified signal from the control unit will be received by the correction unit

which produces a change in the process to correct or change the controlled condition.

Process unit: Process unit is the unit which is being controlled.

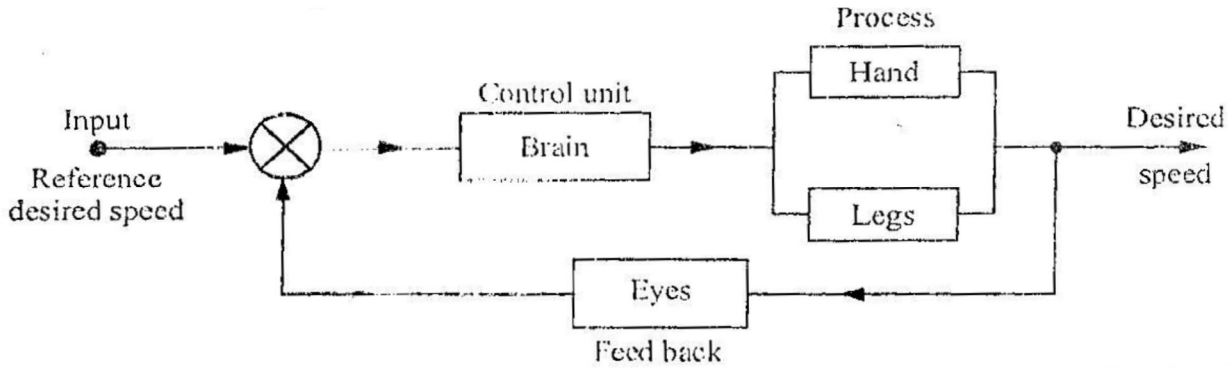
Feedback Unit: Takes input from Process unit and sends the signal back for comparison to attain high degree of control.

Example1. Hand reaching an object.



This is an example of closed loop control system. A person wants to reach for an object. Position of the object is given as reference; feedback signals and the eyes compare the actual position of the hands with reference to the position of the object. Error signal is given to the brain. Brain manipulates this error and gives signals to the hands. This process continues till the hand reaches the object.

Example2. Speed control of an automobile:



The driver observes the speedometer, and based on the speed shown by the speedometer he decides whether the fuel supply should be increased or decreased or gear change is to be made. Here speed shown a speedometer is feedback. A feedback signal from the eye compares the desire speed in the memory of the driver. Error signals are given to brain. Brain manipulates the error signals and gives it to hand and leg and increase the fuel supply if the speed is less than the desired speed, otherwise decrease the fuel supply. Changing of gear and increase or decrease of fuel supply, depends on whether it an upward or downward gradient respectively.

Advantages of closed loop control system:

1. More accurate.

2. Any change in system component can be taken care automatically.

3. Use of feedback system response is relatively insensitive to external disturbances and internal variations in system parameters.

Disadvantages of closed loop control system:

Expensive and complicated to construction.

Sl No.	Open loop control system	Closed loop control system
01	Without feedback unit	With feedback unit
02	Output is depended on input	Input is depended on output
03	Less accurate	More accurate
04	Less expensive and easy to build	Expensive and Complex to build.
05	Slow in response to change in demand	High in response to change in demand
06	Stability can be ensured	May be an unstable at times
07	Input factor is the sole factor for providing the control action.	The control action is provided by the difference between the input command and corresponding output.
08	Control adjustment is depends upon the human judgment and estimation	Control adjustment is depends upon output and feedback element.
09	Any change in system component cannot be taken care automatically	Any change in system component can be taken care automatically
10	**Example:** ON/OFF of electric lamp, Controlling of fan speed, etc	**Example:** automatic washing machine, digital camera, robots etc.,

MODULE 5

Robots & Robotics :-

Robot once a creature of science & fiction is today a reality. It is the off-shoot of the second industrial revolution.

Robots are machine which are flexible, have the ability to hold, move & grab items. They are controlled by microcomputers which when programmed guide the machines through their pre-determined operations.

"Robots can be defined as a programmable multi-functional manipulator designed to move materials, parts, tools or specilized devices through a variable programmed motion for the performance of variety of tasks"

"An industrial Robot is a re programmable, multifunctional manipulator deligned to move materials, parts, tools, special device through variable programmed motions for the performance of variety of tasks"

Robotics may be defined as "the science of deligning & building robots suitable for real life application in automated manufacturing & non-manufacturing environments"

Some advantages of robots are

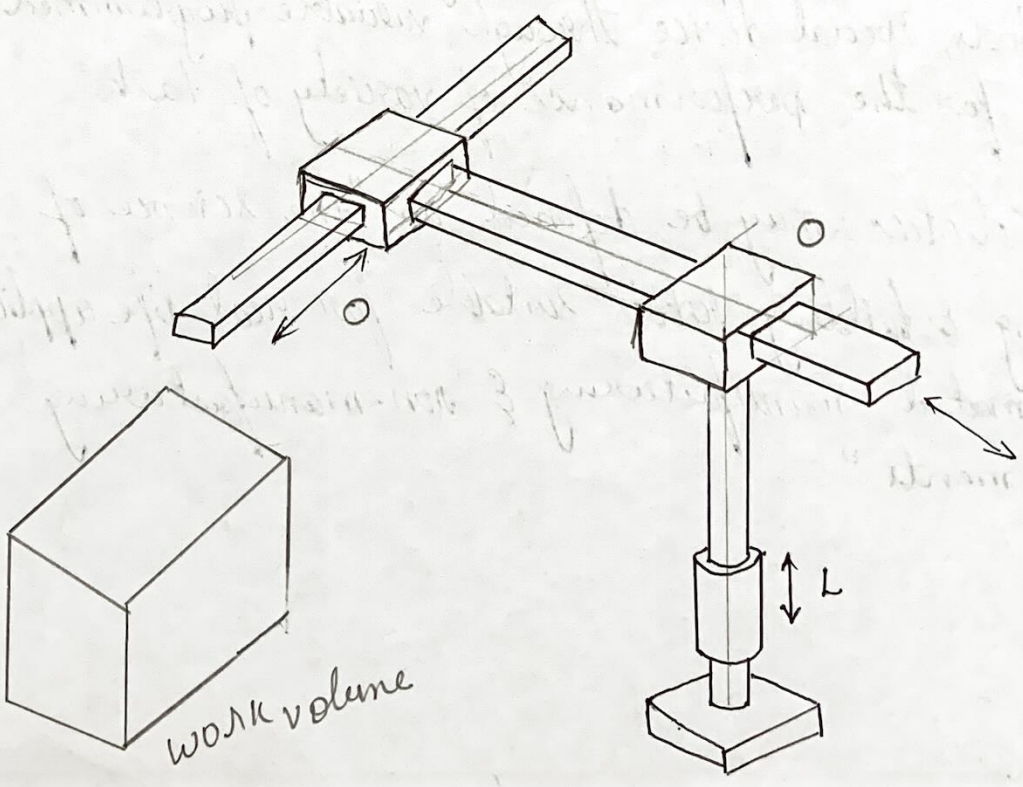
1) Increased flexibility of product type & variation.
2) Improved product quality
3) Low cost in long run
4) Lower rejects & less water than labour intensive production.

Classification of robots based on configurations :-

The majority of commercially available robots can be grouped into four basic configurations.

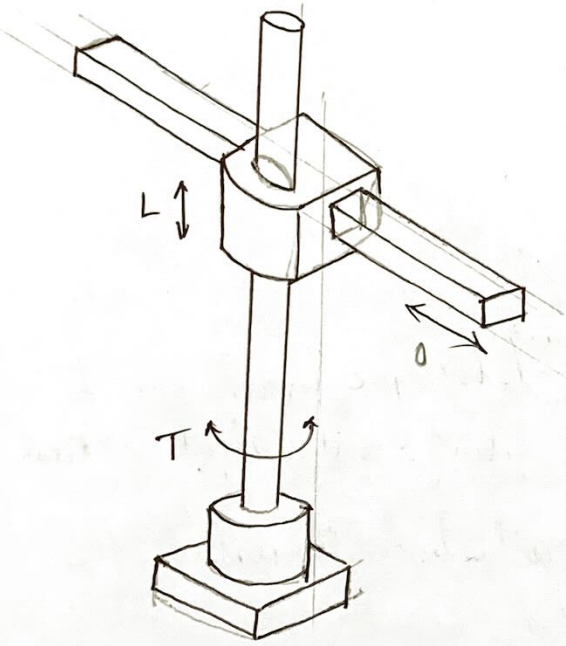
1) Cartesian co-ordinate configuration robots.
2) Cylindrical co-ordinate configuration robots
3) Spherical co-ordinate configuration robots
4) Jointed arm configuration robots

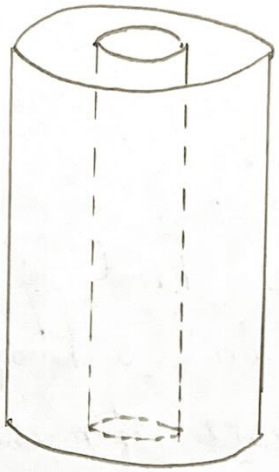
1) Cartesian Co-ordinate Configuration robots :- (L O O)



This configuration robots has three mutually perpendicular axis which define a rectangular work volume. In simplest configuration, the links of the manipulator are constrained to move in linear manner. Axes of robotic device that behave in this way are referred as "prismatic". This robot is also termed as gantry robot.

Cylindrical Co-ordinate Configuration robot :- (TLO)

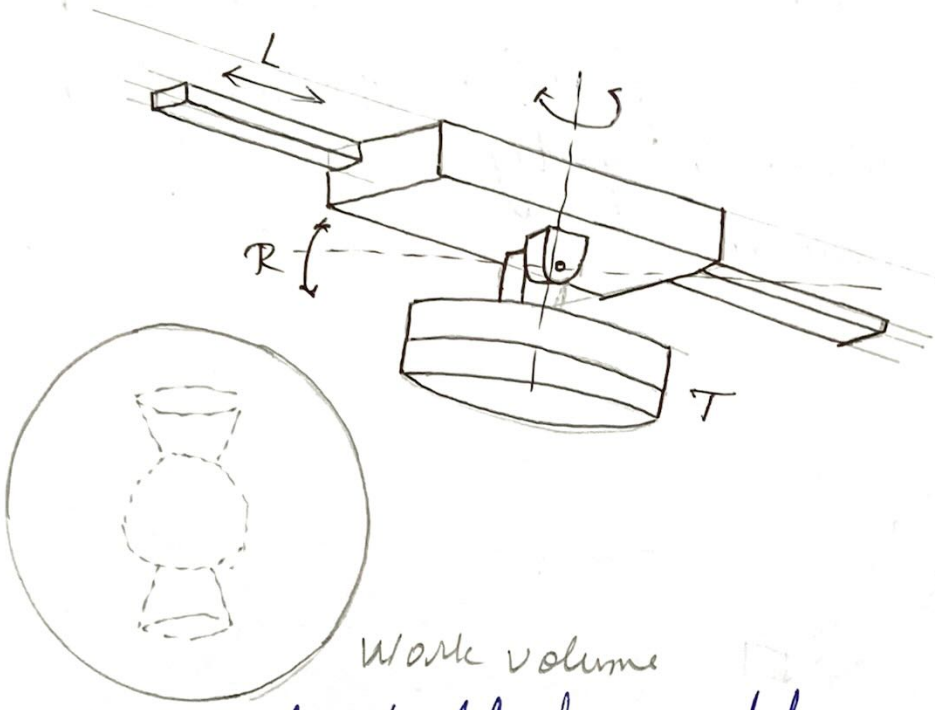




Work volume

This kind of robot has a vertical column with a robot arm attached to a side which can move up & down the column. Simultaneously the arm can move radially with respect to the column. The overall volume or work envelop is a portion of a cylinder. Usually a full 360° rotation is not permitted due to restriction imposed by hydraulic, electric or pneumatic connections.

3) Spherical co-ordinate configuration robot
[Polar co-ordinate configuration] [T R L]



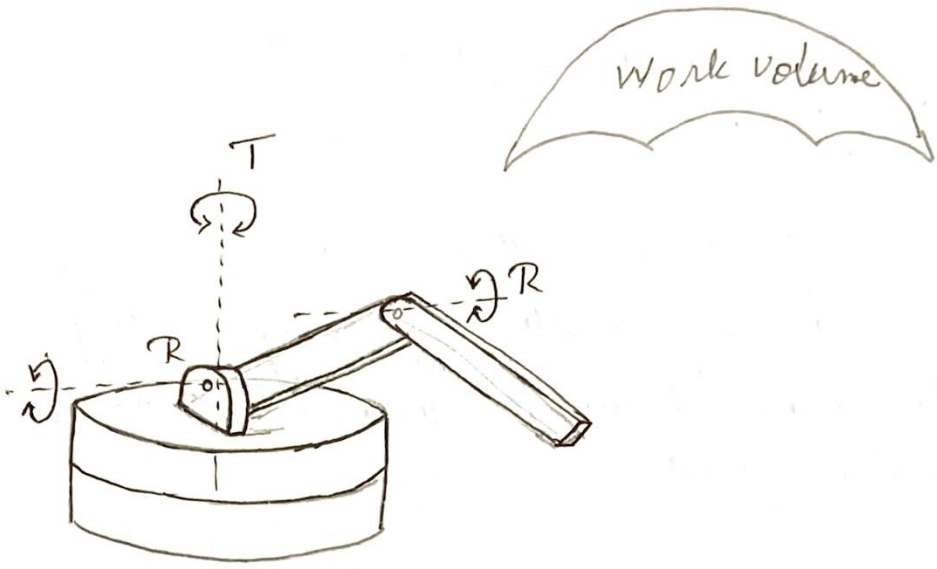
This kind of robot has a telescopic arm which pivots about a horizontal axis & also rotates about vertical axis, because of mechanical & or actuator limitations, the work envelope is portion of sphere.

4) Jointed arm configuration robot. [T R R]

This kind of robot resembles a human arm & consists of a series of links connected by rotary joints which when referenced from base as the shoulder, arm & wrist joints

There are actually three different types of arm robots

a) Pure spherical
b) Parallelogram spherical
c) Cylindrical.



Application of robots :-

1) The most useful application of robots is for processes involving hazardous, unpleasant work environment such as heat sparks, fumes etc., Example of there situations include hot forging, die casting spray painting & foundry operations.

2) Robots are employed in material transfer application in which they are used to move work parts from one location to another. Example pick & place, transfer from conveyor to conveyor etc.,

3) Robots are employed in material loading applications. It involves material handling operations in which the robot is required to supply a production machine which raw work parts &/or to unload finished parts from the machine.

4) The robots are used in welding processes such as spot welding & arc welding

5)

5) Robots are employed in spray painting process of many large consumer products such as automobiles & appliances & most industrial products.

6) Robots are used to perform some processing operations such as drilling, riveting, grinding, polishing, deburring etc.,

7) Now a days robots are used in assembly operations & inspection process.

Advantages of Robots:-

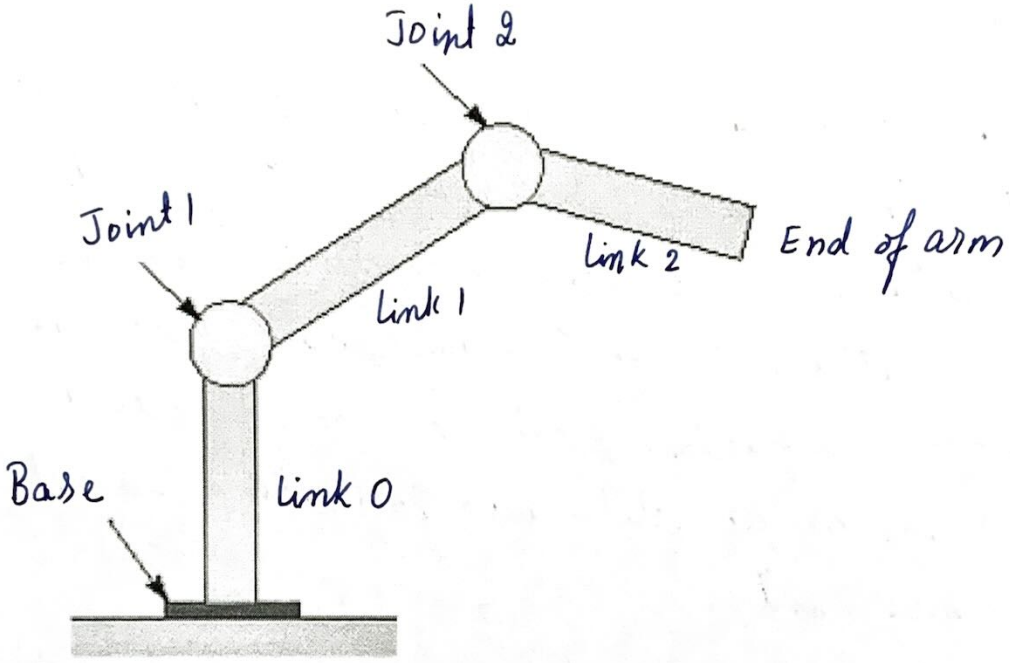
1) Provides consistency & repeatability.
2) Lifting & moving of heavy objects
3) working in hostile environments
4) working during unfavorable hours.
5) Increases productivity, safety, efficiency & quality of products.
6) Achieving more accuracy than human beings.
7) Performing dull or monotonous jobs.

Disadvantages of Robots:-

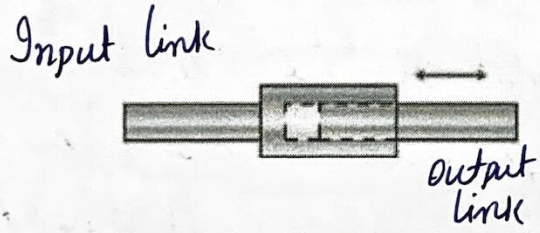
1) Lack of capability to respond in emergencies
2) Initial & installation cost are quite high
3) Replacement of workers causes resentment among workers.

~~Robot~~ Robot Anatomy

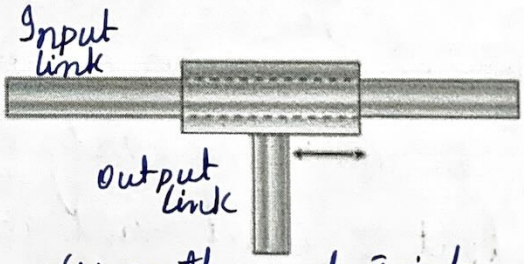
→ Joint provide relative motions
→ Links are rigid members between joints



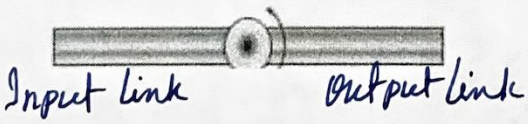
Different types of Robot Joints



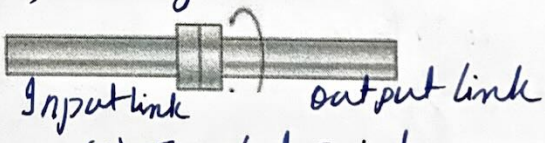
(a) Linear Joint



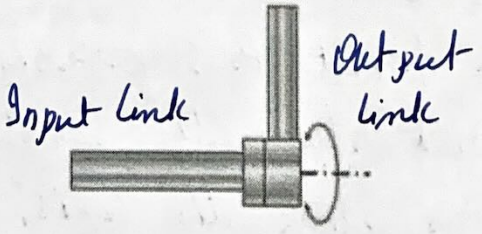
(b) Orthogonal Joint



(c) Rotational Joint



(d) Twisted Joint



(e) Revolving Joint

(a) Rotational Joint

(a) Linear Joint

→ Linear joint can be indicated by the Letter 'L' -joint. This type of joint can perform both translational & sliding movements. There motions will be attained by several ways such as telescopic mechanism & piston. The two links should be in parallel axes for achieving the linear movement.

(b) Orthogonal joint :-

→ Orthogonal joint is indicated by the 'O'-joint. This is somewhat similar to the linear joint. The only difference is that the output & input link will be moving at right angles.

(c) Rotational joint :-

→ Rotational joint is represented by R-joint This type will allow the joints to move in a rotary motion along the axis, which is vertical to the arm axes.

d) Twisting Joint :-

Twisting joint will be referred as T-joint This joints makes twisting motion amoung the output & Input link. During this process, the output link axis will be vertical & to the rotational axis's The output link rotates in relation to the input link.

(e) Revolving Joint :-

Revolving joint is generally known as V-joint Here, the output link axis is perpendicular to the rotational axis, & the input link is parallel to the rotational axes. As like twisting joint, the output link spins about the input link.

1.1 Definition of Automation

The word 'Automation' is derived from Greek words "Auto"(self) and "Matos" (moving). Automation can be defined as the set of technologies of carving out a process or procedure without human assistance and achieves performance superior to manual operation.

1.2 Types of Automation

The automation of production systems can be classified into three basic types:

1. Fixed Automation or Hard Automation
2. Programmable Automation or Soft Automation
3. Flexible Automation

1.2.1 Fixed automation:

Fixed automation or hard automation is a type of automation which uses special purpose equipment in order to automate a fixed sequence of processing or assembly operations. The programmed commands are contained in the equipment in the form of cams, gears, wiring etc. The equipment is designed to be efficient for the fixed set of operations. Usually each of the operation in the sequence is simple involving a plain linear or rotational motion or both. But integration and co-ordination of one or more operations can introduce complexity in the hard automated system. This type of automation is highly recommended for mass production systems that require high rate of production.

Examples are transfer lines found in the automotive industry, paint shops, distillation process, automatic assembly processes, chemical processes, etc.

Advantages of Fixed Automation:

1. The production rates realized are high
2. Since goods are mass produced, the unit cost will be low.
3. Material handling is automated by the specialized equipment and thus special robot intervention is not required

Disadvantages of Fixed Automation:

1. High initial investment for the special purpose equipment
2. Not flexible to accommodate product variety / product changes.

1.2.2 Programmable automation:

The Programmable automation or soft automation is chosen in production systems where the volume of production is relatively low and there are a number of variety of products to be produced. Here, the equipment for production is designed to be adaptable to variations in the product styles/configuration.

The step-by-step instructions in the form of a program controls the sequence of operations and these programs are read and interpreted by the system. For every new batch, the production equipment must be re-programmed and changed over to as per the new product configuration.

Advantages of Programmable Automation:

1. Very much suitable for batch production

2. Flexible to adapt to the changes in the product configuration since sequences can be programmed and re-programmed.

Disadvantages of Programmable Automation:

1. The cost of the general-purpose equipment is high
2. Production time is lost due to frequent setup changes, loading of fixtures and also due to reprogramming. This reduces production rate compared to fixed automation

Examples of Programmable automation include Numerically Controlled (NC) machine tools, industrial robots, and Programmable Logic Controllers (PLC). In industries programmable automation is found in production of brackets, hinges, locks, door knobs, musical instruments, weaving, etc.

1.2.3 Flexible automation:

This type of automation is used for mid production size and combines the features of both fixed automation and programmable automation. The flexible automated system is built in a way such that it can both produce a variety of products and with almost no time lost for setup changes from one configuration to another. Even reprogramming does not cause lost production time. This is because programming is done off-line at a computer terminal without using the production equipment itself. The system is therefore capable of producing many varieties in the product mix under various schedules without need for batch changes.

Advantages of Flexible Automation:

1. For the variety of product configurations, continuous production is possible
2. Flexible to adapt to the changes in the product configuration in very less time using an off-line computer terminal for programming and re-programming.
3. Improved quality of the product

Disadvantages of Flexible Automation:

1. The cost of investment is huge since the equipment is custom-built
2. Only medium production rates can be achieved unlike fixed automation
3. Compared to fixed automation, unit cost of the product is higher.

Example of a Flexible Automation System is the use of CNC Machine Tools along with Robots and Automated Guided Vehicles (AGV). In industries, flexible automation systems are used in fabrication, assembly and machining processes.

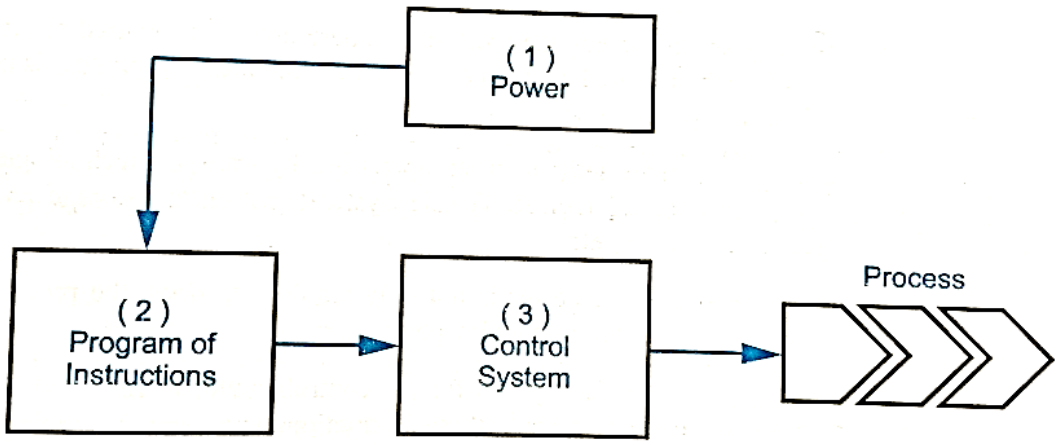
1.3 Basic Elements of an Automated System

An Automated system is the system that is used to realize automation.

As shown in below there are three basic elements of an automated system. The three basic elements of an automated system are

1. A Power sources
2. A program of instructions
3. A control system

Principally in an automated system, the program of instructions is fed to the control system where these instructions are executed and a power source is used to provide power to drive the process as well as operate the control system. The process then becomes an "automated process"



Basic elements of an automated system

1. Power Source: An automated system is used to automatically complete the tasks in a process. To accomplish this, a power source has to drive both the process and the controls.

The commonly used power source in an automated system is electric power.

Electric power is widely preferred power source for an automated system due to its wide availability at reasonable cost, its ease of conversion into other forms of energy like mechanical, thermal, hydraulic, pneumatic, etc., its easy storage I long-life high-performance batteries which makes it conveniently available at any place and its usage at lower levels to carryout signal transmission, information processing, data storage and communication.

Other power sources can be conventional sources such as fossil fuels, or non-conventional sources such as solar energy, wind energy, etc. These are generally used in combination with electrical power. Example: Fossil fuels are used to heat the furnace in casting. but electricity is used in the control system to regulate temperature and time cycle.

Even other energy sources can be converted to electrical energy and used to operate the process and its automation. Example: Conversion of Solar energy to electricity to operate an automated system.

2. Program of Instructions: The set of actions that is accomplished by an automated system are determined by the program of instructions. Each part produced in a manufacturing operation requires following of sequential processing steps within a work cycle. These processing steps for the work cycle are specified in a work cycle program. In NC machines, we call these as Part Programs

1.4 Advantage of automation

1. Automation results in increase of productivity: Use of automated systems can increase the efficiency in performing tasks which results in higher productivity.

2. Improvement in Product Quality: Automated systems perform the manufacturing process with less variability compared to human workers and hence product quality is improved.
3. Increase in accuracy and repeatability: When an automated system is programmed to carry out a task over and over again, the accuracy and repeatability compared to a human worker is far greater.
4. Improved safety at the workplace: Automated systems can perform tasks in hazardous and unfriendly environment which when done by humans would be prone to injuries and accidents. This improves workplace safety.
5. Reduction in manufacturing lead time: Automated Systems can reduce the lead time for manufacturing due to speed, consistency and less/zero defects.
6. Reduced direct human labour costs and expenses: Using automated systems implies less number of employees are required to get the job done. By having less number of employees, there are numerous costs that are directly reduced such as payroll, benefits, sick days, etc.
7. Mitigation of Potential Labour Shortages: Automation can mitigate the effects of potential labour shortages. It decreases dependency on skilled labour and fills the void created due to a skilled worker retirement.
8. Automated Systems can carry out processes that cannot be done manually. Example, automated systems can carry out certain processes in a nuclear radiation environment which is not possible by human labour.
9. Automation can reduce or eliminate day-to-day manual and clerical jobs.

1.5 Disadvantages of Automation

1. Though automation effectively replaces human labour in performing various tasks, it results in increased unemployment and poverty which counters job creation efforts.
2. High initial cost: The initial investment involved in the automation of a new product or plant is very large. Though the cost of automation may be amortized or spread among many units of products over some time period, the unit cost of the product manufactured using automation will still be higher compared to the product manufactured without automation. This may be at competitive disadvantage.
3. Automated systems can pose Security Threats since with a limited level of intelligence it is more susceptible to committing errors outside of its immediate scope of knowledge (Example, lack of application of simple rules of logic to general propositions).
4. Additional Costs: Other than a high investment cost, automated systems also involve excessive development costs due to research and development, preventive maintenance and cost of training personnel to operate automated systems. These costs offset the costs supposed to have been saved by automation.
5. With excessive automation, humans become slaves of automated machines creating too much dependency on machines rather than human intelligence.

Introduction to IOT

Contents: Introduction to IOT: Definition and Characteristics, Physical design, protocols, Logical design of IoT, Functional blocks, and communication models.

1 Introduction to IOT:

The Internet of Things refers to the rapidly growing network of connected objects that can collect and exchange data in real-time using embedded sensors.

Cars, lights, refrigerators, and appliances can all be connected to the IoT.

The Internet of things is a connecting bridge between the physical world and the cyber world and Machine to Machine communication

Any physical object can be transformed into an IoT device if it can be connected to the internet to be controlled or communicate information. A lightbulb that can be switched on using a smartphone app is an IoT device, as is a motion sensor

2 Definition

“Internet of Things means a network of physical things (objects) sending, receiving, or communicating information using the Internet or other communication technologies and network just as the computers, tablets and mobiles do, and thus enabling the monitoring, coordinating or controlling process across the Internet or another data network”

OR

“Internet of Things is the network of physical objects or 'things' embedded with electronics, software, sensors and connectivity to enable it to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure”

OR

“IoT is a dynamic global network infrastructure of physical and virtual objects having unique identities, which are embedded with software, sensors, actuators, electronic and network connectivity to facilitate intelligent applications by collecting and exchanging data”

OR

“A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network, often communicate data associated with users and their environments”

3 Characteristics,

Characteristics of the Internet of Things:

1. **Connectivity**: Connectivity is an important requirement of the IoT infrastructure. Things of IoT should be connected to the IoT infrastructure. Anyone, anywhere, anytime can

connect, this should be guaranteed at all times. For example, the connection between people through internet devices like mobile phones, and other gadgets, also a connection between Internet devices such as routers, gateways, sensors, etc.

2. **Intelligence and Identity:** The extraction of knowledge from the generated data is very important. For example, a sensor generates data, but that data will only be useful if it is interpreted properly. Each IoT device has a unique identity. This identification is helpful in tracking the equipment and at times for querying its status.
3. **Scalability:** The number of elements connected to the IoT zone is increasing day by day. Hence, an IoT setup should be capable of handling the massive expansion. The data generated as an outcome is enormous, and it should be handled appropriately.
4. **Dynamic and Self-Adapting (Complexity):** IoT devices should dynamically adapt themselves to changing contexts and scenarios. Assume a camera meant for surveillance. It should be adaptable to work in different conditions and different light situations (morning, afternoon, and night).
5. **Architecture:** IoT architecture cannot be homogeneous in nature. It should be hybrid, supporting different manufacturers 'products to function in the IoT network. IoT is not owned by anyone engineering branch. IoT is a reality when multiple domains come together.
6. **Safety:** There is a danger of the sensitive personal details of the users getting compromised when all his/her devices are connected to the internet. This can cause a loss to the user. Hence, data security is the major challenge. Besides, the equipment involved is huge. IoT networks may also be at the risk. Therefore, equipment safety is also critical.

Advantages	Disadvantages
Minimizes the human work and effort	Increased privacy concerns
Saves time and effort	Increased unemployment rates
Good for personal safety and security	Highly dependent on the internet
Useful in traffic and other tracking or monitoring systems	Lack of mental and physical activity by humans leading to health issues.
Beneficial for the healthcare industry	Complex system for maintenance
Improved security in homes and offices	Lack of security
Reduced use of many electronic devices as one device does the job of a lot of other devices	Absence of international standards for better communication

4 Physical design,

A physical design of an IoT system refers to the individual node devices and their protocols that are utilized to create a functional IoT ecosystem.

Each node device can perform tasks such as remote sensing, actuating, monitoring, etc., by relying on physically connected devices. It may also be capable of transmitting information through different types of wireless or wired connections.

The things/devices in the IoT system are used for:

1. Building connections
2. Data processing
3. Providing storage
4. Providing interfaces
5. Providing graphical interfaces

The devices generate data, and the data is used to perform analysis and do operations for improving the system. For instance, a moisture sensor is used to obtain the moisture data from a location, and the system analyses it to give an output.

Things/Devices

Things/Devices are used to build a connection, process data, provide interfaces, provide storage, and provide graphics interfaces in an IoT system. all these generate data in a form that can be analyzed by an analytical system and program to perform operations and used to improve the system.

for example, temperature sensor that is used to analyze the temperature generates the data from a location and is then determined by algorithms.

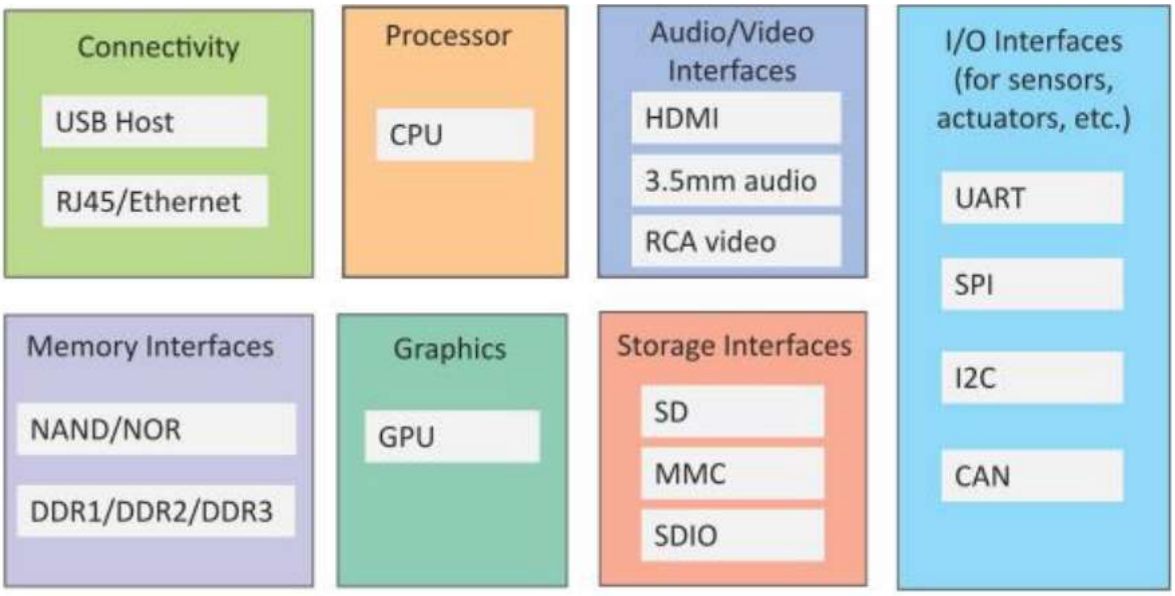


Figure 4.1: Generic block diagram of an IoT Device

Connectivity: Devices like USB hosts and ETHERNET are used for connectivity between the devices and the server.

Processor: A processor like a CPU and other units are used to process the data. these data are further used to improve the decision quality of an IoT system.

Audio/Video Interfaces: An interface like HDMI and RCA devices is used to record audio and videos in a system.

Input/Output interface: To give input and output signals to sensors, and actuators we use things like UART, SPI, CAN, etc.

Storage Interfaces: Things like SD, MMC, and SDIO are used to store the data generated from an IoT device.

Other things like DDR and GPU are used to control the activity of an IoT system

5 Protocols

These protocols are used to establish communication between a node device and a server over the internet. it helps to send commands to an IoT device and receive data from an IoT device over the internet. we use different types of protocols that are present on both the server and client side and these protocols are managed by network layers like application, transport, network, and link layer.

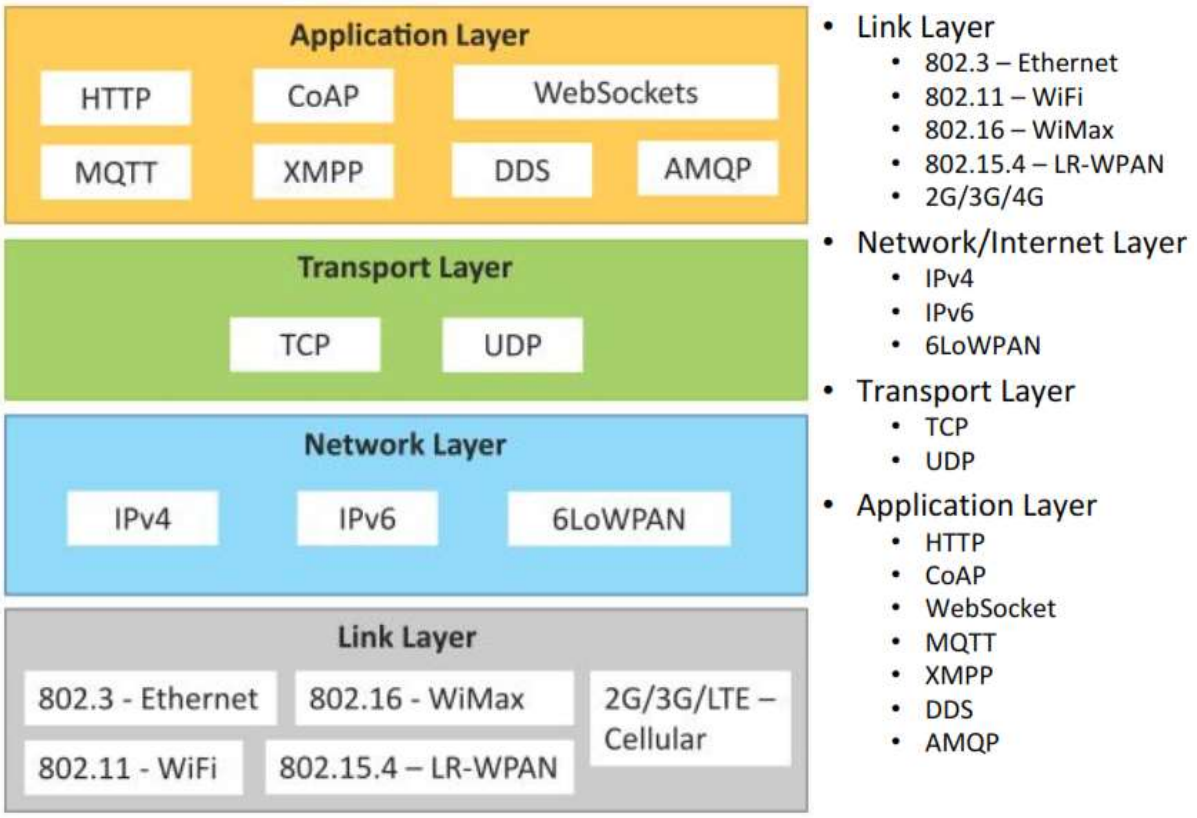


Figure 5.1: IoT Protocols

5.1 Application Layer protocol

In this layer, protocols define how the data can be sent over the network with the lower layer protocols using the application interface. these protocols include HTTP, WebSocket, XMPP, MQTT, DDS, and AMQP protocols.

5.1.1 HTTP

Hypertext transfer protocol is a protocol that presents in an application layer for transmitting media documents. it is used to communicate between web browsers and servers. it makes a request to a server and then waits till it receives a response and in between the request server does not keep any data between the two requests.

5.1.2 WebSocket

This protocol enables two-way communication between a client and a host that can be run on an untrusted code in a controlled environment. This protocol is commonly used by web browsers.

5.1.3 MQTT

It is a machine-to-machine connectivity protocol that was designed as a publish/subscribe messaging transport. and it is used for remote locations where a small code footprint is required.

5.2 Transport Layer

This layer is used to control the flow of data segments and handle error control. also, these layer protocols provide end-to-end message transfer capability independent of the underlying network.

5.2.1 TCP

The transmission control protocol is a protocol that defines how to establish and maintain a network that can exchange data in a proper manner using the internet protocol.

5.2.2 UDP

a user datagram protocol is a part of an internet protocol called the connectionless protocol. this protocol is not required to establish the connection to transfer data.

5.3 Network Layer

This layer is used to send datagrams from the source network to the destination network. we use IPv4 and IPv6 protocols as host identification that transfers data in packets.

5.3.1 IPv4

This is a protocol address that is a unique and numerical label assigned to each device connected to the network. an IP address performs two main functions host and location addressing. IPv4 is an IP address that is 32-bit long.

5.3.2 IPv6

It is a successor of IPv4 that uses 128 bits for an IP address. it is developed by the IETF task force to deal with long-anticipated problems.

5.4 Link Layer

Link-layer protocols are used to send data over the network's physical layer. it also determines how the packets are coded and signaled by the devices.

5.4.1 Ethernet

It is a set of technologies and protocols that are used primarily in LANs. it defines the physical layer and the medium access control for wired ethernet networks.

5.4.2 WiFi

It is a set of LAN protocols and specifies the set of media access control and physical layer protocols for implementing wireless local area networks.

6 Logical design of IoT,

A logical design for an IoT system is the actual design of how its components (computers, sensors, and actuators) should be arranged to complete a particular function. It doesn't go into

the depth of describing how each component will be built with low-level programming specifics.

IoT logical design includes:

1. IoT functional blocks
2. IoT communications models
3. IoT communication APIs

6.1 IoT functional blocks

IoT systems include several functional blocks such as Devices, communication, security, services, and application.

The functional blocks provide sensing, identification, actuation, management, and communication capability. These functional blocks consist of devices that handle the communication between the server and the host, enable monitoring control functions, manage the data transfer, secure the IoT system using authentication and different functions, and provide an interface for controlling and monitoring various terms.

The Functional blocks are:

1. **Device**: An IoT system comprises of devices that provide sensing, actuation, monitoring, and control functions.
2. **Communication**: Handles the communication for the IoT system.
3. **Services**: services for device monitoring, device control service, data publishing services, and services for device discovery.
4. **Management**: this block provides various functions to govern the IoT system.
5. **Security**: This block secures the IoT system and by providing functions such as authentication, authorization, message and content integrity, and data security.
6. **Application**: This is an interface that the users can use to control and monitor various aspects of the IoT system. The application also allows users to view the system status and view or analyze the processed data.

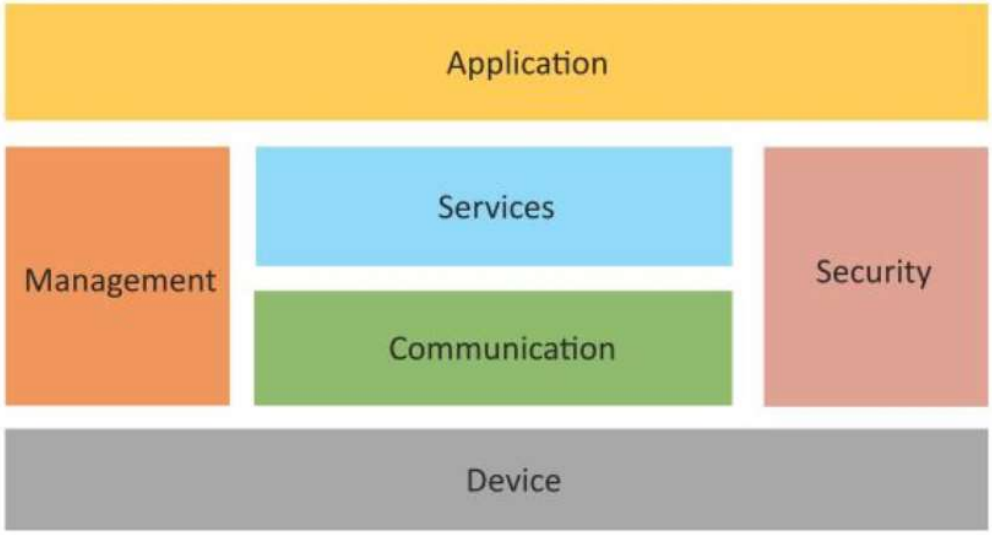


Figure 6.1: Logical Design of IoT

6.2 Difference Between Physical and Logical Design of IoT

Physical Design	Logical Design
Physical design is highly detailed.	Logical design is a high-level design and doesn't provide any detail.
Physical design is more graphical than textual; however, it can comprise both.	Logical design can be textual, graphic, or both.
A physical design focuses on specific solutions explaining how they are assembled or configured.	A logical design focuses on satisfying the design factors, including risks, requirements, constraints, and assumptions.

6.3 IoT Communication Models

There are multiple kinds of models available in an Internet of Things system that is used for communicating between the system and server, such as:

6.3.1 Request-Response Model

Request-response model is a communication model in which the client sends requests to the server and the server responds to the requests. When the server receives a request, it decides how to respond, fetches the data, retrieves resource representation, prepares the response, and then sends the response to the client. Request-response is a stateless communication model and each request-response pair is independent of the others.

HTTP works as a request-response protocol between a client and a server. A web browser may be the client, and an application on a computer that hosts a website may be the server.

Example: A client (browser) submits an HTTP request to the server; then the server returns a response to the client. The response contains status information about the request and may also contain the requested content.

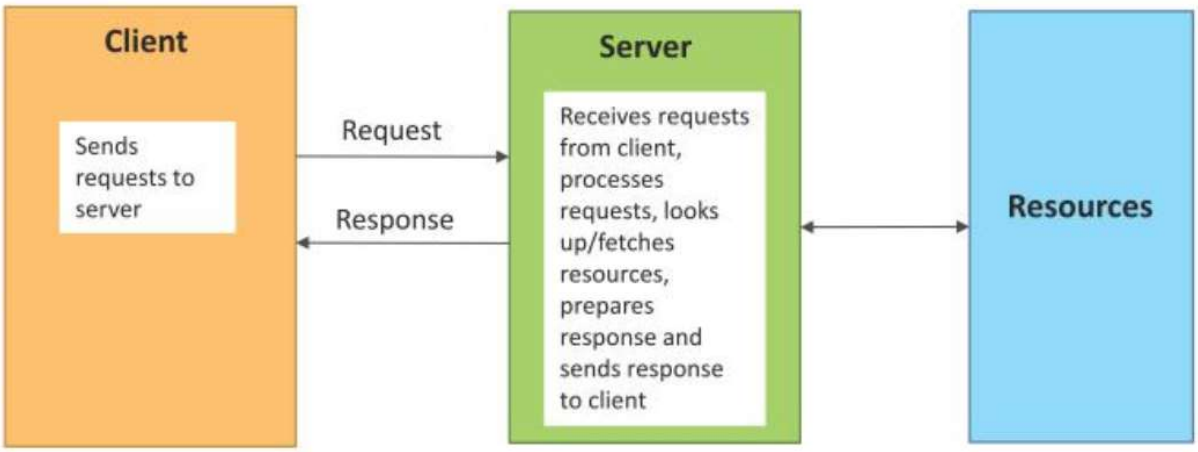


Figure 6.2: Request-Response communication model

6.3.2 Publisher-Subscriber Model

This model comprises three entities: Publishers, Brokers, and Consumers.

Publishers are the source of data. It sends the data to the topic which is managed by the broker. They are not aware of consumers.

Consumers subscribe to the topics which are managed by the broker.

Brokers' responsibility is to accept data from publishers and send it to the appropriate consumers. The broker only has the information regarding the consumer to which a particular topic belongs which the publisher is unaware.

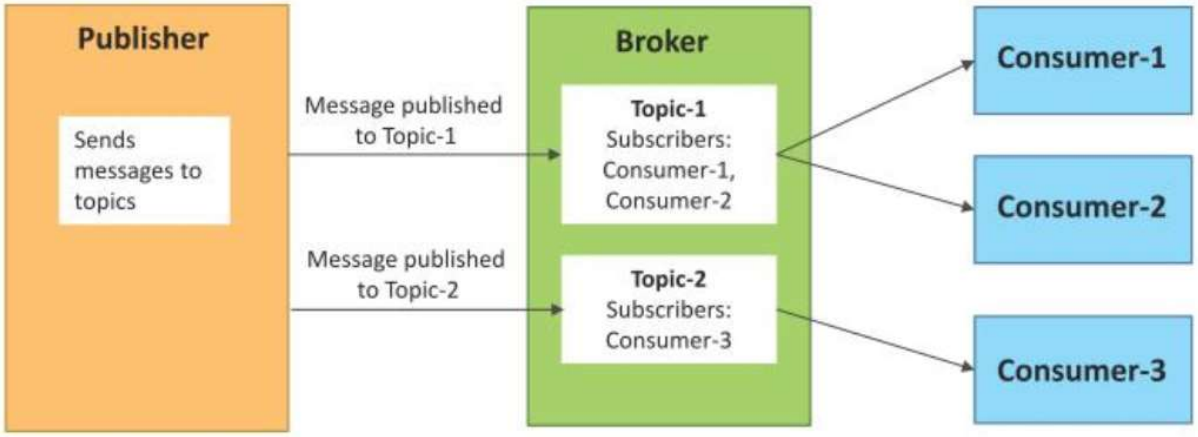


Figure 6.3: Publish-Subscribe communication model

6.3.3 Push-Pull Model

The push-pull model constitutes data publishers, data consumers, and data queues.

Publishers and Consumers are not aware of each other.

Publishers publish the message/data and push it into the queue. The consumers, present on the other side, pull the data out of the queue. Thus, the queue acts as the buffer for the message when the difference occurs in the rate of push or pull of data on the side of a publisher and consumer.

Queues help in decoupling the messaging between the producer and consumer. Queues also act as a buffer which helps in situations where there is a mismatch between the rate at which the producers push the data and consumers pull the data.

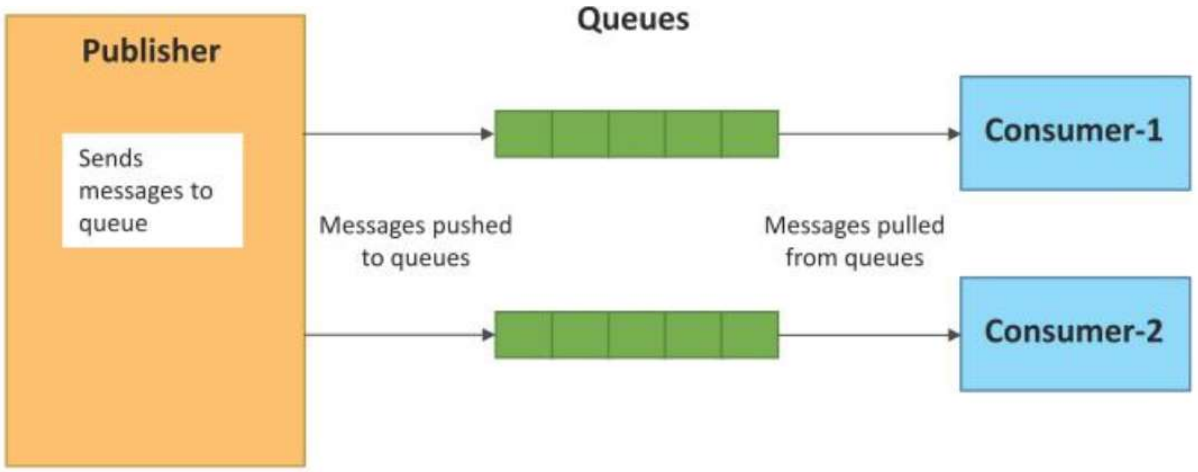


Figure 6.4: Push-Pull communication model

6.3.4 Exclusive Pair

Exclusive Pair is the bi-directional model, including full-duplex communication between client and server. The connection is constant and remains open till the client sends a request to close the connection.

The Server has the record of all the connections which has been opened.

This is a state-full connection model and the server is aware of all open connections.

WebSocket-based communication API is fully based on this model.

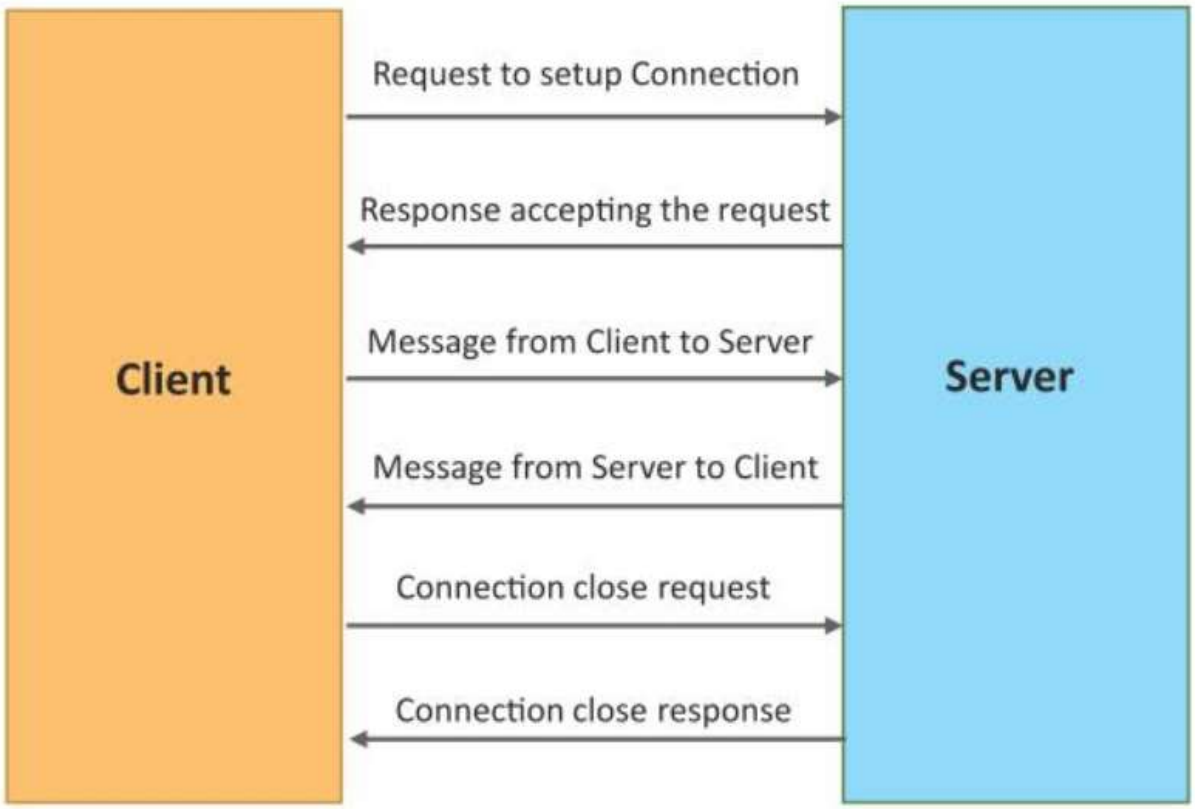


Figure 6.5: Exclusive Pair communication model

6.4 IoT communication API

In IoT, there are 2 communication APIs –

1. REST — based Communication APIs
2. Web Socket — based Communication APIs

Web service can either be implemented using REST principles or using Web Socket Protocol

6.4.1 REST-Based Communication API:

REpresentational State Transfer (REST) is a set of architectural principles by which you can design web services and web APIs that focus on a system's resources and how resource states are addressed and transferred. REST APIs follow the request-response communication model. The REST architectural constraints apply to the components, connectors, and data elements, within a distributed hypermedia system.

6.4.2 Web Socket-Based Communication APIs:

Web Socket APIs allow bi-directional, full-duplex communication between clients and servers. It follows the exclusive pair communication model. This Communication API does not require a new connection to be set up for each message to be sent between clients and servers. Once the connection is set up the messages can be sent and received continuously without any interruption. WebSocket APIs are suitable for IoT Applications with low latency or high throughput requirements.

Difference between Rest API and Web Socket API :

REST API	WEB SOCKET API
It is a Stateless protocol. It will not store the data.	It is Stateful protocol. It will store the data.
It is Uni-directional. Only either server or client will communicate.	It is Bi-directional. Messages can be received or sent by both server and client.
It is a Request-response model.	It is a Full duplex model.
HTTP request contains headers like head section, and title section.	It is suitable for real-time applications. It does not have any overhead.
A new TCP connection will be set up for each HTTP request.	Only Single TCP connection.
Both horizontal and vertical scaling (we can add many resources and a number of users both horizontally and vertically).	Only vertical scaling (we can add resources only vertically).
It depends upon the HTTP methods to retrieve the data	It depends upon the IP address and port number to retrieve the data
It is slower than the web socket regarding the transmission of messages.	web socket transmits messages very fast than REST API.
It does not need memory or buffers to store the data.	It requires memory and buffers to store the data.