ROBOTICS
AND
INTELLIGENT SYSTEM

MODULE 1

AIT304	ROBOTICS AND INTELLIGENT SYSTEM	Category	L	T	P	Credit	Year of Introduction
		PCC	3	1	0	4	2022

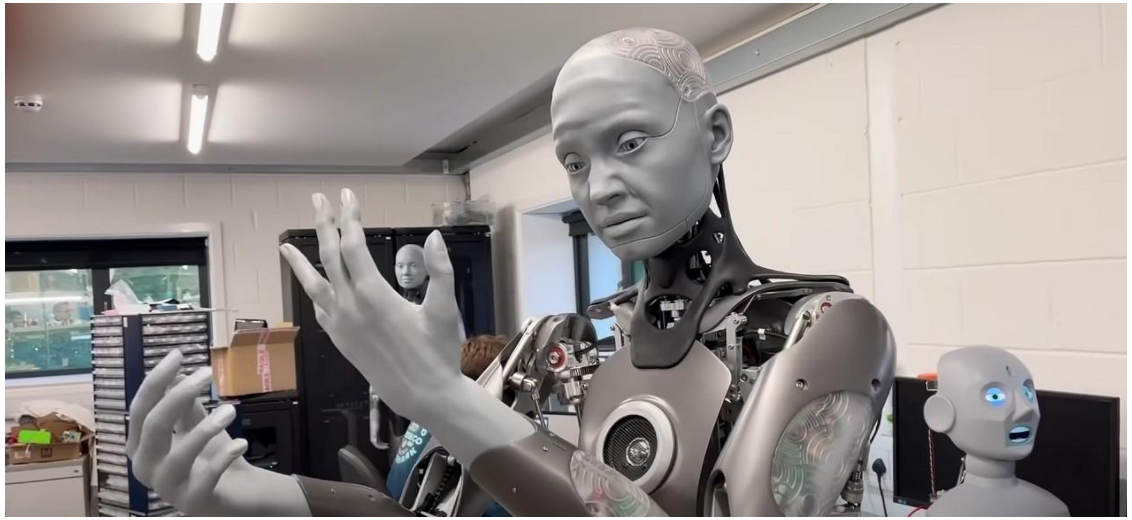
SYLLABUS

Module – 1 (Introduction to robotics)

Introduction to robotics – Degrees of freedom, Robot types- Manipulators- Anatomy of a robotic manipulator-links, joints, actuators, sensors, controllers. Robot configurations-PPP, RPP, RRP, RRR. Mobile robots- wheeled, legged, aerial robots, underwater robots, surface water robots . Dynamic characteristics- speed of motion, load carrying capacity & speed of response. Introduction to End effectors - mechanical grippers, special tools, Magnetic grippers, Vacuum grippers, adhesive grippers, Active and Passive grippers. Ethics in robotics - 3 laws - applications of robots.

ROBOT

- Any automatically operated machine that replaces human effort
- It may not resemble human beings in appearance or perform functions in a humanlike manner



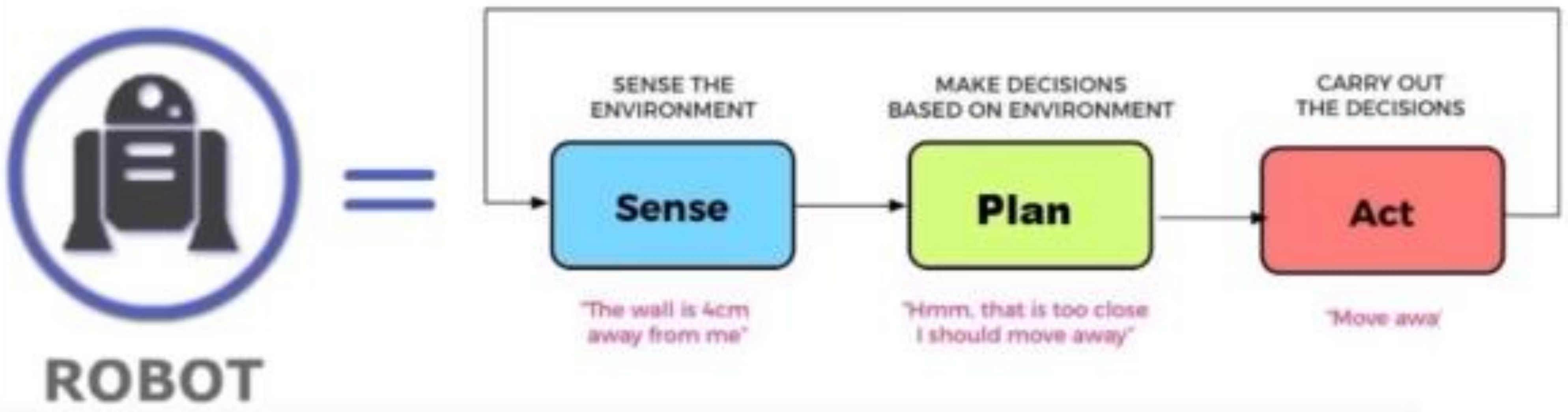
AMECA

FLIPPY

AQUANAUT

FLOOR CLEANING ROBOT

A goal oriented **machine** that generally can **sense**, **plan** and **act autonomously**

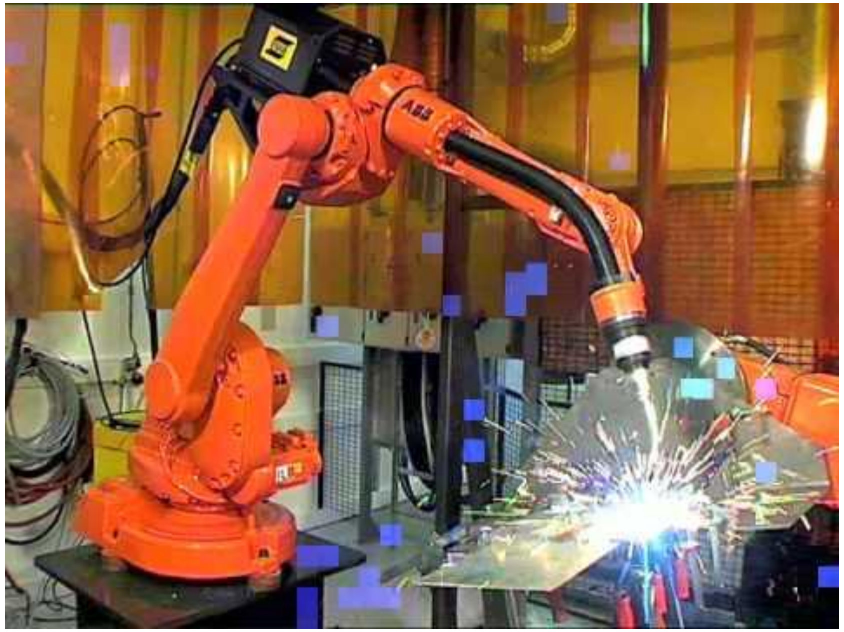


- A robot is a machine, especially one programmable by a computer, capable of carrying out a complex series of actions automatically
- A robot can be guided by an external control device or the control may be embedded within

Ex:

- Welding robots used in a factory
- The quadrupedal military robot
- Humanoid robot

  purpose: Human interaction



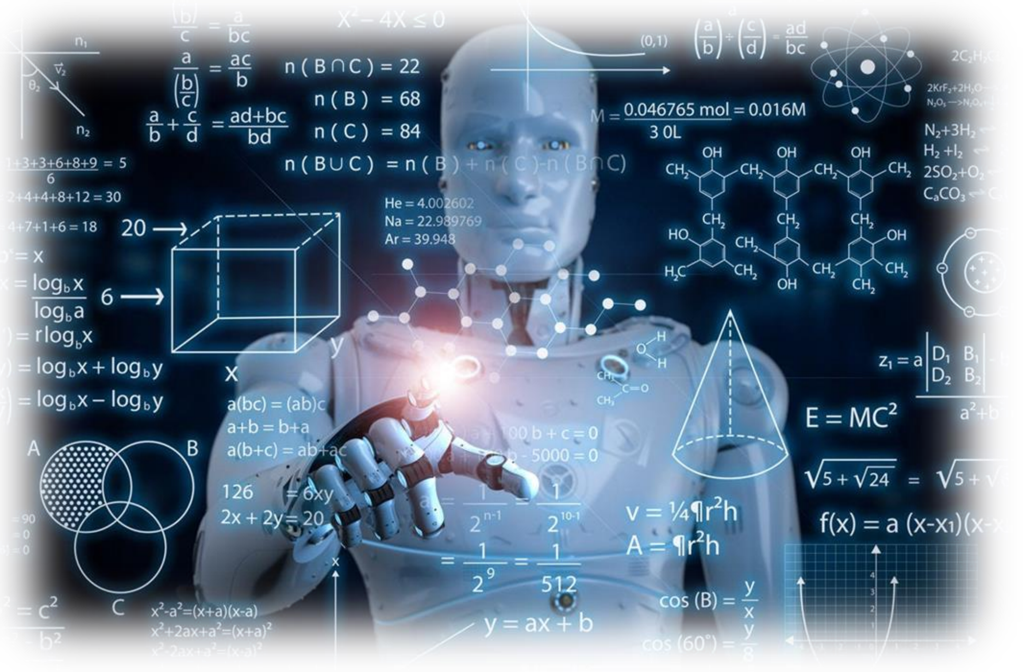
https://www.youtube.com/watch?v=WYFPgdk2FUQ

https://www.youtube.com/watch?v=f93akjQW100

Car Factory ROBOTs🤖: How robots are making cars?🚘Building & Manufacturing cars – How it's build? - YouTube

WHAT IS ROBOTICS ?

- It is the art of designing, construction and operation of a robot
- Robotic system consist of robots, other devices and equipment that are used along with these robots



Robotics is the intersection of science, engineering and technology that produces machines called robots, that replicate or substitute for human actions.

ADVANTAGES OF USING ROBOTS

- They can perform different tasks without needing human interaction
- They can perform tasks very efficiently and fast
- Robots can work without getting tired, leading to increased productivity and efficiency
- Robots can perform tasks that are dangerous for humans, improving overall safety in the workplace
- Reduced labor cost: as robots can perform tasks more cheaply than human workers

DISADVANTAGES

- **Initial cost:** implementing and maintaining a robotic system can be expensive, especially for small and medium sized businesses
- **Job losses:** the increased use of robots may result in job losses for human workers
- **Limited capabilities:** robots are still limited in their capabilities compared to human workers and may not be able to perform tasks requiring creativity
- **Maintenance costs:** robots require regular maintenance and repair, which can be time consuming and expensive

APPLICATIONS OF ROBOTICS

1. Security

Imagine if all the security guards are robots? Even thieves would be scared! That’s why robots are being proposed **as security agents** as they can protect humans, and they wouldn’t be in danger like human security guards. Currently, robotics companies are working on pairing robot guards with human security consultants.

2. Agriculture

Agriculture is the sector that is the basis of human civilization. However, agriculture is also a seasonal sector that is dependent on ideal weather conditions optimal soil, etc. Moreover, **there are many repetitive tasks in agriculture that are just a waste of farmer’s time** and can be performed more suitable by robots. These include **seeding, weed control**, **harvesting,** etc. Robots are usually used for harvesting the crops which **allow farmers to be more efficient.**


tech
Dubai Police
Play (k)
The first "Robocop" joined the
Dubai Police Force in May of 2017


PARKING
SECURITY

3. Health Care

Robots have changed healthcare a lot. They can help doctors in performing operations more precisely, can be used as **prosthetic limbs**, provide therapy to patients, etc.

4. Manufacturing

There are many **repetitive and common tasks** in the manufacturing industry that don’t require any usage of the mind like **welding, assembly, packing**, etc. These tasks can be easily done by robots while leaving the mentally challenging and creative tasks to humans.

5. Military

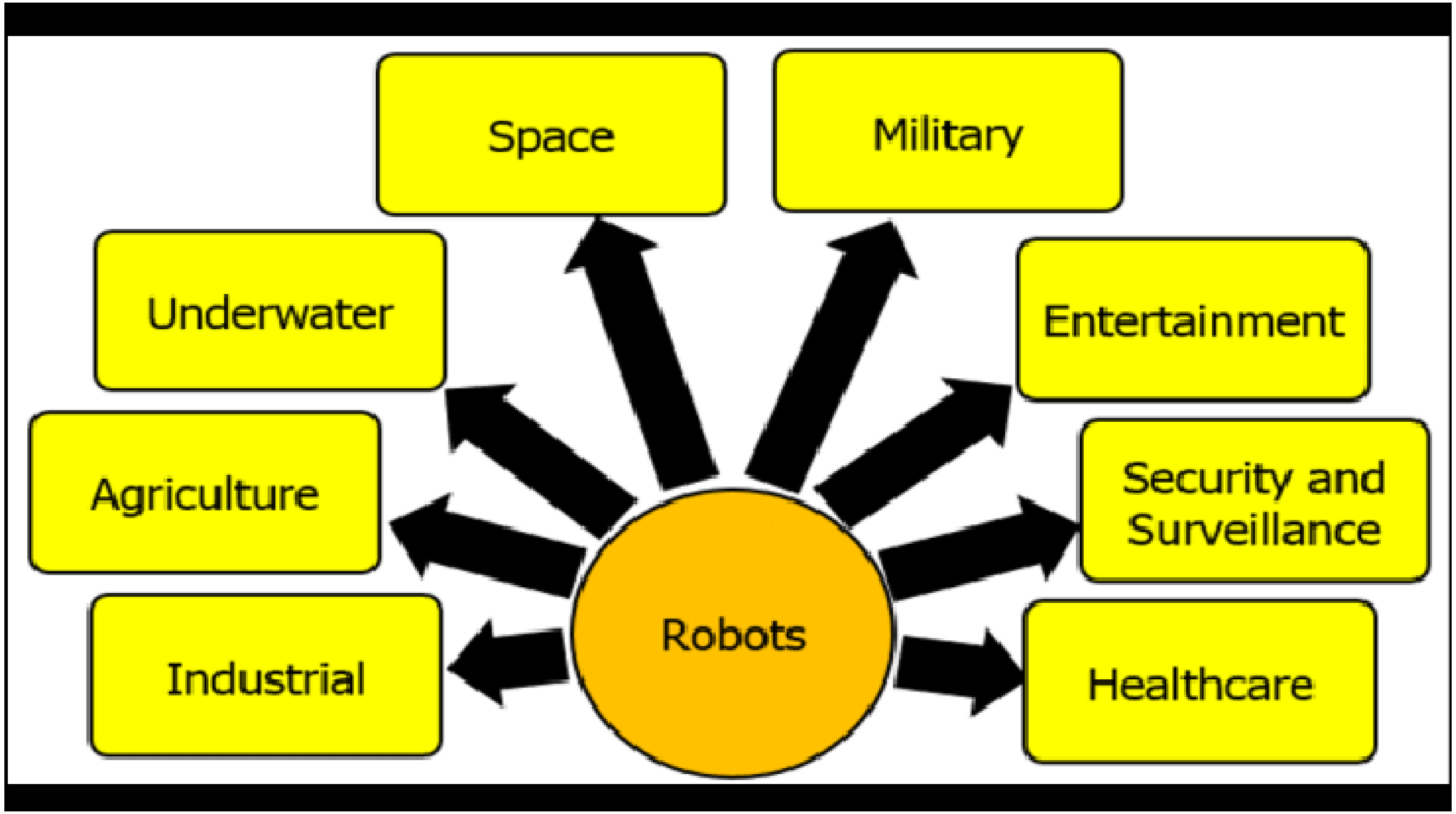
Robots also have many applications in the military. They can be used as drones **to keep surveillance on the enemy**, they can also be used as armed systems **to attack the opposing forces** or as **Medicare agents** to help friendly forces.

6. Underwater Exploration

Robots are a great option **for exploring places that humans cannot reach easily**, like the **depths of the ocean!** There is a lot of water pressure deep in the ocean which means humans cannot go that down and machines such as submarines can only go to a certain depth as well. These robots are remote-controlled, and they can go into depths of the ocean **to collect data and images about the aquatic plant and animal life.**

7. Entertainment

Robots are also a big draw in the entertainment industry. While they cannot exactly become actors and actresses. Robots can also be **used to do stunt work** that is very dangerous for humans but looks pretty **cool in an action movie**. **Theme parks** like Disney World are also using autonomous robots to enhance the magical experience of their customers.


Space
Military
Underwater
Entertainment
Agriculture
Security and Surveillance
Robots
Industrial
Healthcare

TYPES OF ROBOT

While robotics applications vary greatly giving directions, stocking shelves, welding metal in dangerous environments, and much more **today’s robots can generally be grouped into six categories**.

1. AUTONOMOUS MOBILE ROBOT (AMR)

- AMRs move throughout the world and make decisions in real-time.
- Technologies such as sensors and cameras help them ingest information about their surroundings.
- Onboard processing equipment helps them analyze it and make an informed decision.
- It can do various jobs like picking precisely the right parcel, or selecting an appropriate surface to disinfect.
- They’re mobile solutions that require limited human input to do their job.

2. AUTONOMOUS GUIDED VEHICLE (AGV)

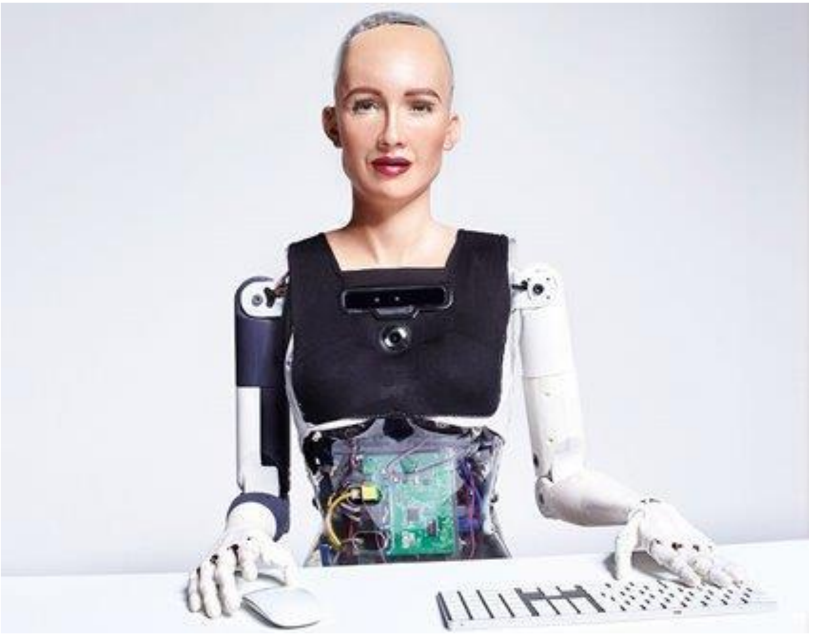
- While AMRs traverse environments freely, AGVs rely on tracks or predefined paths and often require operator oversight.
- These are commonly used to deliver materials and move items in controlled environments such as warehouses and factory floors.

3. ARTICULATED ROBOT

- Articulated robots (also known as robotic arms) are meant to emulate the functions of a human arm.
- Typically, these can feature anywhere from two to 10 rotary joints.
- Each additional joint or axis allows for a greater degree of motion—making these ideal for arc welding, material handling, machine tending, and packaging.

4. HUMANOIDS

- While many mobile humanoid robots may technically fall under the domain of an AMR, the term is used to identify robots that perform human-centric functions and often take human-like forms.
- They use many of the same technology components as AMRs to sense, plan, and act as they carry out tasks such as providing directions or offering services.

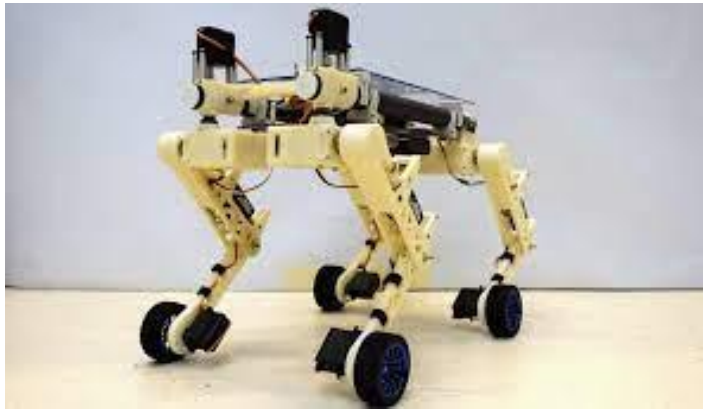


5. COBOTS

- Cobots are designed to function alongside or directly with humans. While most other types of robots perform their tasks independently, or in strictly isolated work areas,
- Cobots can share spaces with workers to help them accomplish more.
- They’re often used to eliminate manual, dangerous, or strenuous tasks from day-to-day workflows.
- In some cases, cobots can operate, by responding to and learning from human movements.

6. HYBRIDS

- The various types of robots are often combined to create hybrid solutions that are capable of more complex tasks.
- For example, an AMR might be combined with a robotic arm to create a robot for handling packages inside of a warehouse.
- As more functionality is combined into single solutions, compute capabilities are also consolidated.



Ethics

- The branch of knowledge that deals with moral principles.

- Moral principles that govern a person's behavior or the conducting of an activity

- Ethics refers to well-founded standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society

Why is robot ethics important?

- Robot ethics combines insights from experts in robotics, AI, computer science, and engineering with insights from experts in philosophy, law, psychology and sociology, in an attempt **to ensure that automation designs and deployments do not create ethical hazards for individuals and society.**

- In considering the individual robot, **the primary aim of robot ethics should be to develop the means to prevent robots from doing harm–harm to people, to themselves, to property, to the environment, to people's feelings, etc.**

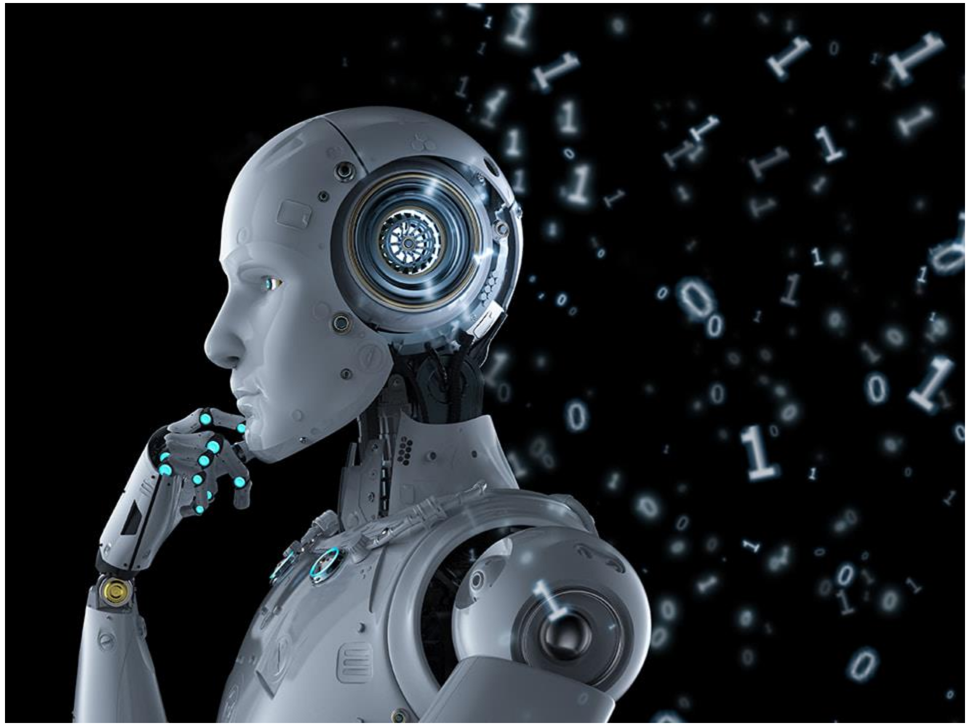
Key aspects of ethics in robotics include:

1. **Safety:** Making sure robots are designed and used in a way that reduces risks to people and other living beings. This includes having safety features, backup systems, and following safety rules.
2. **Transparency and Accountability:** Being clear about what robots can and can't do, and any potential biases. Making sure robots are held responsible for their actions, especially in important areas like healthcare, transportation, and law enforcement.
3. **Privacy and Data Protection:** Protecting people's privacy and sensitive data that robots collect or use. Putting measures in place to keep personal information safe from unauthorized access or misuse.
4. **Fairness and Equity:** Preventing robots from making inequalities worse by addressing issues like bias, discrimination, and accessibility. Making sure robots work fairly for everyone.

5. **Societal Impact:** Considering how robots affect society, including their impact on jobs, education, and human relationships. Planning for and addressing possible problems caused by robots.
6. **Autonomy and Control:** Finding a balance between letting robots make decisions on their own and keeping human control. Deciding how much human involvement is needed and how to intervene when necessary.
7. **Ethical Decision-Making:** Creating rules for robots to make ethical decisions, focusing on doing good, avoiding harm, respecting autonomy, and ensuring fairness. Encouraging cooperation between different fields and involving the public to tackle ethical challenges.

THREE LAWS OF ROBOTICS

- Three laws of robotics, rules developed by science-fiction writer Isaac Asimov, who sought to create an ethical system for humans and robots.



First Law

A robot may not injure a human being or, through inaction, allow a human being to come to harm.

Second Law

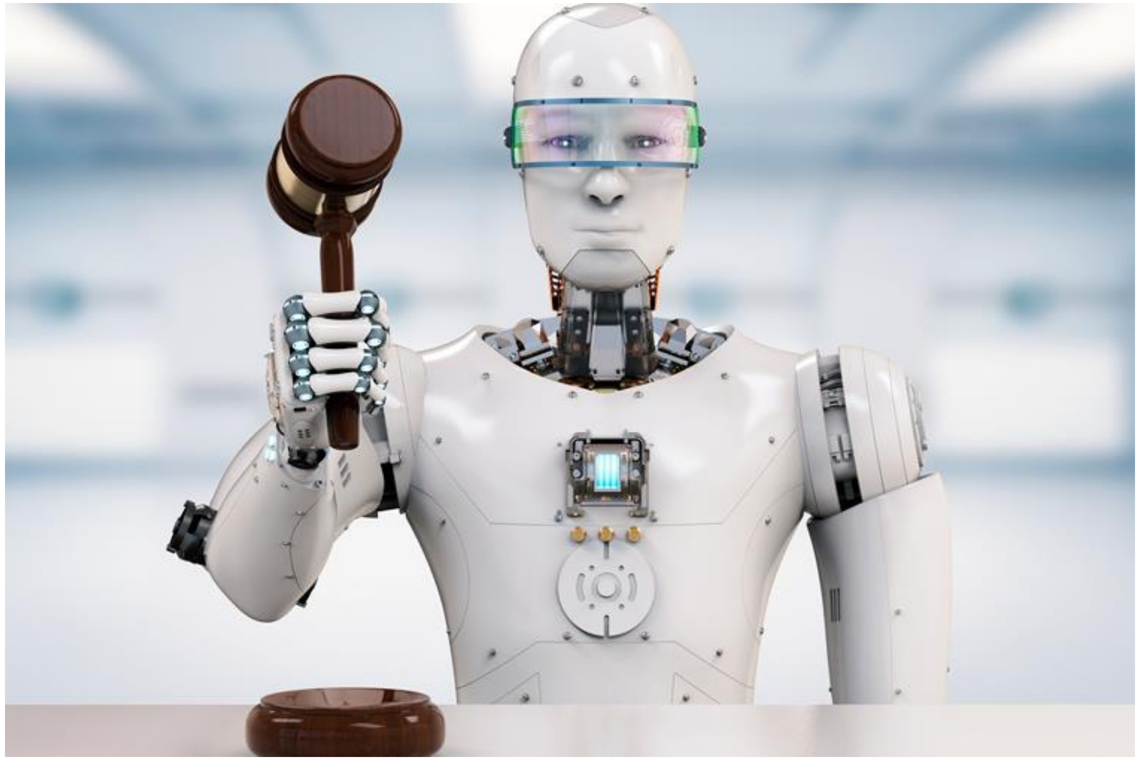
A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

Third Law

A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Fourth or Zeroth Law

A robot may not harm humanity, or, by inaction, allow humanity to come to harm.



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DEGREE OF FREEDOM

Module 1

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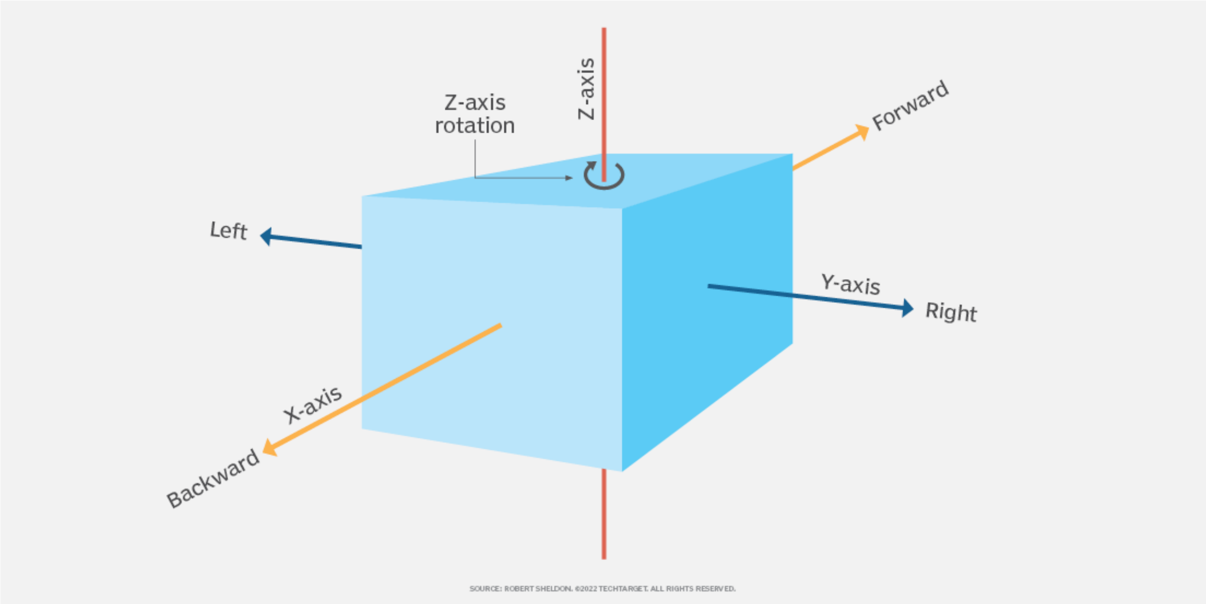
- Degree of freedom basically refers to the number of ways in which an object can move.
- The number of degrees of freedom is equal to the total number of independent displacements or aspects of motion.
- For each Degree of Freedom a joint is required.

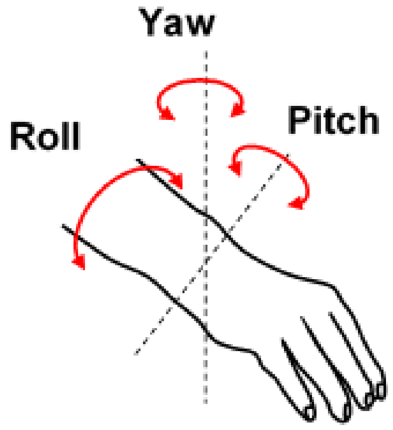
- **There are 2 fundamental means of movement:**
    1. Translation – The motion along a path.
    2. Rotation - The motion of an object around a circular path, in a fixed orbit.

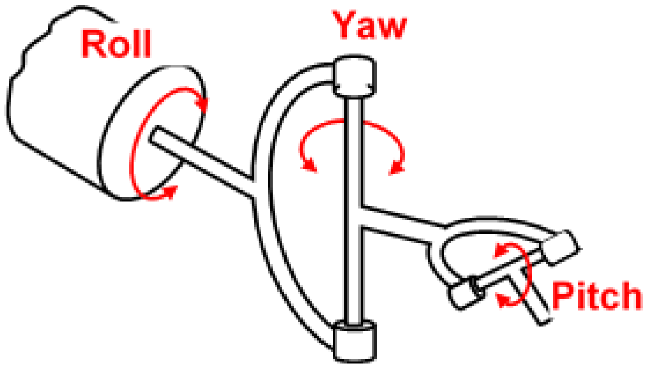
- **Translation can be further broken down into 3 kinds of movements:**
    - Forward - Backward
    - Left - Right
    - Up – Down



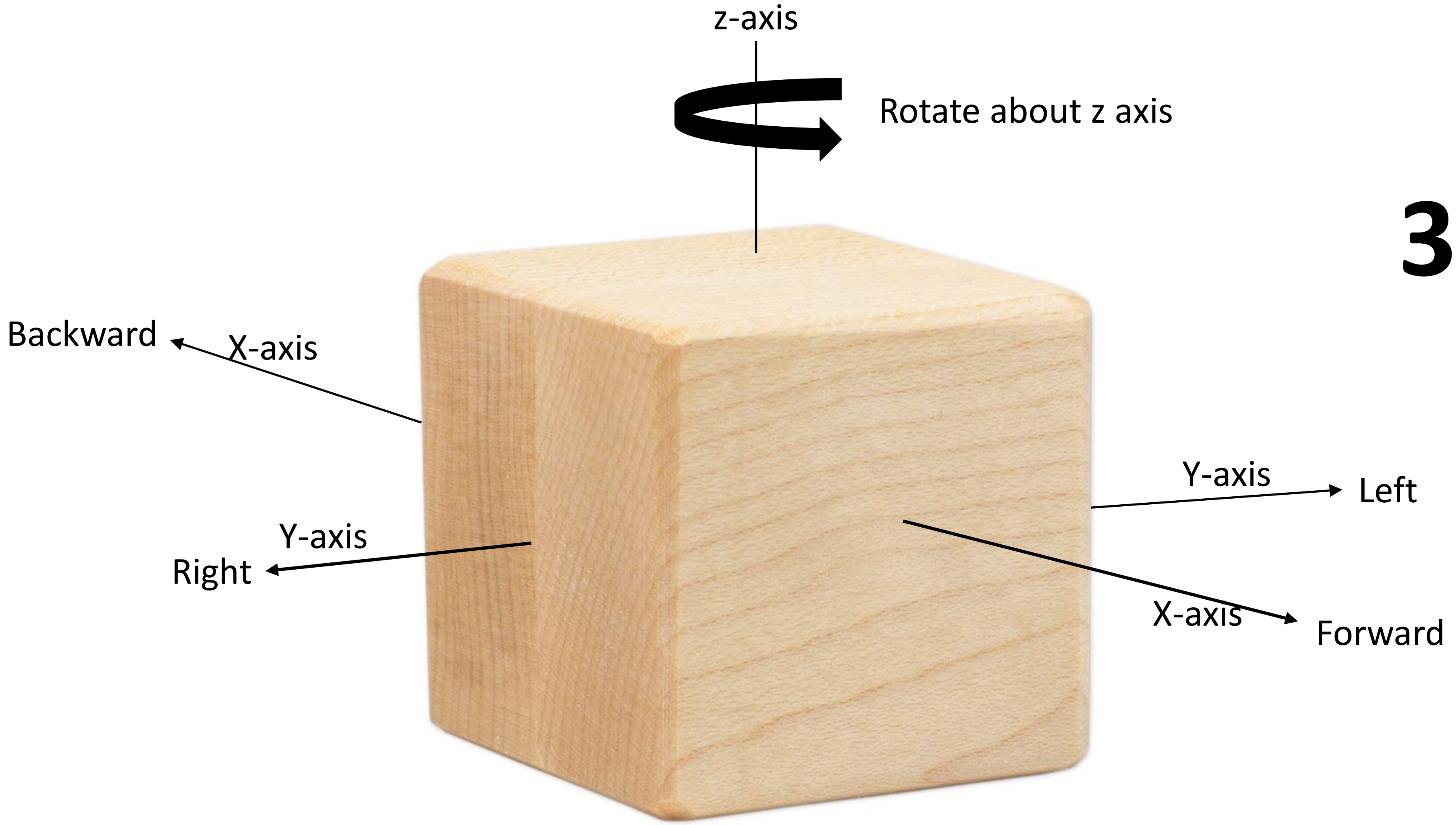
- **Rotation can also be further broken down into 3 kinds of movements:**
  - Pitch
  - Yaw
  - Roll

These are the 6 degrees of freedom.



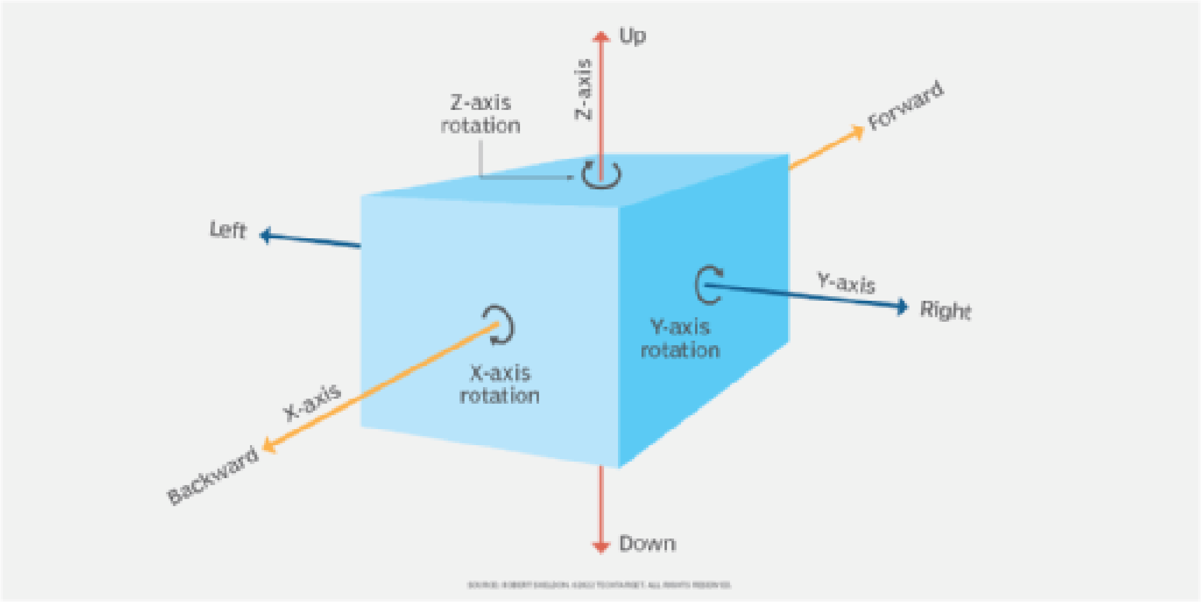


3DOF


z-axis
Rotate about z axis
Backward
X-axis
Y-axis
Right
Y-axis
Left
X-axis
Forward

Explanation

- The above figure shows a block in planar space.
- The block can move linearly forward and backward along the x-axis
- or it can move left or right along the y-axis
- Both type of movements are considered translational motion
- The block can also rotate around the z-axis, which means that it also supports rotational motion
- However the block cannot rotate around the x-axis or y-axis, nor can it move linearly up and down the z-axis



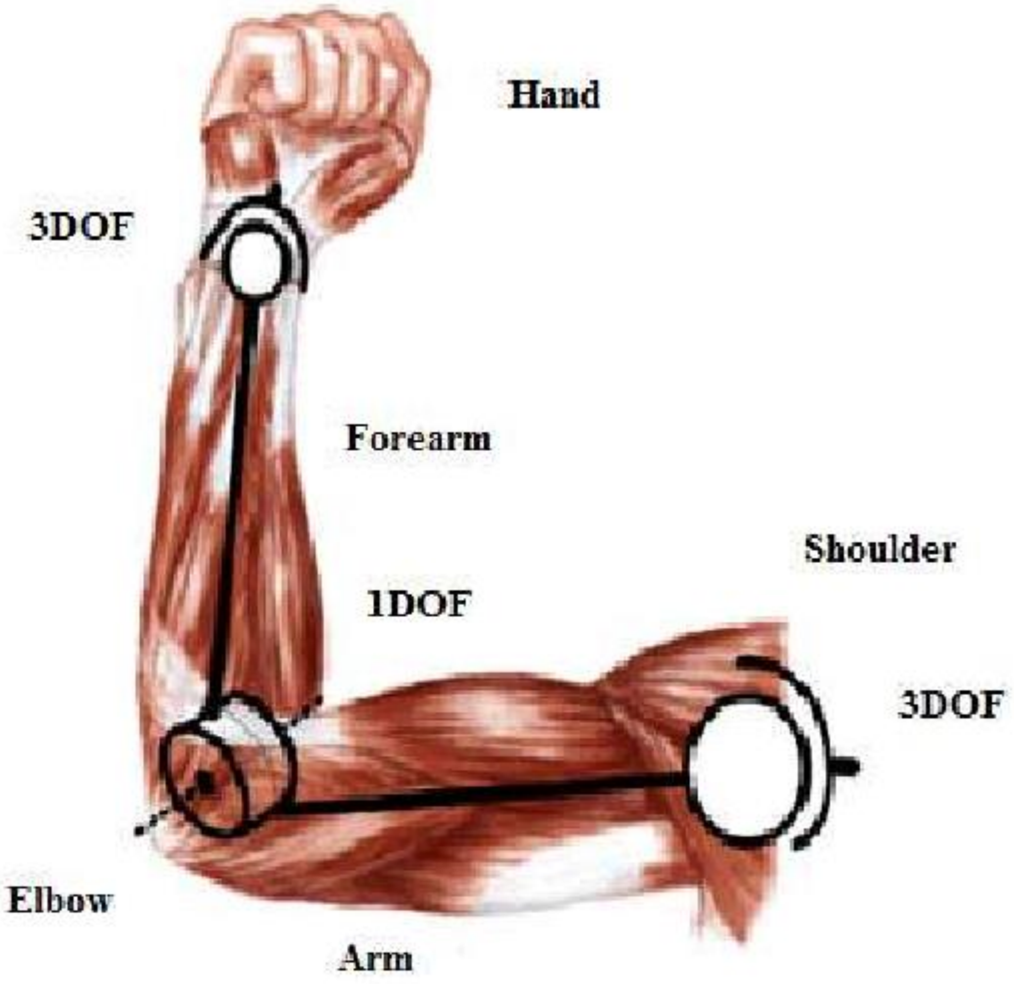
6DOF

A mechanism in three-dimensional space can support upto *6 degrees of freedom*
Three translational and three rotational

Explanation

- Because it is in a three dimensional space, the block can move linearly along all three axes, and it can rotate around all three axes
- The block can move forward or backward along the x-axis and it can rotate around the x-axis
- The block can move left or right along the y-axis and it can rotate around the y-axis
- The block can move u or down the z-axis, and it can rotate around the z-axis

- A human arm is considered to have 7 DOF
- a shoulder gives pitch, yaw and roll
- an elbow allows for pitch
- And a wrist allows for pitch, yaw and roll



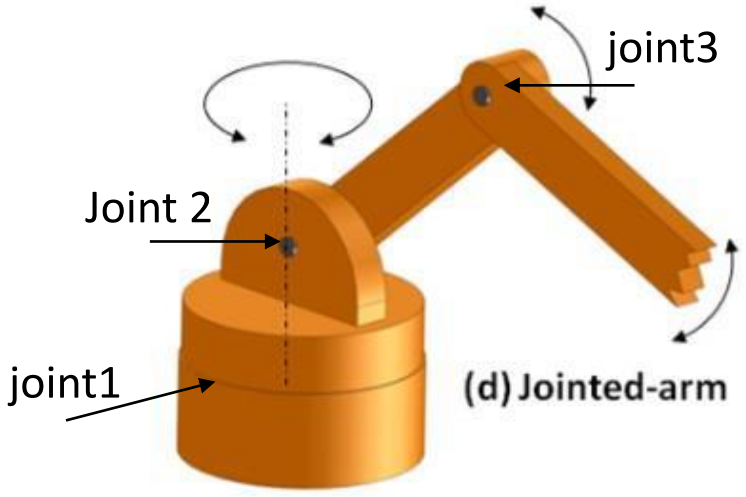
Explanation

- The shoulder can rotate in any direction, giving it 3 degree of rotational freedom
- The elbow can bend in only one direction, resulting in one degree of rotational freedom
- The wrist can rotate in any direction, adding 3 more degrees of rotational freedom

DIFFERENT DEGREE OF FREEDOM IN ROBOTIC ARM

1) 3 Degree of freedom

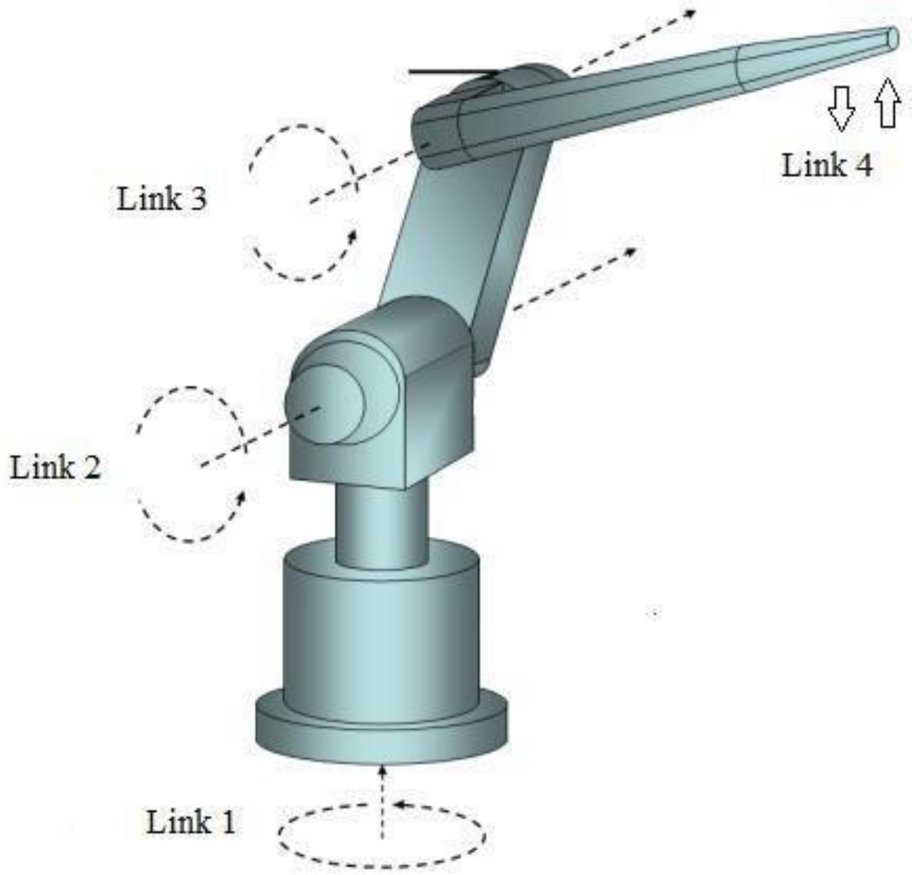
This is a robot that has three joints that work alongside each other to effect movement in a robotic arm. They can be used for all kinds of robotic work from welding, pick and place, machine tending handling, and so many more.



(d) Jointed-arm

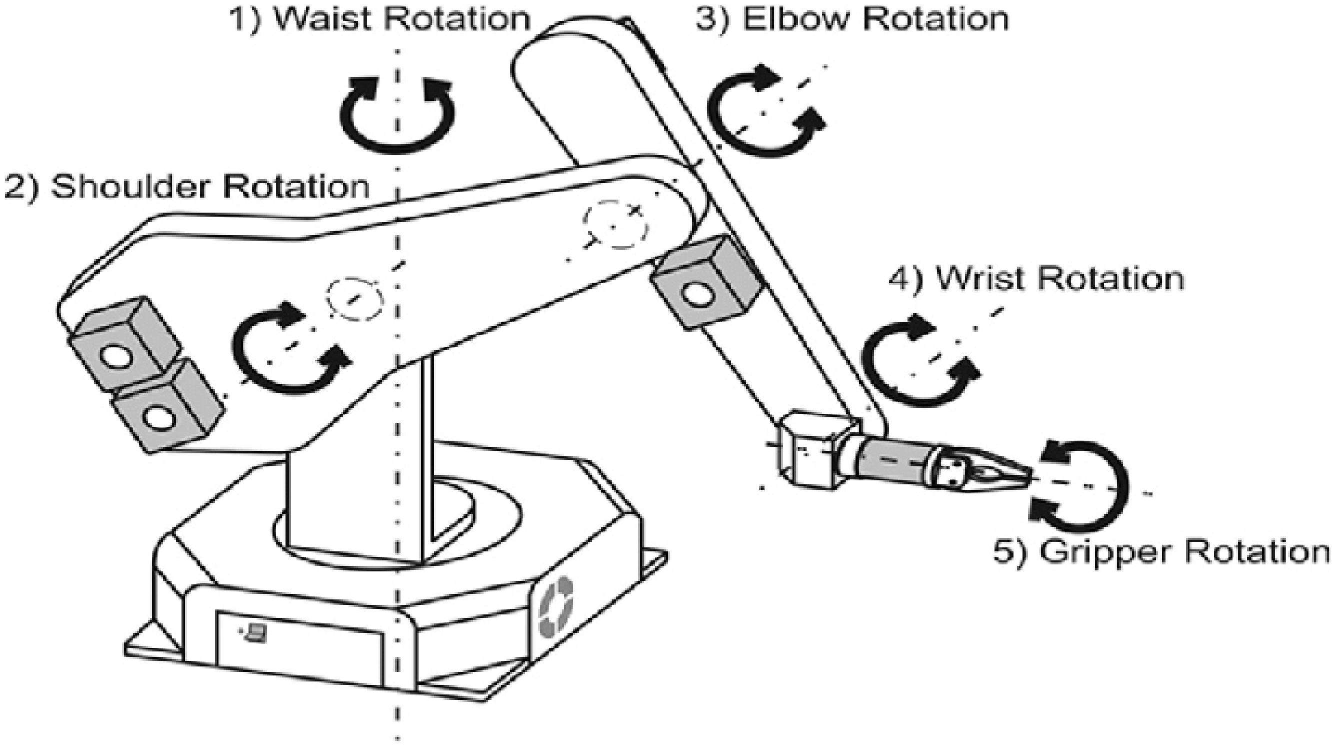
2) 4 Degree of freedom

This is a robot that has four axes or joints. The last axis is located near the base of the robot, and it provides the movement and the stability needed for the entire robotic arm to function correctly. This type of robot is used in palletizing, machine loading, pick and place, automated packaging, among many other roles.



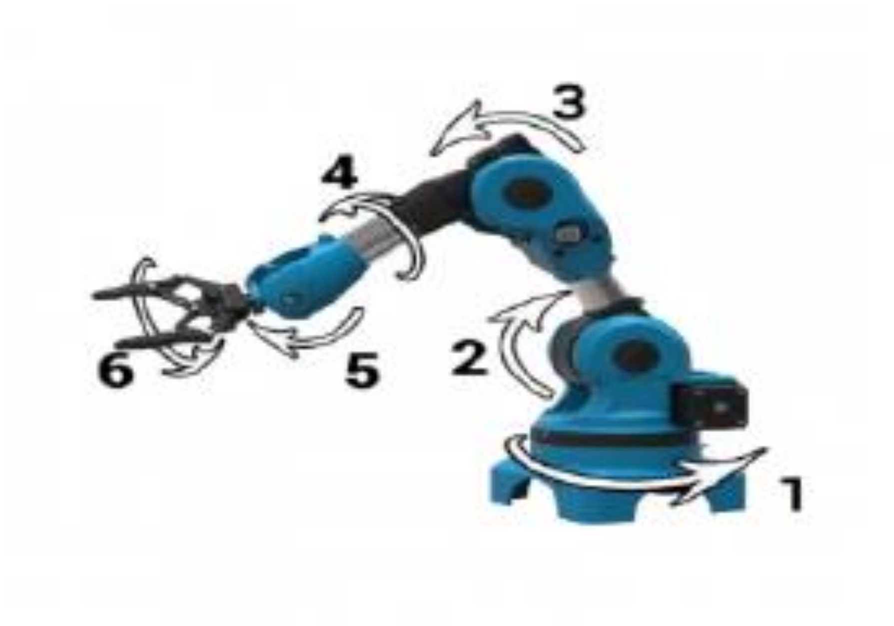
3) 5 Degree of freedom

This is a robotic arm that has five joints, including a manipulator, a servo-motor actuator, and corresponding arm components like the arm, the below, and the wrist. It is more complex than the previous two and can handle more due to the presence of more joints.



4) 6 Degree of freedom

This is a robotic arm that is made of 6 servo-motors, with a corresponding arm, elbow, and wrist. Each joint can move to a certain degree which may be limited a little but is way more than the previous lower versions of DOF. This means that the 6 DOF robotic arm is stronger and faster and can handle even bigger roles in manufacturing.



Thank you…..

Robot Manipulator

- The arm like structure of an industrial robot is known as a robot manipulator
- Also known as a robot arm
- These mechanical devices are composed of a series of jointed segments that form an arm-like manipulator
- It consists of multiple links and joints
- A robotic manipulator is capable of moving or handling objects automatically depending upon its given number of degrees of freedom.

Robotic manipulator

- A robotic manipulator arm is a reprogrammable and multifunctional mechanical device responsible for moving materials, parts, objects, or tools through programmed motions in order to perform various tasks.
- These mechanical devices are composed of a series of jointed segments that form an arm-like manipulator.
- A robotic manipulator is capable of moving or handling objects automatically depending upon its given number of degrees of freedom. Those degrees of freedom are also known as axes. Each axis of a robotic manipulator correlates to the number of motors within the robot.





Robotic manipulators are typically divided into two parts:

a. **Arm and body** - The arm and body of the manipulator control the movement of objects within the robot's work envelope.

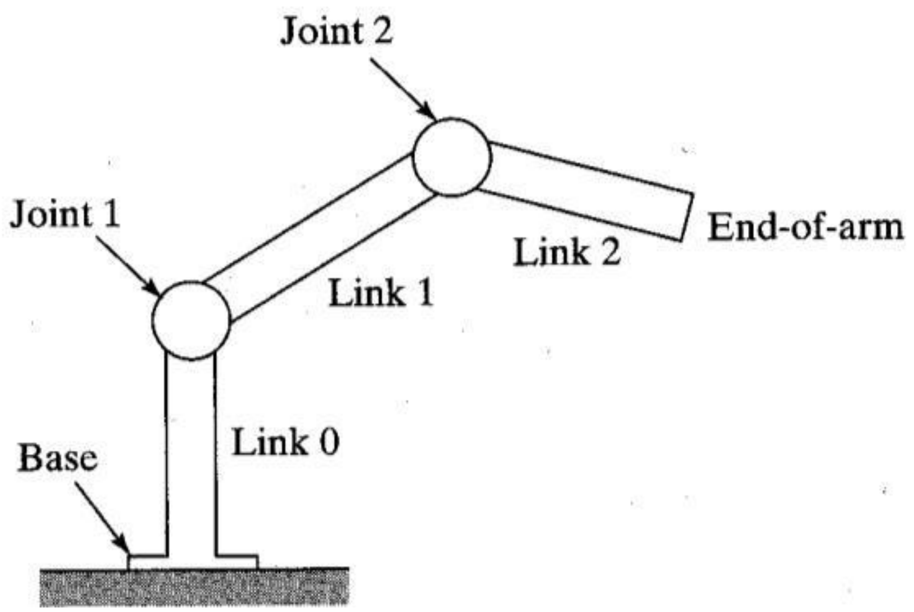
b. Wrist - While the wrist controls the movement of the end-effector, allowing the manipulator to carry out the task it has been programmed.

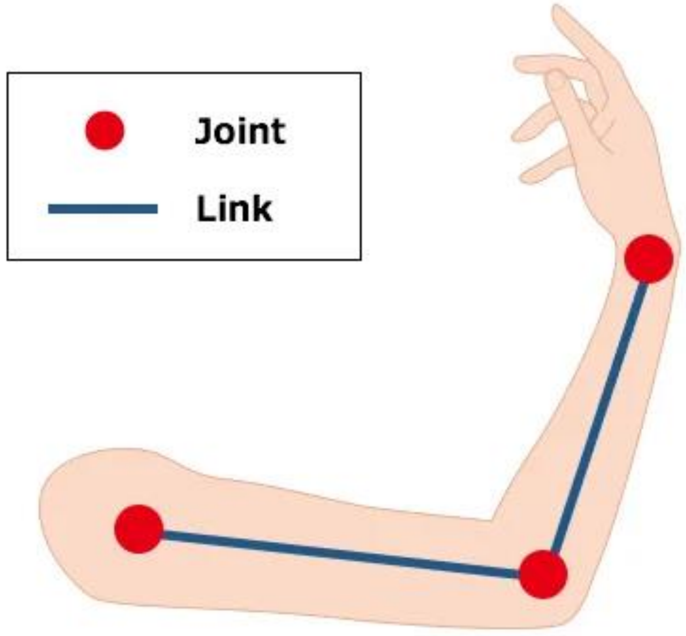
1. Link

➢ A link is a rigid segment of a robot.

➢ Links are connected by joints.

➢ By moving (e.g. rotating) the joints, the links can be moved, and the whole robot can be articulated.





Types of Link

- **Rigid link**: In this type of link, there will not be any deformation while transmitting the motion. For example, the industrial robotic arm is having rigid links, there will not be any deformation while moving the arm

.

- **Flexible link**: In this type of link, there will be a partial deformation while transmitting the motion. One of the examples of flexible links is belt drive.

- **Fluid link**: In this type of link, motion is transmitted with the help of fluid pressure. Hydraulic actuators, brakes are an example of a fluid link.

2. Joints

- A joint is a connection between two or more links, which allows some motion, or potential motion, between the connected links.

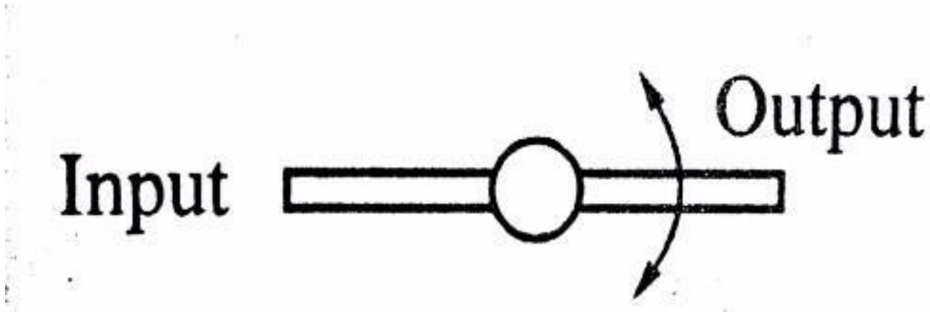
- Robot joints refer to the movable components of the robot that result in relative motions between adjacent links.

- They include two types that provide linear motion and three types that provide rotary motion .These five types of joint areas follows

1. Rotational joint
2. Linear joint
3. Twisting joint
4. Orthogonal joint
5. Revolving joint

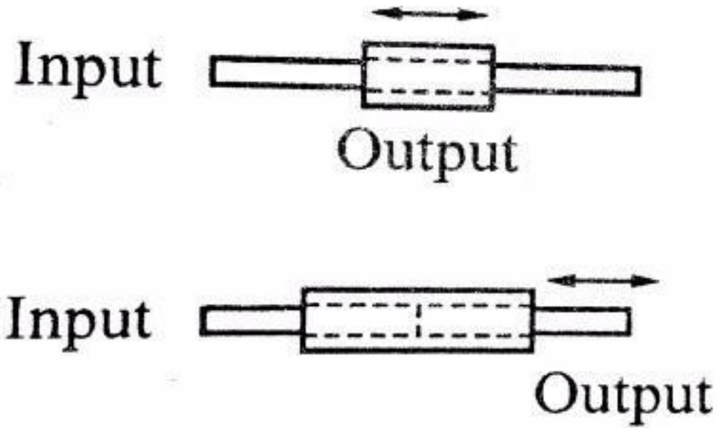
Rotational Joints

When it comes to the rotational joints, you'll find the use of rotational relative motions that come in handy for robot manipulators working multiple workspaces. These movements are carried out with the **axis of rotation perpendicular** to the axes of the input and output links. These rotational joints are also referred to as Type R joints.



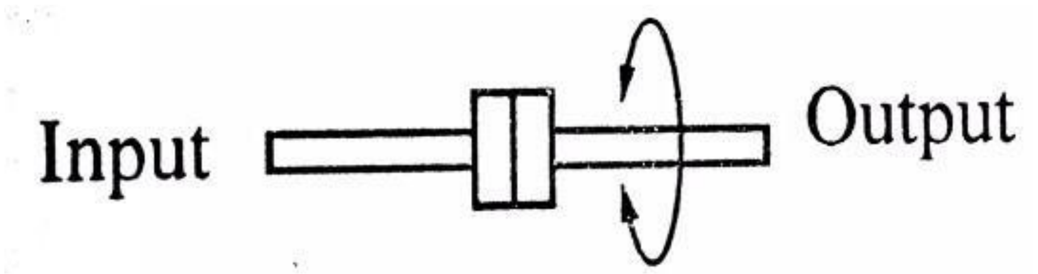
Linear Joints

In the linear joints, the relative motion featured by the **adjacent links is meant to be parallel**. This means that the input and output links **are sliding in a linear motion.** This kind of movement results in a **translational motion.** This kind of linear motion can be achieved in several ways including the use of the telescoping mechanism and piston. This type of joint is also referred to as the **L- joint.**



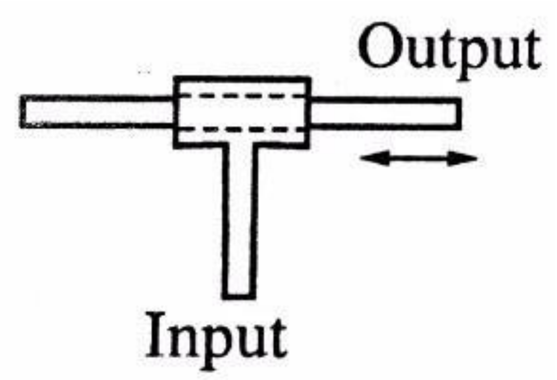
Twisting Joints

This type of joint features **rotary motion** that also results in some degree of rotation when in use. The movement in these joints is relative to the **axis of rotation that is parallel to the axes of the input and output links.** The twisting joints are also referred to as type **T joints.**



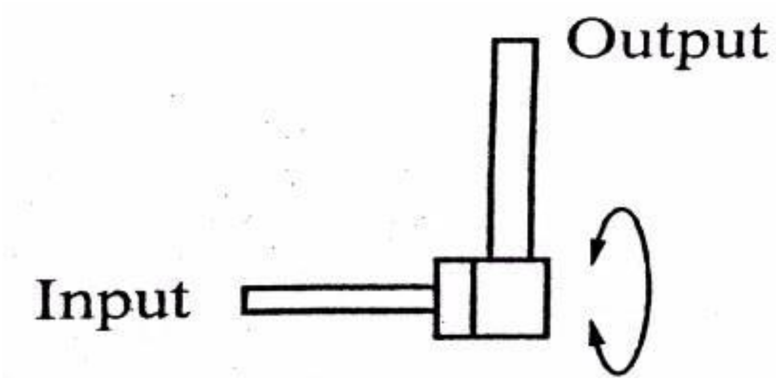
Orthogonal Joints

The orthogonal joints are also popularly referred to as the type **O-joints.** They feature a relative movement taken by the input link and output link. This kind of motion involved in the Orthogonal joints is a **translational sliding motion.** However unlike the linear joints arrangement, with the Orthogonal joint, **the output link is perpendicular to the input link.**



Revolving Joints

In the revolving joints, things are a bit different compared to the others. These joints also feature a **rotational movement** that comes in handy in different applications. The movement of these joints features motion between the two links. **The axis of the input link is designed to be parallel to the axis of rotation of the joint**. On the other hand, **the axis of the output link is designed to be perpendicular to the axis of rotation of the joint.** This type of joint is also referred to as the Type **V joint.**



ROBOT CONFIGURATION

- Industrial robots are available in a wide variety of sizes, shapes, and physical configurations. These configurations are mainly depending on the movement of joints.
- Those joints are known as Prismatic joints or Linear joints denoted by P,

  revolute joints denoted by R,

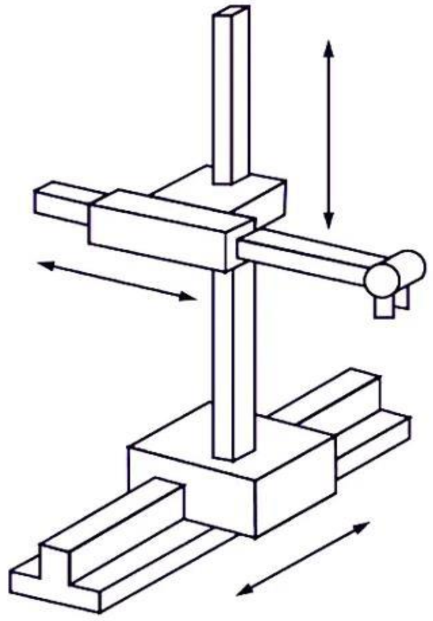
  and spherical joints denoted by S.
- The vast majority of today's commercially available robots possess one of five basic configurations.

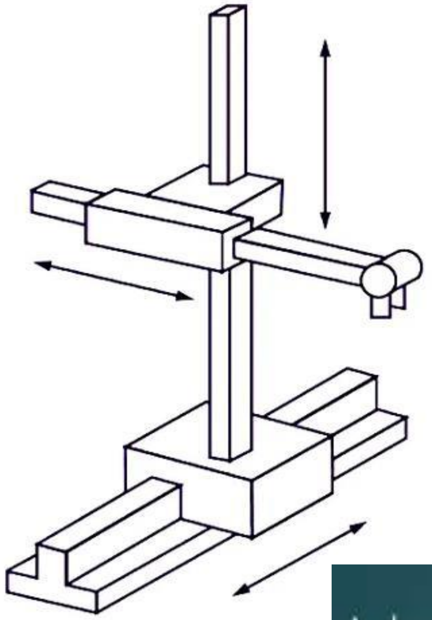
They are

1. **Cartesian configuration (PPP)**
2. **Cylindrical configuration (RPP)**
3. **Polar or Spherical configuration (RRP)**
4. **Jointed-arm configuration (RRR)**
5. **SCARA configuration**

1. Cartesian configuration (PPP)

- These robots are made of three linear joints that position the end effector, which is usually followed by additional revolute joints that orientate the end effector. 3P represents three Prismatic or Linear joints used in the robots.
- By moving the three slides relative to one another, the robot is capable of operating within a rectangular work envelope.





Advantages

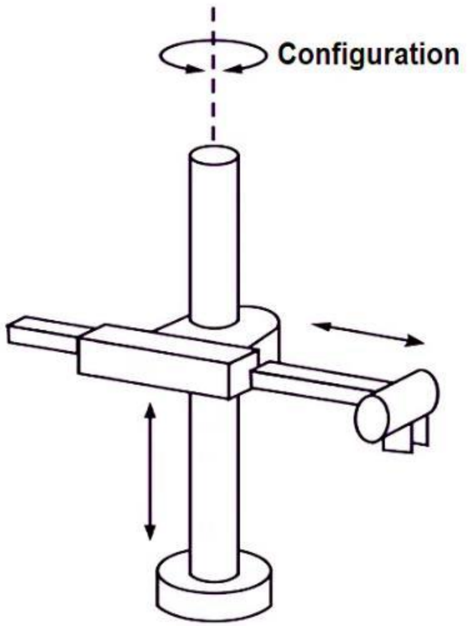
- Easy to visualize
- Have better inherent accuracy than most other types
- Easy to program offline

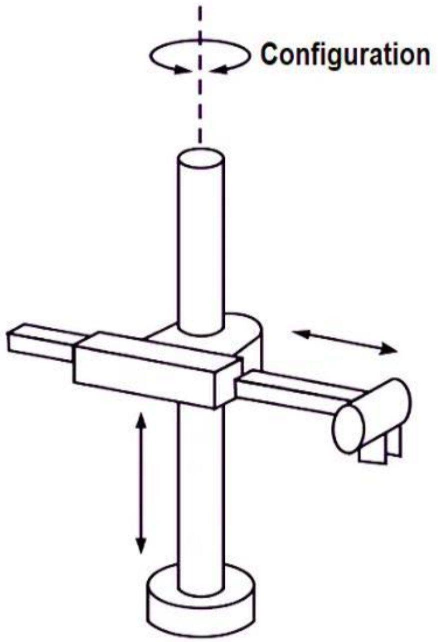
Disadvantages

- Not space efficient
- External frame can be massive
- Z axis "post" frequently in the way
- Axes hard to seal
- Can only reach in front of itself

2. Cylindrical configuration (RPP)

- The cylindrical configuration uses a vertical column and a slide that can be moved up or down along the column. The robot arm is attached to the slide so that it can be moved radially with respect to the column.
- By rotating the column, the robot is capable of achieving a workspace that approximates a cylinder. This cylindrical configuration has two Prismatic or Linear joints and one revolute joint, (PRP) denotes this only.





Advantages

- Large workspace for size
- Easily computed kinematics
- Can reach all around itself
- Reach and height axes rigid

Disadvantages

- Cannot reach above itself
- Horizontal axis frequently in the way
- Largely fallen “out of favor” and not common in new design.

3. Polar or Spherical configuration (RRP)

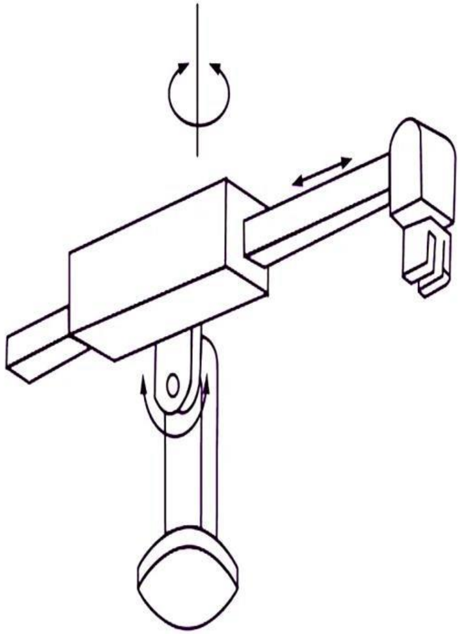
- The polar configuration uses a telescopic arm that can be moved up or down about a horizontal pivot. The pivot is mounted on a rotating base.
- These joints provide the robot with the capability to move its arm within a spherical space and hence the name spherical coordinate robot is sometimes applied to this space.
- This system has one Prismatic and two Revolute joints that denote the RRP.

Advantages

- Large workplace for size
- Easily computed kinematics

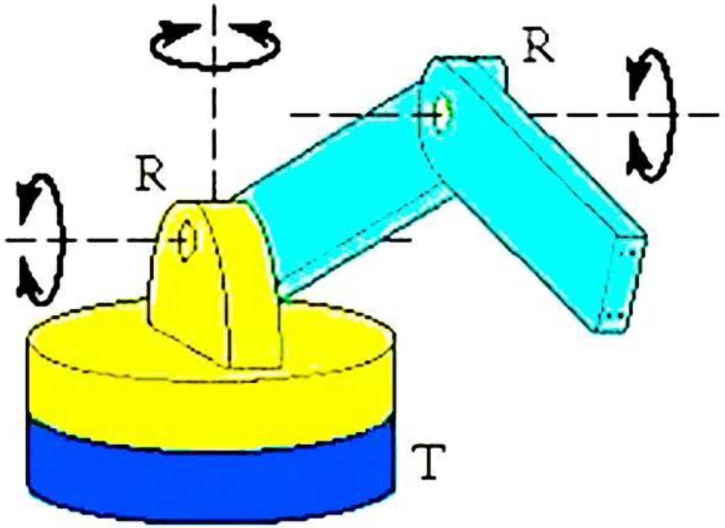
Disadvantages

- Has shot vertical reach
- Horizontal axis frequently in the way
- Also fallen" out of favor" and not common in new design



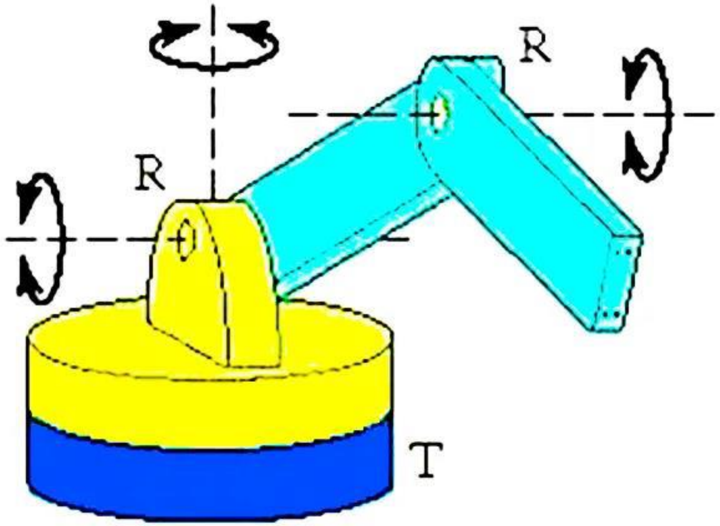
4. Jointed-arm configuration (RRR)

- The jointed Arm configuration is made up of rotating joints. This robot configuration is also sometimes called anthropomorphic as its anatomy is similar to the Human arm.
- These configuration joints are all revolute (3R). They are the most common configuration for industrial robots.



Commonly used for:

- assembly operations
- welding
- weld sealing
- spray painting
- handling at die casting or
- fettling machines



Advantages

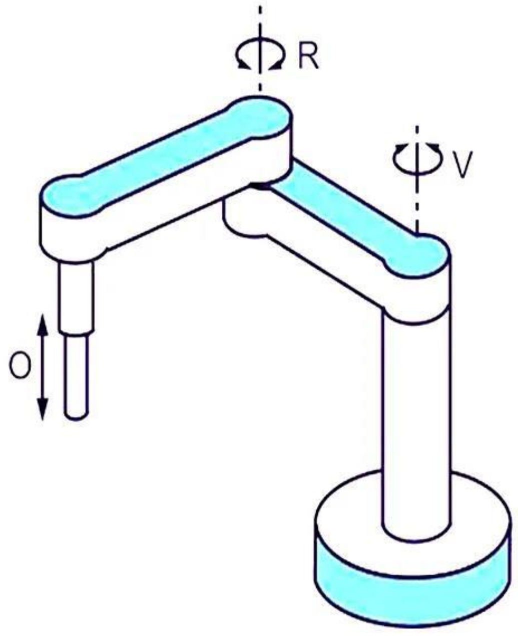
- all rotary joints allows for maximum flexibility
- any point in total volume can be reached.
- all joints can be sealed from the environment.

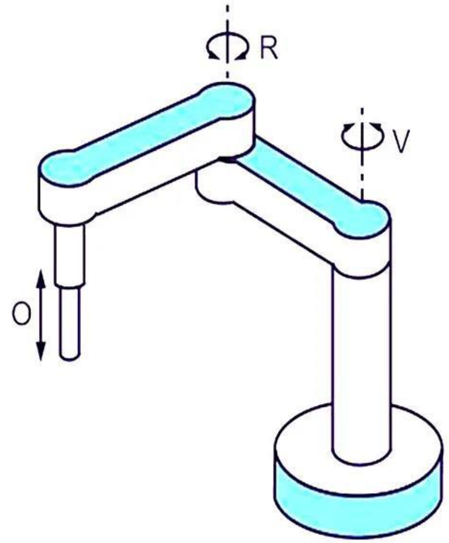
Disadvantages

- extremely difficult to visualize, control, and program.
- restricted volume coverage.
- low accuracy

5. SCARA

- SCARA stands for Selective Compliance Assembly Robot Arm.
- SCARA robots have two or three revolute joints that are parallel and allow the robot to move in a horizontal plane, plus a linear joint that moves vertically.
- SCARA robots are very common in assembly operations.





Advantages

- Fast cycle time
- Excellent repeatability good payload capacity
- Large workplace
- Height axis is rigid

Disadvantages

- Hard to program off-line
- Often limited to planar surfaces
- Typically small with relatively low load capacity
- Two ways to reach same point.

MOBILE ROBOT

- A mobile robot is a type of robot that is designed to move and operate in various environments autonomously or under remote control.
- These robots are equipped with locomotion mechanisms such as wheels, tracks, legs, or a combination of these
- Allowing them to navigate through different surfaces, including indoor spaces, outdoor environments, and even hazardous areas where human access may be limited or dangerous.

- Mobile robots function using a combination of Artificial intelligence (AI) and physical robotic elements like wheels, tracks and legs.
- Mobile robots are popular in different sectors. They are used to assist with work processes and even accomplish tasks that are impossible or dangerous for humans.
- Humanoid robots, entertainment pets, drones, and underwater robots are great examples of mobile robots.
- They are different from other robots because of their ability to move autonomously.
- These robots have the intelligence to decide based on algorithms it takes input and gives the expected output.

Mobile robots can serve a wide range of purposes, including:

- **Exploration:** Mobile robots are often used in exploration missions, such as **planetary exploration** on Mars or **deep-sea exploration**
- **Logistics and Warehousing:** Mobile robots are utilized for tasks such as material handling, inventory management, and transportation of goods within facilities.
- **Security and Surveillance:** Mobile robots equipped with sensors and cameras can be employed for surveillance and security purposes
- **Service and Assistance**: Mobile robots are increasingly being developed to provide various services and assistance to humans, such as home cleaning robots, delivery robots, and healthcare assistants in hospitals.
- **Military and Defense:** Military applications of mobile robots include **bomb disposal**, and **battlefield logistics**, where they can perform tasks to reduce risks to human personnel.

Types of Mobile Robot

- 1. Wheeled robot
- 2. Legged mobile robot
- 3. Aerial robot
- 4. Underwater robot

1. Wheeled Robot

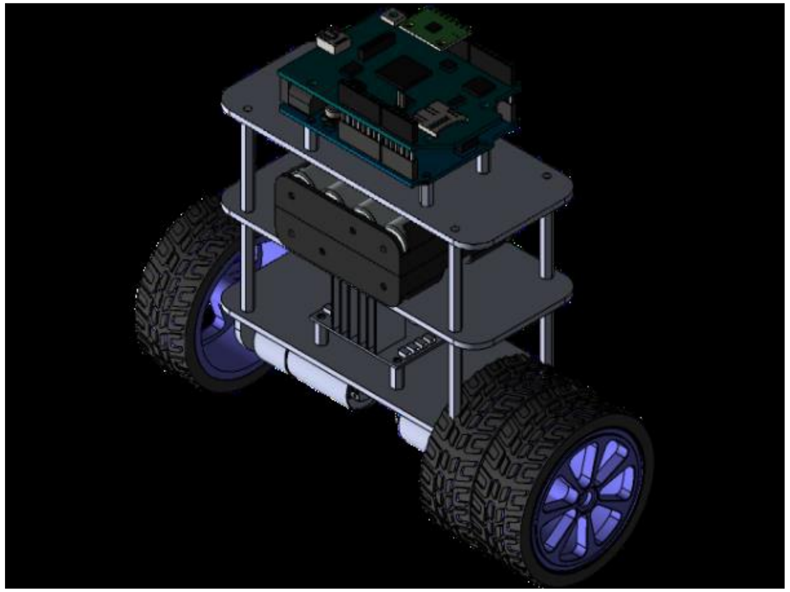
- Wheeled robots are robots that **navigate around the ground using motorized wheels to propel themselves.**
- **This design is simpler** than using treads or legs and by using wheels they are easier to design, build, and program for movement in flat, not-so-rugged surface.
- Wheeled Robots can use any number of wheels to navigate.

a. One wheel robot

One-wheeled robots are **difficult to keep balanced** due to the single point of contact with the ground, They have only one wheel, **It is easier to use a spherical wheel** rather than a typical disc wheel, as the **robot** can move in any direction along the sphere

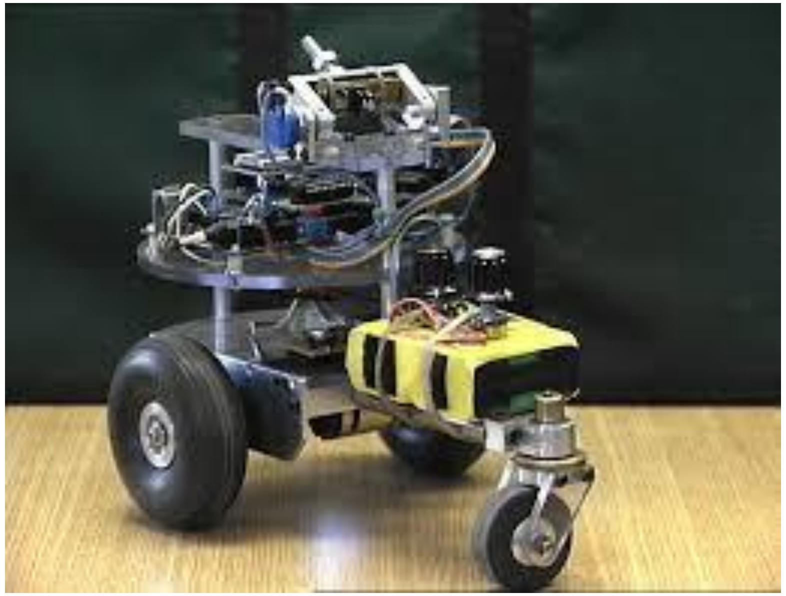
b. Two wheeled Robot

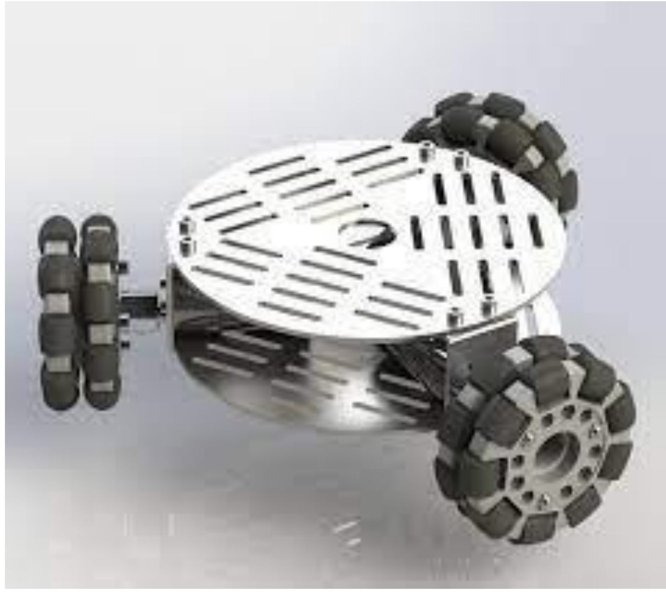
- Two-wheeled robots are simple,
- They have their **wheels parallel to each other,**
- and they are called dicycles, or **one wheel in front of the other,**
- For the robot that has the left and right wheels, it comes with at least two **sensors**,
- The tilt sensor is used to determine tilt angle



c. Three Wheel Robot

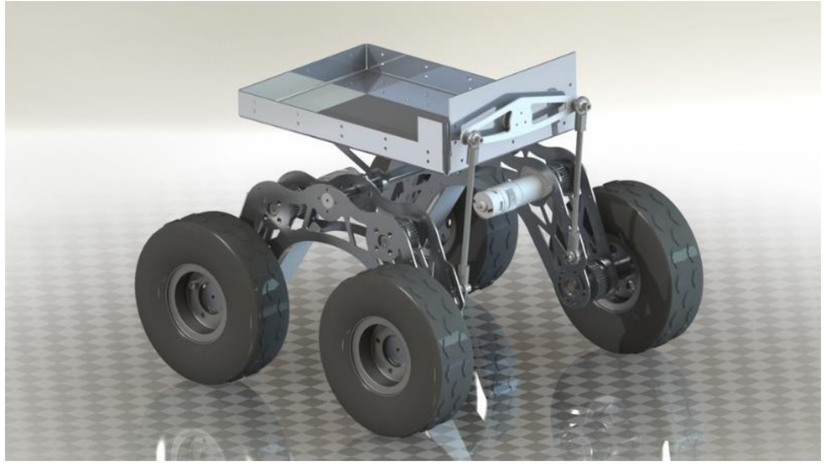
- Three-wheel robots are of **two types** based on the nature of wheels,
- The first type comes with wheels that are separately powered & the third is free rotating purely for balance,
- the second type comes with two wheels that are powered by one source & a different source for the third wheel.





d. Four-wheel Robot

- 4 wheel drive robot comes with **2 pairs of powered wheels**, Each pair can turn in **the same direction,** If the pairs don’t run at the same speed, the robot will slow & won’t be able to drive straight.
- A good design will have to incorporate some form of **car-like steering,** Differential Steering method allows the robot to turn in the same way the car does, when your robot is powered by a combustion engine, It only needs one motor.



2. Legged Mobile robot

- They are **walking robots**, they use their legs to control their locomotion.
- They are used to offer movement in **highly unstructured environments**
- Although they are complex to design, they have a greater edge over wheeled robot in terms of navigation on any kind of path or surface.
- Legged robots can navigate on any kind of surfaces which is inaccessible for wheeled robot.

a. One Legged Robot (Pogo stick robot)

- **Balance and Stability**: A one-legged robot faces challenges in terms of balance and stability. The robot needs to constantly adjust its posture to prevent falling over.
- They **can hop over and move** in any kind of surface as they take a running start and jump over any obstacles.
- They are very efficient, but they come with **complex design & control.**

b. Two - Legged Robot (Bipedal robot)

- Two-legged robots (Bipedal robots) can exhibit bipedal motion,
- Stability is maintained by calculating each step and moving the we
- but they face two primary problems: **stability control** that refers to **motion control** that refers to the robot’s ability to move,
- and the classical example is the Humanoid robot.
- **Types of Movement**:

Walking: Walking algorithms simulate the movement of the human, taking steps while ensuring the robot doesn't fall over.

Jumping: Some two-legged robots are designed with the ability to jump or leap, similar to certain animals like kangaroos. This requires more advanced actuation and control.

Kicking or Manipulating Objects: Some bipedal robots are equipped with extra tools that allow them to interact with objects, which can be useful in rescue missions or other specific tasks.

c. Four-Legged Robot (Quadrupedal robot)

- Quadrupedal robots are statically stable, especially when they are not in motion,
- they have 4 legs and their walking pattern similar to that of animals,
- they are well balanced in posture
- They can move either by moving one leg at a time, ensuring a stable tripod or moving the alternate pair of legs to walk.

d. Six-Legged Robot (Hexapod)

- Six-legged robots (hexapods) offer greater stability than bipedal or quadrupedal robots, They have 6 legs, Their final designs mimic the mechanics of insects, and their gaits may be categorized similarly, These include the slowest wave gait, where pairs of legs move in a “wave” from the back to the front, Tripod gait which is a slightly faster step, **where three legs move at once, The remaining three legs offer a stable tripod for the robot.**

3. **AERIAL ROBOT**

- An aerial robot is a system capable of sustained flight with no direct human control and able to perform a specific task.
- The most important application of aerial robots is aerial observations, which can then be used for terrain map- ping, environmental surveys, crop monitoring, target identification etc.
- The challenges faced by aerial robots span several and distinct fields, including state regulations, man–machine interface design issues, navigation, safety/reliability, collision prevention, and take-off/landing techniques.

a. Unmanned Aerial Vehicle (UAV)

- An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without any human pilot, crew, or passengers on board.
- UAVs are a component of an unmanned aircraft system (UAS), which includes adding a ground-based controller and a system of communications with the UAV ▪
- The flight of UAVs may operate under remote control by a human operator, as remotely-piloted aircraft (RPA)
- These include aerial photography, precision agriculture, forest fire monitoring, river monitoring.

b. Manned aerial vehicle

- Manned aircraft means any aircraft that is carrying or being operated by one or more persons.
- You need a large area covered quickly. Manned aircraft surveying a land mass can cover a lot of areas very quickly.
- A manned vehicle such as a spacecraft has people in it who are operating its controls.

4. UNDERWATER ROBOT

- An underwater robot is an autonomous underwater vehicle (AUV) that can travel underwater without requiring input from an operator.
- Researchers drop an AUV in the ocean at a pre-selected position.
- Two types: **a. Autonomous under water vehicle**
- An underwater robot is an autonomous underwater vehicle (AUV) that can travel underwater without requiring input from an operator..
- **b. Remotely operated underwater vehicles** It is controlled and powered from the surface by an operator/pilot using the remote control.

SURFACE WATER ROBOT

- A surface water robot is a type of autonomous or remotely operated robot designed specifically to operate on the surface of bodies of water such as lakes, rivers, oceans, or even smaller water bodies like ponds or reservoirs. These robots are equipped with sensors, cameras, and sometimes manipulators or sampling equipment depending on their intended purpose.

- Surface water robots can serve various purposes including:

1. **Environmental monitoring:** They can be used to collect data on water quality, temperature, pH levels, turbidity, and other environmental parameters to monitor the health of aquatic ecosystems.
2. **Search and rescue:** Surface water robots equipped with cameras and sensors can be deployed in search and rescue missions to locate and assist individuals in distress on the water.
3. **Hydrographic surveying:** They can be used to map the underwater topography of bodies of water for navigation, construction, or environmental assessment purposes.
4. **Oil spill detection and cleanup:** Surface water robots can be deployed to detect and track oil spills on the water's surface and to assist in cleanup efforts.
5. **Scientific research:** Researchers use surface water robots to study aquatic habitats, marine life, and oceanographic phenomena such as currents and tides.

Dynamic characteristics

In robotics, the **dynamic characteristics** refer to the properties related to

- the movement,
- load handling capabilities,
- responsiveness of robotic systems.

Speed of Motion:

- This refers to how quickly a robot can move its various components, such as joints or end-effectors, from one position to another
- Speed of motion is crucial in determining the efficiency and effectiveness of robotic operations
- Especially in tasks where time is a critical factor, such as assembly lines or pick-and-place operations
- Factors affecting speed of motion include the design of the robot's actuators, its control system, and the mechanical structure

Load Carrying Capacity

- Also known as payload capacity,
- This refers to the maximum weight that a robot can handle while maintaining its intended performance and safety.
- The load carrying capacity is determined by the strength of the robot's structural components, such as its arms or base,
- as well as the capabilities of its actuators and control system.
- It's essential for robots to have adequate load carrying capacity to perform tasks such as lifting heavy objects or manipulating large workpieces.

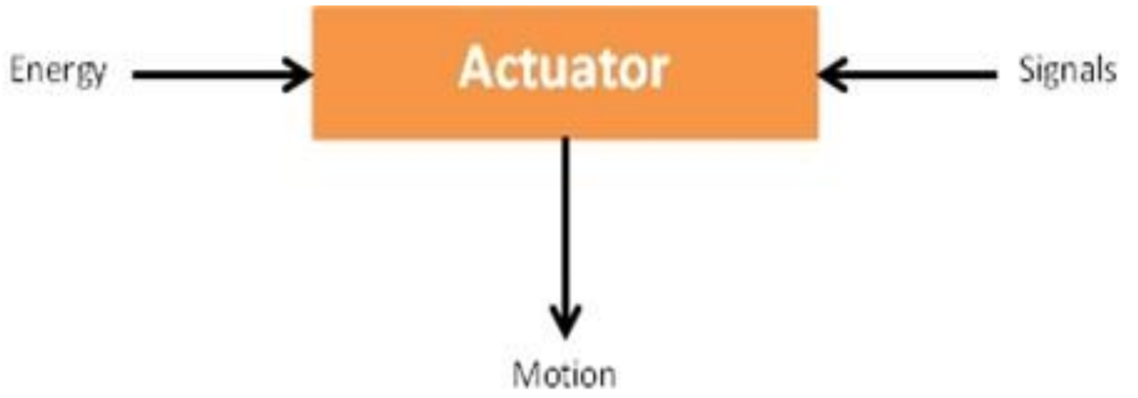
Speed of Response

- This refers to how quickly a robot can react to changes in its environment or inputs from its sensors.
- A fast speed of response is crucial for tasks that require real-time adjustments or interactions with dynamic environments.
- Factors affecting the speed of response include the sensing and processing capabilities of the robot's control system,
- as well as the latency(the delay in network communication) in communication between different components of the robot.
- Robots with a fast speed of response are better equipped to handle tasks such as object avoidance, trajectory tracking, or human-robot collaboration.

- Overall, these dynamic characteristics play a significant role in determining the performance and capabilities of robotic systems across various applications and industries. Balancing these characteristics according to the specific requirements of a task is essential for designing and deploying effective robotic solutions.

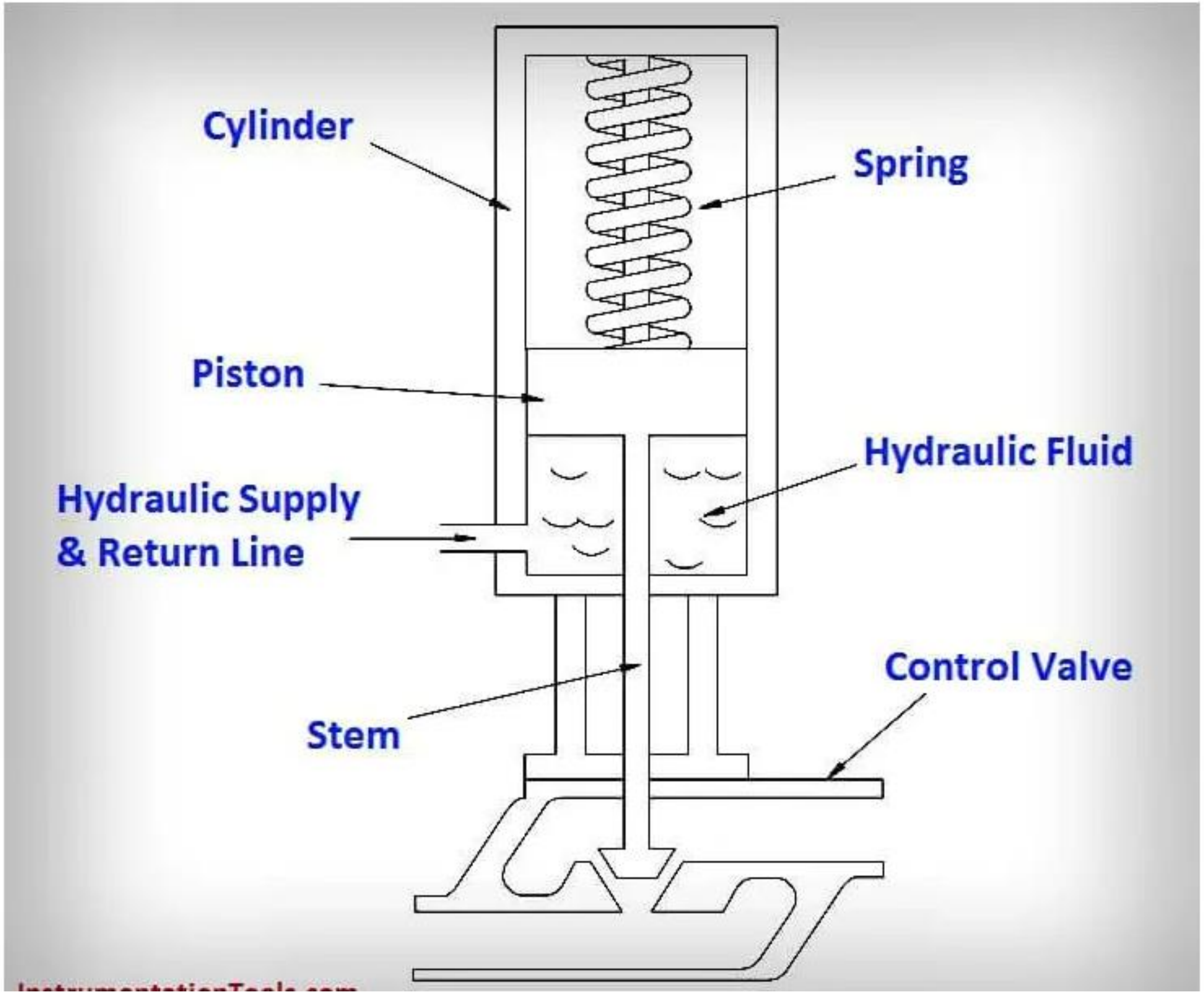
Actuator

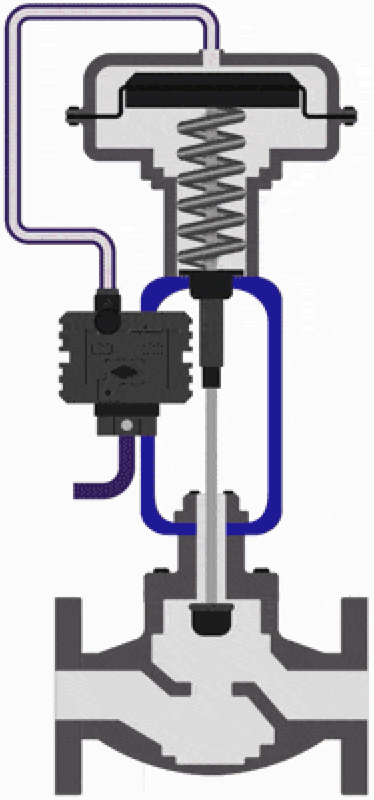
- Device that converts energy (electrical signals) into physical motion



- An actuator is a part of a device or machine that helps it to achieve physical movements by converting energy, often electrical, air, or hydraulic, into mechanical force.

Hydraulic Actuator





Pneumatic actuator

- The motion it produces can be either rotary or linear
- Actuators are the **driving force behind the robot's movement**
- provide motion to the manipulator links and the end-effecter
- An actuator is used in robots to turn the wheels of the robot or to turn robot arm joints

Types of Robotic Actuators

Robotic actuators are classified **into two types** according to the requirements of motion like **linear motion & rotational motion.**

a) For Linear Motion:

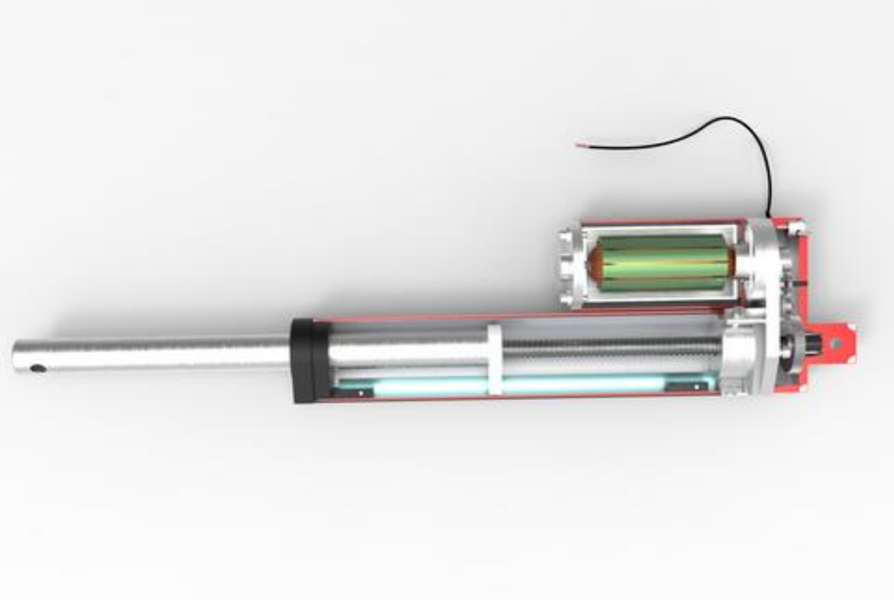
- linear actuators
- solenoid actuators.

b) For Rotational Motion:

- DC motor
- servo motor
- stepper motor.

Linear actuator

- How does a linear actuator work?
- https://www.firgelliauto.com/en-in/blogs/actuators/how-does-a-linear-actuator-work-1

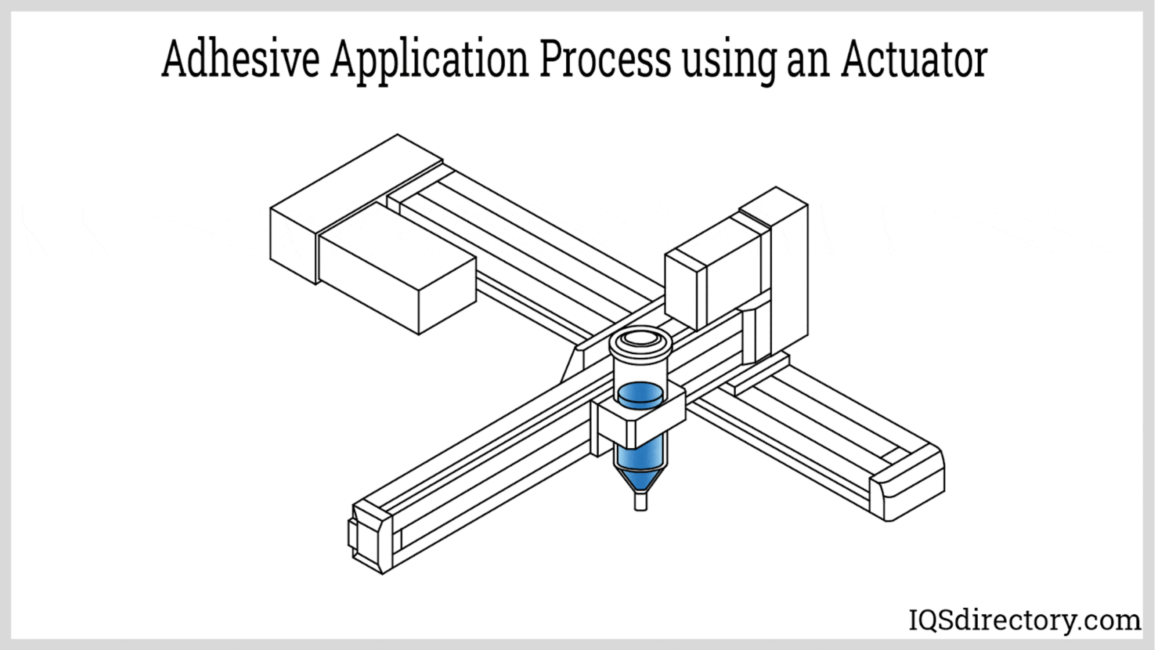


Rotary Actuators

- https://www.youtube.com/watch?v=dizRZSw-QLQ

1. <u>Linear Actuators</u>

- an actuator that creates motion in a straight line
- are used to push or pull the robot
- like move forward or backward & arm extension



Actuators open automatic doors, move car seats forwards and back, and open and close computer disk drives.

2. Solenoid Actuators

- Solenoid actuators are special-purpose linear actuators that include a solenoid latch
- mainly used for controlling the motion of the robot

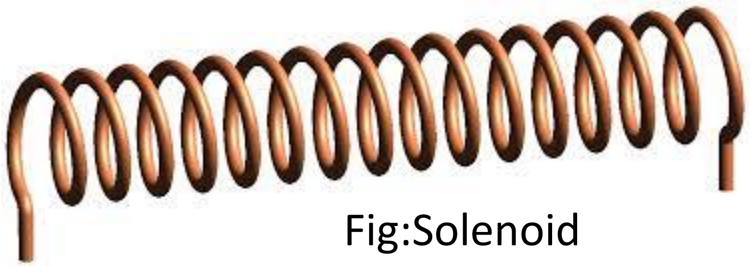
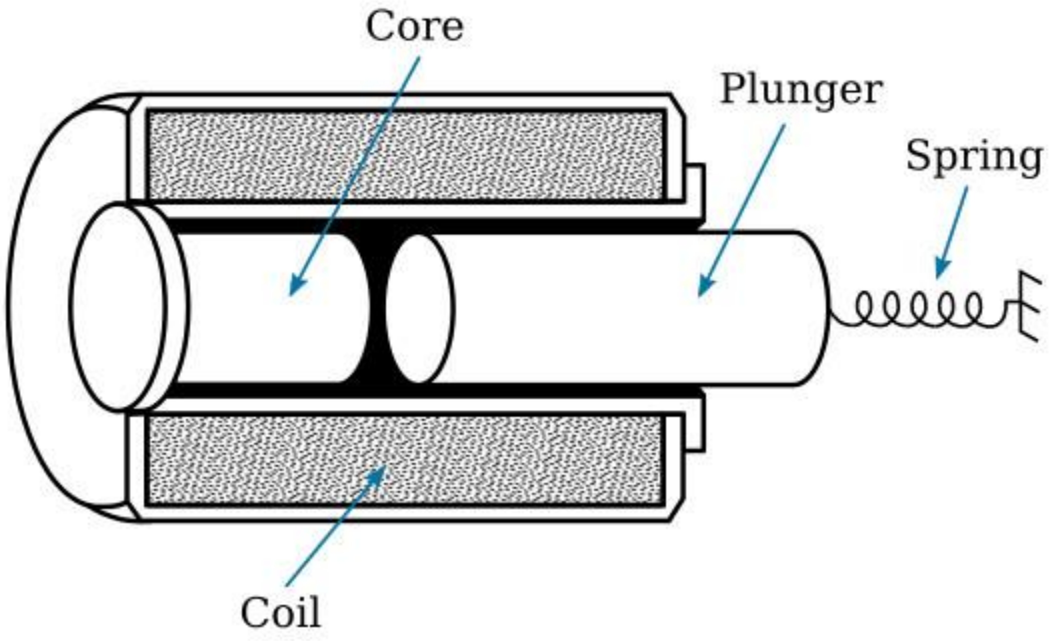


Fig:Solenoid



b) For Rotational Motion:

There are three types of actuators used in robots

- DC motor,
- servo motor,
- stepper motor.

1. **DC Motor Actuators**

- DC motor actuators are generally used for rotary motion.
- DC Motor is a two wire **continuous rotation motor** and the two wires are power and ground.
- When the supply is applied, a DC motor will start rotating until that power is detached.
- Most of the DC motors run at high revolutions per minute (RPM),
- examples are; fans being used in computers
- By using these actuators, different activities like

  robotic drilling & motion of a wheeled robot

  are performed.

2. Servo Actuators

- Servo motor actuators in robotics are mainly used to control & monitor rotating motion.
- that allow 360 degrees of rotation,
- but, continuous revolution is not compulsory.
- it is designed to execute controlled movements.
- These motors are designed for more exact tasks
- like moving a robotic arm
- robot leg within a particular range.

3. Stepper Motor Actuators

- helpful in contributing, repetitive rotating activities within robots.
- So these types of actuators are a combination of both DC & servo motor actuators.
- it includes a continuous rotation DC motor and combined controller circuit,
- These stepper motor actuators are utilized in automation robots where repeatability of any activity is necessary.

SENSORS

- Robots use sensors **to detect and measure the geometric and physical features** of objects in their surroundings.
- Robots, especially autonomous robots, **require the ability to sense** their surroundings.
- Internal and external sensors are **the two types of sensors** that are commonly used.
- **Internal sensors** - provide information on the robot, such as where it is, how fast it is going, and how it accelerates, among other things.
- **External sensors** - collect data from the outside world including information such as the point of contact between a robotic arm and the product its working on.

TYPES OF SENSORS USED IN ROBOTICS

1. LIGHT SENSORS

- A light sensor in robotics is used to detect light and create a voltage differential.
- A computer-controlled camera allows the robot to view and adapt its actions accordingly.
- Photoresistors and Photovoltaic cells are the two most used light sensors in robots.

2. SOUND SENSOR

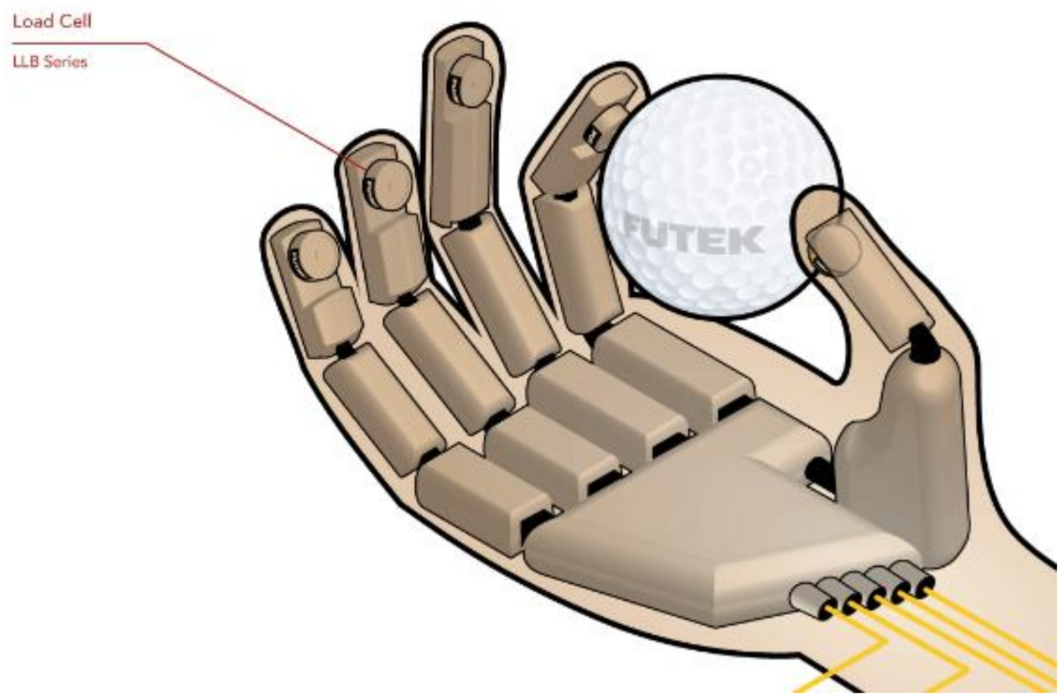
- Sound sensors in robotics work in a similar way as microphones, but they're usually connected to circuits that assess the amplitude of the sounds to a threshold value and report the result to the robot.
- This could be useful for a robot that studies wildlife;
- detecting and following loud noises could be one of the data points used to locate wildlife.

- **3. PROXIMITY SENSOR**

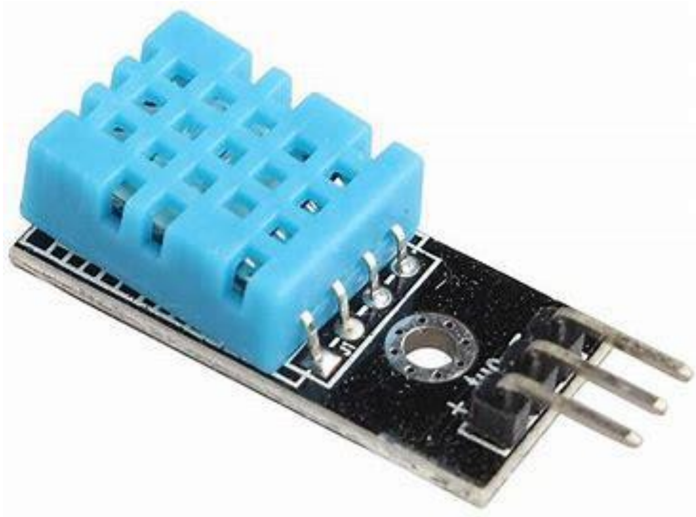
- A proximity sensor in robotics can detect a nearby object without requiring physical touch.
- The transmitter sends electromagnetic radiation to the sensor next to it, and the receiver receives and analyzes the interruption feedback signal.
- As a result, the amount of light received in the area can be utilized to determine whether or not neighboring objects are present.

4. TACTILE SENSOR

- A tactile sensor is a device that determines whether or not an object is in contact.
- A tactile sensor enables the robot to “touch and feel”
- it measures the forces in response to the physical interaction with the environment.
- A common application of tactile sensors is in robotic hands and fingers (i.e. robotic tactile sensing).



- **5. TEMPERATURE SENSOR**
- Temperature sensors in robotics measure heat/temperature changes in the environment
- It works on the concept of a voltage differential change for a temperature change;
- this voltage change provides the equivalent temperature of the surrounding area



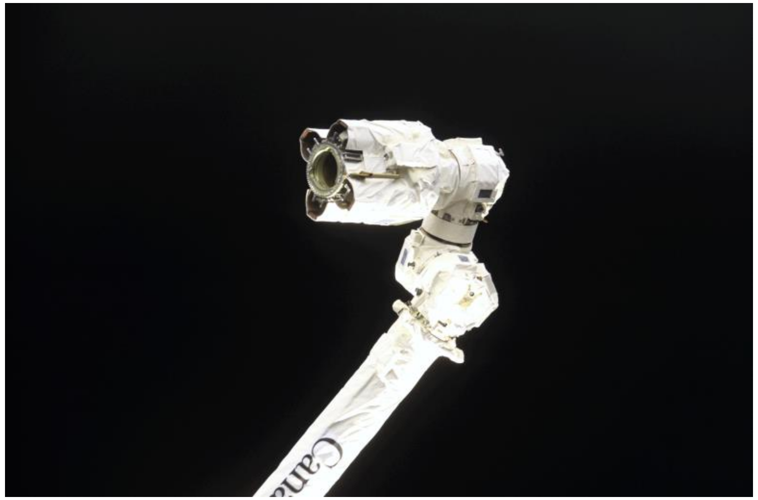
- 6. NAVIGATION AND POSITIONING SENSOR
- Positioning sensors in robotics are used to estimate the robot’s positioning. A GPS is the most common positioning sensor (Global Positioning System). Satellites orbiting our planet send out signals, which are picked up and processed by a robot receiver. Calculate a robot’s approximate position and velocity using the analyzed data.

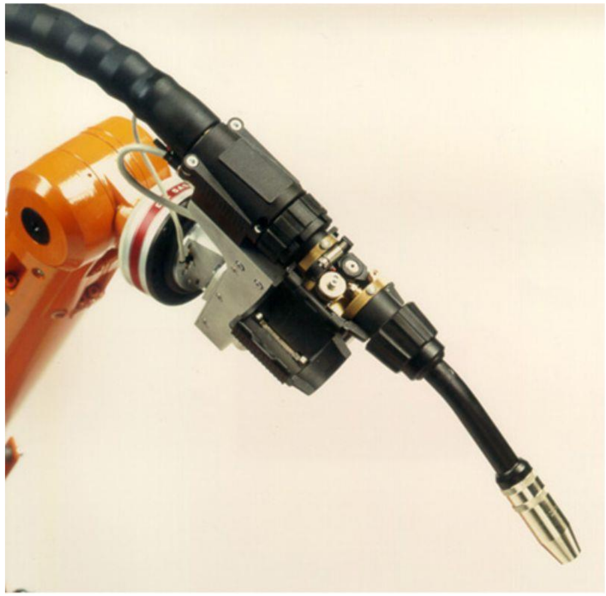
- 7. ACCELERATION SENSOR
- Acceleration sensors in robotics are devices that measure the acceleration and tilt of the robot. An accelerometer is affected by two types of forces:
- • The Static Force – the force that exists between any two objects. We can determine how much the robot tilts by detecting its gravity. This parameter is useful for balancing robots or assessing if a robot is going uphill or downhill.
- • Dynamic Force – The speed with which an object must be moved. The speed/speed at which a robot travels is determined by measuring dynamic force with an accelerometer.

END EFFECTOR

- An end effector is a peripheral device that attaches to a robot's wrist,
- Or mounted onto the end of a robot arm.
- allowing the robot to interact with its task or **interacts with the environment**.
- it is the end effector that picks and places objects, assembles product pieces, stacks cartons and parcels etc.

- End effectors come in various forms **depending on the task** the robot needs to perform.
- Some common types of end effectors include
    - **grippers** for grasping objects,
    - **suction cups** for handling flat surfaces,
    - **welding torches** for joining materials,
    - and **cameras or sensors** for gathering information about the environment.





Grippers

- Used for holding or gripping an objects
- Grippers are the end effectors
  of robotic arms responsible for grasping,
  holding, and manipulating objects.

Active and Passive grippers

Active

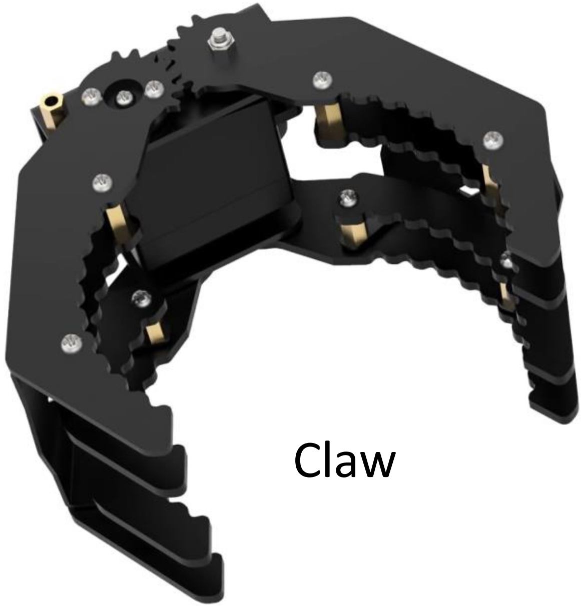
- Motorized Grippers
- Pneumatic Grippers
- Hydraulic Grippers
- Robotic Hands
- Vacuum Grippers

Passive

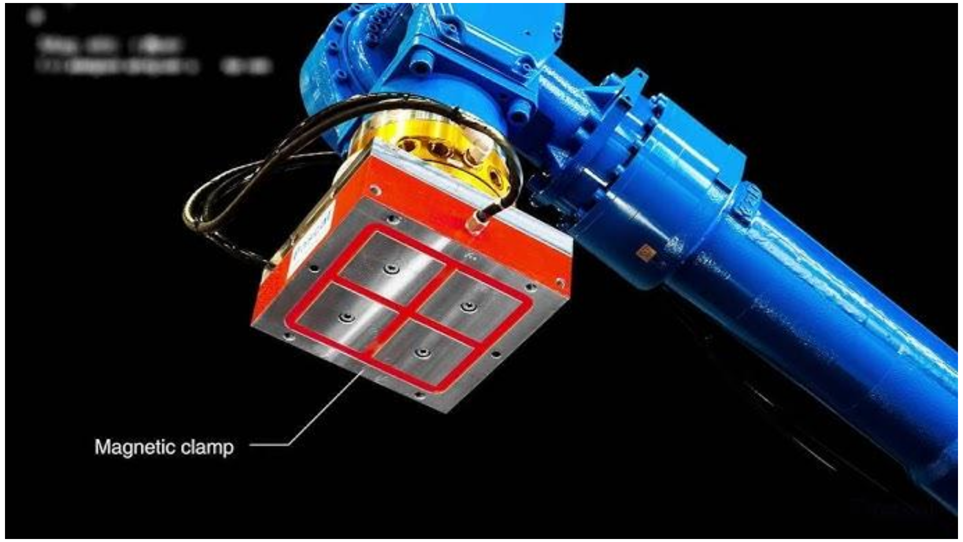
- Claw Grippers
- Jaw Grippers
- Magnetic Grippers
- Suction Cups
- Adhesive Grippers

- Passive grippers in robotics are mechanisms used for grasping and holding objects **without the need for active actuation or powered components.** These grippers typically rely on their mechanical design and the properties of materials to secure objects. Here are some common types of passive grippers:

1. **Claw Grippers**: Claw grippers have a simple design consisting of two or more rigid fingers that can close around an object through mechanical motion. They can be spring-loaded to provide a closing force, and their geometry determines the type of objects they can effectively grasp.
2. **Jaw Grippers**: Similar to claw grippers, jaw grippers **have two opposing jaws** that close around an object. They can be designed with various shapes and surface textures to optimize grip for specific objects.
3. **Magnetic Grippers**: These grippers use magnets to attract and hold ferrous objects. They are passive in the sense that they don't require power to maintain the grip once the object is attracted by the magnetic force. Magnetic grippers are often used in applications where non-contact gripping is preferred.
4. **Suction Cups**: Suction cup grippers use vacuum pressure to adhere to objects and hold them securely. When the vacuum is applied, the atmospheric pressure presses the object against the cup, creating a seal. Suction cup grippers are commonly used in handling objects with smooth, flat surfaces.
5. **Adhesive Grippers**: Adhesive grippers use specialized adhesives or sticky materials to adhere to objects. Once the gripper comes into contact with the object, the adhesive creates a bond, holding the object securely. These grippers are suitable for handling objects with irregular shapes or delicate surfaces.


Claw

Jaw



- Active grippers in robotics are devices designed to grasp and manipulate objects with the assistance of powered components, such as motors, actuators, or other mechanisms. Unlike passive grippers, which rely solely on their mechanical structure or materials properties, active grippers can actively adjust their grip force, position, and orientation to securely hold objects of varying shapes, sizes, and weights. Here are some key characteristics and examples of active grippers:

1. **Motorized Grippers**: Motorized grippers are equipped with electric motors or servo motors that drive the gripping mechanism. These motors enable precise control over the opening and closing of the gripper fingers or jaws, allowing for adaptive grasping of objects with different geometries.
2. **Pneumatic Grippers**: Pneumatic grippers use **compressed air** to actuate their gripping mechanism. When **pressurized air** is supplied to the gripper, it activates internal pistons or actuators, causing the gripper fingers to close around the object. Pneumatic grippers are known for their fast response times and high gripping forces.
3. **Hydraulic Grippers**: Hydraulic grippers operate similarly to pneumatic grippers but **use hydraulic fluid** instead of compressed air to generate force. They are often employed in heavy-duty industrial applications where high gripping forces are required.
4. **Robotic Hands**: Robotic hands are sophisticated active grippers designed to mimic the dexterity and **flexibility of the human hand.** They typically consist of multiple fingers or digits, each equipped with individual actuators for independent control. Robotic hands are capable of grasping a wide range of objects with varying shapes, sizes, and orientations.
5. **Vacuum Grippers**: **Vacuum grippers use suction cups** or vacuum chambers to create a vacuum seal between the gripper and the object, allowing it to be lifted and manipulated. Vacuum grippers are commonly used in applications where non-contact gripping is preferred or when handling objects with smooth, non-porous surfaces.

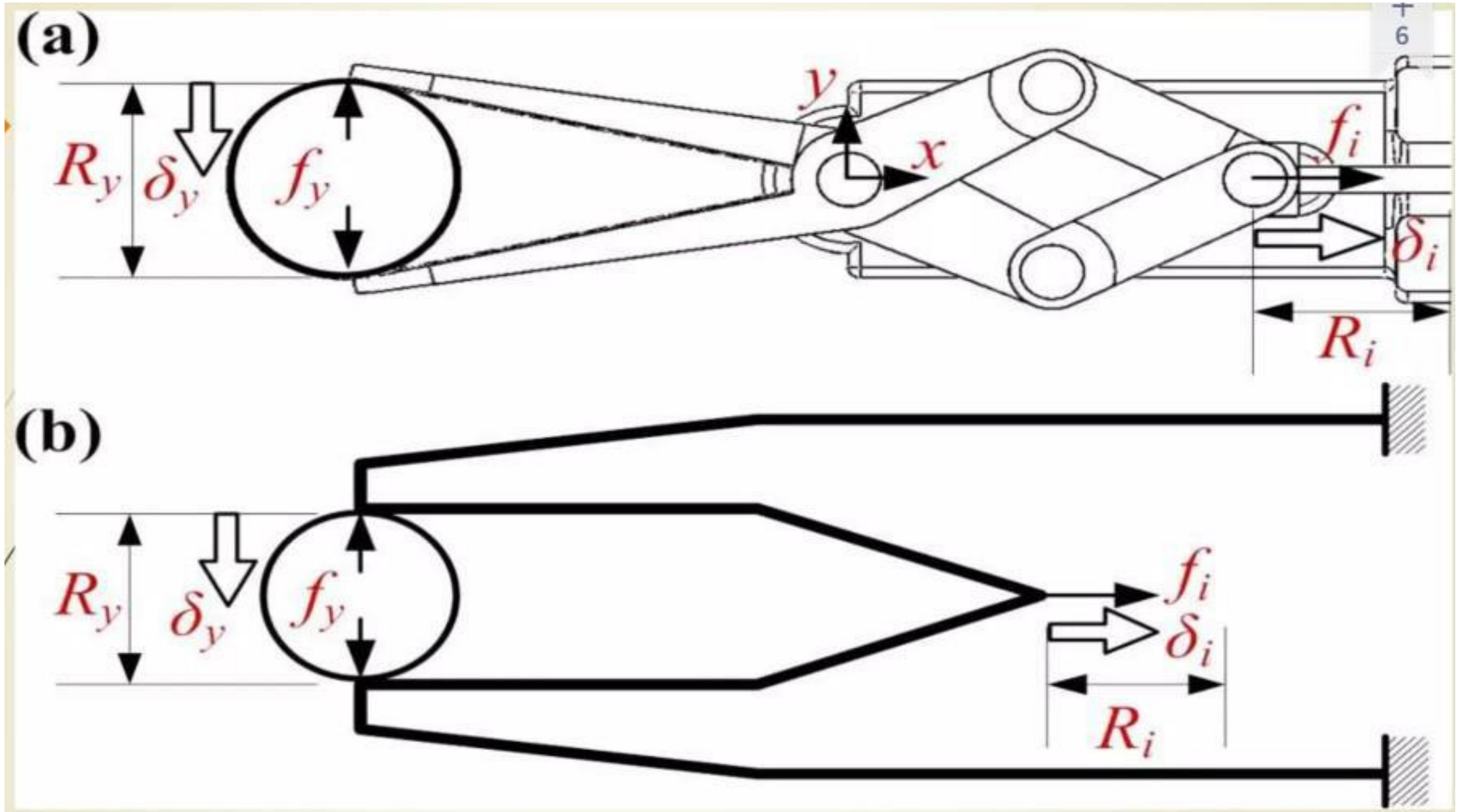
- Active grippers offer several advantages over passive grippers, including greater versatility, adaptability, and precision. They are well-suited for applications that require complex manipulation tasks or handling of objects with diverse characteristics. However, active grippers may also be more complex and expensive to implement compared to passive grippers.

Types of Grippers

1. Mechanical Grippers
2. Hooks and Scoops
3. Magnetics Grippers
4. Vacuum Grippers
5. Expandable Bladder Type Grippers
6. Adhesive Grippers

1) Mechanical Grippers

- We can think of a mechanical gripper as a robot hand. A basic robot hand will have only two or three fingers
- A mechanical hand that wraps around an object will rely on friction in order to secure the object it is holding.
- Friction between the gripper and the object will depend on two things, First is the type of surface whether it be metal on metal, rubber on metal, smooth surfaces or rough surfaces and the second is the force which is pressing the surfaces together.
- Mechanical grippers are often fitted with some type of pad usually made from polyurethane as this provides greater friction. Pads are less likely to damage the work piece. Pads are also used so to have a better grip as the polyurethane will make contact with all parts of the surface when the gripper is closed
- Mechanical grippers can be designed and made for specific purposes and adjusted according to the size of the object. They can also have dual grippers. We are all familiar with the saying 'two hands are better than one" and robots benefit from having dual grippers as they can increase productivity, be used with machines that have two work stations where one robot can load two parts in a single operation, operations in which the size of objects or part change due to the machining processes and where the cycle time of the robot is too slow to keep up with the production of other machines.



Mechanical Grippers design

3) Magnetic Grippers

- Magnetic grippers obviously only work on magnetic objects and therefore are limited in working with certain metals.
- For maximum effect the magnet needs to have complete contact with the surface of the metal to be gripped. Any air gaps will reduce the strength of the magnetic force, therefore flat sheets of metal are best suited to magnetic grippers.
- If the magnet is strong enough, a magnetic gripper can pick up an irregular shaped object. In some cases the shape of the magnet matches the shape of the object
- A disadvantage of using magnetic grippers is the temperature. Permanent magnets tend to become demagnetized when heated and so there is the danger that prolonged contact with a hot work piece will weaken them to the point where they can no longer be used. The effect of heat will depend on the time the magnet spends in contact with the hot part. Most magnetic materials are relatively unaffected by temperatures up to around 100 degrees.
- Electromagnets can be used instead and are operated by a DC electric current and lose nearly all of their magnetism when the power is turned off.
- Permanent magnets are also used in situations where there is an explosive atmosphere and sparks from electrical equipment would cause a hazard

Magnetic Grippers design

- A vacuum gripper is a type of end-effector, or tool, used in robotics to grasp and manipulate objects. Unlike traditional mechanical grippers that use fingers, claws, or jaws to grasp objects, a vacuum gripper utilizes suction to securely hold onto items of various shapes, sizes, and materials.

Here's how a vacuum gripper typically works:

1. **Suction Cup**: The main component of a vacuum gripper is a suction cup or pad, usually made of a soft, flexible material like silicone. This suction cup is pressed against the object to create an airtight seal.
2. **Vacuum System**: The vacuum gripper is connected to a vacuum pump or system that creates negative pressure inside the suction cup when activated. This negative pressure generates suction, causing the suction cup to adhere firmly to the object's surface.
3. **Control System**: The vacuum system is controlled by the robot's software and can be activated or deactivated as needed during the grasping and releasing process.
4. **Feedback Sensors**: Some vacuum grippers are equipped with sensors to provide feedback on the gripping force, ensuring that the object is held securely without causing damage.

Vacuum grippers are commonly used in various industries and applications, including:

- **Packaging and Warehousing**: They are used in robotic systems for picking and placing items in warehouses, distribution centers, and manufacturing facilities.
- **Assembly and Manufacturing**: Vacuum grippers are employed in robotic assembly lines to handle components during production processes, such as picking up parts from conveyor belts or placing them in fixtures.
- **Material Handling**: They are used for handling materials in industries like automotive, electronics, and food and beverage, where delicate or irregularly shaped objects need to be moved without damage.
- **Logistics and E-commerce**: Vacuum grippers are utilized in robotic systems for order fulfillment and sorting tasks in logistics centers and e-commerce warehouses.
- Overall, vacuum grippers offer versatility, reliability, and gentle handling of objects, making them a popular choice in robotic applications where objects vary in size, shape, and weight.

Vacuum gripper design

6) Adhesive Grippers

- Adhesive Substance can be used for grasping action in adhesive grippers.
- In adhesive grippers, the adhesive substance losses its tackiness due to repeated usage. This reduces the reliability of the gripper. In order to overcome this difficulty, the adhesive material is continuously fed to the gripper in the form of ribbon by feeding mechanism.
- A major asset of the adhesive gripper is the fact that it is simple. As long as the adhesive keep its stickiness it will continue to function without maintenance, however, there are certain limitations, the most significant is the fact that the adhesive cannot readily be disabled in order to release the grasp on an object. Some other means, such as devices that lock the gripped object into place, must be used.
- The adhesive grippers are used for handling fabrics and other lightweight materials.