Robot Mechanics & Control

Introduction to Robotics

Origin of the word Robot

- Czech writer, Karel Capek introduced the word Robot to the world in his drama in 1921
- The word Robot is derived from Czech word ‘Robota’ meaning ‘forced labourer’
- A well-known Russian science fiction writer Isaac Asimov introduced the word ‘Robotics’ in his story ‘Runaround’ published in 1942.

Definition of Robot

- According to Robot Institute of America, A Robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks

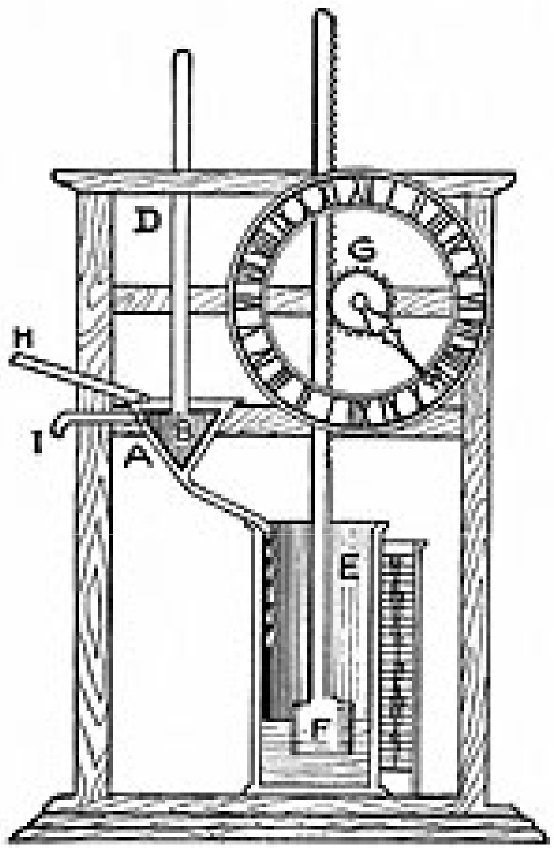
Laws of Robotics

- A Robot should not injure a human being or allow a human to be harmed.
- A Robot must obey orders given by humans except when that conflicts with the first law.
- A Robot must protect its own existence unless that conflicts with the first or second law.

History of Robotics

- The history of robotics has its origins in the ancient world.
- The modern concept began to be developed with the Industrial Revolution.
- In the early 20th century, the notion of humanoid machine was developed.
- Let us have a look of evolution of Robot over the period of time.

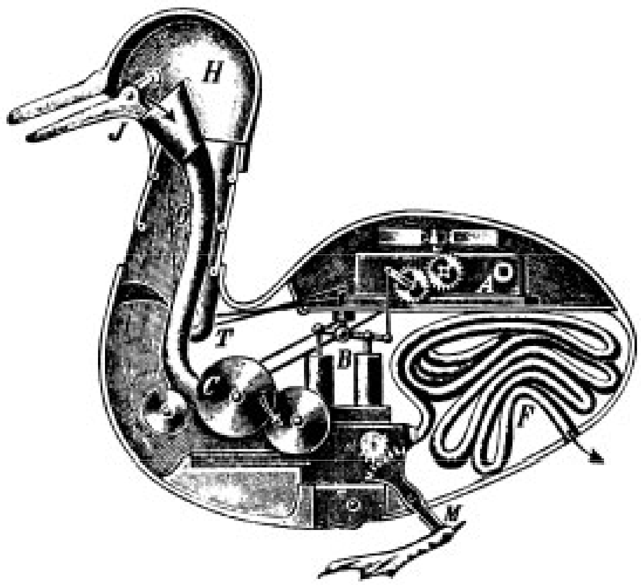
1400 BC



IMPROVED GREEK CLEPSYDRA

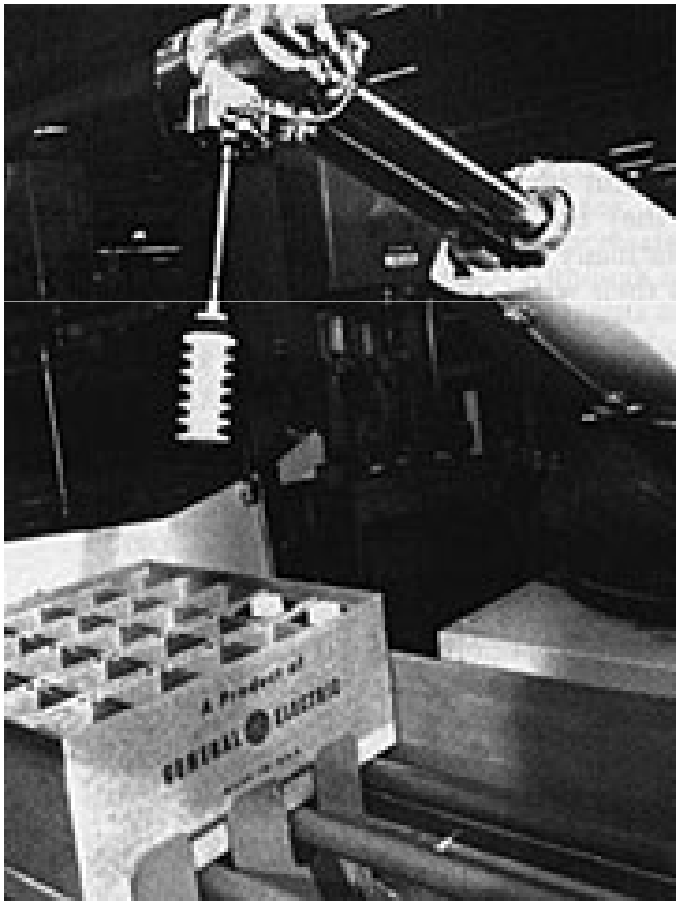
Babylonians develop the clepsydra, a clock that measures time using the flow of water.
It is considered as one of the first "robotic" devices in history.

1737 AC



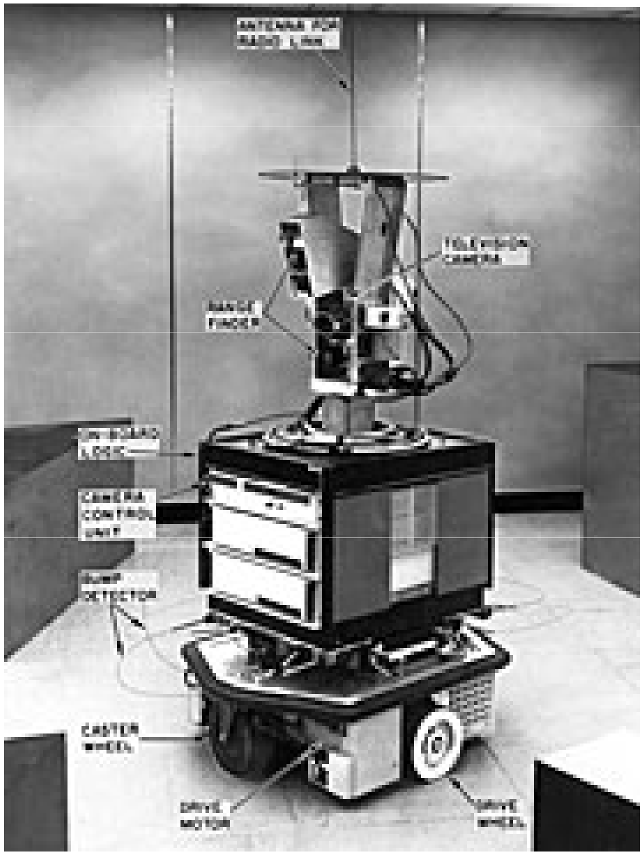
French inventor Jacques de Vaucanson builds a clockwork duck capable of flapping its wings, quacking, eating and digesting food.

1961 AC



Unimate, the world's first industrial robot, goes to work on a General Motors assembly line.

1966 AC



The Artificial Intelligence Center at the Stanford Research Center begins development of Shakey, the first mobile robot.
It is endowed with a limited ability to see and model its environment and is controlled by a computer that fills an entire room.

1969 AC

- This robot arm was designed in 1969 by Victor Scheinman, a Mechanical Engineering student working in the Stanford Artificial Intelligence Lab (SAIL).
- This 6 degree of freedom (6-dof) all-electric mechanical manipulator was one of the first "robots" designed exclusively for computer control.

1976 AC

- Viking I was the first spacecraft to successfully land on Mars to investigate the Red Planet and search for signs of life.
- **The Lander was containing:**
  - Imaging system
  - Gas chromatograph mass spectrometer
  - Seismometer
  - X-ray fluorescence spectrometer
  - Biological laboratory
  - Weather instrument package
  - Remote sampler arm

What a Robot can do?

- The Robot technology is advancing rapidly.
- The industry is moving from current state of automation to robotization.
- Robots and Robot-like manipulators are now commonly employed
  1. In hostile environment, such as at various places in atomic plant for handling radioactive materials
  2. To construct and repair space stations and satellites
  3. In nursing and aiding patients
  4. To do damage control inside human veins
  5. In heavy earth-moving equipments, etc.

Future of Robotics

- Robotic engineers are designing the next generation of robots to look, feel and act more like human.
- Robots and artificial intelligence will displace many jobs.
- New kinds of jobs will appear.
- Robots will become our everyday assistants.

Generalized Block Diagram and Anatomy of a Robot

- An industrial robot is a general-purpose, programmable machine.
- It possesses some human-like characteristics that resemble the human physical structure.
- The robots also respond to sensory signals in a manner that is similar to humans.
- Anthropomorphic characteristics such as mechanical arms are used for various industry tasks.
- Sensory perceptive devices such as sensors allow the robots to communicate and interact with other machines and to take simple decisions.

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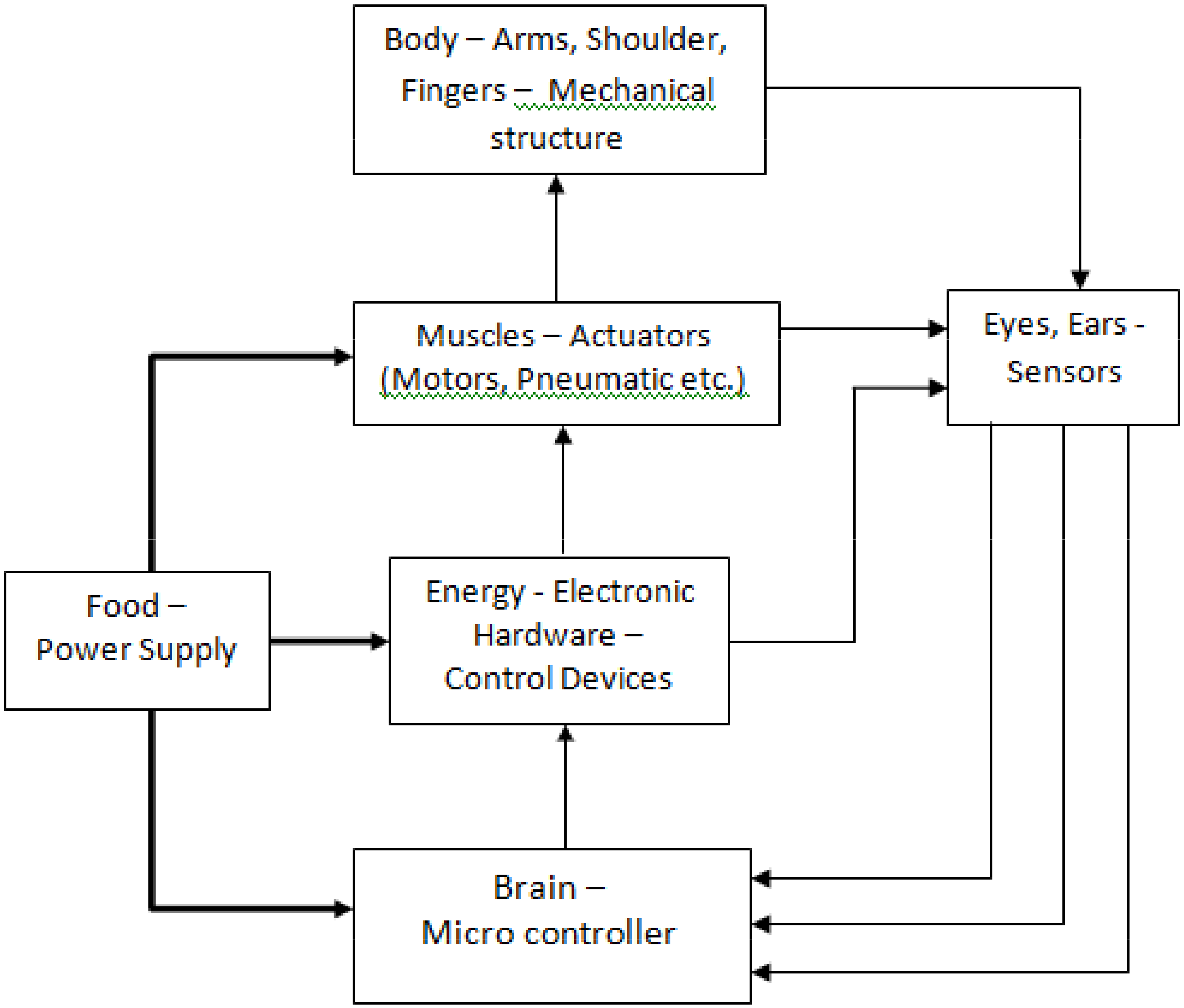
Body – Arms, Shoulder, Fingers – Mechanical structure
Muscles – Actuators (Motors, Pneumatic etc.)
Eyes, Ears - Sensors
Food – Power Supply
Energy - Electronic Hardware – Control Devices
Brain – Micro controller

Robot anatomy and related attributes

- The manipulator of an industrial robot consists of a series of joints and links.
- A robotic joint provides relative motion between two links of the robot.
- Each joint, or axis, provides a certain degree-of-freedom (dof) of motion.
- In most of the cases, only one degree-of-freedom is associated with each joint.
- Therefore the robot's complexity can be classified according to the total number of degrees-of-freedom they possess.

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- Each joint is connected to two links, an input link and an output link.
- Joint provides controlled relative movement between the input link and output link.
- A robotic link is the rigid component of the robot manipulator.
- Most of the robots are mounted upon a stationary base, such as the floor.
- From this base, a joint-link numbering scheme may be recognized as shown in Figure.

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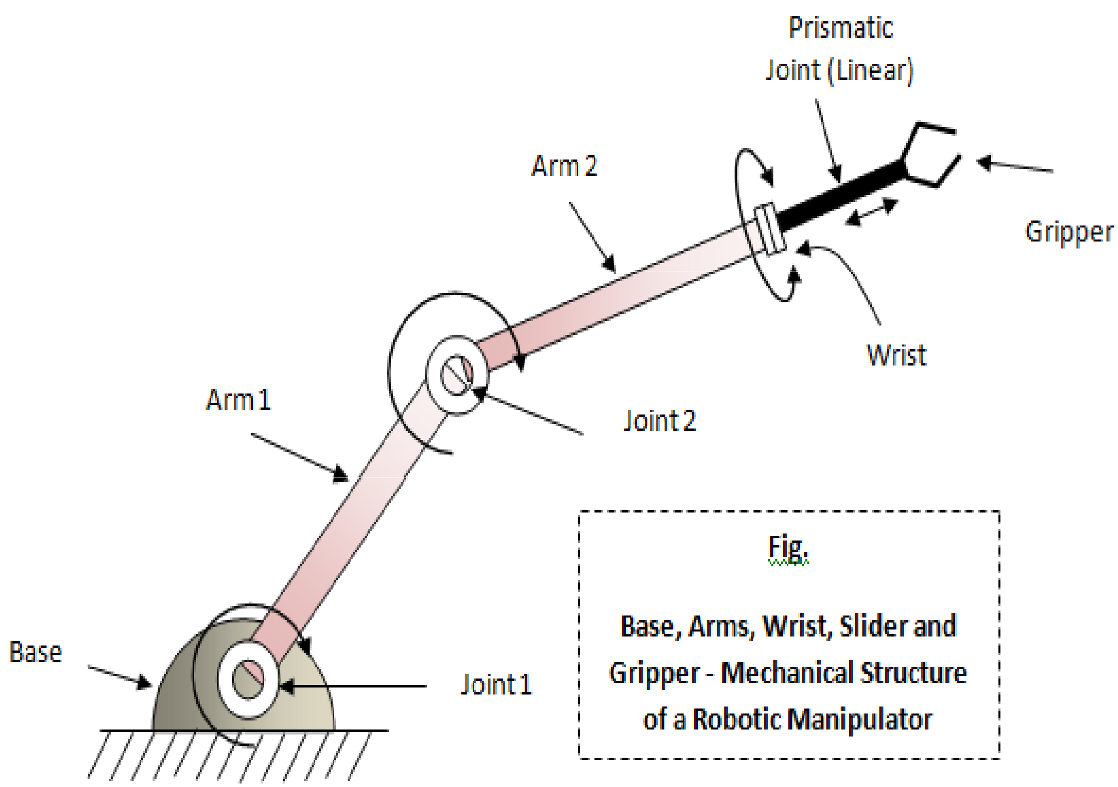
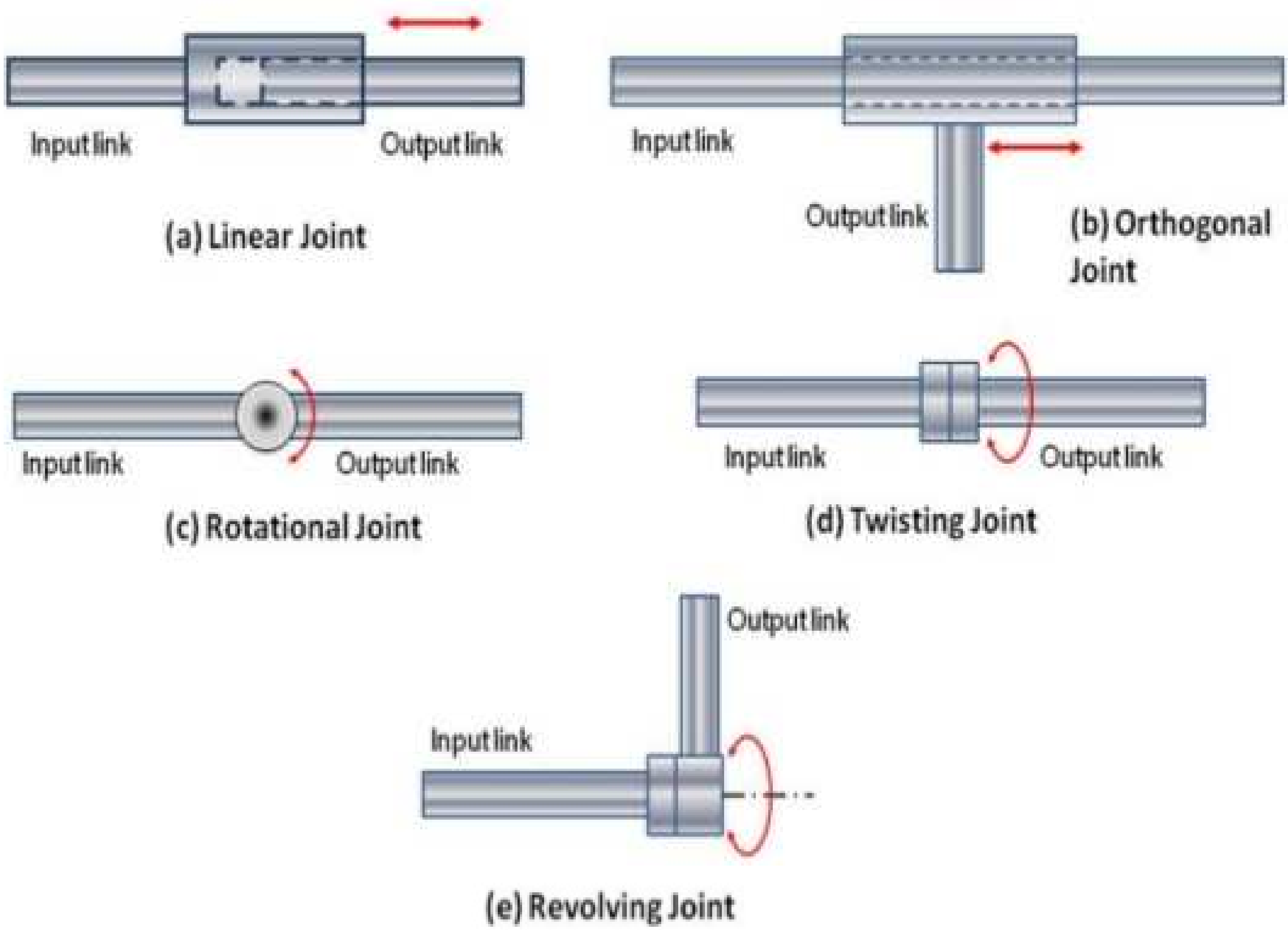


Fig.

Base, Arms, Wrist, Slider and Gripper - Mechanical Structure of a Robotic Manipulator

- The robotic base and its connection to the first joint are termed as link-0.
- The first joint in the sequence is joint-1.
- Link-0 is the input link for joint-1, while the output link from joint-1 is link-1—which leads to joint-2.
- Thus link 1 is, simultaneously, the output link for joint-1 and the input link for joint-2.
- This joint-link-numbering scheme is further followed for all joints and links in the robotic systems.

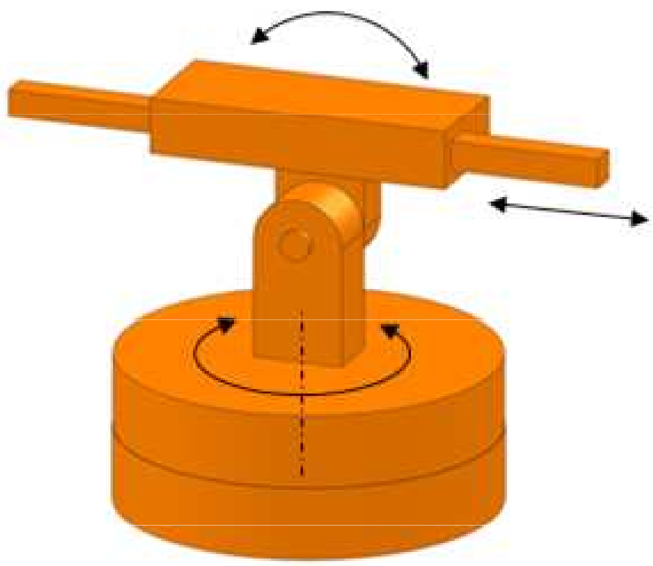
Types of joints



Robot Configurations

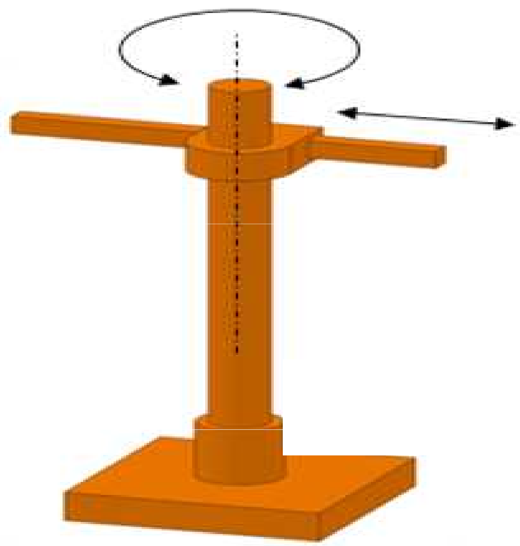
- Basically the robot manipulator has two parts viz. a body-and-arm assembly with three degrees-of-freedom; and a wrist assembly with two or three degrees-of-freedom.
- For body-and-arm configurations, different combinations of joint types are possible for a three-degree-of-freedom robot manipulator.
- Five common body-and-arm configurations are discussed below.

1. Polar configuration



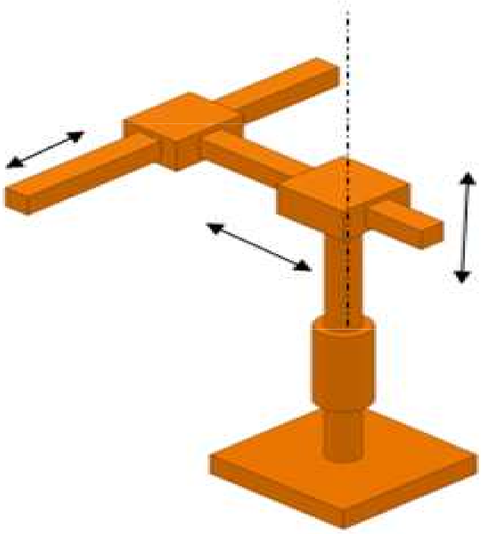
- It consists of a sliding arm L-joint, actuated relative to the body, which rotates around both a vertical axis (T-joint), and horizontal axis (R-joint).

2. Cylindrical configuration



- It consists of a vertical column.
- An arm assembly is moved up or down relative to the vertical column.
- Common configuration is to use a T-joint to rotate the column about its axis.
- An L-joint is used to move the arm assembly vertically along the column, while an O-joint is used to achieve radial movement of the arm.

3. Cartesian configuration



- It is also known as rectilinear robot and x-y-z robot.

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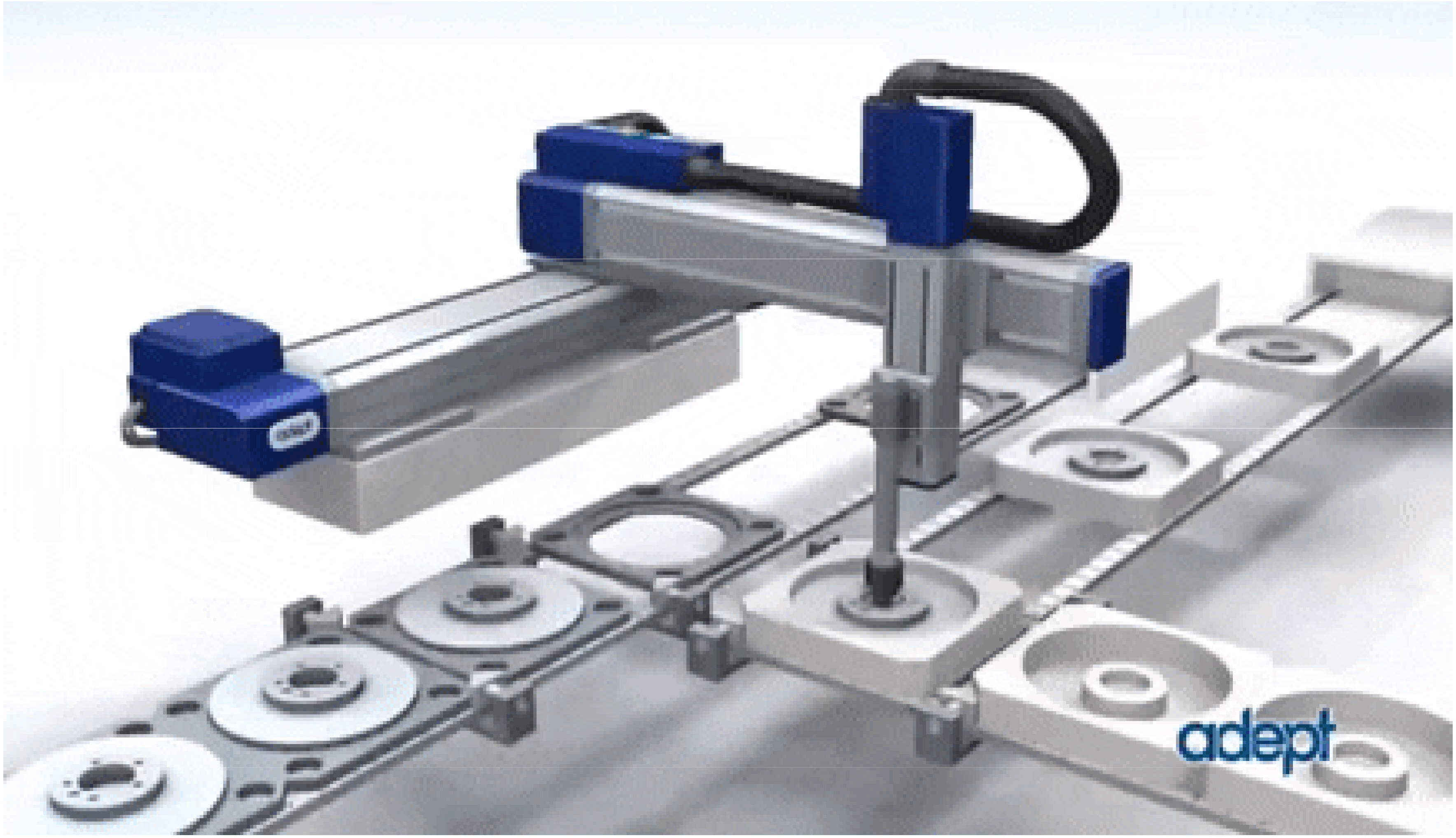

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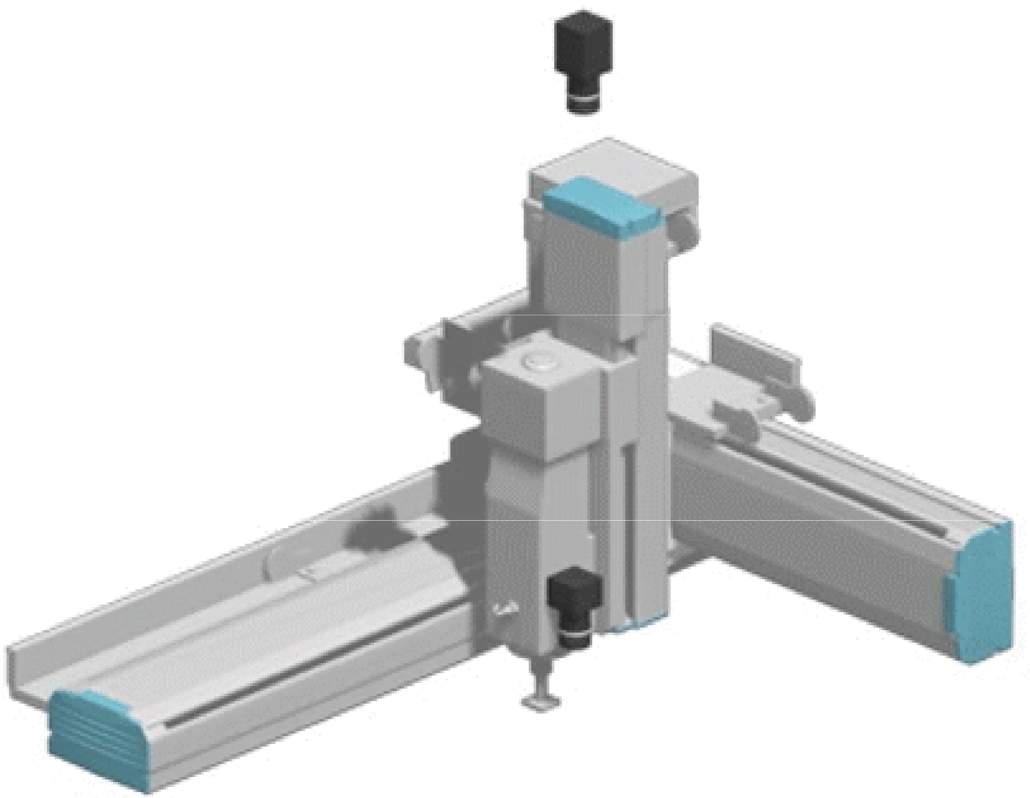
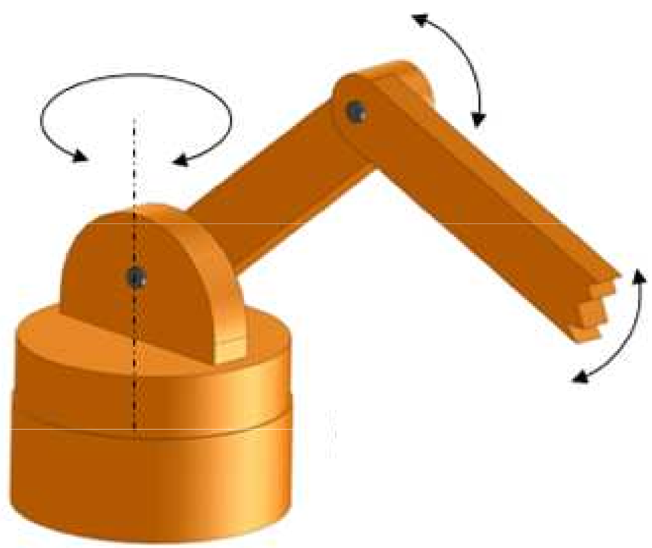
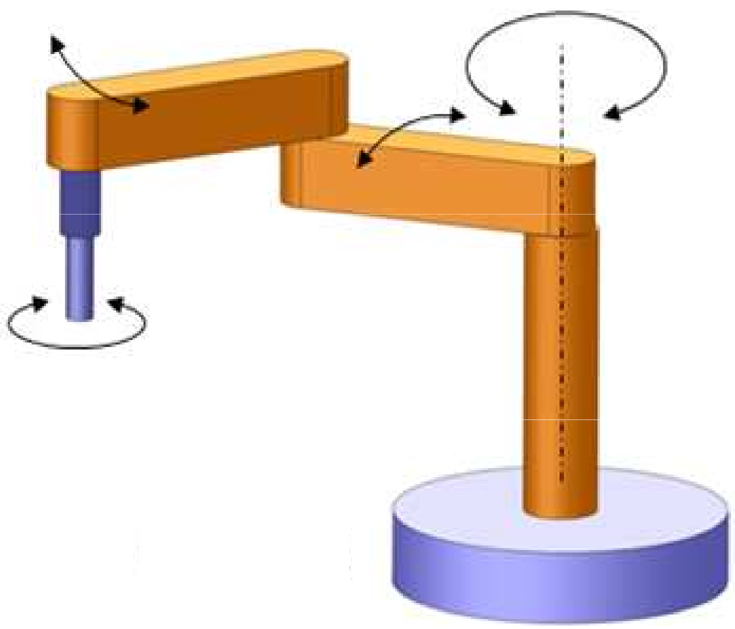


4. Jointed-arm configuration



- It is similar to the configuration of a human arm.
- It consists of a vertical column that swivels about the base using a T-joint.
- Shoulder joint (R-joint) is located at the top of the column.
- The output link is an elbow joint (another R joint).

5. SCARA configuration

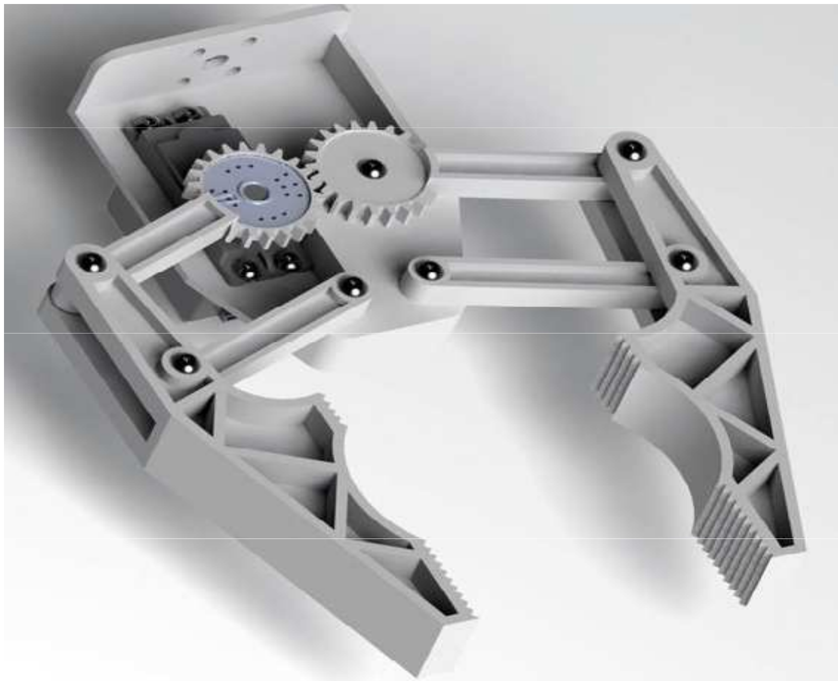


- Its full form is 'Selective Compliance Assembly Robot Arm'.
- Robot wrist assemblies consist of either two or three degrees-of-freedom.
- The roll joint is accomplished by use of a T-joint.
- The pitch joint is achieved by recourse to an R-joint.
- And the yaw joint, a right-and-left motion, is gained by deploying a second R-joint.

Systems used in End Effectors/Grippers

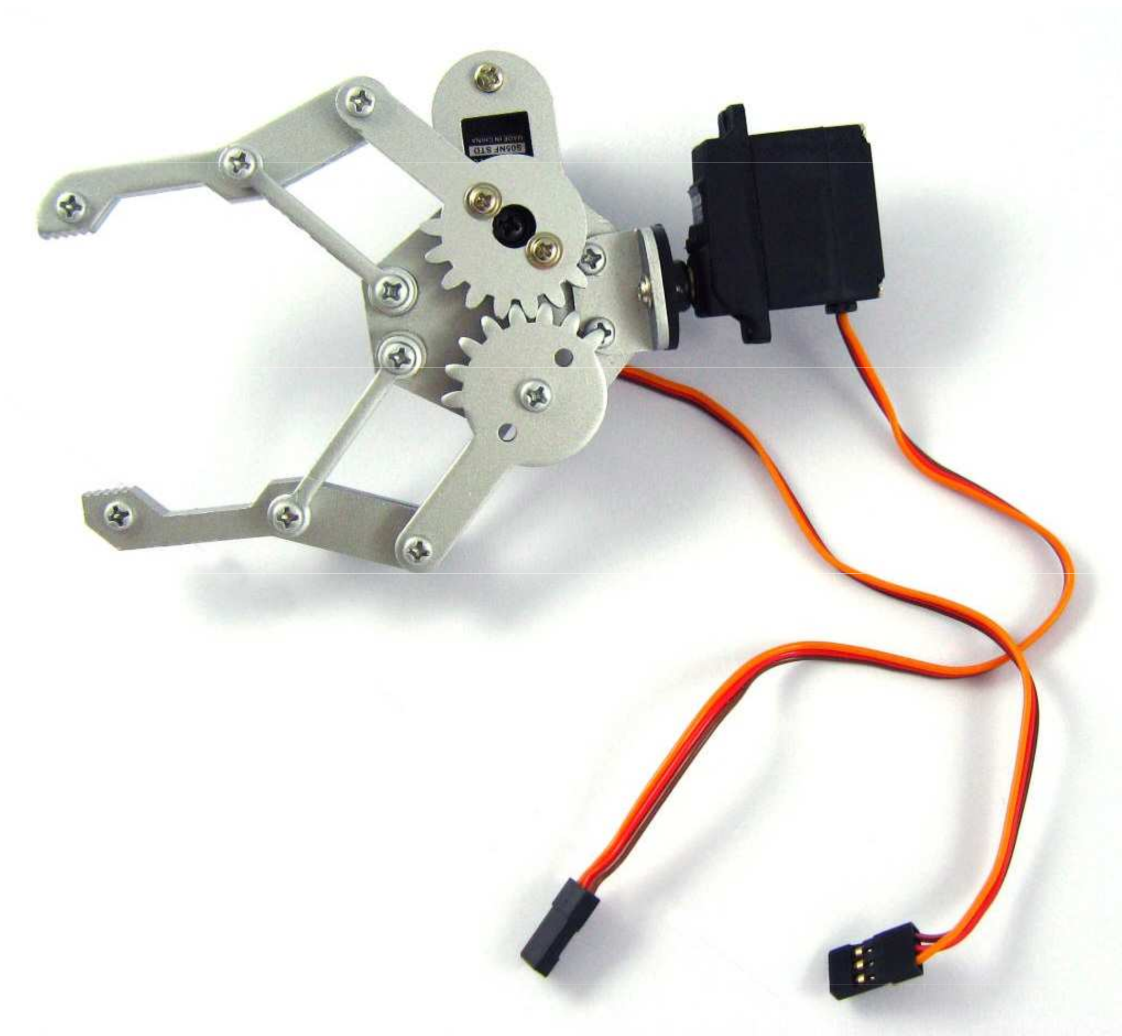
- An end effector is usually attached to the robot's wrist, and it allows the robot to accomplish a specific task.
- Grippers grasp and manipulate the objects during the work cycle.
- Grippers may be custom-designed to suit the physical specifications of work parts.
- Various end-effectors, grippers are discussed below.

1. Mechanical end effectors



- A mechanical gripper is used as an end effector in a robot for grasping the objects with its mechanically operated fingers.
- In industries, two fingers are enough for holding purposes.
- More than three fingers can also be used based on the application.

2. Electrical Gripper



3. Vacuum end effectors

- Suction cups are used to hold flat objects.

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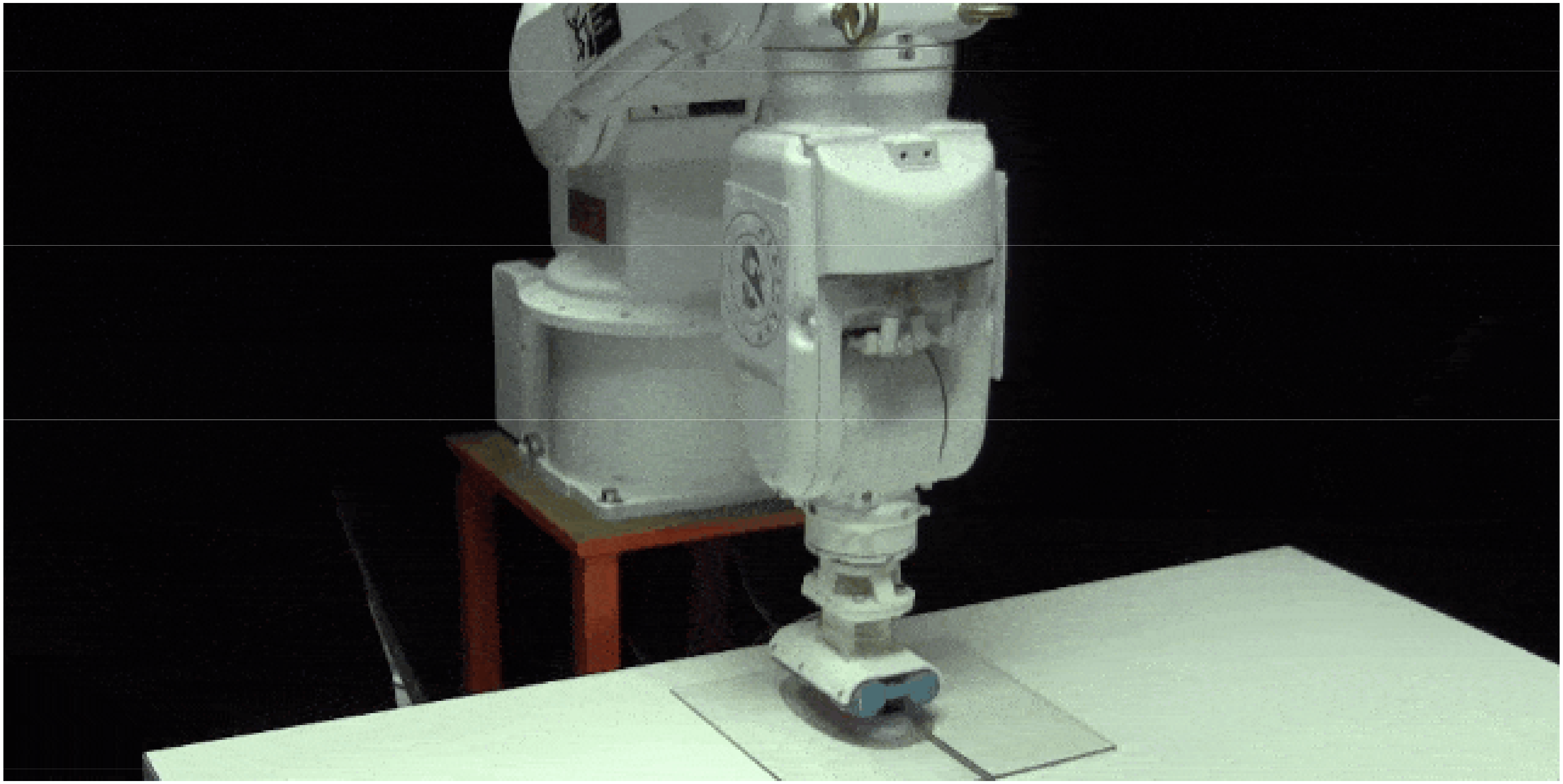

4. Magnetic end effectors

- It's working is based on principle of magnetism.
- These end effectors are used for holding ferrous material.

Tools used in Industrial Robotics

1. Welding gun

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2. Spray paint gun

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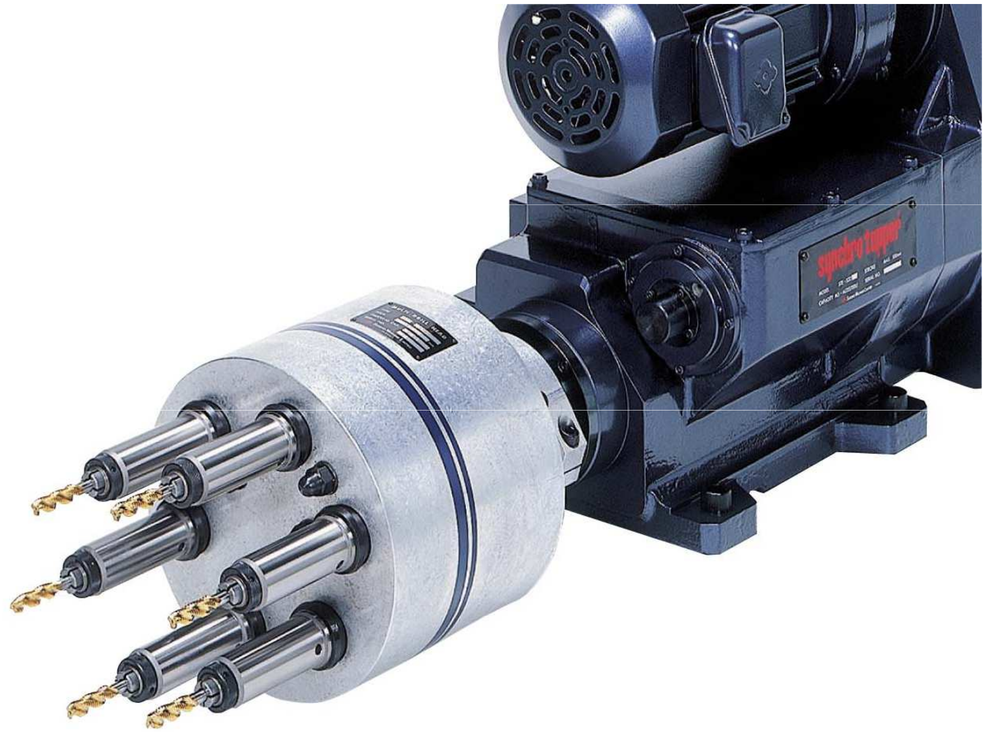
3. Spindle for drilling



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4. Screw driver

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5. Heating torch

Actuators

- An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system.
- An actuator requires a control signal and a source of energy.
- The control signal is relatively low energy and may be electric voltage or current, pneumatic or hydraulic pressure, or even human power.
- On receiving a control signal an actuator responds by converting the signal energy into mechanical motion.

Types of actuators

1. DC Motor
2. 1 phase / 3 phase AC Motor
3. BLDC Motor
4. Stepper Motor
5. AC / DC Servo Motor

DC Motor

- A DC motor is a class of rotary electrical machines that converts direct current electrical energy into mechanical energy.
- A DC motor have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow.

AC Motor

- An AC motor is an electric motor driven by an alternating current (AC).

3 Phase AC Motor

- Three-phase motors are designed to run on the three-phase alternating current (AC) used in many industrial applications.

BLDC Motor

- A brushless DC electric motor (BLDC motor or BL motor), also known as electronically commutated motor (ECM or EC motor).
- These motors provide high efficiency and excellent controllability, and are widely used in many applications.
- The BLDC motor has power-saving advantages relative to other motor types.

Stepper Motor

- A stepper motor, also known as step motor or stepping motor, is a brushless DC electric motor that divides a full rotation into a number of equal steps.

Servo Motor

- A servo motor is an electrical device which can push or rotate an object with great precision.
- If you want to rotate an object at some specific angle or distance, then you can use servo motor.

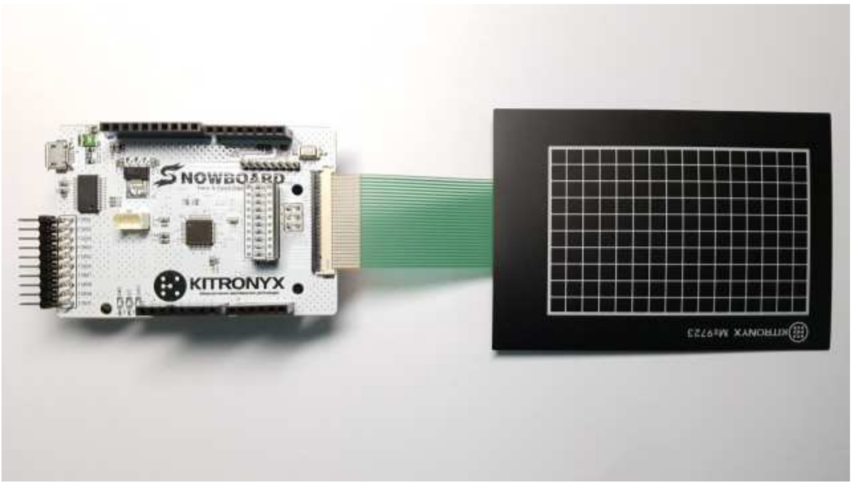
Sensors

- A sensor is a device that detects and responds to some type of input from the physical environment.
- The specific input could be light, heat, motion, moisture, pressure, etc.
- The output is generally a signal that is converted to human-readable display.

1. Proximity sensor (Range sensor)

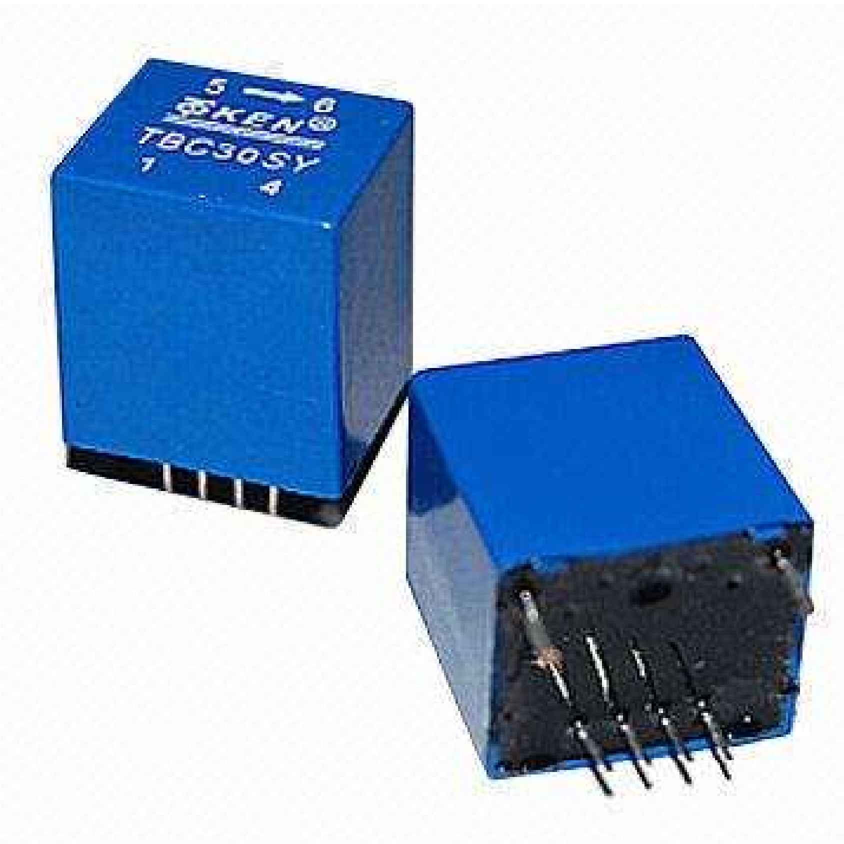
- It is able to detect the presence of nearby objects without any physical contact.

2. Tactile sensor



- A common application of tactile sensors is in touchscreen devices on mobile phones and computing.

3. Current sensor

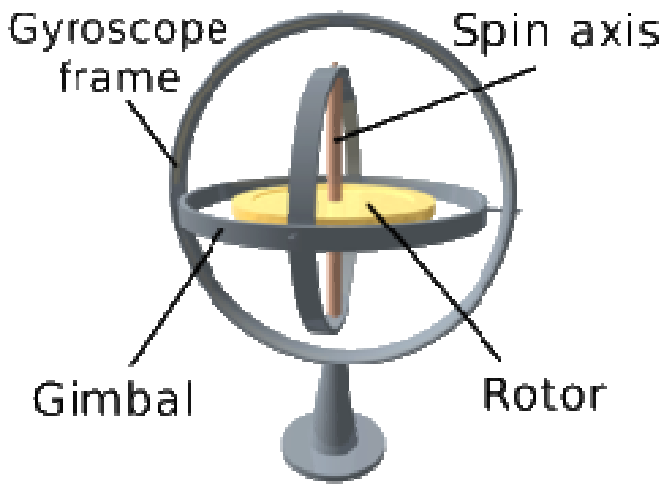


- A current sensor is a device that detects electric current in a wire, and generates a signal proportional to that current.

4. Tilt sensor

- Tilt sensors allow you to detect orientation or inclination.
- They are small, inexpensive, low-power and easy-to-use.

5. Gyroscope



- A gyroscope is a device used for measuring or maintaining orientation and angular velocity.

Programming Interface

- Embedded C
- Python

Many “Proprietary” languages are also used.

- MATLAB – Mathwork
- RobotC – LEGO
- KRL – KUKA
- KAREL – Fanuc

Important terminology used in Robotics

1. **Workspace** – The set of locations that can be reached by the Robot.
2. **Forward Kinematics** – Given joint parameters determine the final location of the end effecter.
3. **Inverse Kinematics** – Given desired end effecter position and orientation, determine the joint parameters.
4. **Dynamics** – What forces and torques need to be applied to joints to achieve the desired velocities/ accelerations.
5. **Trajectory** – A path through the space at the specified velocities.

Specifications of a Robot

- **Accuracy –** It is measure of how close the Robot reaches to the programmed point in the workspace. Nearness to the desired one is accuracy. e.g. If actual weight is 9 Kg and we get readings as 9.001, 9.002, 9.000, 8.999 Kg, then you are very much accurate.
- **Precision –** Being Precise may not be Accurate. This is closeness of many readings together is being Precise. e.g. If readings are 9.04, 9.04, 9.04 Kg then, we have good Precision but off course less Accuracy as compared to the first example.

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- **Repeatability –** It is a measure of how close the Robot reaches to the point previously reached by the Robot. It is ability to do the work again and again with the same quality.
- **Resolution –** It is the smallest movement/measurement or any other output that a Robot is capable of making. If a measuring tape has a scale of 0 – 100 cm in steps of 1 mm and some other tape has a scale of 0 – 100 cm in steps of 0.5 mm, then the second tape has a better Resolution compared to the first one.
- **Degrees of Freedom –** DOF of a mechanical system is the number of independent parameters that define its configuration (Translational, Rotational). The number of DOF is equal to the total number of independent displacements or aspects of motion.

Degrees of Freedom