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Robot control systems

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Tashkent, Uzbekistan, 15-19 May 2023

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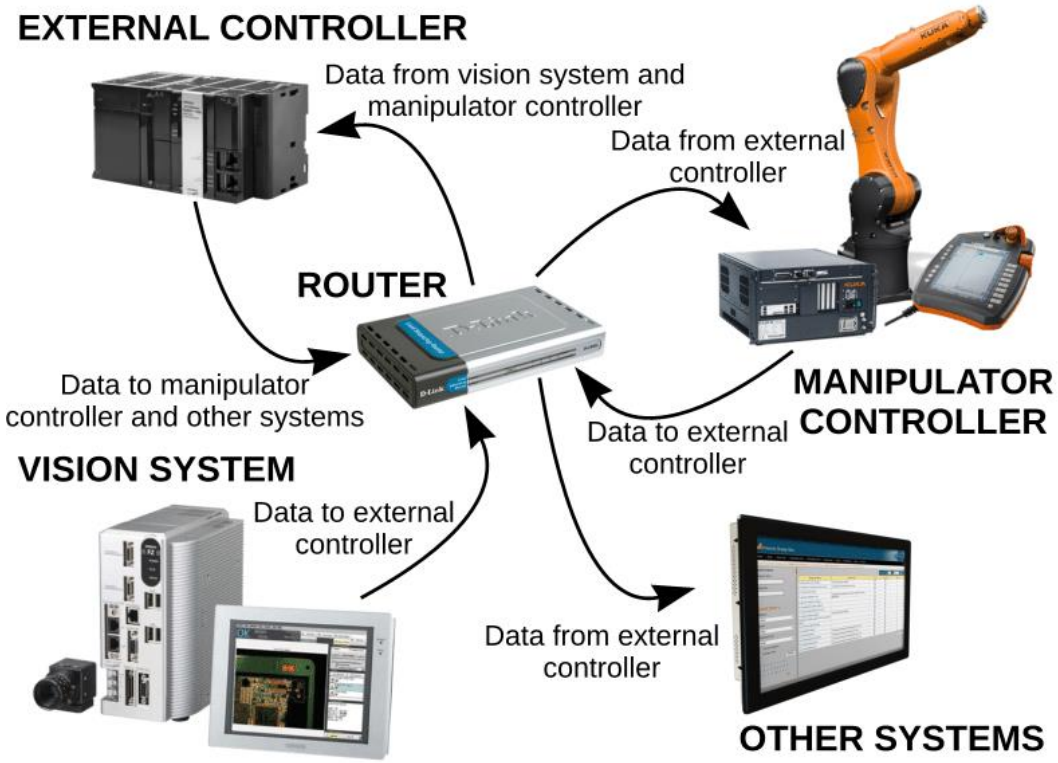
- **Definitions**
- **Structure of industrial robot**
- **Robot programming**
  - **Online programming**
  - **Offline programming**



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Definitions. What is a robot?

Definition of industrial robot proposed by **RIA** (Robotic Institute of America):

industrial robot – re-programmable multi-functional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks, which also acquire information from the environment and move intelligently in response

Definition proposed by **ISO 837317**:

industrial robot - automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.

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Definitions. A list

Joints
Robot kinematics
Degree Of Freedom (DOF)
Axes Orientation
Tool Centre Point (TCP)
Work envelope/Workspace
Speed
Payload
Repeatability

Accuracy
Settling Time
Control Resolution
Coordinates
Classification of robots
Structure of robots
Robots programing
Common Robot Configurations
Direct and inverse kinematic task

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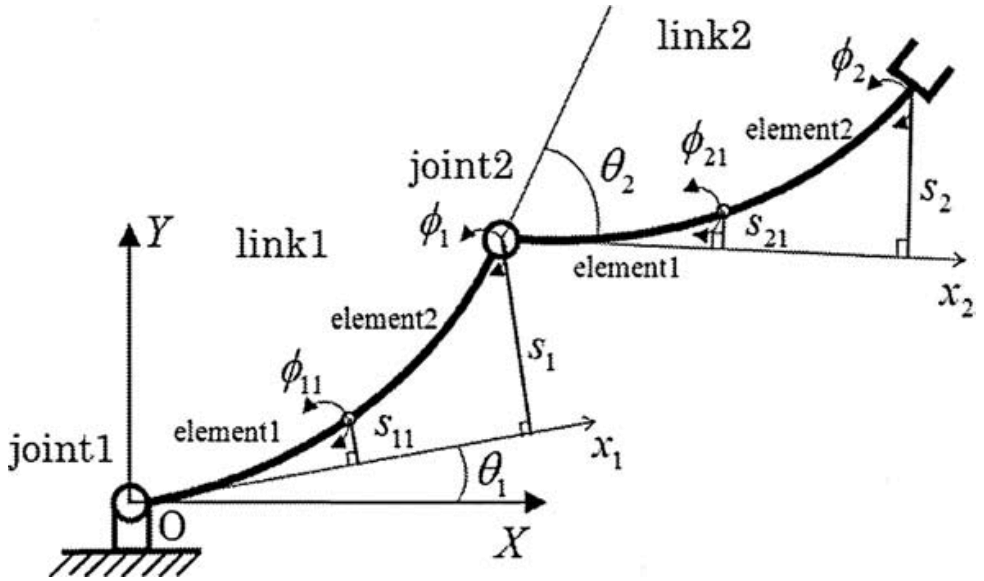
Definitions. Links.

Robot kinematic links can be **rigid or flexible**.
A rigid link is composed of rigid bodies (rigid body) and solving the normal kinematics and dynamics problems generally accepted that this type of link don't have deformation under temperature or load.
Flexible links (flexible links) change their shape in the plane or in space from the load.



Flexible links connected in series and the coordinate system

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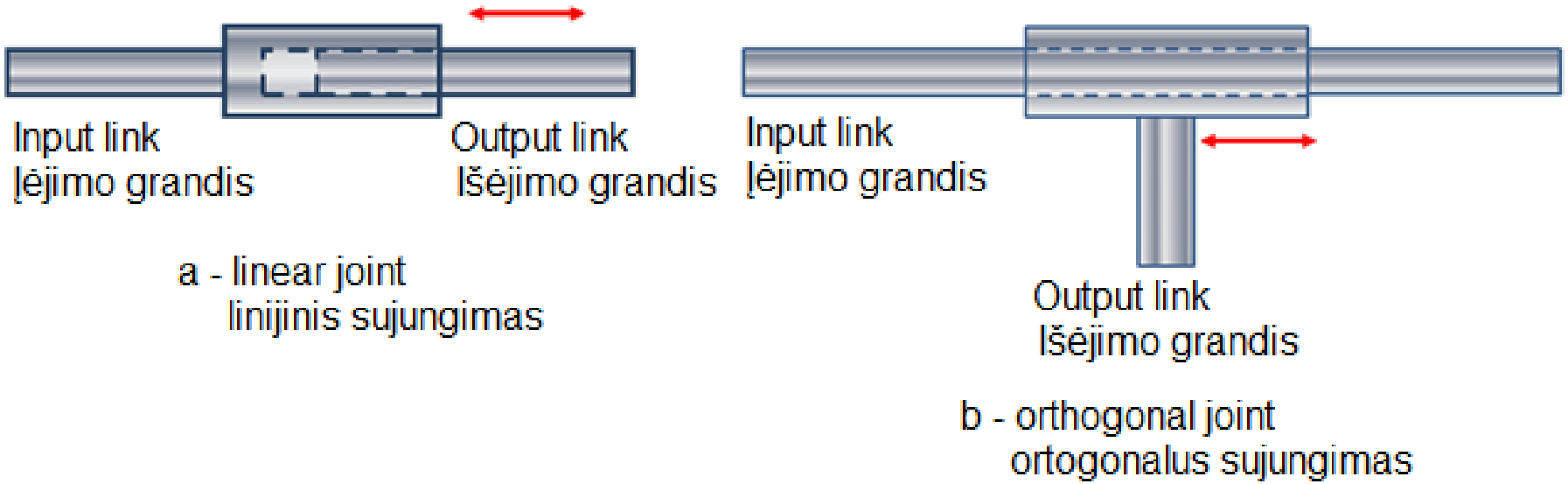
Definitions. Prismatic joints

Connections (Joints) transfer the movement from one chain to another. Two types of connections are mainly used:

Prismatic joint



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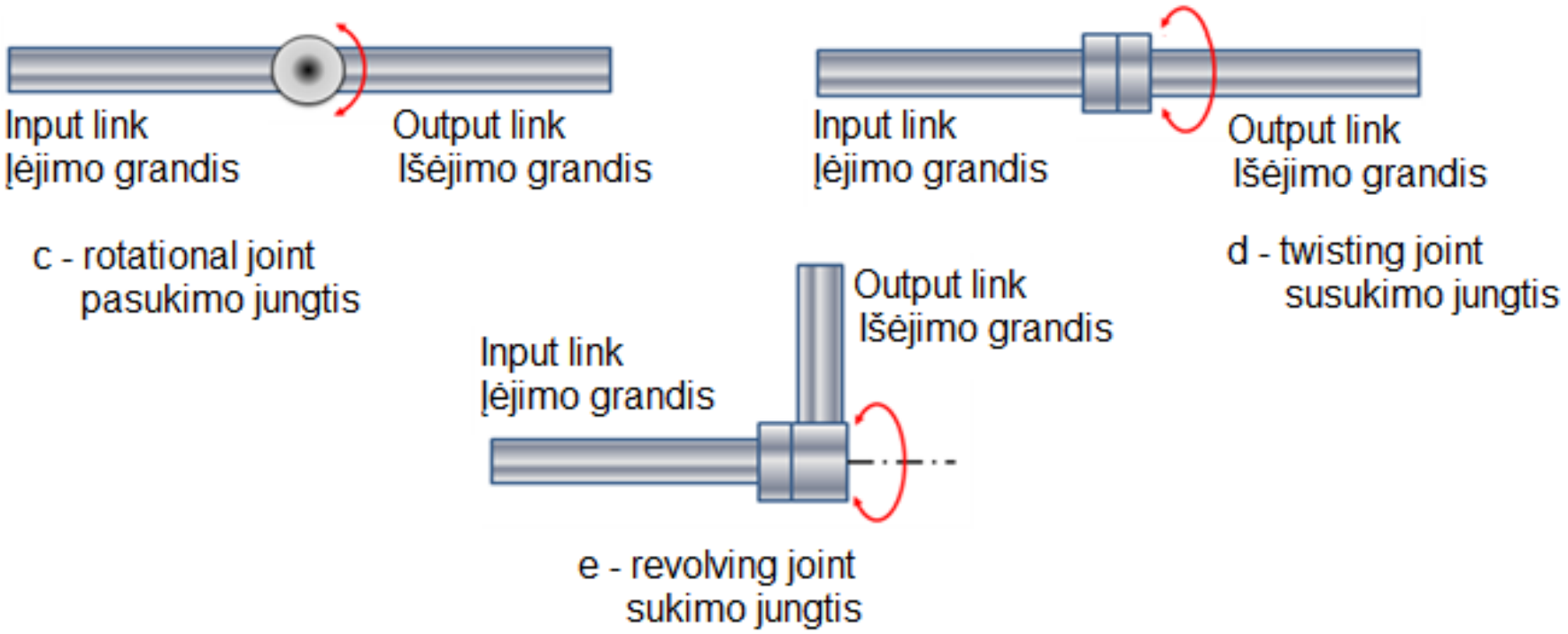
Definitions. Prismatic joints

Connections (Joints) transfer the movement from one chain to another. Two types of connections are mainly used:

Revolute joint.



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Definitions. Joints. Noting

Prismatic:
linear joint (type **L**),
orthogonal joint (type **O**).

Revolving:
rotational joint (type **R**),
twisting (type **T**),
revolving joint (type **V**).

If the output connector orientation is not relevant then two-letter markings are used:
A linear joint (**Prismatic**) is indicated by the letter **P**,
Rotational joint (**Revolute**) is indicated in **R** letter.

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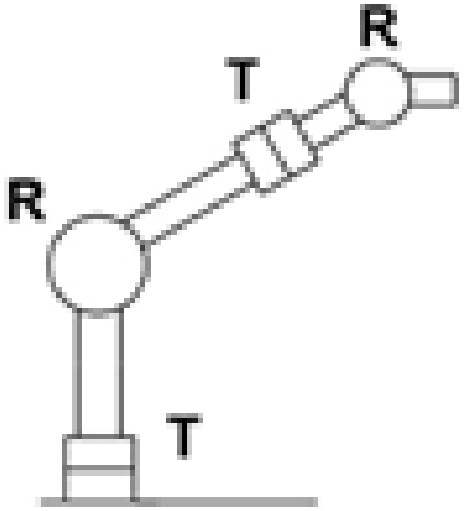
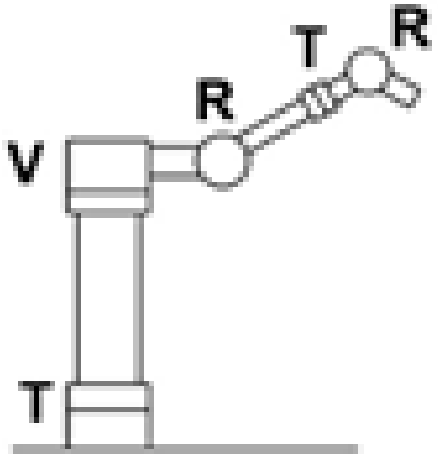
Definitions. Joints. Noting

Connector type symbols (**L, O, R, T, V**) are used to indicate the type of robot couplings.
Robot arm and wrist combinations are separated by a colon.
For example, **TLR: TR**

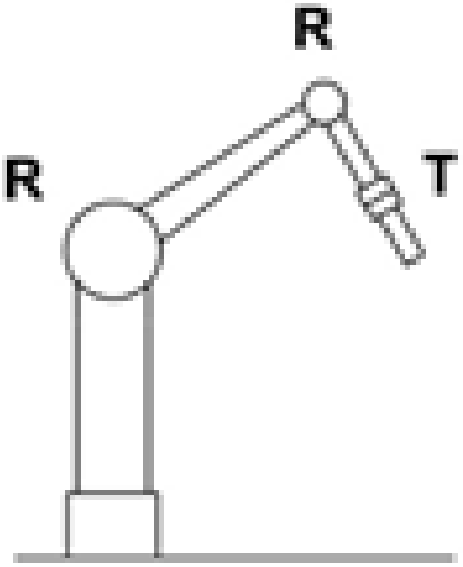
Three robots of different structure shown below.



(a) TRT:R



(b) TVR:TR



(c) RR:T

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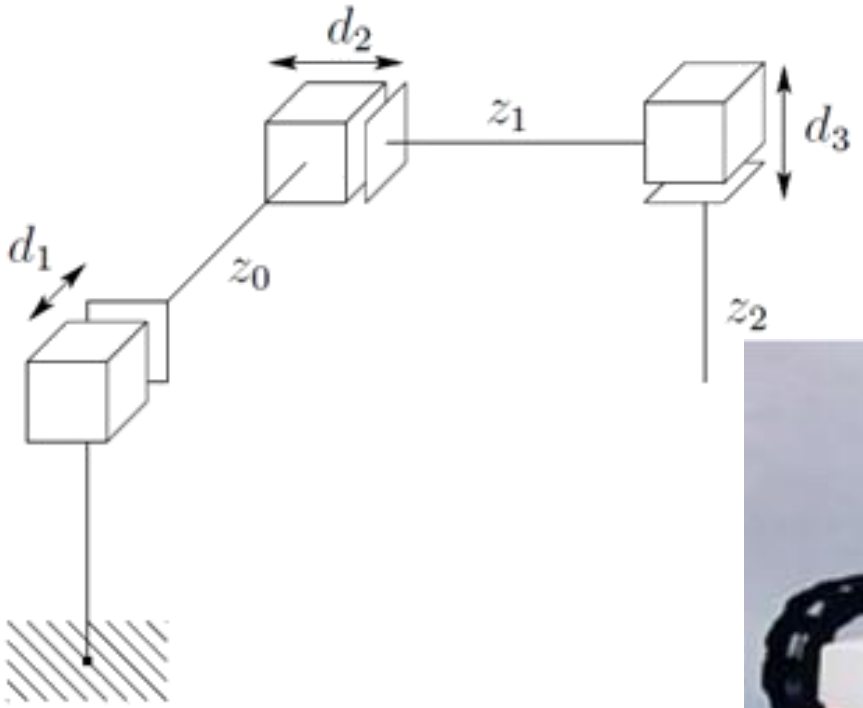
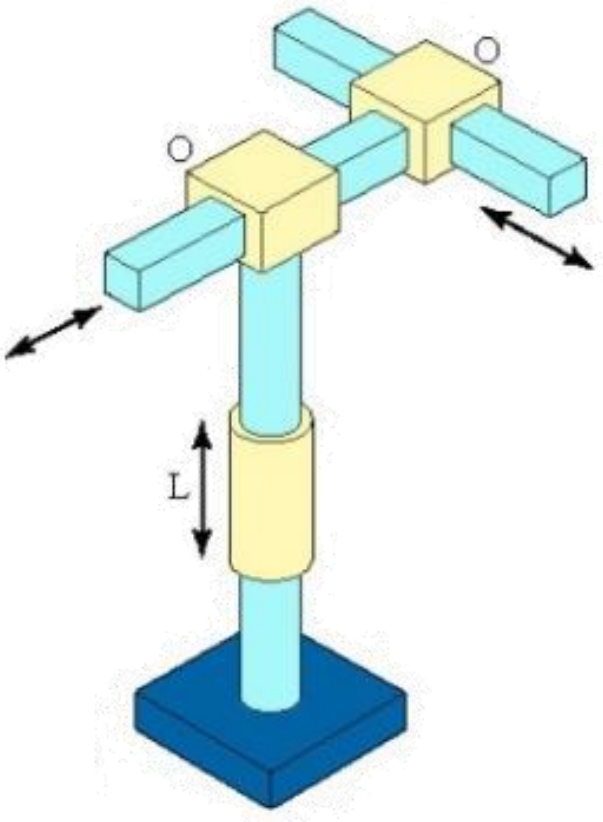
Robot configurations: Cartesian



Cartesian Manipulator
Joints: PPP or LOO



Epson
Cartesian
Robot

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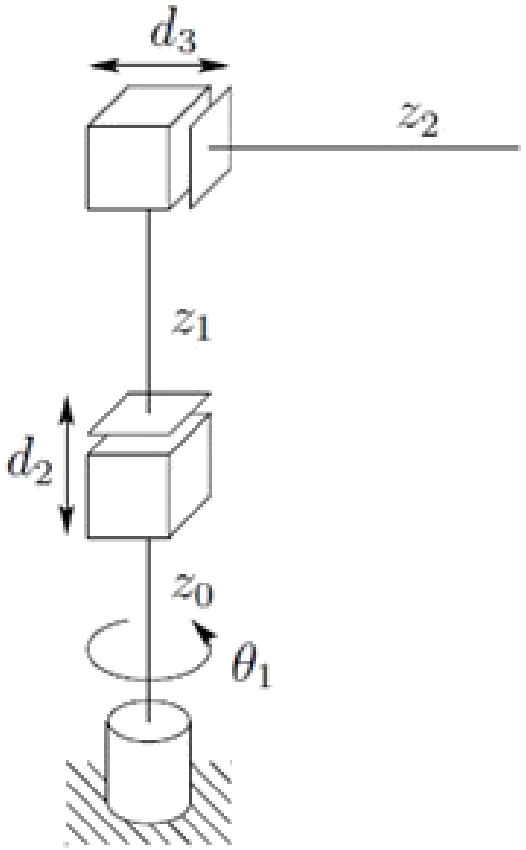
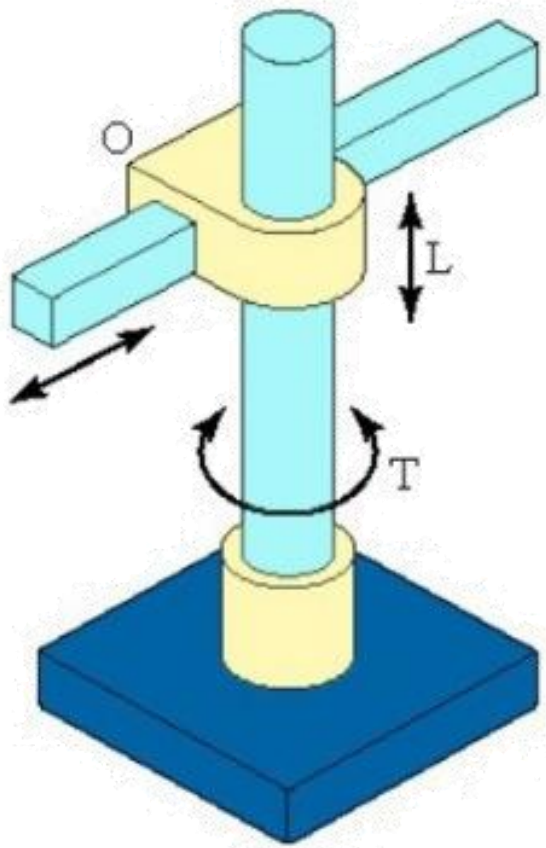
Robot configurations: Cylindrical



Cylindrical Manipulator
Joints: RPP or TLO



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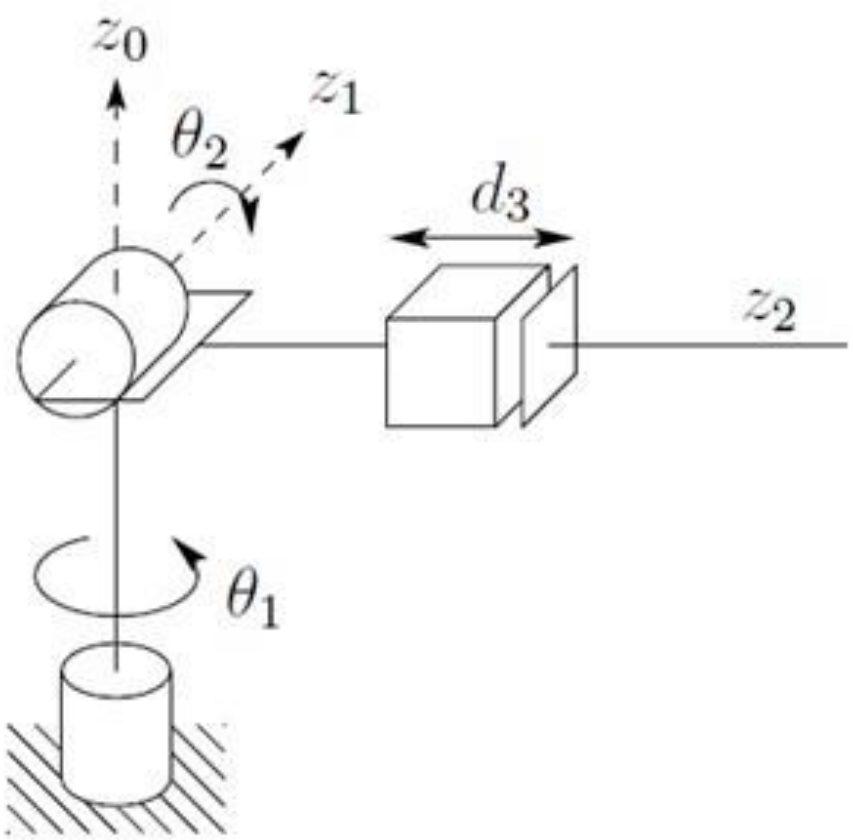
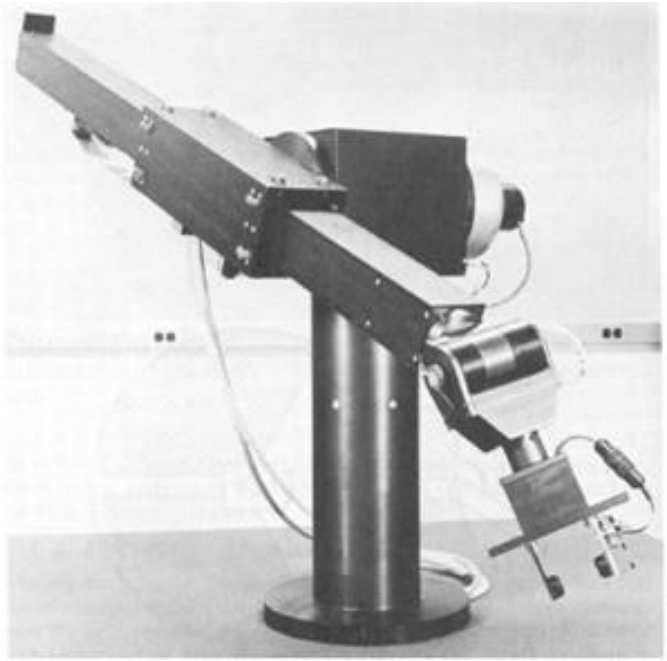
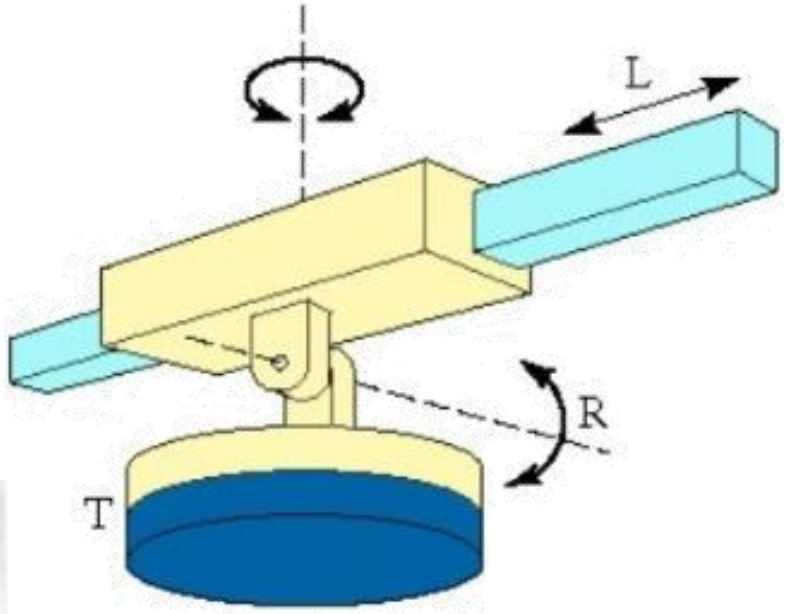
Seiko RT3300

Robot configurations: Sferical



Spherical Manipulator
Joints: RRP or TRL





Stanford Arm

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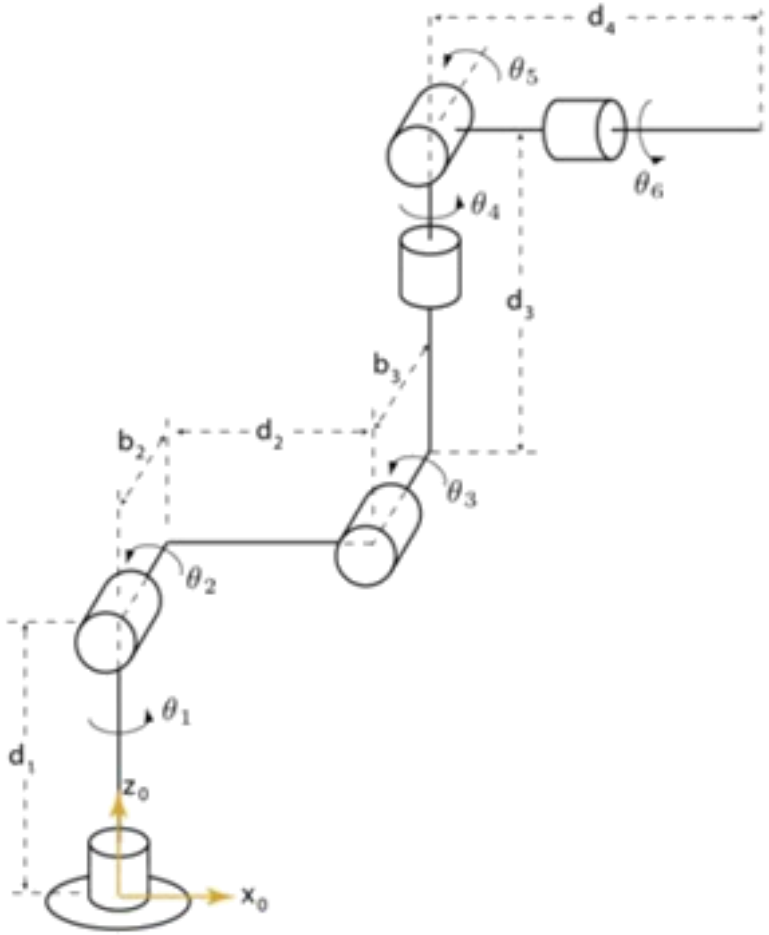
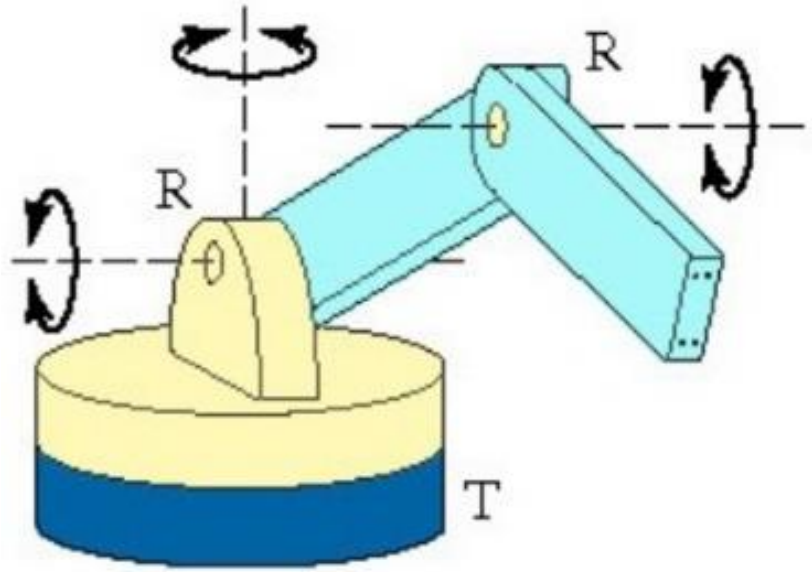
Seiko RT3300

Robot configurations: Articulated



Articulated Robot Joints RRR or TRR



KUKA robot

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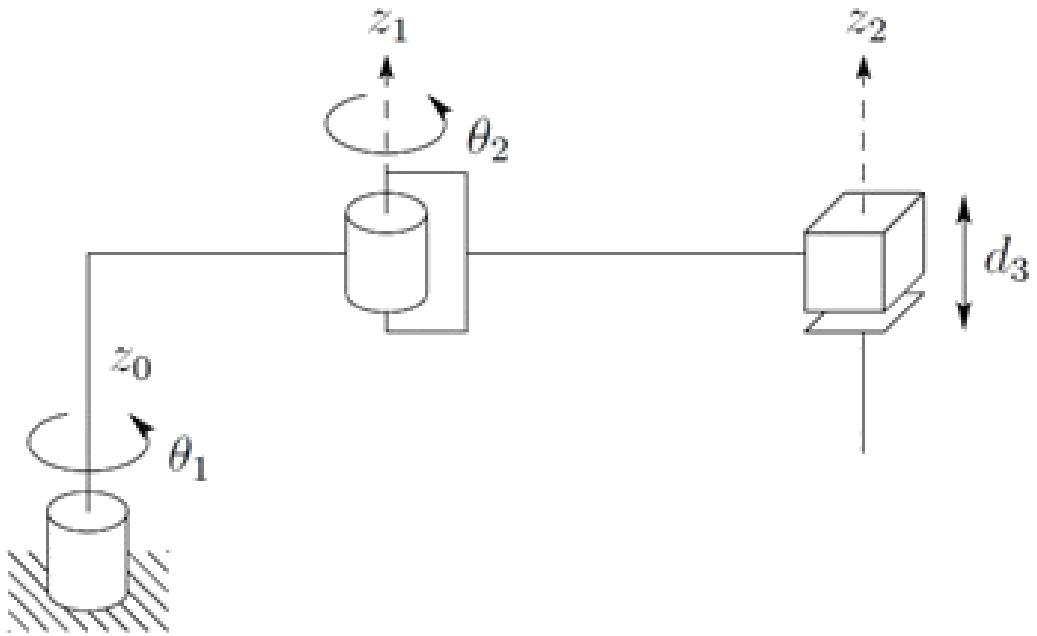
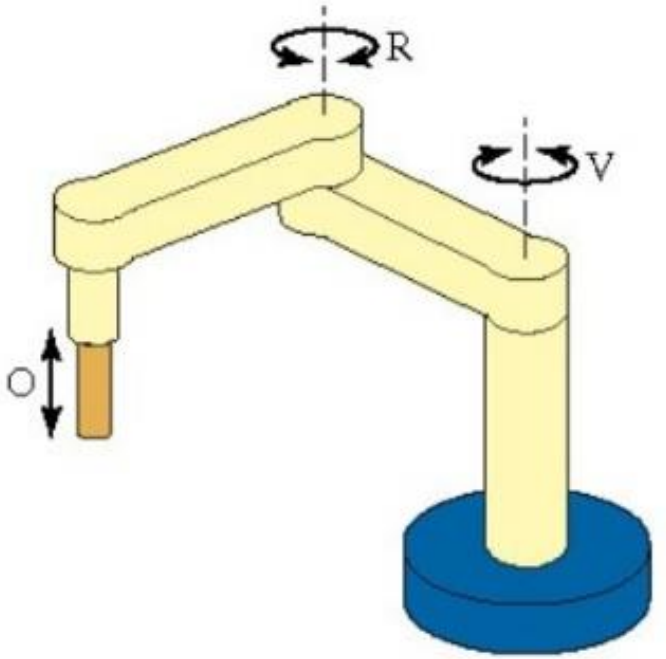
Robot configurations: SCARA

SCARA – Selective Compliant Articulated Robot for Assembly
Joints: RRP or VRO



Epson E2L653S



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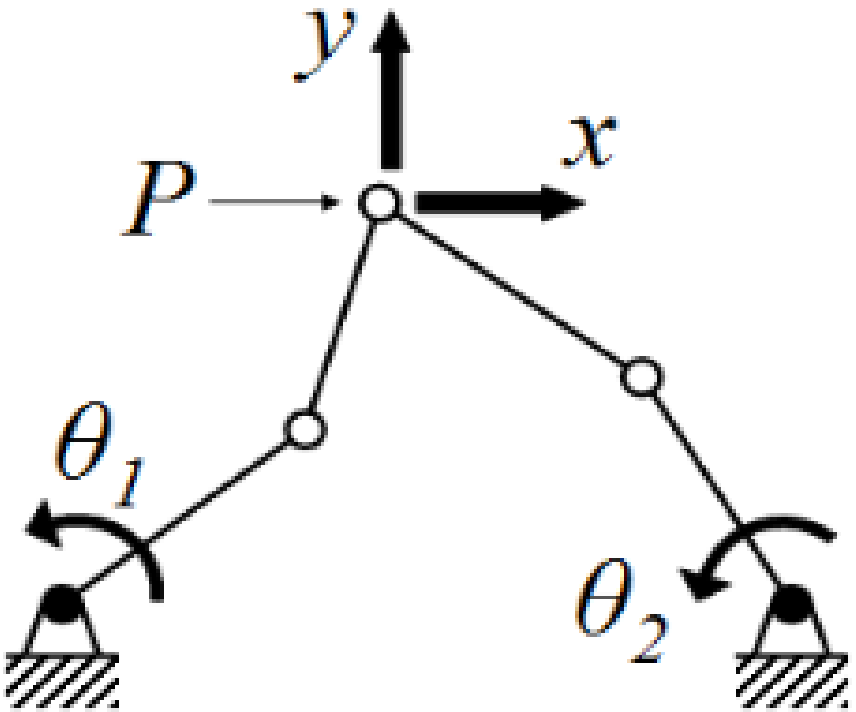
Robot configurations: Parallel

A parallel robot
Joints: RRRRR (5R)



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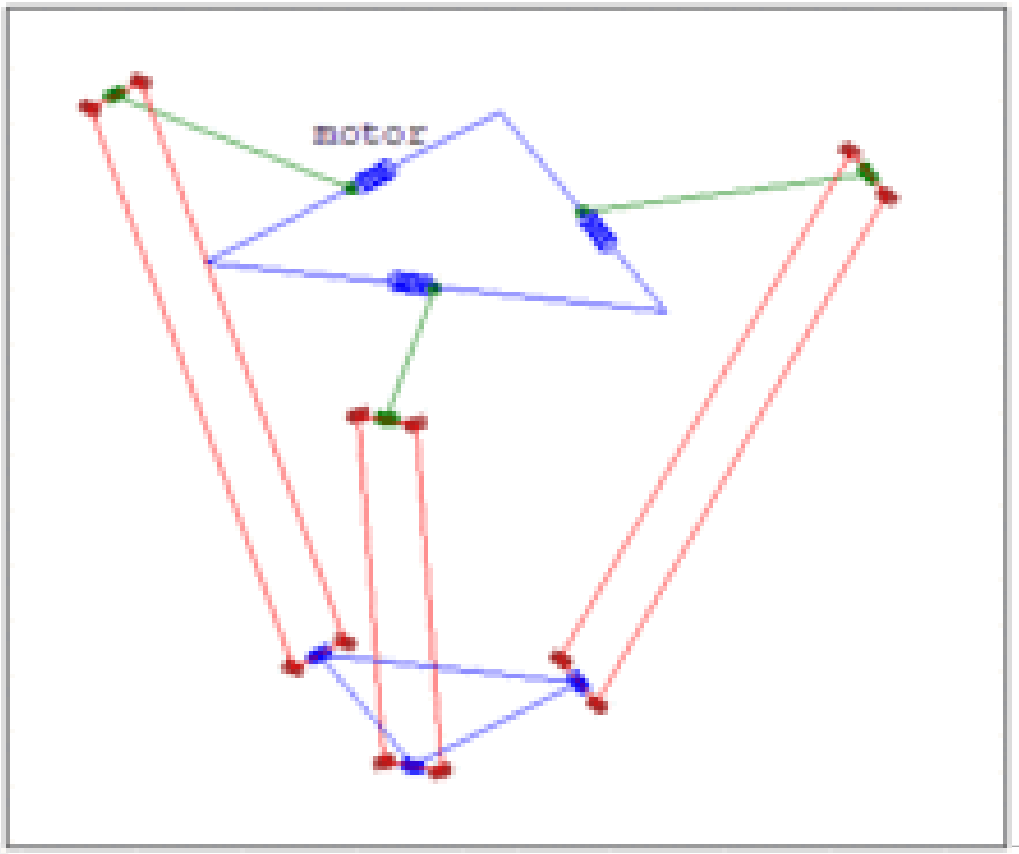
Robot configurations: Parallel

Delta Robot, a delta robot is a type of parallel robot



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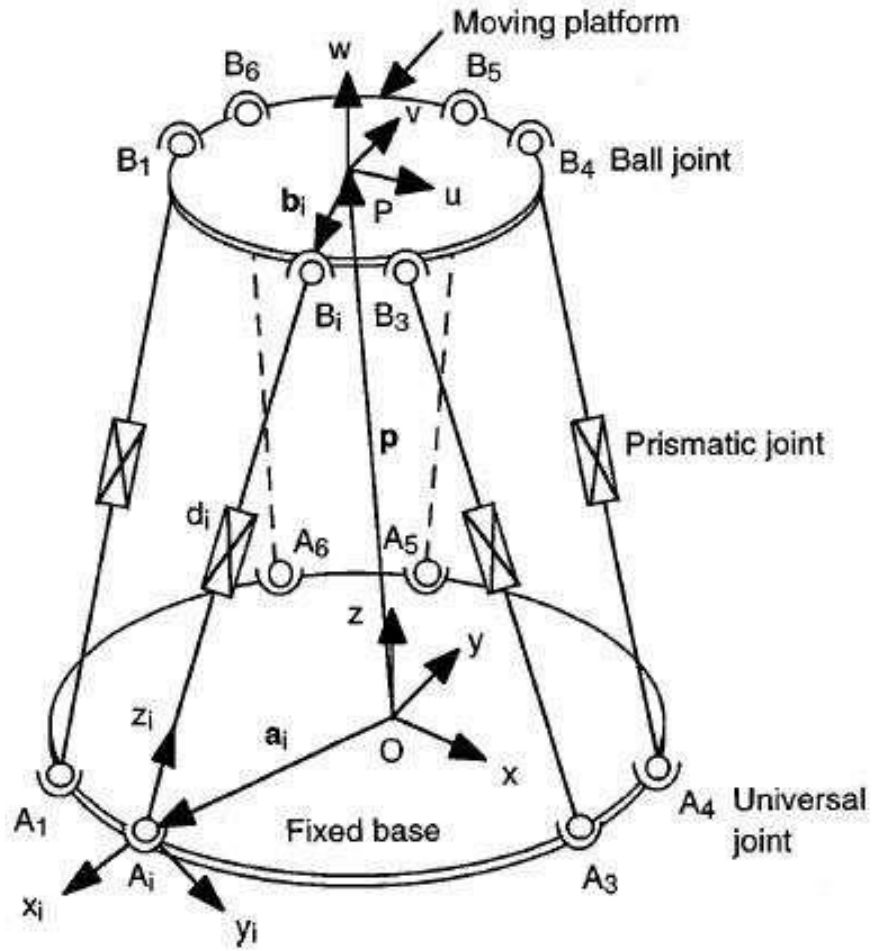
Robot configurations: Stewart platform



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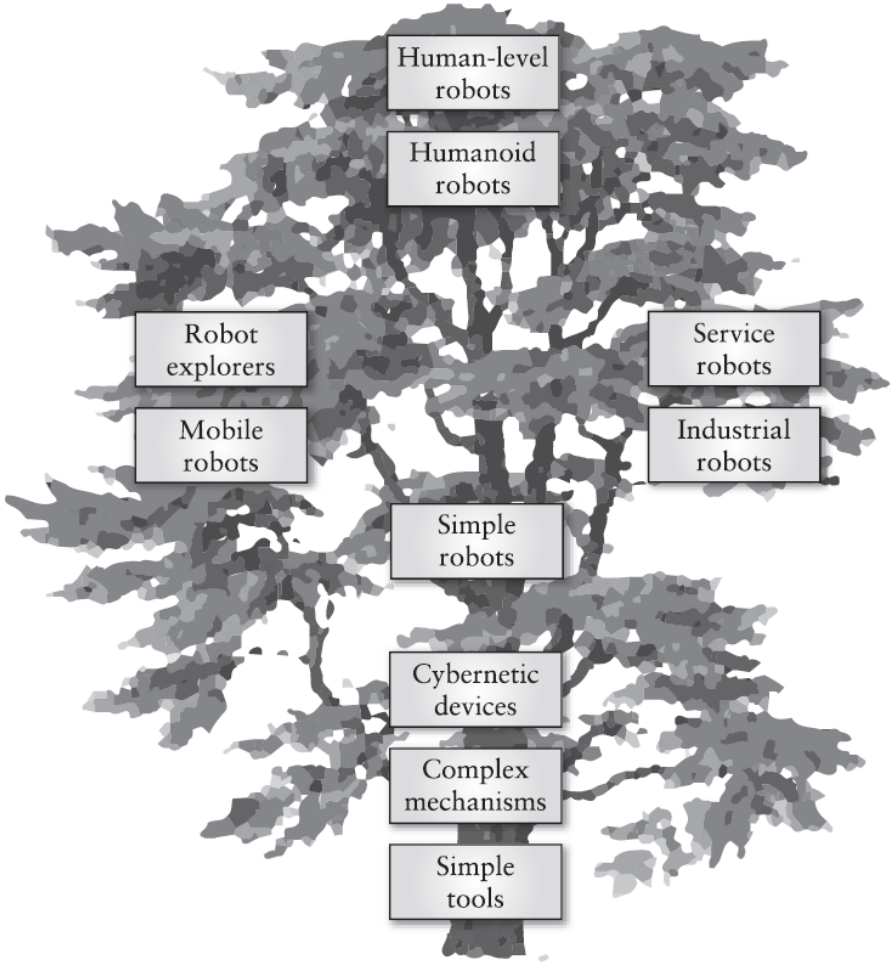
Technological level of industrial robots?



- Well-known robust mechanical structure based on reliable advanced technical solutions.
- Predefined control system with limited interfacing possibilities.
- Robots‘ functionality and safety requirements are strictly defined by international standards.
- Each manufacturer has individual programming languages and corresponding software modules.

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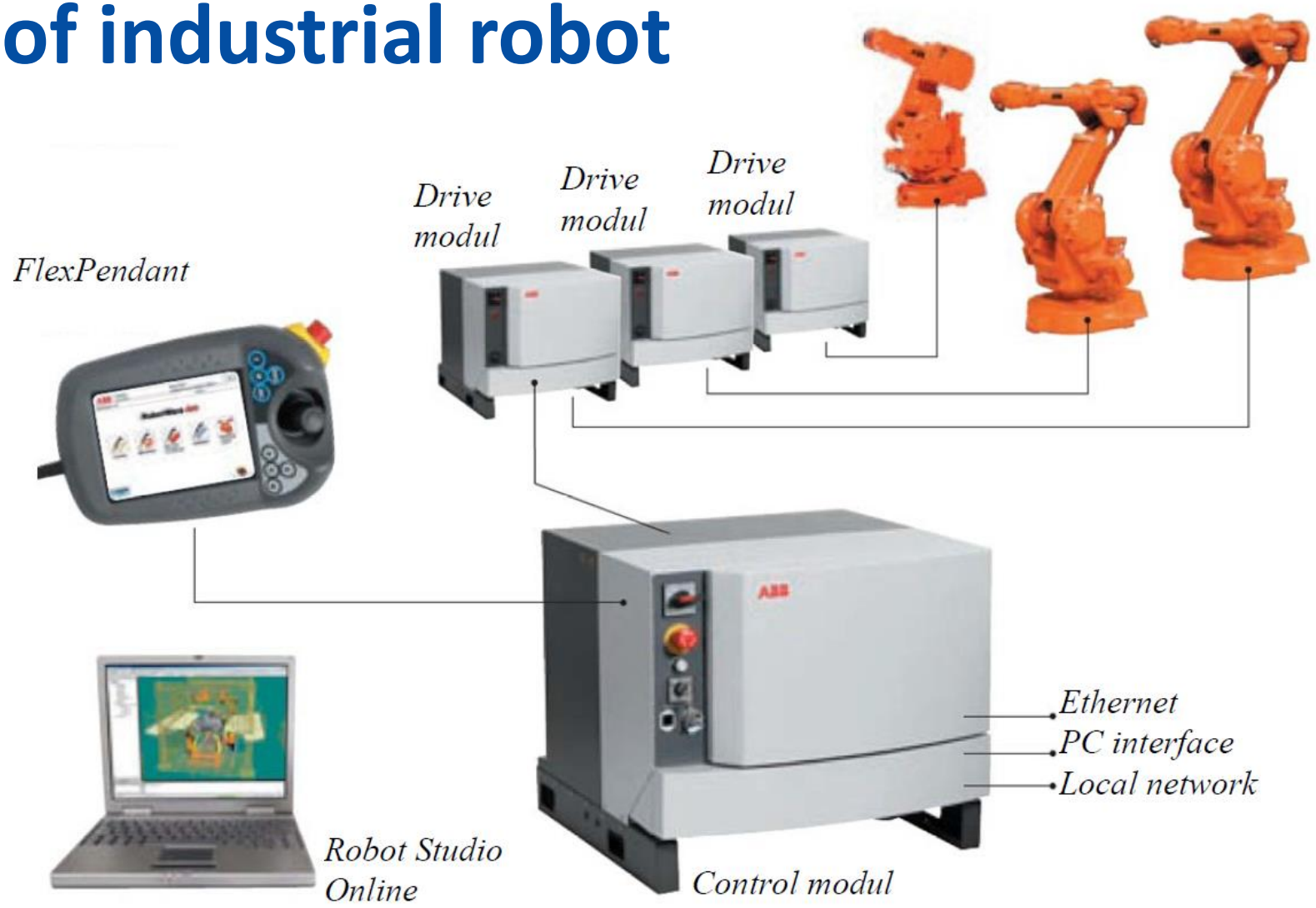
Structure of industrial robot



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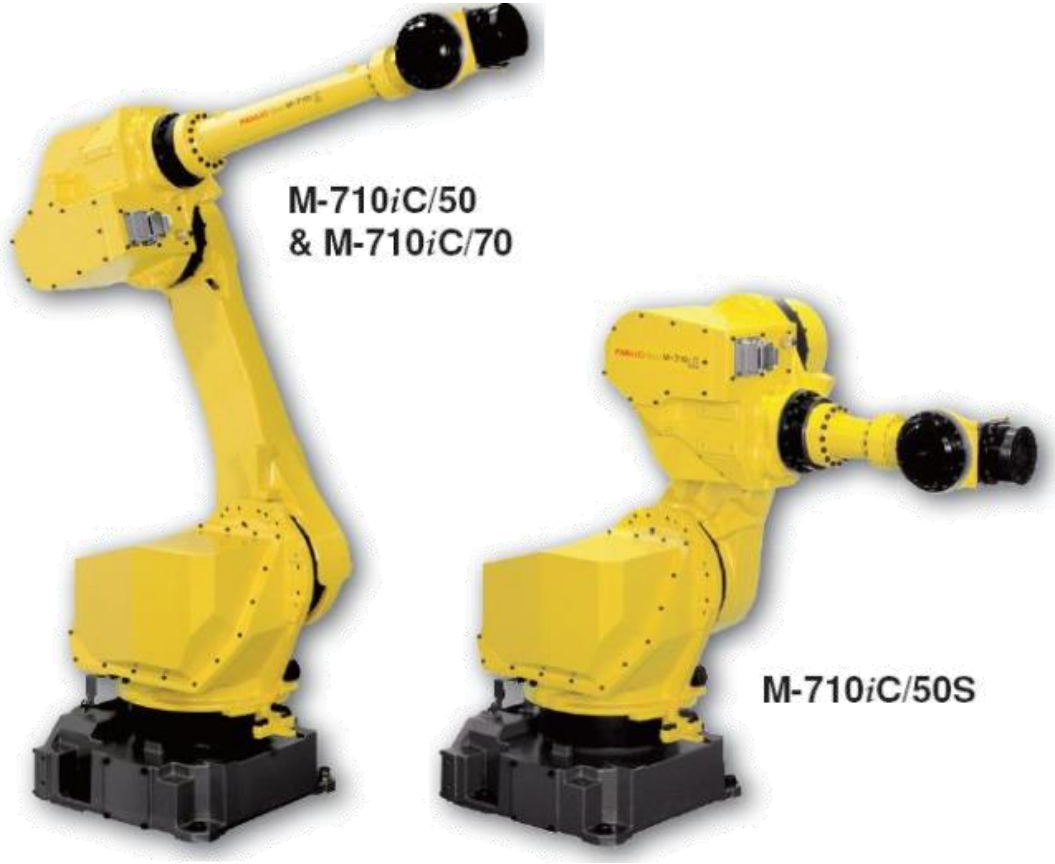
1. Structural structure (base, kinematic nodes and joints between them). Sometimes called a manipulator. The main requirement for a mechanical structure is its rigidity and the distribution of masses of kinematic chains so that the required movement or positioning accuracy is achieved by changing the load. The base can be mobile.



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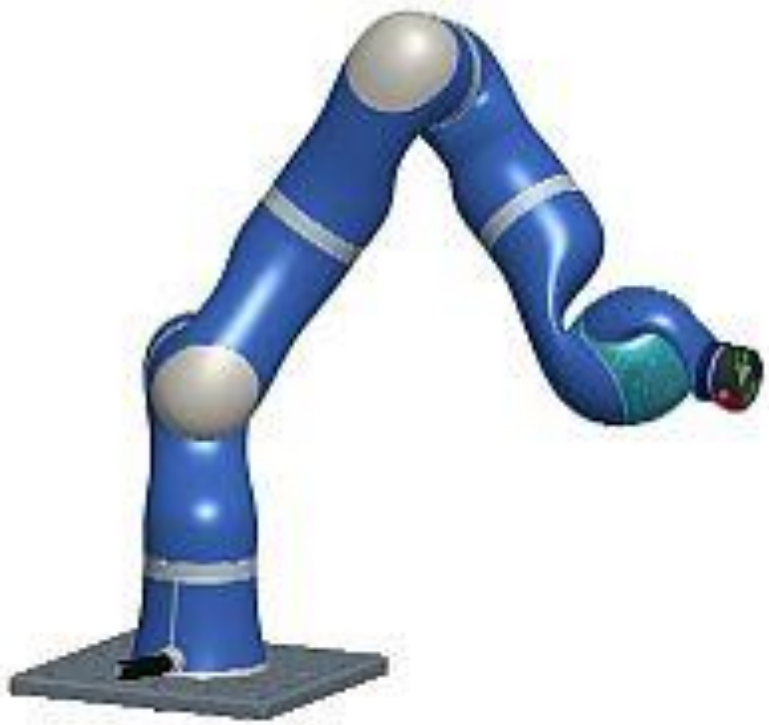
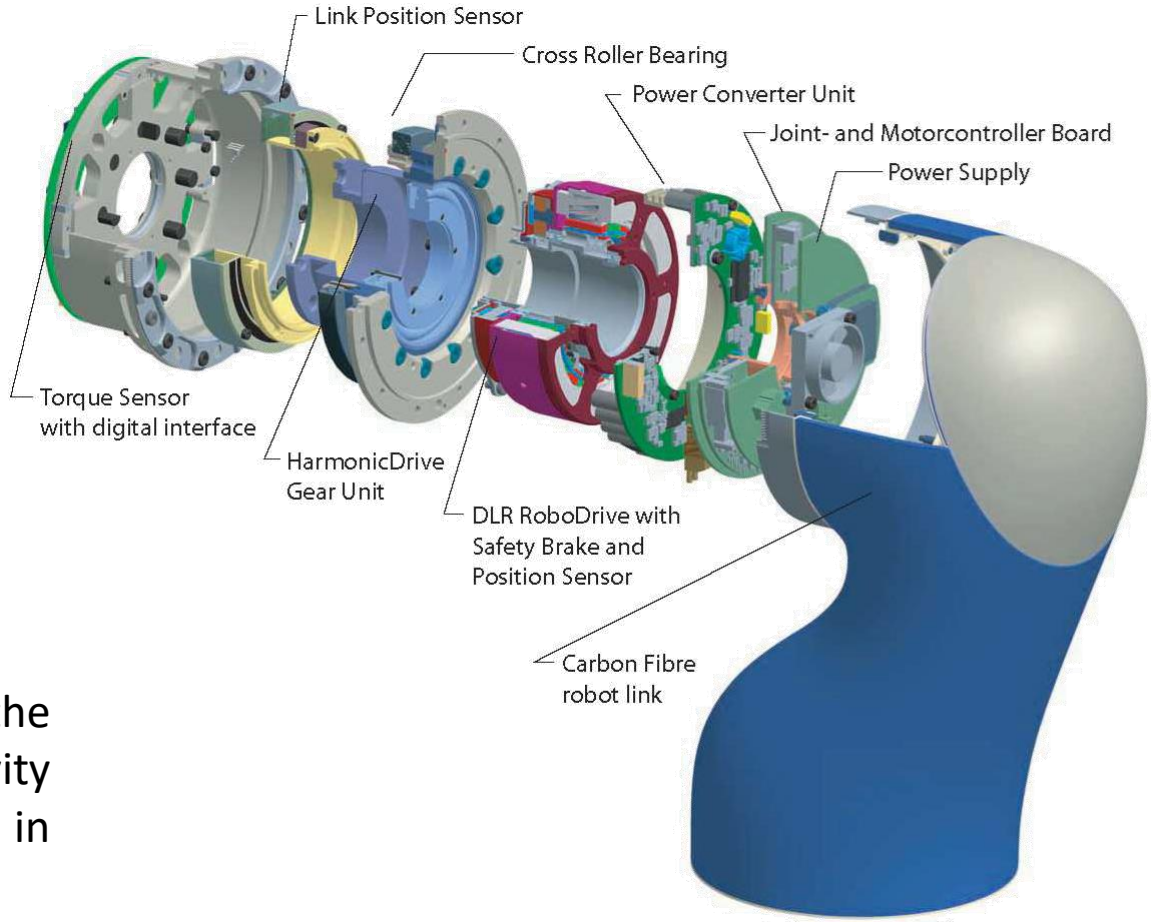


Joint of light-weight robot



Robot arms can be of various designs. One tries to place the motors as close as possible to the base and thus reduce gravity and moments of inertia. In others, the motors are mounted in the joints, thus shortening the kinematic chains.

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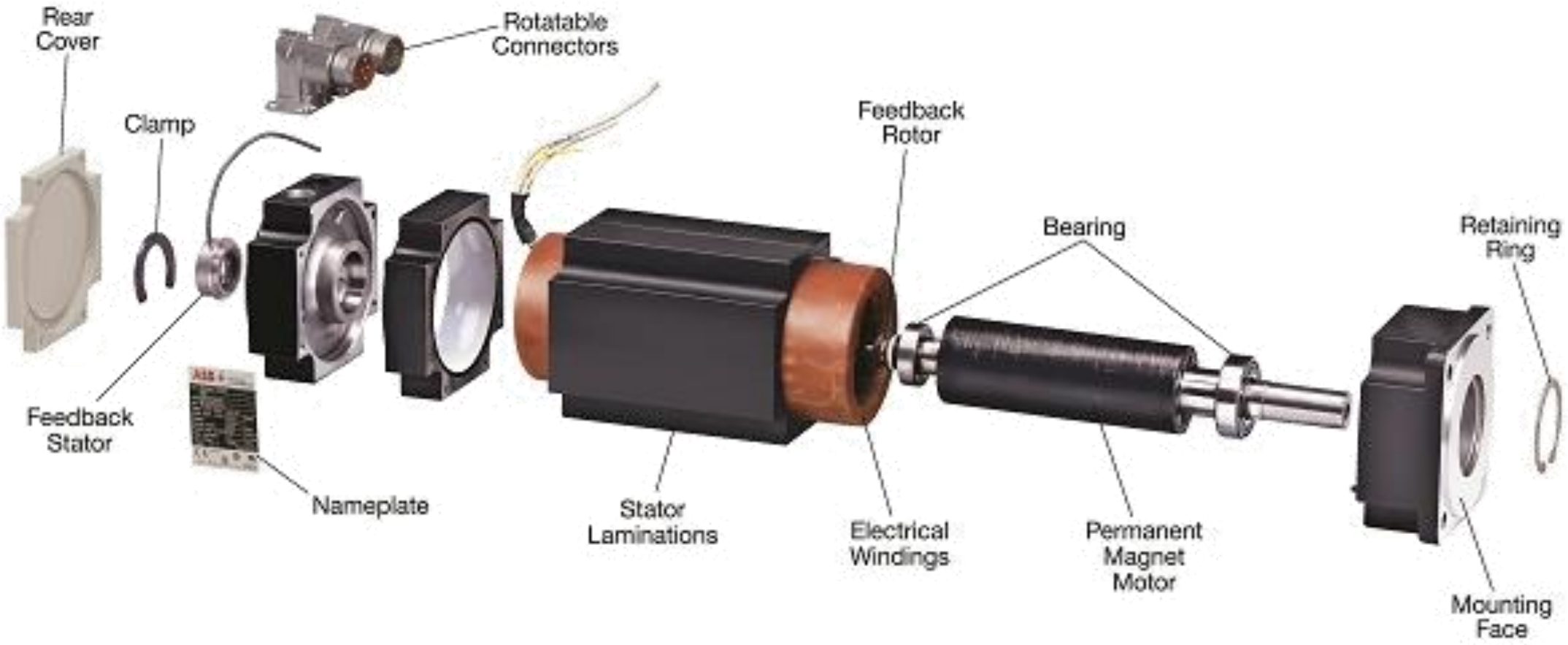
2. Actuators. The electric servo drives are made up of an engine, an encoder, a tach generator, a brake, temperature sensors. Example drive with a resolver.



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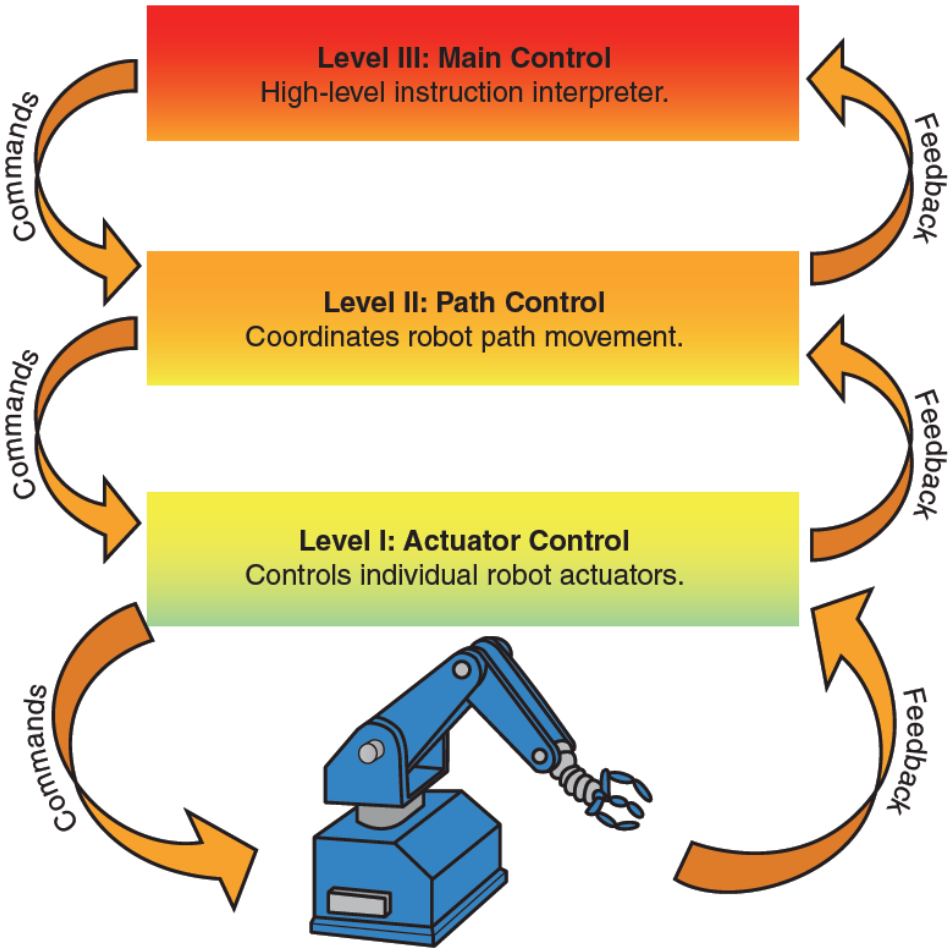
3. Main computer, the controller (Control Computer, Controller) is an intermediary chain between the user and the robot, which controls the joints of the mechanical structure.



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Level III—Main Control. The computer program interprets the man-made program's text and forms commands for the robot. The commands use different variables, input /output values, and transmit to commands understood in Level II control.

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Level II—Path Control. The program, after receiving the peripheral control and motion commands, creates command sequences that manage: Input / Output modules (forming pulse widths, waiting procedures),
form the task for individual drives in order to carry out the required movement (calculates the movements of the speed of the drives for each drive and realizes the sequence mode according to the fastest drive).

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Level I — Actuator Control. The elementary level at which the servo drive is running the sequence mode. The task may be the movement speed, torque or impact force.

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4. End of Arm Tooling – EOAT, End Effector.

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Automatic gripper/tool changer.

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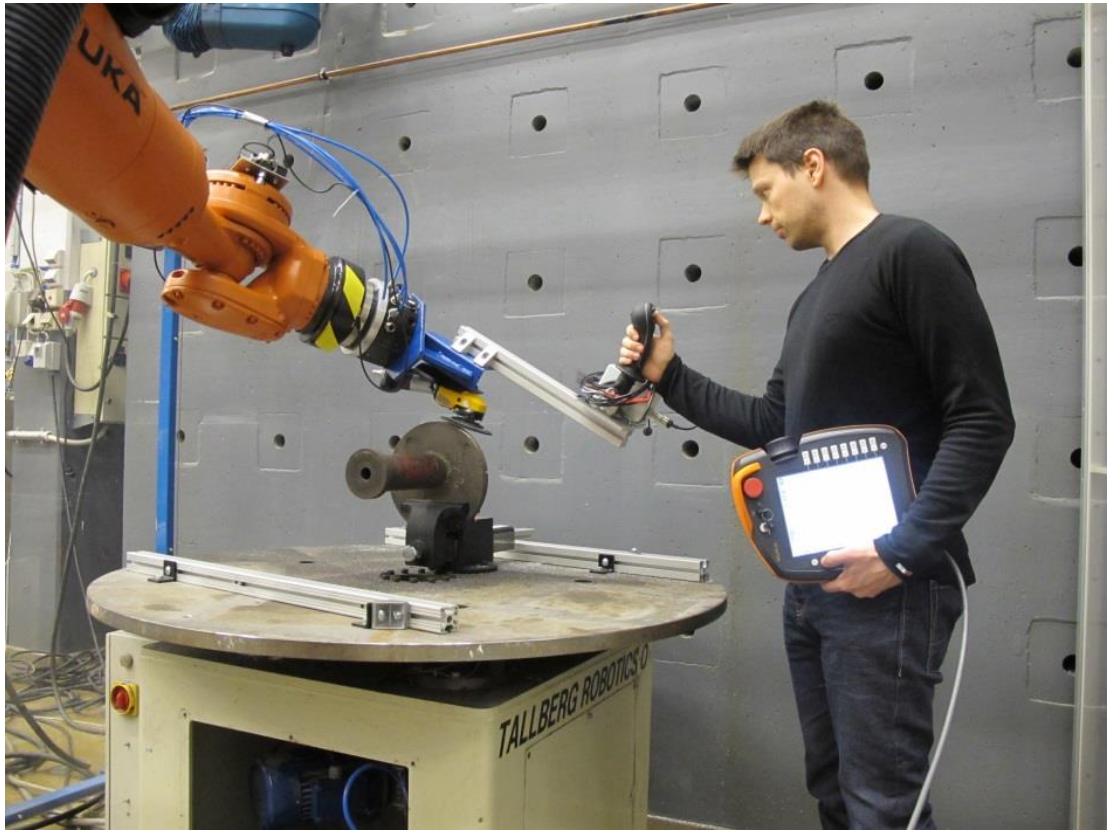
5. Teach pendant or Training joystick.



Joystick one of the most popular tools for programming robots. It is a small device fixed in the gripper of the robot. The user, taking this joystick, guides the robot's arm in the required trajectory and to the required positions.

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Robot programming

Robot programming depends on its design capabilities:

- **Limited Sequence Control**.
- **Point-to-Point Control (PTP) control robot**
- **Continuous Path (CP) Control**.
- **Controlled-path robot (CIRC Circular, LIN Linear motion)**
- **Intelligent Control**

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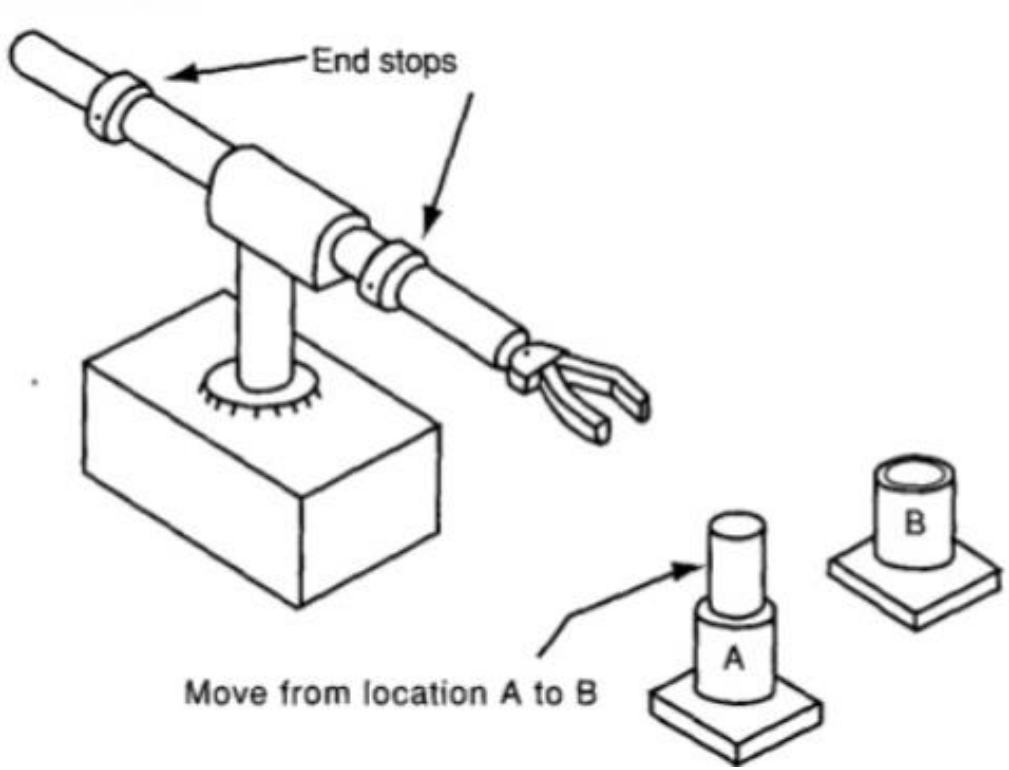
Limited Sequence Control - The most basic way is when the sequence of movements is performed from the support to the support. The sensors only report if they are that the movement is over. Mainly used for pneumatic robots.



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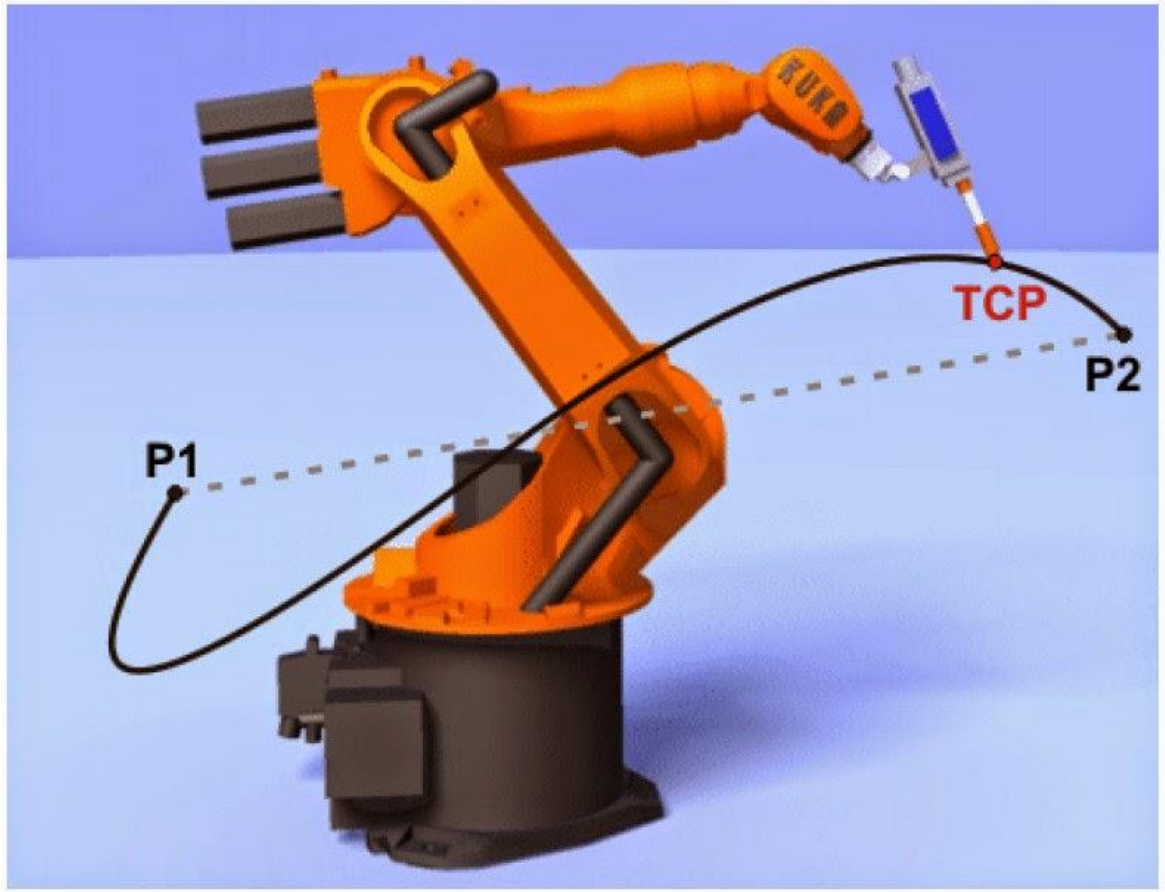
Point-to-Point Control -PTP is such that it takes at least the time or consumes as little energy as possible. It is used for spot welding, hole drilling, machine loading/unloading, and crude assembly operations.



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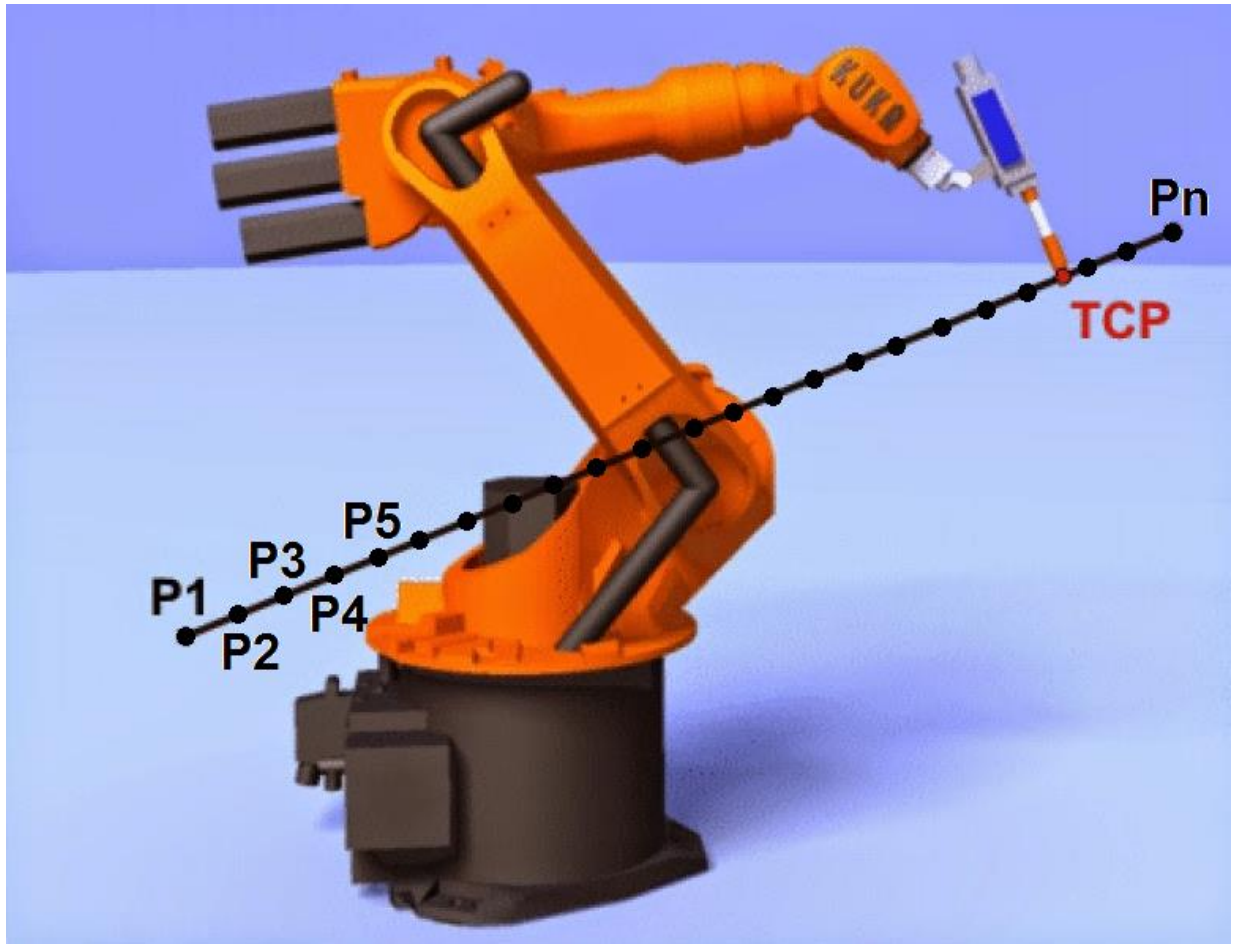
Continuous Path (CP) Control – The robot's TCP can stop at any point in the trajectory, the number of points is selected according to the desired trajectory accuracy. Used for spray painting, finishing, gluing, arc welding.



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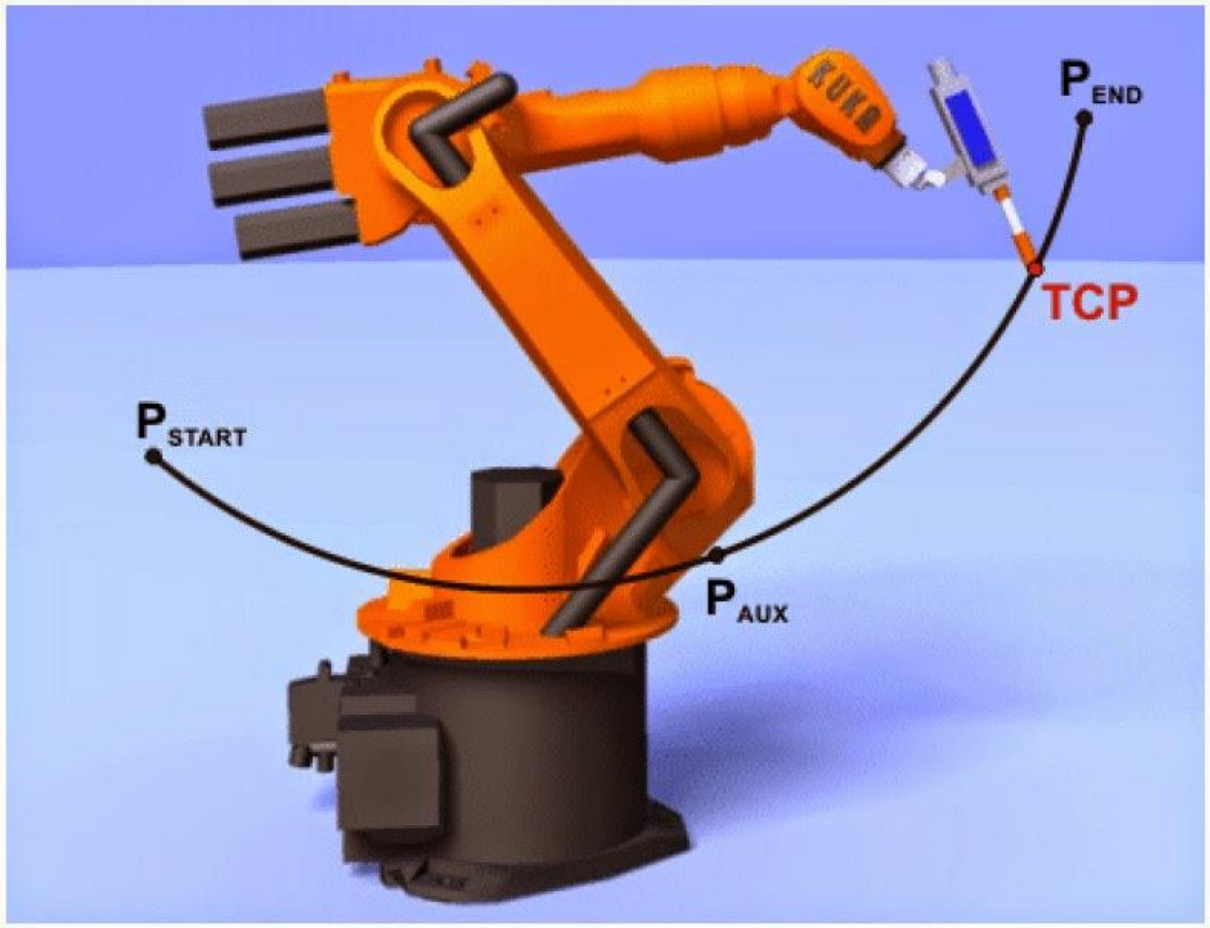
Controlled-path robot (CIRC - Circular motion) - all the axes move so that TCP is always in the arc loop, which is indicated by three dots. The program supports the linear arc speed.



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Intelligent Control – The robot responds to the environment, makes decisions and can change both the trajectory of the movement, the speed, or even the sequence of actions. Intelligent management performs human-specific functions. The environment can be monitored by a standard tactile sensor system and/or computer vision system.

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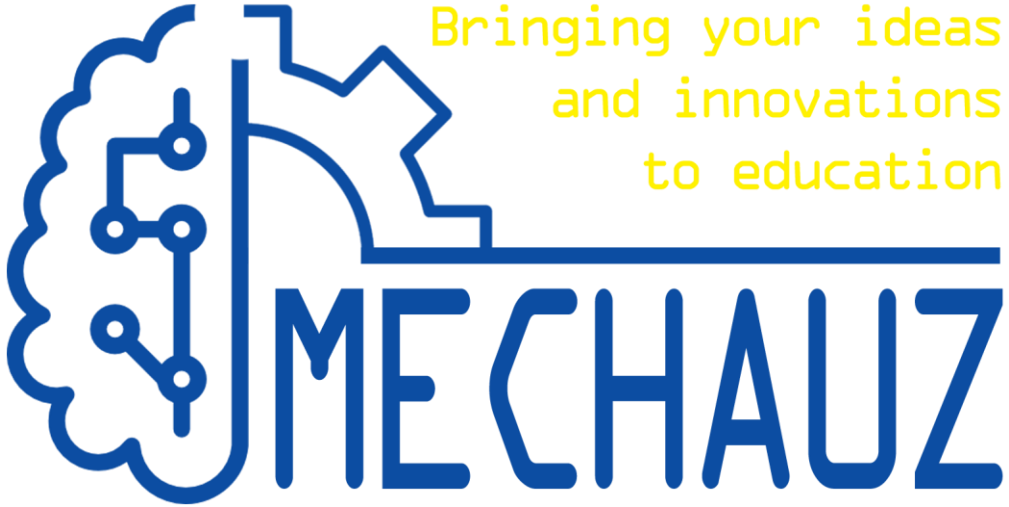

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FOR YOUR ATTENTION

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