History

-- Robot comes from the Czech word "*robota*", that means tireless work.

When did robots, as we know them today, come into existence?

- The first modern industrial robots, called Unimates, were developed by George Devol and Joe Engelberger in the late 50's and early 60's.
- The first robot patents were by Devol for parts-transfer machines.
- Engelberger formed Unimation and was the first to market robots. As a result, Engelberger has been called the 'father of robotics.'

Progressive Advancement in Robots

- **First Generation** (repeating, nonservo, pick and place, or point to point kind) , in present 80% robots are of this kind. 1960
- **Second Generation** (addition of sensing devices , path control capabilities). 1980
- **Third Generation** (On-line computations and control, artificial vision, and active force/torque interaction with the environment). 1992
- **Fourth Generation** (true android or an artificial biological robot or a super humanoid capable of its own clones). 2000

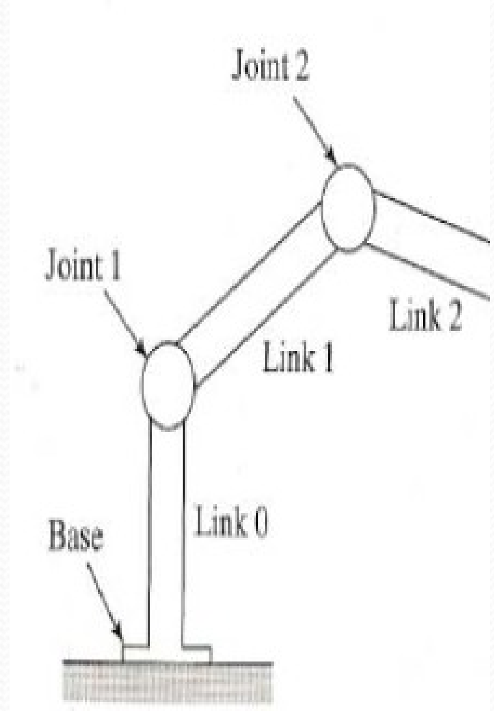
Industrial Robots Definition

"A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or special devices through variable programmed motions for the performance of a variety of tasks"

Robot Institute of America (RIA)

Main Components of Industrial Robots

– Arm or Manipulator.
– End effectors.
– Drive Mechanism.
– Controller.
– Custom features:
  e.g. sensors and transducers.

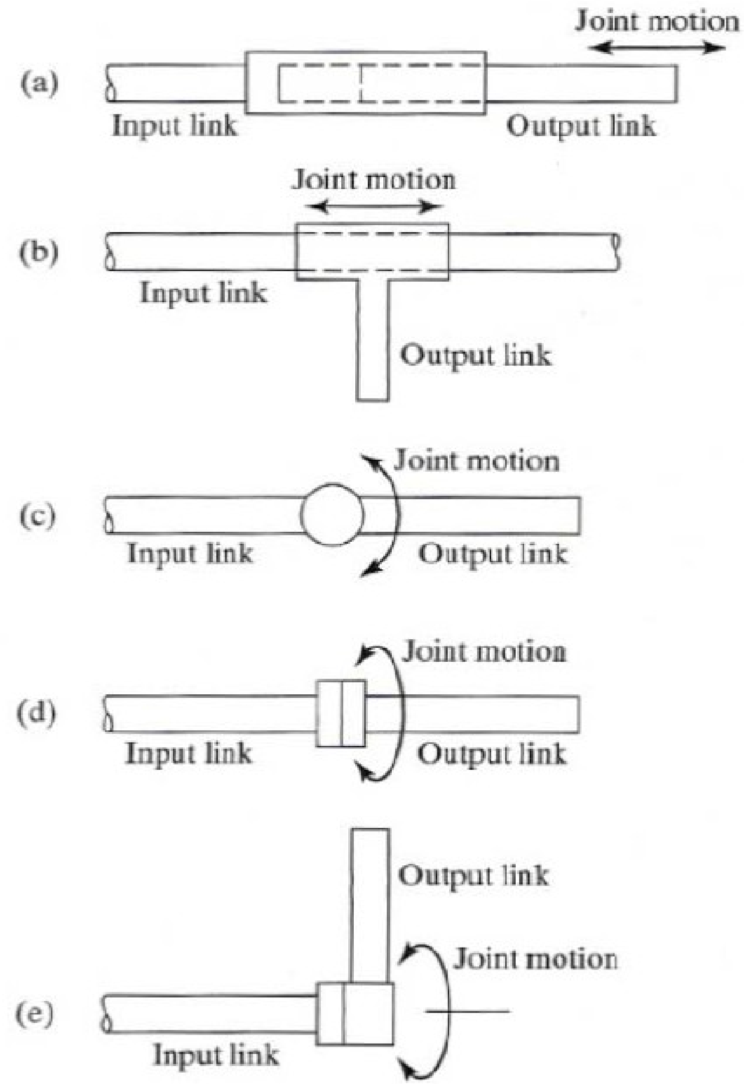


Types of Mechanical Joints for Industrial Robots

There are five types of mechanical joints

- Two provide translational motion
- Three provide rotary motion

1. **Linear joint (type L):** translational motion
   - Axes of input and output link are parallel
2. **Orthogonal joint (type O):** translational motion
   - Input and output links are perpendicular
3. **Rotational joint (type R):** rotary motion
   - Axis of rotation is perpendicular to input and output link axis
4. **Twisting joint (type T):** rotary motion
   - Axis of rotation parallel to axis of links
5. **Revolving joint (type V):** rotary motion
   - Axis of rotation parallel to input but perpendicular to output



Type of Drive System

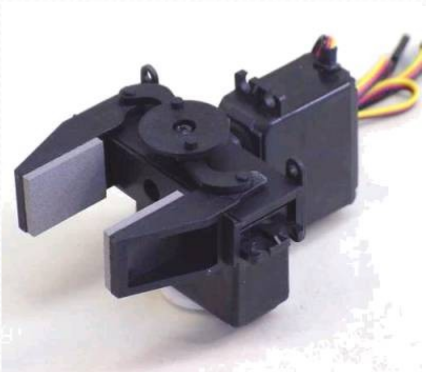
- **Hydraulic**
  - High strength and high speed
  - Large robots, Takes floor space
  - Mechanical Simplicity
  - Used usually for heavy payloads

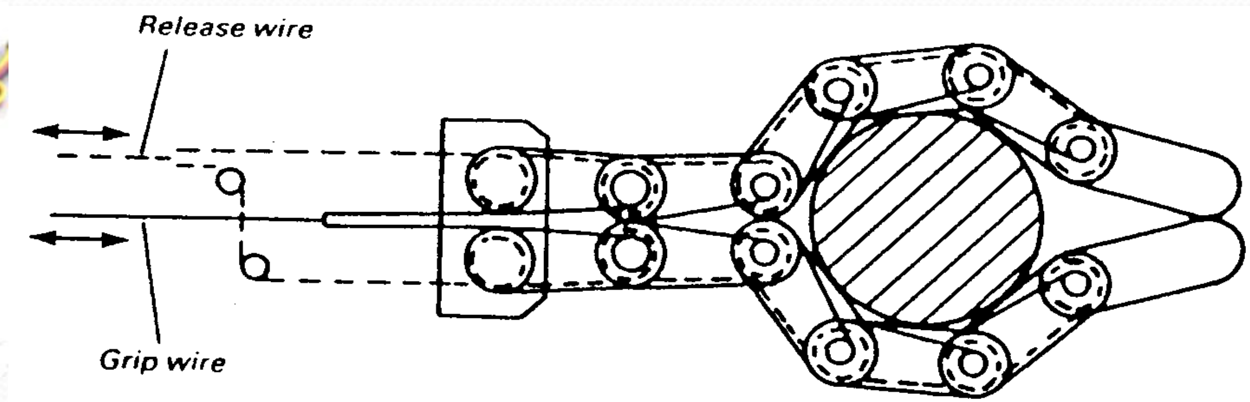
- **Electric Motor (Servo/Stepper)**
  - High accuracy and repeatability
  - Less floor space
  - Low cost
  - Easy maintenance

- **Pneumatic**
  - Smaller units, quick assembly
  - High cycle rate
  - Easy maintenance

End Effectors

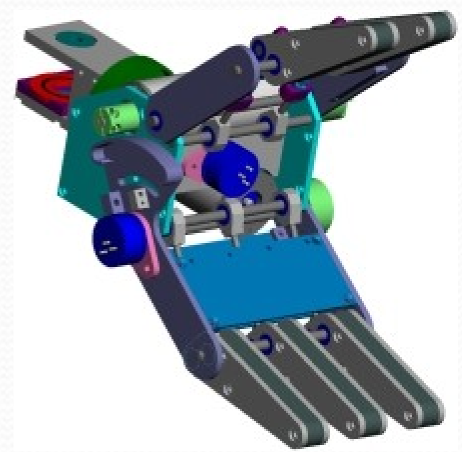
Device attached to the robot's wrist to perform a specific task





Grippers

– Mechanical Grippers
– Suction cups or vacuum cups
– Magnetized grippers
– Hooks
– Scoops (to carry fluids)



End Effectors

Device attached to the robot's wrist to perform a specific task

Tools

– Spot Welding gun
– Arc Welding tools
– Spray painting gun
– Drilling Spindle
– Grinders, Wire brushes
– Heating torches

Motion Control Methods

- **Point to point control**
  - a sequence of discrete points
  - spot welding, pick-and-place, loading & unloading
- **Continuous path control**
  - follow a prescribed path, controlled-path motion
  - Spray painting, Arc welding, Gluing

Sensors in robotics

Types of sensors :

– Tactile sensors (touch sensors, force sensors)

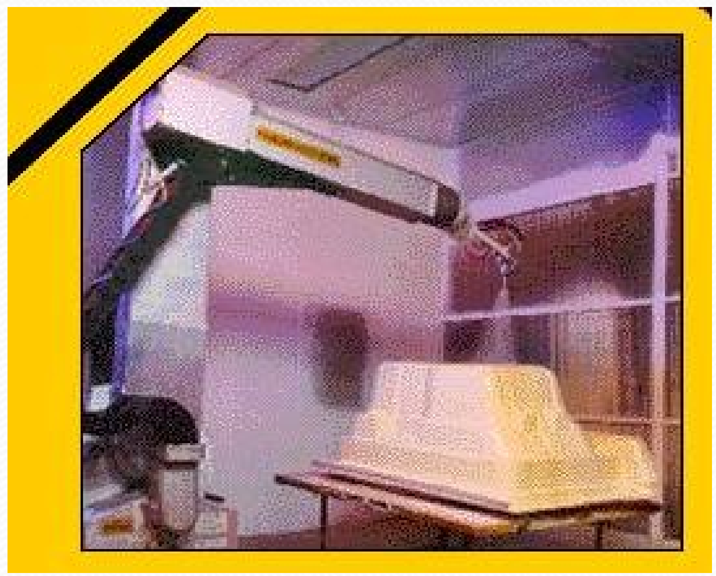
– Proximity and range sensors (optical sensors, acoustical sensors, electromagnetic sensors)

– Miscellaneous sensors (transducers and sensors which sense variables such temperature, pressure, fluid flow, thermocouples, voice sensors)

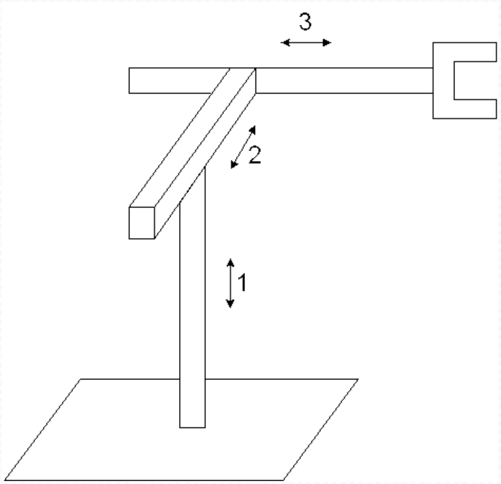
– Machine vision systems

Applications

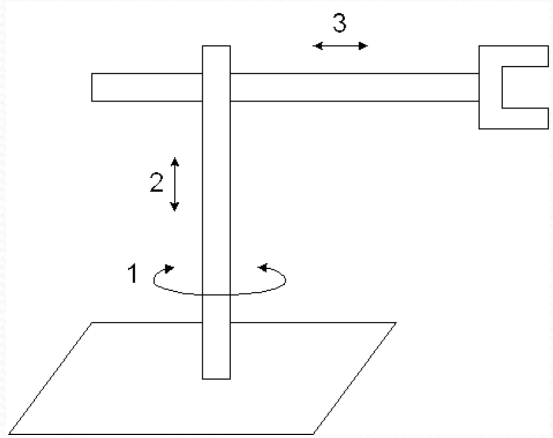
- Material Handling/Palletizing
- Machine Loading/Unloading
- Arc/Spot Welding
- Water jet/Laser cutting
- Spray Coating
- Gluing/Sealing
- Investment casting
- Assembly
- Inspection



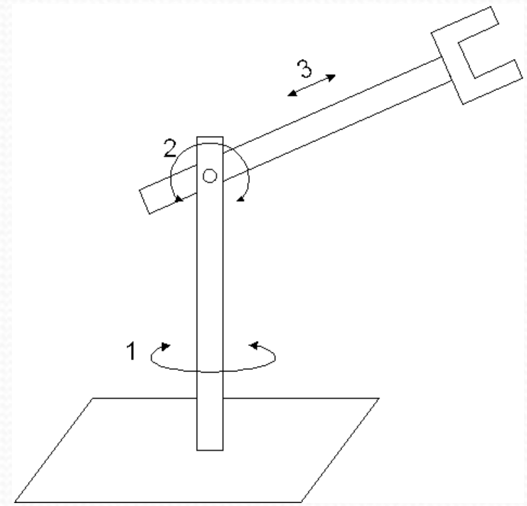
Robot Configuration (geometries)



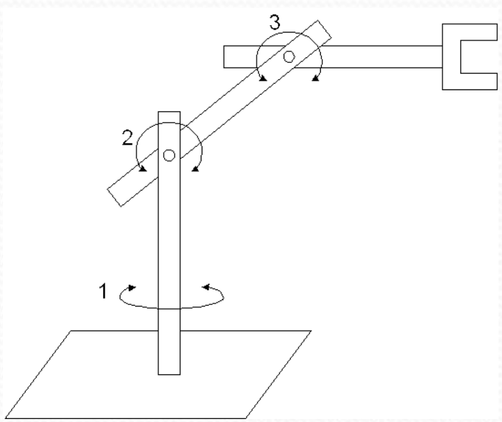
Cartesian: PPP



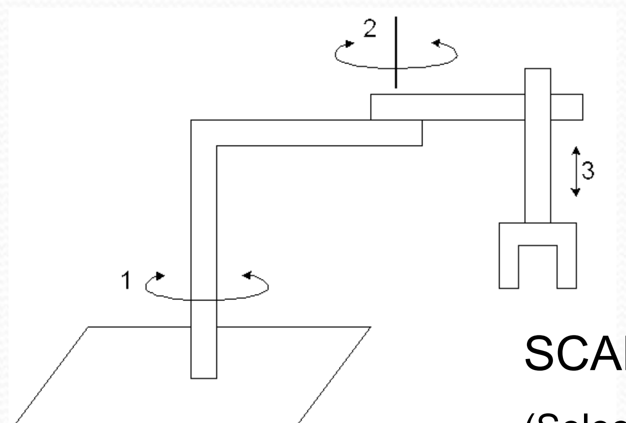
Cylindrical: RPP



Spherical: RRP



Articulated: RRR



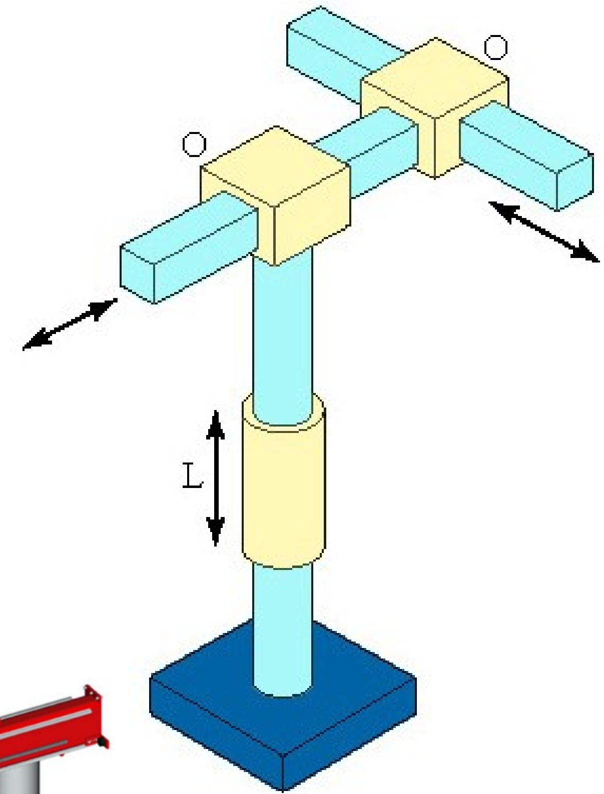
SCARA: RRP

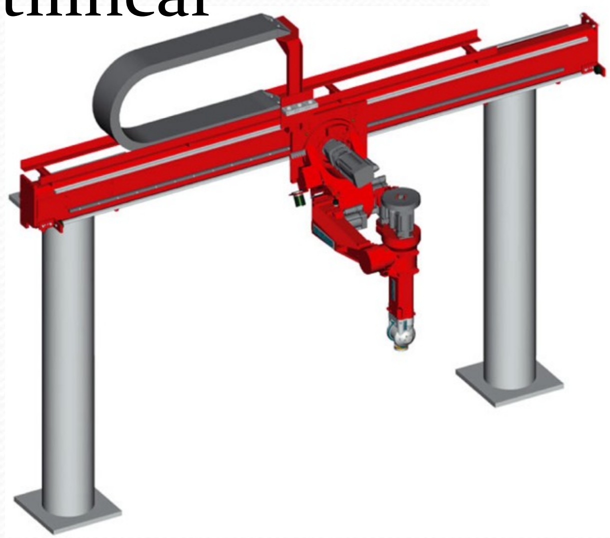
(Selective Compliance
Assembly Robot Arm)

Cartesian Coordinate

- Notation LOO:

- Consists of three sliding joints, two of which are orthogonal
- Other names include rectilinear robot and x-y-z robot

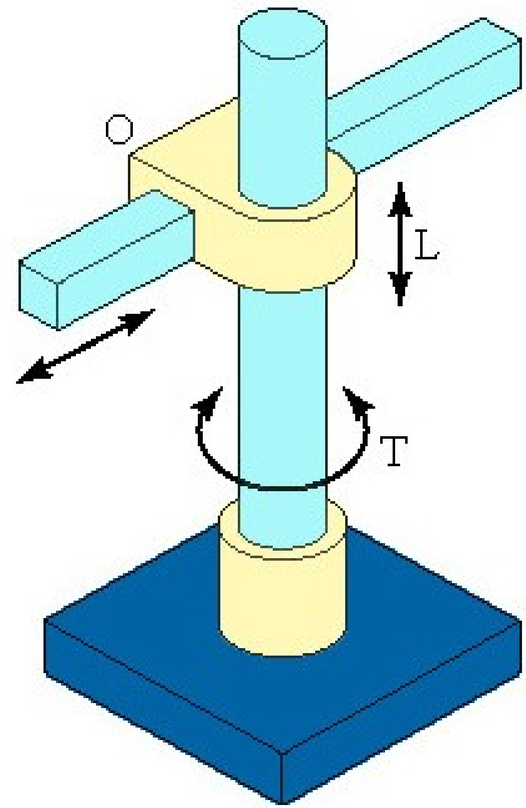




Cylindrical Coordinate

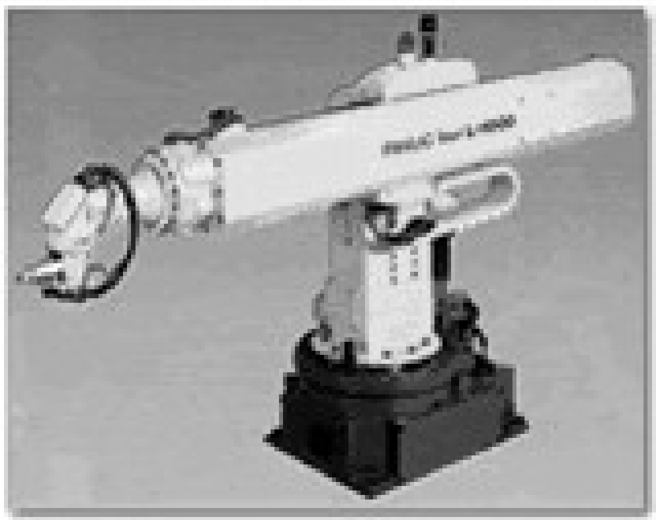
- Notation TLO:

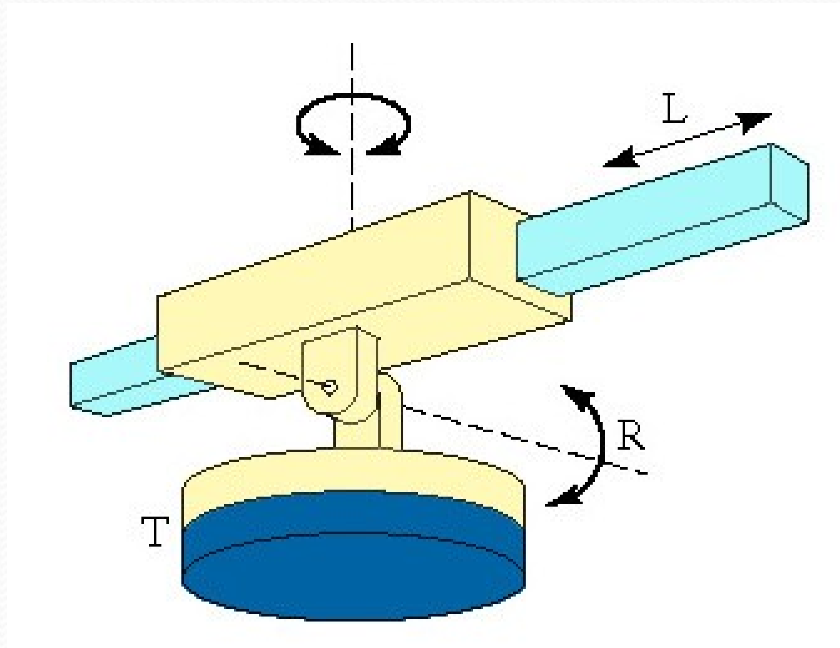
- Consists of a vertical column, relative to which an arm assembly is moved up or down
- The arm can be moved in or out relative to the column



Spherical Coordinate

- Notation TRL:

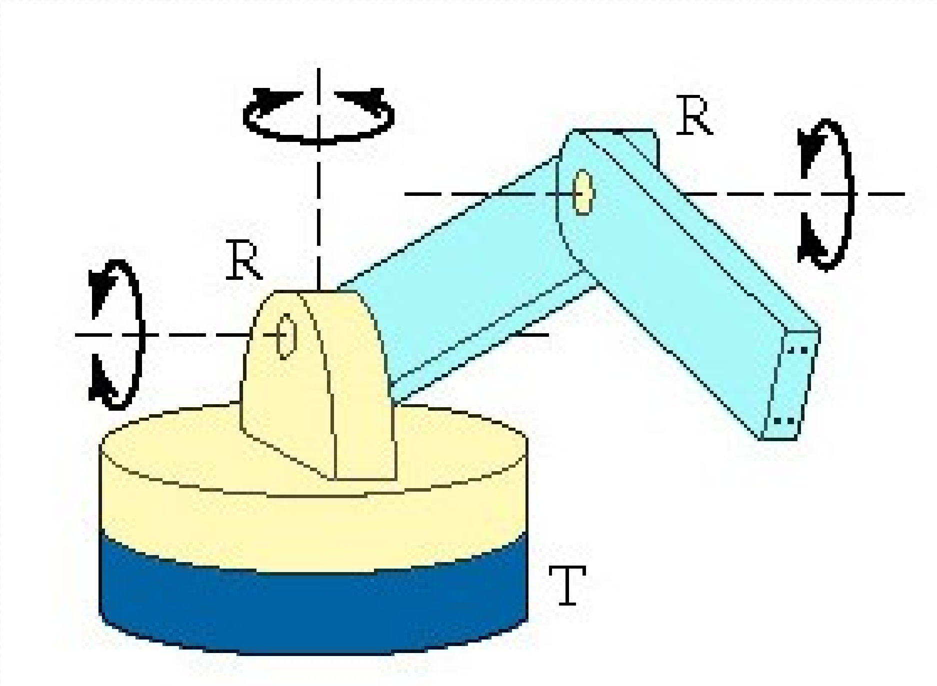




- Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint)

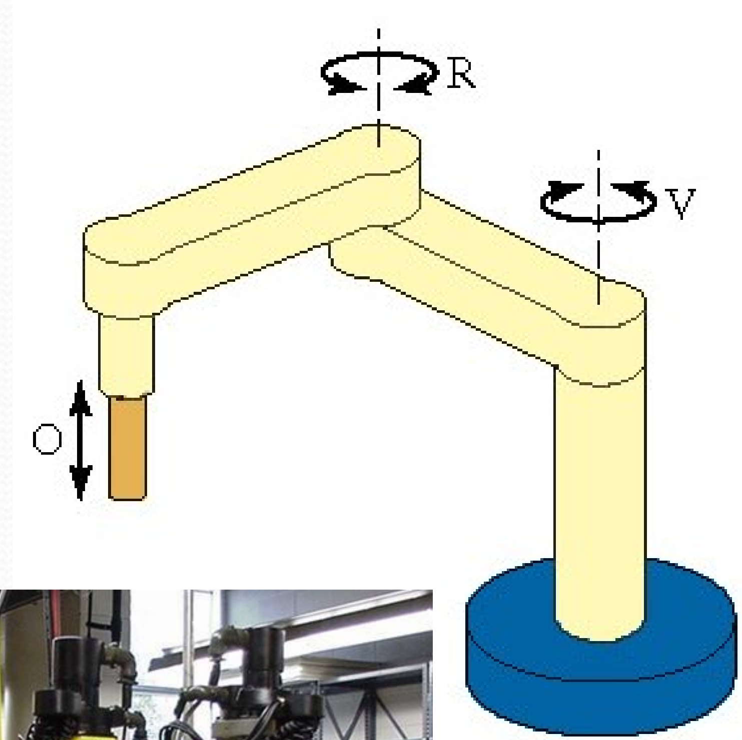
Articulated Coordinate

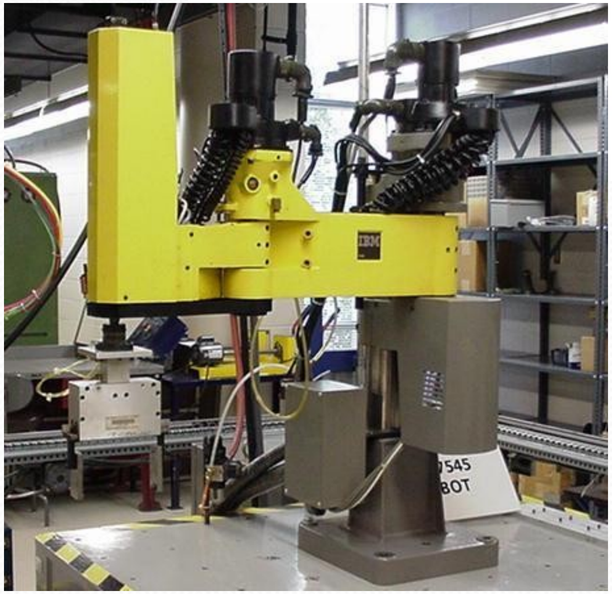
- Notation TRR:



SCARA Robot

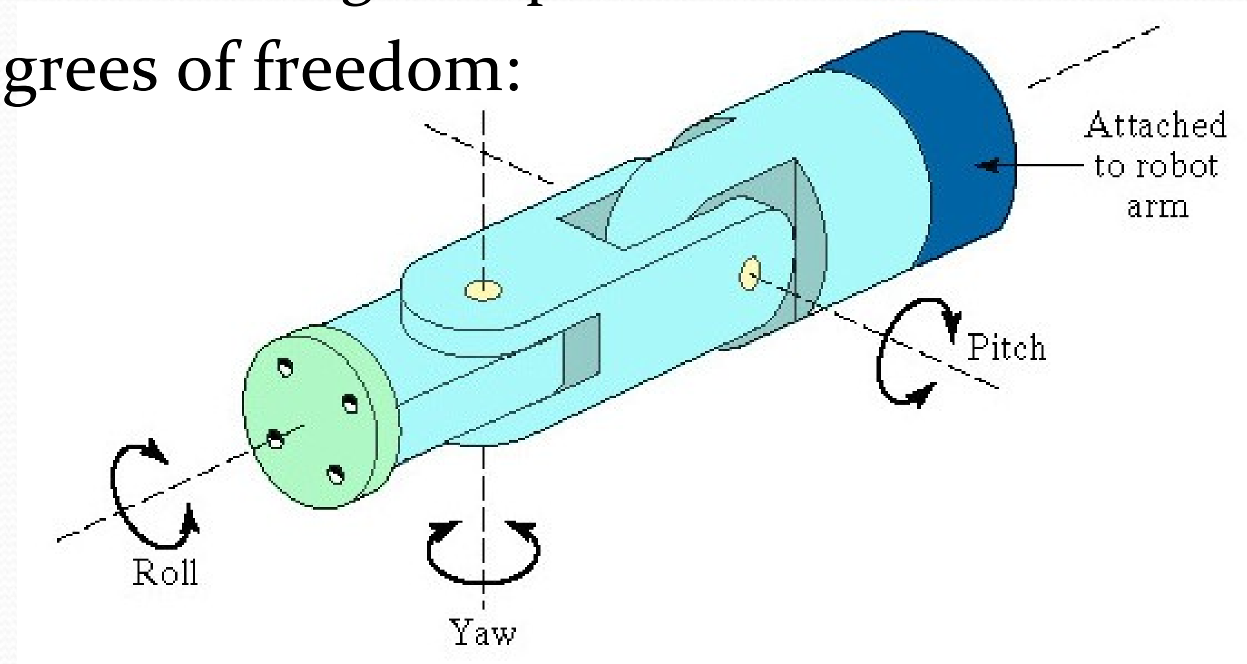
- Notation VRO
- SCARA stands for Selectively Compliant Assembly Robot Arm
- Similar to jointed-arm robot except that vertical axes are used for shoulder and elbow joints to be compliant in horizontal direction for vertical insertion tasks





Wrist Configurations

- Wrist assembly is attached to end-of-arm
- End effector is attached to wrist assembly
- Function of wrist assembly is to orient end effector
  - Body-and-arm determines global position of end effector
- Two or three degrees of freedom:
  - Roll
  - Pitch
  - Yaw
- Notation :RRT



Performance Specifications of Industrial Robots

- Robot Specifications
  - Number of Axes
    - Major axes, (1-3) => Position the wrist
    - Minor axes, (4-6) => Orient the tool
    - Redundant, (7-n) => reaching around obstacles, avoiding undesirable configuration
  - Payload (load capacity).
  - Repeatability.
  - Precision and accuracy.
  - Maximum speed.

Capacity and speed

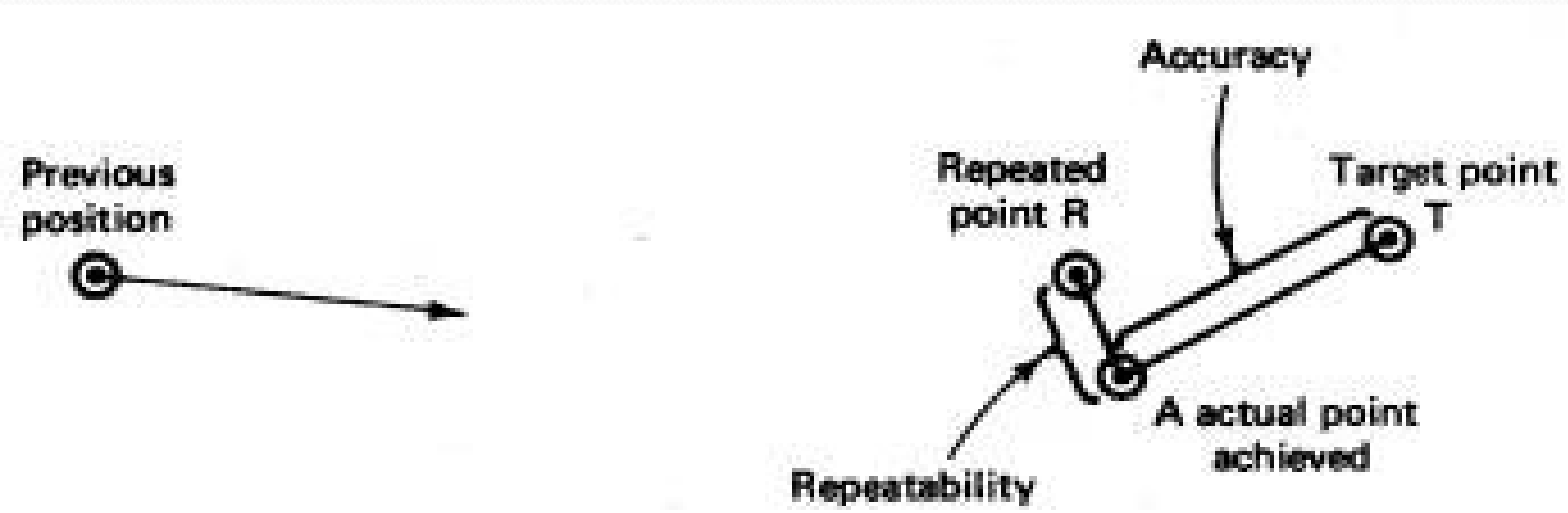
- Load-carrying capacity varies between robots
  - Minimover 5 Microbot educational table-top robot can handle 2.2 Kg load
  - but GCA-XR6 Extended Reach industrial robot is designed for loads of 4928 Kg

- Maximum tool-tip speed may vary between robots
  - Westinghouse Series 4000 => tool-tip speed= 92 mm/sec
  - Adept One SCARA => tool-tip speed= 9000 mm/sec

Repeatability

Ability to position back to a point that was previously taught

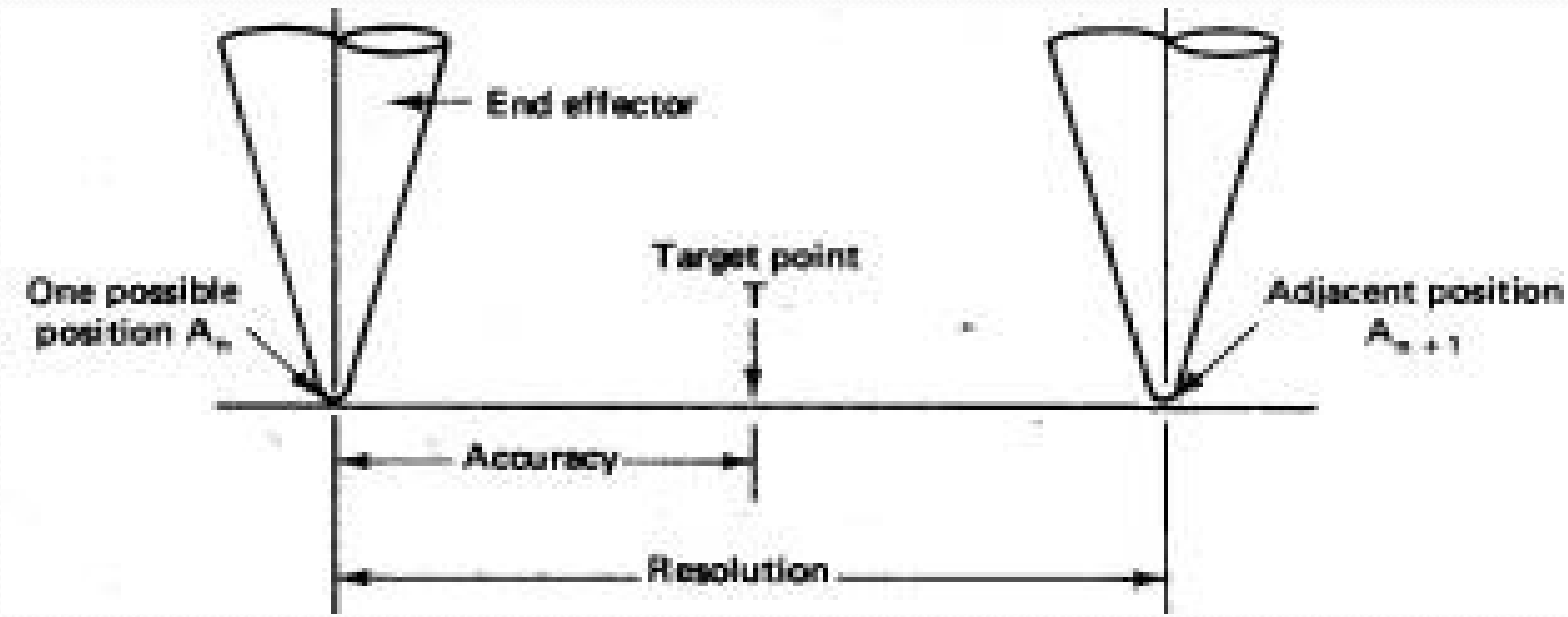
- Repeatability errors form a random variable.
- Mechanical inaccuracies in arm, wrist components
- Larger robots have less precise repeatability values



Spatial Resolution (Precision)

Smallest increment of motion of the tool that can be controlled by the robot

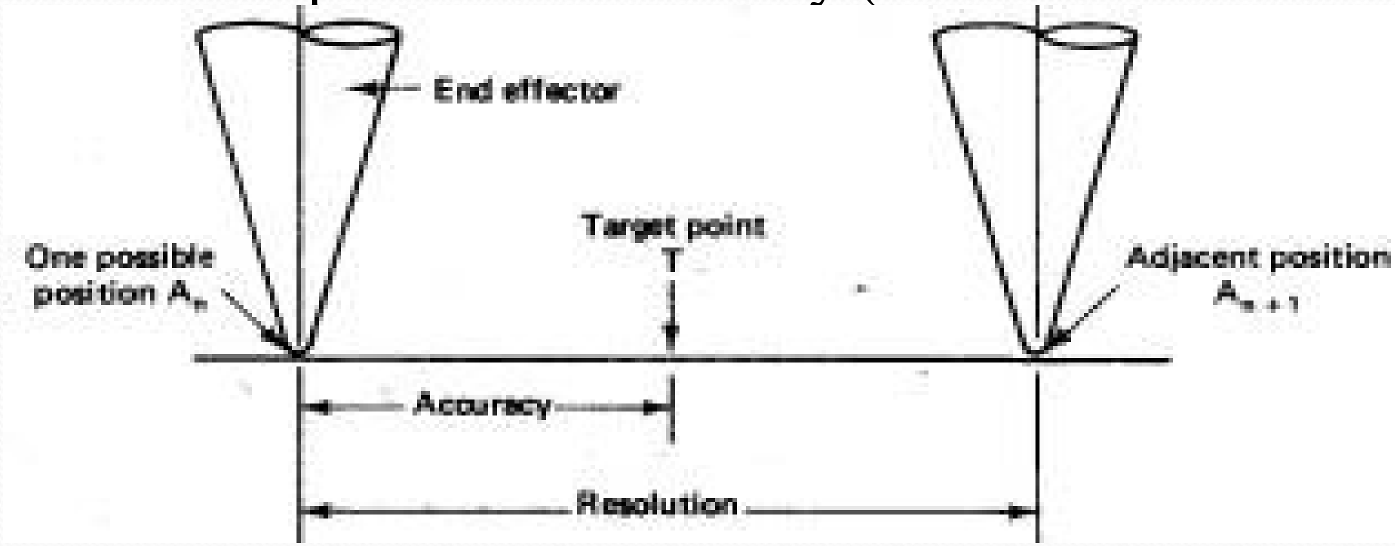
Depends on the position control system, feedback measurement, and mechanical accuracy



Accuracy

Capability to position the tool at a target point in the work volume

- One half of the distance between two adjacent resolution points
- Affected by mechanical Inaccuracies
- Manufacturers don’t provide the accuracy (hard to control)



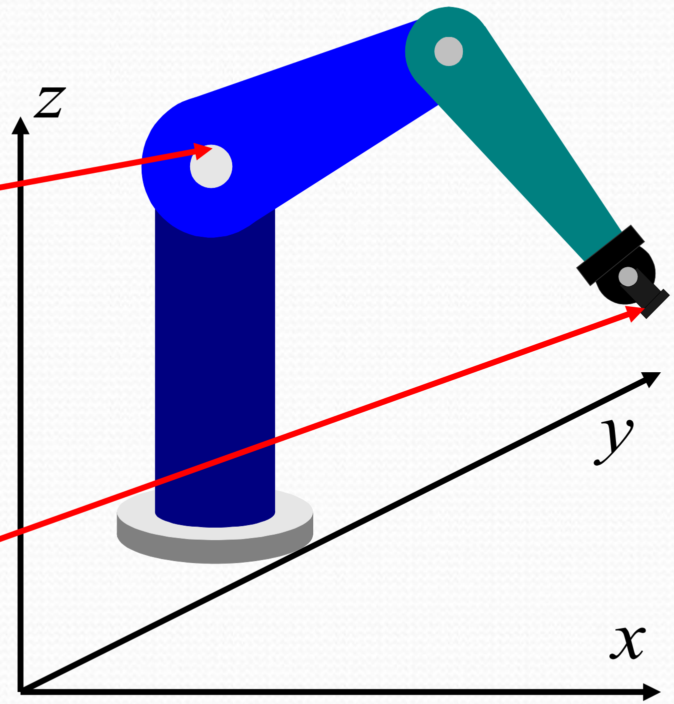
What is Kinematics

- Forward kinematics

Given joint variables

$$q = (q_1, q_2, q_3, q_4, q_5, q_6, \cdots q_n)$$

$$Y = (x, y, z, R_{13}, R_{23}, R_{33})$$



End-effector position and orientation, -Formula?

What is Kinematics

- Inverse kinematics

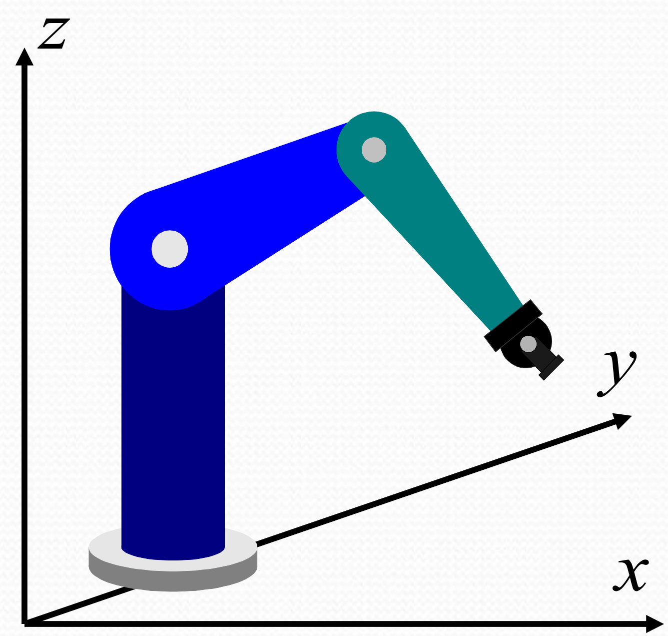
End effector position

and orientation

$$(x, y, z, R_{13}, R_{23}, R_{33})$$

$$\Downarrow$$

$$q = (q_1, q_2, q_3, q_4, q_5, q_6, \cdots q_n)$$



Joint variables -Formula?

Example 1

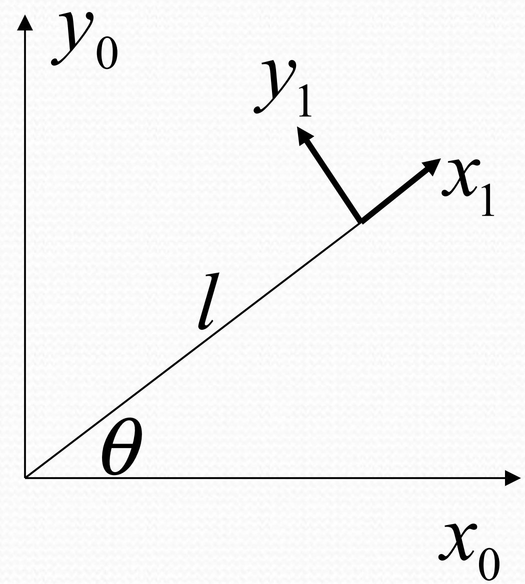
Forward kinematics

$$x_0 = l\cos\theta$$

$$y_0 = l\sin\theta$$

Inverse kinematics

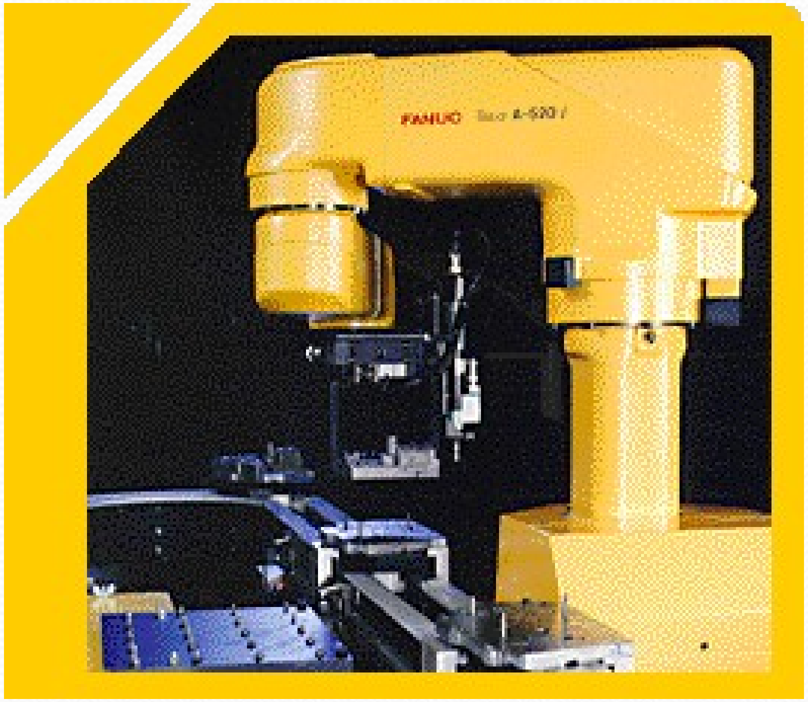
$$\theta = \cos^{-1}(x_0 / l)$$



Robot Applications (Configurations/Characteristics)

SCARA Robot

(Selective Compliance Assembly Robot Arm)



Characteristics:

•Repeatability: < 0.025mm (high)
•No. of axes: min 4 axes
• Vertical motions smoother, quicker, precise (due to dedicated vertical axis)
• Good vertical rigidity, high compliance in the horizontal plane.
•Working envelope: range < 1000mm
•Payload:10-100 kg
•Speed: fast 1000-5000mm/s

Applications:

•Precision, high-speed, light assembly

Robot Applications (Configurations/Characteristics)

Cylindrical Coordinate Robot

Characteristics:

- Wide range of sizes
- Repeatability: vary 0.1-0.5mm
- No. of axes: min 3 arm axes (2 linear)
- Working envelope: typically large (vertical stroke as long as radial stroke)
- The structure is not compact.
- Payload: 5 - 250kg
- Speed: 1000mm/s, average
- Cost: inexpensive for their size and payload

Applications:

- Small robots: precision small assembly tasks
- Large robots: material handling, machine loading/unloading.

Robot Applications (Configurations/Characteristics)

Vertical Articulated Arm Robot

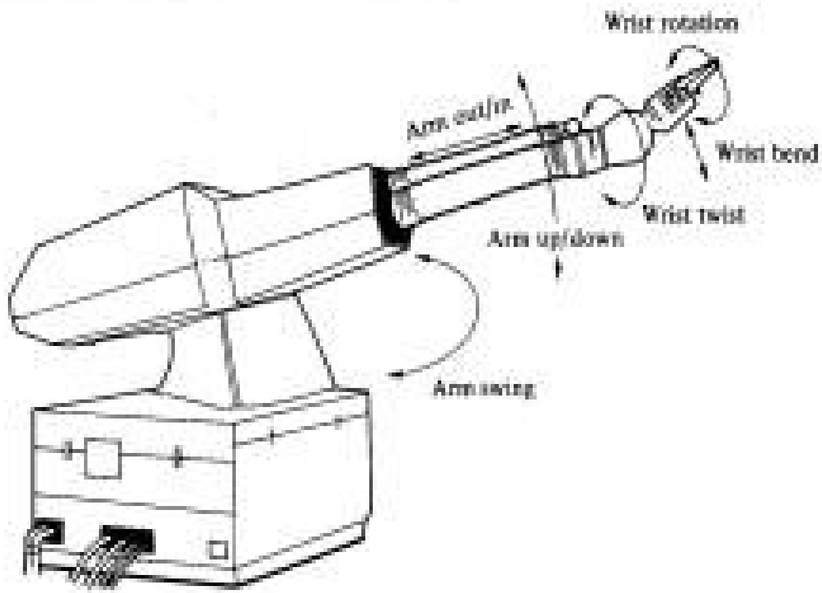
Characteristics:

- Repeatability: 0.1-0.5mm (large sizes not adequate for precision assembly)
- No. of axes: 3 rotary arm-axes, 2-3 additional wrist axis (excellent wrist articulation)
- Working envelope: large relative to the size, Structure compact, but not so rigid
- Payload: 5-130kg
- Tool tip speed: fast 2000mm/s

Applications: Welding, painting, sealing, deburring, and material handling

Robot Applications (Configurations/Characteristics)

Spherical Coordinate Robot



Characteristics:

- Repeatability: poor 0.5-1mm
- No. of axes: 3 arm-axes (1 linear radial), 1-2 additional wrist-axes.
- Working envelope: large vertical envelope relative to the unit size
- Payload: 5-100 kg
- Speed: low (linear motions are not smooth and accurate- require coordination of multiple axes)

Applications: Material handling, spot welding, machine loading

Robot Applications (Configurations/Characteristics)

Cartesian Coordinate Robot

Characteristics:

- Repeatability: high (0.015-0.1)
- No. of axes: 3 linear arm-axis,
- Working envelope:relative large
- Payload:5- 100kg
- Speed: fast

Applications: Precise assembly, arc welding, gluing, material handling

Robot Applications (Configurations/Characteristics)

Gantry Robot

Characteristics:

•Repeatability: 0.1-1mm
•No. of axes: 3 linear traverse-axes, 1-3 additional wrist axes
•Working envelope: very large
•Payload: vary function of size, support very heavy 10-1000kg
•Speed: low for large masses

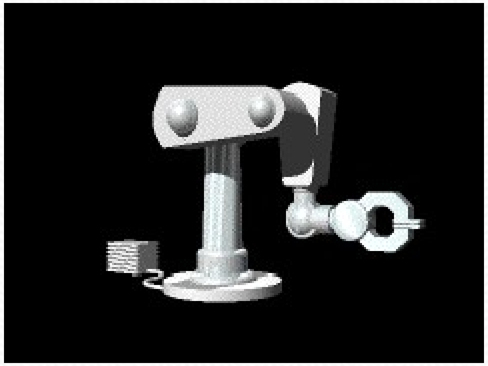
Applications:

Handling very large parts, moving material on long distances, welding, gluing.

The Advantages of Industrial Robots

- **Competitive Advantage**
  - Robots can do some things more efficiently and quicker than humans.
- **Mechanical**
  - Robots never get sick or need to rest, so they can work 24 hours a day, 7 days a week.
  - Greater output per hour with consistent quality
  - Continuous precision in repetitive operation.

Limitations of Robotics



Today's robots:

- Are not creative or innovative
- Can not think independently
- Can not make complicated decisions
- Can not learn from mistakes
- Can not adapt quickly to changes in their surroundings

Every successful business must depend on real people for these abilities.