Robotics

End of Arm Tooling for Industrial Robots

End-of-arm Tooling

- End Effector = Gripper
- Mounted to a tooling plate
- Cost of end-of-arm tooling can account for 20% of the total cost of the robot
- Two Functions:
  1. Hold the part while work is being performed
  2. Hold tool which is performing work on the part

End Effector Types

1) Standard Grippers (Angular and parallel, Pneumatic, hydraulic, electric, spring powered, Power-opened and Spring-closed, PC-SO, PO-PC)
2) Vacuum Grippers (Single or multiple, use venturi or vacuum pump)
3) Vacuum Surfaces (Multiple suction ports, to grasp cloth materials, flat surfaces, sheet material)

End Effector Types

4) Electromagnetic Grippers (often used in conjunction with standard grippers)

5) Air-Pressure Grippers (balloon type)

   1. Pneumatic fingers
   2. Mandrel grippers
   3. Pin grippers

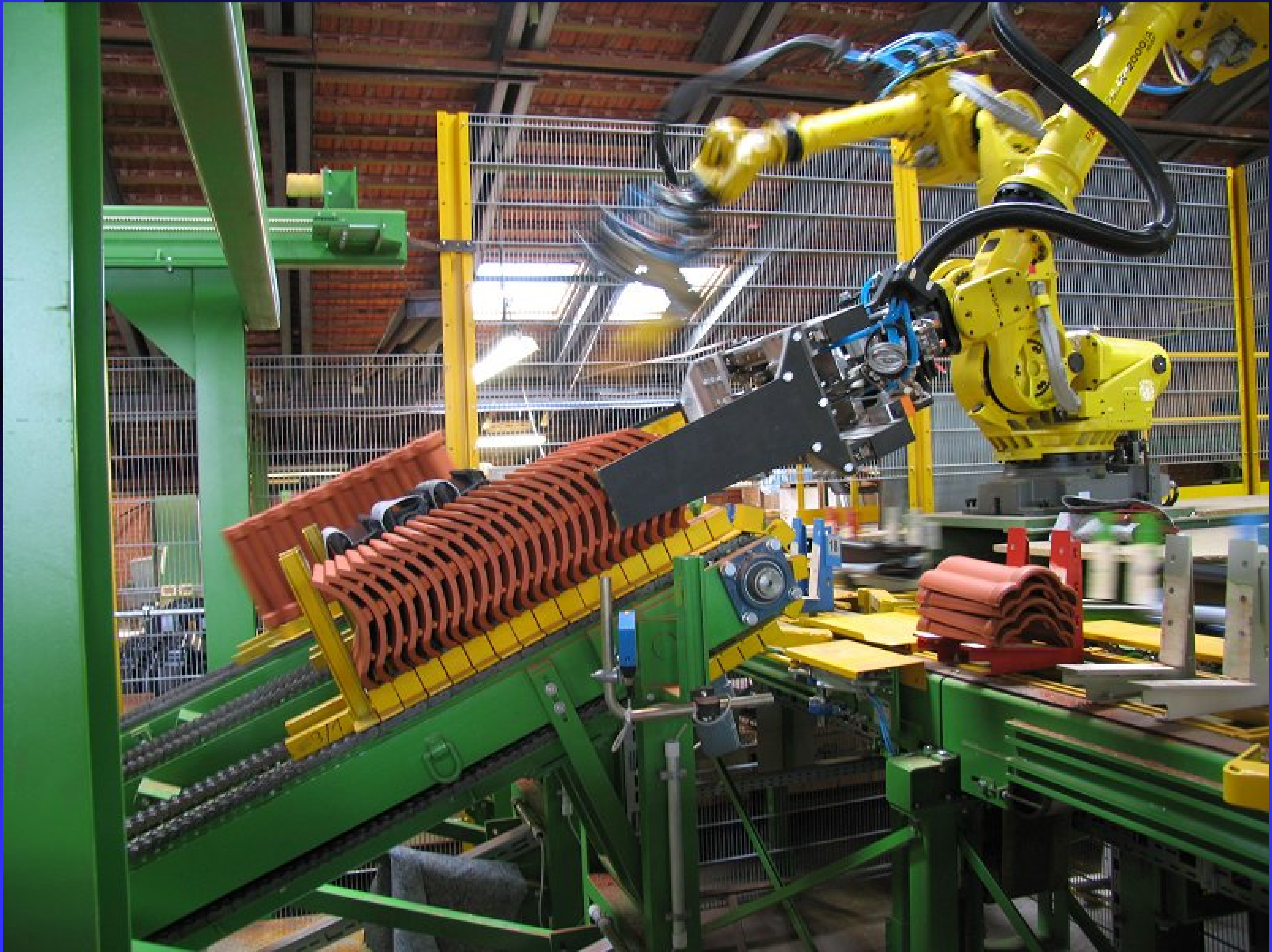
6) Special Purpose Grippers (Hooking devices, custom positioners or tools)

End Effector Types

7) Welding (Mig/Tig, Plasma Arc, Laser, Spot)
8) Pressure Sprayers (painting, waterjet cutting, cleaning)
9) Hot Cutting type (laser, plasma, deflashers-hot knife)
10) Buffing/Grinding/Deburring type
11) Drilling/Milling type
12) Dispensing type (adhesive, sealant, foam)

Standard Parallel Robot Gripper

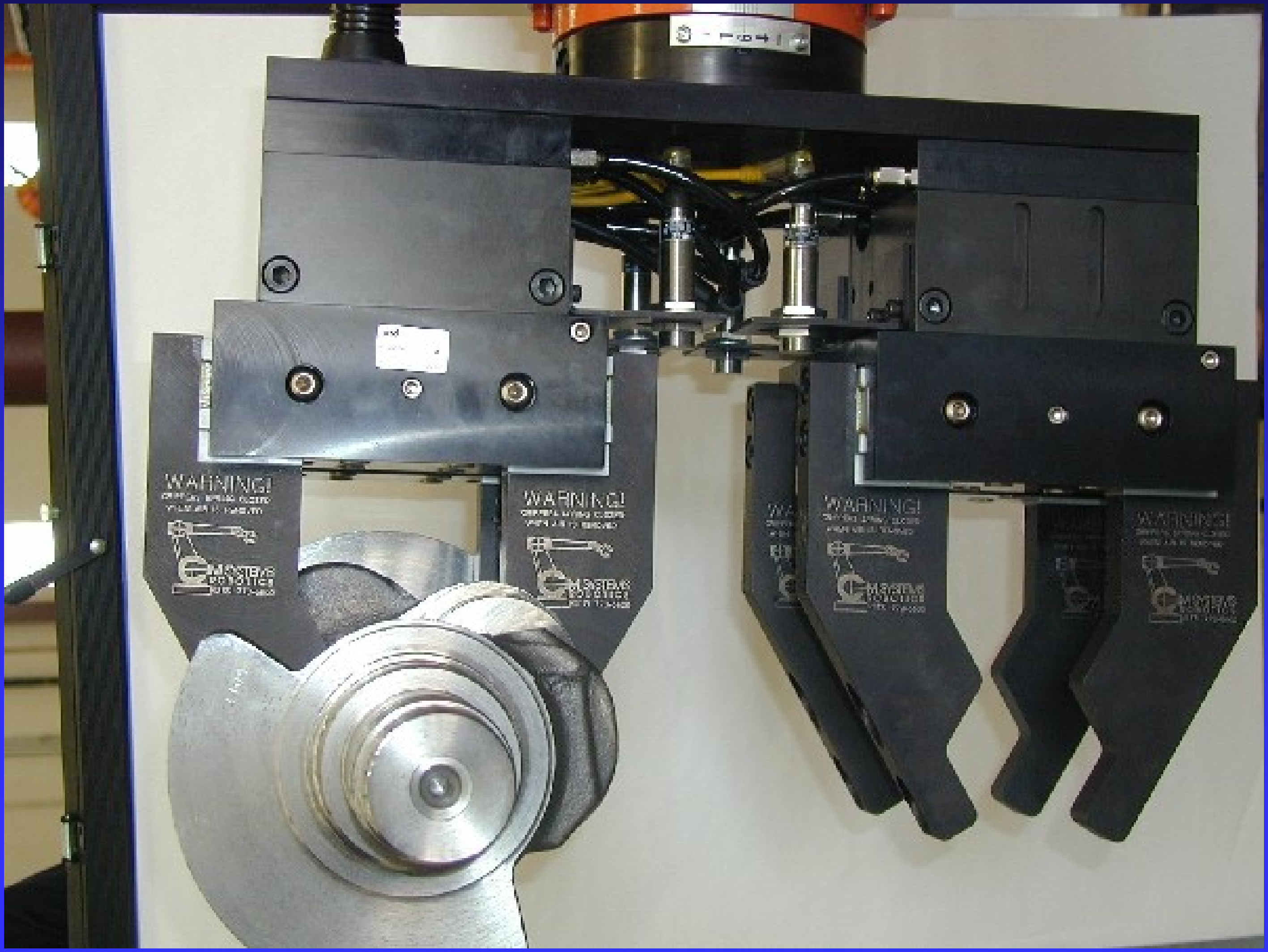
Standard Parallel Robot Gripper



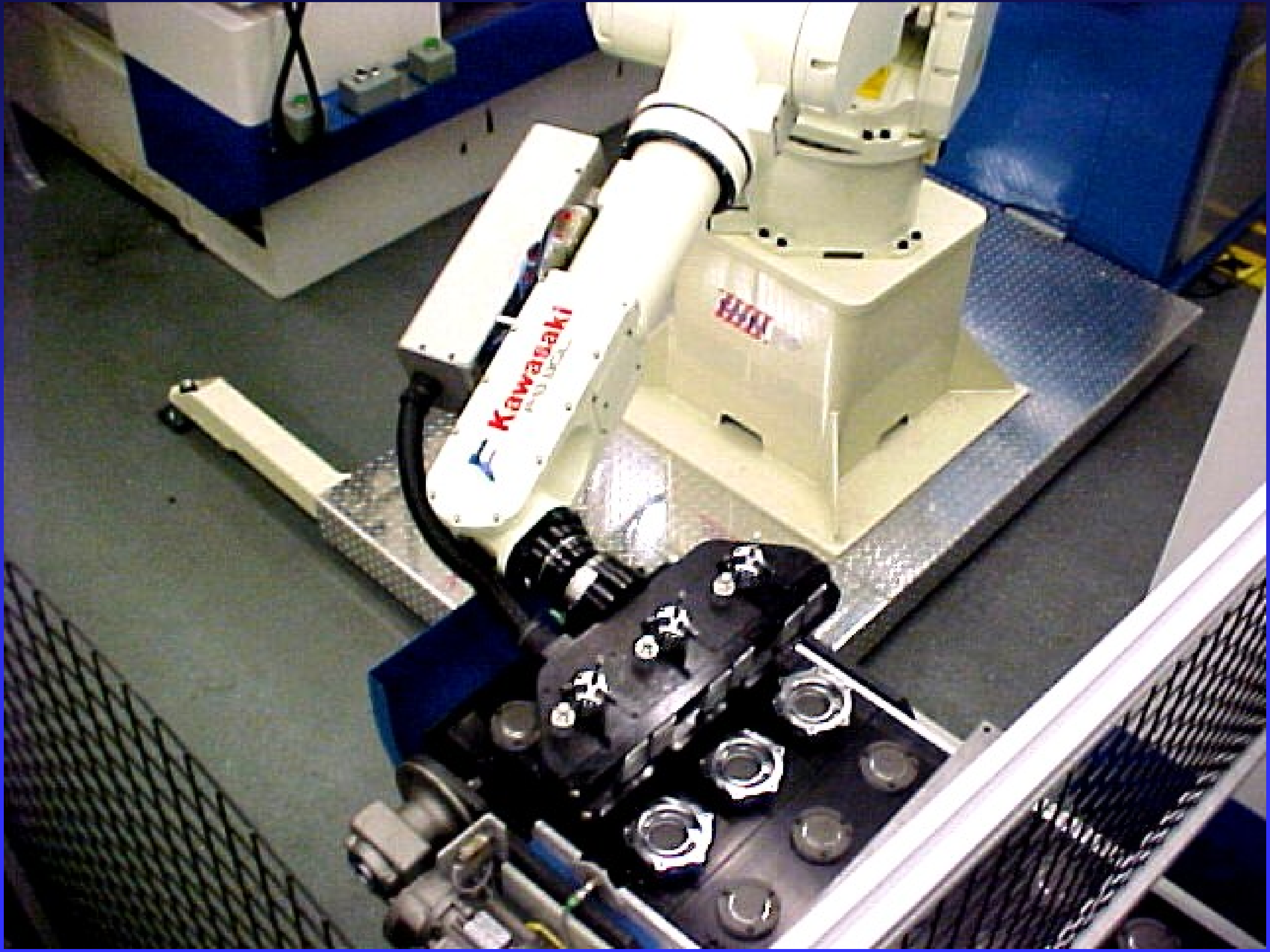
Standard Parallel Robot Gripper

Standard Parallel Robot Gripper

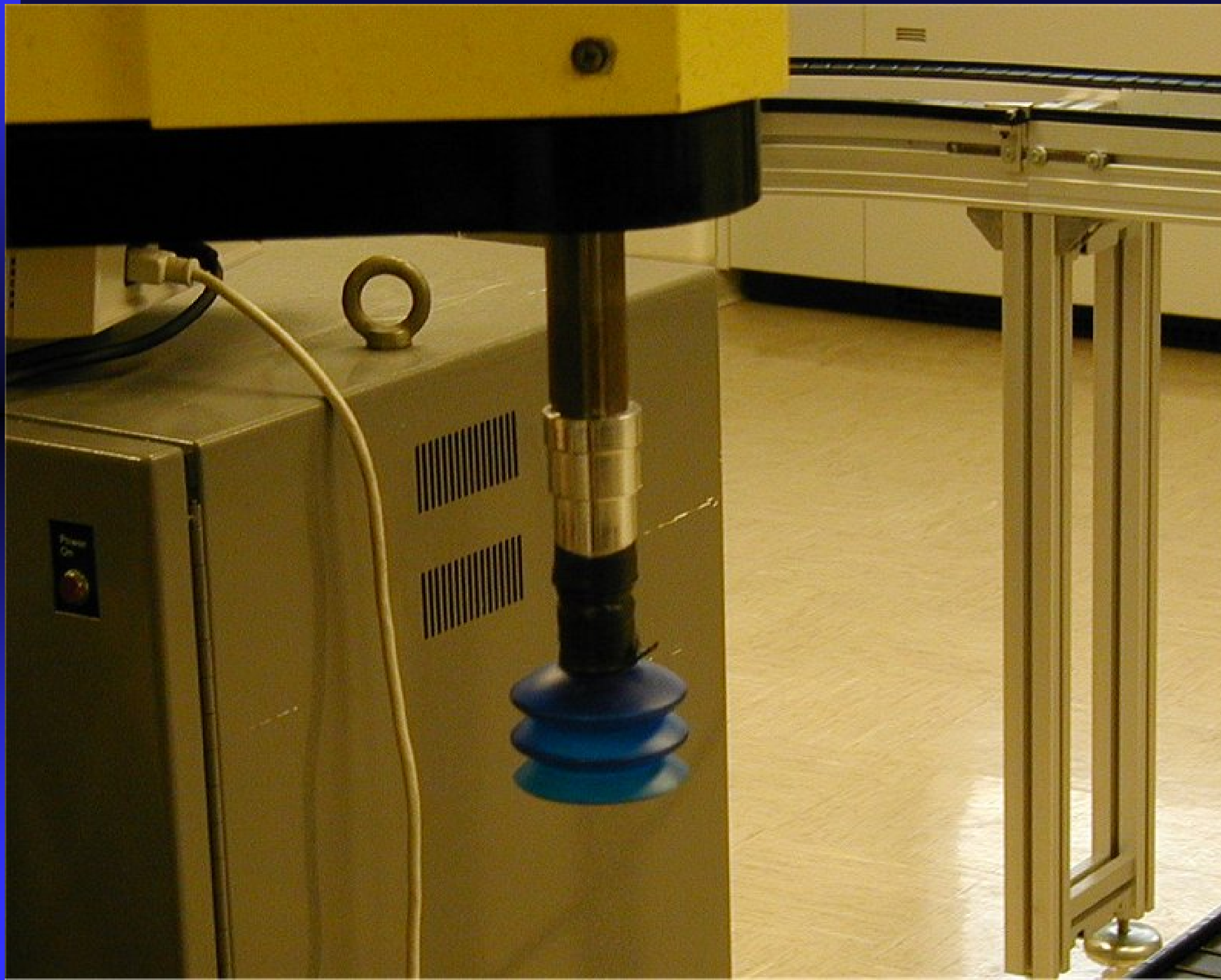
Standard Angular Robot Gripper(multiple end effector)



Multipart Robot Gripper

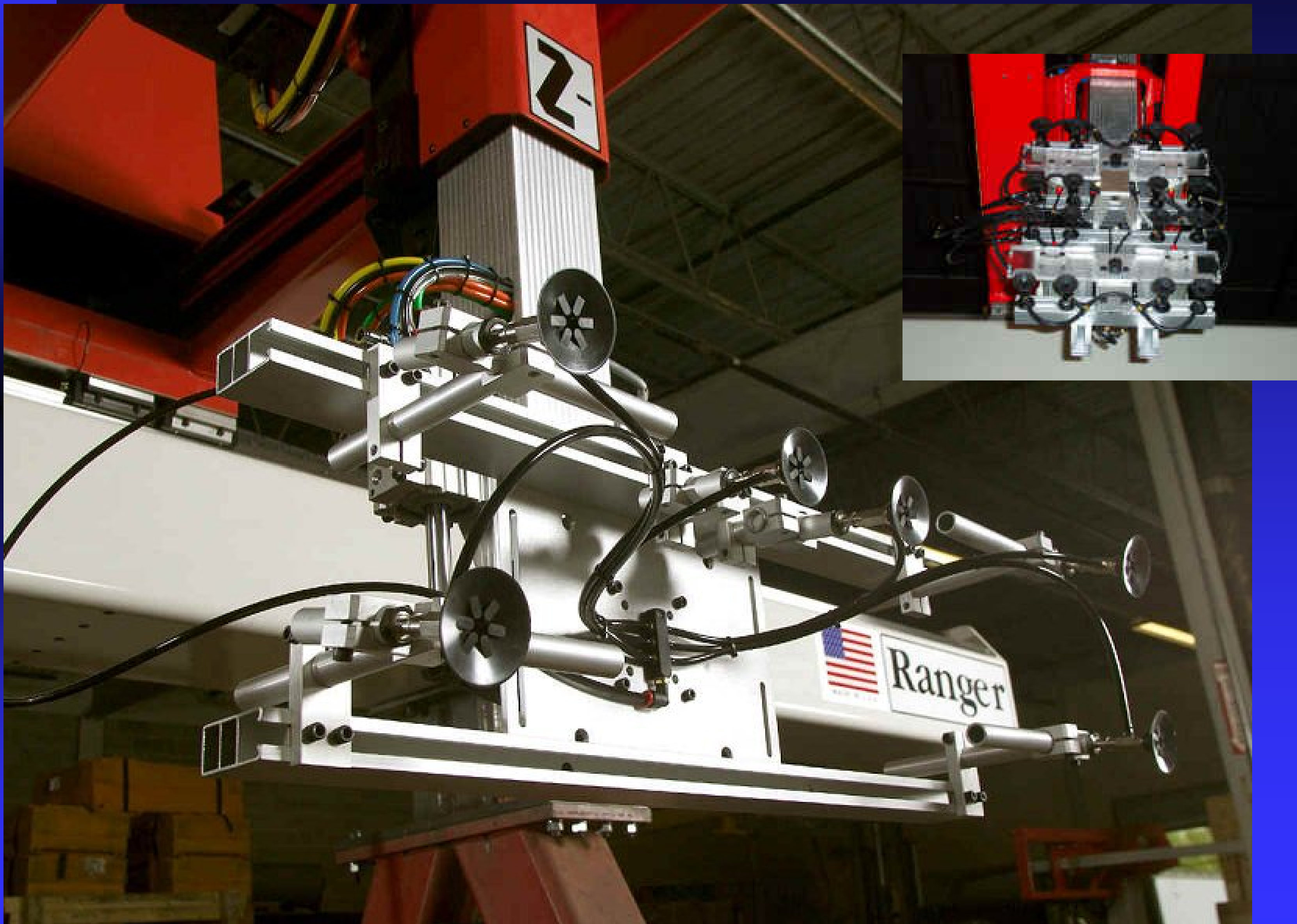


Vacuum Cup Robot Gripper

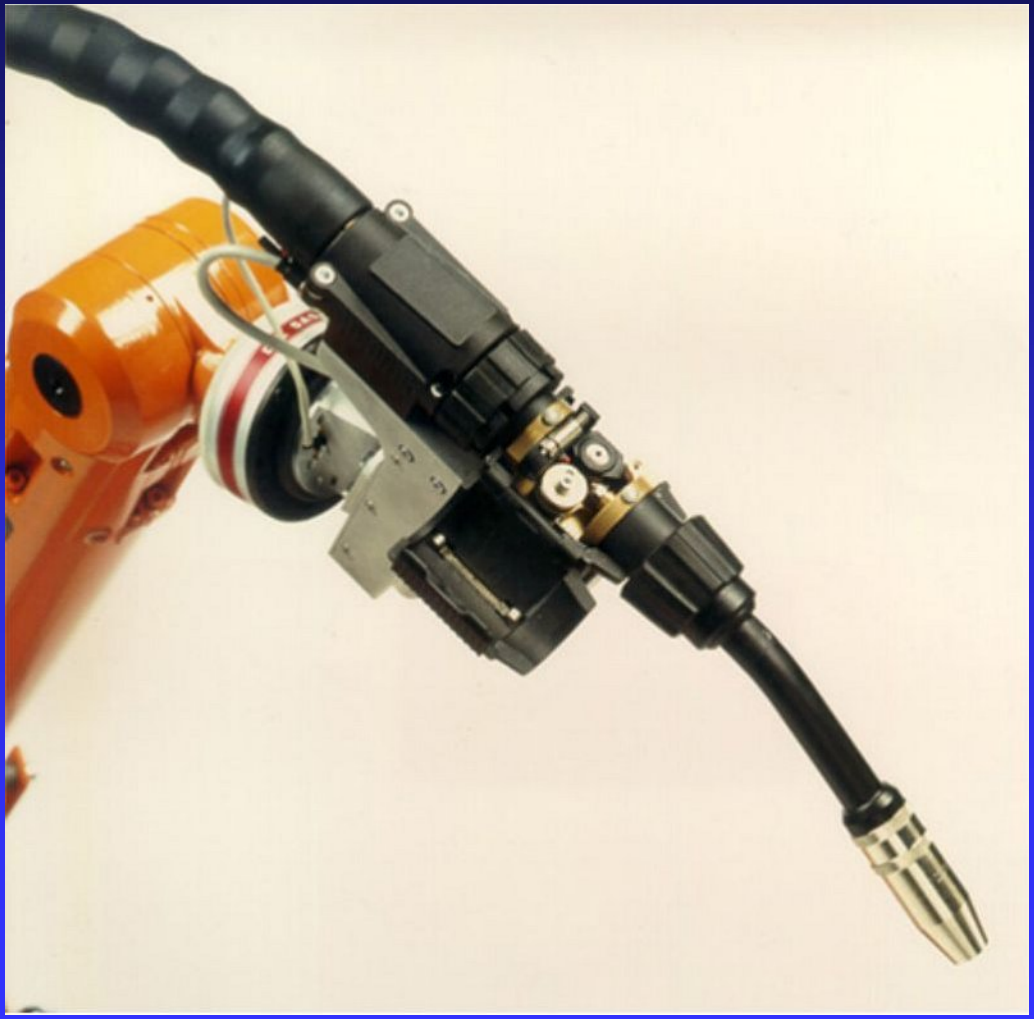


Multiple Vacuum Cup Robot Gripper

Multiple Vacuum Cup Robot Gripper



Robot Arc Welding Torch



Robot Welding Tool

Robot Sprayer

Robot Deburrer

Special Purpose Gripper:Palletizing

Special Purpose Gripper:Bagger

Special Purpose Tool:Sewing Robot

Special Purpose Tool:Palletizing

- Bottle Palletizing Clip

Multiple End-Effector Systems

- Two or more grippers or end-of-arm tools
- Can be used interchangeably in the manufacturing cell

Multiple End-Effector Systems

- Advantages:
  1) Increasing the production capability of the work cell
  2) Reduces process time for operation
  3) Fewer motions

Multiple End-Effector Systems

- Disadvantages:
  1) Additional complexity is added to the tooling
  2) Greater costs for design

Multiple End-Effector System

Robot Compliance

- Relationship between mating parts in an assembly operation
- Means initiated or *allowed part movement* for the purpose of alignment between mating parts

Active Compliance

- Use sensors or vision-type systems for realignment

1) The forces caused by part misalignment are measured by sensors

2) The degree of misalignment in all directions is transmitted back to the robot controller

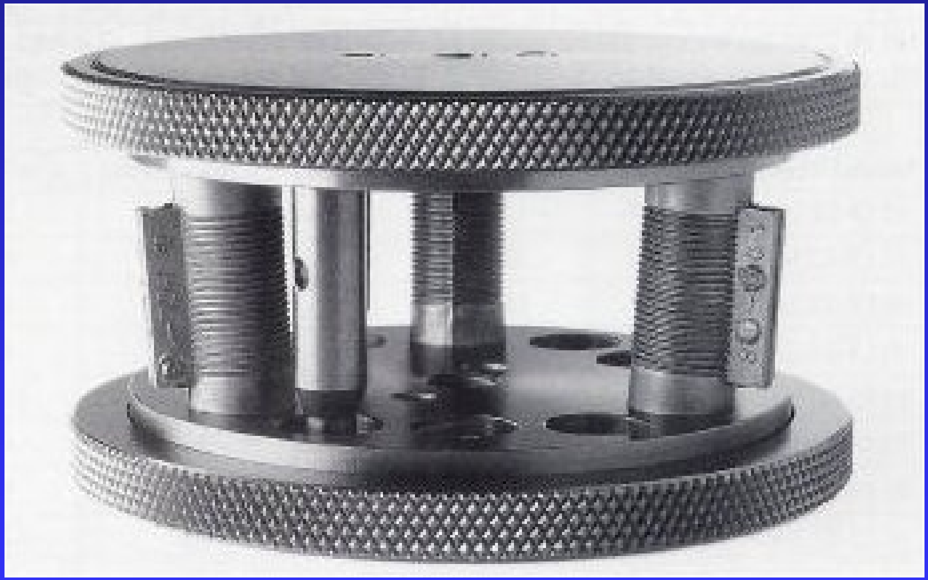
3) The gripper is moved by the controller to correct the misalignment

Passive Compliance

- Provides compliance mechanically by means of a remote center compliance device (RCC)
- Remote center (RCC) results are caused by forces applied to part in the gripper
- Links (rods) are used for compensation for rotary or lateral movements

RCC Device

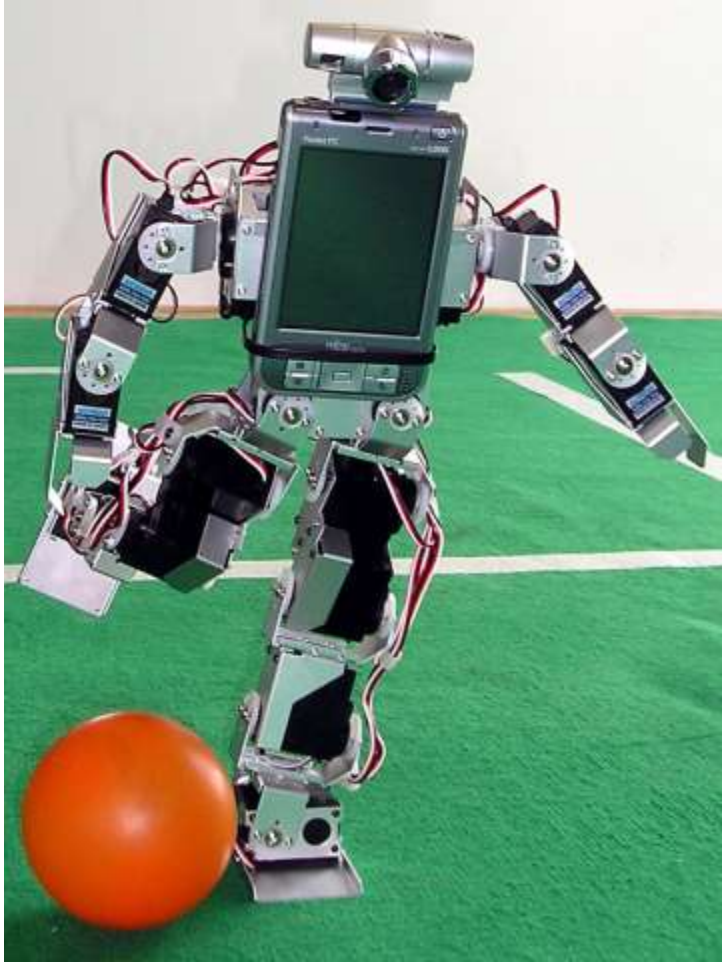
- Click on image for more information.

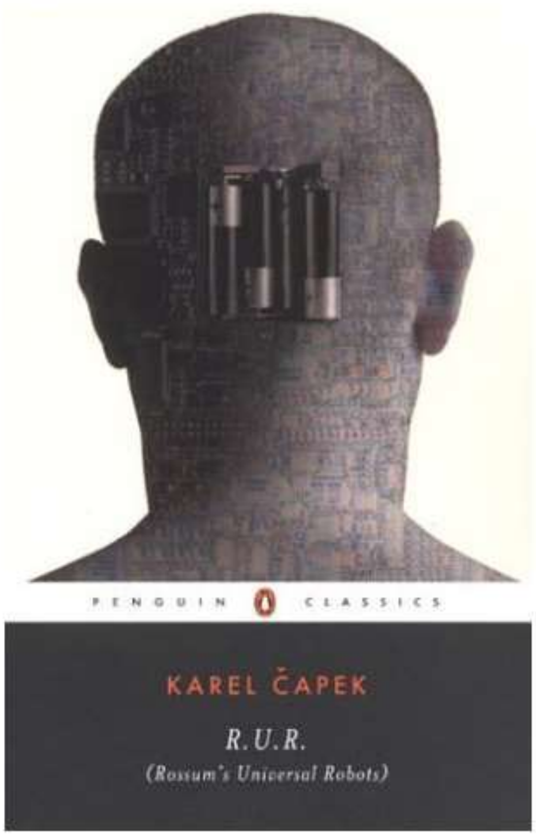


Selective Compliance Articulated Robot Arm (SCARA)

- Movement of end-effector is restricted to a tolerance range after a programmed point is reached (to complete the operation)

Robotics





"Robot" coined by Karel Capek in a 1921 science-fiction Czech play

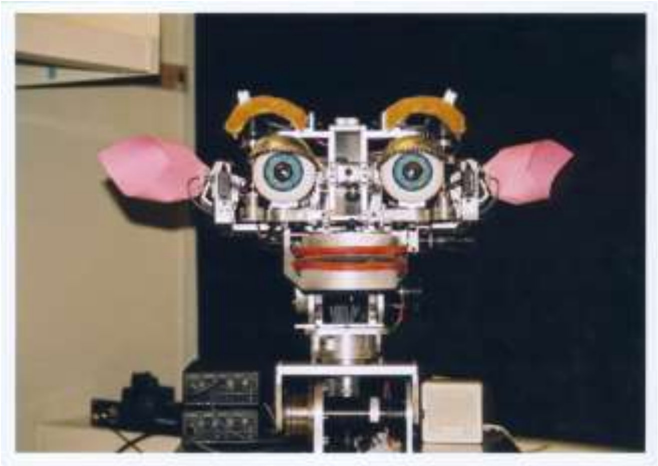
Definition:

"A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." (Robot Institute of America)

Alternate definition:

"A robot is a one-armed, blind idiot with limited memory and which cannot speak, see, or hear."

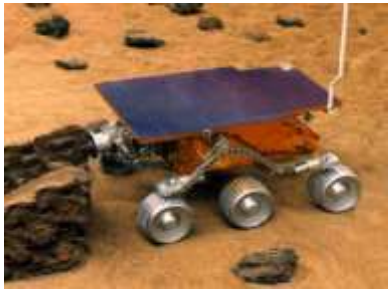
MIT's Kismet: a robot which exhibits expressions, e.g., happy, sad, surprise, disgust.



Ideal Tasks

Tasks which are:

- Dangerous
  - Space exploration
  - chemical spill cleanup
  - disarming bombs
  - disaster cleanup
- Boring and/or repetitive
  - Welding car frames
  - part pick and place
  - manufacturing parts.
- High precision or high speed
  - Electronics testing
  - Surgery
  - precision machining.



Automation vs. robots

- Automation –Machinery designed to carry out a specific task
  - Bottling machine
  - Dishwasher
  - Paint sprayer

(These are always better than robots, because they can be optimally designed for a particular task).

- Robots – machinery designed to carry out a variety of tasks
  - Pick and place arms
  - Mobile robots
  - Computer Numerical Control machines

Types of robots

- Pick and place
  - Moves items between points

A SCARA robot (Selective Compliant Articulated Robot Arm): A pick-and-place robot with angular x-y-z positioning (Adept Technology)

- Continuous path control
  - Moves along a programmable path

A six-axis industrial robot ($60K)(Fanuc Robotics), but an additional $200K is often spent for tooling and programming.

- Sensory
  - Employs sensors for feedback

Pick and Place

- Moves items from one point to another
- Does not need to follow a specific path between points
- Uses include loading and unloading machines, placing components on circuit boards, and moving parts off conveyor belts.

A cartesian robot for picking and placing circuits on circuit-boards

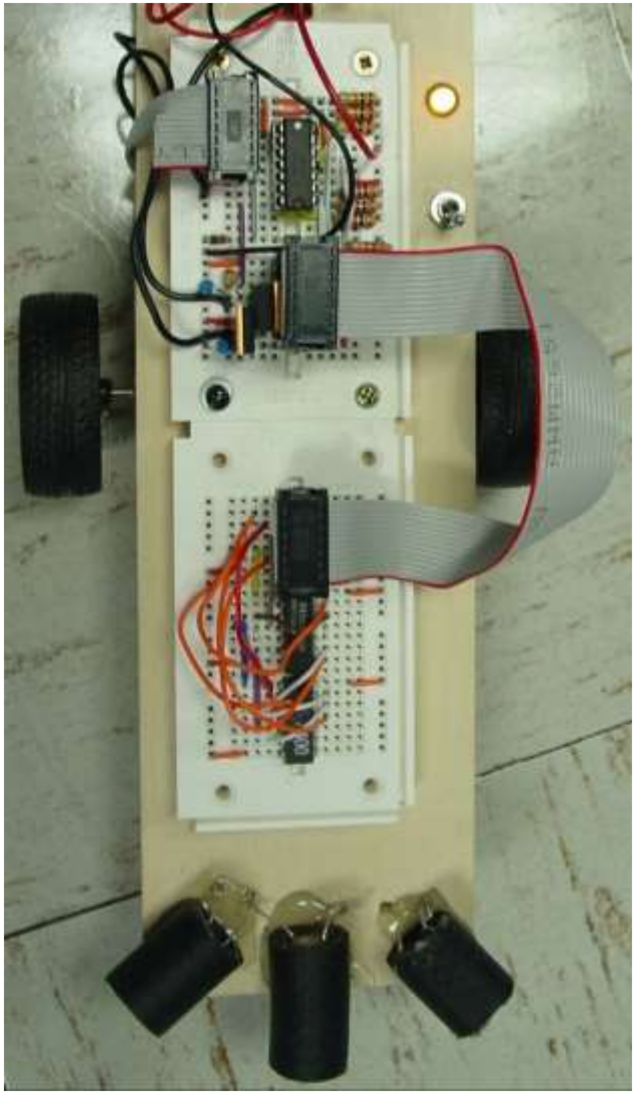
Continuous path control

- Moves along a specific path
- Uses include welding, cutting, machining parts.

Robotic seam welding

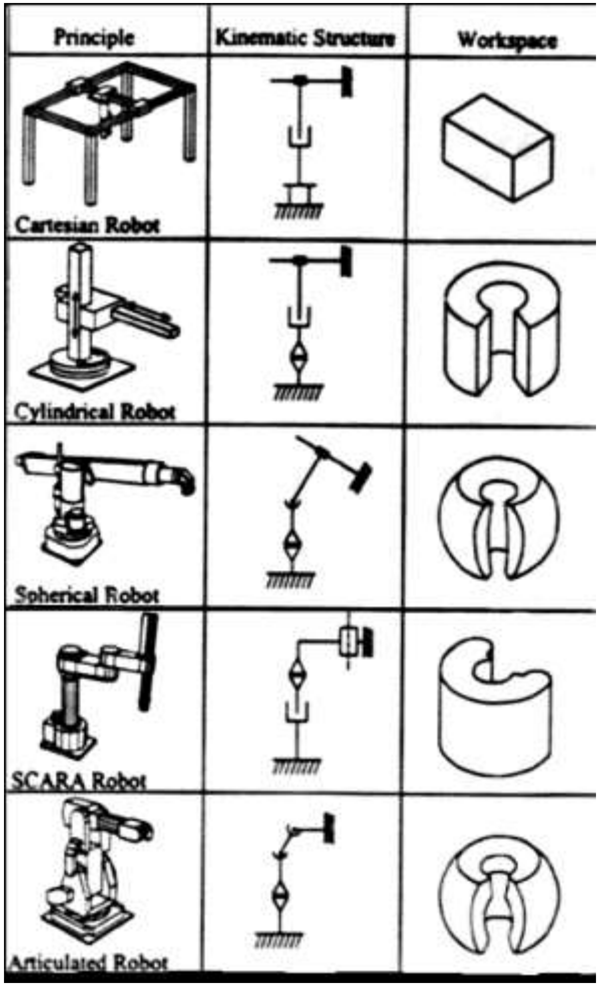
Sensory

- Uses sensors for feedback.
- Closed-loop robots use sensors in conjunction with actuators to gain higher accuracy – servo motors.
- Uses include mobile robotics, telepresence, search and rescue, pick and place with machine vision.



Measures of performance

- Working volume
  - The space within which the robot operates.
  - Larger volume costs more but can increase the capabilities of a robot
- Speed and acceleration
  - Faster speed often reduces resolution or increases cost
  - Varies depending on position, load.
  - Speed can be limited by the task the robot performs (welding, cutting)
- Resolution
  - Often a speed tradeoff
  - The smallest step the robot can take



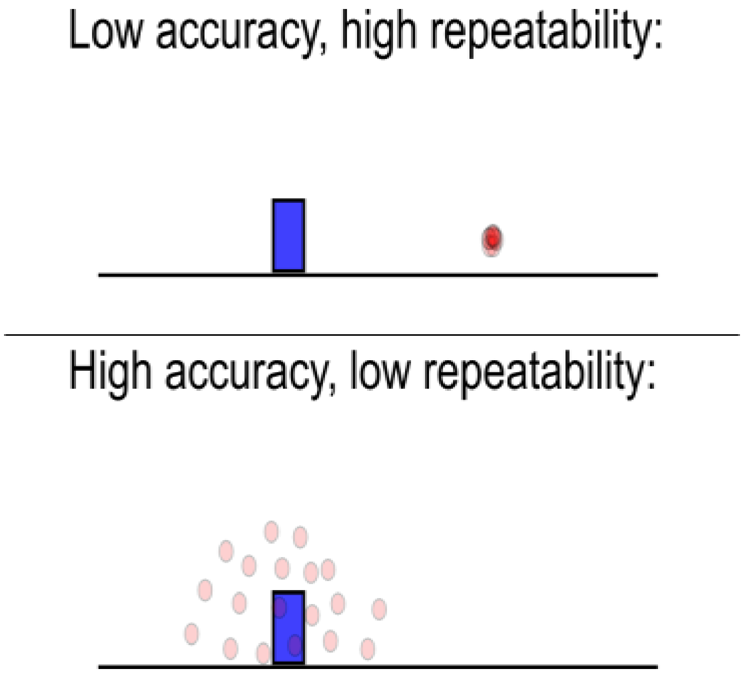
Performance (cont.)

- Accuracy
  - –The difference between the actual position of the robot and the programmed position
- Repeatability

  Will the robot always return to the same point under the same control conditions?

  Increased cost

  Varies depending on position, load



Control

- Open loop, i.e., no feedback, deterministic

- Closed loop, i.e., feedback, maybe a sense of touch and/or vision

Kinematics and dynamics

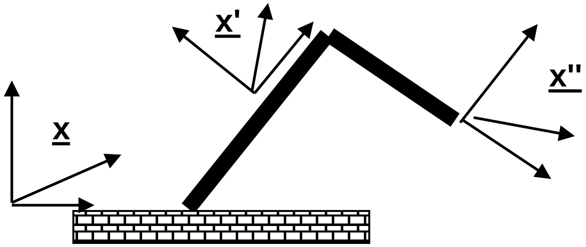
- Degrees of freedom—number of independent motions
  - Translation--3 independent directions
  - Rotation-- 3 independent axes
  - 2D motion = 3 degrees of freedom: 2 translation, 1 rotation
  - 3D motion = 6 degrees of freedom: 3 translation, 3 rotation

Kinematics and dynamics (cont.)

- Actions
  - Simple joints
    - prismatic—sliding joint, e.g., square cylinder in square tube
    - revolute—hinge joint
  - Compound joints
    - ball and socket = 3 revolute joints
    - round cylinder in tube = 1 prismatic, 1 revolute
- Mobility
  - Wheels
  - multipedal (multi-legged with a sequence of actions)

Kinematics and dynamics (cont.)

- Work areas
  - rectangular (x,y,z)
  - cylindrical (r,θ,z)
  - spherical (r,θ,φ)



- Coordinates
  - World coordinate frame
  - End effector frame
  - How to get from coordinate system **x''** to **x'** to **x**

Transformations

- General coordinate transformation from $\underline{\mathbf{x'}}$ to $\underline{\mathbf{x}}$ is $\underline{\mathbf{x}} = B\underline{\mathbf{x'}} + \underline{\mathbf{p}}$, where B is a rotation matrix and $\underline{\mathbf{p}}$ is a translation vector
- More conveniently, one can create an augmented matrix which allows the above equation to be expressed as $\underline{\mathbf{x}} = A\ \underline{\mathbf{x'}}$.
- Coordinate transformations of multilink systems are represented as

$$\underline{\mathbf{x}}_{\underline{\mathbf{0}}} = A_{01}\, A_{12} A_{23} \ldots A_{(n-1)(n)} \underline{\mathbf{x}}_{\mathbf{n}}$$

Dynamics

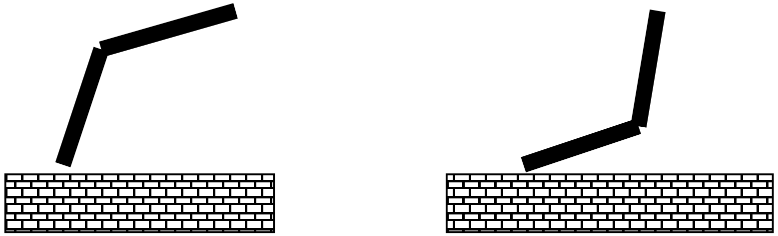
- Velocity, acceleration of end actuator
  - power transmission
  - actuator
    - solenoid –two positions , e.g., in, out
    - motor+gears, belts, screws, levers—continuum of positions
    - stepper motor—range of positions in discrete increments

Problems

- Joint play, compounded through N joints
- Accelerating masses produce vibration, elastic deformations in links
- Torques, stresses transmitted depending on end actuator loads

Control and Programming

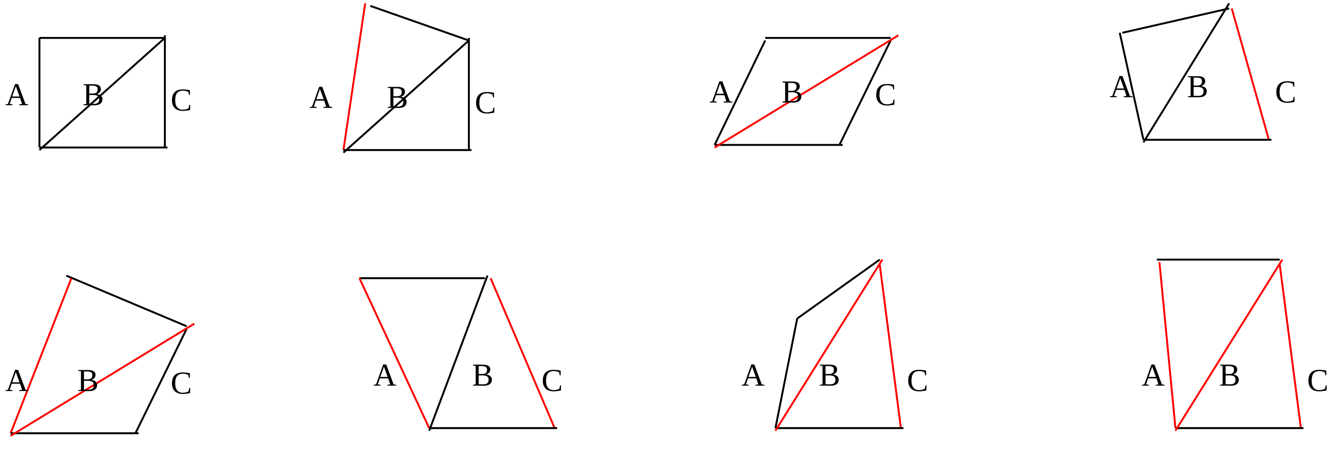
- Position of end actuator
  - multiple solutions



- Trajectory of end actuator—how to get end actuator from point A to B
  - programming for coordinated motion of each link
  - problem—sometimes no closed-form solution

A 2-D "binary" robot segment

- Example of a 2D robotic link having three solenoids to determine geometry. All members are linked by pin joints; members A,B,C have two states—in, out—controlled by in-line solenoids. Note that the geometry of such a link can be represented in terms of three binary digits corresponding to the states of A,B,C, e.g., 010 represents A,C in, B out. Links can be chained together and controlled by sets of three bit codes.



Feedback control

- Rotation encoders
- Cameras
- Pressure sensors
- Temperature sensors
- Limit switches
- Optical sensors
- Sonar

Robotics
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New directions

- Haptics--tactile sensing
- Other kinematic mechanisms,
  e.g. snake motion
- Robots that can learn

A snake robot (OCRobotics)