Industrial Robotics

Sections:

1. Robot Anatomy
2. Robot Control Systems
3. End Effectors
4. Industrial Robot Applications
5. Robot Programming

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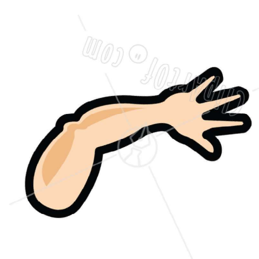
Industrial Robot Defined

A general-purpose, programmable machine possessing certain anthropomorphic characteristics

- Hazardous work environments
- Repetitive work cycle
- Consistency and accuracy
- Difficult handling task for humans
- Multishift operations
- Reprogrammable, flexible
- Interfaced to other computer systems



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Robot Anatomy

- Manipulator consists of joints and links
  - Joints provide relative motion
  - Links are rigid members between joints
  - Various joint types: linear and rotary
  - Each joint provides a “degree-of-freedom”
  - Most robots possess five or six degrees-of-freedom
- Robot manipulator consists of two sections:
  - Body-and-arm – for positioning of objects in the robot's work volume
  - Wrist assembly – for orientation of objects

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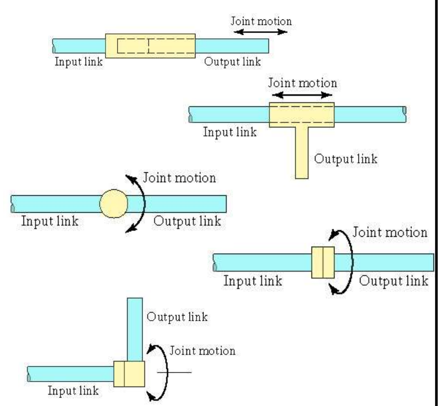
Manipulator Joints

- Translational motion
  - Linear joint (type L)
  - Orthogonal joint (type O)
- Rotary motion
  - Rotational joint (type R)
  - Twisting joint (type T)
  - Revolving joint (type V)



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Joint Notation Scheme

- Uses the joint symbols (L, O, R, T, V) to designate joint types used to construct robot manipulator
- Separates body-and-arm assembly from wrist assembly using a colon (:)
- Example: TLR : TR
- Common body-and-arm configurations …

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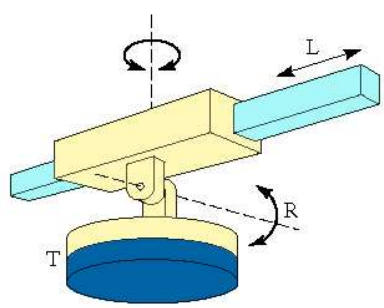
Polar Coordinate Body-and-Arm Assembly

- 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)

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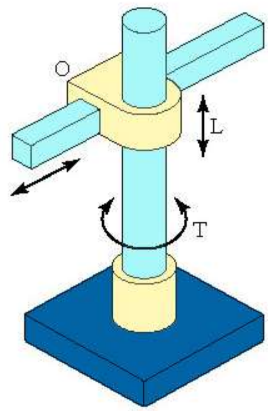
Cylindrical Body-and-Arm Assembly

- 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

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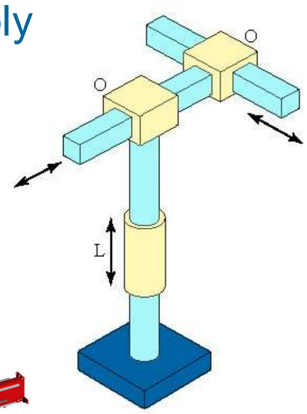
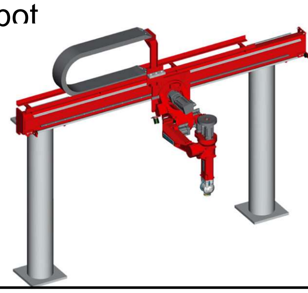
Cartesian Coordinate Body-and-Arm Assembly

- Notation LOO:



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



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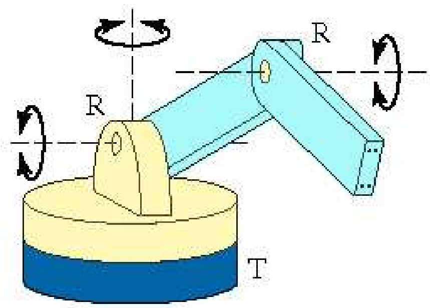
Jointed-Arm Robot

- Notation TRR:



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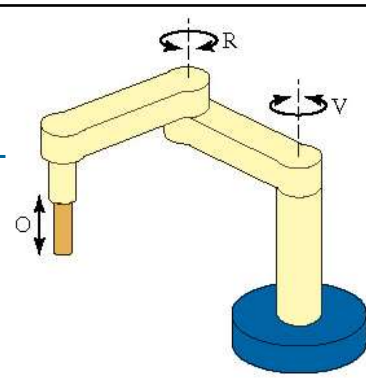
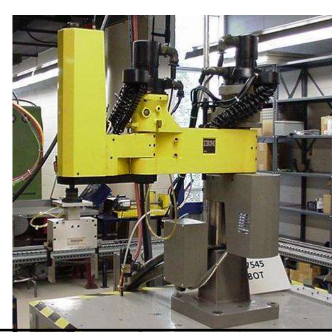
SCARA Robot

- 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





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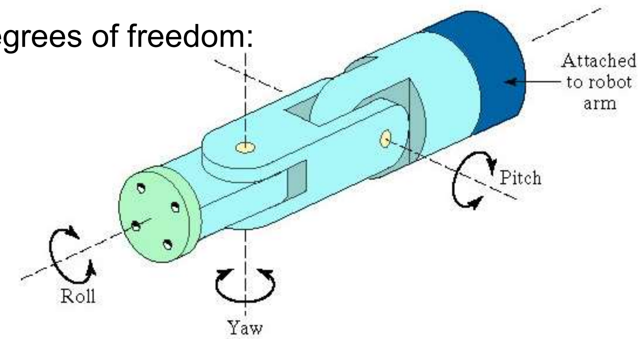
Wrist Configurations

- 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



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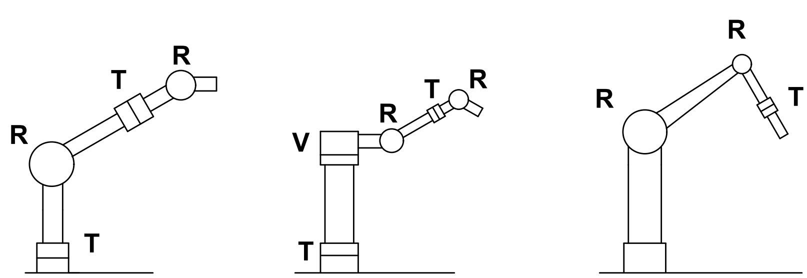
Example

- Sketch following manipulator configurations
- (a) TRT:R, (b) TVR:TR, (c) RR:T.

Solution:



(a) TRT:R (b) TVR:TR (c) RR:T

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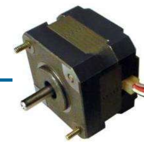
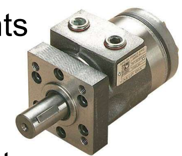
Joint Drive Systems



- Electric
  - Uses electric motors to actuate individual joints
  - Preferred drive system in today's robots



- Hydraulic
  - Uses hydraulic pistons and rotary vane actuators
  - Noted for their high power and lift capacity
- Pneumatic
  - Typically limited to smaller robots and simple material transfer applications

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Robot Control Systems

- **Limited sequence control** – pick-and-place operations using mechanical stops to set positions
- **Playback with point-to-point control** – records work cycle as a sequence of points, then plays back the sequence during program execution
- **Playback with continuous path control** – greater memory capacity and/or interpolation capability to execute paths (in addition to points)
- **Intelligent control** – exhibits behavior that makes it seem intelligent, e.g., responds to sensor inputs, makes decisions, communicates with humans

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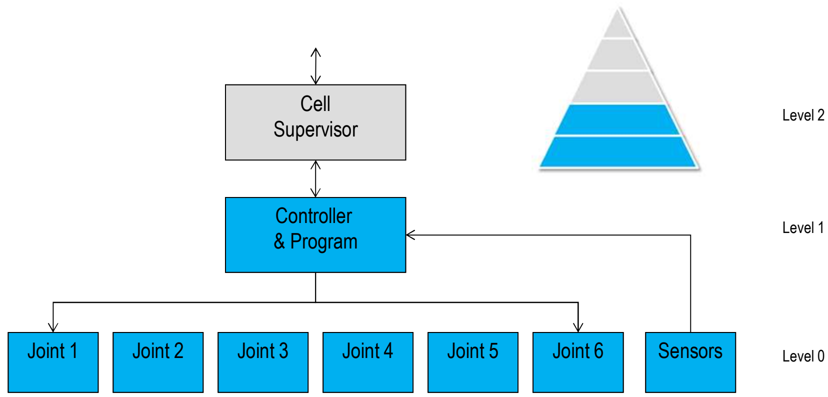
Robot Control System



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End Effectors

- The special tooling for a robot that enables it to perform a specific task
- Two types:
  - Grippers – to grasp and manipulate objects (e.g., parts) during work cycle
  - Tools – to perform a process, e.g., spot welding, spray painting

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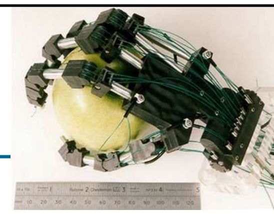
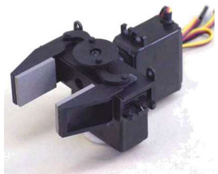
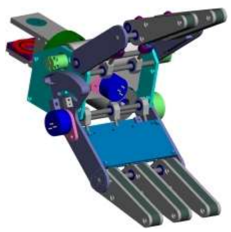
Grippers and Tools







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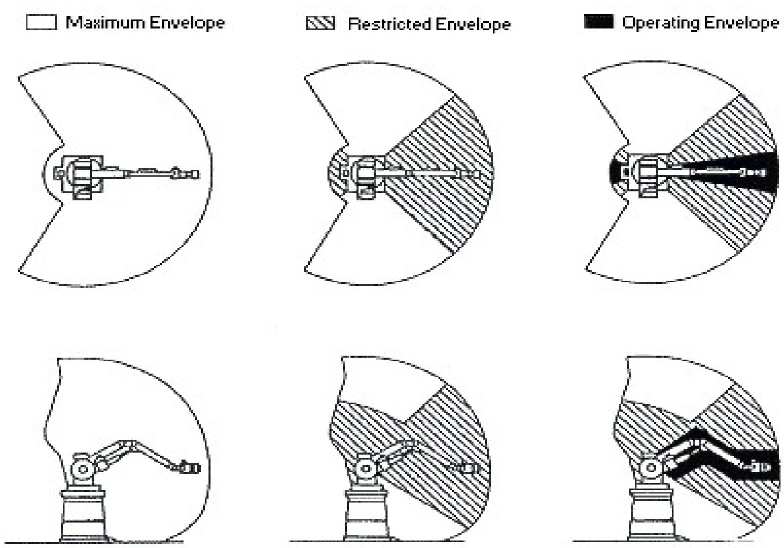
Working Envelope



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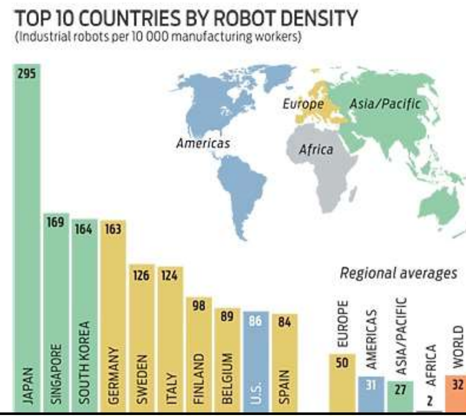
Industrial Robot Applications

1. Material handling applications
   - Material transfer – pick-and-place, palletizing
   - Machine loading and/or unloading
2. Processing operations
   - Welding
   - Spray coating
   - Cutting and grinding
3. Assembly and inspection



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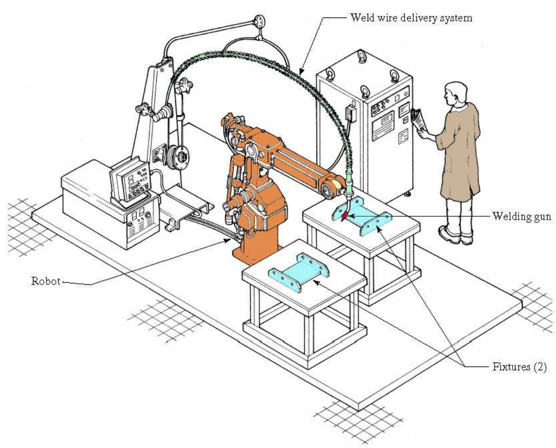
Robotic Arc-Welding Cell

- Robot performs flux-cored arc welding (FCAW) operation at one workstation while fitter changes parts at the other workstation



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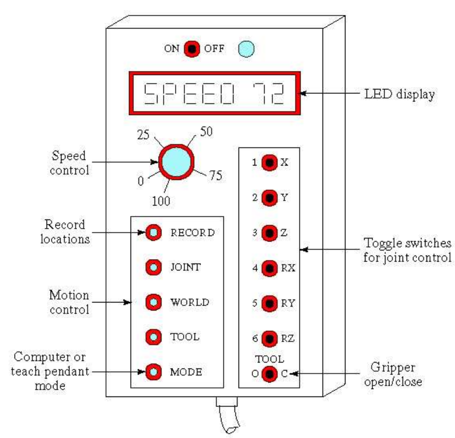
Robot Programming

- Leadthrough programming
  - Work cycle is taught to robot by moving the manipulator through the required motion cycle and simultaneously entering the program into controller memory for later playback
- Robot programming languages
  - Textual programming language to enter commands into robot controller
- Simulation and off-line programming
  - Program is prepared at a remote computer terminal and downloaded to robot controller for execution without need for leadthrough methods

Leadthrough Programming

1. Powered leadthrough
   - Common for point-to-point robots
   - Uses teach pendant
2. Manual leadthrough
   - Convenient for continuous path control robots
   - Human programmer physical moves manipulator



Leadthrough Programming Advantages

- Advantages:
  - Easily learned by shop personnel
  - Logical way to teach a robot
  - No computer programming
- Disadvantages:
  - Downtime during programming
  - Limited programming logic capability
  - Not compatible with supervisory control

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Robot Programming

- Textural programming languages
- Enhanced sensor capabilities
- Improved output capabilities to control external equipment
- Program logic
- Computations and data processing
- Communications with supervisory computers

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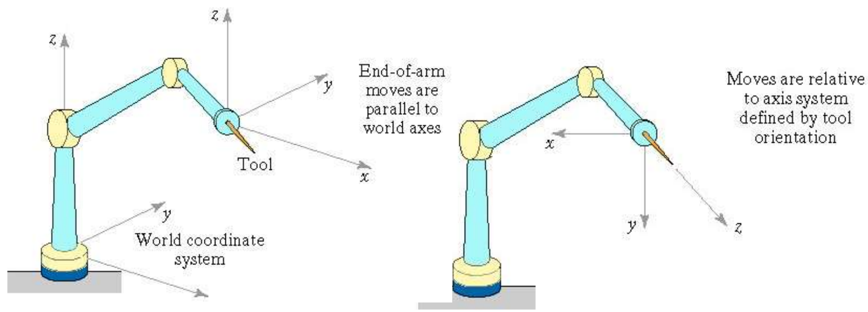
Coordinate Systems



World coordinate system

Tool coordinate system

Motion Commands

MOVE P1
HERE P1 - used during lead through of manipulator
MOVES P1
DMOVE(4, 125)
APPROACH P1, 40 MM
DEPART 40 MM
DEFINE PATH123 = PATH(P1, P2, P3)
MOVE PATH123
SPEED 75

Interlock and Sensor Commands

Interlock Commands

- WAIT 20, ON
- SIGNAL 10, ON
- SIGNAL 10, 6.0
- REACT 25, SAFESTOP

Gripper Commands

- OPEN
- CLOSE
- CLOSE 25 MM
- CLOSE 2.0 N

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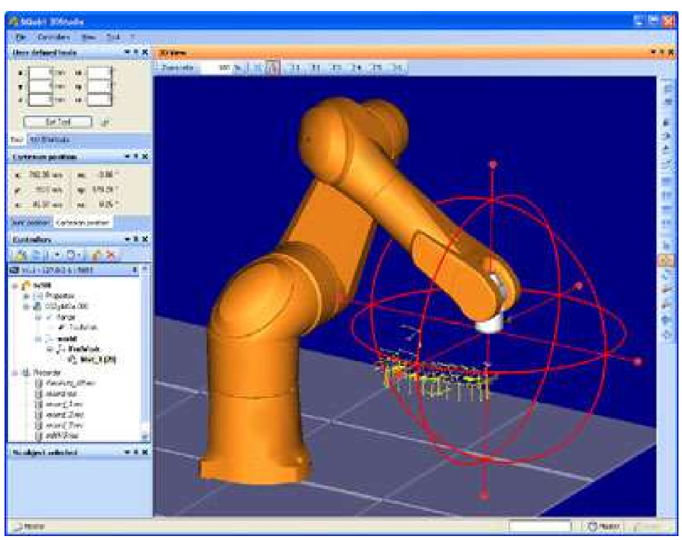
Simulation and Off-Line Programming



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Example

A robot performs a loading and unloading operation for a machine tool as follows:

- Robot pick up part from conveyor and loads into machine (Time=5.5 sec)
- Machining cycle (automatic). (Time=33.0 sec)
- Robot retrieves part from machine and deposits to outgoing conveyor. (Time=4.8 sec)
- Robot moves back to pickup position. (Time=1.7 sec)

Every 30 work parts, the cutting tools in the machine are changed which takes 3.0 minutes. The uptime efficiency of the robot is 97%; and the uptime efficiency of the machine tool is 98% which rarely overlap.

Determine the hourly production rate.

Solution

T_c = 5.5 + 33.0 + 4.8 + 1.7 = 45 sec/cycle

Tool change time T_{tc} = 180 sec/30 pc = 6 sec/pc

Robot uptime E_R = 0.97, lost time = 0.03.

Machine tool uptime E_M = 0.98, lost time = 0.02.

Total time = $T_c + T_{tc}/30$ = 45 + 6 = 51 sec = 0.85 min/pc

R_c = 60/0.85 = 70.59 pc/hr

Accounting for uptime efficiencies,

R_p = 70.59(1.0 - 0.03 - 0.02) = 67.06 pc/hr