



Industrial Robotics

Sections:

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



Industrial Robot Defined

A general-purpose, programmable machine possessing certain anthropomorphic characteristics

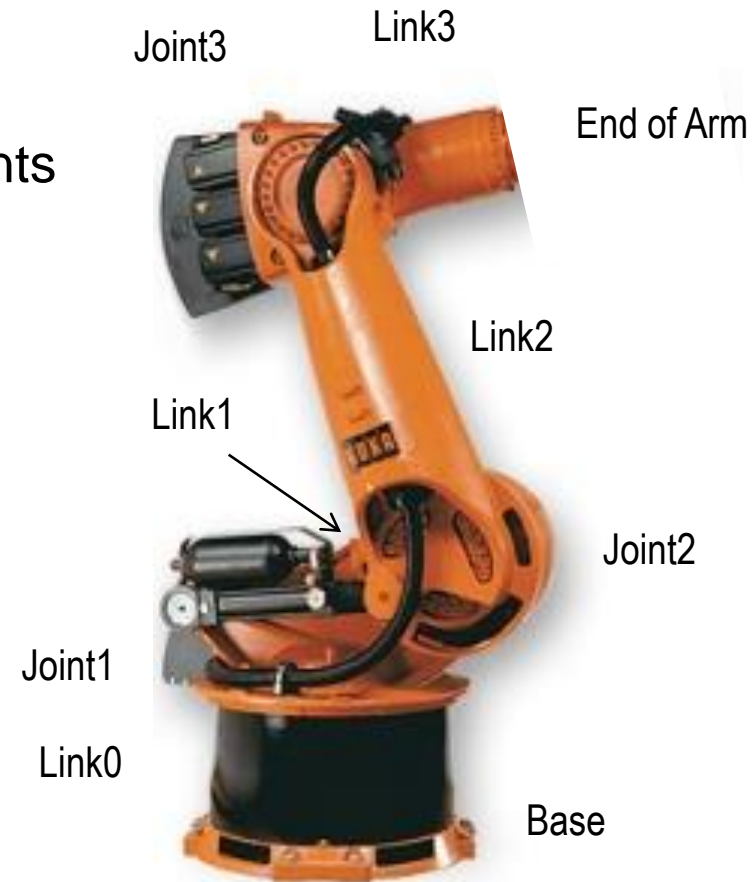
- Hazardous work environments
- Repetitive work cycle
- Consistency and accuracy
- Difficult handling task for humans
- Multishift operations
- Reprogrammable, flexible
- Interfaced to other computer systems





Robot Anatomy

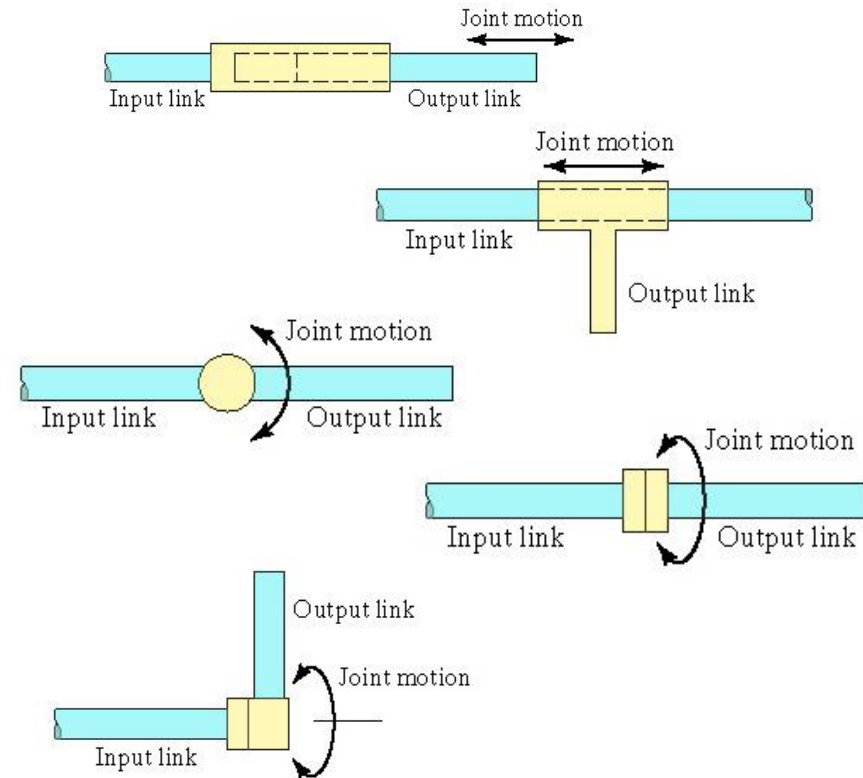
- Manipulator consists of joints and links
 - Joints provide relative motion
 - Links are rigid members between joints
 - Various joint types: linear and rotary
 - Each joint provides a “degree-of-freedom”
 - Most robots possess five or six degrees-of-freedom
- Robot manipulator consists of two sections: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





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)





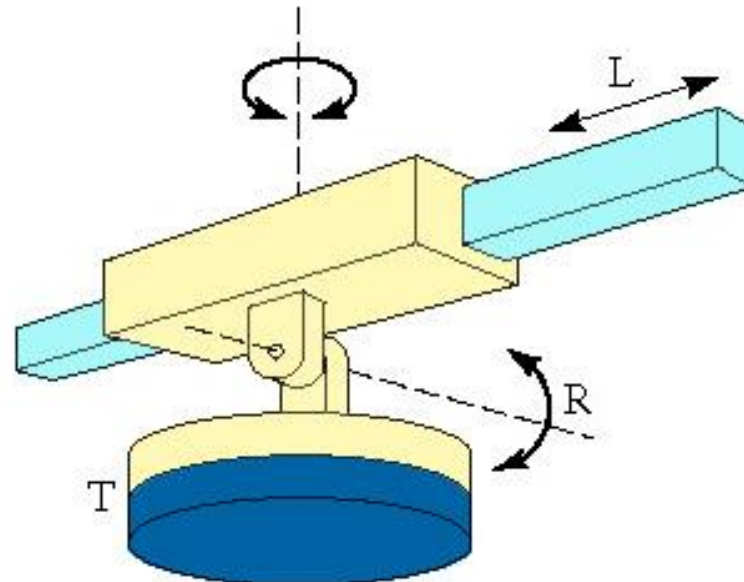
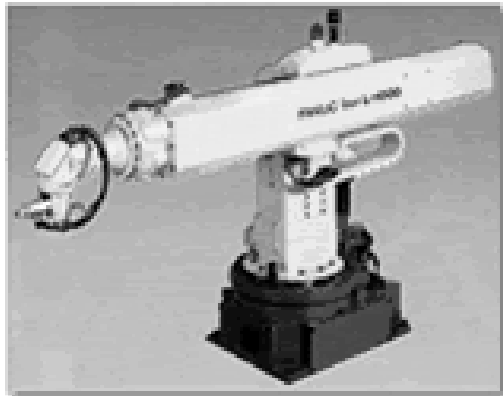
Joint Notation Scheme

- 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 ...



Polar Coordinate Body-and-Arm Assembly

- Notation TRL:

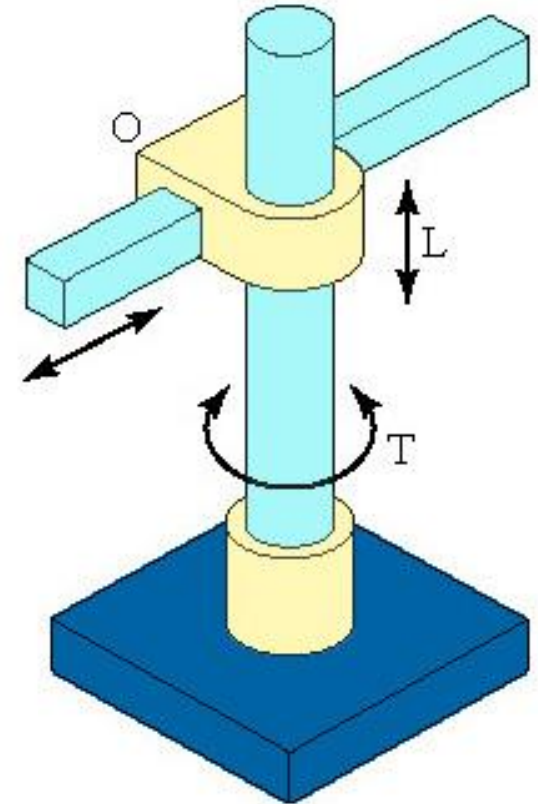


- Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint)



Cylindrical Body-and-Arm Assembly

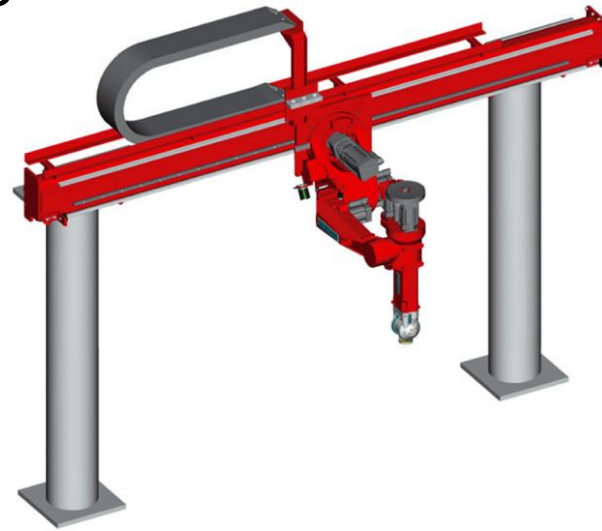
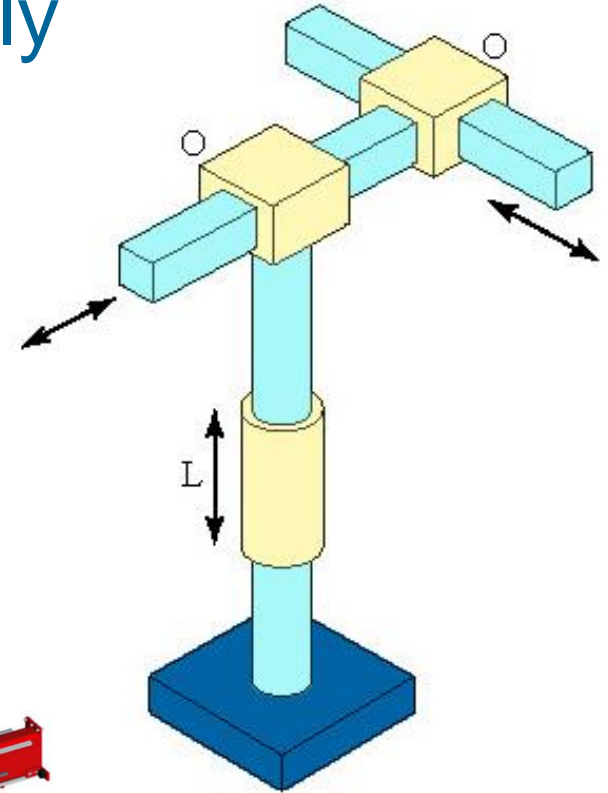
- Notation TLO:
- Consists of a vertical column, relative to which an arm assembly is moved up or down
- The arm can be moved in or out relative to the column





Cartesian Coordinate Body-and-Arm Assembly

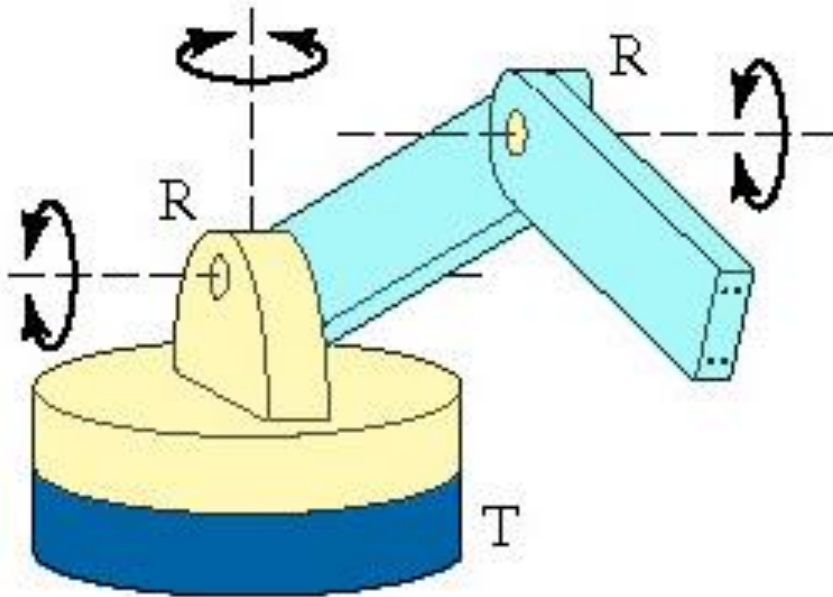
- Notation LOO:
- Consists of three sliding joints, two of which are orthogonal
- Other names include rectilinear robot and x-y-z robot





Jointed-Arm Robot

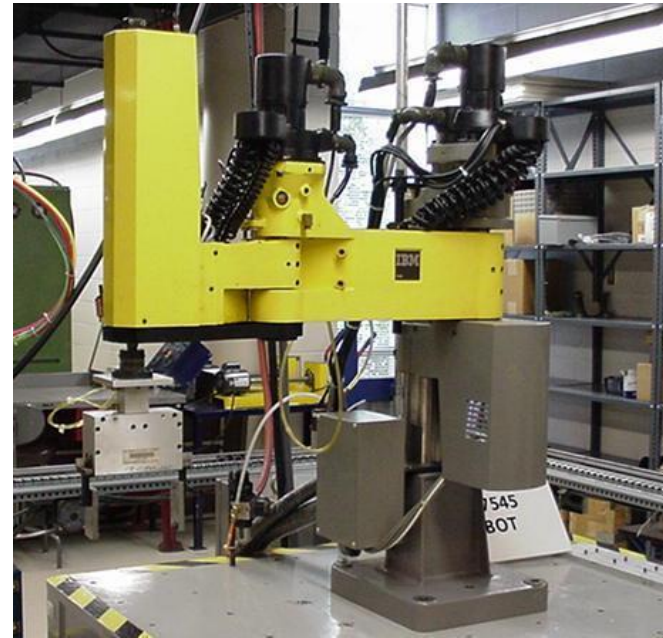
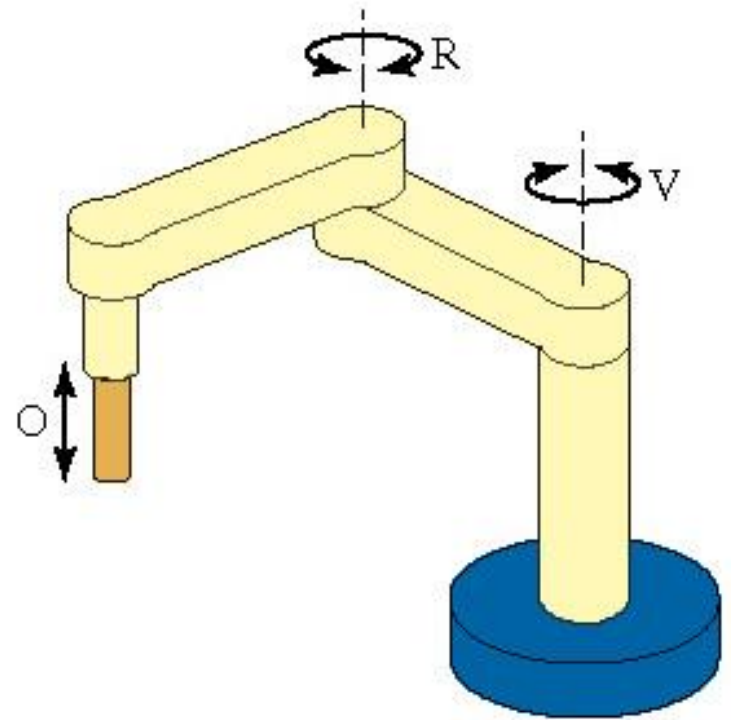
- Notation TRR:





SCARA Robot

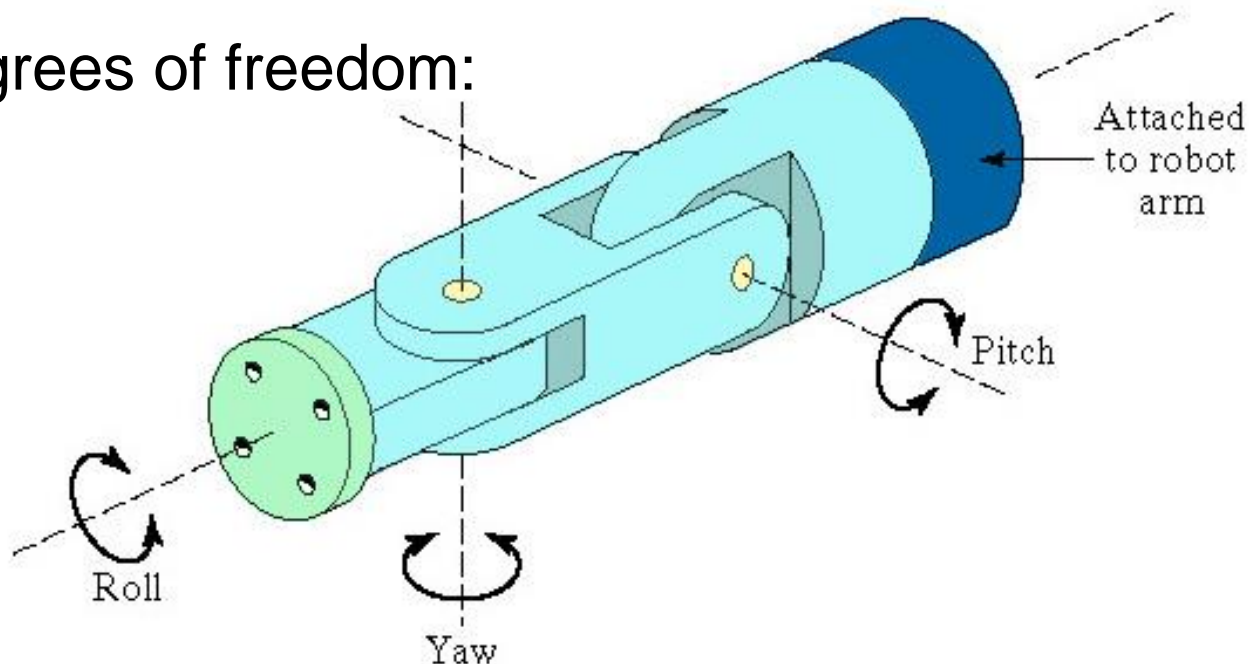
- Notation VRO
- SCARA stands for Selectively Compliant Assembly Robot Arm
- Similar to jointed-arm robot except that vertical axes are used for shoulder and elbow joints to be compliant in horizontal direction for vertical insertion tasks





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

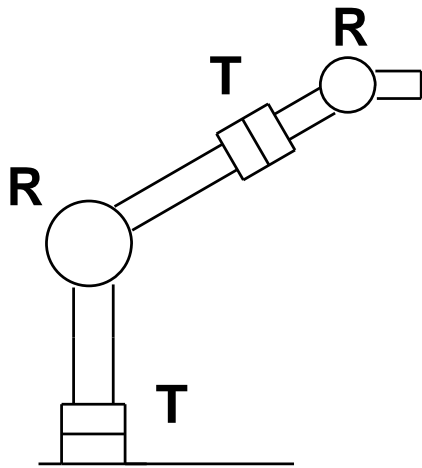




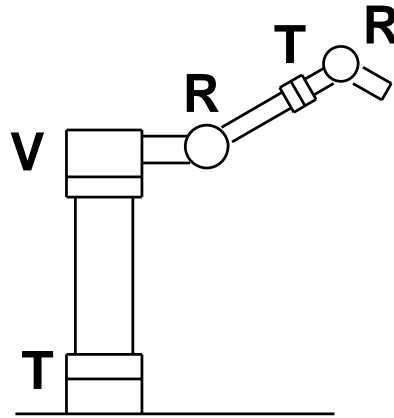
Example

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

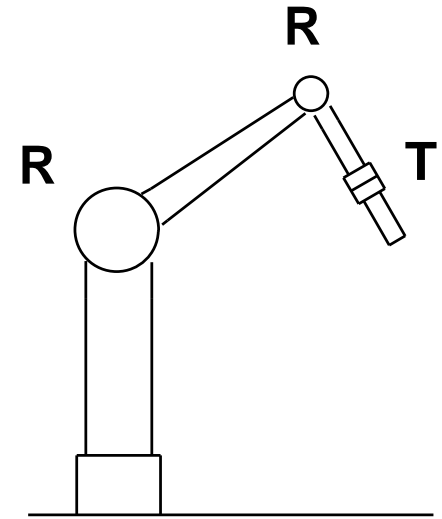
Solution:



(a) TRT:R



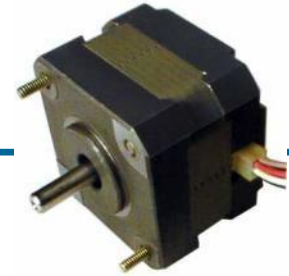
(b) TVR:TR



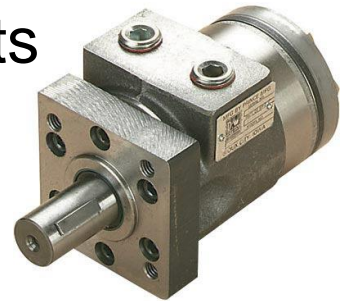
(c) RR:T



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





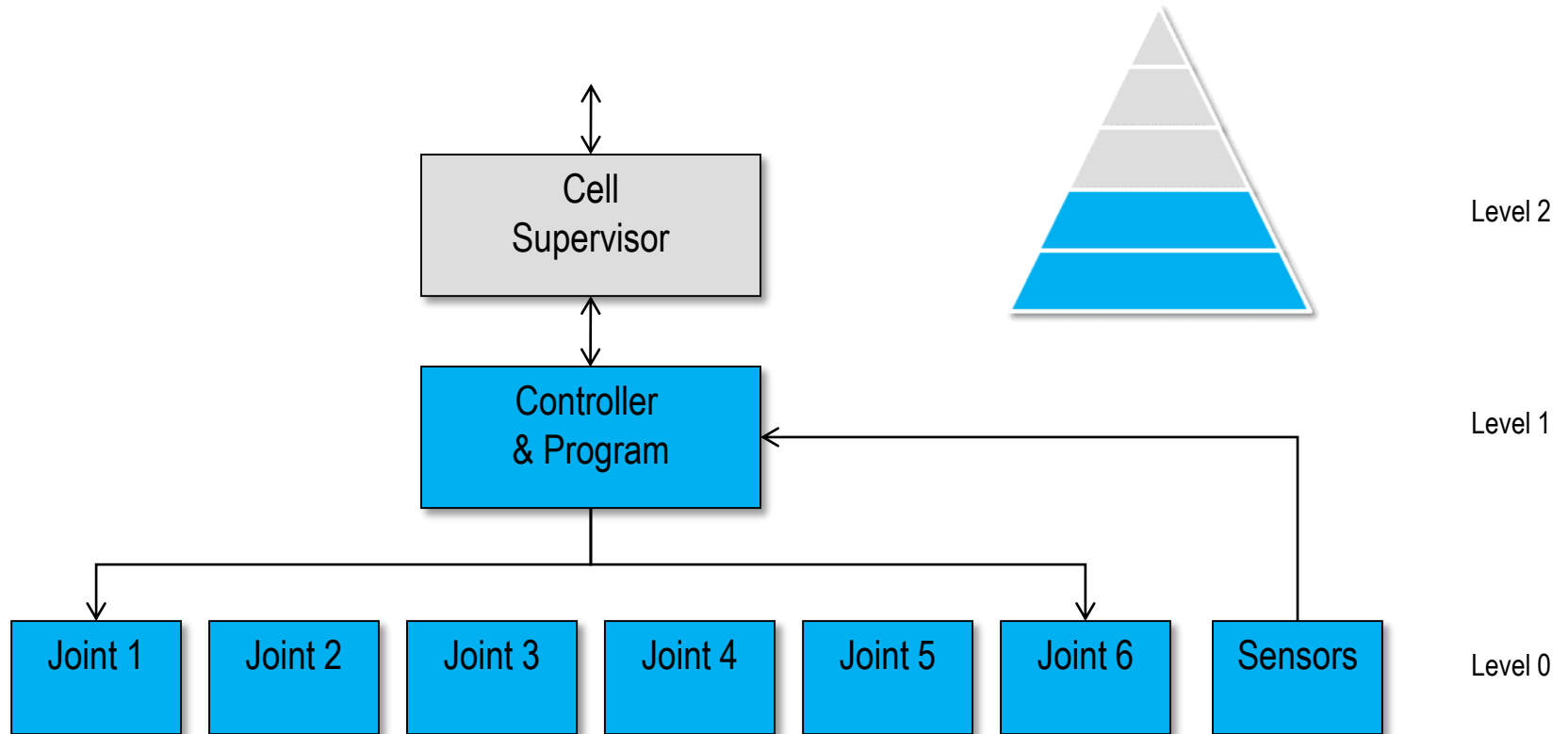
Robot Control Systems

- **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





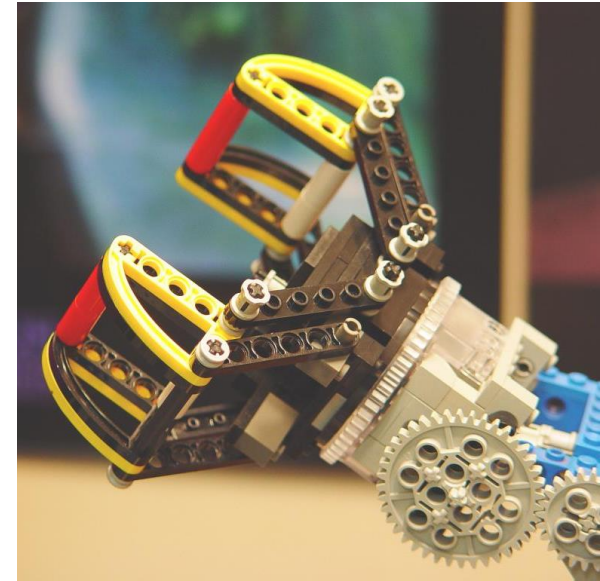
Robot Control System





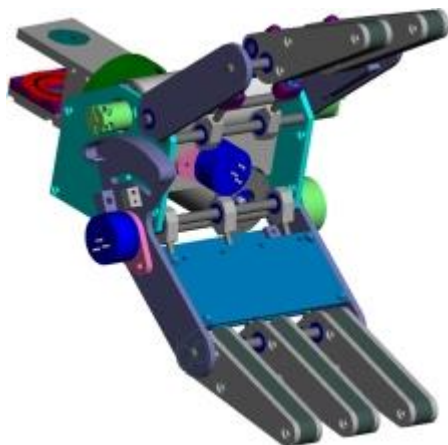
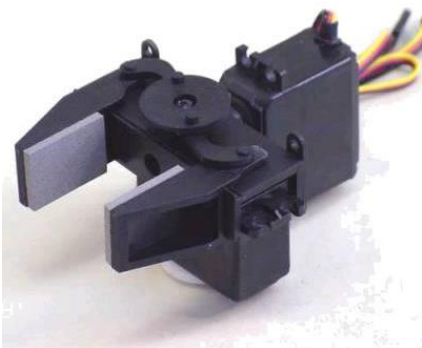
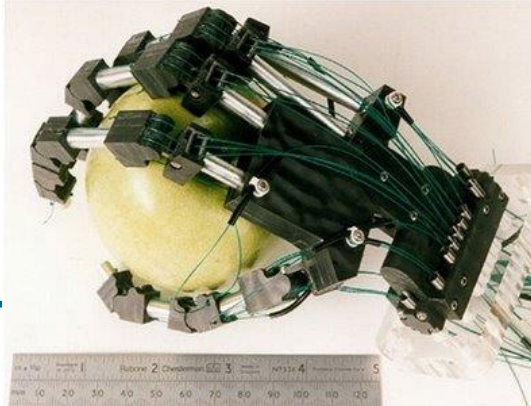
End Effectors

- 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





Grippers and Tools



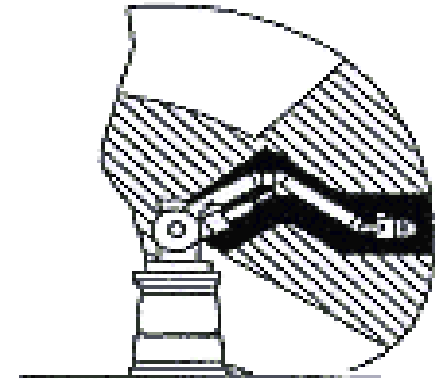
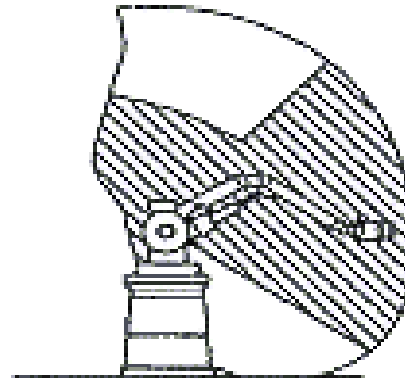
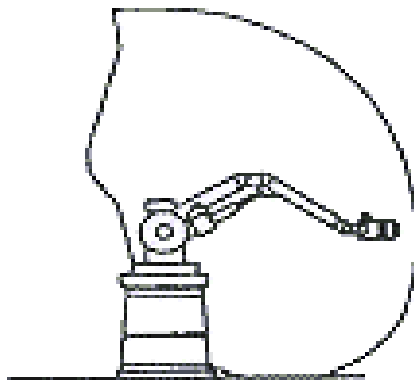
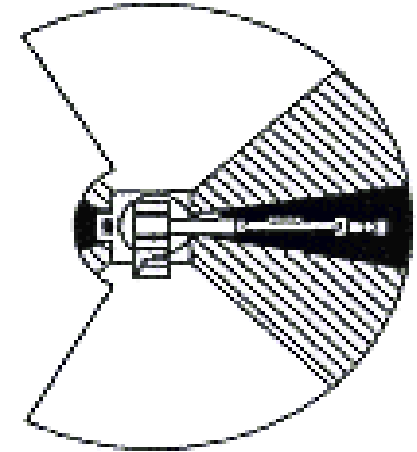
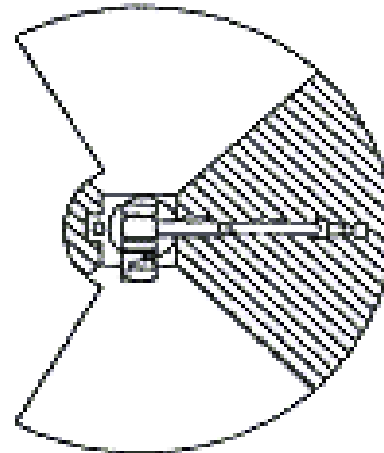
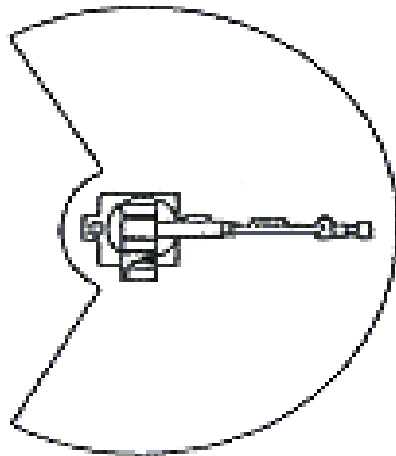


Working Envelope

□ Maximum Envelope

▨ Restricted Envelope

■ Operating Envelope

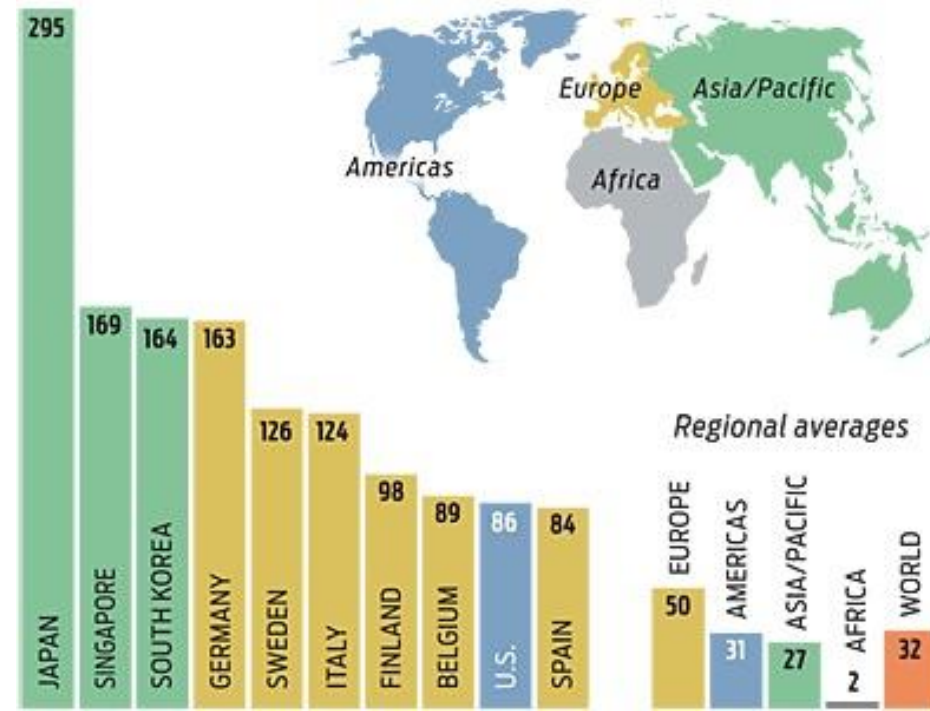




Industrial Robot Applications

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

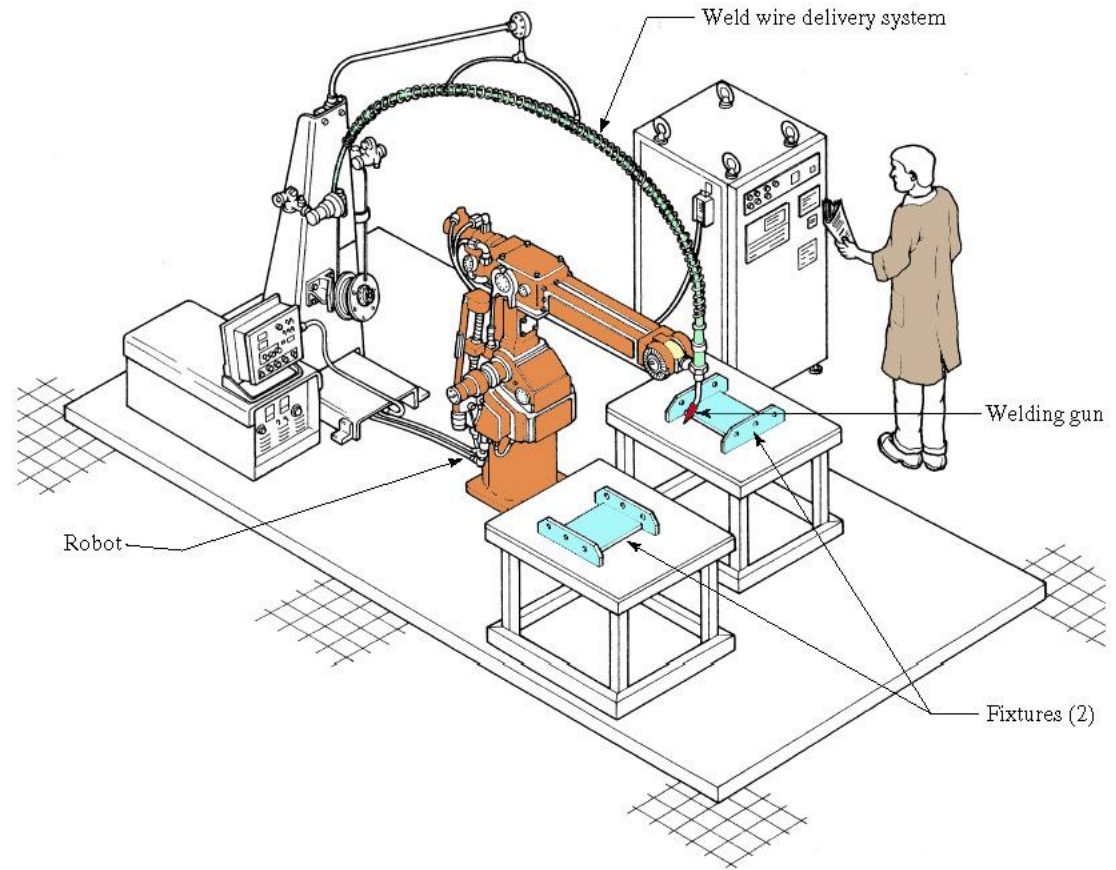
TOP 10 COUNTRIES BY ROBOT DENSITY
(Industrial robots per 10 000 manufacturing workers)





Robotic Arc-Welding Cell

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





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



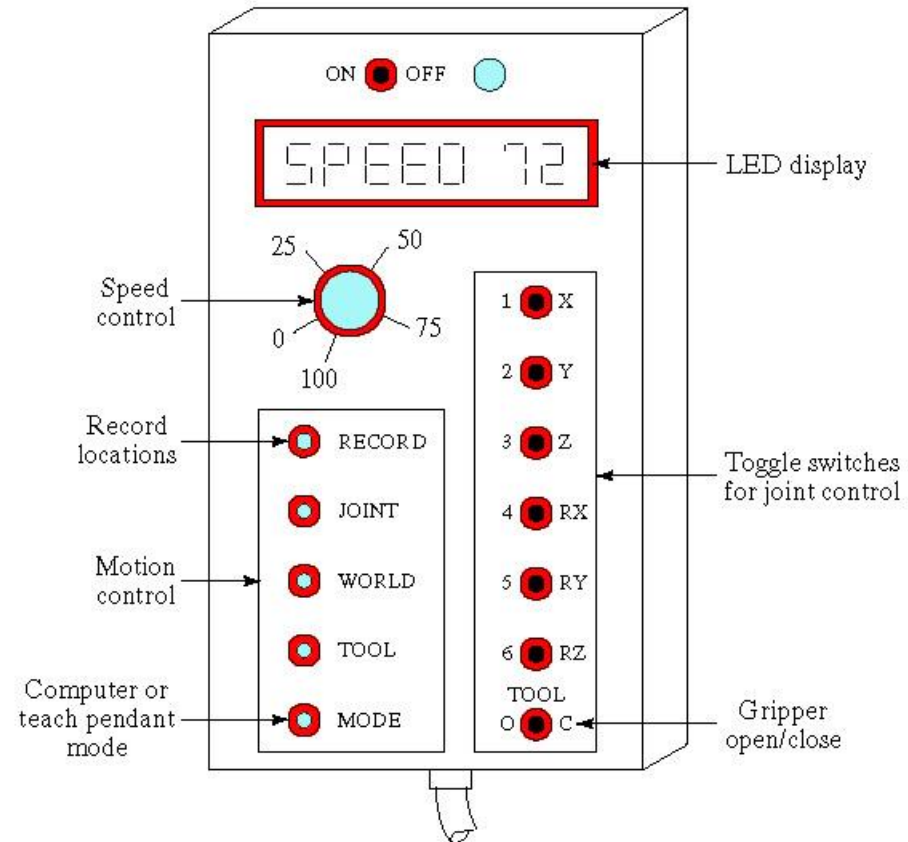
Leadthrough Programming

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





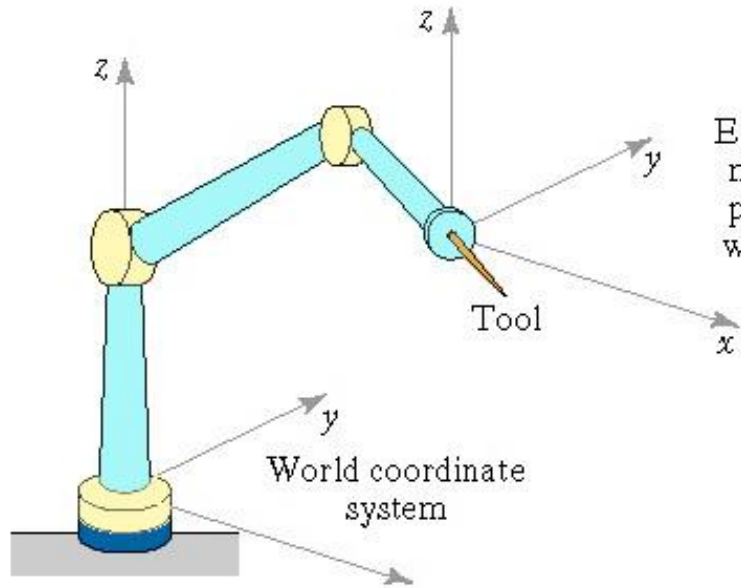
Robot Programming

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



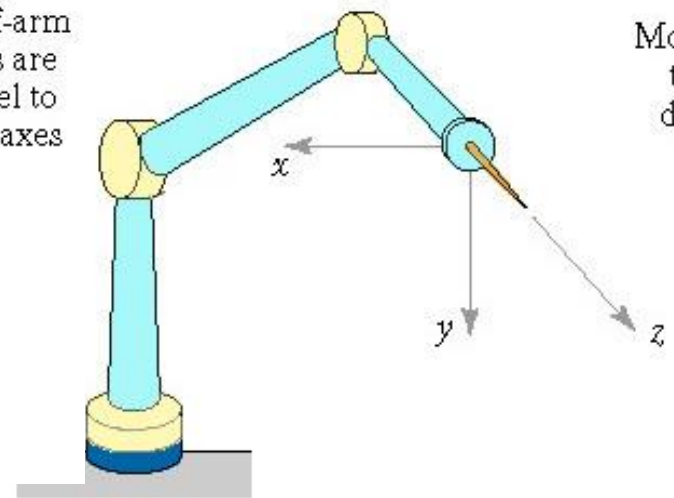


Coordinate Systems



World coordinate system

End-of-arm moves are parallel to world axes



Tool coordinate system

Moves are relative to axis system defined by tool orientation



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

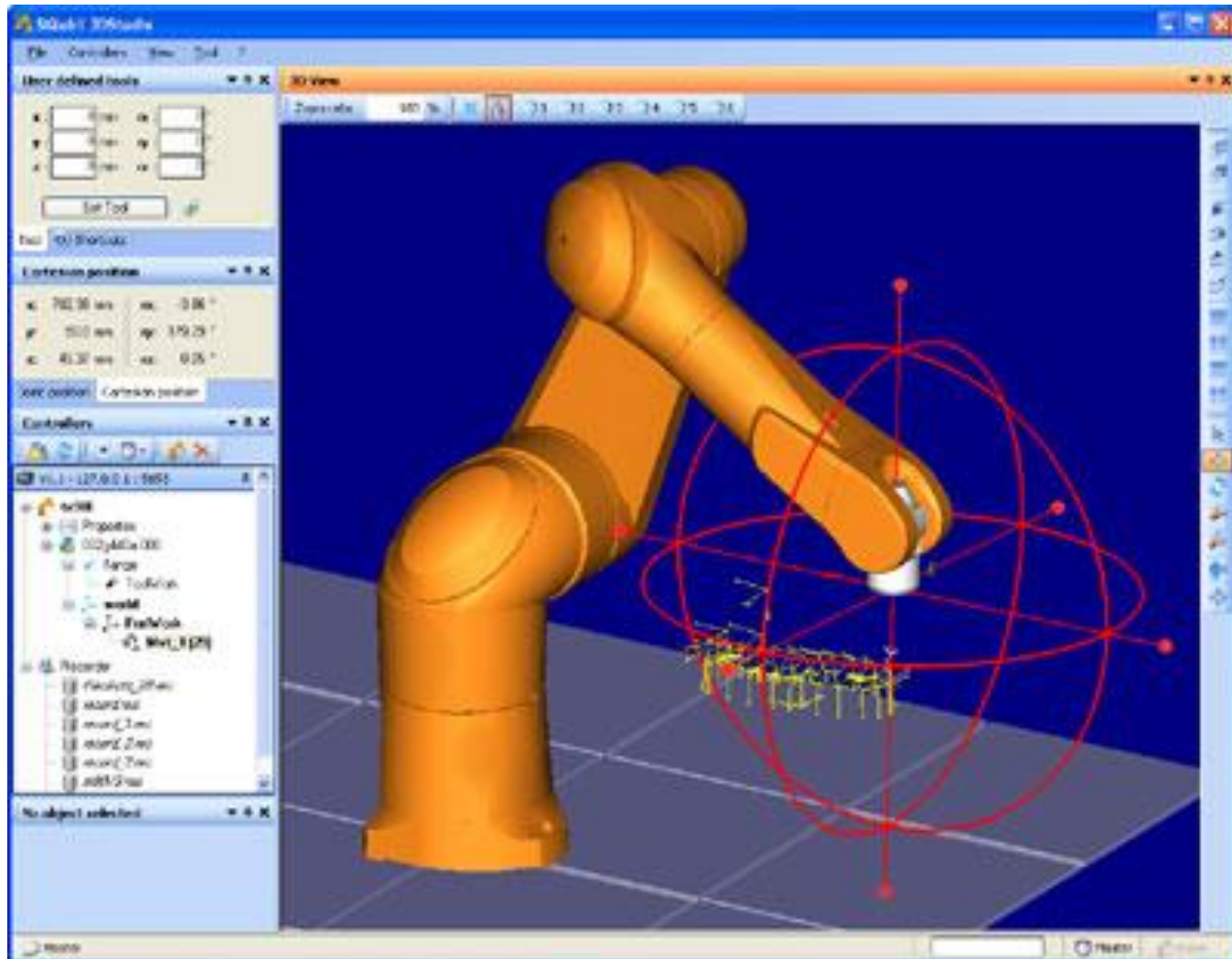
CLOSE

CLOSE 25 MM

CLOSE 2.0 N



Simulation and Off-Line Programming





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

$$T_c = 5.5 + 33.0 + 4.8 + 1.7 = 45 \text{ sec/cycle}$$

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

Robot uptime $E_R = 0.97$, lost time = 0.03.

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

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

$$R_c = 60/0.85 = 70.59 \text{ pc/hr}$$

Accounting for uptime efficiencies,

$$R_p = 70.59(1.0 - 0.03 - 0.02) = 67.06 \text{ pc/hr}$$