Assembly Technology

Lecture 7: Industrial Robotics

Outline

- Robot anatomy and related attributes
- Robot control systems
- End effectors
- Sensor in robotics
- Industrial robot applications
- Robot programming
- Robot accuracy and repeatability

Intended Learning Outcomes

- Describe the main constructs defining industrial robots
- Discuss the use of industrial robot as substitutes for human workers

Industrial robot defined

“Industrial robot as defined by ISO 8373: An 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”

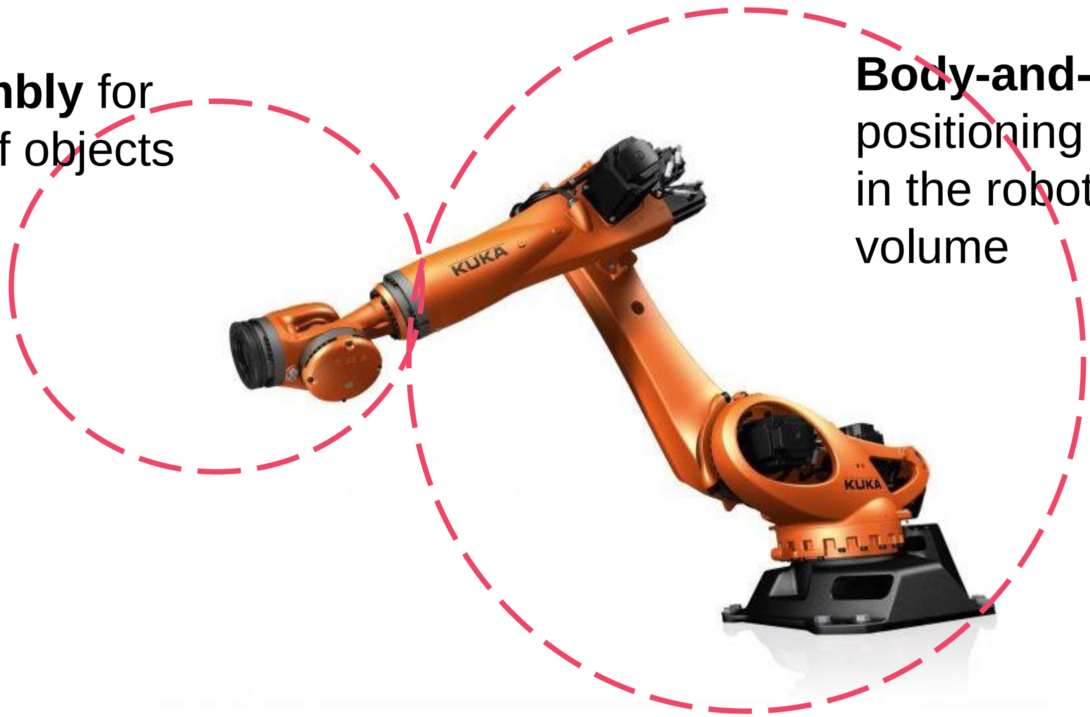
Importance of industrial robots

- Robots can substitute for humans in hazardous work environments
- Consistency and accuracy not attainable by humans
- Can be reprogrammed
- Most robots are controlled by computers and can therefore be interfaced to other computer systems

Robot Anatomy

- Robot manipulator consists of two sections:

Wrist assembly for orientation of objects

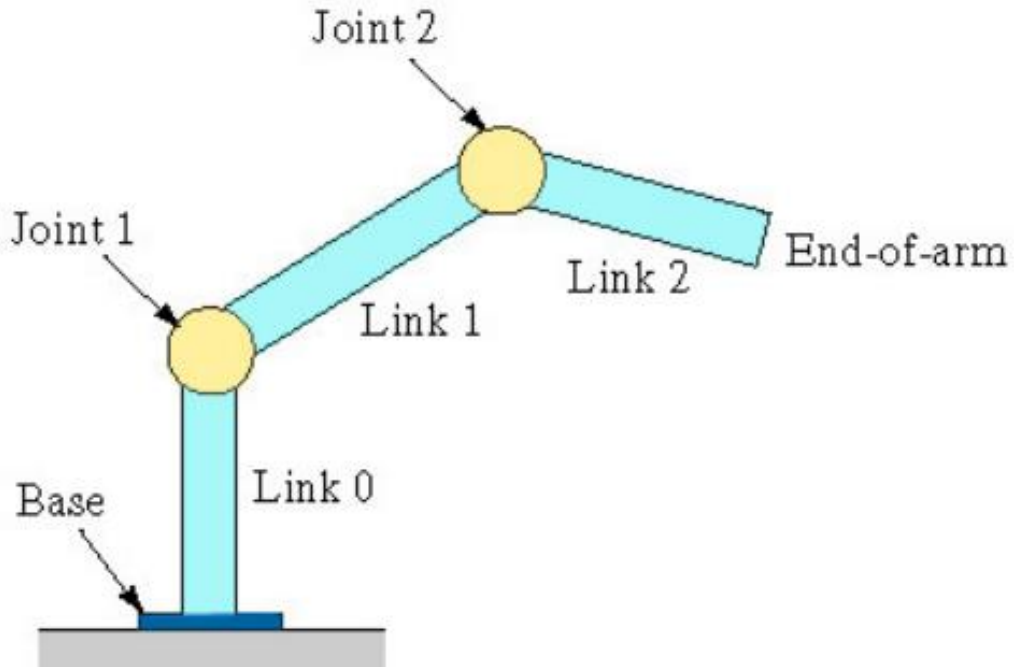


Body-and-arm for positioning of objects in the robot's work volume

Robot Anatomy

Manipulator consists of joints and links:

- **Joints** provide relative motion
- **Links** are rigid members between joints
- Joint types: **linear** and **rotary**
- Each joint provides a "**degree-of-freedom**"
- Most robots possess five or six degrees-of-freedom

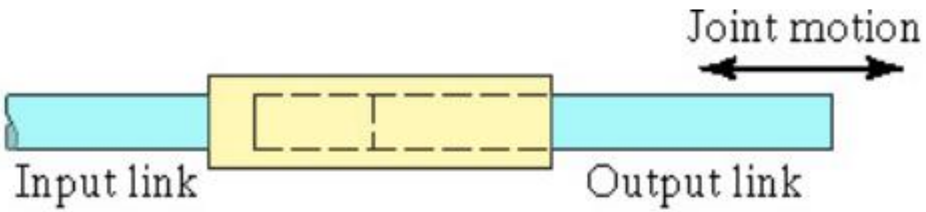


Types of Manipulators Joints

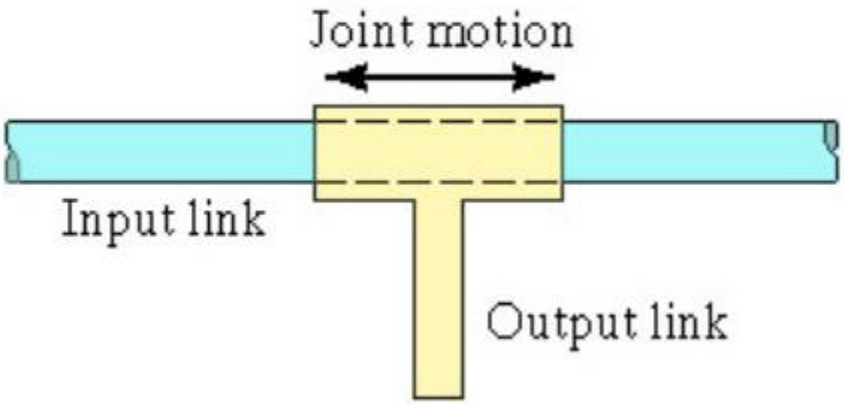
- Translational motion
  - Linear joint (type L)
  - Orthogonal joint (type O)
- Rotary motion
  - Rotational joint (type R)
  - Twisting joint (type T)
  - Revolving joint (type V)

Translational Motion Joints

Linear joint
(type L)

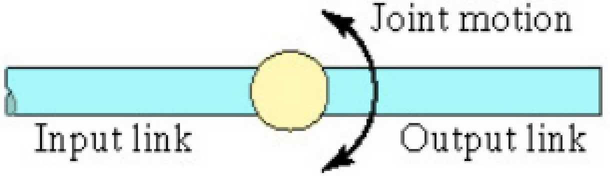


Orthogonal joint
(type O)

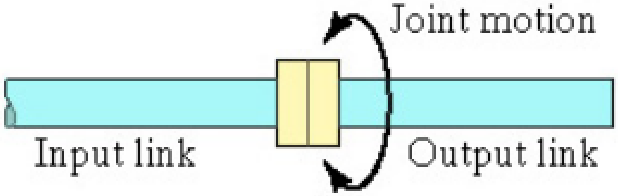


Rotary Motion Joints

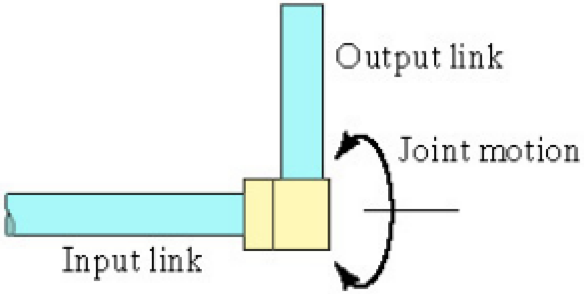
Rotational joint
(type R)



Twisting joint
(type T)



Revolving joint
(type V)



Joint notation scheme

- Use 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

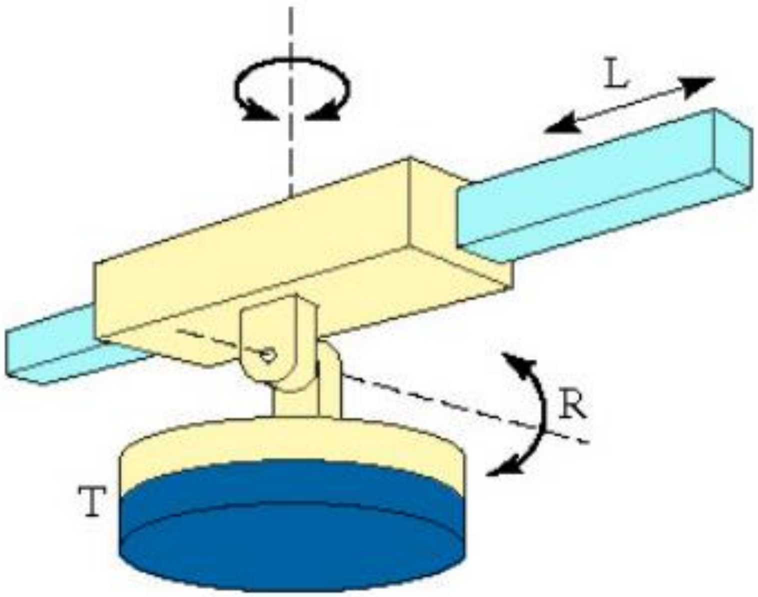
Robot Body-and-Arm configurations

- Five common body-and-arm configurations for industrial robots:
  1. **Polar** coordinate body-and-arm assembly
  2. **Cylindrical** body-and-arm assembly
  3. **Cartesian** coordinate body-and-arm assembly
  4. **Jointed**-arm body-and-arm assembly
  5. Selective Compliance Assembly Robot Arm (**SCARA**)

- Function of body-and-arm assembly is to position an **end effector** (e.g., gripper, tool) in space

Polar coordinates

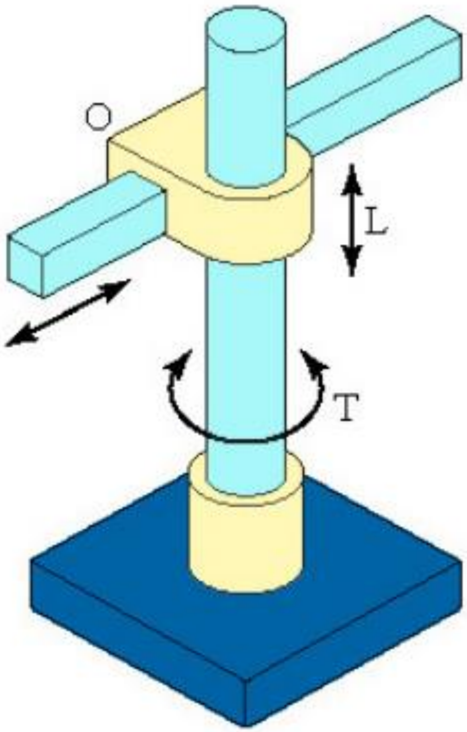
- Notation TRL:



- 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

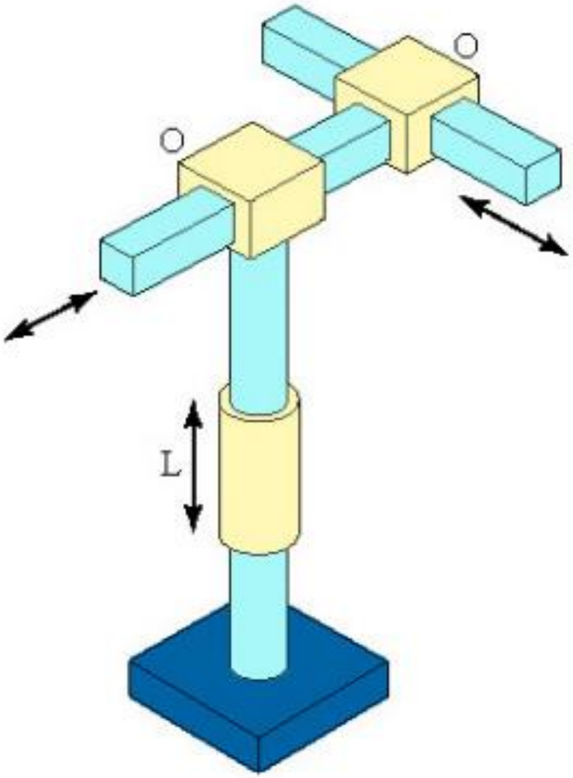
- Notation TLO:
- Consists of a vertical column, relative to which an arm assembly is moved up or down
- The arm can be moved in or outrelative to the column



Cartesian

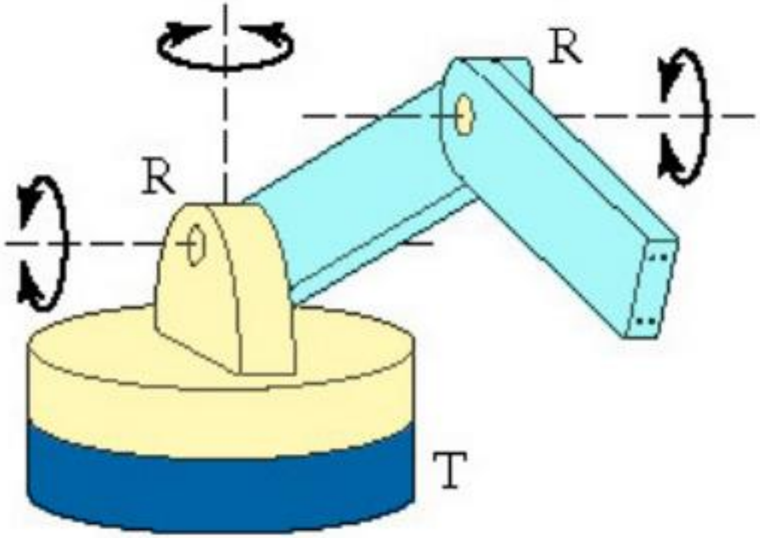
- Notation LOO:

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



Joined

- Notation TRR:

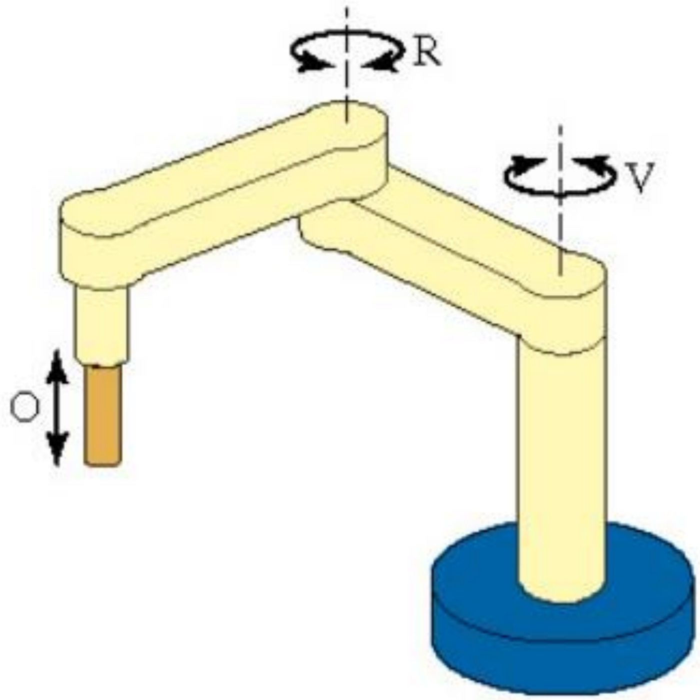


- General configuration of a human arm

SCARA

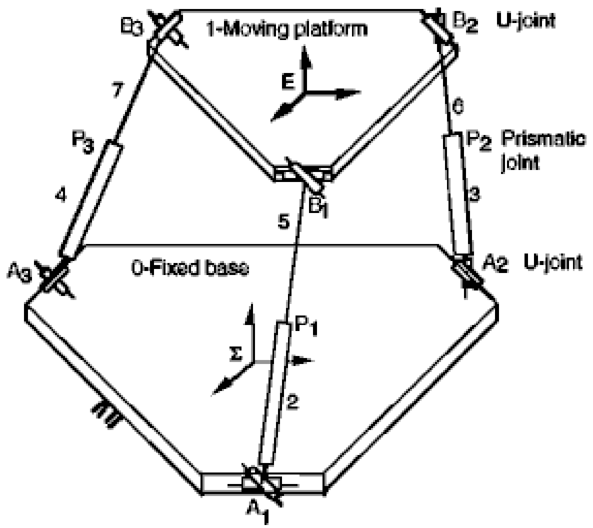
- Notation VRO
- SCARA stands for Selectively Compliant Assembly Robot Arm

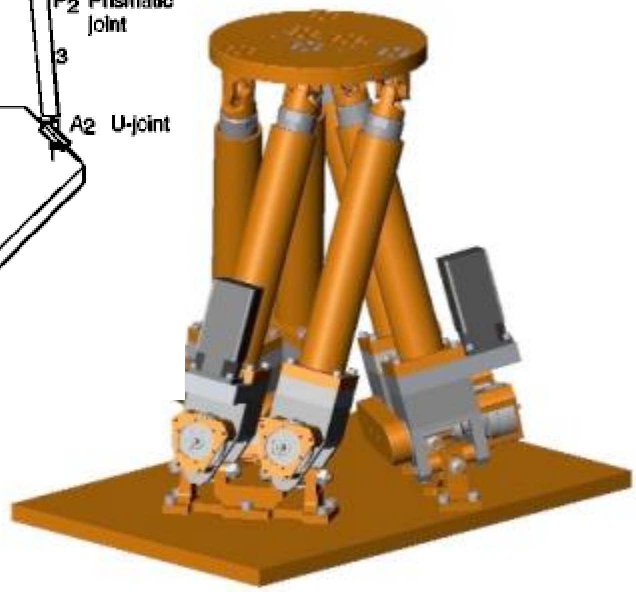
- Similar to jointed-arm robot except that vertical axes are used for shoulder and elbow joints to be compliant in horizontal direction for vertical insertion tasks



Other configuration

- The configuration examined have a serial kinematic structure Joint-Link
- There are other robot with parallel kinematic chains converging in the wrist. They are called **parallel robots**.

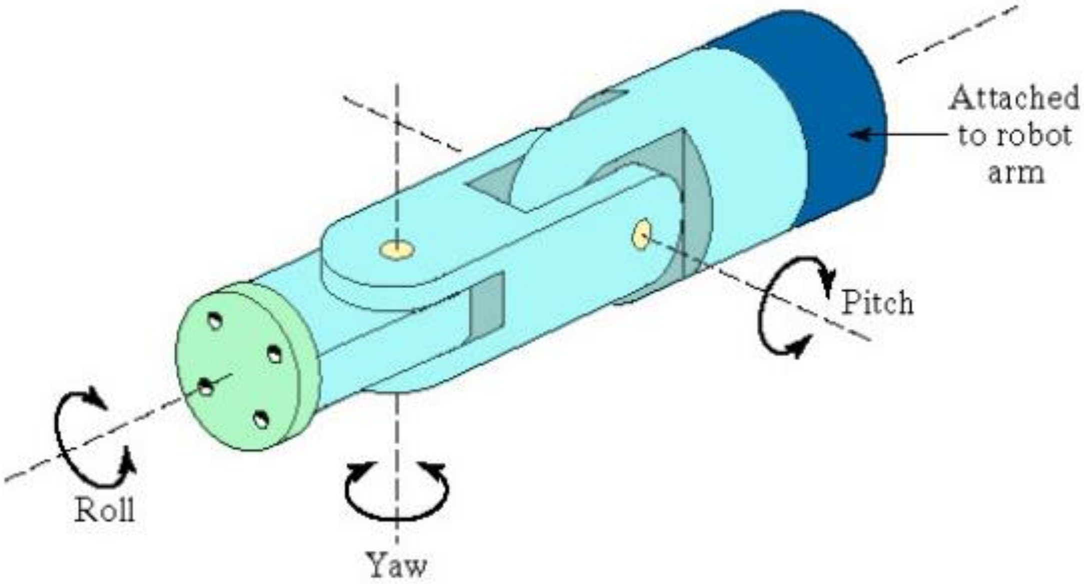




Wrist

- Wrist assembly is attached to end-of-arm
- End effector is attached to wrist assembly
- Function of wrist assembly is to **orient** end effector
- Two or three degrees of freedom:
  - Roll
  - Pitch
  - Yaw

Wrist Configuration

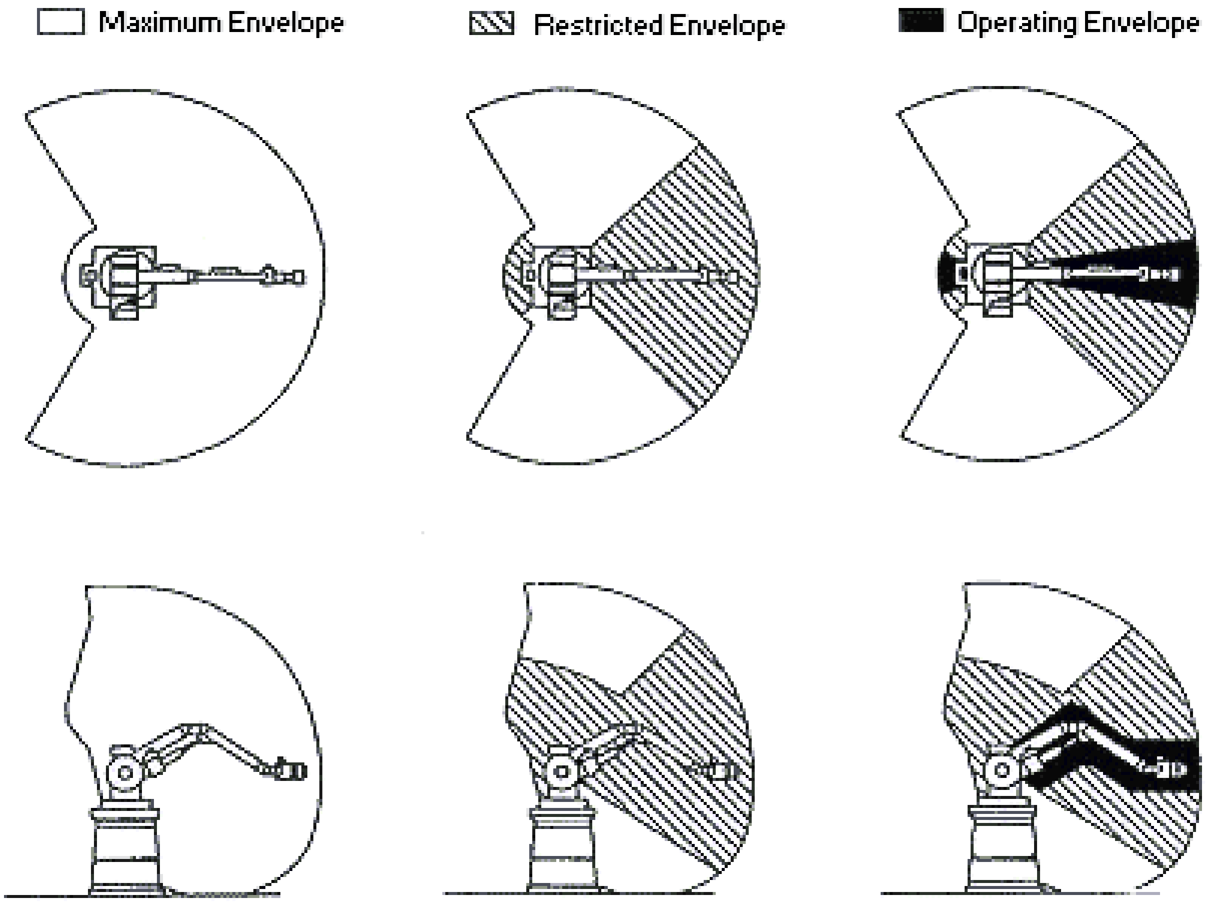


- Typical wrist assembly has two or three degrees-of freedom (shown is a three degree-of freedom wrist)
- Notation :RRT

Work volume

The work volume, or work envelope, *is the three-dimensional space in which the robot can manipulate the end of its wrist*. Work volume is determined by the number and types of joints in the manipulator, the ranges of the various joints, and the physical size of the links. Its actual shape is dependent on the robot's configuration: a polar robotic configuration tends to produce a spherical (or near-spherical) work volume; a cylindrical configuration has a cylindrical work envelope; and a Cartesian co-ordinate robot produces a rectangular work volume.

Work volume or work envelope



Joint Drive System

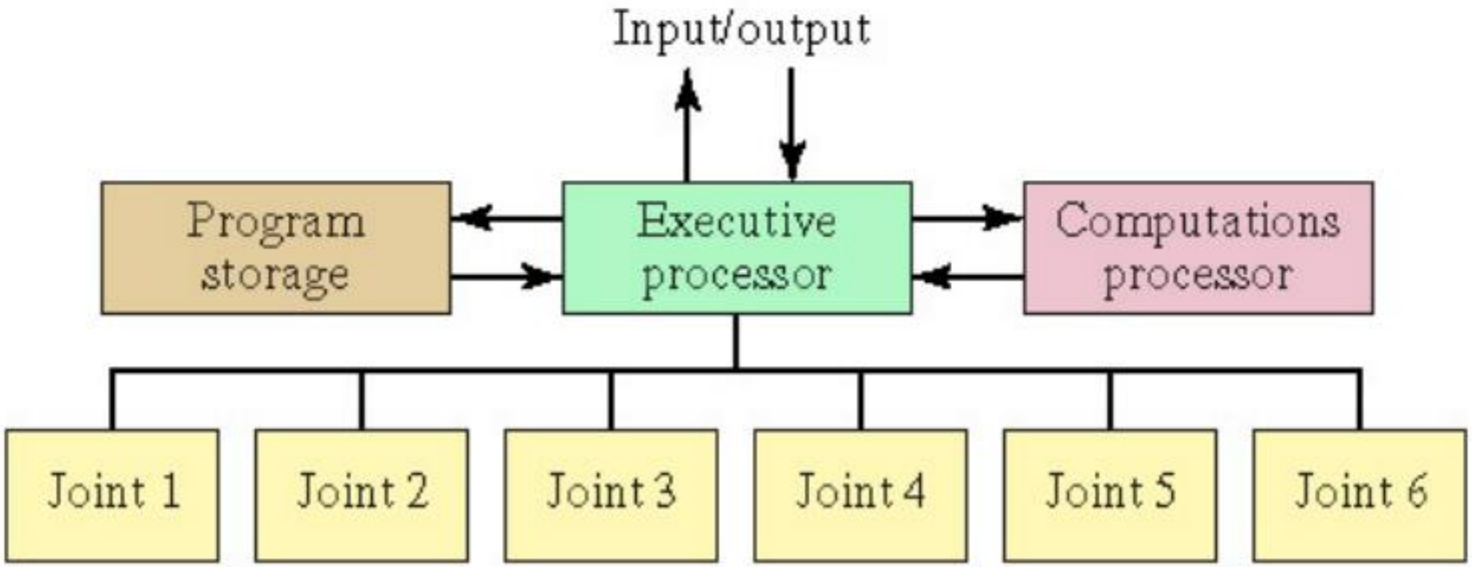
- Electric
  - Uses electric motors to actuate individual joints
  - Preferred drive system in today's robots
- Hydraulic
  - Uses hydraulic pistons and rotary vane actuators
  - Noted for their high power and lift capacity
- Pneumatic
  - Typically limited to smaller robots and simple materialtransfer applications

Robot Control System

- **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

Hierarchical control structure of a robot microcomputer controller



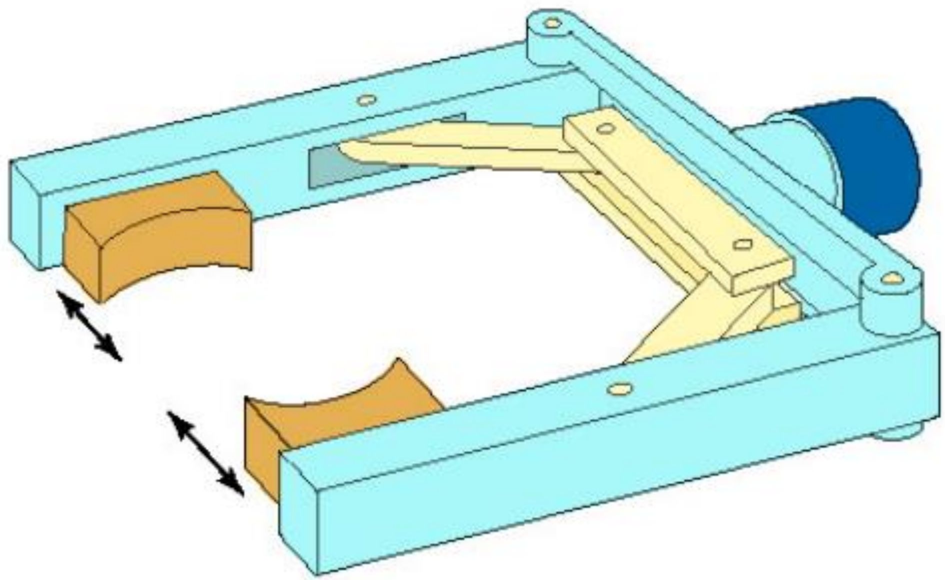
End Effectors

- 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

* Refer to the specific lecture

Robot Grippers

two-finger mechanical gripper for grasping rotational parts



Sensor in Robotics

Two basic categories of sensors used in industrial robots:

1. Internal - used to control position and velocity of the manipulator joints
2. External - used to coordinate the operation of the robot with other equipment in the work cell
    - Tactile - touch sensors and force sensors
    - Proximity - when an object is close to the sensor
    - Optical
    - Machine vision
    - Other sensors - temperature, voltage, etc.

Industrial Robot application

- **Hazardous work for humans**. In situations where the work environment is unsafe, unhealthy, uncomfortable, or otherwise unpleasant for humans, robot application may be considered.
- **Repetitive work cycle**. If the sequence of elements in the work cycle is the same, and the elements consist of relatively simple motions, robots usually perform the work with greater consistency and repeatability than humans.
- **Difficult handling for humans.** If the task requires the use of heavy or difficult-to-handle parts or tools for humans, robots may be able to perform the operation more efficiently.
- **Multi-shift operation.** A robot can replace two or three workers at a time in second or third shifts, thus they can provide a faster financial payback.
- **Infrequent changeovers.** Robot use is justified for long production runs where there are infrequent changeovers, as opposed to batch or job shop production where changeovers are more frequent.
- **Part position and orientation are established in the work cell**. Robots generally don't have vision capabilities, which means parts mustbe precisely placed and oriented for successful robotic operations.

Material Handling application

- **Material transfer**. Chief purpose is to pick up parts at one location and place them at a new location. Part re-orientation may be accomplished during the transfer. The most basic application is a pick-and-place procedure, by a low-technology robot (often pneumatic), using only up to 4 joints. More complex is palletising, where robots retrieve objects from one location, and deposit them on a pallet in a specific area of the pallet, thus the deposit location is slightly different for each object transferred. The robot must be able to compute the correct deposit location via powered lead-through method, or by dimensional analysis. Other applications of material transfer include de-palletising, stacking, and insertion operations.
- **Machine loading and/or unloading**. Chief purpose is to transfer parts into or out-of a production machine. There are three classes to consider:
  - *machine loading*—where the robot loads the machine only;
  - *machine unloading*—where the robot unloads the machine only;
  - *machine loading and unloading*— where the robot performs both actions. Machine loading and/or unloading is used in the following processes: die casting, plastic moulding, metal machining operations, forging, press-working, and heat treating.

Robotic process operation

- **Spot Welding**. Metal joining process in which two sheet metal parts are fused together at localised points of contact by the deployment of two electrodes that squeeze the metal together and apply an electric current. The electrodes constitute the spot welding gun, which is the end effector tool of the welding robot.
- **Arc Welding**. Metal joining process that utilises a continuous rather than contact welding point process, in the same way as above. Again the end effector is the electrodes used to achieve the welding arc. The robot must use continuous path control, and a jointed arm robot consisting of six joints is frequently used.
- **Spray Coating**. Spray coating directs a spray gun at the object to be coated. Paint or some other fluid flows through the nozzle of the spray gun, which is the end effector, and is dispersed and applied over the surface of the object. Again the robot must use continuous path control, and is typically programmed using manual lead-through. Jointed arm robots seem to be the most common anatomy for this application.
- **Other applications** include: drilling, routing, and other machining processes; grinding, wire brushing, and similar operations; waterjet cutting; and laser cutting.

Learning activity

At the end of the lecture there will be some video example of application...but there are many more on the web to search!

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** - uses 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

Two types:

1. Powered leadthrough
    - Common for point-to-point robots
    - Uses teach pendant to move joints to desired position and record that position into memory
2. Manual leadthrough
    - Convenient for continuous path control robots
    - Human programmer physical moves manipulator through motion cycle and records cycle into memory

Leadthrough Programming

- Advantages
  - Can readily be learned by shop personnel
  - A logical way to teach a robot
  - Does not required knowledge of computer programming
- Disadvantages
  - Downtime - Regular production must be interrupted to program the robot
  - Limited programming logic capability
  - Not readily compatible with modern computer-based technologies

Robot programming languages

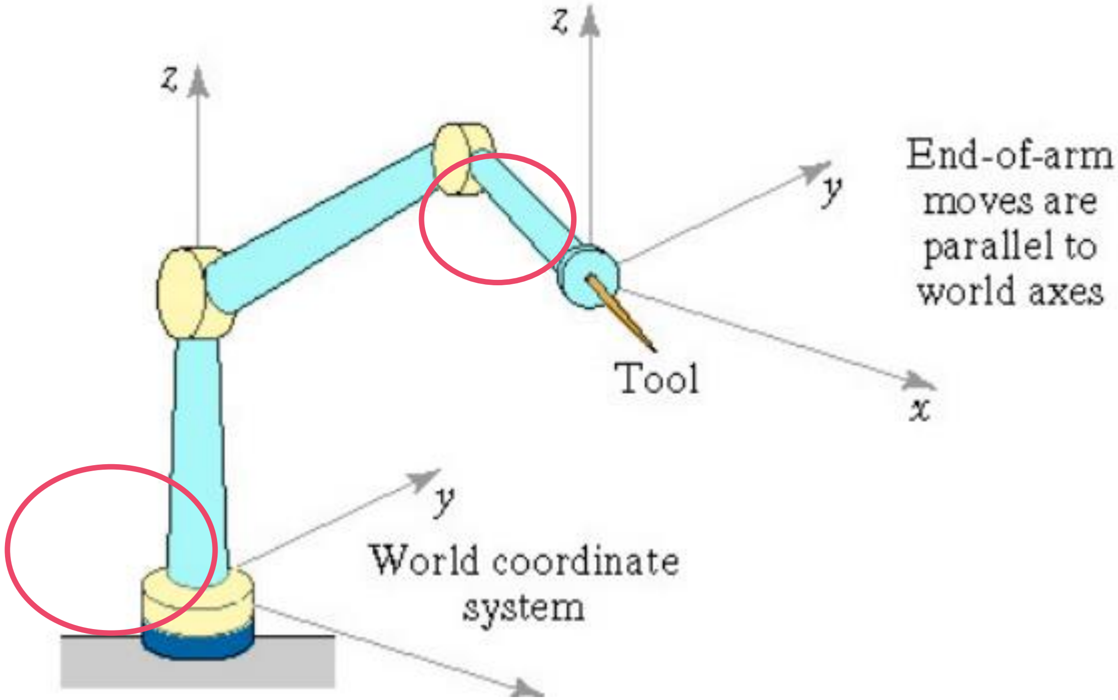
Textural programming languages provide the opportunity to perform the following functions that leadthrough programming cannot readily accomplish: □

- Enhanced sensor capabilities □
- Improved output capabilities to control external equipment □
- Program logic not provided by leadthrough methods □
- Computations and data processing similar to computer programming languages: cycles, loops etc…□
- Communications with other computer systems: reading CAD files

The programs are based on **Coordinate Systems**

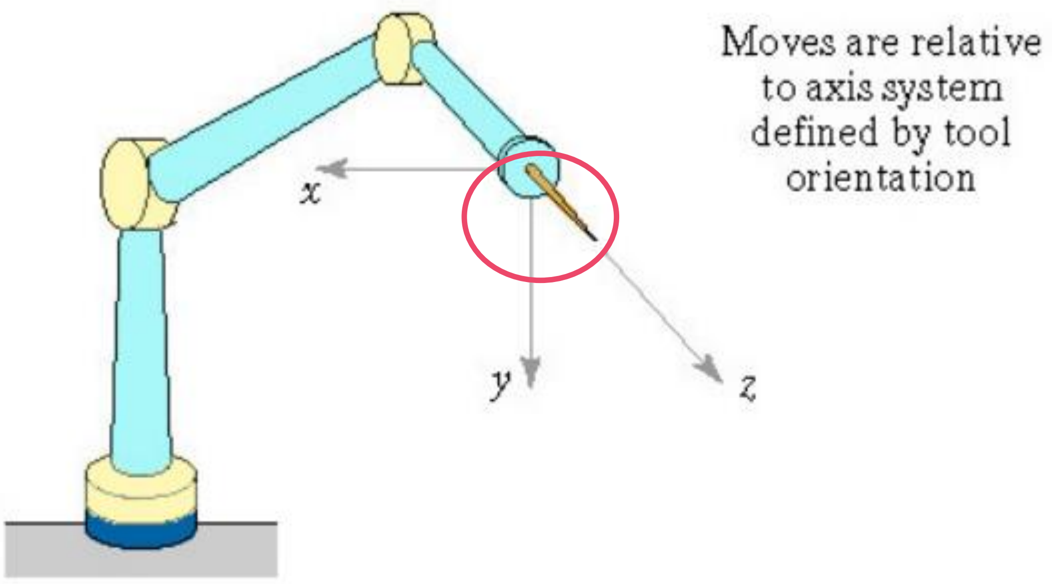
World Coordinate Systems

- Origin and axes of robot manipulator are defined relative to the robot base



Tool Coordinate Systems

Alignment of the axis system is defined relative to the orientation of the wrist faceplate (to which the end effector is attached)



Simulation and off line programming

In conventional usage, robot programming languages still require some production time to be lost in order to define points in the workspace that are referenced in the program: *they therefore involve on-line/off-line programming*.

Advantage of true off-line programming is that the program can be prepared beforehand and downloaded to the controller with no lost production time: graphical simulation is used to construct a 3-D model of the robot cell in which locations of the equipment in the cell have been defined previously

Robot accuracy and repeatability

Three terms used to define precision in robotics, similar to numerical control precision:

1. **Control resolution** - capability of robot's positioning system to divide the motion range of each joint into closely spaced points
2. **Accuracy** - capability to position the robot's wrist at a desired location in the work space, given the limits of the robot's control resolution
3. **Repeatability** - capability to position the wrist at a previously taught point in the work space

Video

- How 6-Axis Industrial Robots Work (02:14)
- Industrial Robots History (06:45)
- ABB Robotics - 10 most popular applications for robots (4:33)
- Assembly Line Robot Arms on How Do They Do It (7:15)

Question for the formative assessment

1. Provide a definition of industrial robot that includes all the salient aspects of these pieces of equipment
2. What are the five types of mechanical joints for robots that may be classified?
3. What are the five basic body-and-arm configurations in robotics?
4. Characterise the joint notation system used for the five joint types of a robotic arm.
5. Define the work envelope.
6. What different types of control are available in robotics?
7. What are the general characteristics of industrial work situations that promote the substitution of robots for human labour?
8. Define lead-through programming.
9. Explain the usefulness of off-line programming.
10. What are the important characteristics of robotic precision?