

# Introduction to Robotics

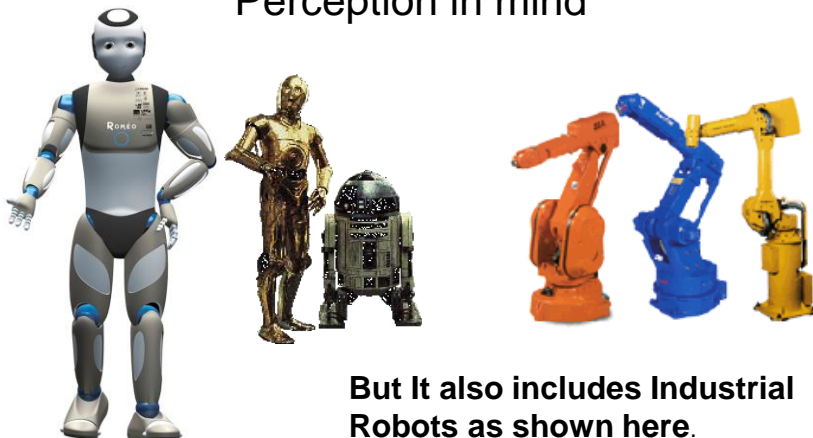
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## Robotics

Perception in mind



**But It also includes Industrial Robots as shown here.**

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## Agenda

- Introduction to Robotics
- Classification of Robots
- Robot accessories
- Robot coordinates
- Work volumes and Reference Frames
- Robot Programming
- Robot Applications in Lean Mfg.

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## Robotics Timeline

- **1922** Czech author Karel Capek wrote a story called Rossum's Universal Robots and introduced the word "Rabota"(meaning worker)
- **1954** George Devol developed the first programmable Robot.
- **1955** Denavit and Hartenberg developed the homogenous transformation matrices
- **1962** Unimation was formed, first industrial Robots appeared.
- **1973** Cincinnati Milacron introduced the T3 model robot, which became very popular in industry.
- **1990** Cincinnati Milacron was acquired by ABB

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## Robot Classification

The following is the classification of Robots according to the Robotics Institute of America

- **Variable-Sequence Robot** : A device that performs the successive stages of a task according to a predetermined method easy to modify
- **Playback Robot** : A human operator performs the task manually by leading the Robot
- **Numerical Control Robot** : The operator supplies the movement program rather than teaching it the task manually.
- **Intelligent Robot** : A robot with the means to understand its environment and the ability to successfully complete a task despite changes to the environment.

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## ROBOT

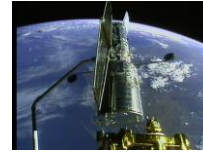
- Defined by Robotics Industry Association (RIA) as  
*A re-programmable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motion for a variety of tasks*
- possess certain anthropomorphic characteristics
  - mechanical arm
  - sensors to respond to input
  - Intelligence to make decisions

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# Robotic System

A Robotic system, consists of the following elements, which are integrated to form a whole:

- **Manipulator / Rover** : This is the main body of the Robot and consists of links, joints and structural elements of the Robot.
- **End Effector** : This is the part that generally handles objects, makes connection to other machines, or performs the required tasks.



It can vary in size and complexity from a end-effector on the space shuttle to a small gripper



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## Accessories

- **Actuators** : Actuators are the muscles of the manipulators. Common types of actuators are servomotors, stepper motors, pneumatic cylinders etc.
- **Sensors** : Sensors are used to collect information about the internal state of the robot or to communicate with the outside environment. Robots are often equipped with external sensory devices such as a vision system, touch and tactile sensors etc which help to communicate with the environment
- **Controller** : The controller receives data from the computer, controls the motions of the actuator and coordinates these motions with the sensory feedback information.



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# Robot Configurations

Some of the commonly used configurations in Robotics are

- **Cartesian/Rectangular Gantry(3P)** : These Robots are made of 3 Linear joints that orient the end effector, which are usually followed by additional revolute joints.

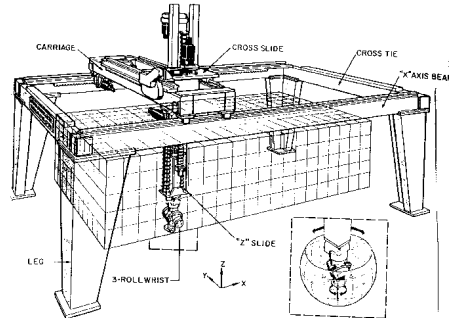
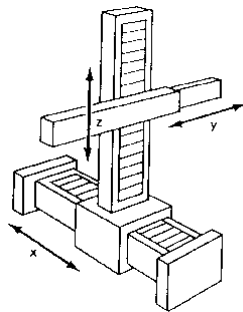
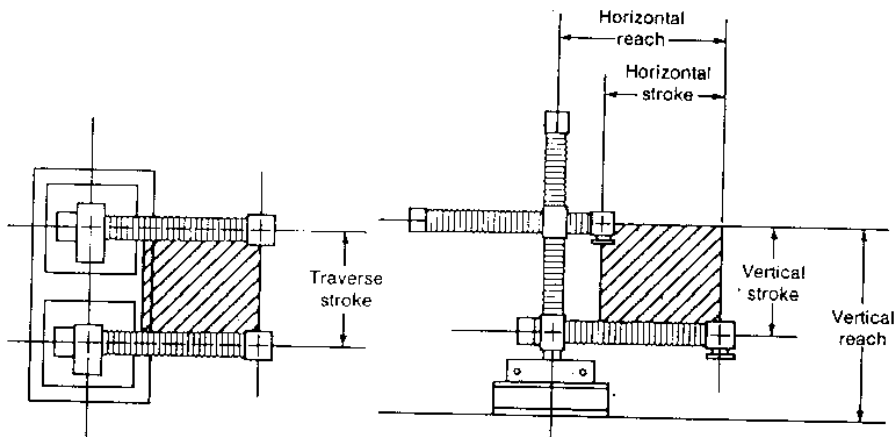


Figure 9.3. Gantry configuration robot. (Courtesy of Cincinnati Milacron.)

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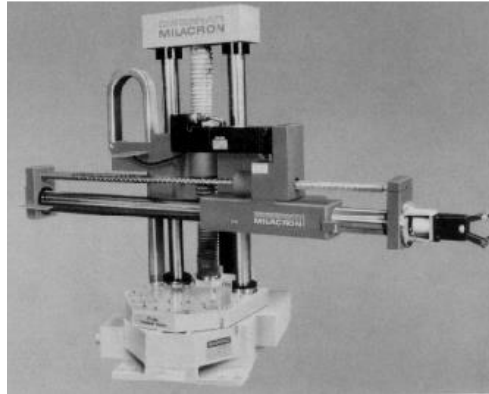
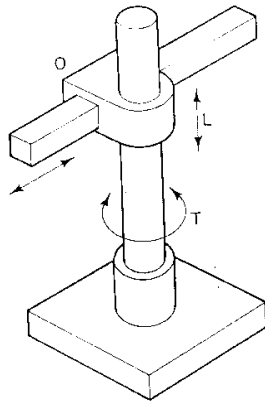
## Cartesian Robot - Work Envelope



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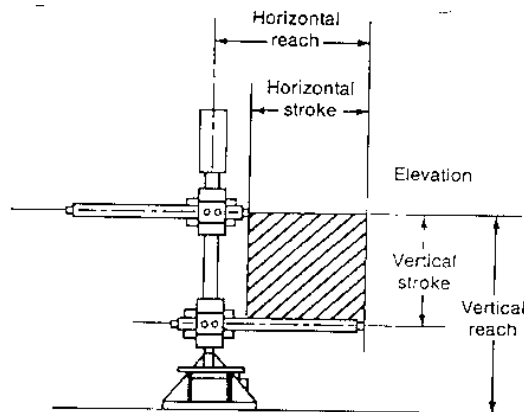
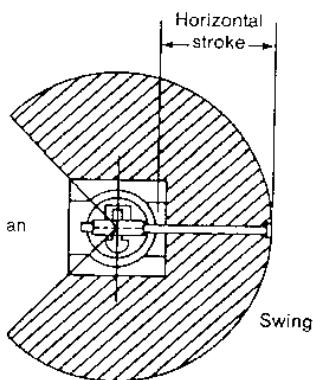
## Robot Configurations (cont'd)

- **Cylindrical (R2P):** Cylindrical coordinate Robots have 2 prismatic joints and one revolute joint.



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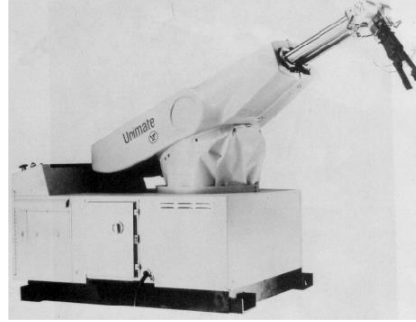
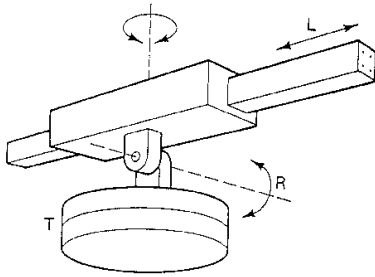
## Cylindrical Robot - Work Envelope



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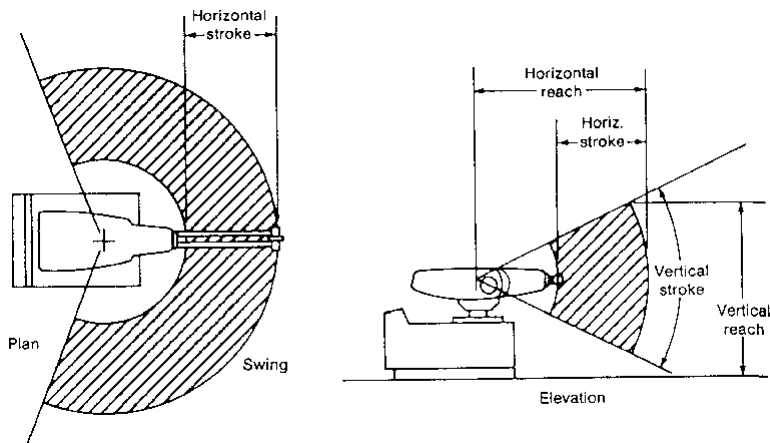
## Robot Configurations (cont'd)

- **Spherical joint (2RP):** They follow a spherical coordinate system, which has one



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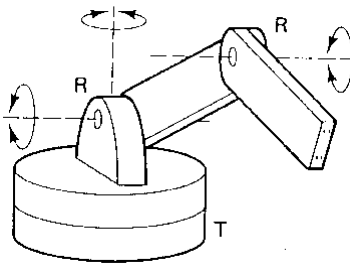
## Spherical Robot - Work Envelope



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## Robot Configurations (cont'd)

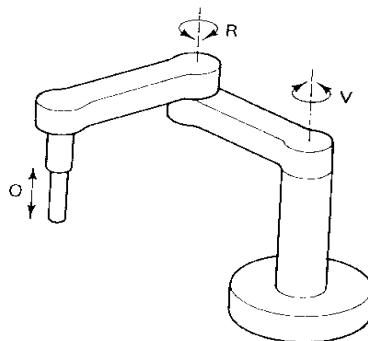
- **Articulated/anthropomorphic(3R)** :An articulated robot's joints are all revolute, similar to a human's arm.



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## Robot Configurations (cont'd)

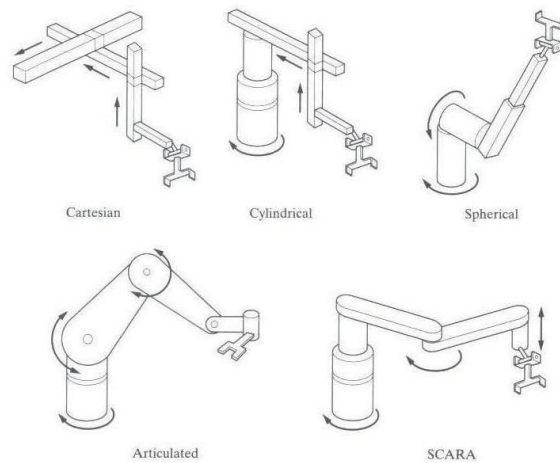
- **Selective Compliance Assembly Robot Arm (SCARA) (2R1P)**: They have two revolute joints that are parallel and allow the Robot to move in a horizontal plane, plus an additional prismatic joint that moves vertically



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# Robot Configurations

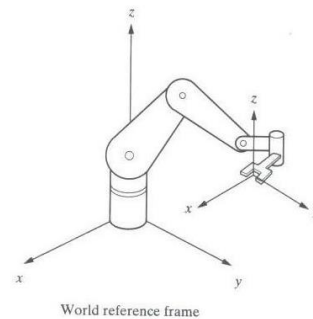


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## Reference Frames

- World Reference Frame
- Joint Reference Frame
- Tool Reference

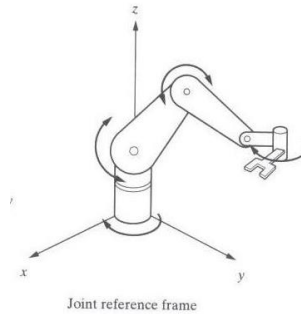
**World Reference Frame** which is a universal coordinate frame, as defined by the x-y-z axes. In this case the joints of the robot move simultaneously so as to create motions along the three major axes.



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## Reference Frames

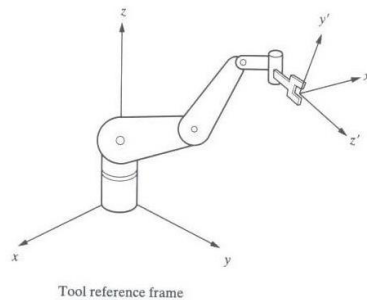
- Joint Reference Frame which is used to specify movements of each individual joint of the Robot. In this case each joint may be accessed individually and thus only one joint moves at a time.



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## Reference Frames

- Tool Reference Frame which specifies the movements of the Robots hand relative to the frame attached to the hand. The  $x'$ ,  $y'$  and  $z'$  axes attached to the hand define the motions of the hand relative to this local frame. All joints of the Robot move simultaneously to create coordinated motions about the Tool frame.



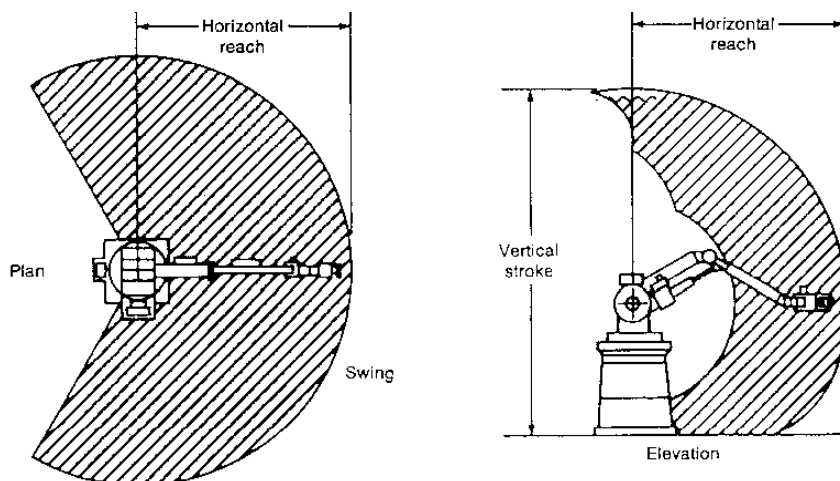
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## Work Envelope concept

- Depending on the configuration and size of the links and wrist joints, robots can reach a collection of points called a **Workspace**.
- Alternately Workspace may be found empirically, by moving each joint through its range of motions and combining all space it can reach and subtracting what space it cannot reach

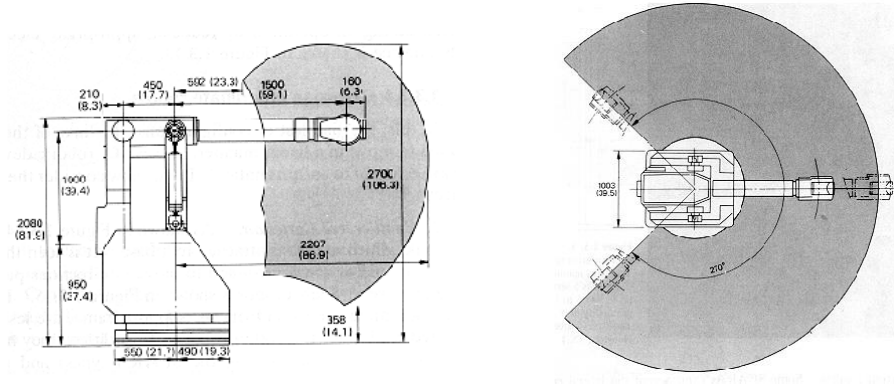
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## Pure Spherical Jointed Arm - Work envelope



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## 2) Parallelogram Jointed



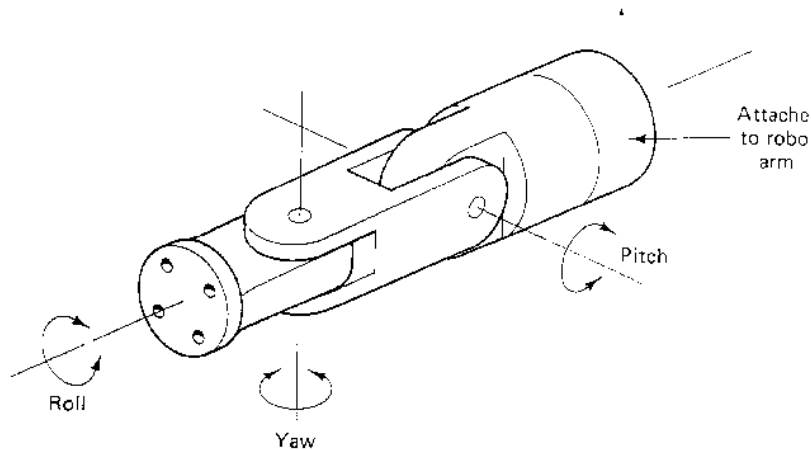
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## WRIST

- typically has 3 degrees of freedom
  - **Roll** involves rotating the wrist about the arm axis
  - **Pitch** up-down rotation of the wrist
  - **Yaw** left-right rotation of the wrist
- End effector is mounted on the wrist

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## WRIST MOTIONS



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## CONTROL METHODS

- ***Non-Servo Control***
  - implemented by setting limits or mechanical stops for each joint and sequencing the actuation of each joint to accomplish the cycle
  - end point robot, limited sequence robot, bang-bang robot
  - No control over the motion at the intermediate points, only end points are known

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- Programming accomplished by
  - setting desired sequence of moves
  - adjusting end stops for each axis accordingly
  - the sequence of moves is controlled by a “sequencer”, which uses feedback received from the end stops to index to next step in the program
- Low cost and easy to maintain, reliable
- relatively high speed
- repeatability of up to 0.01 inch
- limited flexibility
- typically hydraulic, pneumatic drives

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- ***Servo Control***
  - Point to point Control
  - Continuous Path Control
- Closed Loop control used to monitor position, velocity (other variables) of each joint

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## Point-to-Point Control

- Only the end points are programmed, the path used to connect the end points are computed by the controller
- user can control velocity, and may permit linear or piece wise linear motion
- Feedback control is used during motion to ascertain that individual joints have achieved desired location

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- Often used hydraulic drives, recent trend towards servomotors
- loads up to 500lb and large reach
- Applications
  - pick and place type operations
  - palletizing
  - machine loading

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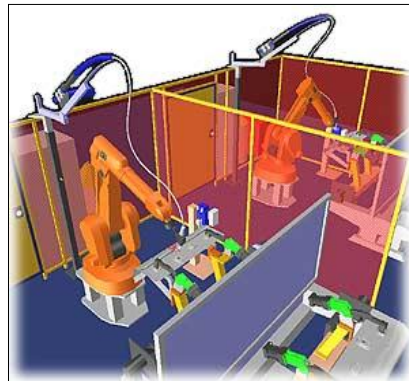
## Continuous Path Controlled

- In addition to the control over the endpoints, the path taken by the end effector can be controlled
- Path is controlled by manipulating the joints throughout the entire motion, via closed loop control
- Applications:
  - spray painting, polishing, grinding, arc welding

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## ROBOT PROGRAMMING

- Typically performed using one of the following
  - Online
    - teach pendant
    - lead through programming
  - Offline
    - robot programming languages
    - task level programming

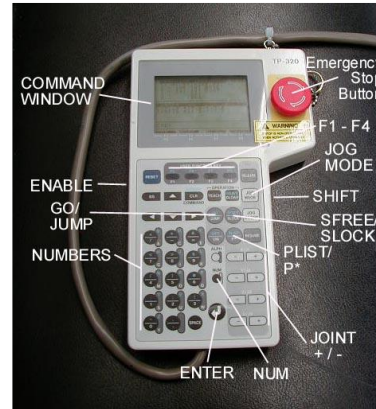


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## Use of Teach Pendant

- Handheld device with switches used to control the robot motions
- End points are recorded in controller memory
- Sequentially played back to execute robot actions
- Trajectory determined by robot controller
- Suited for point-to-point control applications



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- Easy to use, no special programming skills required
- Useful when programming robots for wide range of repetitive tasks for long production runs
- RAPID

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## Lead Through Programming

- lead the robot physically through the required sequence of motions
- trajectory and endpoints are recorded, using a sampling routine which records points at 60-80 times a second
- when played back results in a smooth continuous motion
- large memory requirements

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## Programming Languages

- Motivation
  - need to interface robot control system to external sensors, to provide “real time” changes based on sensory equipment
  - computing based on geometry of environment
  - ability to interface with CAD/CAM systems
  - meaningful task descriptions
  - off-line programming capability

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- Large number of robot languages available
  - AML, VAL, AL, RAIL, RobotStudio, etc. (200+)
- Each robot manufacturer has their own robot programming language
- No standards exist
- Portability of programs virtually non-existent