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

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

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

- Pick and place
  - Moves items between points

- Continuous path control
  - Moves along a programmable path

- Sensory
  - Employs sensors for feedback

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

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

Engineering Innovation
A Summer Program for High School Students

Johns Hopkins Whiting School of Engineering
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.
• 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

Low accuracy, high repeatability:

High accuracy, low repeatability:
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 \((r,\theta,z)\)
  • spherical \((r,\theta,\phi)\)

• Coordinates
  • World coordinate frame
  • End effector frame
  • How to get from coordinate system \(x''\) to \(x'\) to \(x\)
Transformations

• General coordinate transformation from $\mathbf{x}'$ to $\mathbf{x}$ is $\mathbf{x} = \mathbf{B}\mathbf{x}' + \mathbf{p}$, where $\mathbf{B}$ is a rotation matrix and $\mathbf{p}$ is a translation vector.

• More conveniently, one can create an augmented matrix which allows the above equation to be expressed as $\mathbf{x} = \mathbf{A}\mathbf{x}'$.

• Coordinate transformations of multilink systems are represented as

$$\mathbf{x}_0 = A_{01} A_{12} A_{23} \ldots A_{(n-1)(n)} \mathbf{x}_n$$
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
New directions

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

A snake robot (OCRobotics)