ROBOTICS - INTRODUCTION

Robotics is the intelligent connection of the perception to action.

A robot is defined in many ways: "A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks" (Robot Institute of America definition, 1979), "An automatic device that performs functions normally ascribed to humans or a machine in the form of a human." (Webster Dictionary).

The first definition is restricted to what a robot manipulator is doing in a mechanical sense. The second definition is more general but still limited to what robots are supposed to do.

The definition given by M. Bradley, "Robotics is the intelligent connection of the perception to action" considers robotics from a system integration perspective, indicating how robots are doing things. Programmable robots (manipulators, vehicles) provide the action function. A variety of sensors provide the perception capability. Computers provide the framework for integration/connection as well as the intelligence needed to coordinate in a meaningful way the perception and action capabilities.

Bradley's definition recognizes a new step in the evolution of robotics. In the early stages, computers were seen as mere convenient programmable controllers for the sequence of motions to be performed by the articulated mechanical structure that was the robot. Today robots are more and more seen from an artificial intelligence perspective as providing arms, legs and wheels that, together with sensors, allow computer-based intelligent agents to interact with the physical reality.
The robot as a cybernetic alter ego of the human.

**Highlights in the History of Robotics**

1400s  
The first android clocks are developed in Germany and Switzerland.

1770  
Pierre and Henri Jacquet-Droz construct lifelike automata that can write, draw, and play musical instruments and are controlled by cams and driven by springs.

1818  
Eli Whitney invents a milling machine.

1830s  
Charles Babbage devises his analytical engine, the forerunner of the modern digital computer.

1870s  
Herman Hollerith perfects the first automatic calculator.

1921  
Karel Capek’s play Rossum’s Universal Robots introduces the term robot, derived from the Czech word "robota" which means “forced labor".
1930s  The first spray-painting machines with recorded paths are developed.
1940s  Isaac Asimov and John Campbell devise the concept of the intelligent robot that follows instructions, and together they write numerous science fiction stories about robots. Asimov coins the phrase robotics to denote the study of robots.
1942  The first automatic sequence controller is developed at Harvard University.
1944  R. Goertz introduces the first master-salve (teleoperator) manipulator.
1946  George Devol develops the magnetic controller playback device.
1948  J.P. Eckert and John Mauchley complete construction of the ENIAC computer at the University of Pennsylvania.
1949  EDSAC, the first computer with a stored program, is developed at Cambridge University.

  “During the rest of 1945 and early 1946, Leaver .... worked out not only the basic design of a hand-arm machine that could function as either a remotely controlled or a programmed manipulator, but in addition carried his thinking much farther into the general field of making products without using the labour of men. After a characteristically thorough and critical study of all the ways of controlling machine tools automatically, he settled on the system which he called AMCRO. By mid-1946 these ideas were well enough developed to enable me to write a long article for Fortune called “The Automatic Factory”. In the meantime, at this company’s small Toronto plant, Leaver, with the help of G.R. Mounce .... built the first production tool capable of memorizing a skilled workman’s operations and then playing them back to make a product. This basic invention, one of the first contributions to what is today the great field of automation, was operating in their Toronto plant by 1947 .... Canadian, U.S. and foreign patents were granted Leaver and Mounce in 1949.”

1952  The first numerically controlled machine tool is built at MIT.
1954  George Devol designs the first programmable robot.
1955  Denavit and Hartenberg develop their method for determining and specifying the configuration of the various links in a manipulator.
1956  Joseph Engelberger, a Columbia University physics student, buys the rights to Devol’s robot and soon after starts the Unimation Company.
1961  The first Unimate robot is installed in a Trenton, New Jersey, plant of general Motors (to tend a die-casting machine).
1965  A major program in robotics is initiated at the Stanford University Artificial Intelligence Laboratory (SAIL) by John McCarthy.
1968  Kawasaki Heavy Industries in Japan obtains a licensing agreement from Unimation.
1974  Cincinnati Milacron introduces the T3, the first industrial robot to employ a completely revolute configuration.
1975  Unimation Inc. registers its first financial profit.
1978  The first PUMA (whose design is based on Victor Sheinman’s Stanford
manipulator) is shipped to GM by Unimation.

1980  Fujitsu Fanuc Company of Japan develops the first totally automated factory.

SPACE ROBOTICS:

- **NASA Telerobotics Program** addresses the three specific mission and application areas: on-orbit assembly and servicing, science payload tending, and planetary surface robotics. => **Mars Rover**
- **Canadian Space Agency:**
  - In 1981, Canada confirmed its position as a world leader in space technology with the development of the Remote Manipulator System, or **Canadarm**. The RMS can be used: to deploy and retrieve satellites, to hold targets, to explore samples, and to manipulate hardware for the Space Shuttle.
  - In 1988, Canada agreed to join the international partners to build a permanently inhabited Space Station. Canada's contribution is to design, manufacture, and operate a robotic system, the **Mobile Servicing System** (MSS), for assembly, maintenance, and servicing tasks on the Space Station.

---


- **0th law:** "A robot may not injure humanity or, through inaction, allow humanity to come to harm."
- **1st law- updated:** "A robot must not harm a human being or, through inaction allow one to come to harm, unless this would violate the 0th law."
- **2nd law:** “A robot must always obey human beings unless that is in conflict with the 1st law”.
- **3rd law:** “A robot must protect itself from harm unless that is in conflict with the 1st and 2nd law”.

---

**Robot Components and Subsystems**

- **NB:** Most of this *Robot Components and Systems* section represents a summary of chapter *Components and Subsystems* of the reference P.J. McKerrow, *Introduction to Robotics*, Addison-Wesley, 1991.

A robot system is an integrated system providing an intelligent connection of the perception to action. From a mechanical point of view a robot appears, as illustrated in Fig. 2.1, as an articulated structure consisting of a series of links interconnected by joints. Each joint is
driven by a motor which can change the relative position of the two links connected by that joint.

The **functional subsystems of a robot** are process, planning, sensor, control, electrical, and mechanical.

The **process subsystem** includes the task the robot performs, the environment in which it is placed and the interaction between it and the environment. The task the robot is expected to perform must be formulated a sequence of steps that the robot can execute. Task formulation includes the «intelligent » processes of environment perception, task and world modelling and **planning** the actions. Two types of sensors are used: (i) **proprioperceptors** for the measurement/moitoring of the robot's internal state parameters, and (ii) **exteroceptors** for the measurement of the environment's state parameters.

Data from a variety of sensors is fused with mathematical models of the task to form a model of the world. At the perception level, this world model is used to infer the system and environment state, and to assess the consequences of the planned course of the robot's actions. Task execution strategies are converted into robot control programs during the action planning phase.

The task execution programs are executed by the **control subsystem**. This subsystems converts, if needed, high-level robot programming instructions into robot joint-level commands. It also provides the servo-control of the physical actuators driving the robot joints.

The **electrical subsystem** comprises of computers, sensors, motors, electronic interfaces, data transmission/communication links, and power supplies.

The **mechanical subsystem** comprises of all the mechanical components of the robot *manipulators*, *robot vehicles*: links, joints, hands, end effectors, gears, tendons, brakes, frames, wheels, tracks, legs, propellers, etc.
Subsystems of a robotic manipulator

- Motor
- Sensor
- Link
- Hand
- Sensor Interface
- Motor Interface
- Servo Control
- Computer
  * Planning
  * Control

ROBOTICS - INTRODUCTION

MoveJointTo $\Theta$

MoveHandTo $(x,y,z)$