Robotics
Introduction

Tullio Facchinetti
<tullio.facchinetti@unipv.it>

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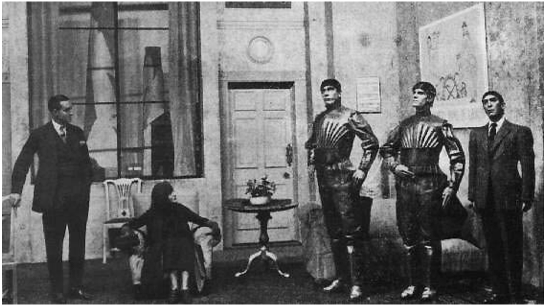
http://robot.unipv.it/toolleeo

Robot



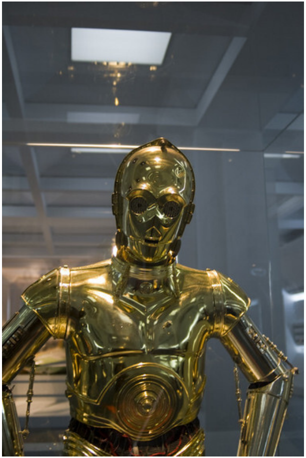
- a robot is a servo-mechanical system able to perform complex operations, often heavy, repetitive or dangerous for human being
- the term has been firstly used by the Czech writer Karel Čapek in his play R.U.R. (Rossum's Universal Robots) in 1920
- origins from the Czech word “robota”, which means work

Robotics

- it is the science that studies robots
- the term has been introduced by Isaac Asimov in 1942 in his story “Lier!”, included in the collection “I, Robot”

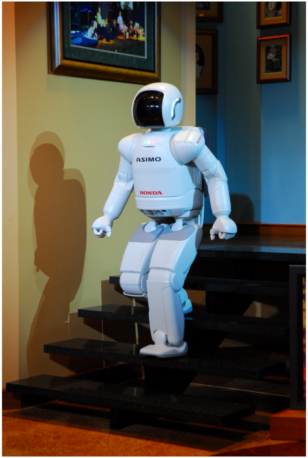
Android

- it is a robot having human appearance
- the term derives from the Greek anèr, andròs, “men”
- it can thus be translated as “having human shape”
- the term has been introduced by George Lucas in his movie Star Wars (1977)



the C-3PO android
in Star Wars (1977)

Android



the ASIMO android (Honda)

Cyborg

- **CYB**ernetic **ORG**anism
- it identifies an automatic system where mechanical and biological parts are merged
- optionally, can have human appearance
- the term derives from a scientific paper written by M. Clynes and N. Kline in 1960, talking about advantages of cyborgs in space missions

the cyborg in the movie Terminator (1984)

Autonomous and non-autonomous robots

autonomous robots

- not operated by humans
- can work in unknown environments
- may use algorithms derived from artificial intelligence

non-autonomous robots

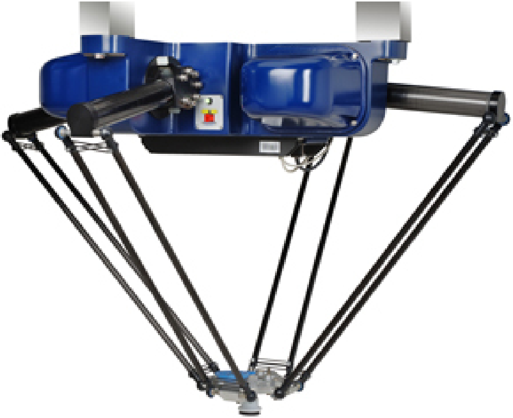
- tele-operated by a human operator
- if not operated, an a-priori behavior is programmed (e.g., a painting robot in an automotive factory)

Industrial robotics

- industrial robots are usually linked to the ground
- adopted in factories to perform high precision, repetitive works
- typical applications: assembly, painting, transportation, packing, etc.

a manipulator for industrial manufacturing

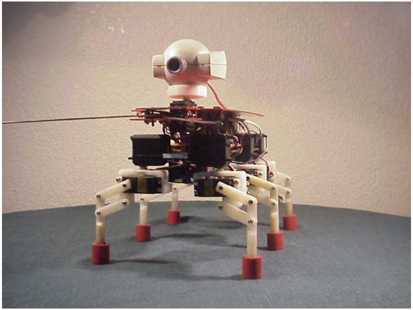
Industrial robot



industrial robot for dedicated manufacturing

Mobile robotics

- mobile robots are not linked to the ground
- applications: demining, SWAT, surveillance, exploration
- can move over different types of terrain by wheels or legs
- can fly or working underwater
- various shapes and size



a mobile legged robot

Mobile robots

the MR-5 mobile robot (Engineering Services Inc.)
used for demining, SWAT and surveillance (tele-operated)

Examples: Spirit and Opportunity

- developed by the NASA
- Spirit landed on Mars in January 2004, stuck in 2009, stop communicating in 2010
- Opportunity worked from 2004 to 2018, around 30 times the expected lifetime
- activities: exploration of Mars, take pictures, geological measurements

Components of a robotics system

what are the common characteristics
of the illustrated robots?

all of them are made by the following types of components:

- mechanical
- electrical
- electronics
- software

Hardware of a robot

1. mechanical frame (chassis)
2. sensors
3. actuators
4. computing devices
5. electric/electronic cables
6. energy supply
7. (tele)communication system

Mechanical frame

it is the mechanical structure (frame) where all components are mounted on

issues/challenges

- payload
- robustness
- rigidity and stability

enabling technologies

- "traditional" mechanical components
- nano-technology
- bio-inspired structures and shapes

Mechanical frame and movement

the choice of the mechanical frame is strictly related to the characteristics of the motion

some options are:

- wheels
- caterpillars
- legs
- creeping
- underwater
- aerial

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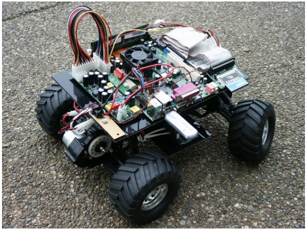

http://www.tantosonline.com/andras/robot.htm

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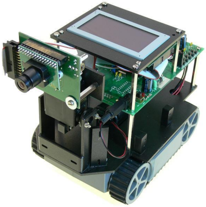

http://www.robotstorehk.com/drrobot/pob.html

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Wall-E

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https://en.wikipedia.org/wiki/Legged_robot

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http://www.moah.org/robotman/the_exhibit/exhibit.html

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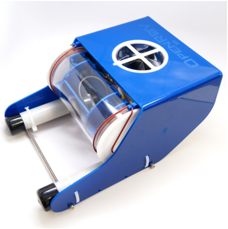

http://www.southernfriedscience.com/

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http://dronelife.com/

Mechanical frame and movement

the issues related to the mechanical frame
are of paramount relevance
for the design and the operation of a robot

however... they are out of the scope of this course

Sensors

sampling of environmental parameters

issues/challenges

- gathering data required for the control
- "closing" the control loop
- error/fault detection

enabling technologies

- mechanics
- electrics/electronics
- chemistry and physics
- Micro/Nano Electro-Mechanical Systems (MEMS/NEMS)

Actuators

perform operations that produce some effect on the surrounding environment

issues/challenges

- robot motion
- specific operations of the robot: grasping, manipulation, transportation, painting, etc.

enabling technologies

- electro-mechanical (motors)
- pneumatic
- shape-memory alloy
- Micro Electro-Mechanical Systems (MEMS)

Embedded computing system (hardware)

onboard data processing

issues/challenges

- processing of sensory data
- implementation of control/behavior algorithms and strategies
- implementation of networking protocols

enabling technologies

- embedded systems
- generic technologies based on microprocessors

Cables (power)

required to dispatch the power supply
to all the necessary active components
(include sensors, actuators, processors, radio)

issues/challenges

- dimensioning of cables
- required voltage/current levels
- weight and occupancy

enabling technologies

- classical electrical tools/knowledge

Cables (signal)

connections to carry around data and information

issues/challenges

- interfacing sensors and actuators with the processing unit
- number and types of interconnected components
- shielding against noise (typically electromagnetic fields)

enabling technologies

- digital (e.g., RS-232, buses as I2C, SPI, RS-485, CAN, ...)
- analog (e.g., 4-20 mA)

Energy source

provide the required energy to power the various components

two distinct situations:

1. plug the robot to the power plug (industrial and home robotics, including mobile)
2. equip the robot with autonomous power sources (mobile robotics)

Power supply: industrial vs consumer robotics

if the robot can be plugged to a power socket
the power supply task
is greatly simplified

issues/challenges

- types of power link
- limited/no mobility

enabling technologies

- cables
- brushes
- wireless (electromagnetic field)

Power supply: mobile robotics

an energy provision must be bundled with the robot

issues/challenges

- trade-offs among weight, occupancy and cost
- limited amount of energy $\rightarrow$ limited lifetime
- power awareness (motion, computing, communication, etc.)
- accessibility to environmental sources (e.g. recharging through solar panels)

enabling technologies

- batteries
- fuels (oil, fuel cell, etc.)
- renewable sources
- energy harvesting/scavenging

Communication

enables the robot to exchange information
with other robots or operators
(not mandatory, but definitely common)

issues/challenges

- connection with a control station
- robot-to-robot interaction (multi-robot systems)
- distance between communicating robots (signal fading)
- noise, interference and possibly data loss

enabling technologies

- wired links
- wireless technologies (radio, laser, infrared, ultrasound)

Software modules of a robot

the software is made by programs that implement control algorithms and management strategies

issues/challenges

- sensor sampling
- control loops of actuators
- robot motion
- trajectory planning and navigation
- communication protocols
- multi-robot coordination strategies
- fault-tolerance and error handling

Robot control

the system can be represented as a dynamical process

system modeling

- model approximation
- parameter estimation
- tolerances on sensors and actuators

control actions

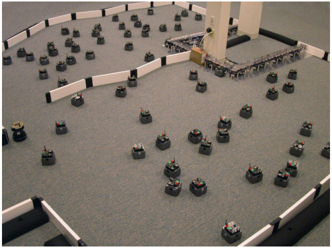
- automatic control

Communication

mandatory in most robotics applications

communication protocols

- interconnection of several robots
- coordination of Multi Robot Systems
- timing of message exchange
- replication/forwarding of messages
- management of errors and data loss
- security



Source: https://people.csail.mit.edu/jamesm/images/swarm/

Factors driving the design options

robots can be based on many different
shapes, components and technologies

some relevant factors that drive the selection of a design solution are:

- the application for which the robot is build
- the available technology
- applicable innovative solutions
- time available for the development
- costs