Robotics
Introduction

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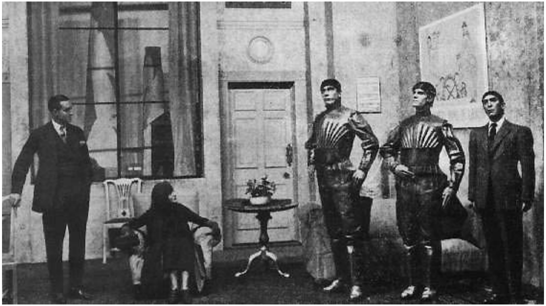
19:27

http://robot.unipv.it/toolleeo

Robot



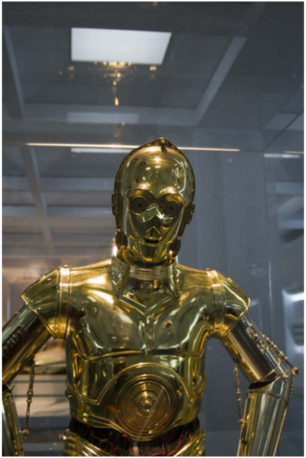
- a robot is a servo-mechanical system able to perform complex operations, often heavy, repetitive or dangerous for human being
- the term has been firstly used by the Czech writer Karel Čapek in his play R.U.R. (Rossum's Universal Robots) in 1920
- origins from the Czech word "robota", which means work

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”

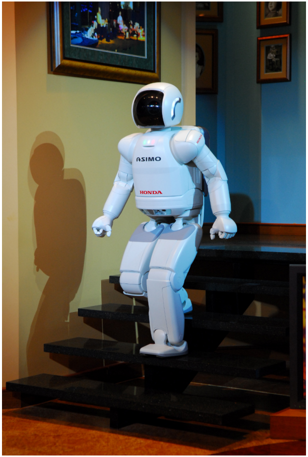
Android

- 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

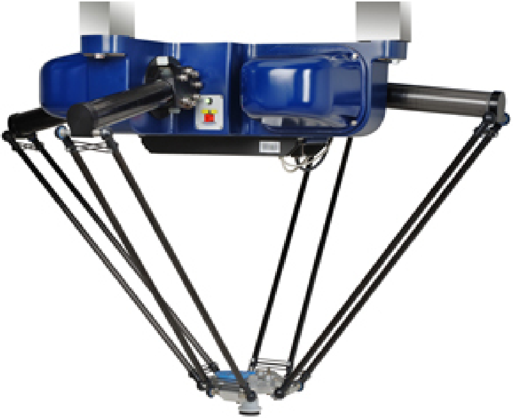
- tele-operated by a human operator
- if not operated, an a-priori behavior is programmed (e.g., a painting robot in an automotive factory)

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

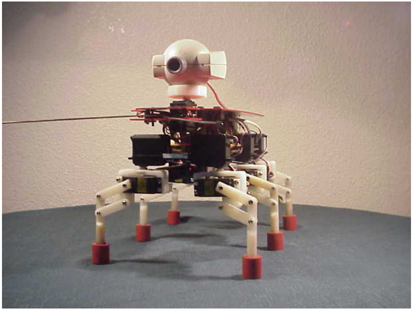
Industrial robot



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
- landed on Mars in January 2004
- designed to work for 90 days, they are still alive
- activities: exploration of Mars, take pictures, geological measurements

Components of a robotics system

what are the common characteristics of illustrated robots?

all of them include some of the following systems:

- 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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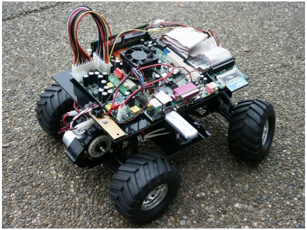

http://www.tantosonline.com/andras/robot.htm

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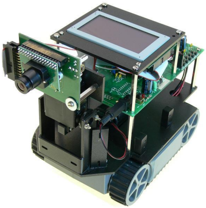

http://www.robotstorehk.com/drrobot/pob.html

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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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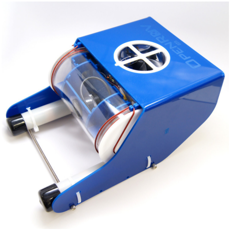

http://www.southernfriedscience.com/

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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
- MicroElectroMechanical 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

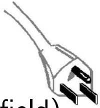
> if the robot can be plugged to a power socket
> the power supply task
> is greatly simplified

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 → 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

“Distribution” of software modules

various scenarios, depending on where programs are executed:

- tele-operation from a remote station
- onboard processing (autonomous robot)
- mixed approaches: suitable distribution of processing between onboard and control station

"Distribution" of software modules

tele-operation from a remote station

- one or more human operators
- possibility of automatic control, even remotely
- in case of MRS, it is a centralized architecture
- usually, simpler organization

onboard processing

- the robot can be fully autonomous
- in case of multi-robot systems, the whole architecture is a distributed system
- more complex management

mixed solutions

- suitable partitioning of logical functions
- implementation flexibility

Example of mixed operations

AR Drone from Parrot

- can be remotely controlled by a PC or smartphone
- equipped with gyros, cameras and proximity sensors
- the stabilization control runs onboard
- application specific tasks (e.g., image processing) can be done remotely

"Distribution" of software components

independently from the architecture
(distributed, centralized or hybrid)
usually, even the robot alone
can be seen as a distributed computing system

- there are several distinct processing units
- each unit is dedicated to one specific function
- units are interconnected
- the interaction among units is challenging

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

Challenges in computing

real-time processing

- response time of processing tasks
- processor computational load

adaptation to cases that are hard to model

- fault/error tolerance approaches
- may use artificial intelligence techniques

energy awareness

- optimization of movement and trajectories
- optimization of computing resources
- optimization of communication

Communication

mandatory in most of robotics applications

communication protocols

- interconnection of several robots
- timing guarantees of message exchange
- replication and forwarding of messages
- management of errors and data loss
- security

Distributed coordination

Multi-Robot Systems (MRS)
based on the cooperation of several robots

- coordination of robot to achieve a common goal
- communication based on wireless technologies

applications of MRS

- formation control (e.g. containment, flocking)
- patrolling
- surveillance
- rescue missions

Cyber-Physical Systems

tight integration between
the physical process and the computing devices

- it studies the effect of processing and communication issues on the physical system
- it is a very recent and rather hot research topic
- it represents the evolution of embedded systems

fields of applications

- avionics and automotive
- medical
- energy/power systems
- military

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

Outline

1. navigation algorithms
2. principles of Finite State Machines
3. real-time computing systems
4. measurement systems
5. principles of sensors
6. MEMS - Micro Electro-Mechanical Systems
7. errors and compensation