MOBILE ROBOTICS

Pedro Lima

Maria Isabel Ribeiro

Instituto Superior Técnico/Instituto de Sistemas e Robótica

March 2002

Course Handouts

Chapter 1 - Introduction

- Concepts / Definitions
- Historical Evolution
- Applications
- Commercial platforms
- Some Examples of Application/R&D projects
- Components of a Mobile Robot
- Course Organization
- Bibliography

Concepts / Definitions

- Robotics
  - Scientific area that studies the link between Perception and Action
- Robot
  - Device able to perform activities as a human
  - Programmable manipulator able to execute multiple operations (e.g., material and part handling), following programmed paths to fulfill a large variety of tasks.

- Mobile Robot / Mobile Platform
  - Platform with a large mobility within its environment (air, land, underwater)
  - A system with the following functional characteristics:
    - Mobility: total mobility relative to the environment
    - A certain level of autonomy: limited human interaction
    - Perception ability: sensing and reacting in the environment

The terms Mobile Robot, Mobile Platform, Vehicle, Robot are often used with the same meaning

Historical Evolution

Historical Evolution

1150-950 a.c.

Anubis - Ancient Egyptian god of the dead, represented as a jackal or as a man with the head of a jackal. In the Early Dynastic period and the Old Kingdom he was preeminent as lord of the dead, but he was later overshadowed by Osiris. **Anubis** was associated with the care of the dead and was credited with the invention of embalming, an art he first practiced on the corpse of Osiris. Later assigned the role of conducting souls into the underworld, he was sometimes identified in the Greco-Roman world with Hermes.

1921

Karel Capek - He is most famous for coining of the word ``robot'', from the Czech robota, work, in his play (Rossum's Universal Robots –RUR) about them taking over the world. The play used to be extremely popular and well-known.

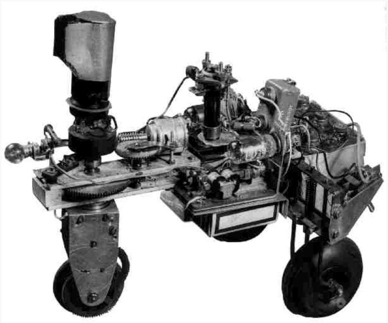
R.U.R. (Rossum's Universal Robots), which introduced the word robot into the English language, conceives a future in which all workers will be automated. Their ultimate revolt when they acquire souls and the ensuing cotastrophe comprise an exciting, vivid theatrical experience

See http://www.agora.qc.ca/reftext.nsf/Documents/Robot--Le_regne_des_robots_par_Karel_Capek for an explanation of RUR.

http://www.plazaearth.com/usr/gasperi/walter.htm

Historical Evolution

1950



Elsie

Grey Walter (UK, University of Bristol) bulit three wheeled, turtle like, mobile robotic vehicles. These vehicles had:

- a light sensor,
- touch sensor,
- propulsion motor,
- steering motor, and a two vacuum tube analog computer.

Even with this simple design, Grey demonstrated that his turtles exhibited complex behaviors. He called his turtles Machina Speculatrix after their speculative tendency to explore their environment.

The Adam and Eve of his robots were named Elmer and Elsie (ELectro MEchanical Robots, Light Sensitive.)

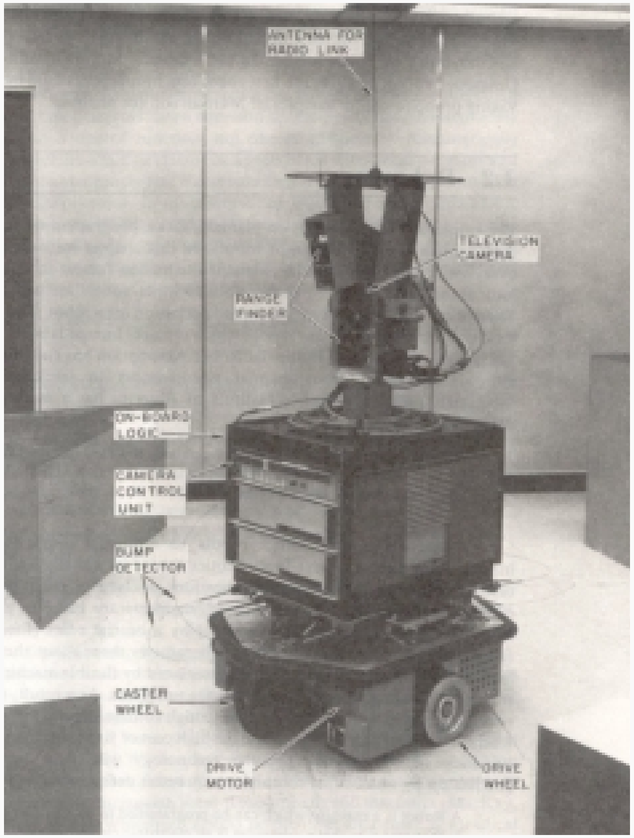
http://www.plazaearth.com/usr/gasperi/walter.htm

The first AGV systems were developed in the 1950s by Barrett Electronics, USA

Historical Evolution

1969

Shakey (Stanford University) it was the first mobile robot to be controlled by vision

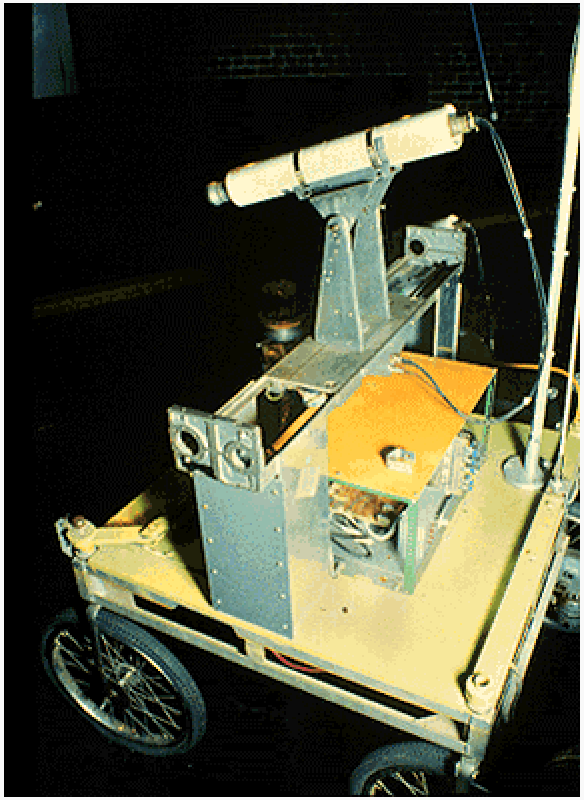


Shakey was set simple tasks to solve:

- To recognize an object using vision
- Find its way to the object
- Perfom some action on the object (for example, to push it over)

Historical Evolution

1979 **Stanford Cart**



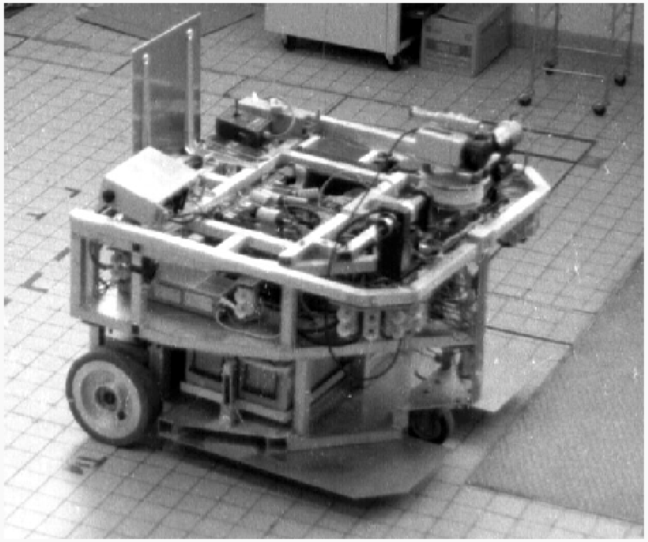
In development since 1967, the Stanford Cart successfully crossed a chair-filled room without human intervention in 1979.

Hans Moravec rebuilt the Stanford Cart in 1977, equipping it with stereo vision. A television camera, mounted on a rail on the top of the cart, took pictures from several different angles and relayed them to a computer. The computer gauged the distance between the cart and obstacles in its path.

Historical Evolution

1977-1992 **The Hilare Family**
LAAS - France

1977 - Hilare I



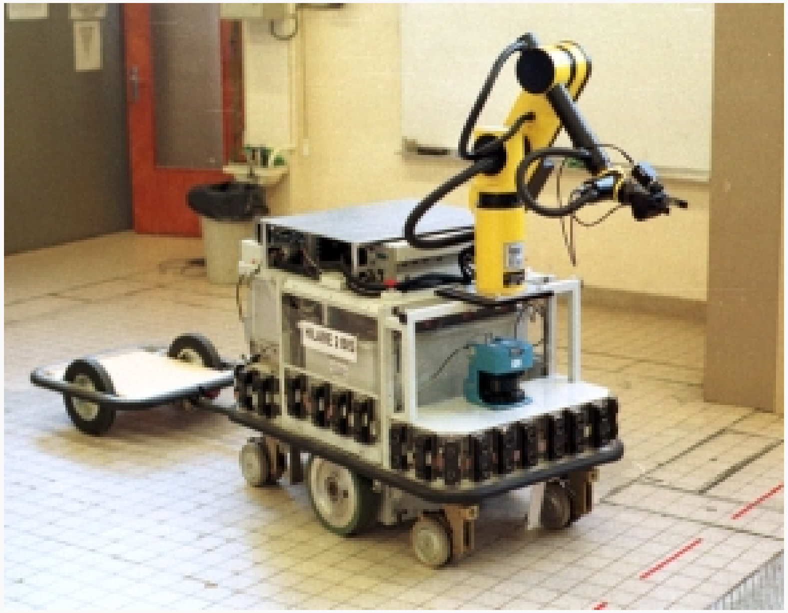
Wheels:
2 driving wheels and a free wheel
Batteries:
24V
Bus:
Multibus
Processors:
4 x Intel 80286
Operating system:
none
Communication:
serial radio modem (9600 bauds)
Sensors:
Odometer,
16 US sensors,
a Laser Range Finder
Dimensions (LxWxH):
80cm x 80cm x 60 cm
Weight:
400kg

Historical Evolution

1990 - Hilare II

Wheels:
    2 driving wheels + 4 free wheels
Batteries:
    48V
Bus:
    VME
Processors:
    4 x Motorola 68040 + 1 Motorola PPC 750
Operating system:
    VxWorks 5.3.1
Communication:
    Ethernet radio modem (3 Mbit/s)
Sensors:
    odometry,
    32 Sonar range sensors,
    2D Laser Range Finder,
    1 Pan/Tilt/Zoom color camera,
    2 Pan/Tilt black and white cameras
Dimensions (LxWxH):
    130cm x 80cm x 80cm
Weight:
    450kg

1992 - Hilare IIbis



Wheels:
 2 driving wheels + 4 free wheels
Batteries:
 48V
Bus:
 1 VME Rack
Processors:
 4 x Motorola 68040 + 1 Motorola PPC 604
Operating system:
 VxWorks 5.3.1
Communication:
 Ethernet radio modem (3 Mbit/s)
Sensors:
 odometry,
 32 Sonar range sensors,
 2D Laser Range Finder,
 1B&W camera
Dimensions (LxWxH):
 130cm x 80cm x 80cm
Weight:
 400kg

http://www.laas.fr/laasve/index.htm

Historical Evolution

1989 Ghenghis

Legged Robot

http://www.ai.mit.edu/projects/genghis/genghis.html

Historical Evolution

1993-1994 Dante II

- legged robot – 8 legs
- Exploration at Antartic and Alaska
- The first robot to use rapell
- Communication channel based on optical fiber to a base station and then to a satelite station
- Colour images, laser and cameras on the legs
- Gas sensors
- Computers on VME bus (Sparc and MC68000)

http://www.ri.cmu.edu/projects/project_163.html

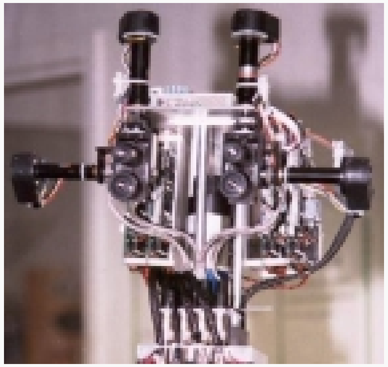
The CMU Field Robotics Center (FRC) developed Dante II, a tethered walking robot, which explored the Mt. Spurr (Aleutian Range, Alaska) volcano in July 1994.

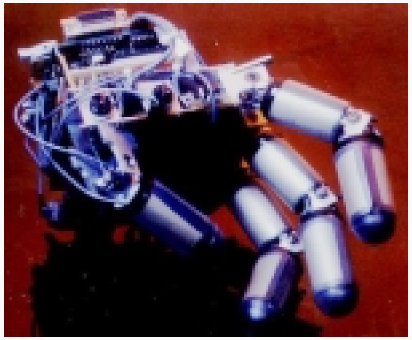
High-temperature, fumaroles gas samples are prized by volcanic science, yet their sampling poses significant challenge. In 1993, eight volcanologists were killed in two separate events while sampling and monitoring volcanoes. The use of robotic explorers, such as Dante II, opens a new era in field techniques by enabling scientists to remotely conduct research and exploration.

Using its tether cable anchored at the crater rim, Dante II is able to descend down sheer crater walls in a rappelling-like manner to gather and analyze high temperature gasses from the crater floor. In addition to contributing to volcanic science, a primary objective of the Dante II program is to demonstrate robotic exploration of extreme (i.e., harsh, barren, steep) terrains such as those found on planetary surfaces.

Historical Evolution

1995 Cog MIT (USA) – Rodney Brooks – Prototyhpe of a humanoid robot.



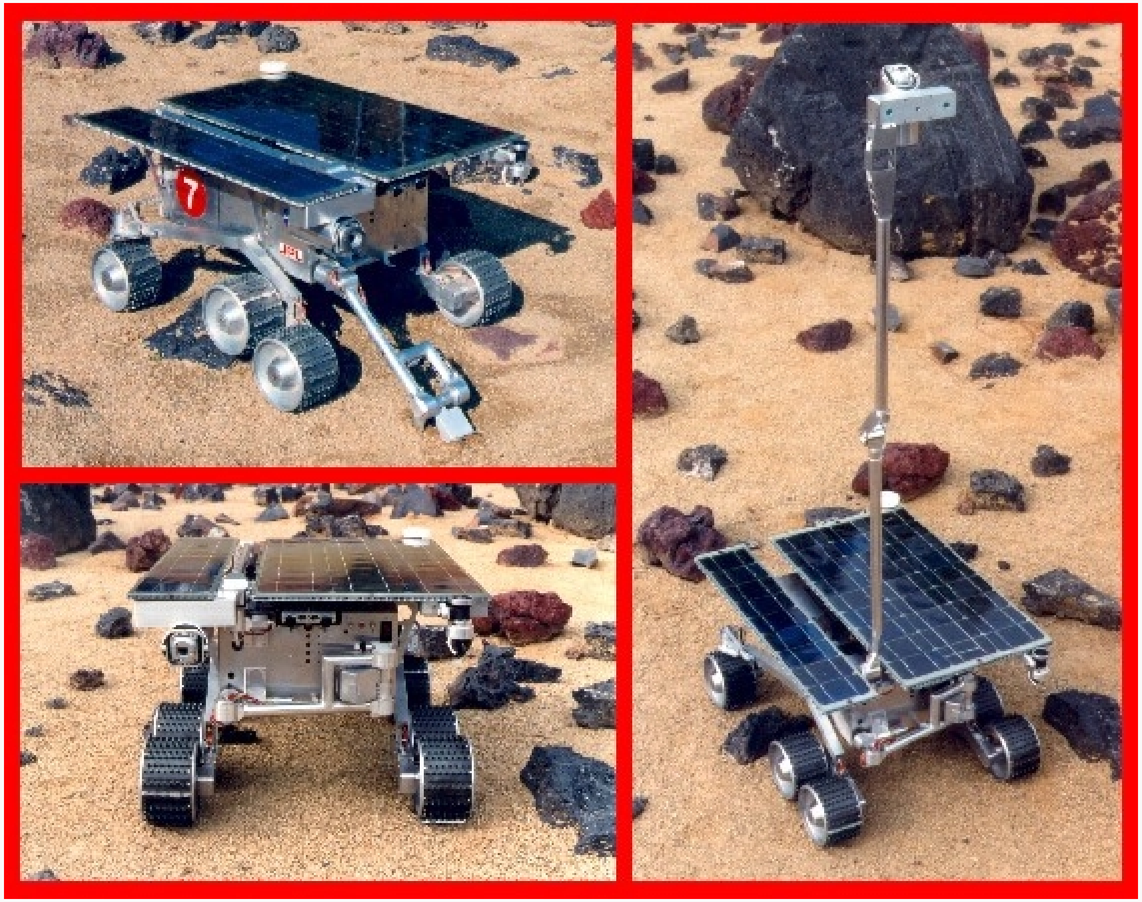


http://www.ai.mit.edu/people/brooks/projects.shtml

Planetary Robotics

NASA JPL Rovers

Planetary Robotics



NASA JPL Rovers

Historical Evolution

1998-2000

Robotic Antarctic Meteorite Search (RAMS)
(William Whittaker *et al@CMU*)

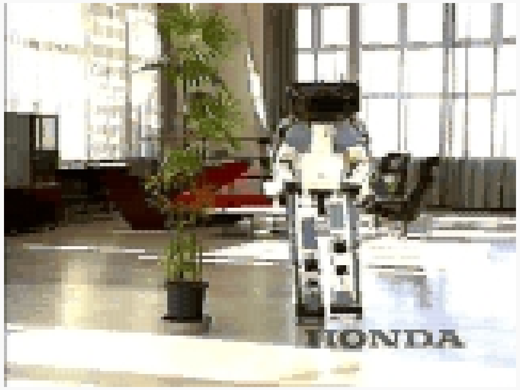
The goal of this initiative is to enable autonomous discovery of Antarctic meteorites using robotic search and on-site automatic classification of rock samples. In January 2000 the Nomad robot explored the remote Antarctic region of Elephant Moraine in search of new meteorite samples. Nomad autonomously found and classified in situ five indigenous meteorites and dozens of terrestrial rocks.

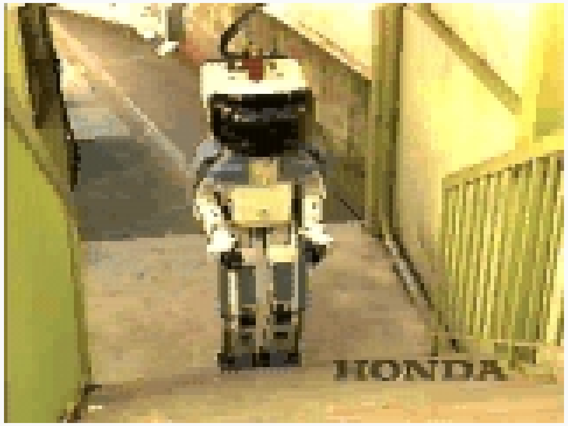
http://www.frc.ri.cmu.edu/projects/meteorobot2000/

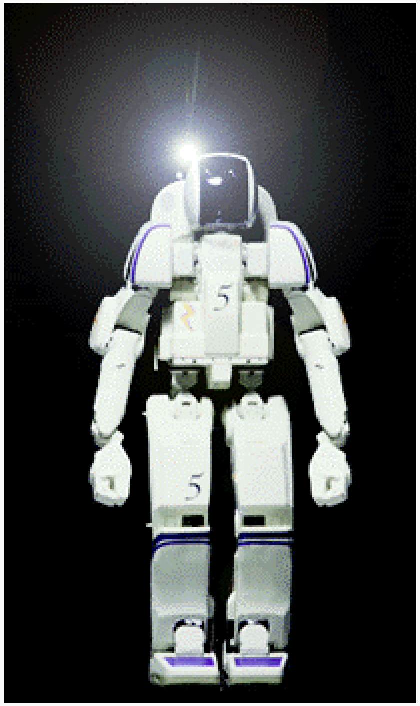
Historical Evolution

http://www.honda-p3.com/english/html/asimo/frameset2.html

http://world.honda.com/robot/







Recent Prototypes and Projects

Autonomous Helicopter Project
T. Kanade *et al* @ CMU

Applications

- The robots have potential application in areas where a vehicle or a mechanic automatic system may exist
- Areas of application:
  - Support to medical services – SERVICE ROBOTS
    - Transportation of food, medication, medical exams,
    - Automation of pharmacy service
  - Automatic cleaning of (large) areas
    - Supermarkets, airports, industrail sites
    - Glass cleaning
    - Domestic vacuum-cleaner
  - Client support
    - Museum tours, exhibitions guides
  - Agricultural
    - Fruit and vegetable picking, fertilization, planting
  - Forests
    - Cleaning, fire preventing, tree cuting

Applications

- Areas of application (ctn):
  - Hazard Environments
    - Inspection of hazard environments (catastrofic areas, vulcanos, nuclear power plants, oil tanqs)
    - Inspection of gas or oil pipes, and power transmission lines
    - Oil tank cleaning
  - Construction and demolishing
  - Space
    - Space exploration
    - Remote inspection of space stations
  - Military
    - Surveilance vehicles
    - Monitoring vehicles
  - Forests
    - Cleaning, fire preventing, tree cuting

Applications

- Areas of application (ctn):
  - Material Handling
    - AGVs, SGVs, LGVs
  - Safety
    - Surveillance of large areas, buildings, airports, car parking lots
  - Civil Transportation
    - Inspection of airplanes, trains,
  - Elderly and Handicapped
    - Assistance to handicapped or elderly people, helping in tansportation, health care,
  - Entertainment
    - RobotDog
    - Aibo – Robot dog from Sony
    - Telepresence

Commercial Platforms

NOMAD XR400

Diameter: 62 cm.
Height: 85 cm.
Weight (Empty): 60 kg.
Weight (With batteries): 150 kg.
Payload: 100 kg.
Max. Acceleration: Translational - 5 m/s2
Max. Acceleration: Rotational - 2 rad/s2
Maximum Translational Speed:- 1.5 m/s
Encoder Resolution:
Base Translation: 1120 counts/cm,
Base Rotation: 422 counts/degree
Caster Orientation: 76 counts/degree
Number of Wheels: 4
Drive Type: Holonomic
Battery Capacity: 1575 watt-hour
CPU: Up to 3 Pentium or Pentium Pro
Power System: Fuel gauge, battery monitoring with onboard charging and full power diagnostics

SuperScout II

Commercial Platforms

Robuter

CIE

Pioneers

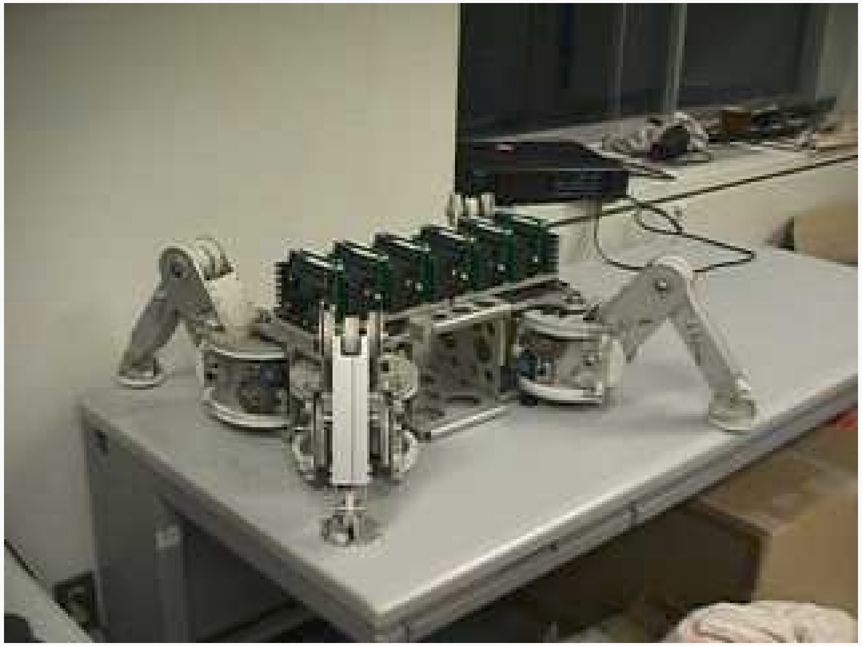
Commercial Platforms (outdoors)

MR-1 is an Advanced EOD Robot. The multi-purpose robot is used by Police, Military, SWAT and other Emergency Response Teams to deal with hazardous situations.

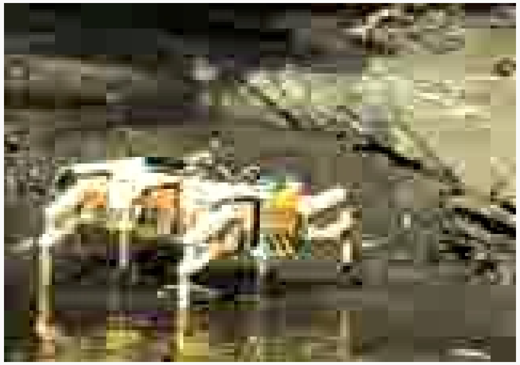
MR1 robot

http://www.esit.com

Commercial Platforms (outdoors)



TITAN (Japan)

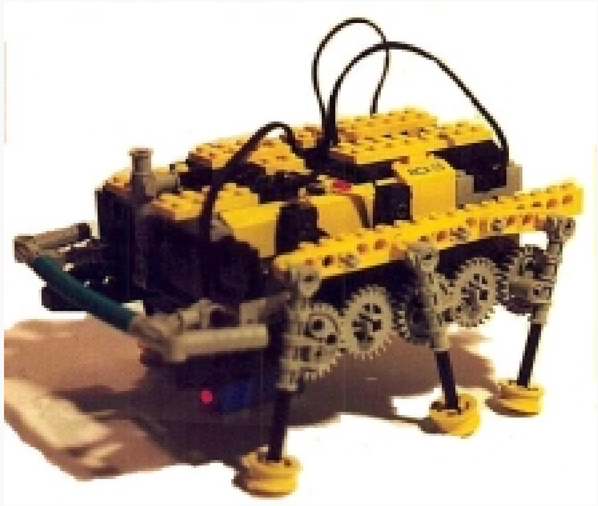


ATRV - Jr

LEGO Mindstorms

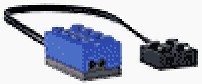
Rotational sensor

Contact sensor



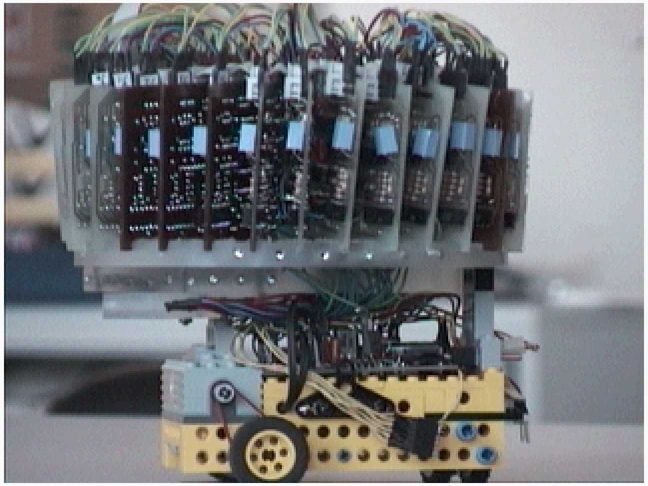
Temperature sensor

CC motor

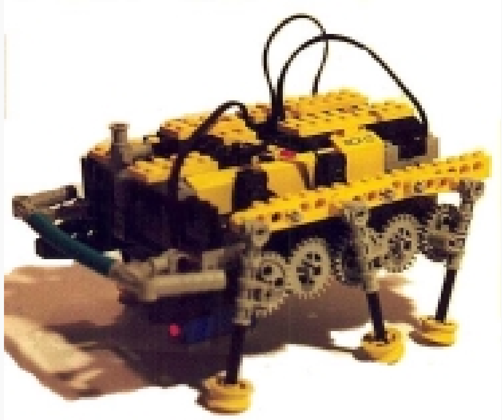


Light sensor (IV)

Research, Education and Entertainement with LEGOS

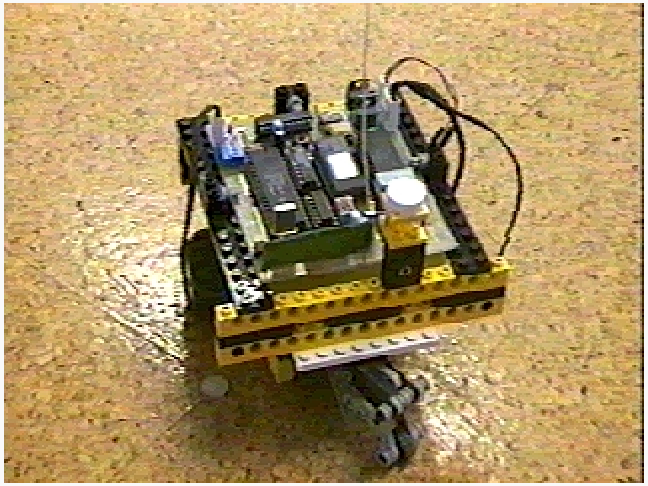


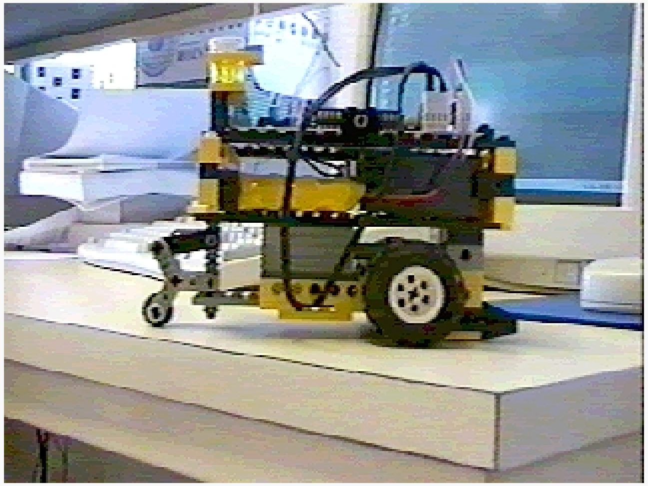
Composed Eye -VisLab@ISR



Lego Mindstorms

IC@ISR





VisLab@ISR

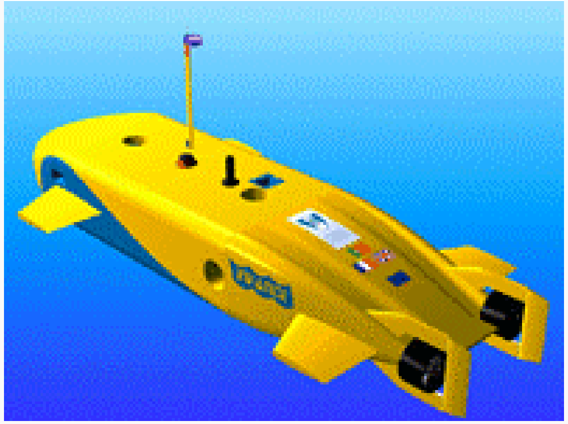
Robots for Non-Land Environments

AIR

Helicopter

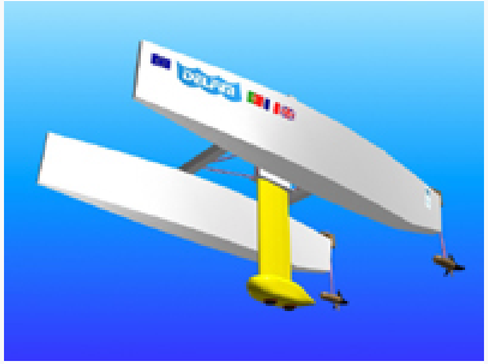
Blimp

UNDERWATER



Infante – DSOR@ISR

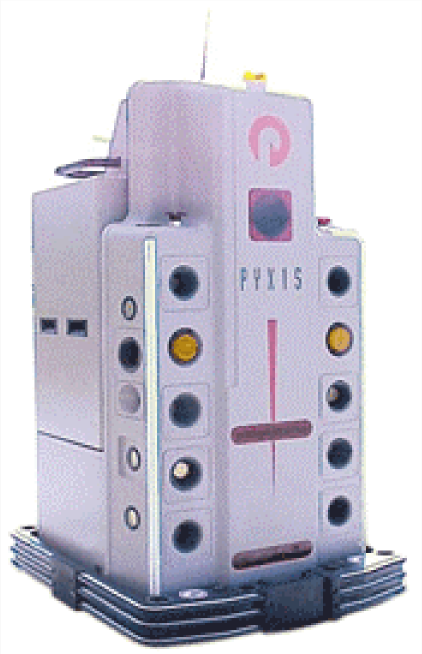
OCEAN



Real Application Examples

Pyxis (former Helpmate)

Hospital Material Transportation



- HELPMATE is a trackless, robotic courier system designed to perform materiall transport tasks throughout the hospital environment.
- Twenty-four hours a day, 365 days a-year, HELPMATE transports pharmaceuticals, lab specimens, equipment and supplies, meals, medical records and radiology films back and forth between support departments and nursing floors.
- Odometric navigation system also supported by ultrasound and laser
- Deals easily with cluttered, unstructured environments
- Gets on and off elevators without assistance
- Painless installation, no disruption to current operations
- Simple user-interface; easy to learn
- Flexible and easy to reprogram
- 6 cubic feet, 200-pound payload
- Battery-operated

http://www.pyxis.com/products/helpmate.asp

Real Application Examples

Minerva – Pittsburgh Museum

Carnegie Mellon's Robotic Tourguide Project

- Minerva is a talking robot designed to accommodate people in public spaces.
- She perceives her environment through her sensors (cameras, laser range finders, ultrasonic sensors), and decides what to do using her computers.
- Minerva actively approaches people, offers tours, and then leads them from exhibit to exhibit. When Minerva is happy, she sings and smiles at nearby people. But don't block her way too often--otherwise, she'll become frustrated and might frown at you and honk her horn!

http://www-2.cs.cmu.edu/~minerva/

Wheelesley: Development of a Robotic Wheelchair System

MIT-USA

- Wheelesley, consists of an electric wheelchair outfitted with a computer and sensors and a Macintosh Powerbook that is used for the user interface.
- The robot can travel semi-autonomously in an indoor environment. This allows the user to issue general directional commands and to rely upon the robot to carry out the low level routines such as object avoidance and wall following.
- The user interface developed allows the user to operate in three modes: manual, joystick and user interface. In manual mode, the wheelchair functions as a normal electric wheelchair. In joystick mode, the user issues directional commands through the joystick while the robot will avoid objects in the requested path. In user interface mode, the
- user interacts with the robot solely through the user interface.
- To date, the chair has been driven using the EagleEyes system and a single switch.

http://www.ai.mit.edu/people/holly/wheelesley/

http://www.cs.bc.edu/~eagleeye/

Real Application Examples

AGV for rack handling

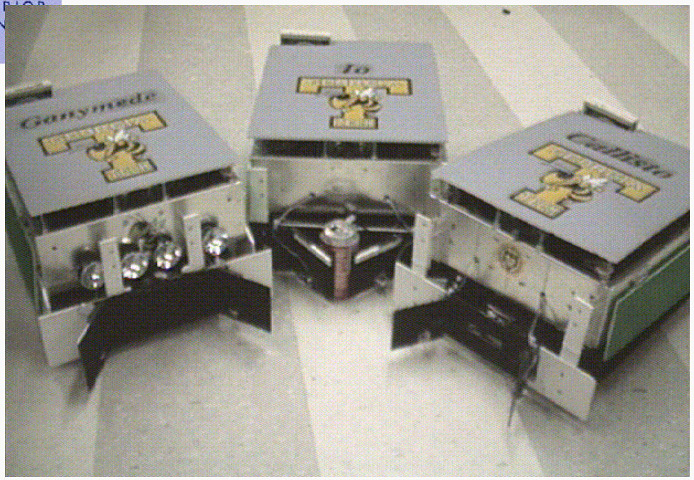
Manufecturer: AGV electronics

http://www.agve.se/gallery.htm

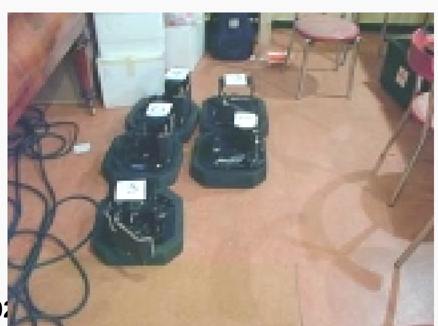
LGV – Laser Guided Vehicle

Technology from: NDC, Sweden

Real Application Examples



Yo, Ganimede and Callisto (Trash Cleaning Team @ Georgia Tech University)



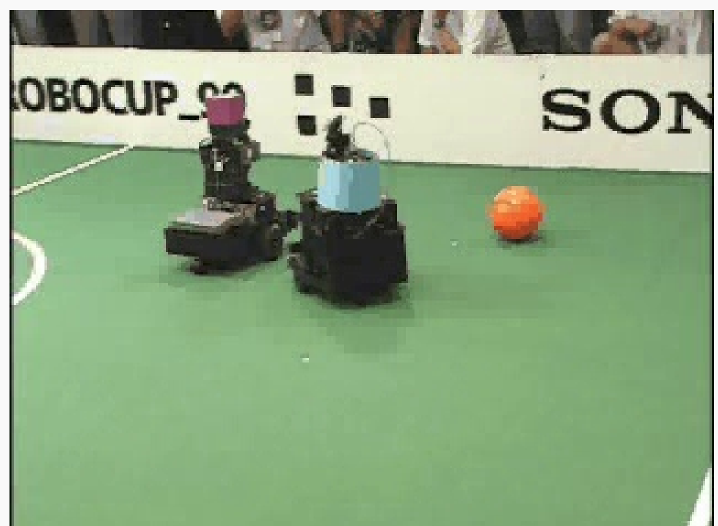
Sample of RoboCup middle-size soccer teams

CS Freiburg soccer team

Real Application Examples /R&D projects

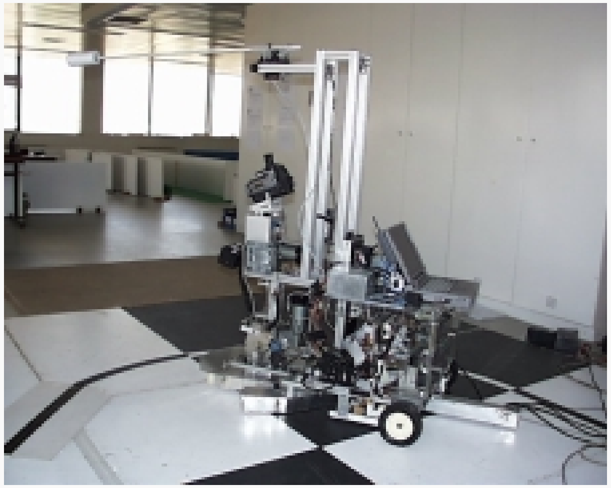
Robot Soccer

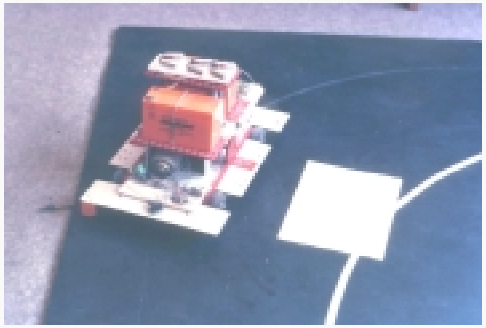
Robotic Goalkeeper
Guarda-Redes Robótico

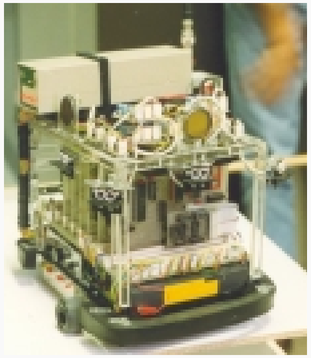


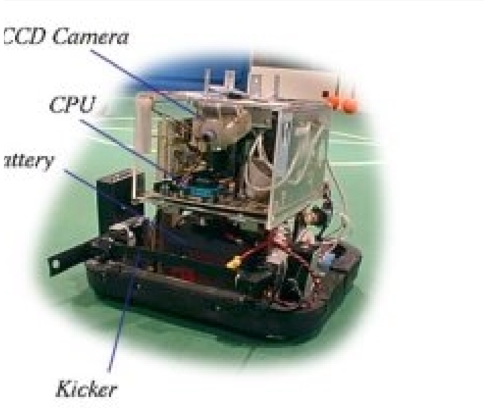
Mobile Robot prototypes developped @ ISR/IST

IQ99









Components of a Mobile Robot (an example)

Proximity sensor

RF Communication antenna

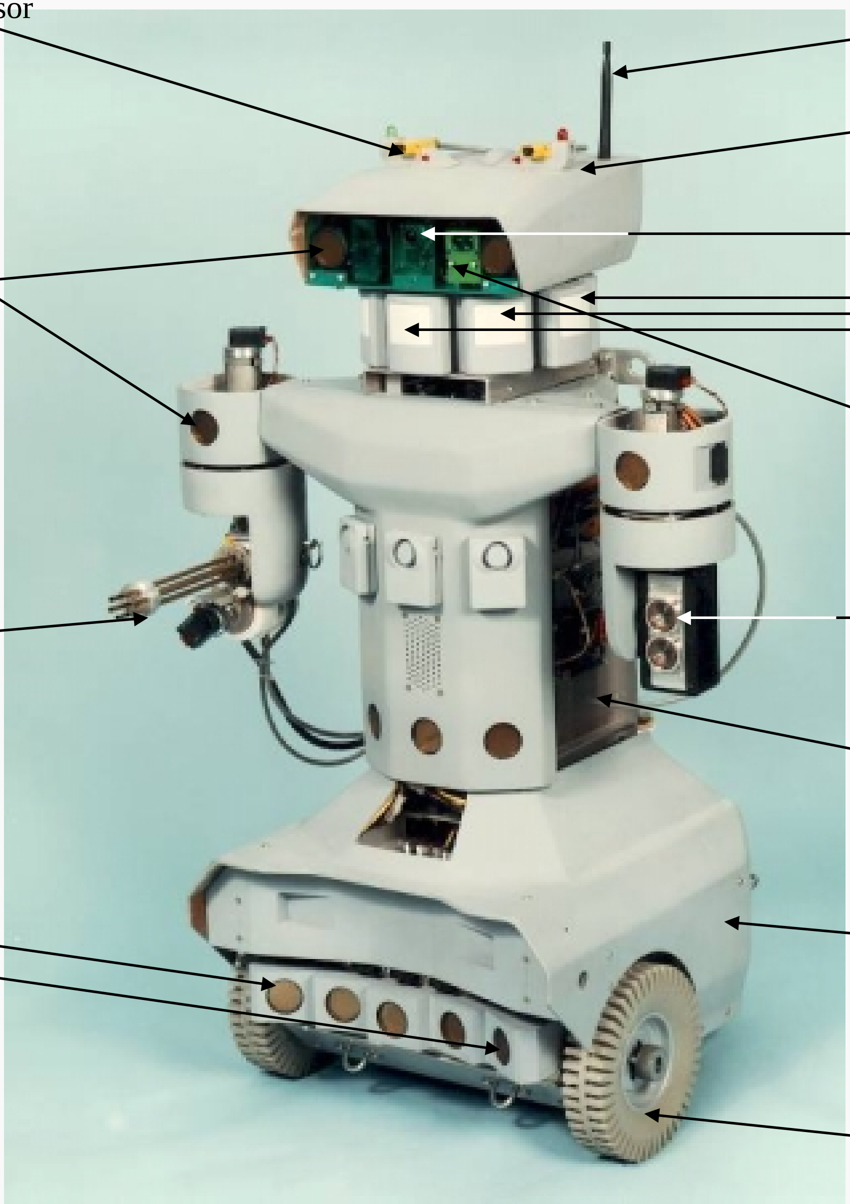
microphone

Ultrasound transducer (sonar) Polaroid

Video camera

Ring of IV sensors

Microwave motion detector



range-finder

disparador pneumático de setas

On-board computer; magnetic compass to measure robot orientation; temperature transducers

Ring of Polaroid sonar sensors

Bateries 12V, 80 Ah

Wheel and motor from a whelchair

Components of a Mobile Robot

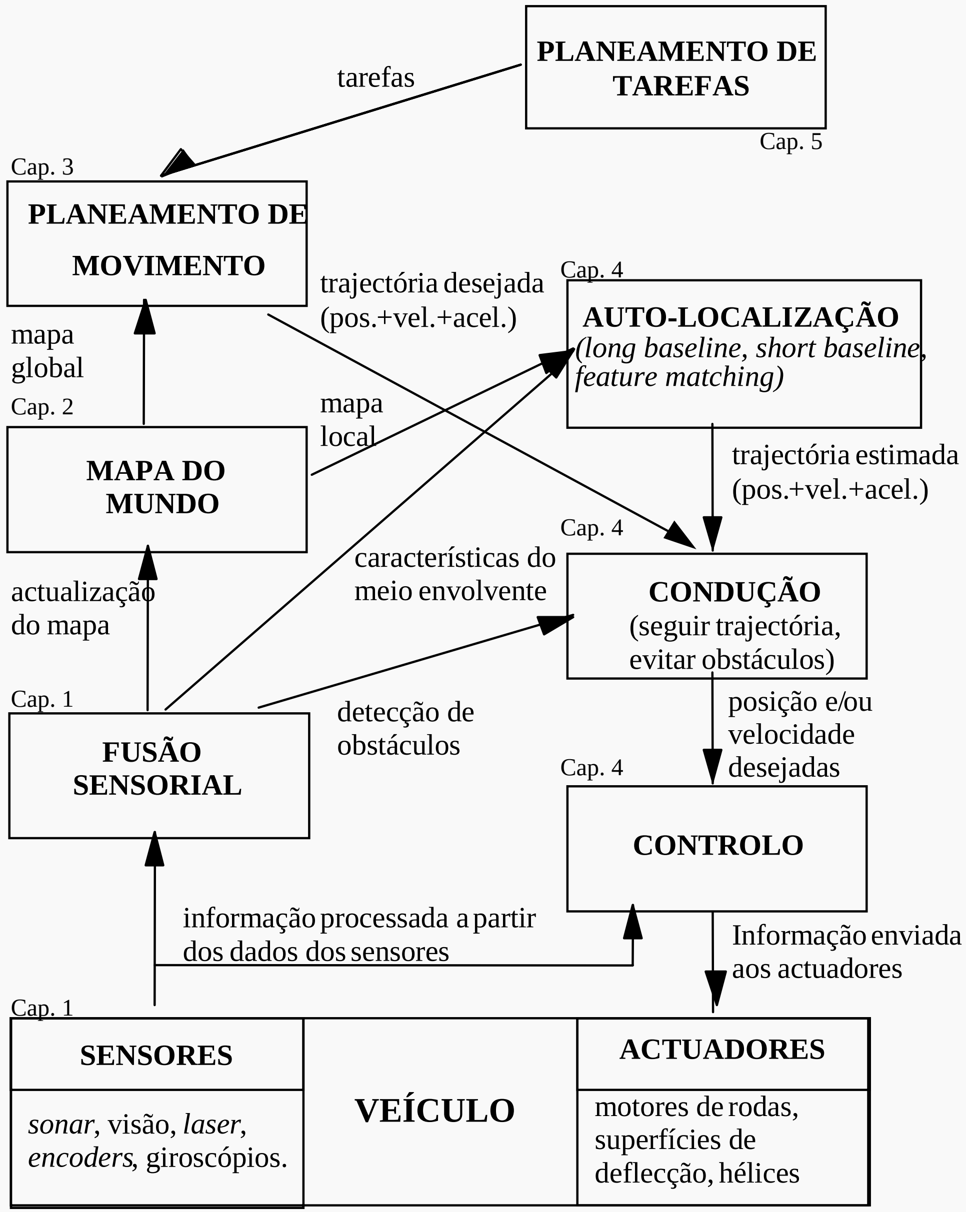
- A mobile robot is a combination of various physical (hardware) and computational (software) components.

- In terms of hardware components, a mobile robot can be considered as a collection of subsystems for:
  - **Locomotion** – how the robot moves through its environment
  - **Sensing** – how the robot measures properties of itself and its environment
  - **Reasoning** – how the robot maps the measurements into actions
  - **Communication** – how the robot communicates with an outside operator

- In terms of software components, a set of subsystems are responsible for:
  - **Planning** in its various aspects

Classical cycle: SENSING – PROCESSING - ACTING

Course Organization



References

- Book Chapters
  - Gregory Ducdeck, Michael Jenkin, *Computational Principles of Mobile Robotics,* Cambridge University Press, 2000 (Chapters 1 and part of 2)
  - H. R. Everet, *Sensors for Mobile Robots-Theory and Applications*, A.K.Peters, 1995 (Chapter 1)
  - Phillip McKerrow, *Introduction to Robotics*, Addison-Wesley, 1991 (Chapter 1).
  - Ronald Arkin, *Behavior Based Robotics, MIT Press, 1998 (Chapter 1)*
- Video
  - Robots – History Channel