



Robotics 1

Service robotics

Prof. Alessandro De Luca

DIPARTIMENTO DI INGEGNERIA INFORMATICA
AUTOMATICA E GESTIONALE ANTONIO RUBERTI



SAPIENZA
UNIVERSITÀ DI ROMA

Some application domains



- extreme environments
 - space
 - underwater
- medical robotics
 - assistive
 - rehabilitative
 - surgical
- home cleaning
- agriculture
- lawn mowing
- food industry
- mine exploration
- de-mining
- civil and naval construction
- automatic refueling
- museum guide
- fire fighting
- inspection and surveillance
- emergency rescue
- entertainment
- humanoids

professional & personal service robots

Service robots on the market!



Bluebotics Esatroll - Paquito 2.0
logistics in factory floor



Yujin GoCart2
elderly and health care



Cyberdyne HAL
exoskeleton for walking



Lely Vector automated feeding

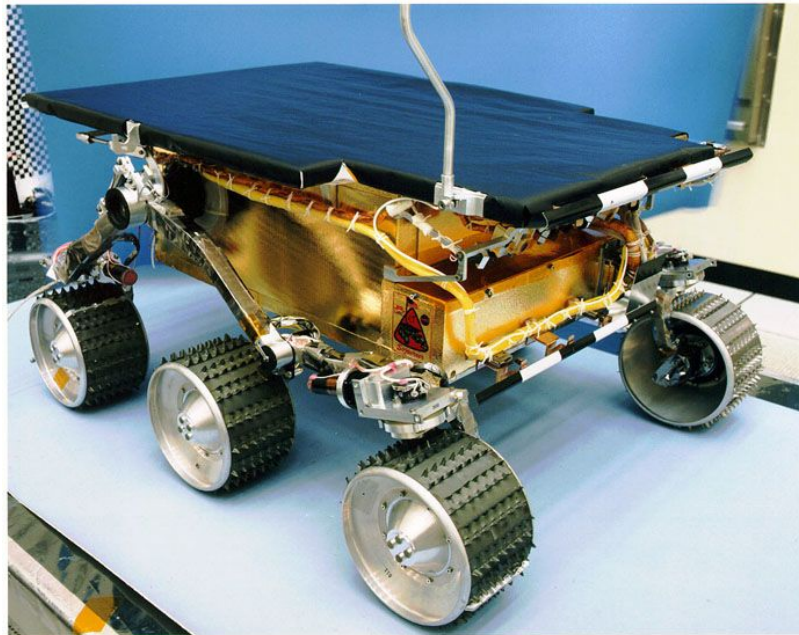


Vorwerk
vacuum cleaner

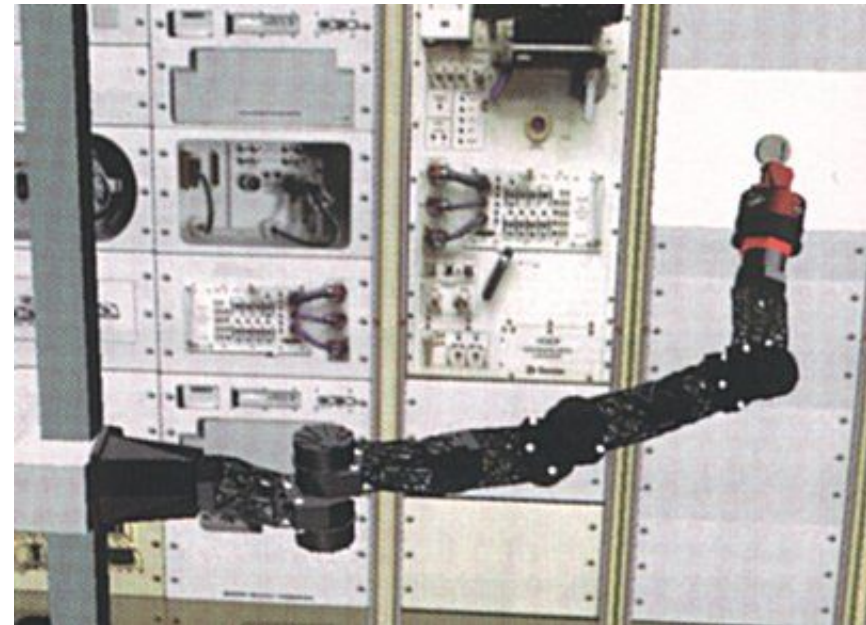


Thymio educational
mobile robot

Space robotics



- NASA *Sojourner*, first robot to explore Mars in 1997



- DLR *Rotex* robot arm in a set of experiments of the Spacelab-D2 mission on the Columbia shuttle in 1993

Space robotics



video



wheels untrapping
on sandy soil

video

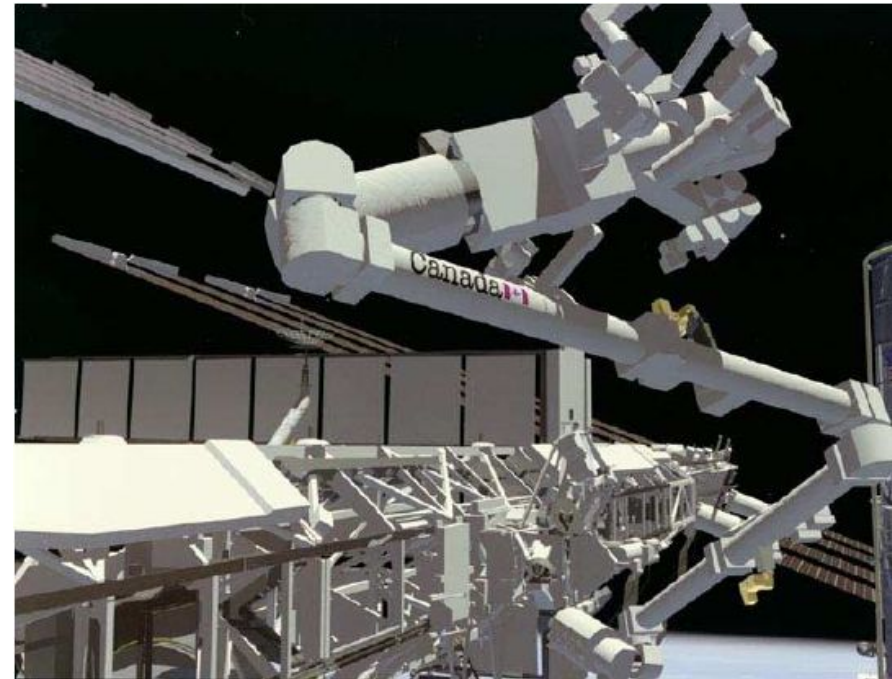


catching floating objects
with *Rotex*

Space robotics



- robotic arm *SSRMS (Canadarm)* in operation on the Space Shuttle, with outstretch of about 30 meters



- the service manipulator on the ISS is mounted on a supporting rail

Robots on ISS



video



Canadarm2 delivering Destiny Lab from Space Shuttle Atlantis to ISS (Feb 2001)

video



service manipulator and Robonaut on the ISS (artistic views)

Underwater robotics



- Odyssey-IV (MIT)



- Odin-III, **omni-directional** (University of Hawaii)

- typically actuated by thrusters (directional forces on the tail)
- cannot translate sideways ("maneuvers" are necessary)



- ROMEO in Antarctica (CNR, Automazione Navale, Genova)

Underwater robotics



Ansaldo underwater arm performing a cable hooking task (SAUVIM project)

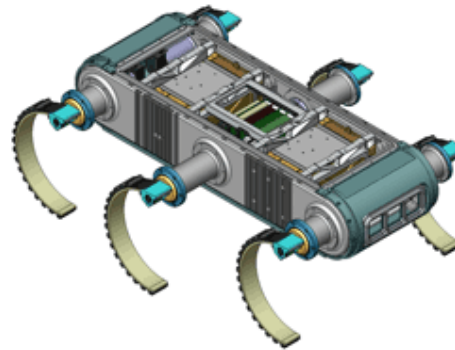
video

video

UBC Gavia underwater robot (University of British Columbia)

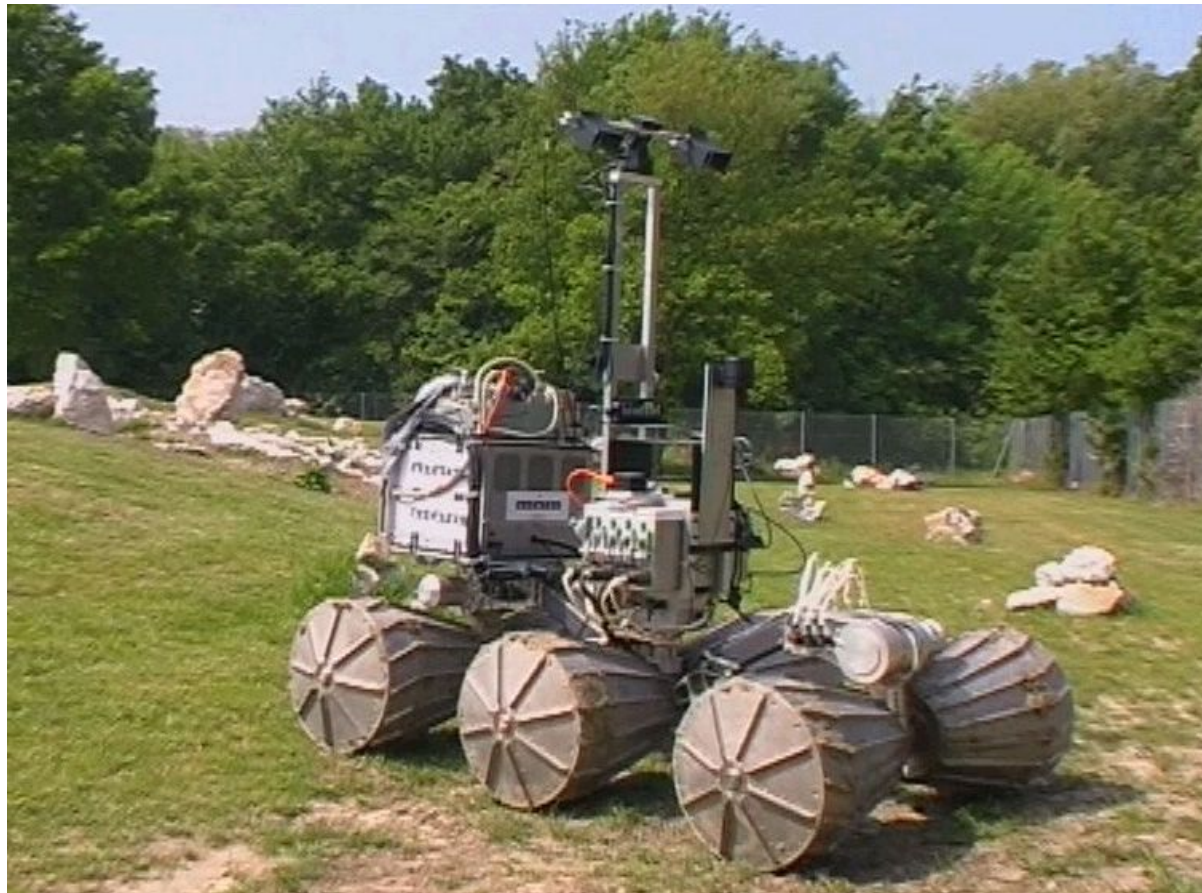


Underwater robotics



- Aqua robot, amphibious robotic vehicle (McGill University)
- size and weight: 50x65x13 cm, 18 kg
- locomotion: through six independently actuated flippers
- maximum depth: 37 m
- sensors: two cameras (front/back), acoustic sensor for localization (sonar), tri-ocular sensor (structured light)
- power source: 48V lithium battery

Outdoor exploration



- the *LAMA* robot at CNRS-LAAS (Toulouse) is a french-russian cooperation

Volcanology



video

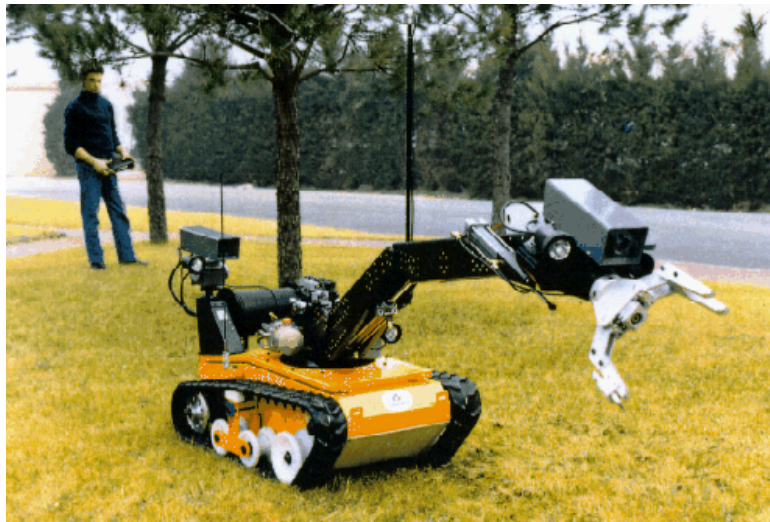


video



RoboVolc vehicles on the surface
of the Etna volcano:
wheeled and tracked robots
(University of Catania, 2003)

De-mining



- teleoperated mobile robot on tracks used by the police for bomb disposal



- PEMEX lightweight anti-personnel mine detector (EPFL, Lausanne)
- weight: 16 kg, max 6 kg for wheel
- two 70 W DC motors (vel 2 m/s)
- oscillating sensorized head

Medical robotics

patient aid



- deambulation support system
PAM-AID (Trinity College, Ireland)

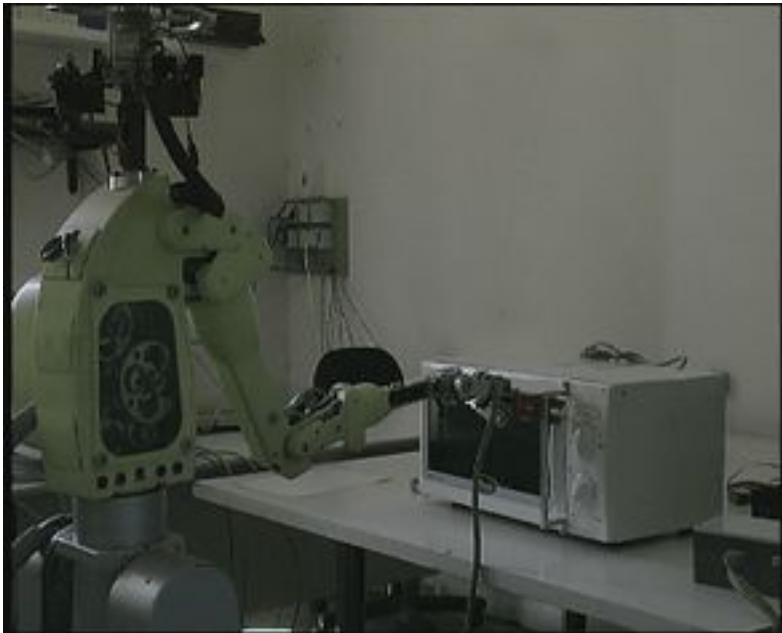


- *MOVAID* project for the aid of disabled people in home activities (Scuola Sup Sant'Anna, Pisa)

MOVAID project



video

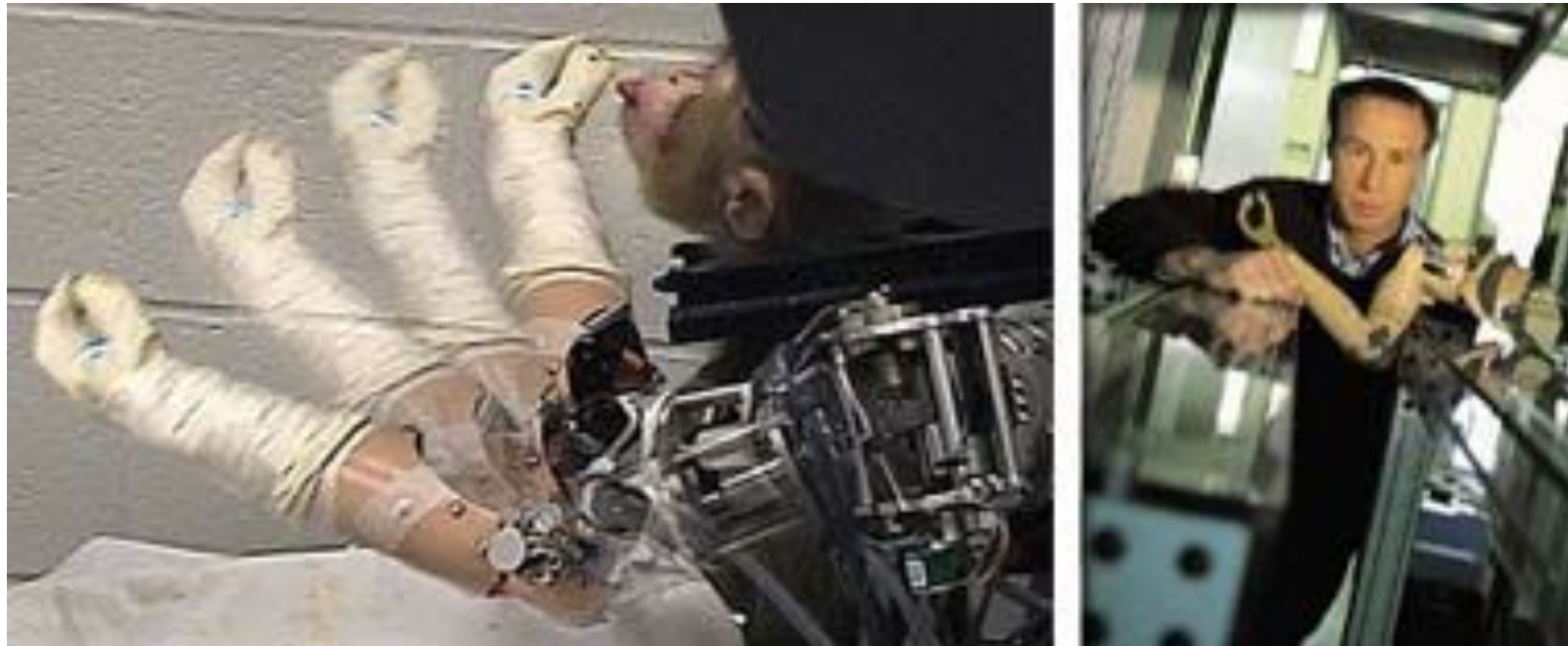


video



domestic activities using the 7R *Dexter* arm

Medical Robotics rehabilitative



- robotic arm with shoulder and elbow having full mobility and with a gripper hand (Pittsburgh University)
- in tests on monkeys (with immobilized upper limbs), motion commands sent to the arm by the central nervous system (brain) are measured by a set of electrodes and used to command the robotic arm

Medical robotics rehabilitative



- commercialized by Ossur (Iceland)
- a prosthesis sensorized at the knee (angle and force), capable of processing sensor data and of extracting a gait model of the user, so as to adapt its dynamical behavior (knee motion and stiffness)

Medical robotics rehabilitative



- "RUPERT" Robotic Upper Extremity Repetitive Therapy (Arizona State University + Kinetic Muscles, Inc.)
- sustains the human arm with pneumatic muscles (McKibben actuators)
- it can be programmed for the execution of cyclic exercises of rehabilitation

Exoskeletons



video



SARCOS master-slave for teleoperation

Medical robotics

hospital and nursing



video



- *HELPmate* mobile robot (USA) works in hospitals as auxiliary personnel

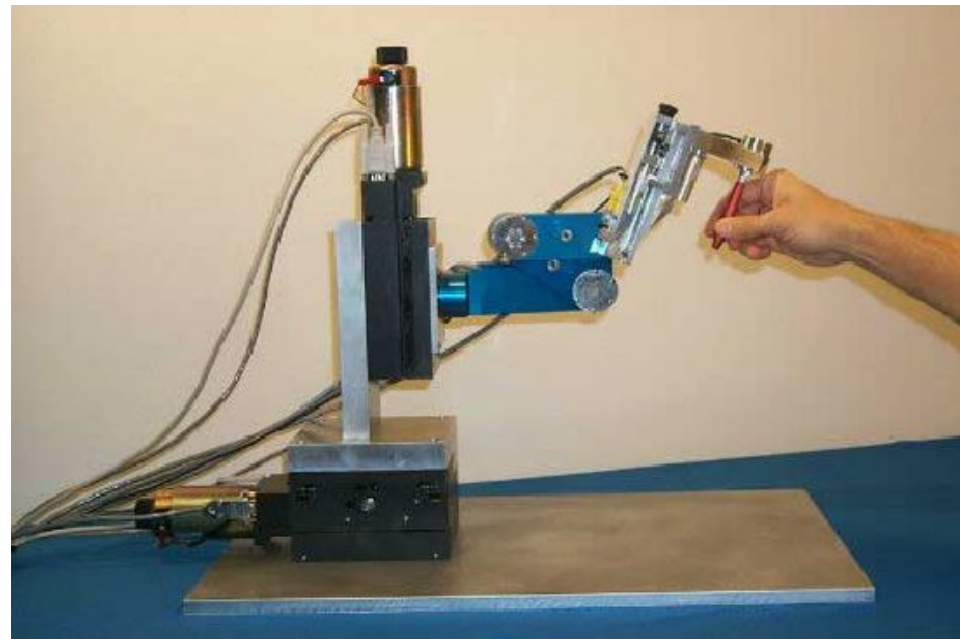


- user interface of the *Care-O-Bot* robot nurse (IPA Fraunhofer, Germany)

Surgical robotics

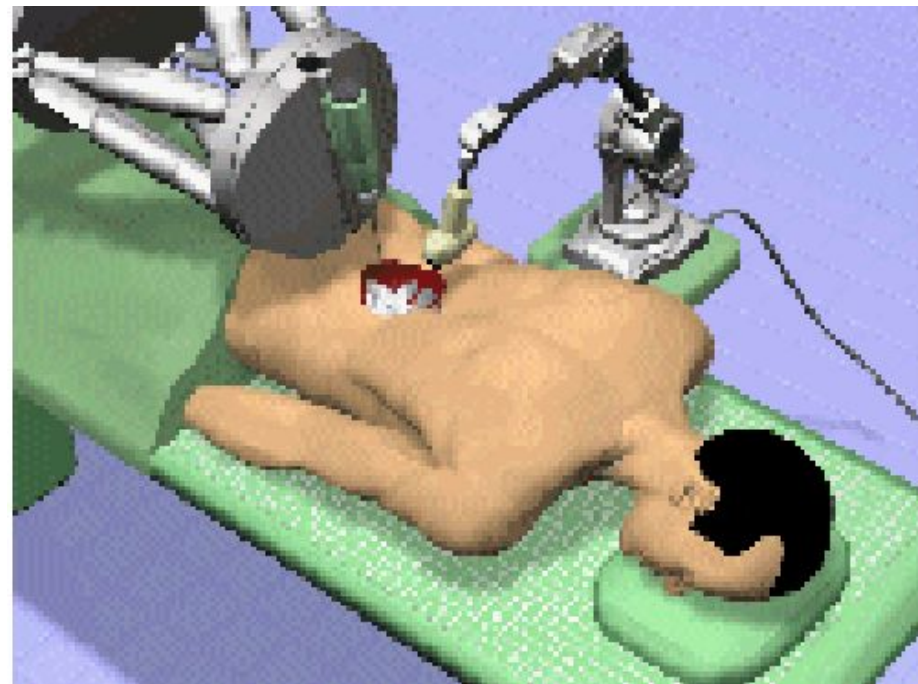
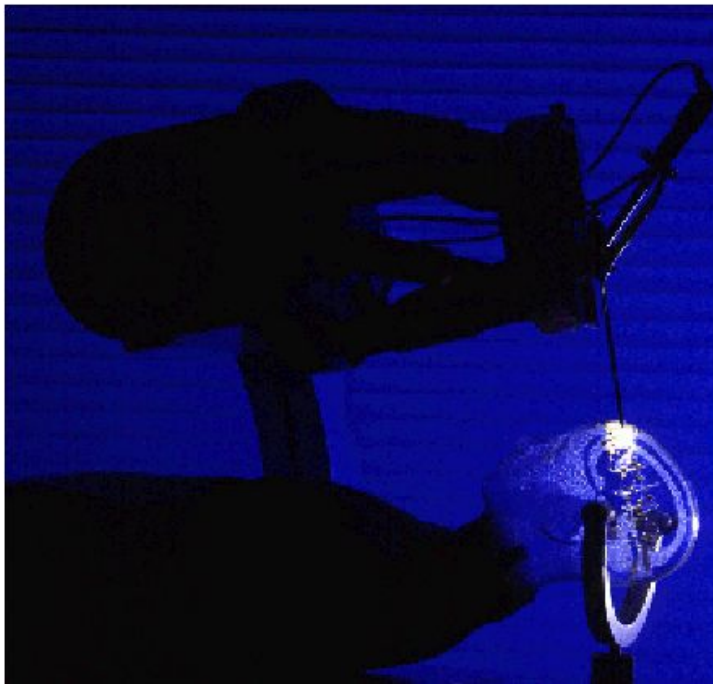


- *Robodoc* by Integrated Surgical Systems (USA) was used first for orthopedic surgery (ankle replacement)



- *Steady-Hand* force-assisted system (Johns Hopkins Univ) improves accuracy and repeatability of surgeons allowing task-driven compliance

Surgical robotics



- emulation of a laser brain surgery operation and graphic rendering of a surgery intervention on the spinal cord patient is first "mapped" off-line by a series of CAT scans; data are then "localized" in the actual operation field (IPA Fraunhofer)

Surgical robotics



overview of the operating room



command station



(haptic) interface

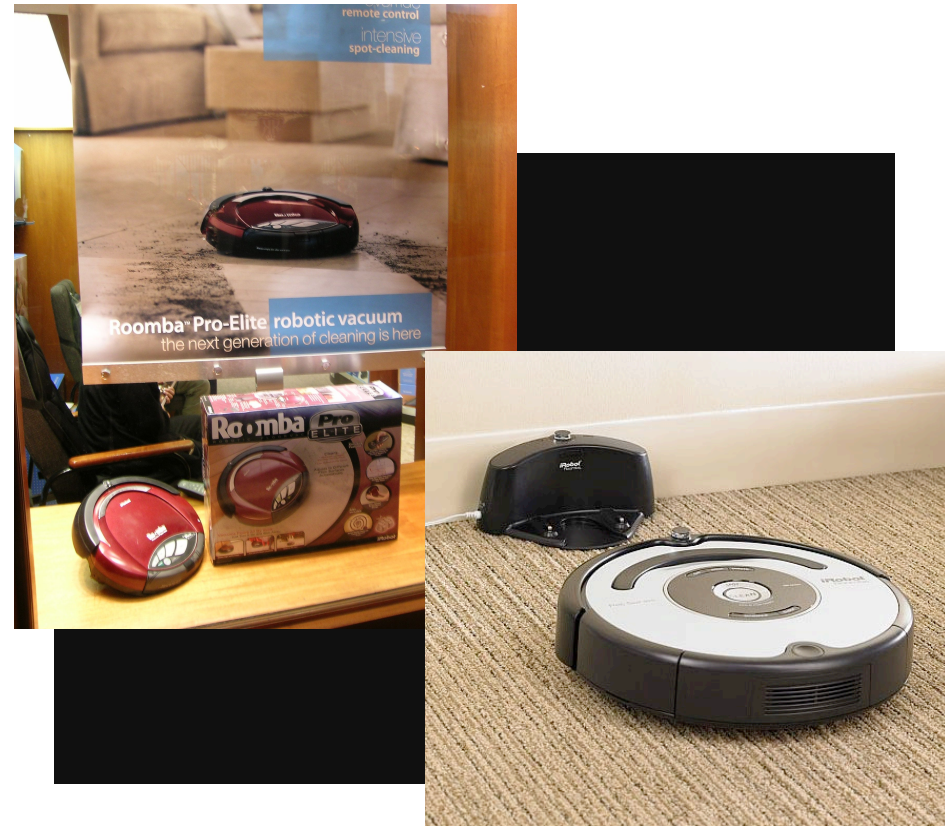
- da Vinci[©] system (Intuitive Surgical Inc.)
[see the course "Medical Robotics"]



Home cleaning



- vacuum cleaner robot
Trilobite by Electrolux (Sweden)



- commercial **video**
iRobot *Roomba 560* (USA)
— now available everywhere!

Cleaning robot contest



- competition among robot vacuum cleaners in home environments (IROS'02, Lausanne)

Cleaning of external surfaces



- *Skywash* cleans civil airplane bodies and is “the largest robot worldwide” (AEG/Dornier/FhG-IPA/Putzmeister)
- a robot prototype for cleaning large glass windows of civil buildings

Lawn mowers



video

- *Automower* autonomous robot by Husqvarna (Sweden) has low power consumption (biocut) and solar recharge

Food industry



video

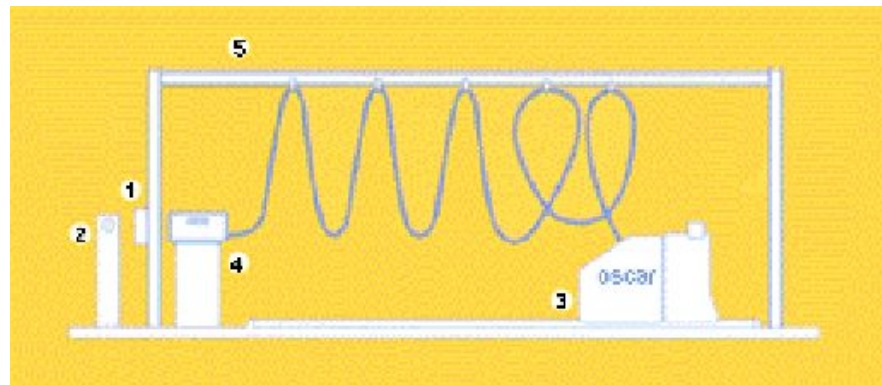


- *Ulixes* robot by IMT (Germany) aligns 10000 sausages per hour



- *AdeptOne* SCARA robot with 4-sausage gripper

Automatic refueling



- OSCAR robot (France) for gasoline refuel of fleets of transportation busses



Automatic refueling



a "kit" is available for all car models:
tank cap, transponder, pipe union

Autofill system in two tank stations of
OK (Mörgby, Sweden) and BP (USA)



Automatic refueling



- cooperation of Reis Robotics, Mercedes, BMW, and IPA Fraunhofer



- *Smart Pump* system (USA)

Inspection and surveillance



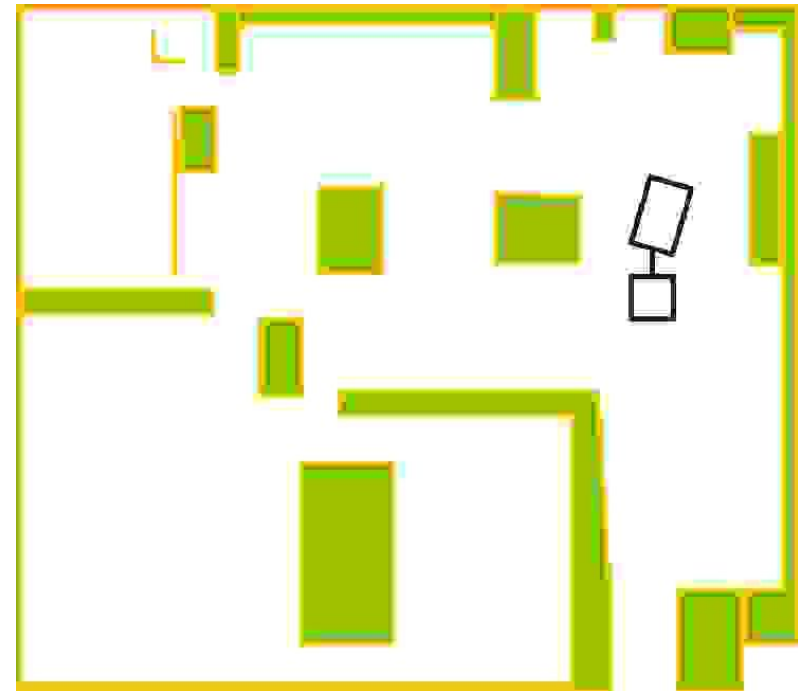
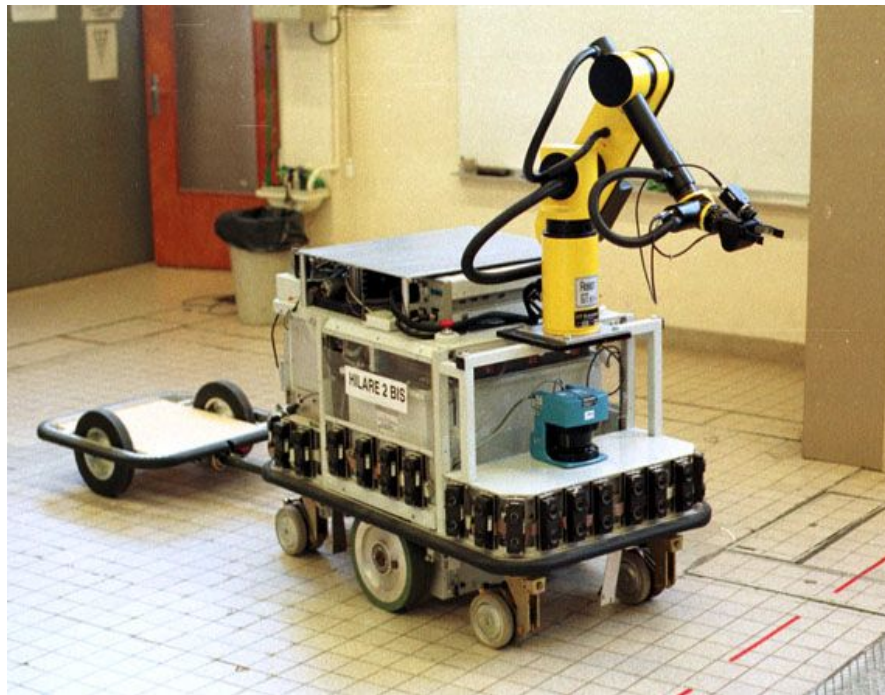
- 6-dof *Puma* arm mounted on the *Nomad XR400* (multiple steering wheels, synchro-driven)



- 5-dof *Scorbot* arm mounted on a *ATRV-JR* (fixed wheels, skid-steering vehicle)

two examples of
mobile manipulators

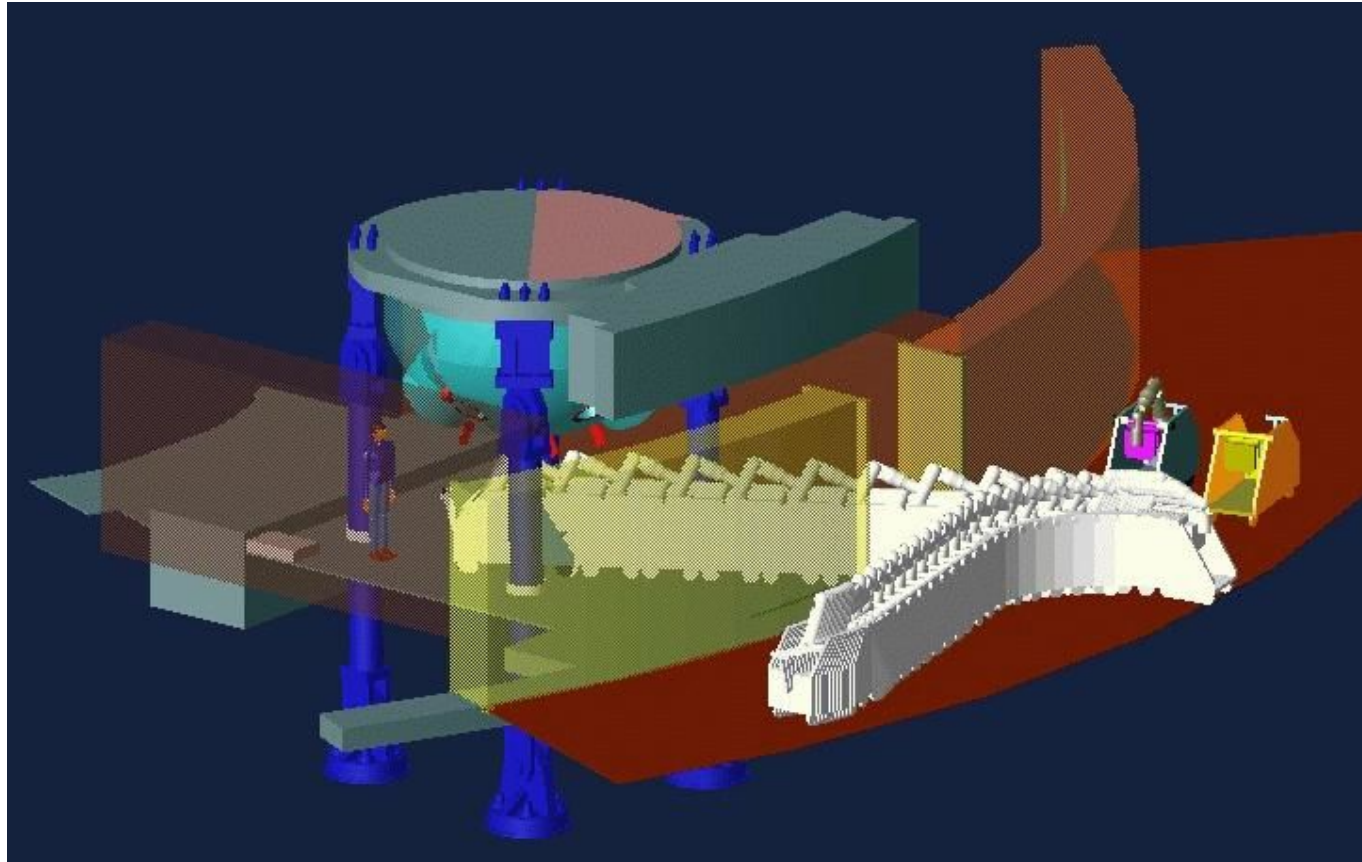
Inspection and surveillance



- *Hilare 2bis* mobile robot (LAAS), with trailer and manipulator arm, and its localization on a indoor map

sensors: encoders (on wheels and arm joints),
ultrasound, SICK laser, and camera on end-effector gripper

Inspection and surveillance



- motion planning of a robotized inspection task inside an electricity power plant (*Move3D* simulation)

Mine exploration



- *Groundhog* (Carnegie Mellon)
- 750 kg, double axes, articulated
- movable SICK laser (rangefinder)
- gas and immersion sensors
- SLAM algorithm (Simultaneous Localization And Mapping)

RoboCup and RoboRescue



- RoboCup middle-size league (wheeled mobile robots, here with omni-directional vision)
- *Orpheus* robot won the RoboRescue (exploration and search of victims in a disaster environment)

2003 edition, Padova Fair

DARPA Grand Challenge



5 SICK lasers for mapping and localization on the 2005 winning VW Touareg "Stanley"



the "Ghostrider" motorcycle testing in Nevada

- competition for fully **autonomous** vehicles on a long mixed-type track

DARPA Grand Challenge



video interview

video



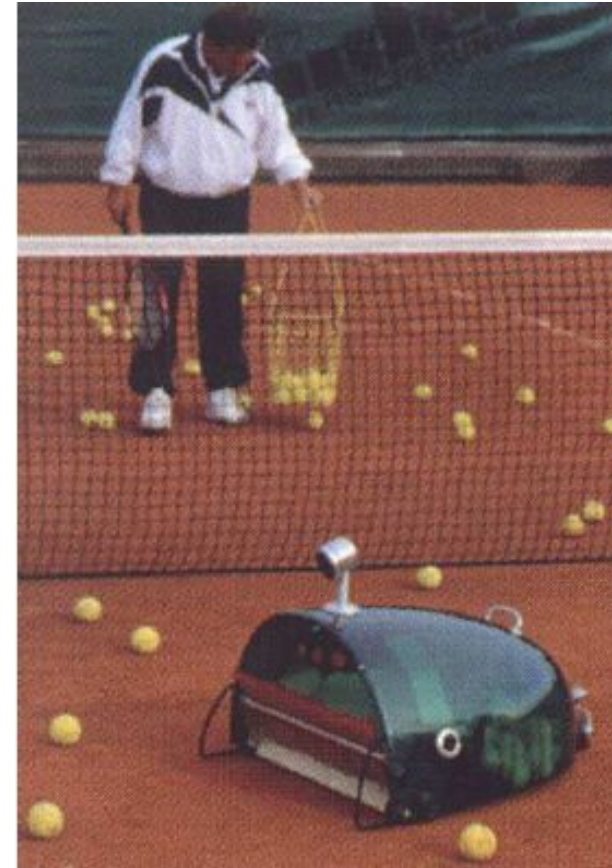
S. Thrun of **Stanford Racing**
(Stanford Univ+VW America+many more)

A. Levandowski of **Blue Team**
(LaRaison Inc+Univ Berkeley+Texas A&M)

Stanley navigation:
GPS, laser scanners,
vision, radar

Ghost rider navigation:
GPS, inertial unit, motorcycle
dynamics, stereovision

Free time



- bartender robot by Erhardt+Abt (Germany)
- the robotic ball boy (RWI and Carnegie Mellon Univ, USA) that won in 1996 the "Clean up the tennis court!" competition of the AAAI



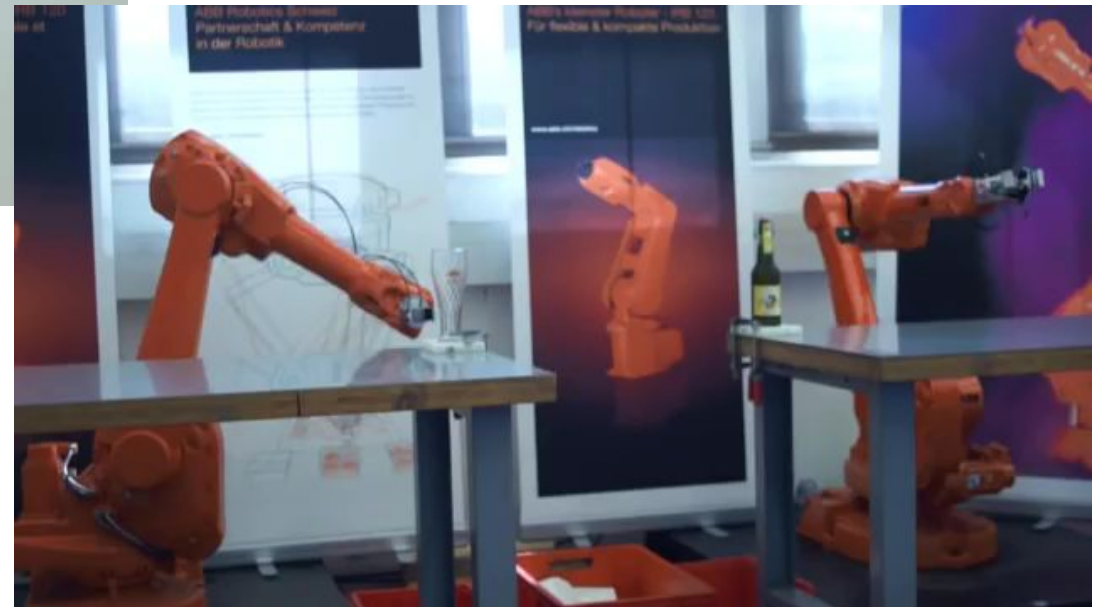
Robots filling a glass of beer



a single KUKA robot

video

two cooperating ABB robots



video

Museum guidance



- three mobile robots for museum guidance (Museum für Kommunikation, Berlin)

Entertainment



- the *Anaconda* robot (Edge Innovations, USA) weights various tons, has 60 artificial spinal vertebrae, is 12 meters long, and is actuated by hydraulic motors so as to reach a speed of up to 60 km/h

Human motion replication



- the anthropomorphic robot by Sarcos Entertainment Systems (USA) replicates the movements of a human wearing a sensorized exoskeleton

Human-Robot Interaction



- **physical** and **cognitive** interaction between a Sarcos robot and a human
intrinsic mechanical compliance in the robot structure
is here more important than accuracy in motion execution

Human-Robot Interaction (HRI)



video



cognitive interaction (cHRI)
in **Robot@CWE** EU Project

video



physical interaction (pHRI)
in **PHRIENDS** EU Project

Human-robot cooperation

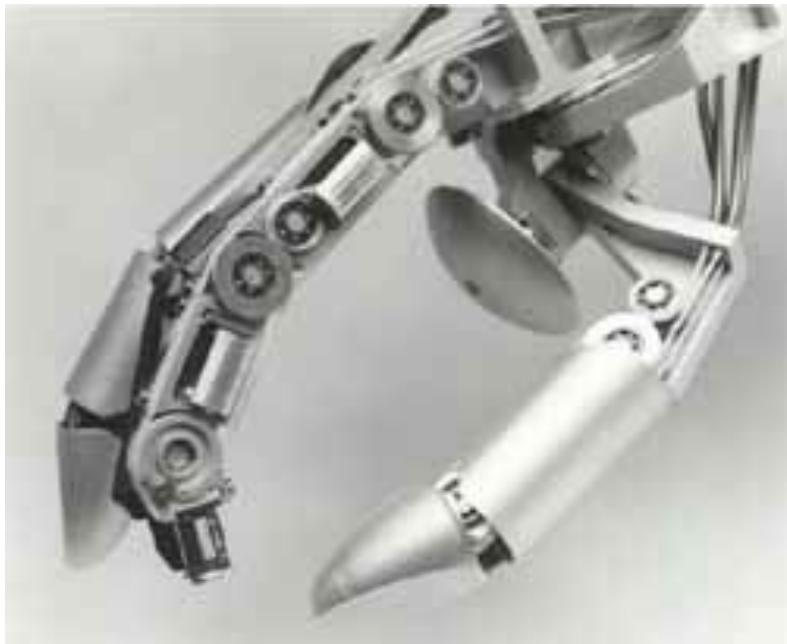


- *Mr. Helper* (Tohoku Univ) cooperates in carrying heavy and/or large loads



- *CoBot* scooter-like robot for mounting car doors (General Motors)

Robot hands



- the *UBHand* series of robot dexterous hands (Univ Bologna)
 - 3 fingers with 9 degrees of freedom, tendon actuation, supporting palm, and tactile sensors on all phalanges

Anthropomorphic UBHand IV

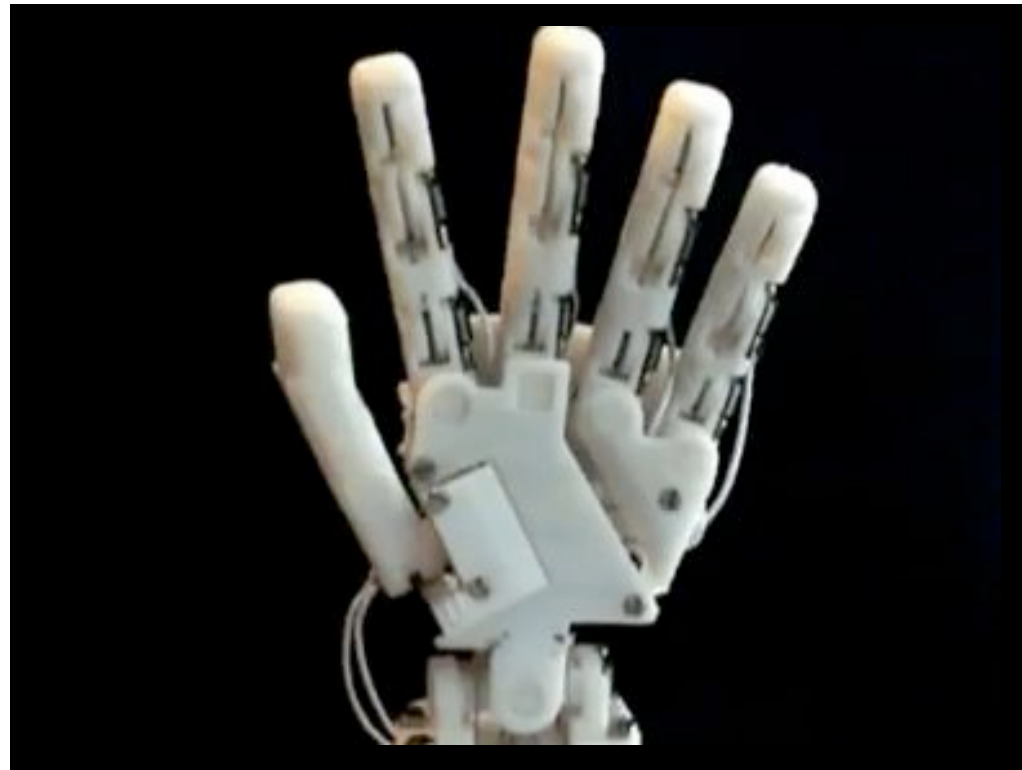
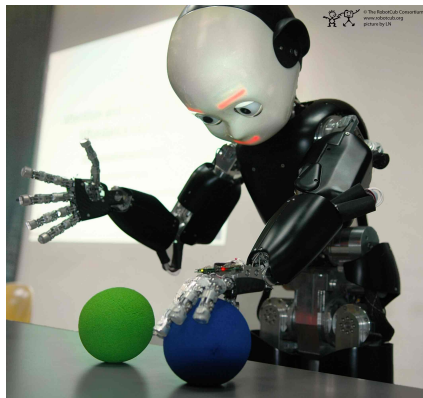


video

← data glove
for motion
capturing

- the *UBHand IV* has **deformable** elements as joint hinges (compliant mechanisms); the endo-skeletal structure with **5 fingers** may host distributed sensors and continuous compliant cover (G. Vassura, Univ Bologna)

New robot hand for the iCub



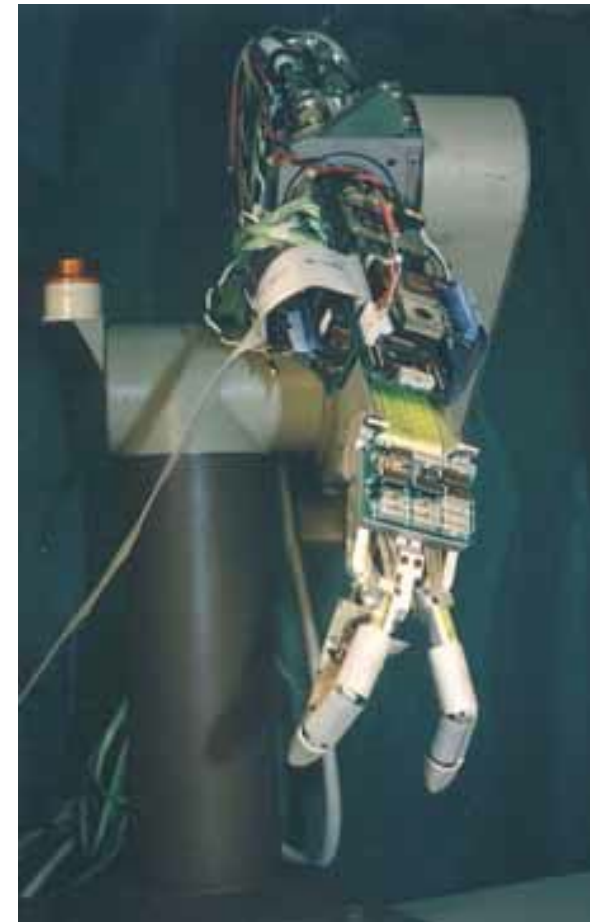
video

- *iCub* robot is like a 3.5y old child, developed by IIT Genova in 2005 in the [RobotCub](#) EU Project (platform distributed openly, with open-source SW)

Integration of robot hand + arm



- the complete *UBHand II*, with electrical motors and electronics presented at EXPO92 in Seville
 - integration in the forearm of the *Unimation PUMA 560*

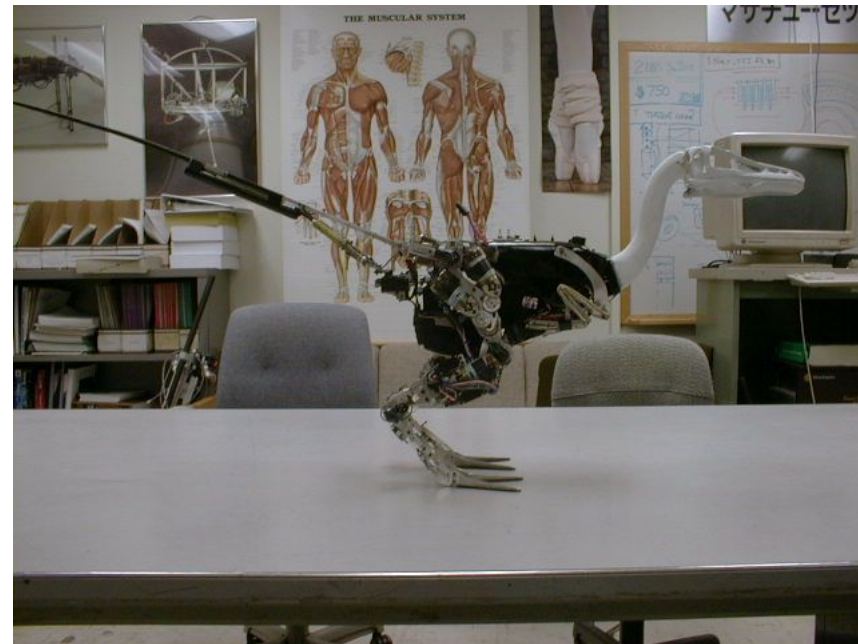


... a “minimalistic” solution



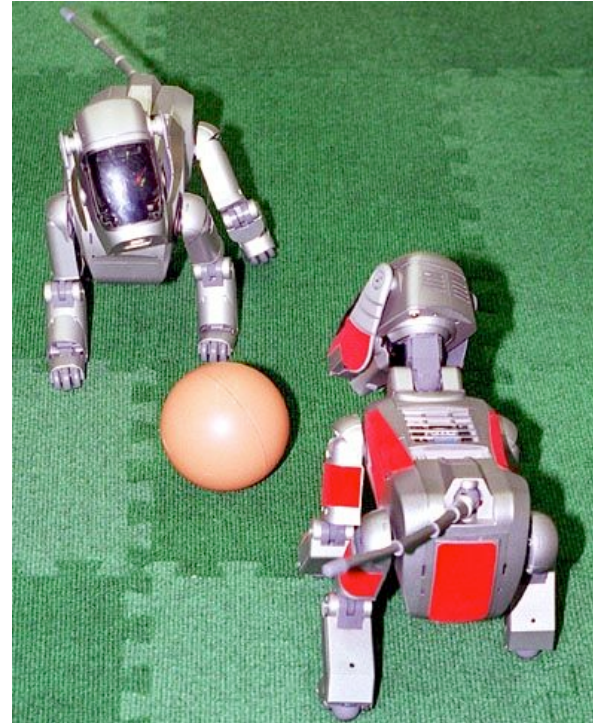
- **5D manipulation** of objects of arbitrary form, using only two linear actuators and sensorized contact surfaces (Univ Pisa)

Biomorphic robots



- biomorphic robots by MIT Leg Lab, USA:
Troody dinosaur and *Flamingo* bird

Four-legged locomotion



- *AIBO ERS-210* by Sony, playing on the soccer field of RoboCup
 - 16 actuated dofs with encoders, color camera, 3 accelerometers, ultrasound sensors, tactile and micro-switch (feet), battery: everything in 1.6 kg!

Anthropomorphic upper limbs



- *Justin* robot has 7+7+3 degrees of freedom + many dofs in the two hands (DLR, Germany)



- the robot developed in the German national project on humanoids

Justin robotic system @ DLR



video



Justin

A humanoid upper body system for two-handed manipulation experiments.



Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Fraunhofer-Gesellschaft

Humanoid robots

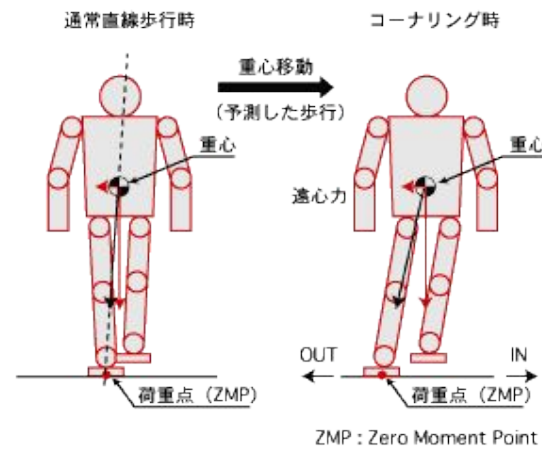


- Metropolis (Fritz Lang, 1927)



- Pino by ZMP (2003)

Humanoid robots



- the *ASIMO* project by Honda started in 1986

ASIMO in action



ASIMO
climbing stairs
(Robodex 2003)



first and
second series
(smaller size)



video



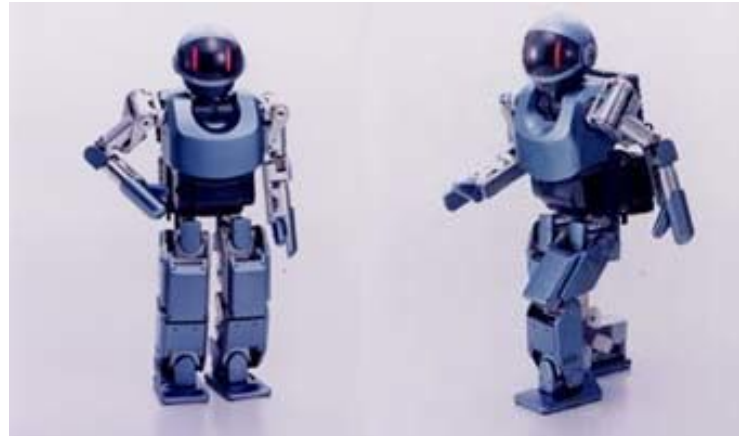
video



Humanoid robots



- *HRP-2*
(58 kg, 150 cm, 30 dofs)
2002 Tokyo Univ



- Sony *SDR-3X*
(about 60 cm)



- humanoid robot
(Q. Huang, PR China)

Sony Q-RIO



group dancing [video](#) (2003)

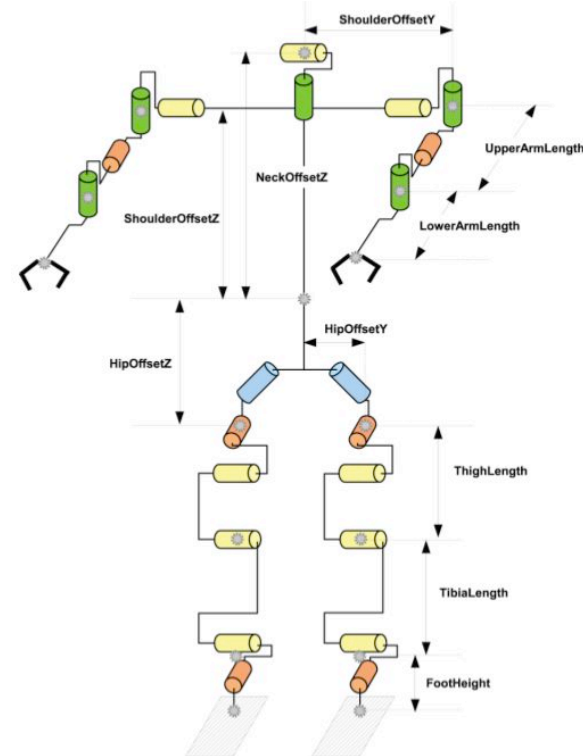
- Sony *Q-RIO*
the first robot able to balance on a surf and stand up from the floor
(**dead in 2006...**)



Humanoid robots



height = 57 cm
weight = 4.5 kg



kinematic
description

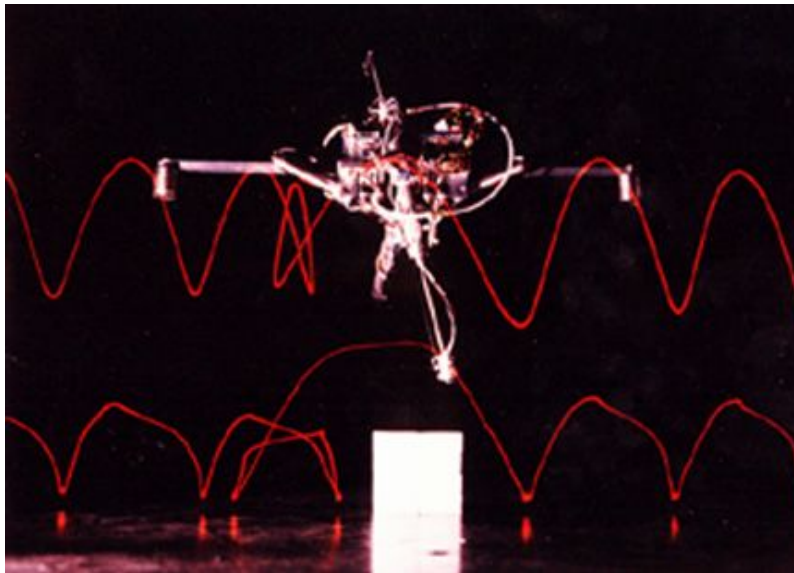
- NAO, Aldebaran Robotics
since 2008, replaces AIBO quadrupeds in RoboCup standard league

NAO playtime



Aldebaran Robotics
commercial [video](#)

... what about dynamic stability?



video

- the *One-Leg Hopper* robot (MIT, USA) demonstrated back in 1982 the feasibility of maintaining a purely **dynamic** equilibrium during motion

we could go on and on, forever...



video



MIT planar two-legged robot doing a flip (1984)

video



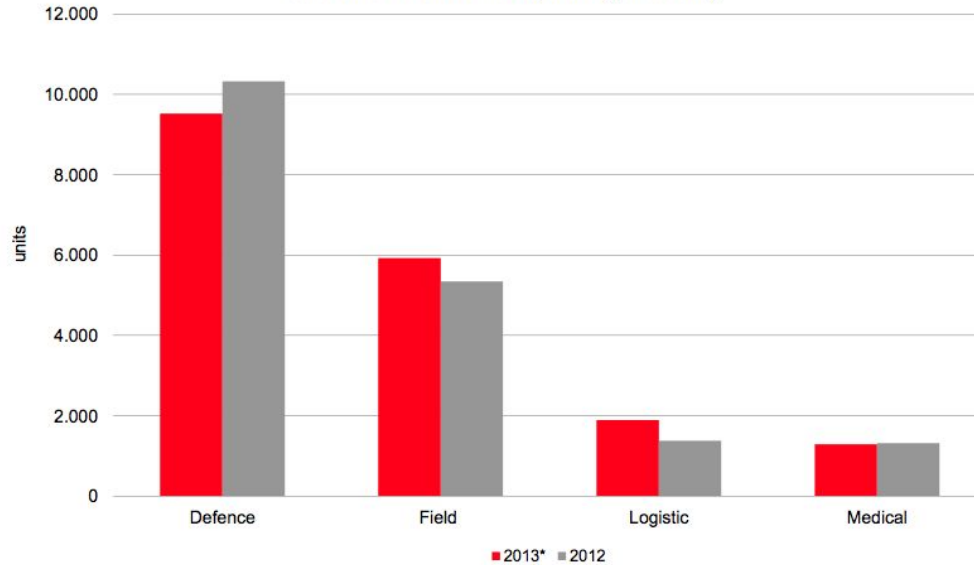
ping-pong with KUKA KR5 robot

the beauty of **dynamics** and **juggling**

Diffusion of service robots for professional use



Service robots for professional use.
Sold units 2013 and 2012 (main applications)



about 21,000 service robots for professional use were sold in 2013

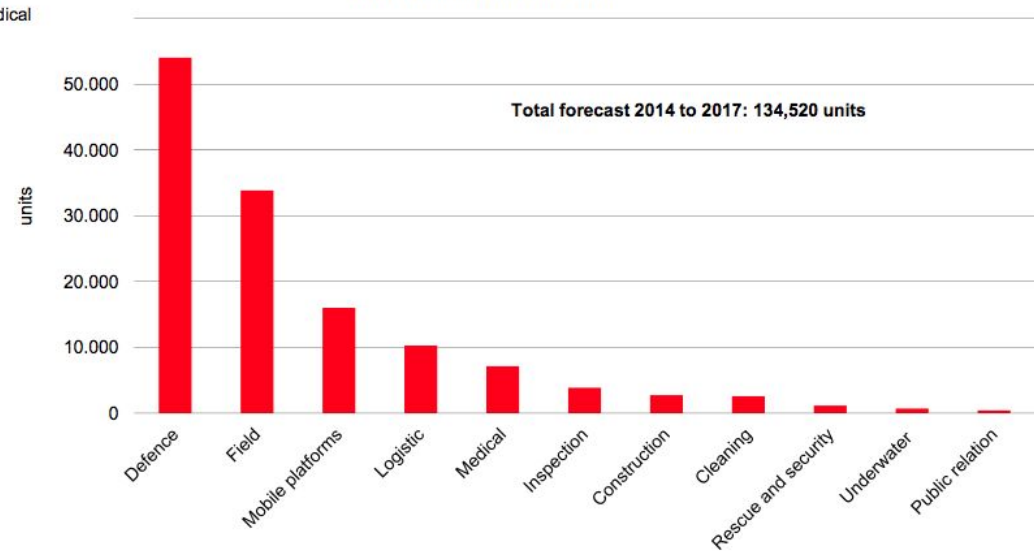
← main sectors with more than 1K sells

smaller markets include: mobile platforms, construction, cleaning, underwater, inspection

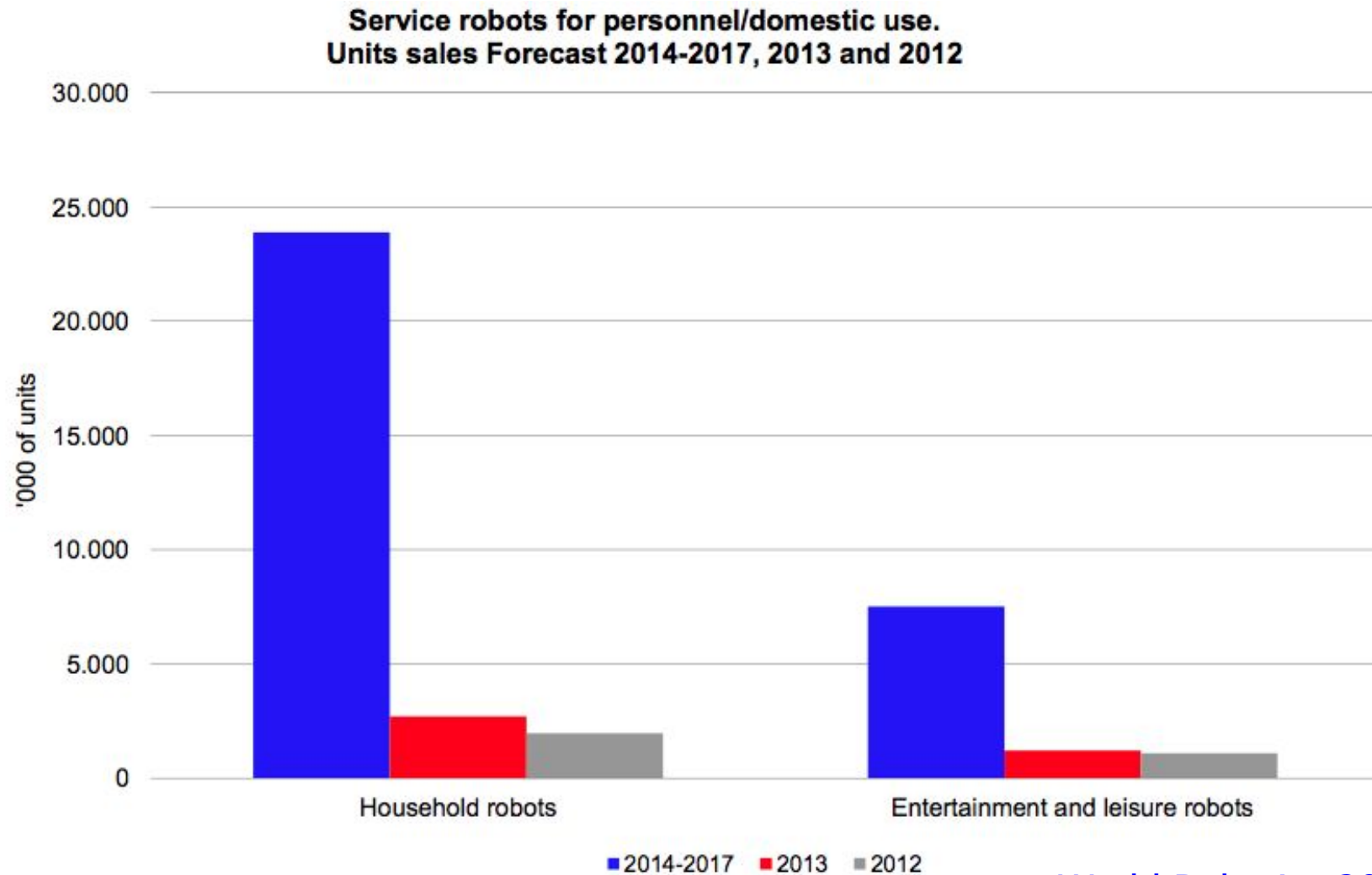
World Robotics 2014

about 134,500 new service robots in 2014-17

Service robots for professional use.
Unit forecast 2014 to 2017



Diffusion of service robots for personnel/domestic use



World Robotics 2014

Web sites



- <http://video.ieee-ras.org>

Full collection of *440 video clips* from the 1991 to the 2006 editions of the IEEE Int. Conf. on Robotics and Automation (*ICRA*) – **needs log**

– *become a student member of the IEEE Robotics & Automation Society!!!* –

- <http://www.service-robots.org>

Technical Committee on Service Robots of the IEEE (*Institute of Electrical and Electronics Engineers*) - RAS

- <http://www.euron.org>

EUropean RObotics research Network, with a gallery of robots, videos, European robotics projects (no longer updated since 2012)

- <http://www.eu-robotics.net>

The new *European Robotics AIBSL*, with euRobotics Forum & Week, etc.

- <http://www.youtube.com/user/RoboticsLabSapienza>

YouTube channel of *DIAG Robotics Lab*, with videos of our latest research