Robots Moving Closer to Humans

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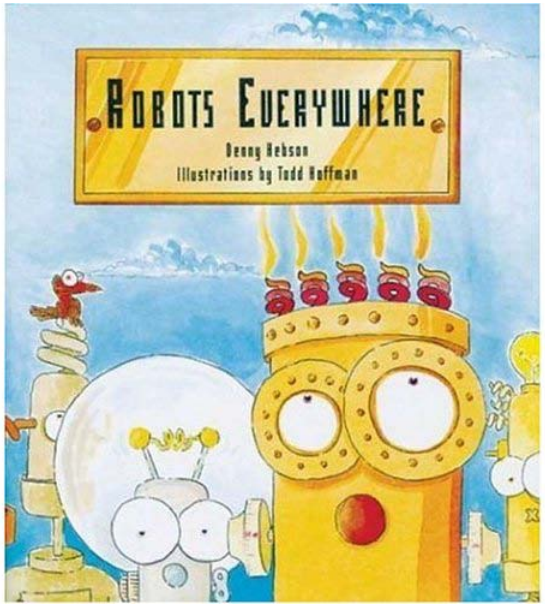
Robots !!!



Today

Mars
Oceans
Hospitals
Factories
Schools
Homes
…

Intelligent
Personal
Pervasive
Disappearing
Ubiquitous

Tomorrow

Evolution of Robotics

Humans' DREAM of replicating themselves

NEED for useful machines

1960-1980

Industrial Robotics

Manufacturing Applications

1980-2000

Field Robotics

Spatial Applications

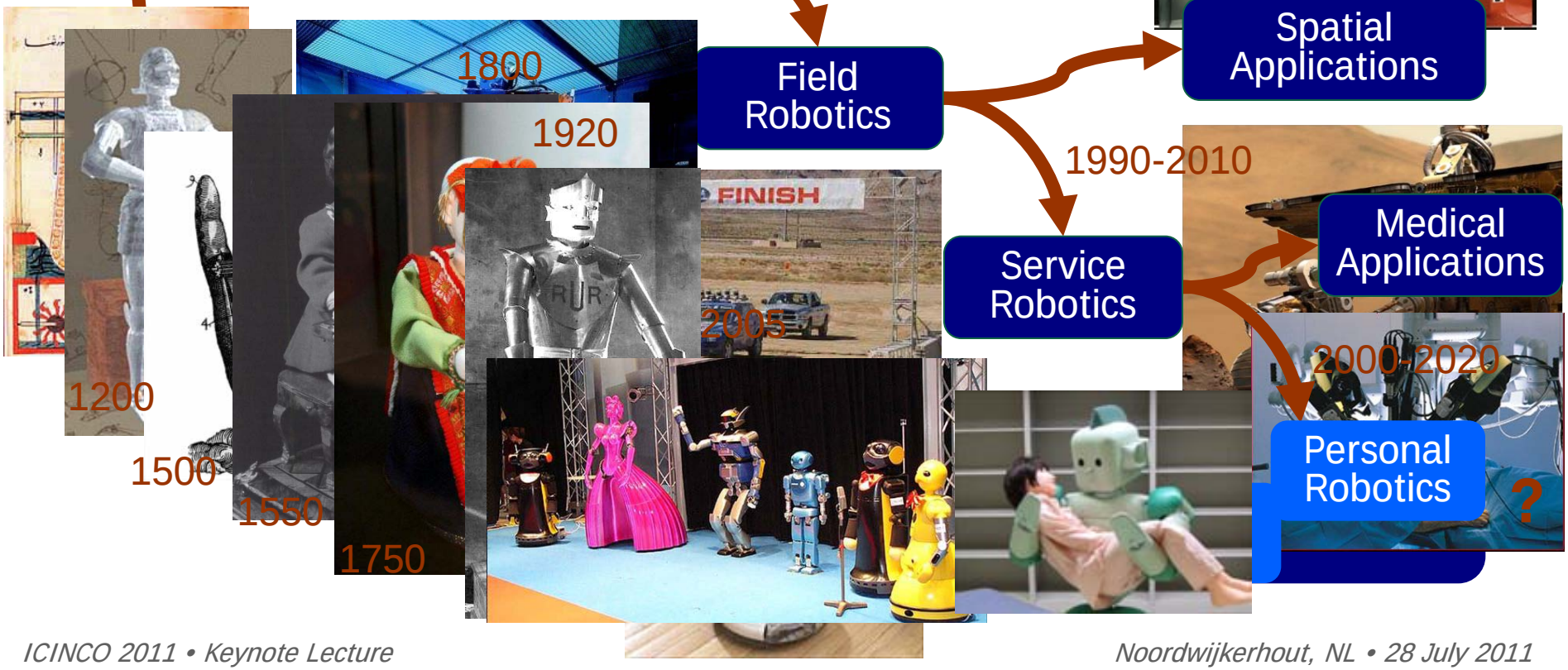
1990-2010

Service Robotics

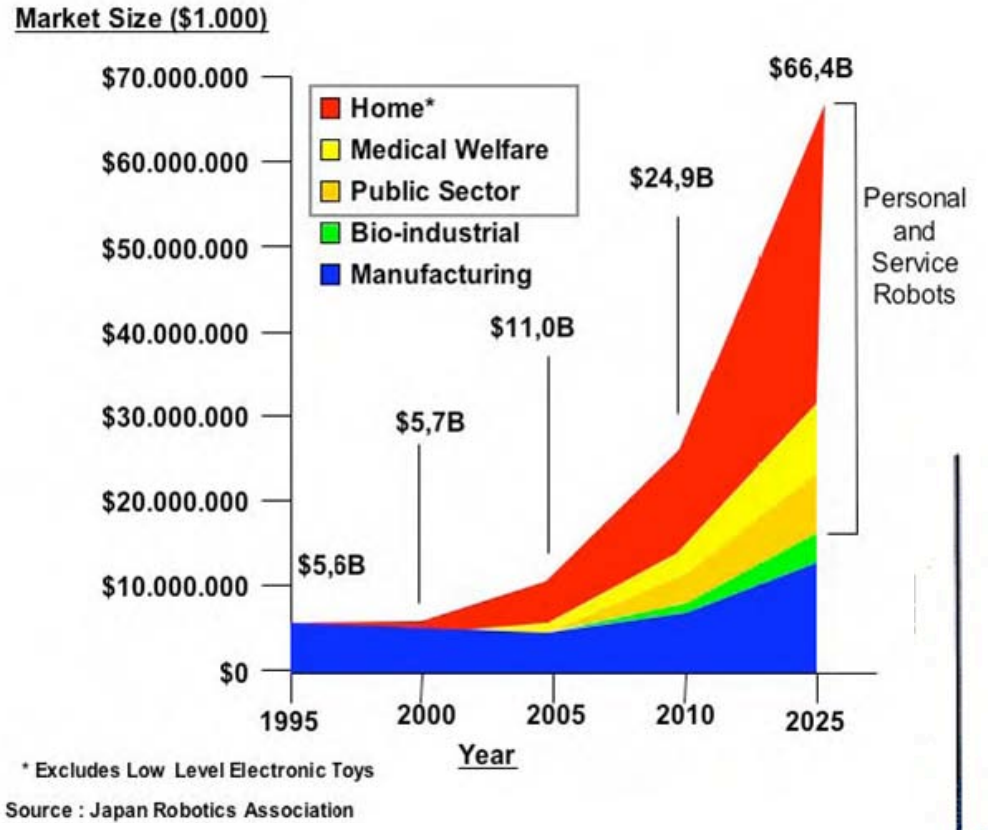
Medical Applications

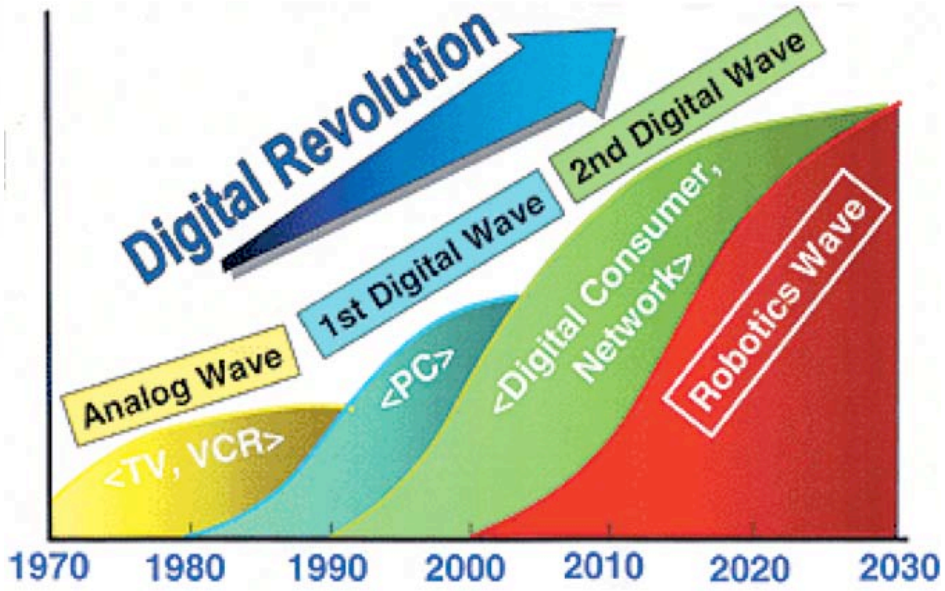
2000-2020

Personal Robotics ?



Interesting Economics



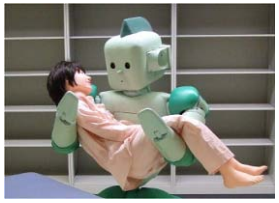


European Strategic Research Agenda (2009)



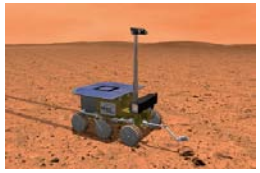











industrial

robotics market

converging technologies need cross-fertilisation

domestic service

professional service

security

space

www.robotics-platform.eu

From Factories to Our Homes

Industry

Automotive
Chemical
Electronics
Food

Field

Aerial
Space
Underwater
Search and rescue

Service

Domestic
Edutainment
Rehabilitation
Medical

Level of Autonomy

Service Robots

- Robots find applications in “4D tasks”
  - Dull
  - Dangerous
  - Dirty
  - Dumb
- Service robots
  - Health care
  - Entertainment
  - Security
  - Personal assistance
  - Construction
  - Cleaning

Personal Robots

- Service robots that are consumer products
  - Education/hobbyist robots
  - Entertainment robots
  - Smart toys
  - Robotic pets
  - Automated home
  - Partner robots

Biological Inspiration

«la scienza m'interessa proprio nel mio sforzo per uscire da una conoscenza antropomorfa; ma nello stesso tempo sono convinto che la nostra immaginazione non può essere che antropomorfa»

Italo Calvino

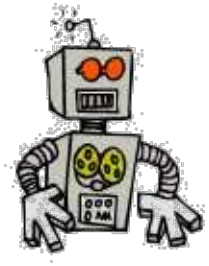
human beings knowledge

BIOLOGY

biomechanics
neurosciences
psychology

ROBOTICS

mechanics
control
sensors



hypotheses and models validation

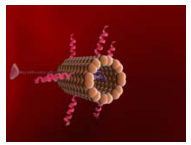
humanoids

zoomorphic

prostheses

cyborgs

micro/nano



New Emerging Areas

- By dawn of new millennium, robotics has undergone a major transformation in scope and dimensions
  - Maturity of field and advances in its related technologies
- Expansion into challenges of human world (human-centered and life-like robotics)
  - New generation of robots expected to safely and dependably co-habitat with humans in homes, workplaces, and communities, providing support in services, entertainment, education, healthcare, manufacturing, and assistance

Human-Robot Interaction

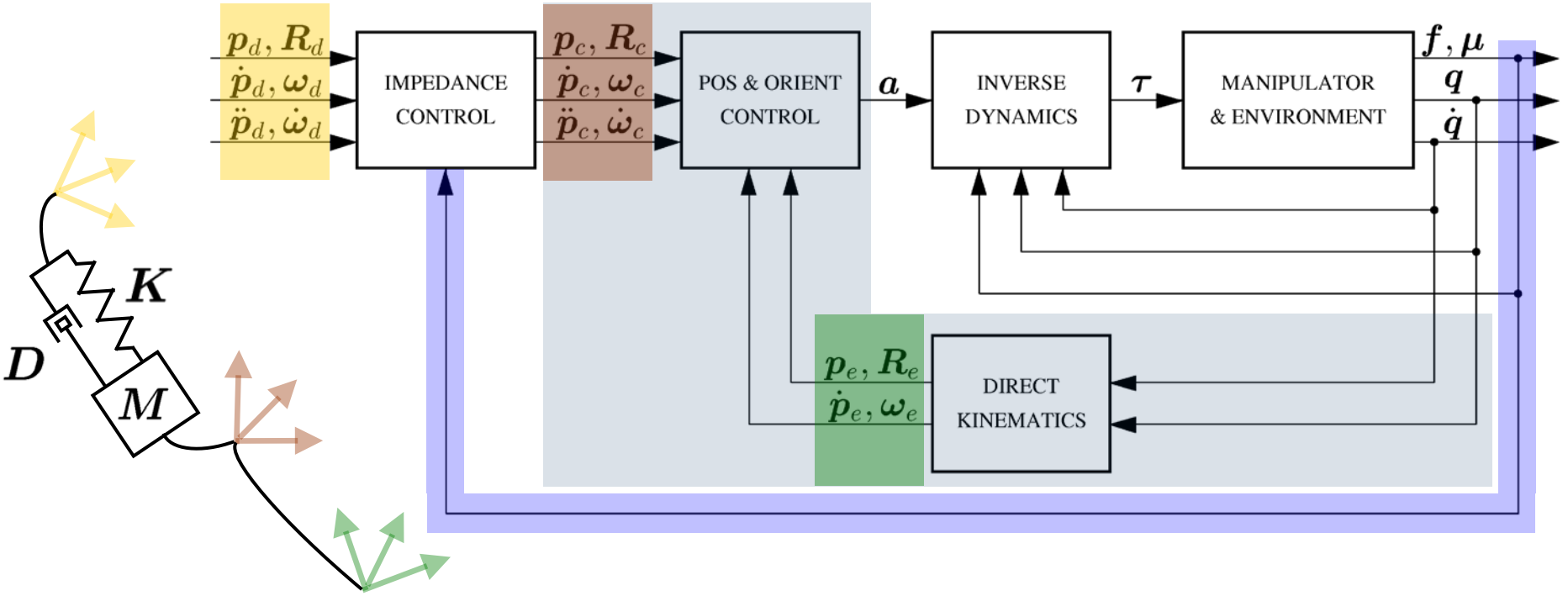
- Intelligent machines working in contact with humans (human augmentation)
  - Haptic interfaces and teleoperators
  - Cooperative material handling
  - Power extenders
  - Rehabilitation and physical training
  - Entertainment

- Advanced industrial robotics
  - Traditionally segmented workspace for machines and humans
  - Safe and productive human-aware space-sharing robot (cooperative, no fences)

- Human-Robot Interaction (HRI)
  - Cognitive issues [cHRI]: perception, awareness, mental models
  - Physical issues [pHRI]: safety, dependability, dexterity
  - Ethical issues: motivations and critics about HRI, acceptability

- Risks for robots interacting with humans
  - Heavy moving parts and objects transported
  - Sensory data reliability
  - Level of autonomy/unpredictable behaviours
- Solutions for collaborative human-robot operation
  - Design of non-conventional actuators (passive safety)
  - Interaction control (active safety)
  - Dependable algorithms for supervision and planning
  - Fault tolerance
  - Need for quantitative metrics

- Impedance control with inner motion control loop
  - Force/torque measurements for linear and decoupled impedance
  - Compliant frame between desired and EE frame (disturbance rejection)



Interaction with Environment

- Set-up
  - COMAU Smart 3-S robot
  - Open control architecture
  - ATI force/torque sensor
  - 6-DOF spatial impedance

surface contact

low compliance
high damping

high compliance
low damping

high compliance
high damping

- Physical Human Robot Interaction: DepENDability and Safety

PHRIENDS

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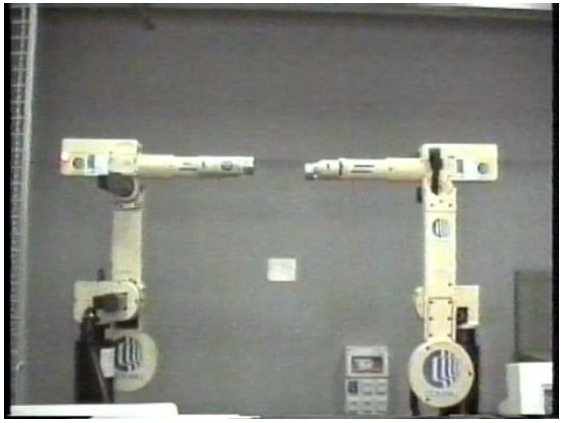
SAPHARI

Safe and Autonomous Physical Human-Aware Robot Interaction

Dual-Arm Manipulation

- Dual-arm set-up
  - 6ax robot
  - 7ax robot

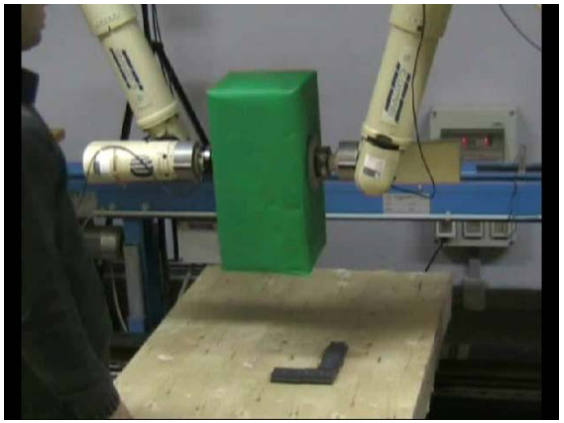
peg-in-hole assembly
6-DOF impedance



control of absolute motion
and internal forces

absolute & relative impedance

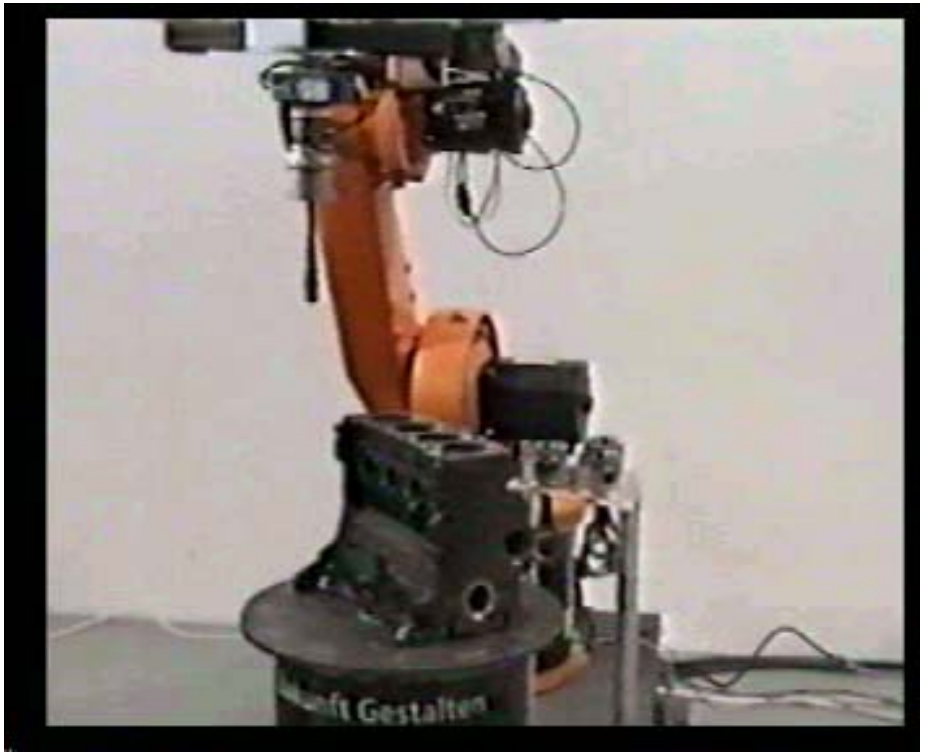
absolute impedance



human-object interaction

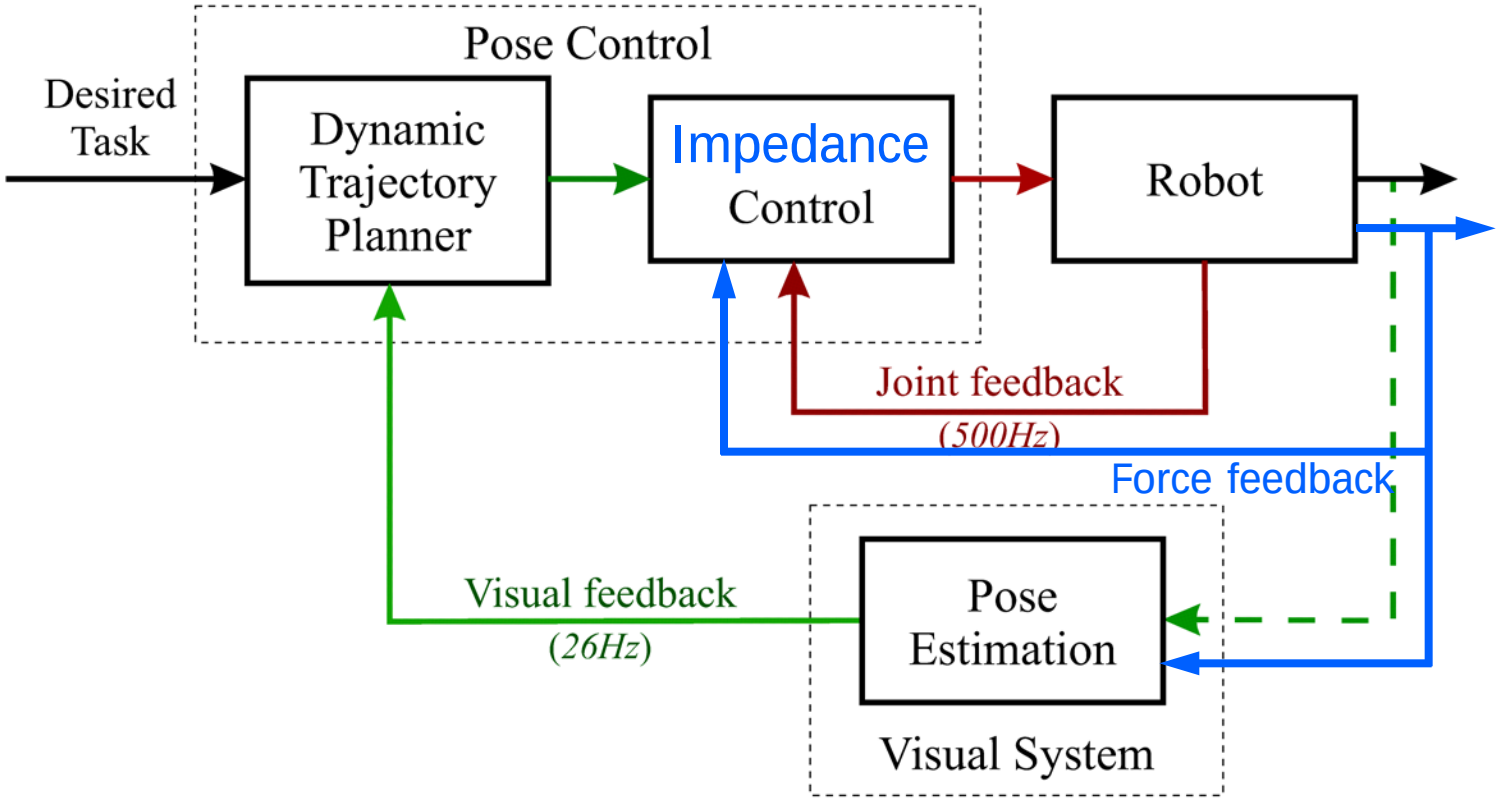
Force and Visual Control

- Set-up @ DLR
  - KUKA robot with force sensor and camera embedded in the gripper
- Integration of vision and force
  - Visual feedback in gross motion
  - Force feedback in fine motion



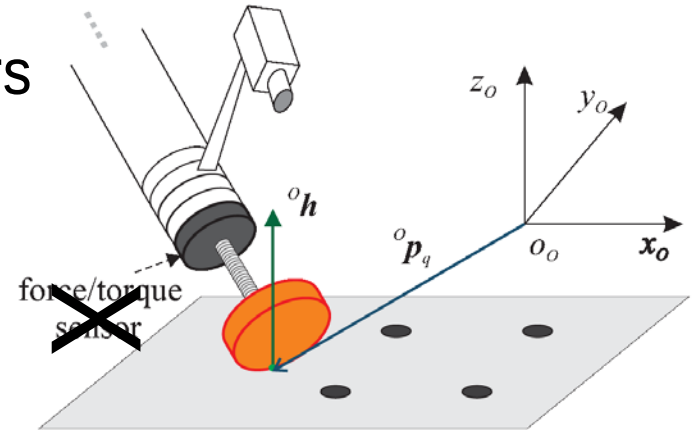
Visual Impedance

- Position-based visual impedance

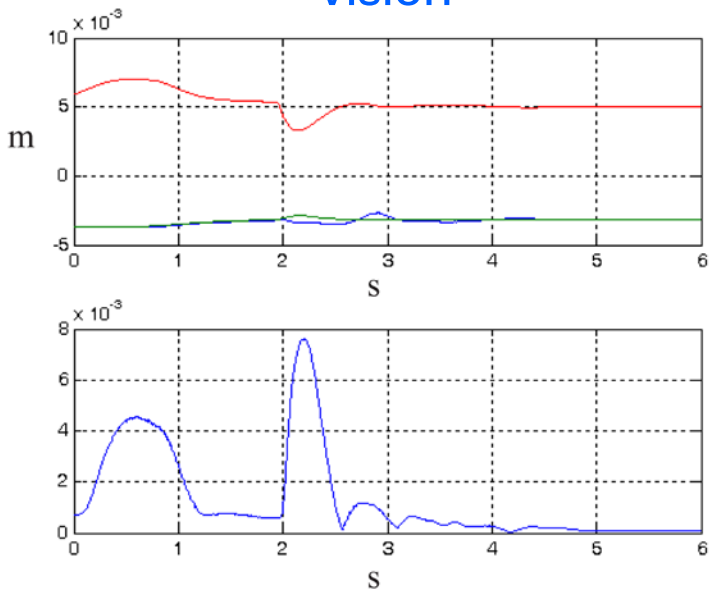


Interaction with Environment

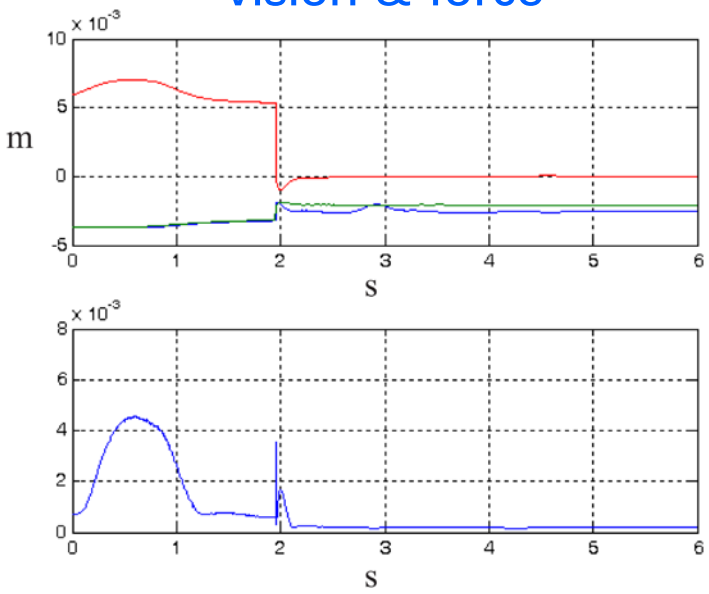
- Pose estimation errors



vision

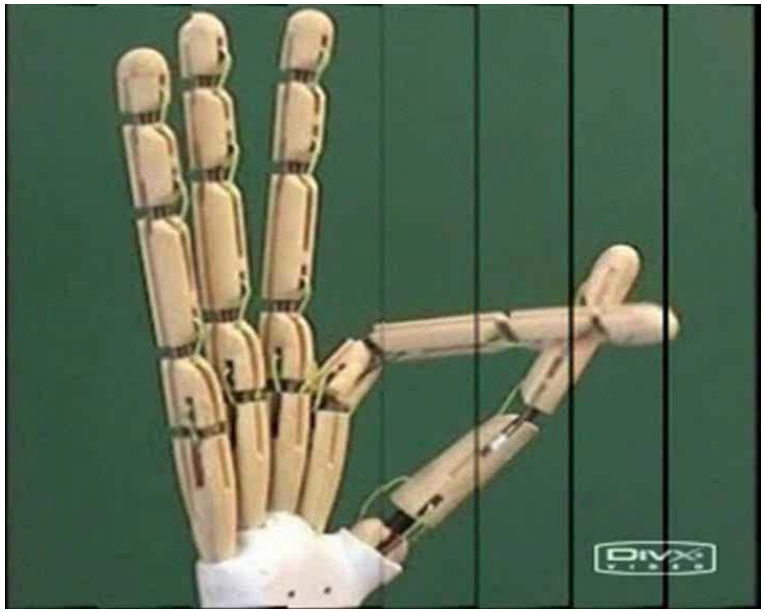


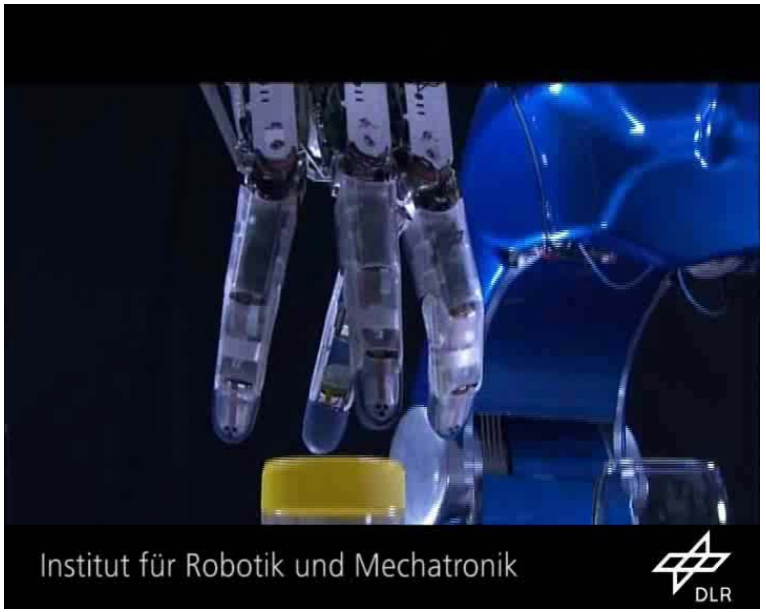
vision & force



Dexterity

- DEXterous and autonomous dual-arm/hand robotic manipulation with sMART sensory-motor skills: A bridge from natural to artificial cognition





DEXMART

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OMG
OxfordMetricsGroup

Challenges and Outreach

- Beyond its impact on physical robots, robotics has produced body of knowledge for much wider range of applications
  - Biomechanics, haptics, neurosciences, virtual prototyping, animation, surgery, and sensor networks among others
  - Challenges of new emerging areas proving abundant source of stimulation and insights for robotics field
  - Most striking advances happening at intersection of disciplines
- New communities of users and developers with growing connections to robotics research core
  - Strategic goal for robotics community is one of outreach and scientific cooperation with these communities
  - Future developments and expected growth of field will largely depend on research community's abilities to achieve this objective

Looking Beyond

- Research challenges
  - Biomechanics
  - Haptics
  - Neurosciences
  - Machine learning
  - Virtual prototyping
  - Animation
  - Surgery
  - Sensor networks
  - ...

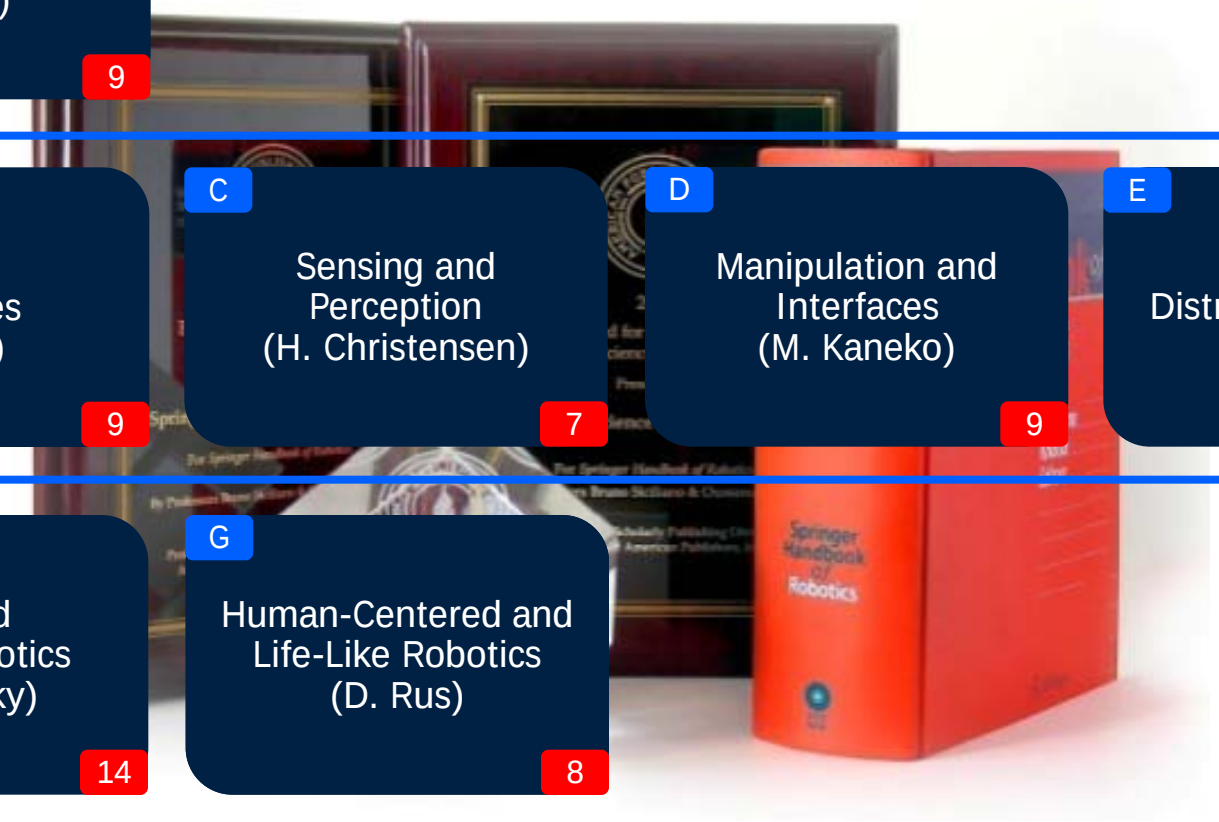
Roboethics

Human-centered ethics guiding design, construction and use of robots

- Outreach toward new communities
  - Growing connection with robotics research core

B. Siciliano & O. Khatib (Editors)

s for Excellence in Physical Sciences & Mathematics +
ngineering & Technology (February 2009)



A Robotics Foundations (D. Orin) 9

B Robot Structures (F. Park) 9

C Sensing and Perception (H. Christensen) 7

D Manipulation and Interfaces (M. Kaneko) 9

E Mobile and Distributed Robotics (R. Chatila) 8

F Field and Service Robotics (A. Zelinsky) 14

G Human-Centered and Life-Like Robotics (D. Rus) 8


robots are
with us,
within us
and among us

Thanks very much indeed [:]