Controlling reaching movements while working against different physical loads
Controlling Physical Devices: Robotic Limbs

http://www.lyromotion.com/images/jpg/00arm3.jpg

Goal Directed Reach and Grasp/Release
(Demo by Aziz Caplan/Misha Semuya,
Chris Flaherty, Maryam Saleh)

@ Carnegie Mellon University
Interactive Systems in LIST

VIRTUAL REALITY, HUMAN-COMPUTER INTERACTION

INTERACTIVE ROBOTICS

KNOWLEDGE ENGINEERING

MAN-MACHINE COOPERATION

Medical applications

Disabled people assistance

MASTER

AVISO

IMMEDIATE

ALFRED
Industrial applications

Tactile Interfaces

Automotive

Communicating Devices

Virtual Reality

Edutainment

Wearable Haptic Devices

MUVII
I. May I help? — Adaptive Shared Autonomy

Marnix Nuttin. Katholieke Universiteit Leuven & Elleen Lew. IDIAP

the intelligent controller relieves the user from low-level tasks without sacrificing her cognitive superiority and adaptability
Paolo Dario
Scuola Superiore Sant'Anna
Pisa, Italy

- Scuola Superiore Sant’Anna and Polo Sant’Anna Valdera
- ARTS and CRIM Labs and their mission
- History of research on Biorobotics and on Brain Computer Interfaces at ARTS and CRIM Labs
- Current activities:
  - implantable interfaces (Silvestro Micera)
  - non invasive brain machine interfaces (Oliver Tonet)
  - natural interfaces (Cecilia Laschi)

Spin-off\start-up companies generated by SSSA (1991-2004)

18 spin-off/
start-up

- 00 highly qualified jobs (besides owners)
- More than 70% of the owners hold a PhD degree or have an equivalent research experience
- Average turnover 2 M€
- Survival rate: 94%
Potential of CRIM technologies

Legged Capsule Prototype:
- Diameter: 17 mm
- Length: 32 mm
- Internal space for Miro unit D 8 mm x L 28 mm

Leg:
- Superalastic legs made by W-EDM machining.
- Length from 15 mm to 20 mm for navigation
- Thickness 0.25 - 0.5 mm
RoboCasa model for the Italy-Japan cooperation

The ARTS humanoid robot

- **Anthropomorphic head & retina-like vision system**
  - 7 d.o.f.s (neck & eyes)
  - 7 proprioceptive sensors
  - 2 cameras

- **Anthropomorphic arm**
  - 8 d.o.f.s
  - 16 proprioceptive sensors

- **Biomechatronic hand**
  - 10 d.o.f.s
  - 16 proprioceptive sensors
  - 135 tact. Sensors

Total:
- d.o.f.s: 25
- Visual sensors: 2
- Proprioceptive sensors: 39
- Tactile sensors: 135

Biorobotics science

PHENOMENON TO BE EXPLAINED

Movement
Lead force
Grip force

HYPOTHESIS AND MODEL

IMPLEMENTATION IN A ROBOT

Validation of the model

EXPERIMENT
Comparison between robot and biological system performance

NEUROBOTICS
The fusion of NEUROscience and roBOTICS

Starting date: 01/01/2004
Duration: 48 months
Funding: 5.640 k€

Roboticians and technologists
1. Scuola Superiore Sant'Anna, Italy (prof. Paolo Dario) – Project Coordinator
2. Deutsches Zentrum für Luft- und Raumfahrt, Germany (prof. Jorg Hinzinger)
3. Kungliga Tekniska Högskolan, Sweden (prof. Henrik Christensen)
4. National Technical University of Athens, Greece (prof. Kostas Kynigos)
5. University of Genova, Italy (prof. Giulo Sandini)
6. Fraunhofer Institute for Biomedical Engineering, Germany (prof. Klaus Peter Hofmann)

Neuroscientists
1. Collège de France, CNRS, France (prof. Alain Berthoz)
2. Karolinska Institutet, Sweden (prof. Sten Grillner)
4. Umeå University, Sweden (prof. Roland Johansson)
5. Universitat Autònoma de Barcelona, Spain (prof. Xavier Navarro)
6. University of Padova, Italy (prof. Giacomo Rizzolatti)
7. Université P. et M. Curie / INSERM U683, France (prof. Yves Burnod)
8. Università Campus BioMedico, Italy (prof. Paolo Maria Rossini)
9. Università di Ferrara, Italy (prof. Luciano Fadiga)

Collaboration with non-EU research groups
1. Brown University, USA (prof. John Donoghue)
2. Waseda University, Japan (prof. Akihisa Takanishi)

Management
Pont-Tech, Italy (dr. Fabrizio Vecchi)
Joint design of hybrid bionic systems

A step further in the two-way collaboration between Neuroscience and Robotics

NEW SCIENCE

ROBOTS (existing prototypes)

NEW TECHNOLOGY

Biomedical Applications

NEW HYBRID BIONIC SYSTEMS ARE DESIGNED TOGETHER BY ROBOTICISTS AND NEUROSCIENTISTS

Conceptual scheme of jointly designed hybrid bionic systems
The CYBERHAND Project
IST 2001 35054 (05/01/2002-10/31/2005)

8. Decoding patient's intentions and Embedded closed-loop control of the artificial hand

Neural interfaces:
3. afferent nerve
4. efferent nerve

1. Biomechatronic Hand

5. Implanted neural interface:
   - ENO: efficient signal recording (patient's intention detection)
   - Afferent nerves stimulation to provide sensory feedback to the patient

6. Receiver
7. Transmitter

Project Coordinator
Prof. Paolo Dario
The Consortium
1. Scuola Superiore Sant'Anna
2. Fraunhofer Institute for Biomedical Engineering
3. Universidad Autonoma de Barcelona
4. Centro Nacional de Microelectronica
5. Center for Sensory-Motor Interaction

New skin sensors for level 3

- Bare silicon sensor:
  - Fn overload 3N
  - Ft overload 0.5N
  - Sensitivities: $S_x = S_y = \sim 10 \text{mN}^{-1} - \sim 100 \text{mN}^{-1}$
  - $S_z = \sim 10 \text{mN}^{-1} - \sim 50 \text{mN}^{-1}$
  - Dimensions: 1.5mm x 1.5mm, about 1.4 mm$^3$

- Hybrid architecture: possibility to assemble the sensor on additional silicon chip
  - IC integration – local signal processing integration important for arrays of sensors

Cosmetic Glove
Tri-axial tactile microsensor (magnified)
Sensorized Fingertips with Embedded Sensor Array
The BIOMECHATRONIC approach: “duplicating” the natural hand

**Neuroscience Models for Cybernetic Hand**

- Anticipatory Predictions
- Feedforward control
- Preshaping and grasp primitives
- Impedance Control
- Agonistic/Antagonistic Redundant Actuators System

Identification of crucial mechanical events for phase transition
- Detection in grasping and manipulation

**Intention**

- **High Level Control**
  - Controller: Central Nervous System (CNS)
  - Activation
  - Efferent Path

**Sensors and Perception**

- Physiological Sensory system

**Mechanism**

- Skeletal systems + External load

**Low Level Control**

- Force

**Actuation**

- Motors: Muscles