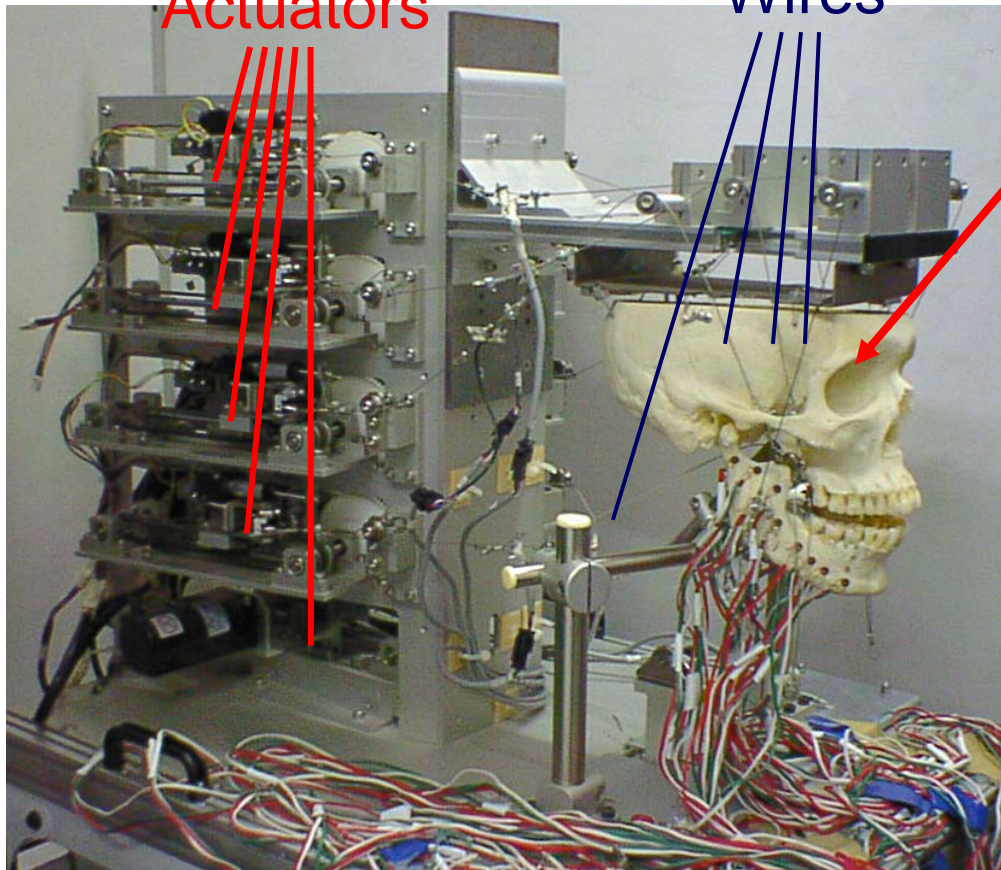


# Dental Robotics: Clarify Human Mastication with Mastication Scientists

Artificial Muscle  
Actuators

Tendon Driving  
Wires

Real Human Dry Skull



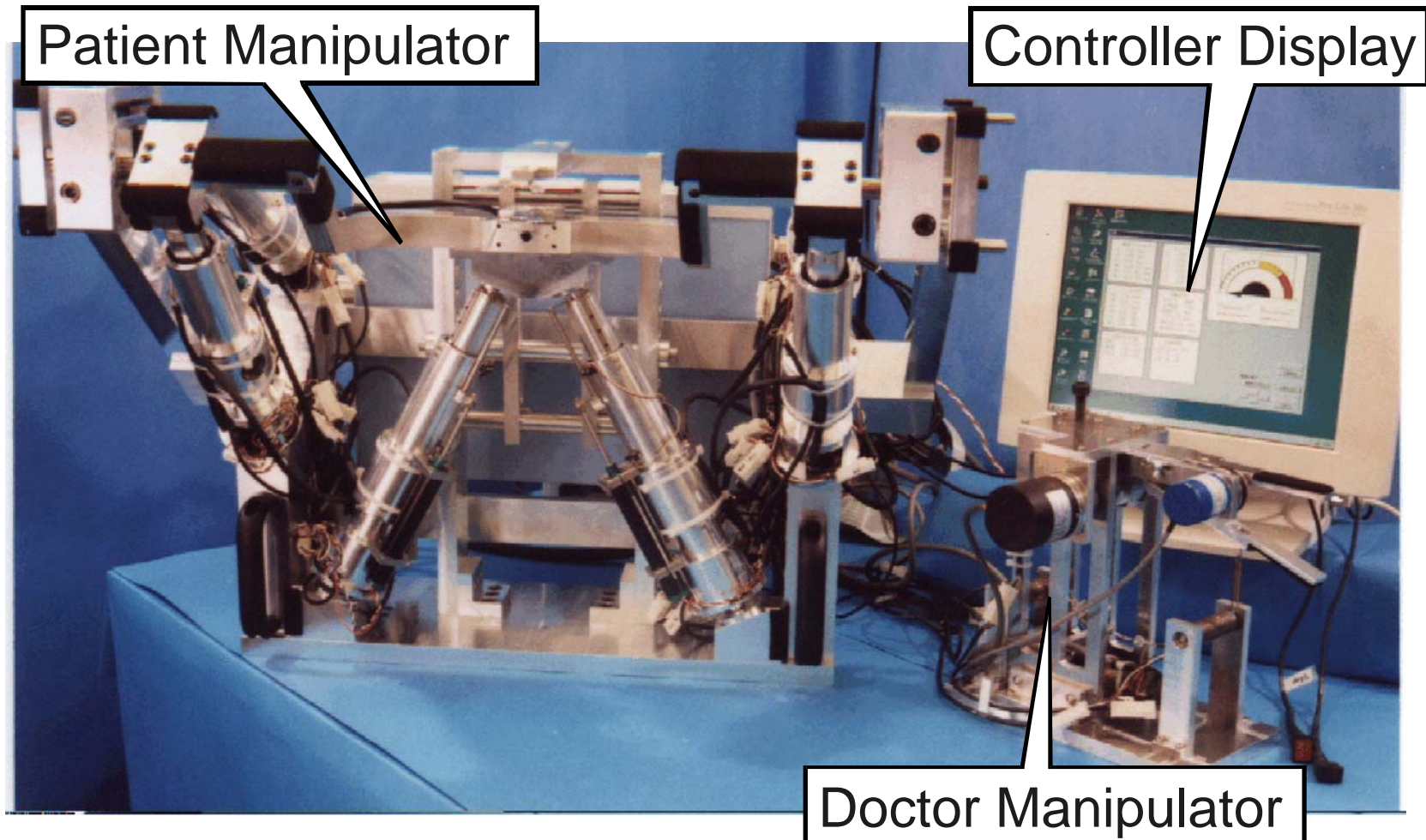
Height : 510 [mm]  
Width : 450 [mm]  
Depth : 600 [mm]

**9 DOF**

- 9 AC Servo Motors
- Wire Drive
- Nonlinear Viscoelasticity

With OKINO Industries

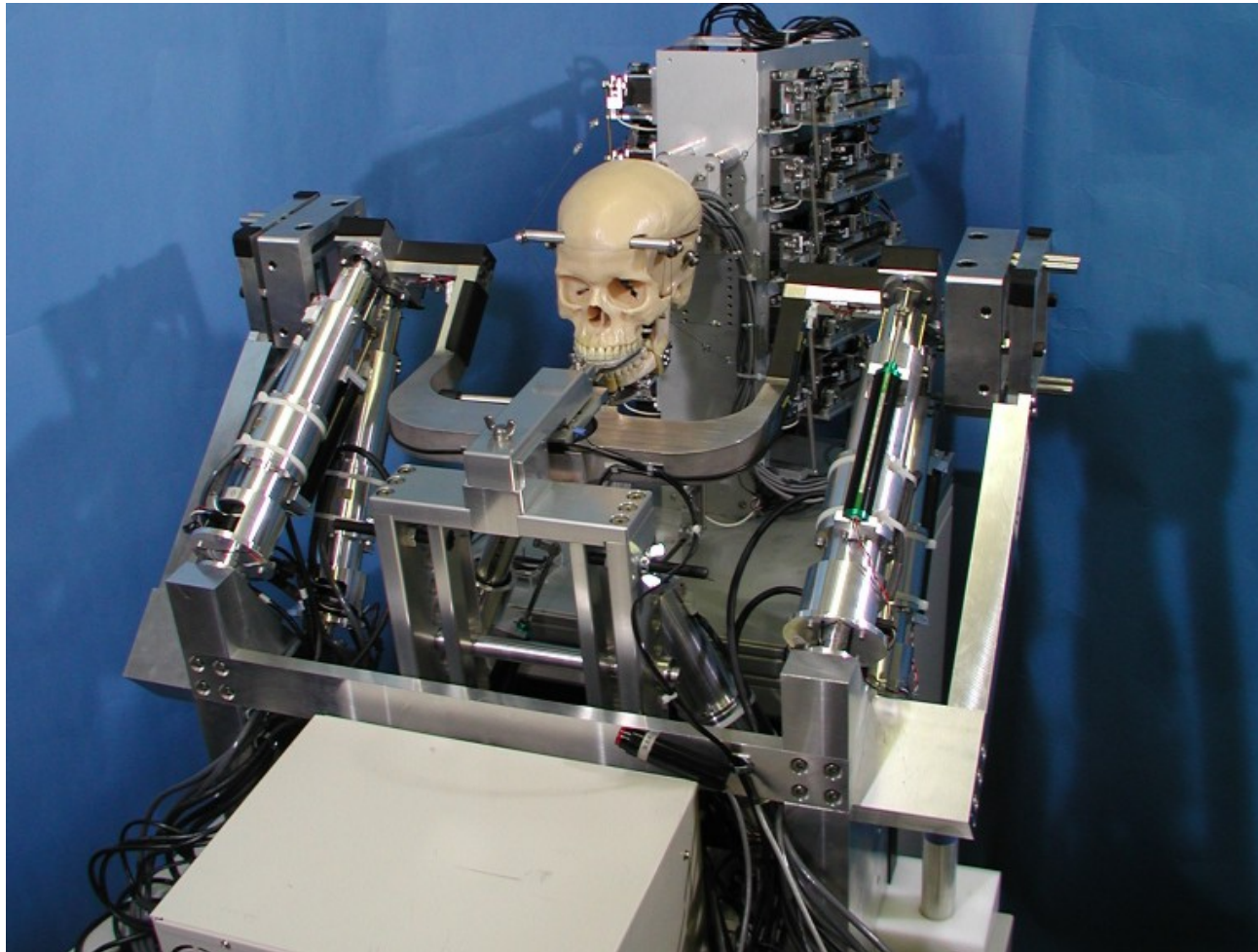
# Jaw Training Robot for TMD Patients Designed using Human Mastication Model





# Jaw Training Robot and Patient Simulator Robot for Exploring New Robotic Treatment Methodology

WASEDA UNIV.  
HRI

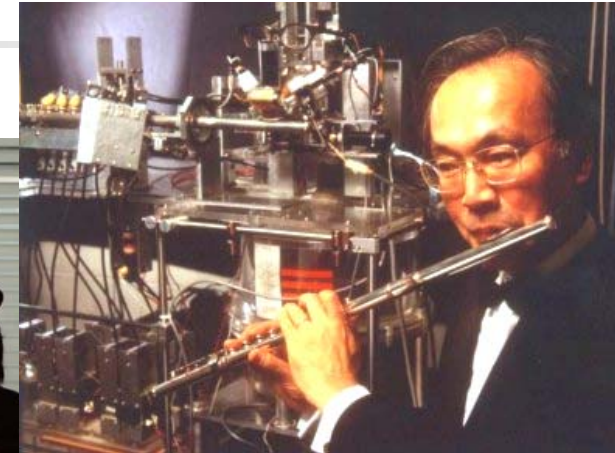
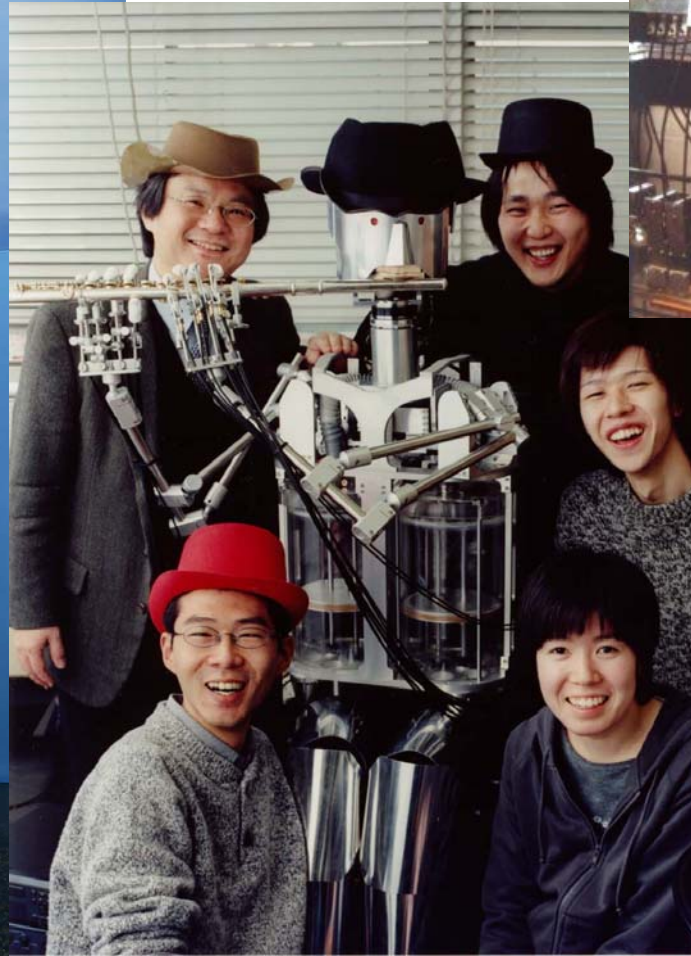


# Flutist Robot for Simulating Human Flute Playing:WF-4

WASEDA UNIV.  
HRI



  
SolidWorks

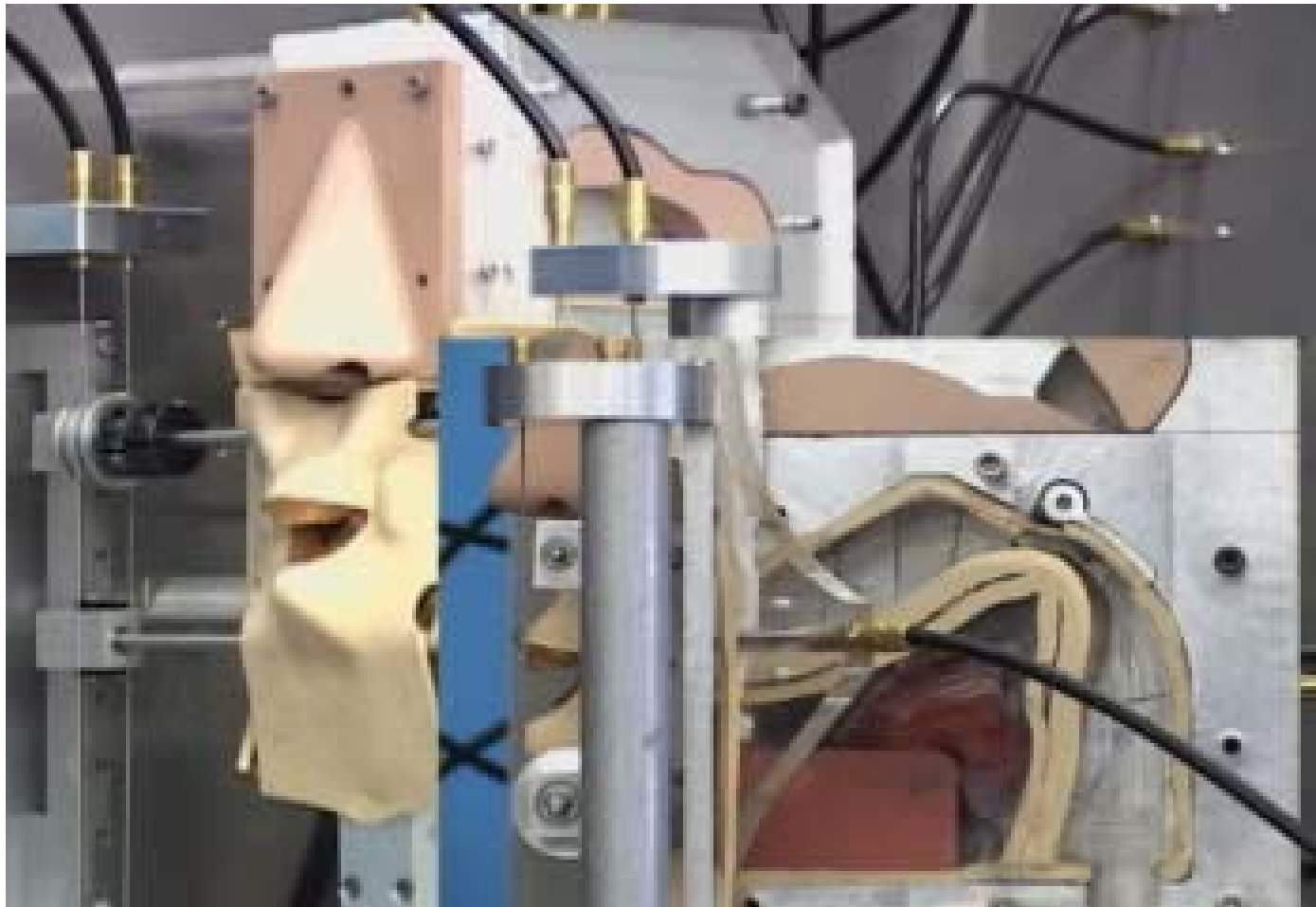


Professional Flutist: Mr.  
Kunimitsu Wakamatsu

GIFU-WASEDA WABOT-HOUSE Project

# Modeling of Human Speech Production Using Talking Robots: WT-3/4

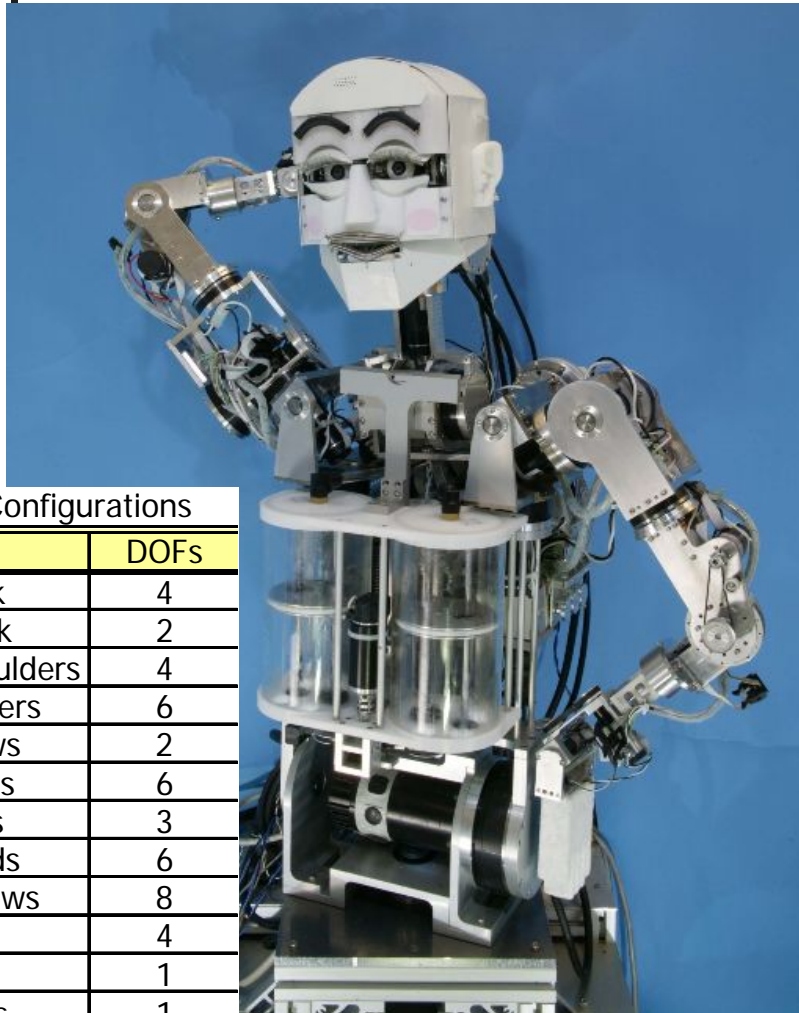
WASEDA UNIV.  
HRI



Waseda Daigaku (Waseda University)

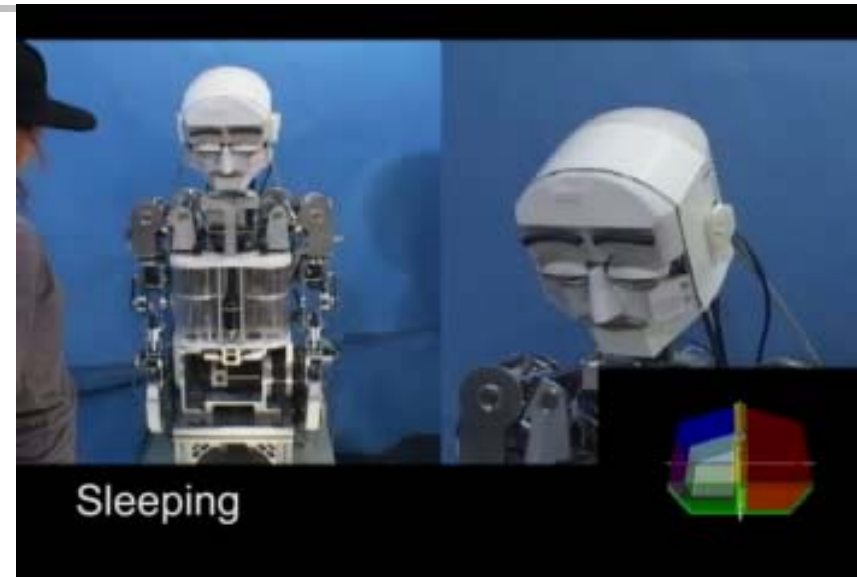


# Emotion Expression Humanoid EYE-Chan: WE-4R for Modeling Human Mind



DOFs Configurations

Part	DOFs
Neck	4
Trunk	2
Base Shoulders	4
Shoulders	6
Elbows	2
Wrists	6
Eyes	3
Eyelids	6
Eyebrows	8
Lids	4
Jaw	1
Lungs	1
<b>Total</b>	<b>47</b>





# SANT'ANNA WASEDA PARTNERSHIP



**ROBOCASA**  
HUMANOID & PERSONAL ROBOTICS  
ロボ・カーサ  
ヒューマノイド&パーソナル ロボティクス

Con il contributo del Ministero degli Affari Esteri, Direzione Generale per la Promozione e la Cooperazione Culturale  
With the support of the Italian Ministry of Foreign Affairs, General Directorate for Cultural Promotion and Cooperation

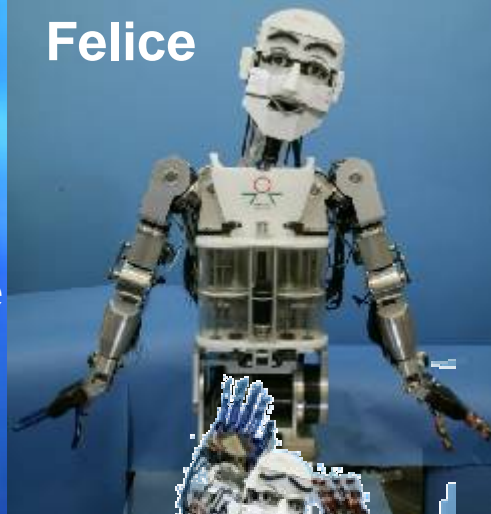
本連携は、イタリア外務省文化交流振興局の支援による研究、発表、産業応用事業です

Un laboratorio congiunto per la ricerca in Robotica Umanoide & Personale  
A joint laboratory for research on Humanoid & Personal Robotics  
ヒューマノイド国際共同研究室



Robot come strumenti per studiare l'interazione uomo-robot

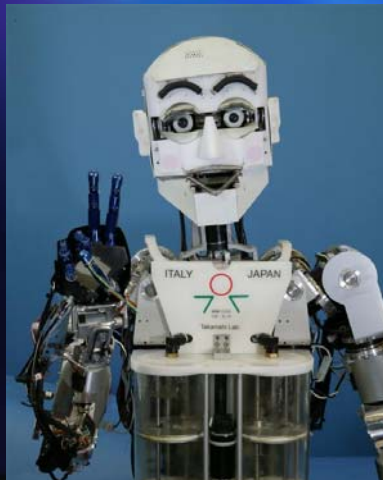
Felice



Sorpreso



Robot come strumenti per le neuroscienze



Disgustato

*RoboCasa Tokyo*



# Robot-An, Laboratorio congiunto italo-giapponese



Inaugurazione ufficiale di RoboHan,  
Laboratorio congiunto italo-  
giapponese, Pisa, Febbraio 2006



Un robot gemello del **Wabian2**  
viene sviluppato a Robot-An

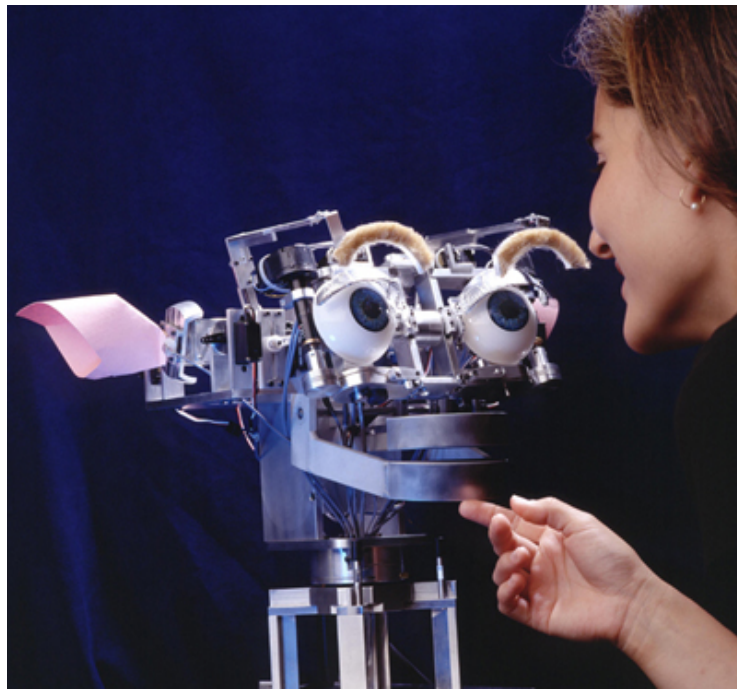




# COG and Kismet, MIT

- *Human-like intelligence cannot be developed without a human-like body*

*Prof. Rodney Brooks, MIT*



Kismet: a sociable humanoid



COG (Cognitive Robot)

# Neuro-Robotic research at the Human Information Science Lab, ATR, Japan



## Computational Neuroscience Project Prof. Mitsuo Kawato

to understand brain mechanisms,  
including vision and motor systems,  
which support the adaptive  
behaviour of humans by adopting a  
“Computational approach”, i.e.  
developing an artificial brain in order  
to understand the brain

Neuro-Robotic research at the AI Lab, Department of  
Information Technology,  
University of Zürich, Switzerland

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to understand natural forms of intelligence (humans, animals) by designing and build intelligent systems (computer programs, robots, other artefacts)

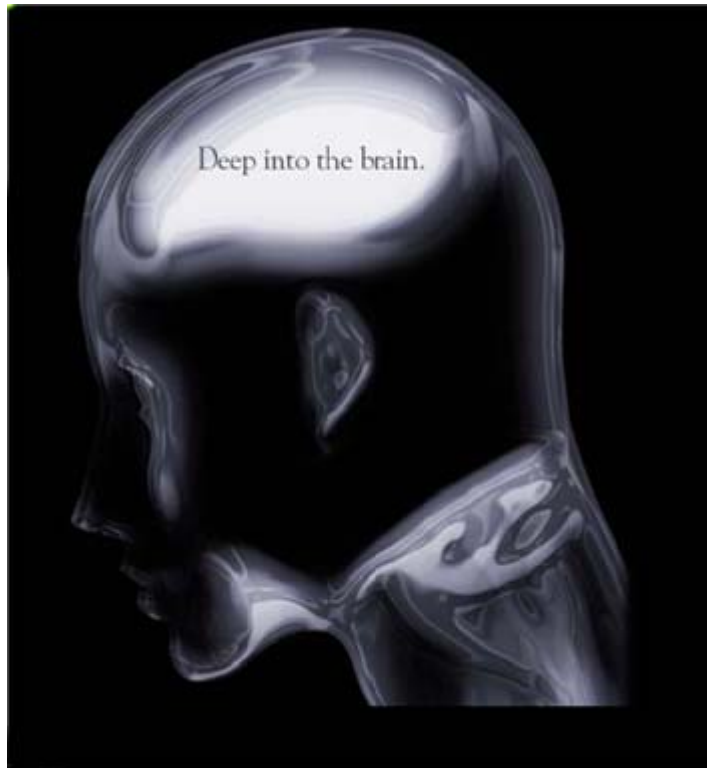
“Understanding by building” approach

- modelling aspects of a biological system,
- abstracting and exploring general principles of intelligence,
- using these principles in the design of artefacts.



# Neuro-Robotic research at the RIKEN Brain Science Institute, Japan

## Research Groups and Laboratories



### Understanding the Brain

- [Neuronal Function Research Group](#)
- [Neuronal Circuit Mechanisms Research Group](#)
- [Cognitive Brain Science Group](#)
- [RIKEN-MIT Neuroscience Research Center](#)

### Protecting the Brain

- [Developmental Brain Science Group](#)
- [Molecular Neuropathology Group](#)
- [Aging and Psychiatric Research Group](#)
- [Recovery Mechanisms Research Group](#)

### Creating the Brain

- [Brainway Group](#)
- [Brain-Style Intelligence Research Group](#)
- [Brain-Style Information Systems Research Group](#)

# 前進

## Striding Forward

### A Strategic Target Timetable developed for the areas of "Understanding the Brain," "Protecting the Brain" and "Creating the Brain."

Research programs aimed at achieving specific goals, together with the scientific knowledge accumulated to date allow us to forecast the next 20 years of scientific research. During this period, science will present many research findings that can be formulated into strategic objectives in the three main branches of "Understanding the Brain," "Protecting the Brain" and "Creating the Brain."

Strategic Target Timetable of Brain Science

## Understanding the Brain

Elucidation of brain functions

	5 years from now	10 years from now	15 years from now	20 years from now
<b>To elucidate the structure and function of brain regions responsible for "perception," "emotion" and "consciousness"</b>	<ul style="list-style-type: none"> <li>Elucidation of neural circuits of perception</li> <li>Identification of brain regions responsible for perception, emotion and consciousness</li> <li>Understanding of the basic mechanisms of memory and learning</li> </ul>	<ul style="list-style-type: none"> <li>Elucidation of the organizational processes of the brain</li> <li>Understanding of the basic mechanisms of perception and motor function</li> <li>Elucidation of emotion, and decision-making</li> </ul>	<ul style="list-style-type: none"> <li>Elucidation of systemic integration and motor control in the entire brain system</li> <li>Elucidation of memory, thought processes, being, feeling and creative process</li> </ul>	<ul style="list-style-type: none"> <li>Elucidation of the neural basis of the mind</li> <li>Elucidation of states of consciousness and unconsciousness</li> <li>Understanding of the relationship between mind, brain and society</li> </ul>
<b>To elucidate brain functions involved in communication</b>	<ul style="list-style-type: none"> <li>Elucidation of language representation in the brain</li> <li>Understanding of the differences in</li> </ul>	<ul style="list-style-type: none"> <li>Elucidation of word translation representation in the brain</li> <li>Understanding of emotional communication (eg. body posture, feelings, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>Elucidation of group and social behavior</li> </ul>	
<b>Examples of advantages of understanding the brain</b>	Understanding basic mechanisms of the brain	Understanding the brain system	Useful information on child rearing and education	Understanding human beings and the development of society

## Protecting the Brain

Elimination of brain disorders

<b>To control the developmental and aging processes of the brain</b>	<ul style="list-style-type: none"> <li>Identification of genes associated with the development and differentiation of the brain</li> <li>Identification of factors associated with the aging process of the brain</li> </ul>	<ul style="list-style-type: none"> <li>Development of methods for the regulation of normal brain development in neonatal animals</li> <li>Control of the aging process using natural means</li> <li>Development of a drug delivery system for the brain</li> </ul>	<ul style="list-style-type: none"> <li>Development of methods for the regulation of normal brain development in human</li> <li>Control of the aging process of the brain in animals</li> </ul>	<ul style="list-style-type: none"> <li>Prevention of the development of brain diseases</li> <li>Control of the aging process of the brain in humans</li> </ul>
<b>To prevent neurological and psychiatric diseases and restore damaged brain tissue</b>	<ul style="list-style-type: none"> <li>Elucidation of the mechanisms of neurodegeneration (Alzheimer's disease)</li> <li>Elucidation of the mechanisms of stroke recovery (the cycling of reactive oxygen to ROS, etc.)</li> <li>Development of methods for the regeneration and transplantation of neural tissue</li> </ul>	<ul style="list-style-type: none"> <li>Restoration of the recovery of brain diseases caused by stroke</li> <li>Elucidation of the mechanisms of stress disorder caused by stress</li> <li>Elucidation of the mechanisms of biological rhythm disorders</li> <li>Restoration of gene therapy</li> <li>Development of methods for transplantation of neural tissue</li> </ul>	<ul style="list-style-type: none"> <li>Development of therapeutic methods for neurodegenerative brain diseases</li> <li>Elucidation of the mechanisms of neurologic and psychiatric disorders</li> <li>Development of methods of gene therapy</li> <li>Prevention of neurologic disorders</li> <li>Elucidation of brain diseases caused by stroke</li> </ul>	<ul style="list-style-type: none"> <li>Development of artificial nerves, muscles and sensory organs</li> <li>Prevention of psychiatric diseases</li> </ul>
<b>Examples of brain disorders to be overcome</b>	Cerebral palsy, drug dependence	Huntington's disease, psychosomatic diseases, multiple sclerosis (MS)	Prevention of Alzheimer's disease, Parkinson's disease, cerebrovascular diseases	Control of the brain's aging process, schizophrenia, bipolar disorder and other psychiatric disorders

## Creating the Brain

Development of brain-style computers

<b>To establish and elucidate the principles involved in information processing in the brain</b>	<ul style="list-style-type: none"> <li>Determination of the calculation principle for cognition in the mammal cortex</li> <li>Establishment of brain measurement technology and a set data analysis method</li> </ul>	<ul style="list-style-type: none"> <li>Determination of the calculation principle for decision-making and attentional integration</li> <li>Establishment of measurement methods</li> </ul>		
<b>To develop brain-style devices and neural architecture</b>	<ul style="list-style-type: none"> <li>Development of memory devices with synaptic modification (one million synaptic units)</li> <li>Development of neural analog computer, recognition chip</li> </ul>	<ul style="list-style-type: none"> <li>Development of a neural architecture for thinking mechanisms (100 million synapses)</li> <li>Development of a memory-based machine with self-learning algorithm</li> </ul>		
<b>To design brain-style systems for information generation and processing</b>	<ul style="list-style-type: none"> <li>Development of a brain-style hybrid memory system</li> <li>Development of systems for planning and supervising robotic control</li> <li>Development of systems for learning and control</li> </ul>	<ul style="list-style-type: none"> <li>Development of a self-organizing memory system with information integration</li> <li>Development of a system for the integration of multiple thinking and neural learning</li> </ul>	<ul style="list-style-type: none"> <li>Development of a neural architecture for thinking mechanisms (100 million synapses)</li> <li>Development of a memory-based machine with self-learning algorithm</li> </ul>	<ul style="list-style-type: none"> <li>Development of human-machine network-controlled neurocomputers that are synthetic and human beings</li> <li>Development of robot systems that support human activities</li> </ul>
<b>Examples of brain-style computers to be developed</b>	Information-processing technologies working in fluctuating, uncertain and noisy environments	Active information-processing technologies based on associative memory and flexible neural network learning	Tools for developing an information-oriented society with intelligence	System which understands and responds to human intentions and emotions

The Long-term Strategy for Research and Development of the Brain (Brain Science Committee, May 1994, revised July 2000)

# Understanding the Brain

Elucidation of brain functions

## 5 years from now

To elucidate the structure and function of brain regions responsible for 'perception,' 'emotion' and 'consciousness'

- Elucidation of neurofunctions of molecules
- Identification of brain regions representing 'perception,' 'emotion', and 'consciousness'
- Understanding of the brain mechanisms of 'memory' and 'learning'

To elucidate brain functions involved in communication

- Elucidation of language representation in the brain
- Understanding of the differences in

Examples of advantages of understanding the brain

Understanding basic mechanisms of the brain

## 10 years from now

- Elucidation of the organizational principles of the brain
- Understanding of the brain mechanisms of 'recognition' and 'motor function'
- Elucidation of emotions, instinctive actions and

- Elucidation of word information representation in the brain
- Understanding of nonverbal communication (e.g. body gestures, feelings, etc.)

Understanding the brain system

## 15 years from now

- Elucidation of function integration and control mechanisms of the central nervous system
- Elucidation of attention, thought processes, feelings, reasoning and creative processes

- Elucidation of group and social behavior

Useful information on child rearing and education

## 20 years from now

- Elucidation of the material basis of the mind
- Elucidation of states of consciousness and unconsciousness
- Understanding of the relationship between an individual and society

Understanding human beings and the development of society



# Protecting the Brain

## Elimination of brain disorders

To control the developmental and aging processes of the brain

5 years from now

- Identification of genes associated with the development and differentiation of the brain
- Identification of factors associated with the aging process of the brain

To prevent neurological and psychiatric diseases and restore damaged brain tissue

- Elucidation of the mechanisms of neurological and psychiatric disorders
- Elucidation of the mechanisms of toxic psychosis [To develop restorative methods for brain damage]
- Development of methods for the regeneration and transplantation of neural tissue

Examples of brain disorders to be overcome

Encephalitis, drug dependence

10 years from now

15 years from now

20 years from now

- Development of methods for the regulation of normal brain development in nonhuman animals
- Control of the aging process using cultured neurons
- Development of a drug delivery system for the

- Development of methods for the regulation of normal brain development in human
- Control of the aging process of the brain in animals

- Prevention of the development of brain disorders
- Control of the aging process of the brain in humans

- Elucidation of the mechanisms of brain disorders caused by a single gene
- Elucidation of the mechanisms of mental disorders caused by stress
- Elucidation of the mechanisms of biological rhythm disorders
- Development of gene therapy
- Implementation of methods for transplantation of neural tissue

- Development of therapeutic methods for endogenous mental disorders
- Elucidation of the mechanisms of neurological and psychiatric disorders
- Implementation of methods of gene therapy
- Prevention of neurological disorders
- Elucidation of brain disorders caused by a single gene

- Development of artificial nerves, muscles and sensory organs
- Prevention of psychiatric diseases

Huntington's disease, psychosomatic diseases, multiple sclerosis (MS)

Prevention of Alzheimer's disease, Parkinson's disease, cerebrovascular diseases

Control of the brain's aging process, schizophrenia, bipolar disorder and other psychiatric disorders

# Creating the Brain

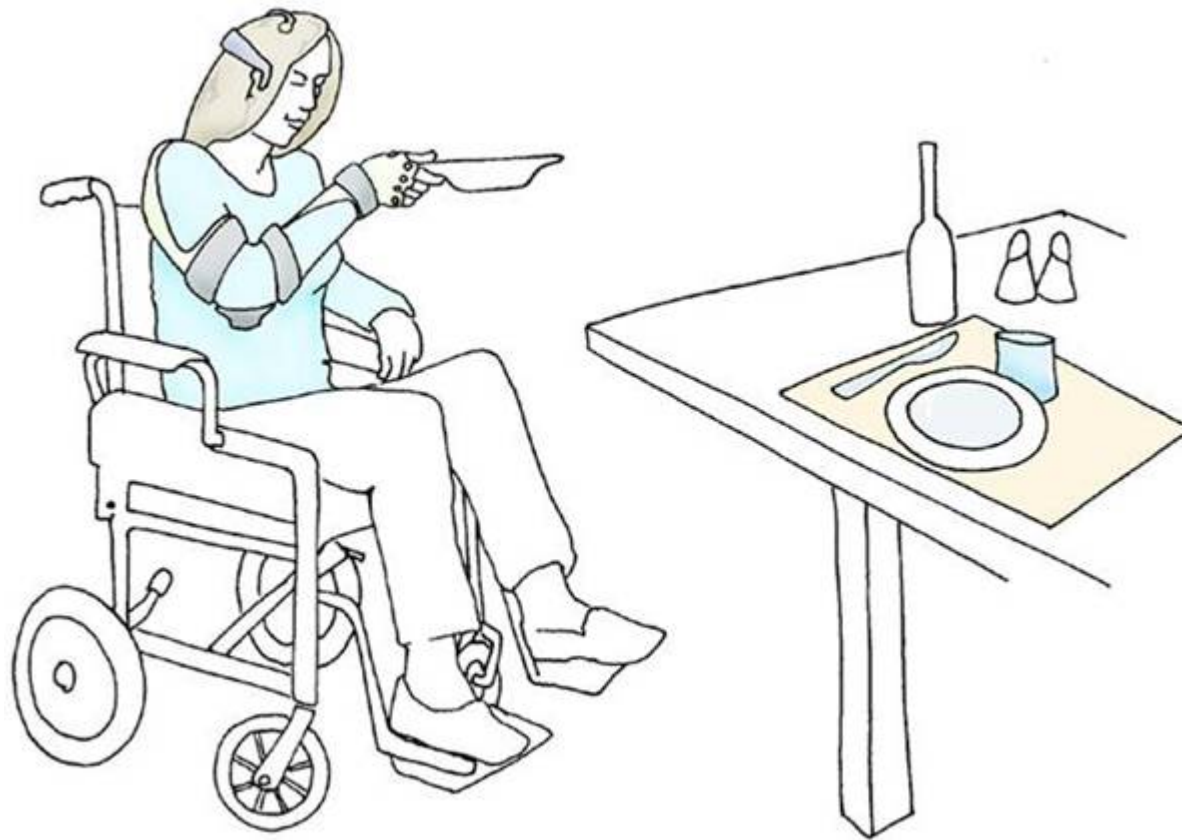
## Development of brain-style computers

5 years from now	
To establish and elucidate the principles involved in information processing in the brain	<ul style="list-style-type: none"> <li>● Determination of the calculation principle for cognitive and motion control</li> <li>● Establishment of brain measurement technology and brain data analytical methods</li> </ul>
To develop brain-style devices and neural architecture	<ul style="list-style-type: none"> <li>■ Development of memory neurochips with synapse modification (one million synapse scale)</li> <li>■ To develop multimodal intelligent recognition chips</li> </ul>
To design brain-style systems for information generation and processing	<ul style="list-style-type: none"> <li>■ Development of brain-style dynamic memory systems</li> <li>■ Development of systems for planning and supervising adaptive control</li> <li>■ Development of systems for thinking and decision</li> </ul>
<b>Examples of brain-style computers to be developed</b>	<b>Information-processing technologies working in fluctuating, uncertain and fuzzy environments</b>

10 years from now	15 years from now	20 years from now
<ul style="list-style-type: none"> <li>● Determination of the calculation principle for decisions, memory and information integration</li> <li>● Establishment of neuroinformatics</li> </ul>	<p>[Integration]</p> <ul style="list-style-type: none"> <li>■ Development of computer systems equipped with intellectual, emotional and willing abilities</li> <li>● Design of novel creative information systems</li> </ul>	<ul style="list-style-type: none"> <li>● Development of human-friendly network-compatible neurocomputers that are symbiotic with human beings</li> <li>● Development of robot systems that support human intellectual life</li> </ul>
<ul style="list-style-type: none"> <li>● Development of a neural architecture for thinking mechanisms (100 million synapsescale)</li> <li>● Development of a memory-based machine with self-acquired algorithms</li> </ul>		
<ul style="list-style-type: none"> <li>● Development of a self-organizing memory system with information integration</li> <li>● Development of a system for the integration of intuitive thinking and logical reasoning</li> </ul>		
<b>Active information-processing technologies based on associative memory and flexible recall intuitive thinking</b>	<b>Basis for developing an information-oriented society with intelligence</b>	<b>System which understands and responds to human intentions and emotions</b>

# Bionica

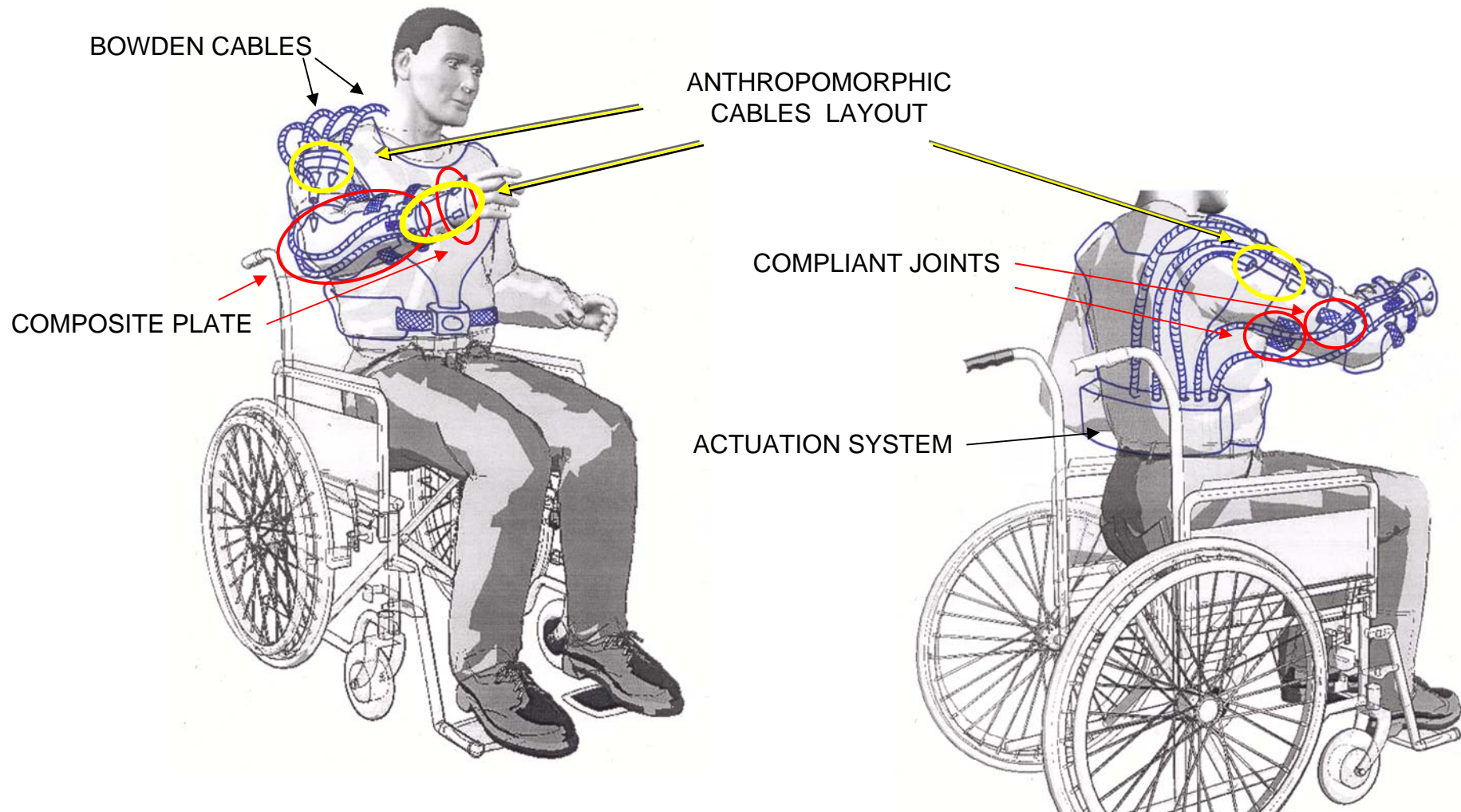
## scenario 'Beyond orthoses'



Recover the sensory-motor manipulation capabilities of a disabled person's arm



# POWERSUITE under development by SSSA in the NEUROBOTICS Project



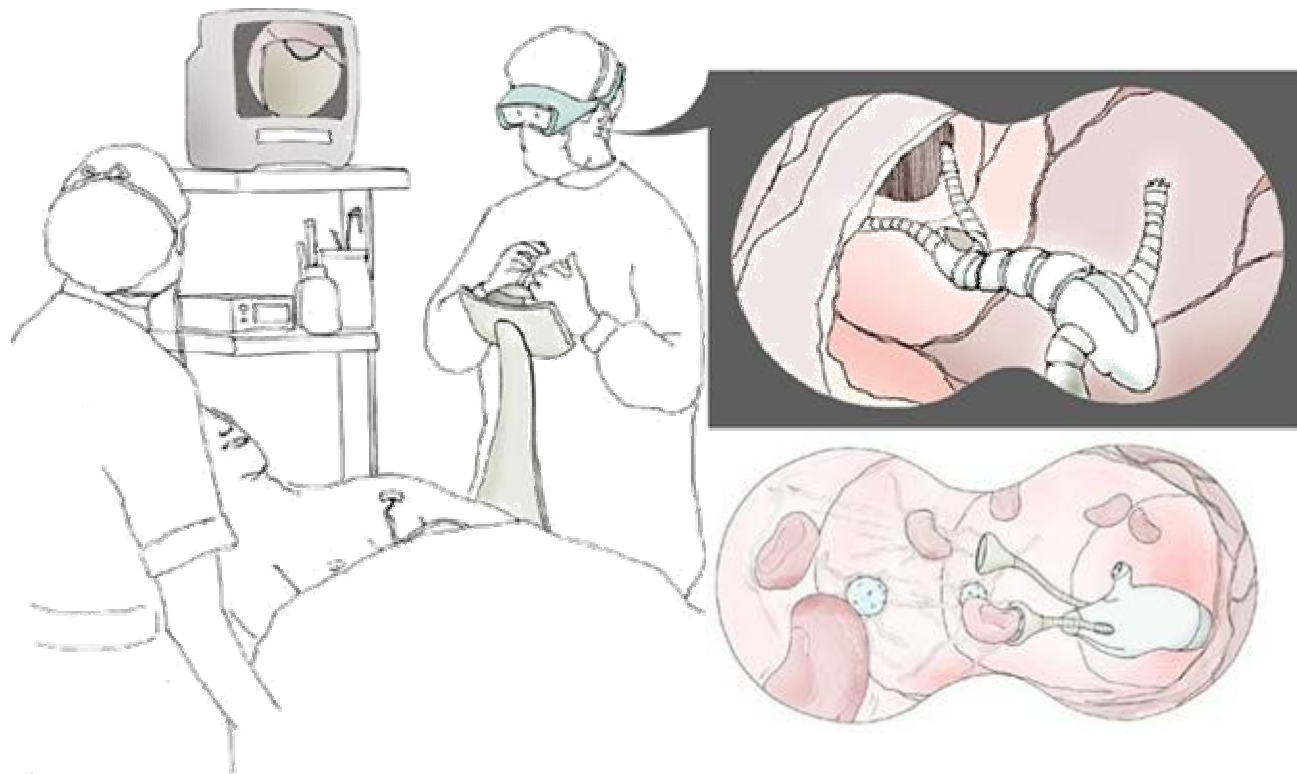
# Bionica

## scenario 'Beyond prostheses'

Additional arm/hand systems



# Bionica scenario 'Beyond teleoperation'



Explorations  
inside the  
human body,  
with full  
sensory  
feed-back





Information Society Technologies



Future and Emerging Technologies

# *The NEUROBOTICS IP Project* (Duration: 5 years)

*The fusion of NEUROscience and RoBOTICS for  
augmenting human capabilities*

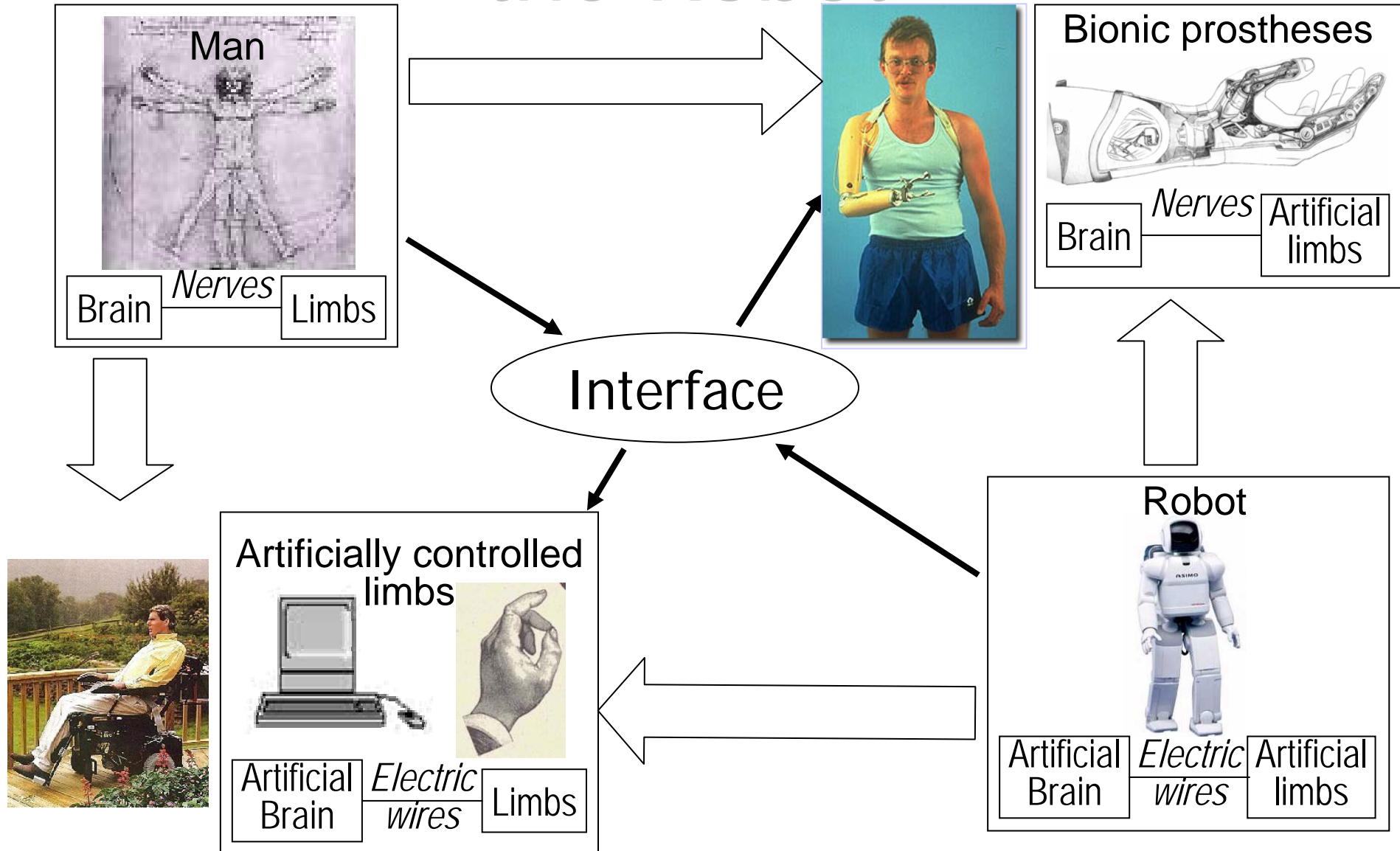
## **Participants**

- 1. SSSA: Scuola Superiore Sant'Anna, Pisa, Italy (prof. Paolo Dario) – Project Coordinator**
2. CDF: Collège de France, CNRS, Paris, France (prof. Alain Berthoz)
3. DLR: Deutsches Zentrum für Luft und Raumfahrt, Oberpfaffenhofen, Germany (prof. Gerd Hirzinger)
4. IBMT: Fraunhofer Institute for Biomedical Engineering, St. Ingbert, Germany (Dr. Thomas Stieglitz)
5. KI: Karolinska Institutet, Stockholm, Sweden (prof. Sten Grillner)
6. KUL: KU Leuven, Belgium (prof. Guy Orban)
7. KTH: Kungl Tekniska Högskolan, Stockholm, Sweden (prof. Henrik Christensen)
8. NTUA: National Technical University of Athens, Greece (prof. Kostas Kyriakopoulos)
9. UMEA: Umeå Universitet, Sweden (prof. Roland Johansson)
10. UAB: Universitat Autònoma de Barcelona, Spain (prof. Xavier Navarro)
11. UGDIST: University of Genova, Italy (prof. Giulio Sandini)
12. UNIPR: University of Parma, Italy (prof. Giacomo Rizzolatti)
13. UPMC: Université P. et M. Curie / INSERM U483, Paris, France (prof. Yves Burnod)

## **International Partners:**

Brown University, Providence, RI, USA (Prof. John Donoghue)  
Waseda University, Tokyo, Japan (Prof. Atsuo Takanishi)

# "Connecting" the Man and the Robot





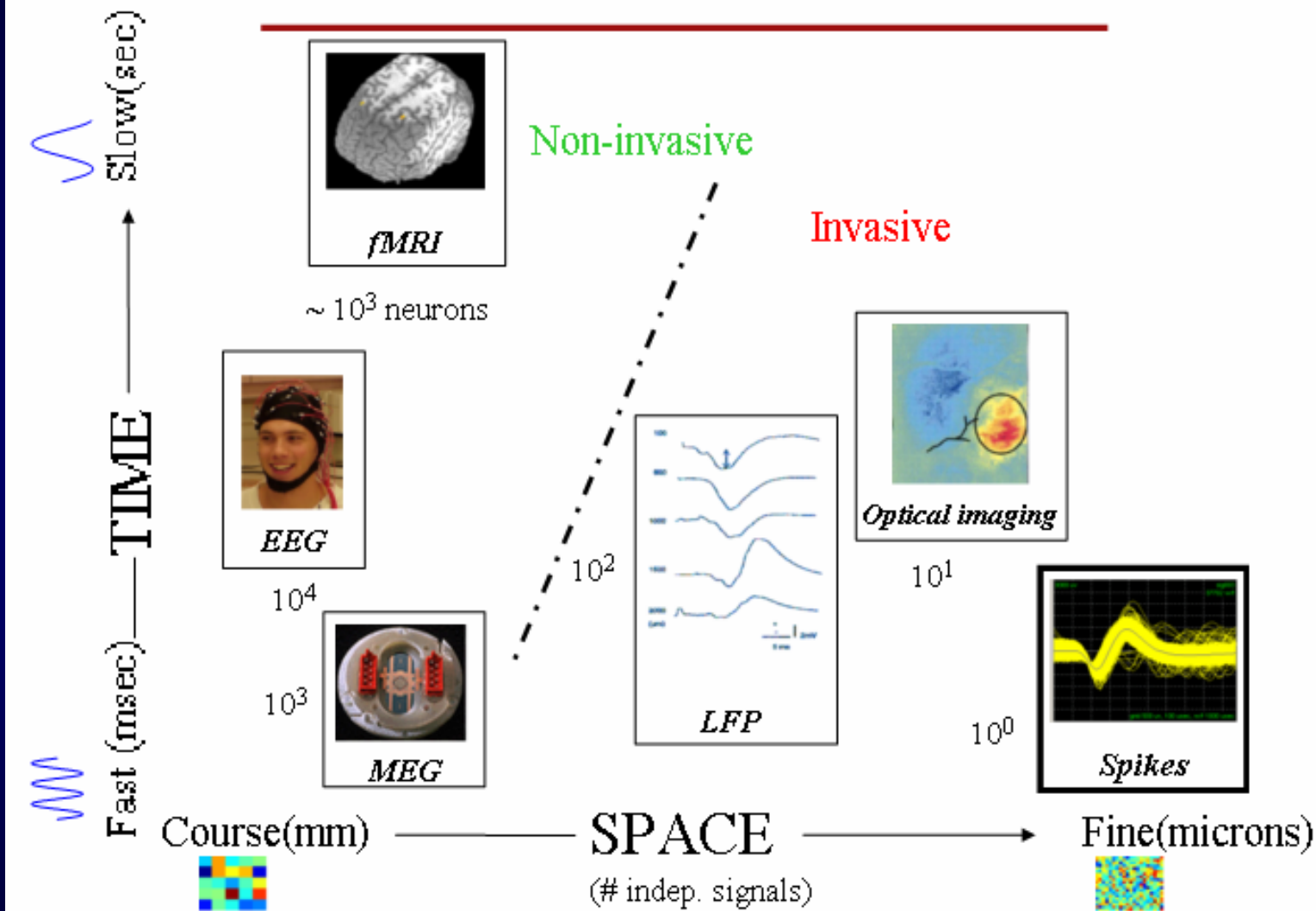
**“Brain to Computer Interface  
is one of the 10 Emerging  
Technologies that will change  
the world”**



***Technology Review, January/February, 2001***



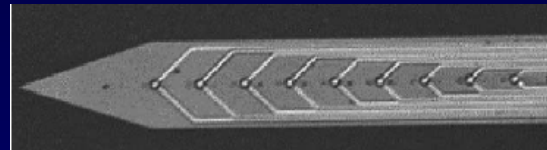
# SENSING THE BRAIN



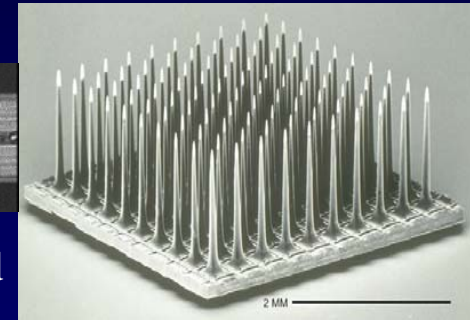
Sensing technologies that can be used to observe neural activity, divided by non-invasive vs. invasive, spatial and temporal resolution.

# Brain Computer Interfaces

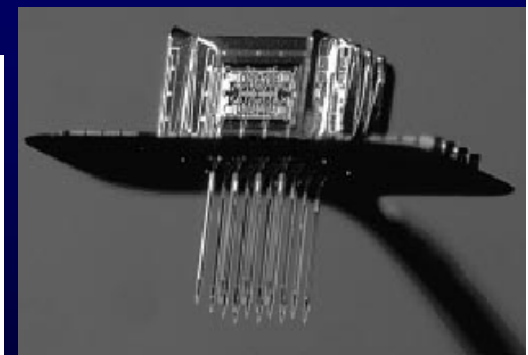
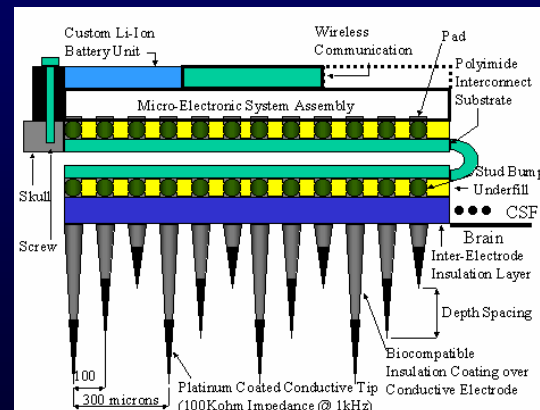
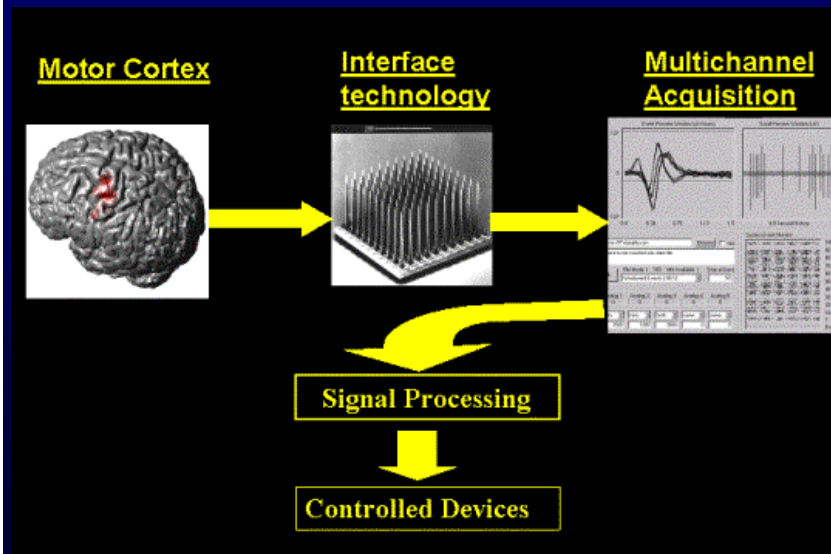
Develop new neural implant technologies to establish *reliable*, *high-capacity*, and *long-term* information channels between the brain and external world.



IBMT, Germany, Sensors and Actuators, 2002

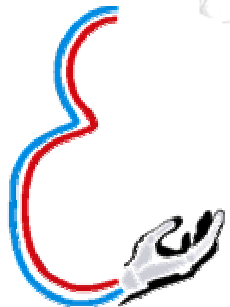
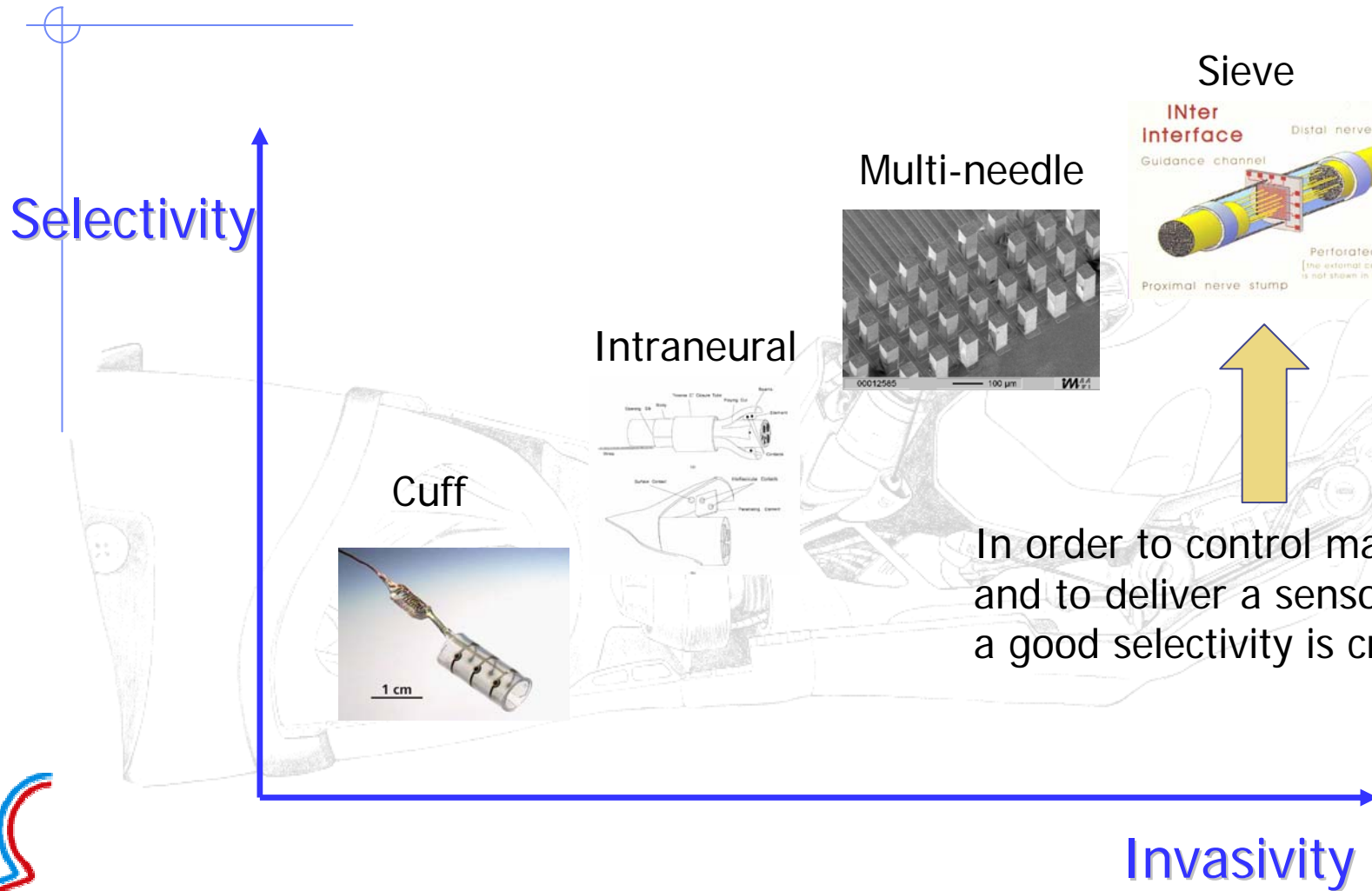


Utah Electrode Array, Bionic Technologies



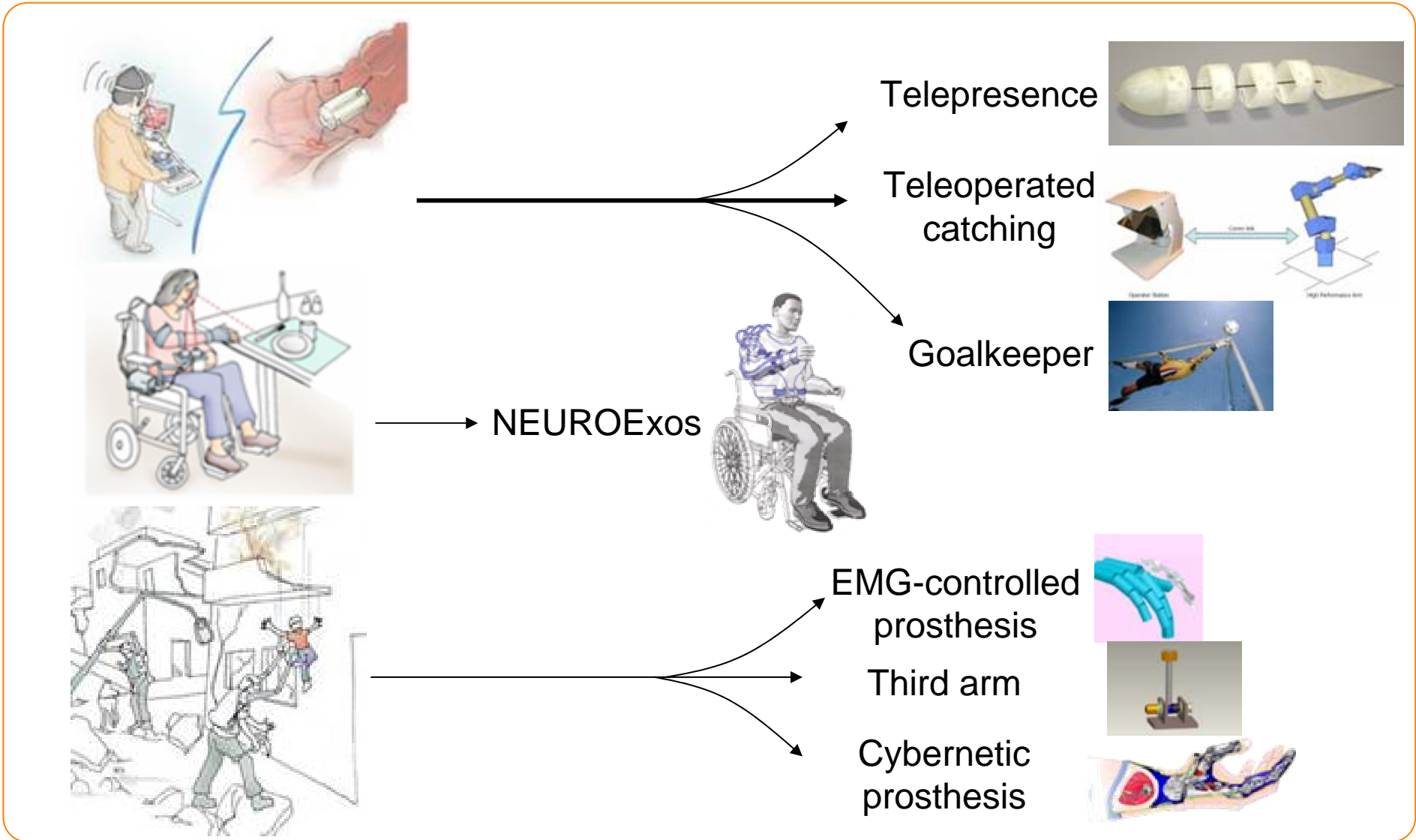
Bai and Wise, IEEE Trans Biomed Eng 2001

# Interfaces with the PNS

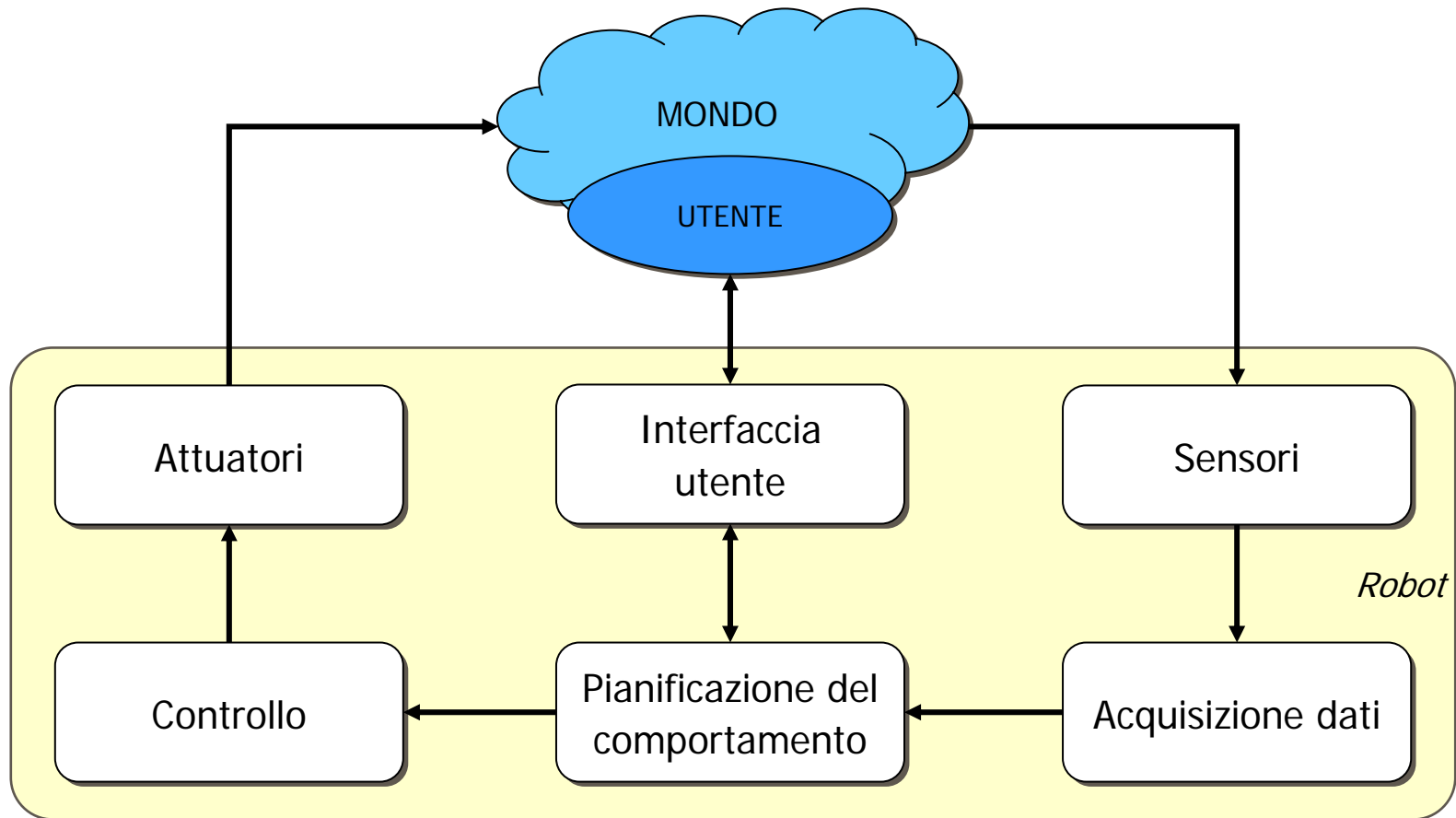




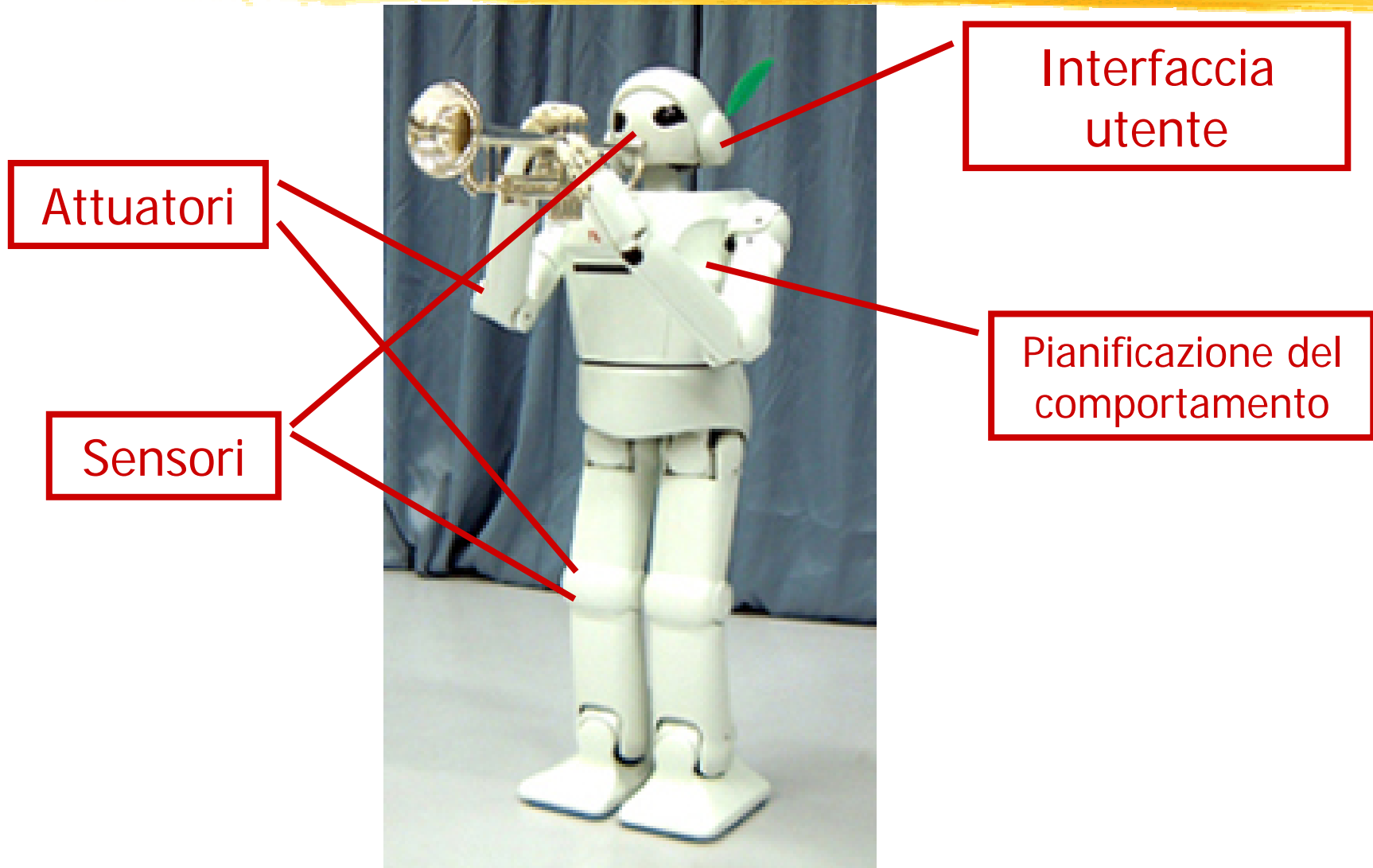
# From concepts to real NEUROBOTICS platforms



# Schema tipico di un sistema robotico



# Componenti fondamentali di un sistema robotico





# Componenti fondamentali di un sistema robotico

