A Network of Excellence at the Interface between Cognitive/Neurosciences and Information Technology

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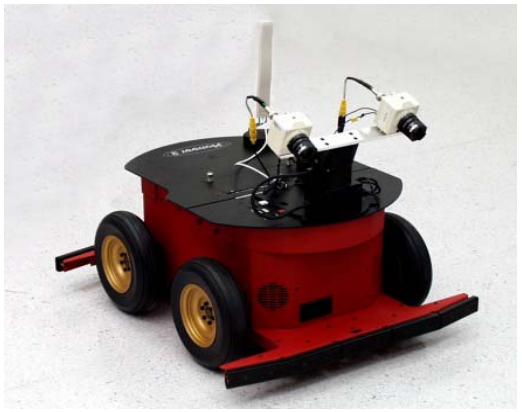
LS Informatik VI – Robotics and Embedded Systems

- Artificial Intelligence, Neuroinformatics and Brain Research are well established as scientific disciplines in their own right
- There has been a fair amount of exchange between researchers of these disciplines:
  - Roboticists try to capitalise on ideas from life sciences
  - Cognitive Scientists use robots for simulating (the evolution of) simple cognitive processes
- However, the interaction often remains at a level of inspiration and replication
- Hence the machines in use today are much less adaptable and intelligent (if at all) than biological systems – mostly because range and type of adaptation are determined as part of the initial design
- And: (not only) for lack of appropriate technology the concept of a *physically embodied* "Artefact that lives and grows" (ALG) has not been evolved into a theory for the design of embodied physical agents

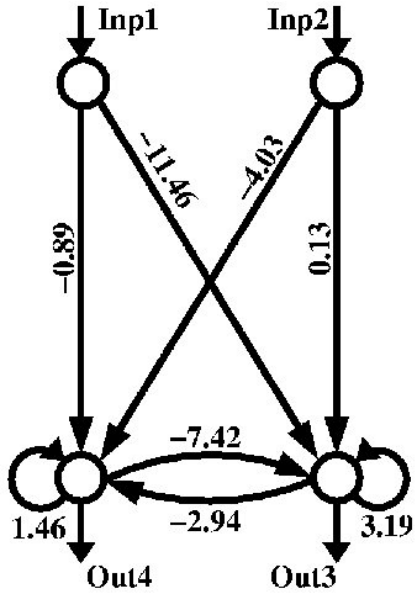


Max Planck Institute for **Psychological** Research

Fixed humanoid robot developed by Sarcos Corp. for use in the **Kawato Dynamic Brain** project

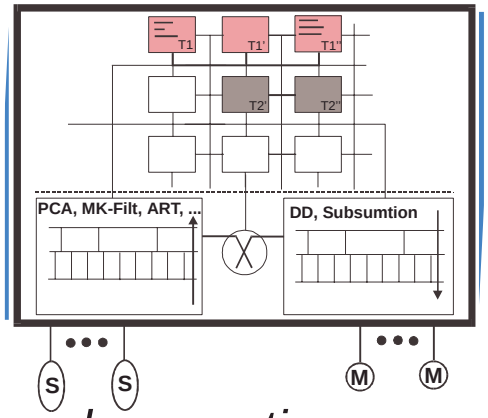
- The term Neuro-IT was coined to express that we aim to create a new scientific working area – different from what is traditionally called Neuro-Informatics (NI) with the following objectives:
  - build a critical mass of new interdisciplinary research excellence at the interface between NS (Neurosciences) and IT (Information Technologies)
  - help solve the fundamental problems linked to the emergence and the modelling of cognitive and awareness processes.
  - making known the potential of the basic research conducted within the EU funded Neuro-IT Initiatives ALG (Artefacts that Live and Grow), LPS (Life-like Perception Systems), and NoS (Neuron on Silicon) to related scientific communities
  - help to discover new unexplored research domains that could lead to breakthrough in Neuro-IT in the long term.

- Fostering development of
  - Innovative methods of automatic adaptation beyond programming and parameter adjustment
  - Innovative methods for building evolvable body structures
  - Innovative approaches aiming at solving the fundamental problems linked to the emergence and the modelling of cognitive and awareness processes
    through a systematic iterative discourse between "wet" and computational neurosciences, cognitive sciences and robotics
  - A systemic view: robots serve as physical simulators for (the development of) these cognition processes



An essential aspect of physically embodied ALGs is a holistic approach to their design, evolution, deployment and use

- **Structure/Organization:** Architectures must be *scalable* to change over time and adapt to growth. Facilities for flexible shifts between distributed and centralised control for different tasks. Transition over time from explicit commanding to "sub-conscious" (reflex-like) execution of well-known responses ("Cortex → Cerebellum").



- **Knowledge Representation and Planning:** *Continuously operating artefacts* will face an immense flow of information: complexity reduction, automatic limitation of the size of internal models, utilise existing knowledge to process, interpret and organise new knowledge. Organization of knowledge must include dimensions like context, temporal evolution, response structures, etc. Redirecting focus of attention mechanisms that limit search and processing, memorising and forgetting strategies.
- **Communication:** Peer-to-peer and to artefact(s) to human(s), situatedness, multimodality, expression of emotions.

- **Drives/Self Motivation:** Instincts (search for food, curiosity, etc.) for acquiring information and interact with the environment. Methods that enable an artefact to remain interesting/interested.
- **Development/Learning Principles:** Encoding of key “machine parameters” for growth. Biology: genotype (compact encoding across generations) and vey slow evolution of this information to provide the basis for transcendence. Faster evolution/growth techniques or circumventing evolution through engineering.
- **Embodiment and structural coupling:** Interaction and sensing is tightly coupled to the shape of individual components and their integration into a system (e.g. stereo vision possible with two eyes that form a baseline).
- **Integration of knowledge, emotions and creativity:** Traditionally, *knowledge* was regarded as significantly distinct from *emotions* and the *creative* aspect of human intelligence. Integration of them will advance the development of ALGs.

- An important goal of the network is the definition of *Grand Challenges* (“man-to-the-moon-projects”) embedded into useful application scenarios of increasing difficulty. Examples are:

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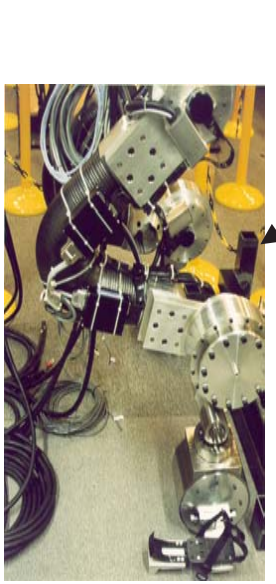
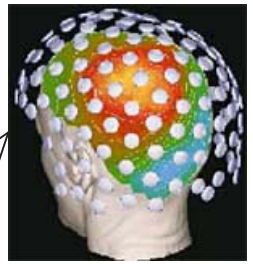
- **Gastrobots:** Build an artefact that implements metabolic structures allowing it to digest plants and other natural food and to survive for an extended period of time.

- **Superhuman/Hybrid Man:** Develop (supportive) prostheses (e.g. for paraplegic persons) that combine super-high-resolution brain imaging with computer/nerve-interfaces and external sensors to achieve highest flexibility and transparent control → total telepresence and teleaction over long distances (mental control of spaceships).



UC Berkeley



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- **Factor 10:** Build an artefact that autonomously (and in a self-stabilising goal-directed way) grows its size, the aptitude of its sensorimotor skills and its general cognitive abilities by a factor of ten within 10 months.

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Anchors of a First Roadmap

nEUro-IT.net

Morphology	Bioanalogue information processing & cognition	Skill Development & Learning Processes	Structural coupling	Habitats
Building blocks for building bodies ▪ *Identification of generalisable elements for larger structures* ▪ *Local intelligence vs. Centralised control* ▪ *Interfacing technology (e.g. neural substrates and silicon-based chips)*	**Hardware considerations ("wires and juice")** ▪ *Design of (pre-) processing modules* ▪ *Generation of functional units* ▪ *Wiring and rewiring of (predefined) brain units*	**Preconditions and control of individual development** ▪ *The role of instincts & emotions* ▪ *Evaluation of short & long-term adaptation successes* ▪ *Stability in huge parameter spaces*	**Adaptation to the environment and to tasks** ▪ *Instinct-based learning* ▪ *Automatic evaluation of action results under a given task specification* ▪ *Life-long learning*	**Scenarios** ▪ *Education and entertainment* ▪ *Service on the shop floor* ▪ *Elderly care* ▪ *Outdoor use* ▪ *Space Missions* ▪ *Rescue*
Basic Physical "Growable" structures and materials ▪ *Growth in two and three dimensions* ▪ *Molecular vs. Macroscopic growth* ▪ *Genetic control of growth* ▪ *Intelligent stimulus control for nerve growth (e.g. after spinal cord lesion)*	**Connectivity, (de-)binding problem and reach** ▪ *Initial and long-term plasticity* ▪ *Evolution of learning rules* ▪ *Grounding, sensing and action* ▪ *Unlearning / Forgetting*	**From brain structure to the formation of mind** ▪ *Minimal structures necessary to start a formation process depending on the environment* ▪ *Evolution of behaviour patterns, categorisation & denominations* ▪ *Generic algorithms for skill learning, formation and for organisation*	**Communicating with peers and humans** ▪ *Development of ontologies and languages* ▪ *Emotion expression and processing* ▪ *Efficient direct coupling with humans*	**Using biomachines for the simulation of** ▪ *Hardware/body evolution* ▪ *Team/social behaviour* ▪ *General cognitive processes at different modelling/granularity levels*
Issues of reproduction and "artificial embryology" ▪ *Initial Identification of reproducible components* ▪ *Issues of the mapping of gene content, morphology and behaviour*	**Processing Architectures** ▪ *Self-organising and recurrent networks* ▪ *Oscillators and motion control* ▪ *High-level symbolic control*	**Interdependence of motor skill and cognitive skill development** ▪ *Evaluation of insights from developmental psychology* ▪ *Attention control* ▪ *Representation and the problem of different body kinematics*	**Learning from "parents" & multimodal imitation** ▪ *Hierarchical and one-shot learning for drastic reduction of convergence times* ▪ *Biological principals in fast learning and representation, e.g. Mirror Neurons*	**Long term autonomy in adverse environments** ▪ *Search for "food"* ▪ *Self-healing* ▪ *Autonomy in perception, cognition, navigation & action* ▪ *Modes and Motivation* ▪ *Social Behavior*
Supplying power to actuators, sensors and processors ▪ *New energy cycles* ▪ *Artificial muscles* ▪ *Sensors and couplers for total telepresence immersion*	**Learning from and interfacing to the brain** ▪ *General evaluation of neuroscience results* ▪ *Role of cross modal interactions* ▪ *Role of representations* ▪ *Temporal organisation*	**Aspects of inheritance** ▪ *Selection of desirable features* ▪ *Non-Darwinian schemes of evolution*		

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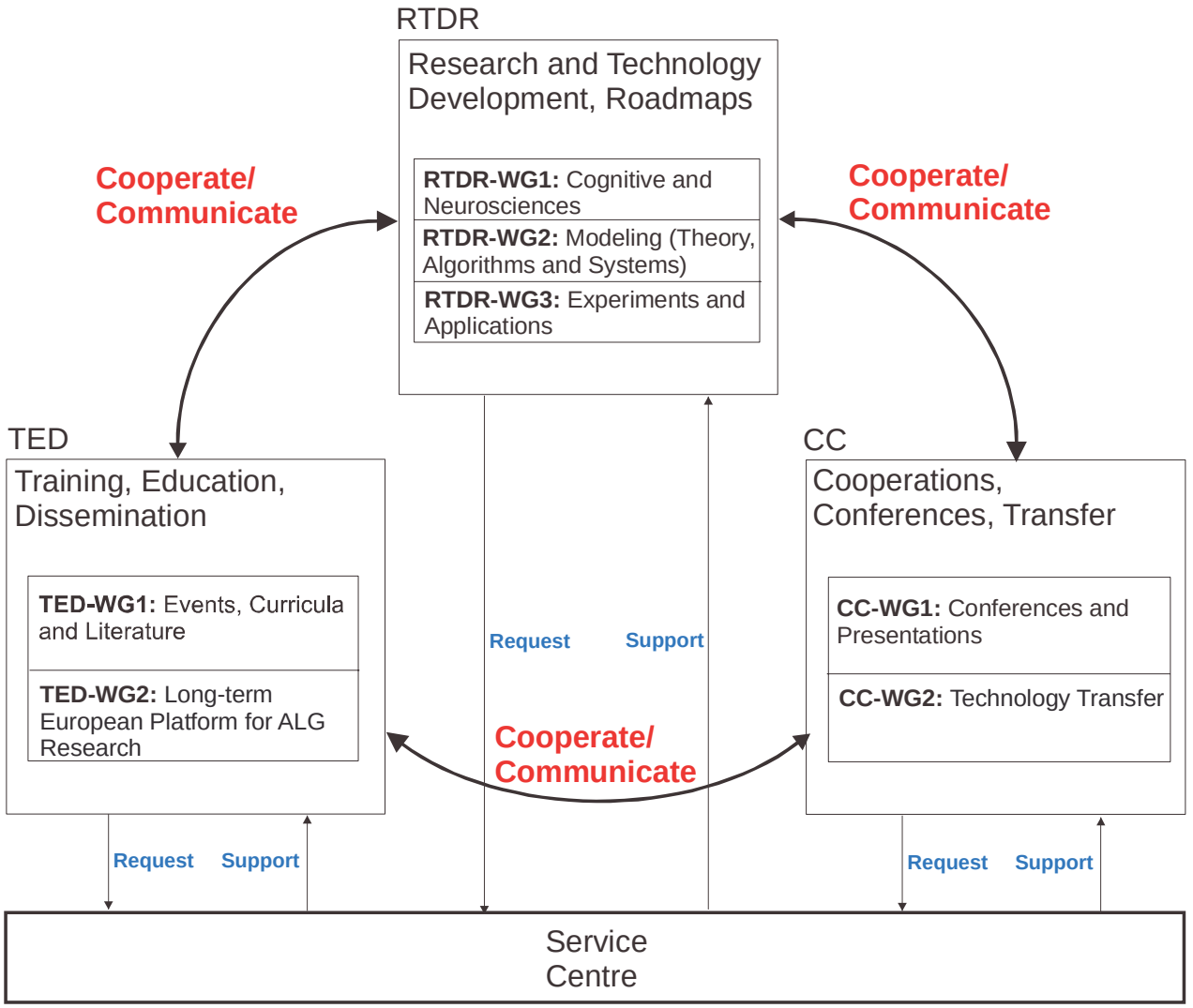
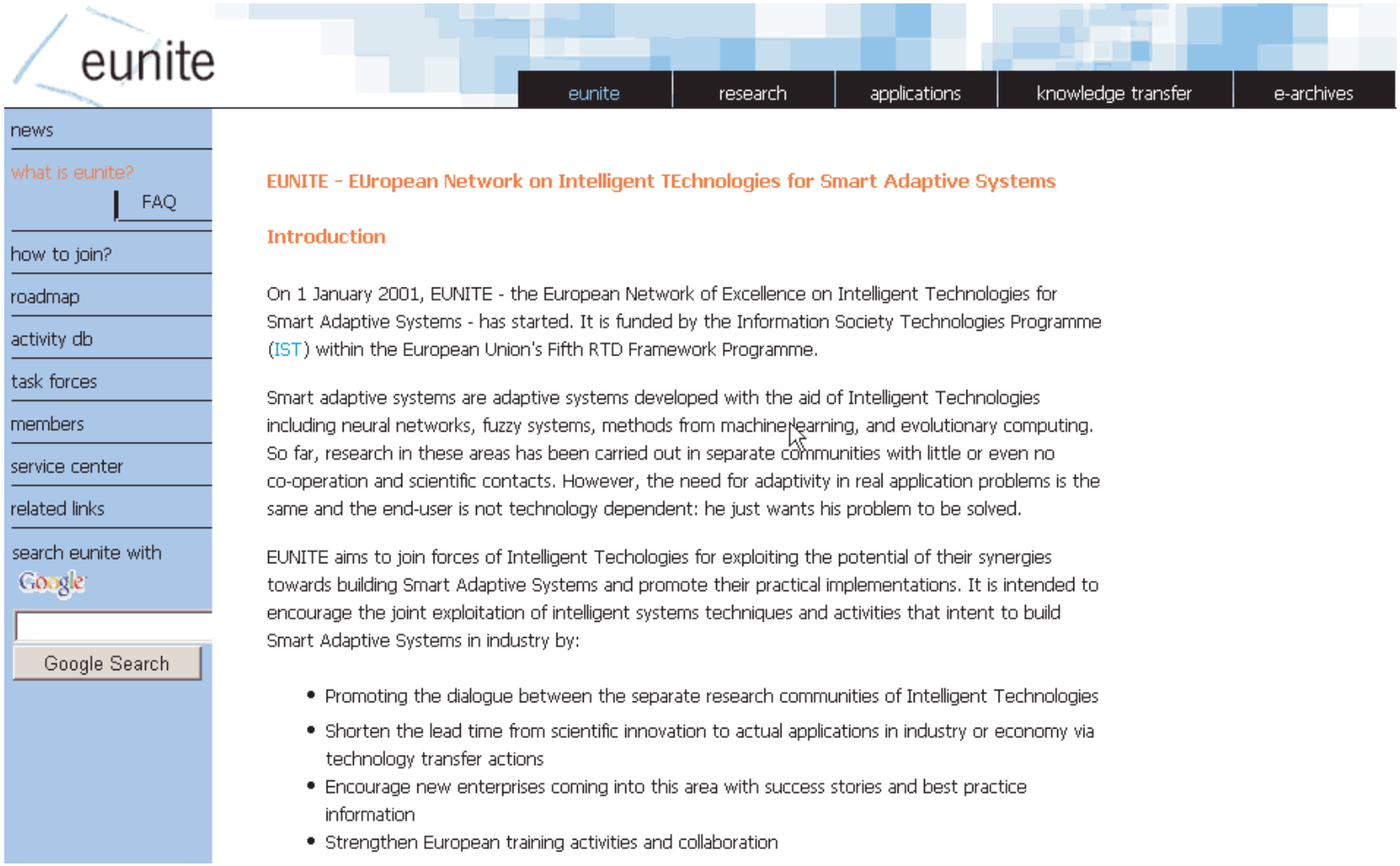
ist information society technologies

- **Core-group:** Consortia from FET-NI & FET-LPS
- **Launch date:** Oct. 1, 2002
- **Steering committee:** 8 members
- **Key nodes:** ~80
- **Funding period:** 4 years



- The *non-standard* activities of **nEUro-IT.net** will include:
  - Symposia on a topic/function across all disciplines, e.g. “from the visual cortex to computer vision systems and back”
  - Fellowships for immersion in biology for engineers and hardware/software design for biologists (up to 12 months to get hands-on experience)
  - Organisation of *ateliers* in which working groups visit each other for a limited period of time to actually work together on a specific question to profit from each other’s equipment (e.g. fMRI systems).
  - Organisation of two international conferences on neuroinformatics
  - Organisation of a *public* high-level scientific *tournament* with live demonstrations
  - Evaluation and funding of proposals for small start-up measures in the different areas, with special emphasis on their cross-disciplinary benefit and potential for later research proposals emerging from them
  - Regular brainstorming sessions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EUNITE – EUropean Network on Intelligent TEchnologies for Smart Adaptive Systems
Introduction
On 1 January 2001, EUNITE - the European Network of Excellence on Intelligent Technologies for Smart Adaptive Systems - has started. It is funded by the Information Society Technologies Programme (IST) within the European Union's Fifth RTD Framework Programme.
Smart adaptive systems are adaptive systems developed with the aid of Intelligent Technologies including neural networks, fuzzy systems, methods from machine learning, and evolutionary computing. So far, research in these areas has been carried out in separate communities with little or even no co-operation and scientific contacts. However, the need for adaptivity in real application problems is the same and the end-user is not technology dependent: he just wants his problem to be solved.
EUNITE aims to join forces of Intelligent Techologies for exploiting the potential of their synergies towards building Smart Adaptive Systems and promote their practical implementations. It is intended to encourage the joint exploitation of intelligent systems techniques and activities that intent to build Smart Adaptive Systems in industry by:
Promoting the dialogue between the separate research communities of Intelligent Technologies
Shorten the lead time from scientific innovation to actual applications in industry or economy via technology transfer actions
Encourage new enterprises coming into this area with success stories and best practice information
Strengthen European training activities and collaboration

EURON – European Robotics Research Network

EURON-I

- Network of excellent on robotics
  - Research planning, Education, Industrial links, Dissemination
  - 125 institutions
  - Activities
    - RoadMap for robotics, white papers on robotics, summerschools, book series (Springer), web site (www.euron.org), …
  - Heavily involved in "Beyond Robotics" definition

1-Dec-02

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EURON – European Robotics Research Network

EURON-II

- Involvement of neuroscience researchers with tight coupling to robotics
- In particular of interest in relation to
  - Human-Augmentation
  - Cognitive Robotics
- Please send interest indications to hic@nada.kth.se

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- nEUro-IT.net will be the **communication infrastructure** for all FET-NI & LPS (+ future proactive initiative) projects
- nEUro-IT.net will organise **all future bi-annual review meetings** (in conjunction with a major event in the scientific fields in Europe)
- nEUro-IT.net will put emphasis on cross-disciplinary **roadmap development**
- nEUro-IT.net will be **open** to scientists and corporations that are willing to actively contribute to the advancement of the field

- Visit the website at

http://www.nEUro-IT.net

- ... which will be *fully* operational at the end of December ...
- and take **active part in the network**!!