Second International ICSC Symposium on

Brain Inspired Cognitive systems

BICS 06

Hotel Delfinia, Molyvos (Mithymna)
Island of Lesvos
Greece

October 10 - 12, 2006

ICSC Interdisciplinary Research
Canada
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Preface

Welcome by the BICS 06 General Chair

I am pleased to welcome the international scientific community to the Island of Lesvos, Greece.

Why this conference? Brain Inspired Cognitive Systems 2006 (BICS 06) aims to bring together leading scientists and engineers who use analytic, syntactic and computational methods both to understand the prodigious processing properties of biological systems and, specifically, of the brain, and to exploit such knowledge to advance computational methods towards ever higher levels of cognitive competence.

Conference Scopes / themes

- Models of Consciousness (MoC)
- Cognitive Neuroscience (CNS)
- Biologically - inspired systems (BIS)
- Neural Computation (NC)

The brain is the most competent information processing system on earth. Therefore Brain Inspired Cognitive Systems (BICS) brings together those who work on trying to understand how the brain achieves its competence and apply this knowledge to the design of ever more intelligent computers. Neurologists, Psychologists and Computer Scientists are coming to the meeting which will specialise on models of consciousness, computational studies of the brain, the design of brain-like machines and the using of what we know about the brain to write better programs. People who design robots will also be there. BICS 06 is the second conference in the series.

BICS 06 is keeping up the ICSC tradition offering guest talks enabling all participants to join these presentations for different reasons (importance, overview of the topic, experiences, theoretical background, mile stones).

For BICS 2006 approximately 50 papers were submitted, 30 papers were accepted as regular papers and 3 as poster papers. As you will notice in the program, unfortunately some authors are unable to join us for the conference and present their papers, due to funding issues or visa problems.

Nine sessions are organized in patterns that encourage cross-fertilization across the symposia topics. This emphasizes that BICS 2006 will be a major point of contact for researchers and practitioners who can benefit from not only the major advances in their specialist fields but also from the diversity of each other's views.

I express our sincerest gratitude to

- the International Program Committee members for the responsible and hard work done by reviewing the draft papers very conscientiously and promptly.
- the authors of the papers for contributing their ideas and research results and for the effort in producing the final versions.
- the Local Organizing Committee, who worked tirelessly to make this conference a success
-

We wish you a pleasant stay and successful scientific work.

Professor Igor Aleksander
General Chair BICS 06, Molyvos in Lesvos, Greece

CONFERENCE VENUE

Address of the Conference Site

Hotel Delphinia
Molyvos (Methumna), GR 81108, Lesvos, Greece.
Tel: + 30 2 2530 71315, 71502-3,
Fax: + 30 2 2530 71524
email: info@hoteldelfinia.com

HOTEL DELPHINIA is located approximately 1 kilometre from Molyvos (Methymna), at the north-western end of the island of Lesvos. The complex offers accommodation for up to 250 guests in hotel apartments and bungalows. This premier hotel complex is set in 355,000 square metres (87 acres) of a beautifully landscaped paradise sloping down to the sea, including a natural park with trees and thousands of plants.

The historical village of Molyvos is located on the magical island of Lesvos, a site which inspired philosophers and poets since 600 BC. It is an ideal place for discussion and enjoyment of hospitality, Greek style. The weather is always pleasant for those who wish to extend their stay.

Registration Desk/Hospitality Desk

The registration desk will be located at The Hotel Delphinia, please follow the signs.

Refreshments during the breaks and the poster sessions are held in the same area.

Opening times of Registration Desk:

Monday, 9th October., 2006	18.00 h – 20.00 h
Tuesday, 10th October 2006	08.00 h - 09.00 h
Wednesday, 11th October 2006	08.00 h – 09.00 h
Thursday, 12th October 2006	08.00 h - 09.00 h

Paper Presentations

Please note that the scheduling of the presentations is final and changes cannot be made without affecting many other speakers and listeners. Thank you for your cooperation.

Each paper will be presented by one of the authors. The speakers are requested to report to the session chairman in the assigned conference room not later than 10 minutes before the session starts.

The time assigned for each paper is 20 minutes (including 5 minutes for discussion). We encourage speakers to give a two minute introduction of their professional background. The bios provided to the organizers by the authors are available on the CD ROM proceedings. All speakers and session chairs must strictly adhere to the time schedule. Each conference room is provided with a data projector only.

Congress Proceedings Publications

The congress proceedings will be available at the conference on CD-ROM. All papers presented at the BICS 06 conference are refereed by the International Program Committee members, accepted and are published in these proceedings. Additional copies of the proceedings are available from ICSC Academic Press, Canada (US$60.00 – each copy plus handling and postage $20.00). Selected papers will be considered for publication in the leading international journal "Neurocomputing" and the electronic **International Journal of Artificial and Natural Computational Intelligence (IJANCI)**

http://www.icsc-naiso.org/conferences/E-Journal/e_journal.html

International Program Committee BICS 06

- S. S. Raza Abidi, Dalhousie University, Canada
- S. Amari, RIKEN Brain Science Institute, Japan
- P. Anderson, RIT, USA
- W. Armstrong, Dendronic Decisions Ltd, Canada
- M. Bishop, Goldsmiths College London, U.K.
- H. H. Bothe, Technical University of Denmark Lyngby, Denmark
- R. Brause, University of Frankfurt, Germany
- R. Chrisley, University of Sussex, U.K.
- H. Cruse, University of Bielefeld, Germany
- V. Di Gesu', University of Palermo, Italy
- G. Dorffner, Austrian Research Institute for AI, Vienna, Austria
- M. Dorigo, Universite' Libre de Bruxelles, Belgium
- R. Douglas, ETH Zurich, Switzerland
- W. Duch, Nanyang Technological University, Singapore
- S. Franklin, Memphis University, USA
- C. Fyfe, University of Paisley Scotland, U.K.
- K. Fukushima, Tokyo University of Technology, Japan
- P. Haikonen, Nokia Research Center, Finland
- A. Hamilton, University of Edinburgh Scotland, U.K.
- D. Heiss, Eudaptics Software.com, Vienna, Austria
- M. Heiss, Siemens AG Austria, Austria
- O. Holland, University of Essex, U.K.
- G. Indiveri, ETH Zurich, Switzerland
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- G.N. Marichal, University of La Laguna Tenerife, Spain
- H. Marques, University of Santiago, Spain
- A. A. Minai, University of Cincinnati, USA
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- E. Oja, Helsinki University of Technology, Finland
- A. Pavlov, S.I.Vavilov State Optical Institute St Petersburg, Russia
- W. Pedrycz, University of Alberta, Canada
- S. Sabatini, University of Genova, Italy
- E. Sanchez, University of Santiago, Spain
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- P. Szczepaniak, Technical University of Lodz, Poland
- J. Taylor, Kings' College London, U.K.
- Th.Vasilakos, University of Thessaly, Greece
- U. Zimmer, Australian National University Canberra, Australia

SYMPOSIUM ORGANIZERS:

- Igor Aleksander, Imperial College of London, U.K.
  General Chair of BICS 06 and Chair for the Symposium on Cognitive Neuroscience (CNS)

- Amir Hussain, University of Stirling, Scotland, U.K.
  Chair for the Symposium on Neural Computation (NC)

- Leslie Smith, University of Stirling, Scotland, U.K
  Chair for the Symposium on Biological Inspired Systems (BIS)

- Ron Chrisley, University of Sussex, U.K.
  Chair for the Symposium on Models of Consciousness(MoC)

Administration:
ICSC Interdisciplinary Research, Canada
Email: planning@icsc.ab.ca
Website: www.icsc-naiso.org

Who is ICSC Interdisciplinary Research?

Mission Statement: To serve the scientific community.

Our long term overall objectives of our group is the encouragement of efficient communication infrastructure between scientists, researchers, engineers and practitioners in all sciences. Sharing the work with people in other, perhaps unrelated, fields, new thinking about their own work is generated. Fresh, lateral thinking is our aim.

We will meet these objectives by the arrangements of international conventions, conferences, mini-tracks, seminars and workshops in collaboration with universities and industries, supporting focused technology transfer activities to new potential application areas and strong interaction between research and industry. Participation in its activities is encouraged on a world-wide basis. The group is particularly interested in encouraging publication of high quality papers through the new ICSC electronic journals. More information is available on: http://www.icsc-naiso.org/html/

The ICSC group is represented by its International Academic Advisory Council (IAAC), designed as a source of academic guidance and active support for future projects. The Council is presided by Peter Anderson , RIT New York, USA

BICS 2006 SPONSORS

University of Stirling, Scotland, U.K.

Imperial College of London, U.K.

ICSC Interdisciplinary Research Canada

Neurocomputing

EEE UK-RI Industrial Applications Chapter

Conference Schedule

Overview

Monday 9th October 2006

19.00	21.30	Registration and Welcome Reception (please follow indicating signs)

Tuesday 10th October 2006 *– SESSION 1 BIS* ***(Session Chair: Ch. v. d. Malsburg)***

08.00	09.00	Registration	Presenter	Title
09.00	10.00	Opening and Guest Keynote	L. S. Smith	Neuroinformatics: what can e-Science offer Neuroscience

Start Time	End Time	Event	Presenter	Title
10.00	10.20	Contributed Paper Session BIS, Session 1	Ch. Bartolozzi	Silicon Synaptic Homeostastis
10.20	10.40	Contributed Paper Session BIS, Session 1	E. Vasilaki	Learning and forgetting visuo-motor associations in a multi-layer Neural Network
10.40	11.00	Contributed paper session BIS/CNS	H.H. Bothe	Artificial Spectro-Temporal Receptive Fields Induced by Long Speech Signals
11.00	11.10	Discussion		
11.10	11.30	Coffee Break		

Tuesday 10h October 2006 – *SESSION 2 CNS/BIS* ***(Chairman: L.S. Smith)***

11.30	12.20	Guest Keynote	H.H. Bothe	Neuroprostheses for the Blind
12.20	12.40	Contributed paper session CNS/BIS session 2	R. Wedeman	A Complex Neural Network Model for Neurotic Conscious and Unconscious Mental Processes
12.40	13.10	Contributed paper session CNS/BIS session 2	I. Serrano	CRI, a Computational Model of Cognitive Reading for Document Indexing
13.10	13.30	Contributed paper session CNS/BIS session 2	G. Brewer	A Spiking Neural Edge Detector for a Neural Object Recognition System
13.30	13.40	General Discussion		
13.40	15.00	Lunch	-	-

Tuesday 10th October 2006 - **Session 3 MOC** (Chairman: I. Aleksander)

15.00	15.50	Guest Keynote	R. Chrisley	Synthetic Phenomenology: Exploiting Embodiment to Specify the Non-Conceptual Content of Visual Experience
15.50	16.10	Contributed paper session MOC	R. Manzotti	***An externalist approach to phenomenal experience: a process based MODEL OF consciousness***
16.10	16.30	Contributed paper session MOC	Allan Barros	Computational Consciousness: Building a Self-Preserving Organism
16.30	17.10	General Discussion		
17.10	17.40	Coffee		
17.40	19.40	Evening Brainstorm 1		

Wednesday 11th October, 2006 *– Session 4 NC* ***(Chairman: Dr. A. Hussain)***

Start Time	End Time	Event	Presenter	Title
08.00	09.00	Registration		
09.00	10.00	Guest Keynote	M. M. Polycarpou	Computational Intelligence in Feedback Systems
10.00	10.20	Contributed paper session NC	Il Song Han	Low power VLSI implementation of pulse-based neural networks with CMOS controlled conductance
10.20	10.40	Contributed paper session NC	Dr Garry Hollier for V. Hodge/S. O'Keefe	A Binary Neural Shape Matcher using Johnson Counters and Chain Codes
10.40	11.00	Contributed paper session NC	A. Carnell	An analysis of the use of Hebbian and Anti-Hebbian Spike Time Dependent Plasticity learning functions within the context of recurrent spiking neural networks.
11.00	11.10	Discussion		
11.10	11.30	Coffee Break		-

Wednesday 11th October, 2006 – **Session 5 BIS/CNS** (Chairman: M. Polycarpou)

11.30	12.20	Guest Keynote	S. Amari	Future Perspective of Brain Science ----Towards Mathematical Neuroscience and Engineering Neurocomputing
12.20	12.40	Contributed paper session BIS/CNS	D. O'Carroll	A Neuromorphic Model for a Robust, Adaptive Motion Detector Based on Insect Vision
12.40	13.10	Contributed Paper Session BIS, Session 1	Rod Adams	Learning and forgetting visuo-motor associations in a multi-layer Neural Network
13.10	13.30	Contributed paper session BIS/CNS	C. Gros	Towards a Rudimentary Autonomous Cognitive System: Principles, implementation and simulation results
13.30	13.40	General Discussion		
13.40	15.00	Lunch	-	-

Wednesday 11th October, 2006 – **Session 6 MOC** (Chairman: R. Manzotti)

15.00	15.50	Guest Keynote	P. Haikonen	Towards the Times of Miracles and Wonder; a Model for a Conscious Machine
15.50	16.10	Contributed paper session MOC	A. Coward	***Constructing a Physiologically Realistic Machine Model of Consciousness***
16.10	16.30	Contributed paper session MOC	S. Kasderidis	A MOTIVATIONAL SYSTEM FOR AUTONOMOUS AGENTS
16.30	17.15	Contributed paper session MOC	Ph. Gerrans	A Neurocomputational Model of Delusion
17.15	17.25	General Discussion		
17.25	18.00	Coffee		
18.00	20.00	Evening Brainstorm 2		

Thursday 12th October, 2006 - Session 7 MOC ***(Chairman: H. Cruse)***

Start time	End time	Event	Presenter	Title
08.00	09.00	Registration		
09.00	10.00	Guest Keynote	I. Aleksander	Axiomatic models and puzzles of consciousness: animals, dreams, volition and illusions
10.00	10.20	Contributed paper session MOC	A. Chella	Sensations And Perceptions in "CICEROBOT", a Museum Guide Robot
10.20	10.40	Contributed paper session MOC	H. Marquez	Minimal architectures for embodied imagination
10.40	11.00	Contributed paper session MOC	V. Tereshko	Language Dynamics: Coexistence and Selection Of Grammars
11.00	11.10	Discussion		
11.10	11.30	Coffee Break		-

Thursday 12th October, 2006 - Session 8 MOC/CNS ***(Chairman: O. Holland)***

11.30	12.20	Guest Keynote	Chr. Von der Malsburg	About the Neural Organization of Consciousness
12.20	12.40	Contributed paper session BIS/CNS	A. Seth	Causal networks in neural systems: From water mazes to consciousness
12.40	13.10	Contributed paper session BIS/CNS	M. Bishop	NESTER: a spiking neuron connectionist implementation of stochastic diffusion search
13.10	13.40	General Discussion		
13.40	15.00	Lunch	-	-

Thursday 12th October, 2006 - **Session 9 MOC (**Chairman: Ron Chrisley**)**

15.00	15.50	Guest Keynote	H. Cruse	Body models as basis for perception, cognition and subjective experience
15.50	16.40	Guest Keynote	O. Holland	From an artificial self to an artificial consciousness?
16.40	17.00	General Discussion and Closing	I. Aleksander	

NOTES:

Detailed Conference Schedule with abstracts

Tuesday 10th October 2006, SESSION 1 BIS
Chair: Ch. Von der Malsburg

9:00 – 10:00 h
L. S. Smith, Guest Keynote
Department of Computer Science
University of Stirling, Scotland

Neuroinformatics: what can e-Science offer Neuroscience

Neuroinformatics is Informatics applied to Neuroscience. Yet Neuroscience has been using computers for decades, so what's new? Unlike Physics or Genomics, Neuroscience data has (with some honourable exceptions) rarely been shared. In particular, hard-won data from recording neurons has often been recorded, analysed within a lab (or set of collaborating labs) and then left spinning on a disk, unavailable for further analysis. Computational neuroscientists would like to have access to such datasets in order to develop and validate their models. But this is not straightforward. Technical problems include supplying all the metadata (information about the recording) so that researchers using the data understand its provenance fully. Commercial problems include ensuring that data supplied is secure while it still retains commercial value (for example, for Pharmaceutical companies). Academic problems include ensuring that neuroscientists are given appropriate credit for their work.

Neuroinformatics is, of course, broader than simply sharing recordings of neural activity: it encompasses the use of Informatics in understanding neural systems all the way from ion channels and microanatomy of spines through to analysing recordings from electroencephalograms. International interest in this area is growing: the International Neuroinformatics Coordinating Facility (INCF) has recently been launched (curently made up from nine countries: the Czech Republic, Finland, Germany, Italy, Japan, Norway, Sweden, Switzerland and the United States). In the UK, a new e-Science project entitled CARMEN (Code Analysis, Repository and Modelling for e-Neuroscience) starts in October 2006, and is a large collaboration between 11 UK Universities, with links to other research groups. This talk will discuss what Neuroinformatics can bring to Cognitive and Computational Neuroscience, and what the CARMEN project hopes to achieve.

Tuesday 10th October 2006, SESSION 1 BIS
Chair: Ch. Von der Malsburg

10:00 – 10:20 h
Ch. Bartolozzi
Institute for Neuroinformatics
UNI | ETH Zurich, , Switzerland
(Co-author: Giacomo Indiveri)

Silicon Synaptic Homeostasis

Abstract: Synaptic homeostasis is a mechanism present in biological neural systems used to stabilize the network's activity. It acts by scaling the synaptic weights in order to keep the neurons firing rate within a functional range, in face of chronic changes of their activity level, while preserving the relative differences between individual synapses. In analog VLSI spike based neural networks, homeostasis is an appealing biologically inspired means to solve technological issues such as mismatch, temperature drifts or long lasting dramatic changes in the input activity level. Here we present a new synaptic circuit, the Diff-Pair-Integrator, designed to reproduce the biological temporal evolution of post-synaptic currents, and compatible with implementation of spike-based learning and homeostasis. We describe the silicon synapse and show how it can be used in conjunction with a software control algorithm to model synaptic scaling homeostatic mechanisms.
Keywords:aVLSI; neuromorphic; synapse; homeostasis; spike-based

10:20 – 10:40 h
E. Vasilaki
Institute of Physiology, University of Bern, Switzerland
(Co-authors: S. Fusi, X.-J. Wang, W. Senn)

Learning and forgetting visuo-motor associations in a multi-layer Neural Network

Which mechanisms enable us to associate sensory information to the appropriate action in a rapidly changing environment? Given the complex structure of the brain, how may synaptic plasticity explain learning and forgetting of memories when the behavioral context changes? We address these questions by using a multi-layer network and a novel biologically plausible learning rule to reproduce monkey behavior in a visuo-motor task.

Tuesday 10th October 2006, SESSION 1 BIS
Chair: Ch. Von der Malsburg

10:40 – 11:00 h
H. H. Bothe
Technical University of Denmark
Centre for Advanced Hearing Research, Lyngby
(Co-author: O. Lassak),

Artificial Spectro-Temporal Receptive Fields Induced by Long Speech Signals

The performance of technical speech processing systems relies strongly on the acoustic or auditory features employed. Our paper proposes to study biological examples for auditory signal processing in order to find suitable types of features, since there is a correlation between the signal processing paradigms, the properties of the sensory system, and the statistics of the respective natural stimuli. Neurons in the primary auditory cortex utilize multidimensional multi-scale receptive activation fields, which are associated to specific frequency bands and to specific timing patterns of the input signal. Such an auditory 'spatio-temporal receptive field (STRF)' can be determined with the help of reverse correlation methods if the activation or output signal pattern of the neuron is known. Since this seems impossible for neurons in the human auditory cortex, only simulations can be preformed, which show that the evolution of respective banks of STRF is possible and also useful from the perspective of an 'optimal' information processing.
Our paper describes a method to emulate the evolution of monaurally-based sets of STRF utilizing nine minutes long, normally articulated speech as input and modified forms of independent component analysis (ICA) plus a sparse matrix criterion for the development of optimal banks of STRF. Only few STRF are on at a time, producing an efficient coding procedure and thus, valuable input variables for further sound processing.
The acoustic speech signal is preprocessed in a biologically plausible form and arrives in the auditory cortex in modified spectrogram representation. The bank of STRF acts on that spectrogram, producing temporal courses of 'micro-features' that can be used for further processing as, for example, recognition, identification, object binding, localization, etc., as they are expected in higher cortical areas.

11.00 – 11.10 h **Discussion**

11.10 – 11.30 h **Coffee Break**

Tuesday 10th October 2006, SESSION 2 CNS/BIS
Chair: L. S. Smith

11.30 – 12.20 h
H. H. Bothe, Guest Keynote
Technical University of Denmark
Centre for Advanced Hearing Research, Lyngby

Neuroprostheses for the Blind

The main aim of Artificial Vision is to restore some degree of sight to the profoundly blind Since blindness can result from defects at many different points along the visual pathway, there are accordingly a wide variety of proposed models for an "Artificial Eye".

12.20 – 12.40 h
R. Wedeman
Instituto de Matem´atica e Estat´ıstica, Universidade do Estado do Rio de Janeiro, Brazil
(Co-authors: L. A.Vidal de Carvalho, R. Donangelo)

A Complex Neural Network Model for Neurotic Conscious and Unconscious Mental Processes

In an earlier paper [1], we described the mental pathology known as neurosis, its aetiology, and the development of symptoms in terms of its relation to memory function. We discussed the Freudian discovery of the compulsion to repeat observed in neurotic behavior and the functioning of psychoanalytical working-through. We proposed a neural network mechanism whereby neurotic behavior may be understood as an associative memory process in the brain, and the symbolic associative process involved in psychoanalytic working-through can be mapped onto a corresponding process of reconfiguration of the network. In this paper we review these basic concepts. As a first approximation, memory was modeled by a Boltzmann machine represented by a complete graph. However, it is known that brain neuronal topology is selectively structured. Here, we further develop the memory model, by including known microscopic mechanisms that control synaptic properties, showing that the network self organizes to a hierarchical, clustered structure. We propose a memory organization where two modules corresponding to sensorial and symbolic memory interact, producing sensorial and symbolic activity, representing unconscious and conscious mental processes. We argue that this process is fundamentally different than the drug therapy involved in psychiatric treatment, although these processes can work in a complementary manner, as observed in clinical practice. The model is illustrated through a computer simulation.
Keywords: Neurosis, Associative memory, Boltzmann machine, Hierarchical network, Self-organization, Unconscious, Conscious.

Tuesday 10th October 2006, SESSION 2 CNS/BIS
Chair: L. S. Smith

12.40 – 13.10 h

I. Serrano
Instituto de Automática Industrial, Spanish Council for Scientific Research, Madrid, Spain
(Co-authors: Mª Dolores del Castillo, Á. Iglesias)

CRI, a Computational Model of Cognitive Reading for Document Indexing

Common document indexing techniques have shown to be useful in some natural language processing tasks like information retrieval or text classification. However, when they represent texts they do not take into account some important aspects of language, mainly grammar and semantics. Other approaches, namely semantic hyperspaces do, and are an improvement on traditional methods. Semantic hyperspaces are mathematical and statistical-based techniques and the output representation is still vector like. To date, humans have done language tasks much better than machines, but perhaps not as fast. This paper thus proposes a computational model of text reading, called Cognitive Reading Indexing (CRI), inspired by some aspects of human reading cognition, such as sequential perception, temporality, memory, forgetting and inferences.
The model is used here for indexing or representing documents so that they can be labeled or retrieved afterwards with promising results. However, the power of the output representation, not a vector but a net of activated concepts, could be used for a great variety of applications in the future. Finally, the system was applied to model human subjects as well, and some interesting results were obtained.

13.10 – 13.30 h

G. Brewer
Department of Computer Science
University of York, U.K.
(Co-author: Jim Austin)

A Spiking Neural Edge Detector for a Neural Object Recognition System

A biologically inspired edge detection technique is presented, based on rank order coding and a spike train representation of data. Pixel intensity values, encoded as a succession of pulses, form the input to an array of edge detecting neurons. By comparing the order in which the input spikes are received to a stored edge profile, the firing frequency of the edge detector can be controlled. The edge detection system is shown to perform as designed, with the output activity of each edge detector corresponding closely to the clarity and orientation of the edge segments presented. One particularly interesting feature of the system is its ability to produce a meaningful output based upon very few input spikes and then improve this initial estimate as more information is received.

13.30 – 13.40 h **General Discussion**

13.40 – 15.00 h **Lunch**

NOTES:

Tuesday 10th October 2006, SESSION 3 MoC
Chair: I. Aleksander

11.30 – 12.20 h
R. L. Chrisley, Guest Keynote
Centre for Research in cognitive Science and PAICS Research Group, University of Sussex, U.K.

An important, but relatively neglected, aspect of machine models of consciousness is the requirement for a scientific phenomenology, or systematic means of characterizing the experiential states being modeled. In those few cases where need of such a phenomenology is acknowledged, the default approach is usually to use language-based specifications, such as "the visual experience of a red bicycle leaning against a white wall". Such specifications are problematic for several reasons: 1) they are not fine-grained enough to capture the full detail of the experience being modelled; 2) they are overly conceptual, in that they can specify the experience only of subjects that possess the concepts used in the specification (e.g., bicycle or leaning); 3) they are "cold" in that there is no essential connection between the experience so specified and affect, while many experiences are "hot", having constitutive implications for action; 4) they are disembodied, in that no explicit reference is made in the specification to the kinds of abilities necessary for being in a experiential state with that content. What is needed, then, is an alternative means of specifying the content of experience that overcomes some or all of these limitations. An obvious way to deal with problems 1) and 2) for the case of visual experiences is to use visual images as specifications. However, it would be a mistake to think that even the non-conceptual experience a given robot is modelling is best specified by displaying the raw output of its video camera. For example; the current "output" of a human retina contains gaps or blindspots that are not part of experience. Furthermore, our visual experience, as opposed to our retinal output, at any given time is stable, encompassing more than the current region of foveation, and is coloured to the periphery. I propose a means of specification, a synthetic phenomenology, that does justice to these aspects of visual experience, by exploiting the interdependencies of perception and action of both the robot and the theorist to whom the specification is presented. In this way, some progress is also made toward overcoming problems 3) and 4).

Tuesday 10th October 2006, SESSION 3 MoC
Chair: I. Aleksander

15.50 – 16.10 h
Riccardo Manzotti
Institute of Human and Environmental Sciences IULM University, Milan Italy

An Externalist Approach to Phenomenal Experience:
A Process Based Model of consciousness

In this paper, I argue in favour of a process-based view of the conscious subject. It is an externalist approach that aims at locating the conscious mind in those processes taking place between the agent and its environment. According to this view, phenomenal consciousness is no longer a private and mysterious property of neural processes – consciousness is a way of describing the processual entanglement between the body and brain of the agent and its environment. The mind is no longer internal to the brain or to the body. The mind is partially external to it. This view suggests a foundation for artificial consciousness – phenomenal processes as physical processes spanning in time and space. I claim that a process-based externalist approach, if true, is a viable support for designing and implementing models for consciousness.

16.10 – 16.30 h
Allan Barros
Universidade Federal do Maranhão, Brazil

Computational Consciousness: Building a Self-Preserving Organism

Consciousness has been a subject of crescent interest among the neuroscience community. However, building machine models of it is quite challenging, as it involves many characteristics and properties of the human brain which are poorly defined or are very abstract. Here I propose to use information theory (IT) to give a mathematical framework to understand consciousness. For this reason, I used the term "computational". This work is grounded on some recent results on the use of IT to understand how the cortex codes information, where redundancy reduction plays a fundamental role. Basically, I propose a system, here called "organism", whose strategy is to extract the maximal amount of information from the environment in order to survive. To highlight the proposed framework, I show a simple organism composed of a single neuron which adapts itself to the outside dynamics by taking into account its internal state, whose perception is understood here to be related to "feelings".

Tuesday 10th October 2006, SESSION 3 MoC
Chair: I. Aleksander

16.30 – 17.10 h **General Discussion**

17.10 – 17.40 h **Coffee Break**

17.40 – 19.40 h **Evening Brainstorm 1**

NOTES:

Wednesday 11th October 2006, SESSION 4 NC
Chair: A. Hussain

9:00 – 10:00 h
M.M. Polycarpou, Guest Keynote
Dept. of Electrical and Computer Engineering
University of Cyprus, Nicosia

Computational Intelligence in Feedback Systems

Recent technological advances in computing hardware, communications and real-time software have provided the infrastructure for designing intelligent decision and control systems. Based on current trends, high performance feedback systems of the future will require greater autonomy in a number of frontiers. First, they need to be able to deal with greater levels of, possibly, time-varying uncertainty. Second, they need to be able to handle uncertainties in the environment, which will allow the feedback system to be more flexible in dealing with unanticipated events such as faults, obstacles and disturbances. Finally, key advances in distributed and mobile computing will allow for exciting possibilities in distributed decision making and control by agent-type systems. This will require feedback systems to operate in distributed environments with cooperative capabilities. One of the key tools for realizing such advances in the performance and autonomy of feedback systems is "learning." Feedback systems with learning capabilities can potentially help reduce modeling uncertainty on-line, make feedback systems more "intelligent" in the presence of uncertainty in the environment, and initiate design methods for cooperative feedback systems in distributed environments. During the last decade there has been a variety of learning techniques developed for feedback systems, based on structures such as neural networks, fuzzy systems, wavelets, etc. The goal of this presentation is to provide a unifying framework for designing and analyzing feedback systems with learning capabilities. Various on-line approximation techniques and learning algorithms will be presented and illustrated, and directions for future research will be discussed.

Wednesday 11th October 2006, SESSION 4 NC
Chair: A. Hussain

10:00 – 10:20 h
Il Song Han
Dept. of EE Engineering
University of Sheffield, U.K.

Low power VLSI implementation of pulse-based neural networks with CMOS controlled conductance

This paper describes a new pulse-based neural network VLSI based on the tunable CMOS linear conductance. The controlled conductance produces the synaptic or neuron function, which are inspired by the biological plausibility and low power supply. The synaptic computation speed is up to maximum pulse frequency. The power consumption is reduced, as active synapses only consume the power. The neuron based on the controlled conductance demonstrates the asynchronous pulse generation with a refractory period, and the behaviour of integration-and-firing with Address-Event Representation (AER). The test circuit was fabricated in AMIS 0.7 micron CMOS technology. The experimentation exhibits the behaviour of linear controlled conductance, as observed in SPICE simulation.

10.20 – 10.40 h
Dr Garry Hollier for V. Hodge/S. O'Keefe
Department of Computer Science
University of York, U.K.
(Co-author: Jim Austin)

A Binary Neural Shape Matcher using Johnson Counters and Chain Codes

In this paper, we introduce a neural network-based shape matching algorithm that uses Johnson Counter codes coupled with chain codes. Shape matching is a fundamental requirement in content-based image retrieval systems. Chain codes describe shapes using sequences of numbers. They are simple and flexible. We couple this power with the efficiency and flexibility of a binary associative-memory neural network. We focus on the implementation details of the algorithm when it is constructed using the neural network. We demonstrate how the binary associative-memory neural network can index and match chain codes where the chain code elements are represented by Johnson codes. KEYWORDS Neural, Associative Memory, Shape Matcher, Binary Encoding.

Wednesday 11th October 2006, SESSION 4 NC
Chair: A. Hussain

10.40 – 11.00
A. Carnell
Dept of Computer Science
University of Bath, U.K.

An analysis of the use of Hebbian and Anti-Hebbian Spike Time Dependent Plasticity learning functions within the context of recurrent spiking neural networks.

It is shown that the application of a form of Spike Time Dependant Plasticity (STDP) within a highly recurrent spiking neural net based upon the LSM, leads to an approximate convergence of the synaptic weights. Convergence is a desired property as it signifies a degree of stability within the network. An *activity link* L is defined which describes the link between the spiking activity on a connection and the weight change of the associated synapse. It is shown that under specific conditions Hebbian and Anti-Hebbian learning can be considered approximately equivalent. Also, It is shown that such a network habituates to a given stimulus and is capable of detecting subtle variations in the *structure* of the stimuli itself.

11.00 - 11.10 h **Discussion**

11.10 – 11.30 h **Coffee Break**

Wednesday 11th October 2006, SESSION 5 BIS/CNS
Chair: M. Polycarpou

11.30 – 12.20 h

Shun-ichi Amari, Guest Keynote
RIKEN Brain Science Institute
Laboratory for Mathematical Neuroscience
Wako-shi, Saitama, Japan

Future Perspective of Brain Science-Towards Mathematical Neuroscience and Engineering Neurocomputing

Abstract: The brain is the most complex, highest performing information processing machine produced by nature. More than simply a sophisticated information processor, the brain is home of the mind, and spirit. Since the brain is a biological organ, life science has studied its structure and function. It ranges from the molecular level, cell level, network level, system level to the behavior level. On the other hand, the brain is an information processing system, so that it is a most important subject of study of information science and technology. It works in a completely different way from the modern computer. It is a most interesting fundamental problem to know how the brain processes information associated with its higher functions, such as thinking, planning, speaking, learning and self-organizing memory. Brain science must integrate information and life science approaches in our efforts to understand the brain.

Theoretical or computational neuroscience focuses on models of parts of the real brain or specific information processing functions of the brain. This approach becomes more and more important to understand the brain, in cooperation with experimental neuroscience where detailed facts are revealed. Another approach is more engineering-oriented, called neurocomputing, where artificial neural networks are used to create new information technology hinted from the brain.

Mathematical neuroscience studies principles of information processing in the brain in abstract mathematical forms. It gives a basis to both computational neuroscience and neurocomputing. Brain science, as well as other life science, is going to mature such that its principles are represented in mathematical forms together with biological facts.

The present lecture overviews brain science, its past and future, and search for possibility of mathematical neuroscience.

Wednesday 11th October 2006, SESSION 5 BIS/CNS
Chair: M. Polycarpou

12.20 – 12.40 h
David C. O'Carroll
Computational Neuroscience Research Cluster
University of Adelaide, Australia
(Co-authors: Paul D. Barnett, Eng Leng Mah, Karin Nordström and Russell S. A. Brinkworth)

A Neuromorphic Model For A Robust, Adaptive Photoreceptor Reduces Variability In Correlation Based Motion Detectors

We present here a parametric model for motion detection based on a correlational elementary motion detector (EMD) and inspired by our analysis of responses of neurons in the motion detection pathway of flying insects. This model incorporates a biomimetic photoreceptor stage that fully accounts for the non-linear adaptive normalization of contrast observed in fly photoreceptors. We find that inclusion of this front-end leads to a substantial improvement in performance compared with a basic EMD model. Our model lends itself to elaboration into analog electronic hardware, including neuromorphic analog VLSI. We have developed an initial implementation of the photoreceptor model and a single EMD using discrete electronic components. We have tested both the hardware and digital simulations of elaborated EMD arrays using high dynamic range (HDR) panoramic scenes derived from nature. Our data confirm that this photoreceptor model is robust enough to have a variety of applications and should be used as a front end wherever wide-field velocity information is of value (e.g. in optical flow analysis).

12.40 – 13.10 h
Rod Adams
School of Computer Science
University of Hertfordshire, Hatfield
(Co-authors: Lee Calcraft, Neil Davey)

Connectivity in Real and Evolved Associative Memories

Finding efficient patterns of connectivity in sparse associative memories is a difficult problem. It is, however, one that real neuronal networks, such as the mammalian cortex, must have solved. We have investigated evolved computational models of sparsely connected associative memories and found that some patterns of connectivity produce both good performance and efficient use of resources. This could illuminate how real biological systems solve the problem.
Keywords: Associative memories, Genetic Algorithm, Connectivity, Real neuronal networks.

Wednesday 11th October 2006, SESSION 5 BIS/CNS
Chair: M. Polycarpou

13.10 – 13.30 h
C. Gros
Institute for Theoretical Physics
J.W. Goethe University Frankfurt aM, Germany

Towards a Rudimentary Autonomous Cognitive System:
Principles, implementation and simulation results

We take the stance that biologically inspired cognitive systems might be developed, albeit at a rudimentary level, within the next decade. We formulate and implement basic principles for a cognitive system based on generalized neural networks, such as locality of operations and autonomous working-point optimization via homeostatic principles. We propose and implement a modular layout for the global architecture with well defined module-interfaces. The individual modules comprise cognitive units for environmental data representation via unsupervised learning, modules for model-building of the environment via internal supervised learning and action-selection modules via learning by reinforcement or learning by error. In addition to the modules for cognitive data processing, diffuse control units (like the Dopamine system of the brain) are necessary for internal status control. We propose that the driving force for the autonomous dynamics of the cognitive system are spontaneous associative thought processes representing time-series of memories in the environmental-data representation module. We present the results of extensive numerical simulations of the above concepts as well as the specific implementation of a few selected modules.

13.30 – 13.40 h **General Discussion**

13.40 – 15.00 h **Lunch**

Wednesday 11th October 2006, SESSION 6 MOC
Chair: R. Manzotti

15.00 – 15.50 h
P. Haikonen, Guest Keynote
Nokia Research Center
NOKIA GROUP, Finland

The Haikonen models of machine consciousness, a summary and update

Folk psychology describes human consciousness like "the immaterial feeling of being here". This is accompanied by the awareness of self, surroundings, personal past, present and expected future, awareness of pain and pleasure, awareness of one's thoughts and mental content. Consciousness is also linked to thinking and imagination, which themselves are often equated to the flow of inner speech and inner imagery. Consciousness is related to self, mind and free will. Consciousness is also seen to allow one to act and execute motions fluently, without any apparent calculations. A seen object can be readily grasped and manipulated. The environment is seen as possibilities for action. Folk psychology is not science, yet these properties would be useful to a robot as such even if they were not accurate descriptions of the "real" consciousness.
An engineering approach to machine consciousness may be inspired by the folk psychology properties of consciousness; in doing so useful robots may be designed and perhaps some understanding about the "real" consciousness may be achieved as well. In order to do this the folk psychology properties of consciousness must be evaluated in the terms of cognitive psychology and neurosciences and corresponding electronic systems must be devised. The speaker has developed a machine model for consciousness along these lines. This model utilizes neural signals as transparent carriers of information; the material machinery remains hidden from the system and only the actual meanings matter. The neural signals operate as distributed representations in a massively parallel perceptual architecture. This architecture supports the flow of inner speech and imagery. The system is controlled by motivational factors that arise from hard-wired and learned emotional values. The cognitive machine is supposed to have a body with possibilities for physical action. These actions are executed lucidly as responses to imagination or perceived environment, without numeric computations. Consciousness in the machine is seen as cooperative states between the numerous modalities; this leads to a large number of cross-associations and hence to the possibility to report the situation to the machine itself and to others in various ways and also remember it for a while; the past will be connected to the present in "a stream of consciousness".
The speaker foresees that the presently seen development of various models for conscious machines and robots will eventually converge and lead to practical machines that appear to be conscious and may even possess some kind of autonomous mind. These machines will find important applications in robotics and in information technology.

Wednesday 11th October 2006, SESSION 6 MOC
Chair: R. Manzotti

15.50 – 16.10 h
A. Coward
Department of Computer Science
Australian National University

Constructing a Physiologically Realistic Machine Model of Consciousness
There are a set of theoretical bounds on any system which must learn to perform a complex combination of features with limited information handling resources. A cognitive architecture implemented within these bounds has the capability to generate human-like "conscious" behaviours with mechanisms that are physiologically plausible.

16.10 – 16.30 h
Stathis Kasderidis
Foundation for Research and Technology - Hellas
Heraklion, Greece

A Motivational System for Autonomous Agents
We present initial ideas and work in progress on a Motivational System for Autonomous Agents. We develop a model of primary drives, study their complex dynamics in various scenarios and provide evidence for its efficiency through simulations. We also discuss the relation between drives and agent goals.

Wednesday 11th October 2006, SESSION 6 MOC
Chair: R. Manzotti

16.30 – 17.15 h
Ph. Gerrans
Philosophy Department
University of Adelaide Australia

A Neurocomputational Model of Delusion

Delusions are currently characterised as false beliefs produced by incorrect inference about external reality (DSM IV, 1994). This inferential account has proved hard to link to explanations pitched at the level of neurobiology and neuroanatomy. This paper provides that link via a neurocomputational theory, based on evolutionary considerations, of the role of the prefrontal cortex (PFC) in managing responses to experience. Neural network theory distinguishes between weight-based and activation based-processing. This distinction maps (roughly) to a distinction between modularised online cognition conducted by perceptual and sensory systems and offline cognition under the control of the PFC. The PFC regulates activation-based processing in transient neural networks constructed to deal with experiences produced as outputs of weight-based sensory and perceptual systems. The advantages of this implementation-level account are explored via a comparison with Shitij Kapur's influential attempt to link dopamine dysregulation to the phenomenology of schizophrenia.

17.15 – 17.25 h **General Discussion**

17.25 – 18.00 h **Coffee**

18.00 – 20.00 h **Evening Brainstorm 2**

Thursday 12th October 2006, SESSION 7 MOC
Chair: H. Cruse

09.00 – 10.00 h
I. Aleksander, Guest Keynote
Imperial College London, U.K.

Axiomatic models and puzzles of consciousness: animals, dreams, volition and illusions

When looking at mechanistic models of what it is that makes our neural systems create a personal sense of consciousness, it is helpful to break this phenomenon down into components called 'axioms'. This recognises that consciousness is not one thing but a combination of several phenomena each of which has specific supporting neural mechanisms. They are, at least, (1) perception of a world with one's self in it, (2) imagination of experiences or fiction, (3) attentive selection of experience, (4) planning future action, (5) emotional evaluation of plans. The neural mechanisms implied by these mechanisms are discussed in order to address some major puzzles about consciousness. Are animals conscious? It depends on the neural mechanisms that can be discovered in their brains. What are dreams? This can be answered using automata theory that flows from the axiomatic mechanisms. Current work on the emotional valuation of plans and some visual illusions will be described.

10.00 – 10.20 h
A. Chella
Dipartimento di Ingegneria Informatica
Università di Palermo, Italy
(Co-author: Irene Macaluso)

Sensations and Perceptions in "Cicerobot", a Museum Guide Robot

The paper discusses the distinction between sensations and perceptions in consciousness literature and it proposes a robot architecture based on a comparison between the effective sensations and the expected sensations generated by a 3D robot/environment simulator. The robot perceptions are generated by the simulator driven by this comparison process. The architecture is operating in "Cicerobot" a museum robot offering guided tours at the Archaeological Museum of Agrigento, Italy.

Thursday 12th October 2006, SESSION 7 MOC
Chair: H. Cruse

10.20 – 10.40 h
H. G. Marquez
Department of Computer Science
University of Essex, U.K.
(Co-author: O.Holland)

Minimal architectures for embodied imagination

It is only recently that there has been a revival of interest in the phenomenon of imagination; our interest is in exploring imagination from the perspective of an embodied agent. We define imagination as the process of manipulating information not present to the senses (i.e. counterfactuals) and obtaining a functional advantage from doing so. There are two broad possibilities for enabling imagination: reusing sensory-motor components in an off-line manner; or building and using copies of the sensory-motor components instead. We have analysed the minimal architectures required for the first possibility, and have explored two situations: finding and using the first acceptable solution to a simple problem (First-X), and finding and using the best solution obtained within a fixed time frame (Best-X). We find that a minimal First-X architecture requires 9 components, and a minimal Best-X architecture requires 12, and we have successfully simulated both architectures using an adaptation of the Player/Stage simulation program.

10.40 – 11.00 h
V. Tereshko
School of Computing, University of Paisley, Scotland

Language Dynamics: Coexistence and Selections of Grammars

Abstract: Language dynamics is modelled by a dynamical system where the ensemble of individuals consist of teachers and learners. Depending on the level of (spatial) communication among the individuals, different grammars can either coexist or compete with each others. The latter results in selection of an unique grammar, the phenomenon emerging due to the enhancement of the individual's communication level. Keywords: Language, Evolution, Population, Interaction, Fitness

11.00 – 11.10 h **Discussion**

11.10 – 11.30 h **Lunch**

Thursday 12th October 2006, SESSION 8 MOC/CNS
Chair: O. Holland

11.30 – 12.20 h
Ch. V.d. Malsburg, Guest Keynote
Frankfurt Institute of Advanced Studies and Computer Science Dept., University of Southern California, Los Angeles USA

About the Neural Organization of Consciousness

To create artificial consciousness we need to first understand its neural implementation in the brain. I will point to two issues that are crucial for progress on this front -- the data structure of brain state, and the mechanism by which the brain organizes the neural equivalent of algorithms. Both issues are at present distorted grossly by generally held prejudices. We know that the neurons of our brain, or at least many of them, can be interpreted as elementary symbols. The single cell dogma has it that my brain's state is fully characterized by a vector of positive numbers specifying which of the neurons are active in my brain or, equivalently, which of the elementary symbols are active in my mind at the present time. This raises the by now widely discussed binding problem, which is but the tip of an iceberg that will eventually sink the single cell dogma. A more promising data structure are dynamical graphs, composed of nodes (which roughly correspond to the neuron-symbols) and links. Links represent relatedness between connected nodes, and they vary dynamically on the same time scale as node activities. In distinction to activity vectors, dynamical graphs constitute a rich structural universe. The other prejudice, inherited from computer science and artificial intelligence, is the virtually complete disregard of the issue of how functional procedures (algorithms) are generated and a narrow focus on nothing but their execution.
I will claim that the essential function of consciousness is the ability to bring to bear all of the brain's knowledge and abilities on acute problems the individual is facing. Essential for this is the ability to recognize the homomorphy of the actual situation with past ones in the light of all possible sub-systems and modalities. This ability is the central mechanism to organize new functional capabilities and it cannot even be formulated with vectors as data structure. Important neuronal correlates of consciousness are the details of dynamic link implementation in the brain.

Thursday 12th October 2006, SESSION 8 MOC/CNS
Chair: O. Holland

12.20 – 12.40 h

A. Seth
The Neurosciences Institute
10640 John Jay Hopkins Drive
San Diego, USA

Causal networks in neural systems: From water mazes to consciousness

Neurons engage in causal interactions with one another and with the surrounding body and environment. Neural systems can therefore be analyzed in terms of causal networks, without assumptions about information processing, neural coding, and the like. Here, we describe the analysis of causal networks in simulated neural systems using a combination of time-series analysis ("Granger causality") and network theory. Implications are drawn for causal pathways in the hippocampus, for the relation between synaptic plasticity and behavioral learning, and for the neural dynamics underlying consciousness.

12.40 – 13.10 h

J. M. Bishop
Department of Computing, Goldsmiths College, New Cross, London, UK
(Co-authors: S.J. Nasuto, K. De Meyer)

NESTER: a spiking neuron connectionist implementation of stochastic diffusion search

A novel artificial neural network is presented and a new information-processing paradigm in the brain is proposed. The mechanism is based on temporal encoding and multiplexing of information and utilises recent qualitative findings in neuroscience. The network will locate the best fit of an external world stimulus (the target), defined by the specific pattern of micro-features (the memory), detected on a retina (the search space). The network described herein merits interest for three significant reasons. Firstly, it is extremely robust and efficient: as it mimics the Swarm Intelligence paradigm Stochastic Diffusion Search it will find the global best fit of the target with probability one, in a time growing at most linearly with retinal size. Secondly, neurons communicate bi-variate information encoded in the Inter-Spike Intervals and hence process knowledge as `tokens' and not as `types'. This contrasts information processing in most associative networks, where knowledge is represented as simple types (defined by vectors in Euclidean space). Finally, it may constitute a simple model of emergence from a low level neural information processing of higher cognitive characteristics, like cognitive learning or partial matching

Thursday 12th October 2006, SESSION 8 MOC/CNS
Chair: O. Holland

13.10 – 13.40 h **General Discussion**

13.40 - 15.00 h **Lunch**

15.00 – 15.50 h
H. Cruse, Guest Keynote
Department of Biological Cybernetics
Faculty of Biology
University of Bielefeld, Germany

Body models as basis for perception, cognition and subjective experience.

An alternative solution to control behaviour in a reactive way is given by cognitive systems capable of planning ahead. To this end the system has to be equipped with some kind of internal world model. A sensible basis of an internal world model might be a model of the systems own body. Using specific recurrent neural networks, I show that a reactive system with the ability to control a body of complex geometry requires only a slight reorganization to form a cognitive system. This implies that the assumption that the evolution of cognitive properties requires the introduction of new, additional modules, namely internal world models, is not justified. Rather, these modules may already have existed before the system obtained cognitive properties. Furthermore, I discuss whether the occurrence of such world models may lead to systems having internal perspective.

Thursday 12th October 2006, SESSION 8 MOC
Chair: R. Chrisley

15.50 – 16.40 h
O. Holland, Guest Keynote
University of Essex, U.K.

From an artificial self to an artificial consciousness?

This talk will present a line of thought showing how the problem of constructing a truly autonomous intelligent robot may also constitute an approach to building a conscious machine. The basis of the theory is that an intelligent robot will need to simulate both itself and its environment in order to make good decisions about actions, and that the nature and operation of the internal self-model may well support some consciousness-related phenomena. It seems unlikely that a typical modern research robot would require a self-model complex enough to be relevant to consciousness, but what sort of robot would be suitable? We believe that the best candidate would be a robot that did not merely fit within a human envelope, but one that was anthropomimetic - with a human-like skeleton, muscles, tendons, eyeballs, etc. - a robot that would have to control itself using motor programs qualitatively similar to those of humans. We have built such a robot. The early indications are that these robots are very different from conventional humanoids; the many degrees of freedom and the presence of active and passive elasticity do provide strikingly lifelike movement, but the control problems may not be tractable using conventional robotic methods. We have also developed an accurate physics-based simulation of the robot that is capable both of interacting with a physics-based representation of the world, and also of serving as the basis of the robot's self-model. With the basic components for testing our theory now in place, we are now in a position to implement a functioning architecture within which to study the characteristics of an artificial self, and to attempt to relate them to our knowledge of consciousness.

16.40 – 17.00 h **General Discussion and Closing**

20.00 h **Conference Dinner**