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CILIA

Customized Intelligent Life-Inspired Arrays

Integrated Project

Information Society Technologies
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Proactive Initiative BIO-I3

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CILIA SUMMER SCHOOL

FROM BIOLOGICAL TO BIONIC SYSTEMS

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CO	Confidential, only for members of the consortium (including the Commission Services)	

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INTRODUCTION

PURPOSE OF THE DOCUMENT

The purpose of this document is to give an overview over the lectures held at the CILIA Summer School which took place from 30 March to 3 April 2008 in Sant Feliu de Guixols, Girona, Spain.

EXECUTIVE SUMMARY

The CILIA Summer School took place from 30 March to 3 April 2008 in Sant Feliu de Guixols, Girona, Spain (http://www.cilia-bionics.org/summer_school_details).

The Summer School covered the topics

- Biological Mechanosensory systems
- Fluid dynamics
- Modelling of System Dynamics
- Artificial Sensors
- Robotics.

It was targeted to address PhD students and young researchers, as well as newcomers in the field of Mechanosensor Systems and to give an opportunity for establishment of scientific and personal contacts between the participants. The lectures were given by well-known experts in the scientific disciplines of the School:

- Prof. Christoph Brücker (TU Bergakademie Freiberg, Germany)
- Prof. Friedrich G. Barth (University of Vienna, Austria)
- Prof. Ray Meddis (University of Essex, UK)
- Prof. Mitra J. Hartmann (California Institute of Technology, USA)
- Prof. J. Leo van Hemmen (Technische Universität München, Germany – member of CILIA consortium)
- Prof. Jason Lohn (NASA Ames Research Center, CA, USA)
- Dr. Sietse van Netten (University of Groningen, The Netherlands)
- Prof. John R. Buck (University of Massachusetts Dartmouth, USA)
- Dr. Wolf Hanke (Harvard University Cambridge, USA)
- Prof. Werner Gnatzy (Universität Frankfurt, Germany)
- Prof. Joseph A. C. Humphrey (University of Virginia, USA)
- Prof. John Miller (Montana State University, USA)
- Prof. Gijs Krijnen (University of Twente, The Netherlands – member of CILIA consortium)
- Prof. Herbert Peremans (Universiteit Antwerpen, Belgium - member of CILIA consortium)
- Dr. Andrew Dacks (University of Arizona, USA)
- Prof. Horst Bleckmann (Rheinische Friedrich-Wilhelms Universität Bonn, Germany – member of CILIA consortium)

Notes have been published by the organisers and distributed to the participants in printed form.

LECTURES

TIME SCHEDULE

	Sunday (30 March)	Monday (31 March)	Tuesday (1 April)	Wednesday (2 April)	Thursday (3 April)
08:00-09:00		*breakfast buffet*	*breakfast buffet*	*breakfast buffet*	*breakfast buffet*
		09:00-13:00 Session 1: Biological Mechanosensory systems	09:00-13:00 Session 3: Biological Mechanosensory systems, continued	09:00-13:00 Session 4: Modelling of System Dynamics	09:00-13:00 Session 6: Artificial Sensors (continued), Robotics
09:00-10:10		1. John Miller: Functional organization of the array of filiform mechanoreceptors on the cricket cercus	6. Mitra Hartmann: Encoding and processing of mechanical variables by the rat vibrissal/trigeminal system	9. Sietse van Netten: Mechanical characteristics of the peripheral lateral line organ and sensory hair cells: clues for bionic mechanosensory systems	15. Herbert Peremans: Sonar sensing for robots: the future is biomimetic
10:10-11:20		2. Werner Gnatzy: Digger wasp vs. Cricket: Neuroethology of a predator-prey interaction	7. Wolf Hanke: Mechanoreception in seal vibrissae	10. Ray Meddis: A computer model of the mammalian inner hair cell	16. Jason Lohn: Evolutionary antenna design
11:20-11:50		*coffee break*	*coffee break*	*coffee break*	*coffee break*
11:50-13:00		3. Friedrich Barth: The power of stimulus transformation - Spider mechanosensors	8. John Buck: Cepstral signal processing models for bat biosonar	11. Joseph Humphrey: Capturing the essential physics of complex sensory systems with simple models: Applications to fluid motion and odor sensing in biology and engineering	17. Jason Lohn: Case Studies in evolving antennas
13:00-14:00		*poster session*	*lunch buffet*	*lunch buffet*	*lunch buffet*
14:00-15:00		*lunch buffet*	14:30-19:30 Trip to Girona	*free time*	about 14:00 end of summer school
15:00-16:00		*free time*		**poster session** *together with coffee break*	
16:00-17:00		*coffee break 16:20-16:50*		16:00-19:20 Session 5: Modelling of System Dynamics (continued), Artificial Sensors	
		17:00-19:20 Session 2: Biological Mechanosensory systems, continued		12. Leo van Hemmen: Theory of neuronal information processing in mechanosensory systems: Common traits and differences in cricket, frog, and fish	
17:00-18:10	17:00 Arrival and Check-in	4. Andrew Dacks: Probing Activity Across Neural Networks Using Multichannel Recording: Techniques, Advantages and Limitations		13. Gijs Krijnen: Biomimetic hairsensors: can MEMS bring them to life?	
18:10-19:20	*19:00 come-together*	5. Horst Bleckmann: Lateral line systems in fish: Structural, functional and ecological aspects		14. Christoph Brücker: Flow sensors based on flexible micro-hairs	
19:30-21:30	*dinner buffet*	*Evening talk: Werner Gnatzy: Insects under the SEM (19:30-20:30)*	*20:00 gala dinner*	*dinner buffet*	
		dinner buffet			

SUMMARY OF THE SESSIONS

Session 1: Biological Mechanosensory Systems
Monday, March 31st 2008
Chaired by Jerome Casas

The first session opened with the talk of John P. Miller who presented an overview of the past and ongoing work on the cricket cercal system. His recent work on hair mapping and concept of a delay line along the cercus attracted a lot of attention. Bringing a cricket's predator in our understanding of the prey escape system was the point of the talk of Werner Gnatzy, whose overall perspective is truly integrative. A highlight of this talk was the scanning electron microscopy video of a single hair being moved and the cuticule deformation at its base being observed in real time. This session ended with an overview of the cricket predator's point of view of air flow sensing, the spider, by Friedrich Barth. The seamless merging of fine details of hair physics within the more general neuroethology of the spider, and the explanations for the variety of details found in nature, impressed the audience. His latest results using video recording of the hair's movement during the passage of a fly nearby represents exactly the kind of data several groups are currently trying to obtain.

Session 2: Biological Mechanosensory Systems
Monday, March 31st 2008
Chaired by Andreas Offenhaeusser

This session included one presentation on multisite neuronal recordings and one on the lateral line system of fish. Both contributions provided excellent overviews of the topics covered and the state-of-the art. The first talk in this session, by Andrew Dacks, introduced the method of multisite extracellular ensemble-recordings from neuronal networks in the antennal lobe of insects. He described in detail how the recorded signals are analysed to distinguish single units and ways to identify extracellularly recorded neurons. Finally, he showed how to analyse interactions between units.. The second talk, by Horst Bleckmann, introduced the lateral line sensory system of fish. Here, Horst Bleckmann in particular highlighted the distribution of the neuromasts over the body of fish, the characterization of the water velocity as function of space and time and the neuronal response properties of fish.

Session 3: Biological Mechanosensory Systems
Tuesday, Apr 1st 2008
Chaired by Joachim Mogdans

The first two talks in this session were concerned with vibrissae, or whiskers, specialized hairs that are usually employed by mammals for tactile sensation. They are organized

systematically in arrays and although different in structure from cricket filiform hairs and fish neuromasts, they have similar hydrodynamic properties and function. In her presentation, Mitra Hartmann demonstrated that rats are capable of reconstructing the shape of 3D-objects from information gathered by the 2D whiskers array and presented an hypothesis how this might be accomplished neuronally. In a second talk, Wolf Hanke showed that aquatic mammals like seals can use their whisker array to distinguish objects and to follow the hydrodynamic trail generated by objects moving in the water. The final talk in this session session was given by John Buck who suggested a Cepstrum-based mechanism for the analysis of multi-glint ultrasonic echoes perceived by echolocating bats. The algorithm that he suggested allows to reconstruct the distance to multiple targets in space and is therefore of particular interest to those in the CILIA consortium investigating theoretical and neuronal signal processing.

Session 4: Modelling of System Dynamics

Wednesday, Apr 2nd 2008

Chaired by John Hallam

This session focussed on modelling system dynamics and comprised 3 talks. The first, by Sietse van Netten, addressed modelling the mechanical properties of the lateral line sensory system, in particular the relationship of the filtering properties of the sensor to its mechanical construction. Next, an enlightening talk by Raymond Meddis illuminated the complexity of a faithful model of the transduction process implemented in the mammalian cochlea. Finally, Joseph (Pepe) Humphreys presented an excellent talk on modelling the fundamental physics associated with hair transduction of fluid motion and with odour plume sensing, illustrating how suitable physical models can point to the essential parameters affecting a particular sensory behaviour and allow interesting "what-if" explorations of sensor design.

Session 5: Artificial Sensors

Wednesday, Apr 2nd 2008

Chaired by George Jeronimidis

This session included one presentation on neuronal processing and two on artificial hair-sensing systems. All the contributions provided very high quality overviews of the topics covered and the state-of-the art.

In his talk on neuronal information processing in biological mechanosensing systems, Leo van Hemmen (member of the CILIA consortium) underlined the importance of maps as neuronal representations of the external world and of spatial-temporal patterns distributions of delays to help with source localisation and identification. The concept of pupil-teacher interactions between different sensory systems was also discussed.

Gijs Krijnen's (member of the CILIA consortium) presentation on MEMS-based biomimetic hairsensors discussed the latest design and fabrication developments being carried out to enhance the sensitivity of the current systems, compared to the hair sensors of crickets, and the strategies for sensor arrays. Sensor adaptability via Electrostatic Spring Softening of the

capacitive sensing system currently being implemented provides a very effective means of "tuning" the sensor. Negative Spring-Stiffness, a concept derived from biological sensing systems such as the lateral line, can also be implemented via DC biasing to improve amplification.

Christoph Brücker's presentation on bio-inpired sensors for near-wall flow in liquids introduced a technology based on artificial soft and flexible hairs, with functionality similar to that of the neuromasts. His approach for technical solutions relies on a combination of flexible Micro-Pillars, comparatively easy to fabricate, and CCD camera capture of the movement of the ends of the pillars. Essentially, using arrays of pillars, this method allows to retrieve information on the fluid velocity field in order to measure and characterise liquid flow near wall or obstacles. Of particular interest was the capture and visualisation of wall shear-stress in turbulent flow.

Session 6: Artificial Sensors and Robotics

Thursday, Apr 3rd 2008

Chaired by Rolf Müller

The focus of this session was on the interface between research on biological systems and technology development. Herbert Peremans (member of the CILIA consortium) gave a presentation in which he summarized the state of the art in sonar sensing for (mobile) robots and contrasted it with the biomimetic approach that is taken in the CILIA project. This talk was immediately relevant to the progress of the project, because it outlined opportunities to improve existing technology by biomimetic solutions. Jason D. Lohn (invited speaker from the NASA Ames Research Center) gave two talks, one to introduce the method of genetic algorithms and its relationship to antenna design and a second talk to discuss case studies of antenna designs that have been evolved using genetic algorithms. These talks were relevant to the project, because they established a strong link between conventional engineering development of technology and the biomimetic approach and because of the direct parallelism between electromagnetic and ultrasonic beamforming.

Participants of CILIA Summer School Mechanosensors: From biological to bionic systems