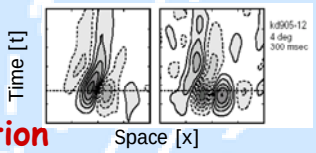
Department of Biophysical and Electronic Engineering - University of Genoa

PSPC
The Physical Structure of Perception and Computation



The Physical Structure of Perception and Computation

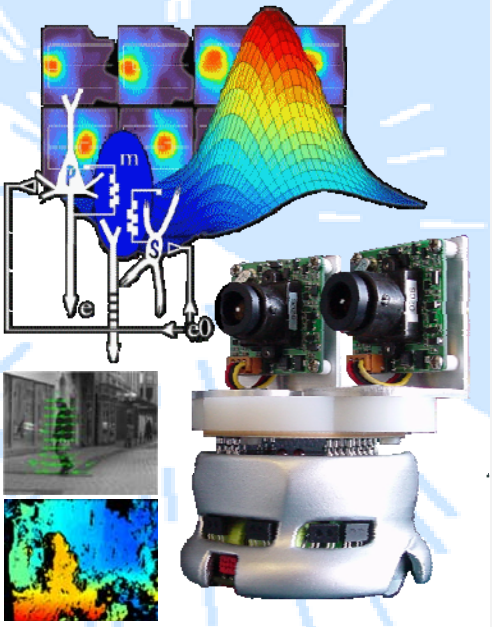
Prof. Silvio Sabatini

Natural perceptual systems

- **Representation and coding of multidimensional signals**
  Operators and architectures for an efficient representation of visual features and their relationships.
- **Visuospatial perception and sensorimotor control**
  Cortical models for stereo and motion processing and sensorimotor coordination in the peripersonal (e.g., reaching and grasping) and extrapersonal (e.g., navigation) space.
- **Interactive systems for visuomotor rehabilitation**
  Virtual/augmented reality for recovering from neurosensorial and motor skill pathologies.

Artificial perceptual systems

- **Bio-inspired solutions for active/behavioral vision in Humanoid Robotics**
  Early perception-action embodiment of visual functions for learning coordinated binocular eye movements and intentional exploration of the scene.
- **Perceptual Machines for everyday life applications**
  Video surveillance and sensory communication systems (e.g., human-machine interfaces and low-vision aids).



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How the research can be framed?
The general framework of the research conducted in the PSPC-lab relates, in the long run, to the development of artificial systems with true perceptive/cognitive capabilities. Such systems should be able to collect information about the external environment, analyze (them), weight (them), and eventually use them to act. In this framework, a multidisciplinary approach, which links bidirectionally with the Brain Sciences is crucial: from one side, it fosters the transfer towards artificial systems of the knowledge gained from the study of biological systems (i.e., models specified in hardware, software or wetware that embody in an essential form their principles, architectures and functionalities), and, from the other side, it demonstrates the usefulness of the "artificial" approach as a method for the investigation of the nervous systems.

Which are the relationships with Artificial Intelligence?
A computer with intelligent visual skills comparable to biological ones has been an ambitious research goal of AI, ever since the field of computer vision took off some 30 years ago. As an alternative to mathematical approaches, especially when they fall short of their expectations, attempts to mimic the processing of the brain have been pursued, but implementing the result into computer vision systems is still in its infancy. In general, there is a gap between early (low-level) and cognitive vision paradigms. Early vision processes are usually based on distributed computation (cf. parallel distributed processing), that can be directly associated to neuronal mechanisms (cf. neuromorphic approach). On the other hand, cognitive processes are traditionally associated to the AI approach, grounded on knowledge-based rules and logic, operating in terms of symbols and propositions, and performing a relational analysis of the extracted visual features. By contrast, in visual cortex, the relationships in the sensorial data emerge through dense intra- and inter-area feedback/re-entrant interconnections that integrate context information by modulating cells' responses, adapting their tuning and refining their selectivity, eventually building the relational code necessary for perceptual grouping. We can therefore introduce the term "early cognitive analysis" to refer to the possibility of re-considering cognitive processing in structural terms. In this way, new computational strategies can be conceived that allow a more direct interaction between "early" and "cognitive" vision", which can be directly employed in the new-generation machine vision systems that efficiently integrate bottom-up (i.e., data-driven) with top-down approaches. In this way, it would be possible to achieve perceptual/cognitive capabilities through a "physicalist" computation on structural representations in space and time, without explicitly resorting to symbolic computation or AI rules.

Which are the relationships with Neuroscience research?
When the realization of artificial systems corresponds to a "reverse engineering" process of the natural systems, such implementations could greatly contribute to the advancement of knowledge on the basic information processing mechanisms adopted by the brain and their neuronal correlates. From this perspective the strengthen of the existing collaborations between information technology and biomedical components plays a strategic role to the coalescence of a scientific community where all the components contribute to / get a real progress of science in a multidisciplinary cooperation.

Which are the perspectives and the relevance of these research topics in the international scenario?
The PSPC-Lab was established in 1995, from an attempt of expanding the functionalities of microelectronic implementations of neural networks with neuromorphic architectures. From a "historical" point of view, the research mission can be considered as the development and the confluence of research issues, which had been previously conducted in Microelectronics (parallel distributed processing systems) and, limited to the methodological aspects, in Molecular Electronics (computational interpretation of the behavior of a physical system), with new contributions, typical of Computer Science and Cybernetics, related to the information processing and representation in neuronal systems and to machine vision algorithms.
Since then, in the international scenario such approach imposed itself through the (1) definition of specific Research Programs aimed to overcome the formal framework of artificial neural networks and to relate more decisively to models derived from neuroscience research, and through (2) the consolidation of Labs, research Groups and Network of Excellence active on these topics (e.g., see the recent EU programs "Neuroinformatics for living artefacts (2000)", "Life-like Perception Systems (2001)", "Beyond Robotics (2002)", "Bio-inspired Intelligent Information Systems (2003)", and "Toward Natural Cognition (2005)", and the Thematic Networks "European Research Network for Cognitive AI-enabled Computer Vision Systems 'ECVision' (2002-05)" and "*Neuro-IT*-Net Thematic Network (2002-06)").
In this scenario, our group has participated as promoter or research partner to several multisciplinary research projects with the specific goal of valuing multisciplinary collaborations that gather contributions from Engineering, Cybernetics and Neuroscience. Among them, we cite the "ECoVision" consortium, established in Genoa in December 1999 from our own initiative ("Optic Flow Analysis in Animals and Machines: Cortical Computational Paradigms and Artificial Vision Systems", Genoa 9-10.12.99) with the objective of exploring the cortical mechanisms on the basis of adaptive processing in visual perception. These mechanisms could indeed be embedded with high efficiency in novel hardware-software artificial systems for a vision-based analysis of complex dynamic scenes in navigation tasks and visuo-motor control. The consortium activity led to the EU projects ECoVision - "Artificial vision systems based on early-cognitive cortical processing" [EC IST-FET, 2002-04] - and Drivsco - "Learning to emulate perception-action cycles in a driving shool scenario" [EC IST-FET, 2006-09]. More recently, the coordination of the EC project EYESHOTS – "Heterogeneous 3D perception across visual fragments" [EC ICT, 2008-2011], (**http://www.eyeshots.it/**) and the participation to the EC project SEARISE "Smart Eyes: Attending and Recognizing Instances of Salient Events" [EC ICT, 2008-2011], (**http://www.searise.eu**).

Genoa, 30th September 2011