

SPARK

Spatial-temporal Patterns for Action-oriented perception in Roving robots

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The SPARK project was funded by the European Commission, under the Cognitive Systems call of the 6th Framework. SPARK was constituted by six partners: the University of Catania, Dipartimento di Ingegneria Elettrica Elettronica e dei Sistemi - DIEES (coordinator), the Instituto Pluridisciplinar of the Universidad Complutense de Madrid (IP-UCM), the University of Edinburgh, Institute of Perception Action and Behaviour (UNIED), the University of Bielefeld, Institute for Biological Cybernetics (UNIBI), and two SMEs, ANALOGIC Computers (Hungary) and ANAFOCUS (Spain).

The aim of the SPARK Project was to introduce completely new sensing-perceiving-moving artifacts inspired by the basic principles of living systems and based on the concept of "self-organization". Sensors were treated as devices processing signals distributed in space and also showing non linear time dynamics. Perception was formulated as an emergent phenomenon in spatio-temporal pattern forming architecture, determined by information deriving from sensors and directly influencing the particular associated motor behaviour. The whole methodology was implemented in a new architecture, a Spatial-temporal array computer based structure, providing a new paradigm for active perception based on principles borrowed from psychology, synergetics, artificial intelligence and nonlinear dynamical systems theory. The project had high challenging targets that were reached.

The active collaboration resulted in the introduction of a new general model for action-oriented perception.

This is a hierarchical structure, which takes inspiration from previous work on environmentally mediated perception, but enhances the existing models in several aspects, reflecting each individual partner's expertise. In particular, primary attention was given to the integration of vision into the general perception scheme; due to the complexity of visual sensing and the difficulty of extracting relevant aspects for real time perception/action purposes, this issue is not often evaluated. The availability of a visual hardware chip from ANAFOCUS (the Eye-Ris 1.2 visual system), able to extract in real time several different and concurrent salient features, allows visual information to be efficiently processed and fused with other sensor stimuli. The expertise of UNIED on sound perception in insects was very useful to efficiently process sound signals, while the Walknet architecture for decentralised locomotion control from UNIBI allowed the tactile sensory structure and robot leg control to be included directly within the perception-action scheme. Here, parallel pre-cognitive behaviours (basic behaviours), acting as hardwired systems, cooperate to provide suitable actions to drive the robot from the very beginning of its navigation. Higher structures provide an ever increasing level of adaptation, including plasticity and learning. In particular a proto-cognitive correlation layer is devoted to detect time varying causal correlations among the basic behaviours so as to learn to anticipate one behaviour through another. This layer was defined starting from several different views by UNIED, IP-UCM and DIEES during full weeks of joint work at the University of Catania.

A further layer provides "Representations" of the environment. These are conceived as emergent dynamical flows in complex nonlinear dynamical cellular systems, under the form of *Turing Patterns*. These provide an abstract and concise representation of the environment as an emerging pattern, whose codified version is used to learn, without supervision, the suitable modulation of the proto-cognitive behaviours of the lower levels. The highest level, called "motivation layer" hosts a Reward function (RF), which defines the overall mission for

the robot. During learning, a series of punishments and rewards guides learning of the actions to be associated to the emerging pattern in the representation layer. The RF also modulates the input to the Representation layer, in order to plastically modify the basins of attraction of the emerging patterns, further enhancing the role of the representation layer as a kind of mirror of the various environment conditions. Further memory models save successful sequences of modulated behaviours for future exploitation.

The technical objective was represented by some robot prototypes, both legged and wheeled. All of them are autonomous. Robotic research in the design and realisation of such prototypes was not focussed only to produce new robots as such: these are considered as test beds to assess and evaluate the suitability of the perceptual architectures designed in the previous phase. This leads to the production of different types of robots, as a function of the particular perceptual module to test. All of the prototypes are able to actively interact with the environment. They were designed and realised in order to show active integration of sensor stimuli, creation of an iconic, abstract and concise representation of the environment under the form of a dynamically emergent pattern and generation of a sequence of proper motor actions to reach a pre-specified target.

Further details about the methodology, the model as well as experimental results are reported in the SPARK web page.

The introduction of the new architecture for action-oriented perception, based on principles borrowed by insect neural principles, nonlinear dynamics and complex system theory, was implemented in robotic test beds, leading to some results that are really encouraging for the future exploitation, further assessment, optimization and generalization of the SPARK architecture to different and more complex robots. These are the main topics upon which a new EC funded project SPARK II will develop during the next three years.

References

P. Arena, L. Patanè (Eds.), **Spatial Temporal Patterns for action-oriented perception in Roving Robots**, Springer, to appear in 2008.

SPARK web site, available online: www.spark.diees.unict.it