UNIVERSITÀ DEGLI STUDI DI TRENTO

Dipartimento di Informatica e Studi Aziendali

SEMINARI DISA

Evolving Systems and Their Modelling: From Quantum-, and Molecular-, To Cognitive, and Evolutionary

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Everything is evolving – from the micro-, to the macro systems. But what are the rules that make these systems evolve at a different functional and structural level? How do we learn these rules, that are also evolving in time? How can we use them to create evolving models, rather than pre-fixed ones?

The talk addresses these general questions and some more specific ones and offers some solutions. By an *evolving* system, here we mean a system that is *developing, revealing, unfolding* in time.

The brain, being probably the most complex evolving system, evolves its structure and functionality at different levels – quantum-, molecular (genetic)-, single neuron-, ensemble of neurons-, cognitive-, evolutionary. At the quantum level, particles (atoms, ions, electrons, etc.), that make every molecule in the material world, are moving continuously, being in a superposition of several states and characterised by probability, phase, frequency, energy.

At a molecular level, DNA, RNA and protein molecules evolve in a cell and interact in a continuous way, based on the stored information in the DNA and on external factors, and affect the functioning of a cell (neuron). At the level of a neuron, the internal processes and the external stimuli in their interplay cause a neuron to produce a signal that carries information transferred to other neurons, which process is a continuous, evolving. At the level of neuronal ensembles, all neurons operate in a “concert”, defining the function of the ensemble through continuous learning, for instance perception of a spoken word. At the level of the whole brain, cognitive processes take place in a life-long learning mode, such as language and reasoning, and global information processes are manifested, such as consciousness. At the level of evolution, a population of individuals evolve through generations, if necessary – changing their genetic code for a better adaptation.

The information processes at each level described above are very complex and difficult to understand, but more difficult to understand are the rules of interaction between the different levels. It may be that understanding the interaction through its modeling would be a key to understanding each level of information processing in a complex system and perhaps the system as a whole.

The talk describes evolving connectionist systems (ECOS) as a general paradigm for modeling evolving systems. ECOS integrate principles from different functional levels This paradigm is represented by several concrete models and their applications:

- Simple evolving neural networks and evolving neuro-fuzzy systems;
- Evolving interaction and gene regulatory networks;
- Evolving spiking neural networks, where brain-like spiking neuronal models are used to incrementally evolve large networks;
- Evolving neuro-genetic models, where evolving gene networks are integrated with evolving spiking neural networks to model brain data
- Quantum-inspired evolutionary computation and ECOS, where quantum principles such as superposition and entanglement, are used to globally optimize the features and the structure of an ECOS

The above ECOS are demonstrated on challenging problems from bioinformatics, brain study, medical decision support, adaptive multimodal information processing and biometrics, autonomous robot control, ecological risk prognosis, financial on-line prediction.

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