Title: Edge of Chaos: The Élan Vital of Emergent Phenomena

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Abstract: Complex phenomena may emerge in an open system if and only if some of its components may enter an operating regime, referred to as Local Activity, where, under suitable polarization, they feature small-signal amplification capability. This concept, known as the Local Activity Principle [1], may be interpreted as a new Law of Thermodynamics, envisaging a non-monotonic trend for the entropy as a function of time in non-isolated systems. The Local Activity Principle allows to explain the hidden mechanisms underlying emergent phenomena in the most disparate fields, from ecology, to biology, from physics and chemistry to electronics, allowing to predict the origin of complexity even in economics and in sociology. To cite but a couple of significant examples, only by applying the concepts from the Theory of Local Activity [2] may one gain a deep insight into the emergence of heterogeneous patterns in homogeneous media, what Turing [3] called Instability of the Homogeneous, and Ilya Prigogine [4] defined as Symmetry-Breaking Instabilities, as well as resolve the widely-known paradox, which mesmerized Stephen Smale [5], when he observed that coupling diffusively two identical cells, being silent on their own, allows to wake them up, exciting oscillatory modes in the resulting array.

This seminar presents the foundations of the Theory of Local Activity, with special emphasis on the Edge of Chaos, a subset of the Local Activity domain, in which a stable state hides in fact a high degree of excitability. The theoretical concepts are explained with illustrative examples from electronics, and biology [6]. Part of the lecture is devoted to the exploration of the fascinating dynamics of the Hodgkin and Huxley model [7], universally recognized as the most accurate mathematical description of a biological neuron. The Theory of Local Activity allows to shed light into the origin of the All-or-None spiking behavior of the neurons, a mystery which remained unsolved for 60 years [8]. Given that the sodium and potassium ion channels in the neuron axon membrane are locally-active memristors [9], the recent fabrication of solid-state devices with memristive fingerprints and small-signal amplification capability [10]-[12] opens new fascinating opportunities in the design of energy-efficient bio-inspired circuits, besides paving the way toward the realization of neuromorphic systems with closer resemblance to neural networks in the brain.

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