PHYSICAL MATHEMATICS SEMINAR

TOPIC: MINIMAL PATHS AND SIGNAL PROPAGATION IN A MODEL CORTEX

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ABSTRACT:

The cortex is the outer shell of the brain largely responsible for sensory and higher faculties, each of which relies on collective processing by a large number of neurons. Given the complexity of cortical function, a natural first step in a theoretical approach consists in delineating the constraints imposed upon 'macroscopic' processing, and in particular upon 'macroscopic' length and time scales, by 'microscopic' parameters such as local wiring and single-neuron dynamics.

Experiments demonstrate the existence of cortex-spanning paths of synaptically connected neurons with no more than about ten synapses. At the same time, only few long axons are available for the construction of such paths. Is a fine-tuned 'design' of cortical wiring necessary to resolve this paradox? Based on experimental data, we introduce a simple model of random ('non-designed') wiring, in which the probability of a synapse between two neurons decreases algebraically with the distance separating the two neurons. (This model can be viewed as a random graph embedded in a metric space, and serves as a natural interpolation between usual random graphs and locally connected lattices.) We then show that the number of synapses needed in a path spanning a distance r grows very slowly with r, as a power of $\ln(r)$. Thus, according to this model, paths that crisscross the cortex with a few synapses are present even in the absence of any 'design.'

Beyond purely structural questions, we turn to dynamics and ask how neural activity propagates in the (model) cortex, a question for which precise experimental data are again available. Here, the central conceptual difficulty lies in the requirement that the dynamics be at the same time sensitive to weak stimuli and stable with respect to stronger ones. We present preliminary results on the mechanisms of signal propagation and on its dependence upon 'microscopic' parameters, based on a crude model of single-neuron dynamics. To conclude, we mention a number of interesting questions suggested by our approach.

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TIME: 2:30 PM

LOCATION: Building 2, Room 338

Refreshments at 3:30 PM in Building 2, Room 349.

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