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SEMINAR ANNOUNCEMENT

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Neurons are trees! Should AI reckon with neuroscience?

Speaker
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Abstract: Biological nervous systems can be aptly described as directionally interconnected networks of neurons, each emitting binary signals (spikes) when the combined inputs received from other neurons exceeds a threshold. The connection (synapse) between two neurons changes its weight continuously in an activity-dependent manner, but its sign remains constant and is uniquely determined by the excitatory or inhibitory nature of the sending neuron. In this traditional "neural network" model, spatial-temporal neural patterns (which neurons spike and when) represent the content – memories, decisions, plans, etc. – whereas synaptic plasticity (weight changes) underlie learning. Another organizational principle of nervous systems is *not* well captured in AI models, namely that brain connectivity is extremely sparse: a typical mammalian neuron "only" contacts ~10k other neurons, i.e. less than 0.01% of the whole network even in small rodent brains. Moreover, connectivity is exquisitely specific and structurally plastic. In other words, (1) any given neuron has a limited pool of partners (typically ~100k or ~0.1% of all neurons) that it can possibly connect to, defining a crucial blueprint of that particular functional circuit (say, visual recognition vs. spatial navigation); and (2) which 10% of its 'partner pool' a neuron actually contacts varies over time based on their activity, providing a core substrate for memory storage and retrieval. An even less appreciated architectural principle of biological neural circuits is that the input and output lines of nerve cells are branching trees. This physical structure sets precise connectivity relations that translate into direct computational constraints. On the one hand, this explains certain cognitive aspects such as background information gated learning. On the other, it endows brains with the powerful ability to discriminate between causal associations and spurious co-occurrences, enabling one-shot learning. Artificial neural networks such as deep learning can emulate certain elements of such an organization by layered all-to-all connectivity and a majority of quasi-zero weights, but fail to capture other potentially essential aspects. Incorporating these neuroscience principles in next-gen machine learning designs could lead to technological and scientific breakthroughs.

Bio: Dr. Giorgio A. Ascoli received a Ph.D. in Biochemistry and Neuroscience from the Scuola Normale Superiore of Pisa, Italy, and continued his research at the National Institutes of Health in Bethesda, MD, to investigate protein structure and binding in the nervous system. He moved to the Krasnow Institute for Advanced Study at George Mason University in 1997, where he is Distinguished University Professor in the Bioengineering Department and Neuroscience Program. He is also founder and Director of the Center for Neural Informatics, Structures, & Plasticity, a transdisciplinary research group that includes biologists, physicists, psychologists, computer scientists, mathematicians, engineers, and physicians. Dr. Ascoli is founding Editor-in-Chief of the journal Neuroinformatics and an editorial board member of several other international journals. He serves on the advisory board of numerous scientific organizations and is Past President of the Potomac Chapter of the Society for Neuroscience. Dr. Ascoli contributed to the establishment of the fields of computational neuroanatomy and neuroinformatics. His own laboratory investigates the relationship between brain structure, activity, and function from the cellular to the circuit level. Dr. Ascoli received the 2012 Outstanding Faculty Award of the State Council for Higher Education of Virginia. His 2015 book "Trees of the Brain, Roots of the Mind" was published by MIT Press. He was elected AIMBE fellow in 2022 and won the Beck Presidential Medal for Excellence in Research and Scholarship as well as the NIH/FASEB DataWorks!Challenge 'Distinguished Achievement Award' in 2023.

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