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ECE Spring 2025 Colloquium Series

Friday, February 21, 2025
11:15 am ITE 336
(Refreshments in ITE 301 at 11 am)

Neuromorphic Computing: From Biological Inspiration to Energy-Efficient AI through Full-Stack Co-Design

Dr. Anup Das

As semiconductor technology approaches the physical limits of two-dimensional scaling, there is a growing need for specialized computing systems that can achieve dramatic energy savings through hardware-software co-design, particularly in artificial intelligence applications. This talk focuses on Spiking Neural Networks (SNNs) and neuromorphic computing as a promising path forward. We begin with fundamental neurobiological concepts underlying SNNs and their theoretical foundations that form the computational basis of neuromorphic systems. We then present our team's significant progress in designing large-scale neuromorphic systems, starting from the ground up with the implementation of biological neuron and synapse models using CMOS and non-volatile memories to create a many-core architecture with time-multiplexed interconnect. Our design also includes a novel memory organization and a programmable interconnect to support millions of neurons and synapses, along with a hardware-software interface designed to enhance system programmability.

Next, we introduce our comprehensive full-stack co-design methodology, which spans from computational neuroscience to novel devices and materials, demonstrating its effectiveness in improving system dependability and enabling on-chip learning. This approach is particularly crucial for developing AI systems capable of learning from continuous data streams and adapting their decisions in real-time, similar to biological systems. We demonstrate this through flexibility path planning applications, where a system can dynamically adapt its routing policies in response to changing conditions. The talk concludes by examining two emerging frontiers: dendritic computations for solving classical computer science problems like dynamic programming, and astrocyte-inspired designs for fault-tolerant computing. These developments highlight the potential impact of neuromorphic computing on creating robust, large-scale systems for robotics and other emerging applications that require parallel sensory processing and adaptive environmental responses, bringing us closer to the efficiency and adaptability of biological neural systems.

Bio:

Dr. Anup Das is an Associate Professor in the Department of Electrical and Computer Engineering at Drexel University, where he also serves as the Associate Department Head for Graduate Affairs. He received his Ph.D. in Embedded Systems from the National University of Singapore in 2014. Following his Ph.D., he completed postdoctoral research at the University of Southampton and worked as a senior researcher at IMEC in the Netherlands. His research interests focus on neuromorphic computing and architectural exploration. His research is supported via grants from federal agencies and industry, including the National Science Foundation CAREER Award (2020) and the Department of Energy CAREER Award (2021) on neuromorphic computing

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