

Expressivity, Stability, and Sustainability of Spiking Neural Networks

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Spiking neural networks (SNNs) are increasingly viewed as a promising foundation for next-generation artificial intelligence due to their event-driven computation, temporal processing capabilities, and potential for highly energy-efficient implementations on neuromorphic hardware. In contrast to the current trend of continuously scaling classical deep learning architectures, SNNs offer a biologically inspired and potentially more sustainable alternative for temporal and sequential learning tasks.

In this talk, we discuss recent advances on the mathematical foundations of recurrent spiking neural networks with a focus on expressivity, dynamics, and stability. We first study the approximation power of discrete-time and recurrent SNN architectures for sequence modeling and analyze under which conditions spike-based systems can efficiently encode complex temporal dependencies. We then investigate random spiking neural networks and show that they exhibit remarkable stability properties together with a surprisingly simple spectral structure, providing new insights into their trainability and dynamical behavior.

These results contribute to a deeper theoretical understanding of spike-based computation and highlight how mathematically principled SNN architectures may enable reliable and sustainable AI systems beyond the paradigm of pure scale.