



## SPECIAL SESSION

### SYSTEMS-THEORETIC APPROACHES TO LEARNING 4.0: FROM CLASSICAL TO QUANTUM NEURAL NETWORKS

The application of dynamical systems theory to enhance learning efficiency has emerged as a powerful paradigm, offering a principled foundation for understanding, designing, and optimizing intelligent systems. By providing a structured framework to analyze information flow, stability, and convergence, dynamical systems theory not only improves explainability and interpretability but also enables provable guarantees in both classical and quantum neural networks. This perspective bridges learning, optimization, and control, transforming training processes into well-posed control problems that enhance robustness, adaptability, and theoretical rigor. As advances in areas such as continuous-time modeling, physics-informed learning, and quantum machine learning continue to expand, dynamical systems theory provides the common language needed to unify these developments and guide the next generation of learning architectures.

The special session will focus on the role of systems theory in advancing learning algorithms, particularly within dynamic and evolving environments. It will showcase cutting-edge developments at the intersection of systems-theoretic principles and learning methodologies, emphasizing both foundational frameworks and real-world applications. Key topics include real-time and lifelong learning, continual and curriculum learning, federated and distributed learning architectures, adaptive control in deep neural networks, reinforcement learning in single- and multi-agent systems, adaptive dynamic programming for optimal control in evolving systems, physics-informed neural networks (PINNs), neural ordinary differential equations (Neural ODEs), quantum computing and quantum machine learning algorithms and their applications, and system identification techniques such as SINDy, Koopman operator theory, and other spectral/pseudo-spectral methods. Expert researchers in

these areas will present their findings, demonstrating how integrating systems theory enhances performance, robustness, and interpretability in modern learning-based approaches. Attendees will gain insights into the synergy between dynamical systems theory and both classical and quantum machine learning, uncovering how these domains complement and reinforce one another. This special session promises a comprehensive exploration of innovative approaches and their transformative potential for next generation learning paradigms.

#### SPECIAL SESSION ORGANIZERS

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#### IMPORTANT DATES

31 January: Paper submission deadline (23:59, anywhere on Earth)

15 March: Paper acceptance notification

15 April: Camera-ready papers