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Ensemble Reservoir Computing for Physical Systems

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Physical computing exploits unconventional physical substrates to overcome limitations such as the high energy consumption inherent in digital computation. However, intrinsic noise and temporal fluctuations (e.g., oscillations) generally deteriorate computational performance. Here, we propose ensemble reservoir computing (ERC), a novel framework that employs ensemble averaging of spatially multiplexed systems to achieve robust information processing despite noise and temporal fluctuations. First, we prove that ensemble averaging in ERC eliminates temporal fluctuations and noise from dynamical states under certain conditions, thereby restoring computational performance to its noise-free level. Next, we show that ERC not only removes the noise and fluctuations but also actively exploits the computational capabilities that conventional reservoir computing (RC) leaves unutilized. This computational enhancement is demonstrated across diverse dynamical systems (e.g., periodic, chaotic, and strange-nonchaotic systems), in which ERC outperforms conventional RC. Finally, using energy-efficient spin-torque oscillators (STOs), we demonstrate that ERC maintains high performance even under realistic conditions, in which noise and temporal fluctuations coexist: STOs with ERC achieved 99% accuracy on an error detection test, where conventional STO reservoir with linear regression only shows a chance level performance, highlighting ERC's robustness and performance gains for physical systems.

Keywords: Reservoir Computing, Nonlinear dynamics, Machine learning, Ensemble average, Spin-torque oscillator

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