Te Photonic Synapses for Physical Reservoir Computing

Hongseok Oh
Department of Physics, Integrative Institute of Basic Sciences, and Department of Intelligent Semiconductors, Soongsil University, Seoul, South Korea

E-mail: hoh@ssu.ac.kr

Physical reservoir computing (PRC) is a new computing framework for energy-efficient machine learning, especially for processing time-series data. Usually, such data is processed using a recurrent neural network (RNN)-based approach, which is powerful but computationally intensive. An alternative approach is reservoir computing (RC). In RC, a reservoir—a set of fixed, randomly connected perceptrons—is driven by the input signal, and only the connections between its readout nodes and output nodes are trained. This approach can significantly reduce computational costs while maintaining comparable or superior performance in learning dynamical systems.[1]

PRC is similar to RC but replaces the digital reservoir with a physical system. Here, the reservoir requires no computational cost during operation, ultimately enabling energy-efficient AI. Any nonlinear physical system with fading memory can serve as a PRC reservoir, including electronic circuits, mechanical systems, and even water surfaces.[2] Recently, PRC systems based on one or a few (opto)electronic devices exhibiting a fading memory effect—where the latest signal contributes most to the device state—have emerged as practical solutions due to their simplicity and compatibility with existing electronics.[3]

In this presentation, we introduce our research progress on PRC utilizing artificial synaptic devices, including tellurium thin-film-based photonic synapses.[4] Our system demonstrated strong performance in tasks such as classification of grayscale handwritten digits and prediction of nonlinear dynamical equations. We also investigate the device physics underlying nonlinear and fading memory characteristics. Our research can enable energy-efficient AI for learning and processing dynamic systems, such as speech, motion, and biological signals.

Reference

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