Canadian Association of Physicists
Association canadienne des physiciens et physiciennes

Contribution ID: **4446** Type: **Oral (Non-Student) / Orale (non-étudiant(e))**

Catch-22s of Reservoir Computing

Monday 27 May 2024 14:15 (15 minutes)

Reservoir Computing (RC) is a simple and efficient machine learning (ML) framework for learning and forecasting the dynamics of nonlinear systems. Despite RC's remarkable successes—for example, learning chaotic dynamics—much remains unknown about its ability to learn the behavior of complex systems from data (and data alone). In particular, real physical systems typically possess multiple stable states—some desirable, others undesirable. Distinguishing which initial conditions go to "good" vs. "bad" states is a fundamental challenge with applications as diverse as power grid resilience, ecosystem management, and cell reprogramming. As such, this problem of *basin prediction* is a key test RC and other ML models must pass before they can be trusted as proxies of large, unknown nonlinear systems.

Here, we show that there exist even simple physical systems which leading RC frameworks utterly fail to learn unless key information about the underlying dynamics is already known. First, we show that predicting the fate of a given initial condition using traditional RC models relies critically on sufficient model initialization. Specifically, one must first "warm-up" the model with almost the entire transient trajectory from the real system, by which point forecasts are moot. Accordingly, we turn to Next-Generation Reservoir Computing (NGRC), a recently-introduced variant of RC that mitigates this requirement. We show that when NGRC models possess the exact nonlinear terms in the original dynamical laws, they can reliably reconstruct intricate and high-dimensional basins of attraction, even with minimal training data (e.g., a single transient trajectory). Yet with any features short of the exact nonlinearities, their predictions can be no better than chance. Our results highlight the challenges faced by data-driven methods in learning the dynamics of multistable physical systems and suggest potential avenues to make these approaches more robust.

Keyword-1

complex systems

Keyword-2

nonlinear dynamics

Keyword-3

machine learning

Authors: Dr ZHANG, Yuanzhao (Santa Fe Institute); Prof. CORNELIUS, Sean (Toronto Metropolitan University)

Presenter: Prof. CORNELIUS, Sean (Toronto Metropolitan University)

Session Classification: (DAPI) M2-6 Applied Physics I | Physique appliquée I (DPAE)

Track Classification: Technical Sessions / Sessions techniques: Applied Physics and Instrumentation / Physique appliquée et de l'instrumentation (DAPI / DPAI)