Harnessing the universality of bifurcations to improve early warning signals of tipping points through deep learning

Abstract: Many early warning indicators are based on mathematical theory that discards higher-order terms of the equations that are either too hard to solve by hand, or too hard to detect through statistical measures. However, these higher-order terms leave signatures in time series that may provide information about an upcoming tipping point. Deep learning algorithms excel at detecting subtle features in temporal data but must be trained on very large amounts of data from the study system, which we often lack for many experimental or field-based study systems. However, the need for system-specific data could be circumvented by training the algorithms on a library of random dynamical systems passing through tipping points. This would exploit the ‘universality’ of tipping points that can make their features so similar across diverse systems. Hence, training a deep learning algorithm on a library of random ordinary differential equations, phase transition models, or bifurcation normal forms could—in principle—provide early warning signals of upcoming regime shifts as well as provide information about what kind of state lies beyond the tipping point, all without the need for simulated or empirical data specific to the system. This talk will illustrate applications of this approach to both simulated and empirical tipping points in systems including temporal transitions in paleo-climate shifts, thermoacoustics, lake sedimentation, and social shifts, and spatio-temporal phase transitions in ecological, physical, and climate systems.