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Predicting Critical Transitions in Complex Dynamical Systems

Complex dynamical systems, ranging from physiological diseases to financial markets and Earth's climate, often exhibit radical changes in their behavior following small changes in their parameters. In physiology, there are spontaneous system failures such as asthma attacks and epileptic seizures; in ecology, sudden collapses of wildlife populations. Data indicate Earth's climate has swung between a 'snowball' and 'tropical' Earth, occurring rapidly on a geologic scale. The common theme in these systems is a drastic change in the behavior due to potentially imperceptible changes in the conditions or parameters. Even with robust mathematical models, predicting such critical transitions prior to their occurrence is notoriously difficult. Recently, a topological approach has been developed which coarsely characterizes the dynamics of these systems. Our research builds upon this framework, using machine learning algorithms in combination with rigorous theorems regarding the underlying dynamics to construct a database which detects and catalogs critical transitions. Exploiting state-of-the-art paradigms in parallel computing, we are making this database efficiently computable for increasingly complex systems.