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Data Analysis Methods Based on Dynamical Systems Theory: Unicorns, Dimensions and Higher-Order Hidden Drivers

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The presentation highlights several newly developed data-analysis methods based on dynamical systems theory. We show that attractor reconstruction based on Takens' theorem allows us not only to estimate the fractal dimension and Lyapunov exponents of a system, but also to identify a wide variety of events and interactions.

First, we introduce a novel anomaly-detection method for identifying unique events, which we call unicorns, in continuous time series. Dynamical systems theory provides a framework for defining the uniqueness of a state even in real-valued time series. We demonstrate the method on various datasets, ranging from ECG signals and gravitational waves to stock market indices.

Second, we introduce the principle of Dimensional Causality (DC) and a method that can identify directed causal interactions and distinguish them from bidirectional connections and interactions mediated by hidden common drivers. We show that hidden common drivers form a rich hierarchy in multivariate time series and introduce a method for uncovering this hidden structure.

Finally, we demonstrate that it is possible not only to detect the existence of a hidden common driver but also to reconstruct its time series, up to topological equivalence.