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Editorial: Recurrence Analysis of Complex Systems Dynamics

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Editorial on the Research Topic

Recurrence Analysis of Complex Systems Dynamics

In the last three decades, recurrence plot (RP) and quantification (RQA) techniques have become important research tools in the analysis of short, noisy, and non-stationary data. Theoretical work on RPs has reached considerable maturity, and the method's popularity in recent years continues to increase due to a large number of practical RP/RQA applications in diverse areas such as physiology, human cognition, engineering, or earth and climate sciences.

This Frontiers Research Topic presents novel advances and new applications of recurrence methods for analyzing complex systems in multidisciplinary fields. For instance, such complex systems may represent spatial systems, whose spatiotemporal dynamics may exhibit recurrences in localized regions only. To analyze the recurrent structure in such local areas, Bonizzi et al. show how the critical regions can first be identified prior to analyzing the local recurrent structures therein. Application to experimental cardiac heart rate data demonstrates the power of the method.

To better understand complex systems and the origin of recurrences, it is important to understand the coupling between sub-units in complex systems. Tolston et al. focus their work on detecting the coupling strength in nonlinear systems. To this end, they compare the nonlinear recurrence analysis with linear cross-correlation analysis and evaluate them using simulated data and experimental interpersonal dynamics data. The authors show that cross-correlation analysis may perform comparably well as recurrence analysis methods, while the linear method is computationally more efficient.

Typically, recurrence analysis is applied to digitized sampled data obtained from an analog complex system. Conversely, Hasselmann and Bosman analyze self-reports of human experience, that are written consecutively over a long series of days. The authors discuss formal, practical, and theoretical issues of such data and introduce the concept of recurrence networks weighted by recurrence time. They conclude that their complex systems approach to analyzing self-reports of human experience is preferable over conventional statistical analysis.

This latter study shows that recurrence analysis is able to extract knowledge from non-standard data sets, e.g., by quantifying cognitive behavior. As an additional example, Angus reviews recurrence analysis techniques applied to human communication data. He concludes that recurrence analysis is a promising tool to analyze human discourse data. Moreover, cognitive behavior is revealed in written text as shown by Lyby et al. The authors detect changes in distress symptoms in cancer patients by recurrence analysis, which points to the patients' cognitive restructuring.

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In medicine, recurrence analysis provides some deeper insights into the underlying physiological dynamics during cognitive requests. For instance, the heart-rate regulatory system is known to form a complex network, which exhibits recurrent dynamics. Dimitriev et al. have studied the heart rate recurrences during mental stress and identified mental workload by recurrence variables.

Even in resting state, i.e., in the absence of cognitive tasks, physiological data exhibit recurrent structures. beim Graben et al. have identified a large number of recurrent metastable states in fMRI-data by recurrence analysis. These states are approached, maintained, and exited subsequently in the course of time, which demonstrates that the brain is active although no cognitive task is present.

Besides cognitive and physiological dynamics in humans, other natural complex systems exhibit recurrent structures as well. Salas et al. reveal the relationship between El Niño-Southern Oscillation and monthly hydrological anomalies of rainfall and stream flows in Colombia by recurrence analysis techniques. The authors show that the hydrological dynamics of Colombia exhibits generalized synchronization with the El Niño-Southern Oscillations.

AUTHOR CONTRIBUTIONS

AH has conceived the structure of the Editorial and all authors have written the Editorial.

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