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About the section *Complexity*

The section on Complexity focuses on original and new research results in systems dynamics. Manuscripts on complex systems, nonlinearity, chaos and fractional dynamics from the thermodynamics or information processing perspectives are solicited. We welcome submissions addressing novel issues, as well as those on more specific topics, illustrating the broad impact of entropy-based techniques in complexity, nonlinearity and fractionality.

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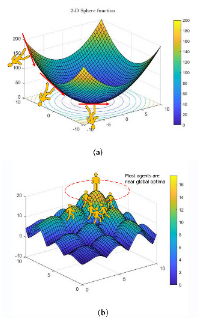
Featured Papers

DOI:10.3390/e23030297

Why Do Big Data and Machine Learning Entail the Fractional Dynamics?

Authors: Haoyu Niu, Yangquan Chen and Bruce J. West

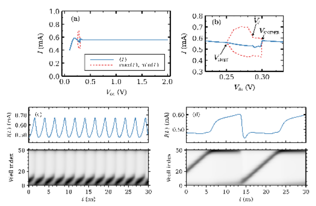


Abstract: Fractional-order calculus is about the differentiation and integration of non-integer orders. Fractional calculus (FC) is based on fractional-order thinking (FOT) and has been shown to help us to understand complex systems better, improve the processing of complex signals, enhance the control of complex systems, increase the performance of optimization, and even extend the enabling of the potential for creativity. In this article, the authors discuss the fractional dynamics, FOT and rich fractional stochastic models. First, the use of fractional dynamics in big data analytics for quantifying big data variability stemming from the generation of complex systems is justified. Second, we show why fractional dynamics is needed in machine learning and optimal randomness when asking: "is there a more optimal way to optimize?". Third, an optimal randomness case study for a stochastic configuration network (SCN) machine-learning method with heavy-tailed distributions is discussed. Finally, views on big data and (physics-informed) machine learning with fractional dynamics for future research are presented with concluding remarks.

DOI:10.3390/e24121702

Hyperchaos, Intermittency, Noise and Disorder in Modified Semiconductor Superlattices

Authors: Luis L. Bonilla, Manuel Carretero and Emanuel Mompó

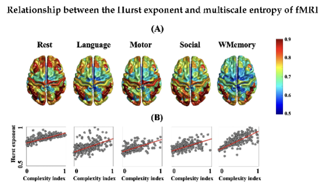


Abstract: Weakly coupled semiconductor superlattices under DC voltage bias are nonlinear systems with many degrees of freedom whose nonlinearity is due to sequential tunneling of electrons. They may exhibit spontaneous chaos at room temperature and act as fast physical random number generator devices. Here we present a general sequential transport model with different voltage drops at quantum wells and barriers that includes noise and fluctuations due to the superlattice epitaxial growth. Excitability and oscillations of the current in superlattices with identical periods are due to nucleation and motion of charge dipole waves that form at the emitter contact when the current drops below a critical value. Insertion of wider wells increases superlattice excitability by allowing wave nucleation at the modified wells and more complex dynamics. Then hyperchaos and different types of intermittent chaos are possible on extended DC voltage ranges. Intrinsic shot and thermal noises and external noises produce minor effects on chaotic attractors. However, random disorder due to growth fluctuations may suppress any regular or chaotic current oscillations. Numerical simulations show that more than 70% of samples remain chaotic when the standard deviation of their fluctuations due to epitaxial growth is below 0.024 nm (10% of a single monolayer) whereas for 0.015 nm disorder suppresses chaos.

DOI:10.3390/e24081148

On the Spatial Distribution of Temporal Complexity in Resting State and Task Functional MRI

Authors: Amir Omidvarnia, Raphaël Liégeois, Enrico Amico, Maria Giulia Preti, Andrew Zalesky and Dimitri Van De Ville

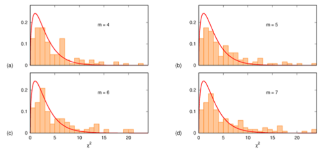


Abstract: Measuring the temporal complexity of functional MRI (fMRI) time series is one approach to assess how brain activity changes over time. In fact, hemodynamic response of the brain is known to exhibit critical behaviour at the edge between order and disorder. In this study, we aimed to revisit the spatial distribution of temporal complexity in resting state and task fMRI of 100 unrelated subjects from the Human Connectome Project (HCP). First, we compared two common choices of complexity measures, i.e., Hurst exponent and multiscale entropy, and observed a high spatial similarity between them. Second, we considered four tasks in the HCP dataset (Language, Motor, Social, and Working Memory) and found high task-specific complexity, even when the task design was regressed out. For the significance thresholding of brain complexity maps, we used a statistical framework based on graph signal processing that incorporates the structural connectome to develop the null distributions of fMRI complexity. The results suggest that the frontoparietal, dorsal attention, visual, and default mode networks represent stronger complex behaviour than the rest of the brain, irrespective of the task engagement. In sum, the findings support the hypothesis of fMRI temporal complexity as a marker of cognition.

DOI:10.3390/e24070853

Estimating Permutation Entropy Variability via Surrogate Time Series

Authors: Leonardo Ricci and Alessio Perinelli



Abstract: In the last decade permutation entropy (PE) has become a popular tool to analyze the degree of randomn ess within a time series. In typical applications, changes in the dynamics of a source are inferred by observing changes of PE computed on different time series generated by that source. However, most works neglect the crucial question related to the statistical significance of these changes. The main reason probably lies in the difficulty of assessing, out of a single time series, not only the PE value, but also its uncertainty. In this paper we propose a method to overcome this issue by using generation of surrogate time series. The analysis conducted on both synthetic and experimental time series shows the reliability of the approach, which can be promptly implemented by means of widely available numerical tools. The method is computationally affordable for a broad range of users.