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Nonlinear Time Series Analysis in Physics: A Qualitative Perspective

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Abstract: *This study investigates the qualitative aspects of nonlinear time series in physical systems, emphasizing the role of nonlinearity, noise, and uncertainty in shaping system dynamics. By employing Qualitative Nonlinear Time Series Analysis (QLNTSA), the research examines attractor reconstruction, deterministic chaos, recurrence properties, and bifurcation phenomena to uncover hidden structures and critical transitions. The methodology highlights the relevance of qualitative indicators for model construction, validation, and predictability assessment, offering insights beyond the limitations of linear and purely quantitative approaches. Case studies in climate dynamics, turbulence, and material failure illustrate the practical utility of QLNTSA, demonstrating its capacity to inform physically faithful, parsimonious, and robust modelling of complex systems. The findings emphasize the importance of integrating qualitative analysis into physical modelling to capture essential dynamical behavior and enhance predictive understanding in the presence of noise and uncertainty.*

Keywords: Nonlinear Time Series, Qualitative Analysis, Attractor Reconstruction, Deterministic Chaos, Recurrence Quantification, Bifurcation, Predictability, Noise and Uncertainty, Physical Modelling, Complex Systems

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