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Identifying shrimps in continuous dynamical systems using recurrence-based methods

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The identification of specific periodic islands (so-called shrimps) in the two-dimensional parameter space of certain complex systems has recently attracted considerable interest. While for discrete systems, a discrimination between periodic and chaotic windows can be easily made based on the maximum Lyapunov exponent of the system, this remains a challenging task for continuous systems, especially if only short time series are available (e.g., in case of experimental data).

In this work, we demonstrate that nonlinear measures based on recurrence plots obtained from individual trajectories provide a practicable alternative for automatically distinguishing periodic and chaotic dynamics and, hence, numerically detecting shrimps. Traditional diagonal line-based measures of recurrence quantification analysis as well as measures from complex network theory are shown to allow an excellent classification of periodic and chaotic behavior in parameter space. Average path length and clustering coefficient of the resulting recurrence networks are found to be particularly powerful discriminatory statistics for the identification of shrimps.

Our results are illustrated in detail for the Roessler system. Implications for detecting bifurcations between regular and chaotic dynamics in other models of geophysical phenomena (such as the Lorenz-84 system) are discussed.