Adaptive Calculation of Lyapunov Exponents from Time Series Observations of Chaotic Time Varying Dynamical Systems

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Abstract: This paper considers the adaptive computation of Lyapunov Exponents (LEs) from time series observations based on the Jacobian approach. It is shown that the LEs can be calculated adaptively in the face of parameter variations of the dynamical system. This is achieved by formulating the regression vector properly and adaptively updating the parameter vector using the Recursive Least-Squares principles. In cases where the structure of the dynamical system is unknown, a general non-linear regression vector for local model fitting based on a locally adaptive algorithm is presented. In this case, the Recursive Least-Squares method is used to fit a suitable local model, then by state space realization in canonical form, the Jacobian matrices are computed which are used in the QR factorization method to calculate the LEs. This method essentially relies on recursive model estimation based on output data. Hence, this on-line dynamical modeling of the process will circumvent the computations typically required in the reconstructed state space. Therefore, difficulties such as the problem of large number of data and high computational effort and time are avoided. Finally, simulation results are presented for some well-known and practical chaotic systems with time varying parameters to show the effectiveness of the proposed adaptive methodology.

Keywords: *Time series; Lyapunov exponents; chaos; time varying chaotic systems; Jacobian matrices; QR factorization; non-linear regressive.*

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