Locating transition behaviour in nonlinear signals

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Abstract. In this paper we compare results obtained in the nonlinear Recurrence Quantification Analysis (RQA) of time series of different dynamic systems (i.e. i) financial time series [1-2], ii) heart rate (HR) time series [3-5] and iii) acoustic emissions [6])

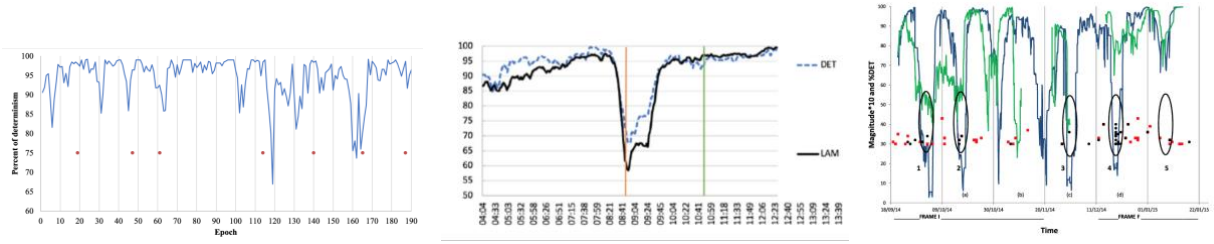
The RQA is fully unconstrained by stationarity limitations, does not require lengthy data streams, and is focused on quantifying the correlation structure of the investigated dynamics. These factors make this analysis method well-suited for locating transitions in signals.

Introduction

A crisis or a critical transition of systems is oftentimes preceded by a substantial increase in both internal correlation and variance. This appears across a wide range of environments spanning from physiology to ecology and finance [7].

Results and discussion

In this work, we show that, in three very different contexts of application, RQA approach drives potentially valuable results. i) Orlando and Zimatore (2018)[1], confirm that RQA may be used for detecting structural changes of a given time series as well as for its characterization and that recurrence plots (RPs) may furnish insights when comparing real-world economic data with simulations used to model financial crises and Black Swans [2]; ii) in physiology, RQA is commonly used to characterize the complexity of HR time series, when, during physical activity, the nonlinear analysis of HR time series is monitored [3] and is a valid alternative to assess metabolic thresholds [4-5]. The implication is that an automated determination method can be implemented to evaluate fitness levels as well as for planning and monitoring training; iii) Acoustic emissions (AE) recorded from crustal rocks by piezoelectric sensors [6] are also a field of application of RQA. Since these emissions occur a few days before major seismic events, the percent of determinism derived from RQA on AE decreases. This suggests the applicability of RQA as an earthquake precursor detection method. However, it is necessary to observe that the coupling of the cardio-respiratory system, where the autonomic nervous system (ASN) modulation can be considered a sort of active feedback mechanism, is more similar to the control of economic fluctuation when exogenous shocks occurred; on the contrary, the self-organization of many interacting components as tectonic plates and faults that contribute to the geocomplexity it is mainly an internal mechanism of the system [8]. In all three systems the accuracy of the location of the transition depends on the sampling time of the time series and on the width of the epoch chosen for the analysis.



a) b) c)

Figure 1: Percent of determinism by epoch-by-epoch RQA calculated from a) financial time series and crisis (dots)[1]; b) heart rate time series during incremental physical exercise [6]; c) acoustic emission time series acquired in Orchi (blue line) and Savoia (green line) stations and seismic events (squares and dots) [7]).

References

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