Identification of complex processes based on analysis of phase space structures

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Abstract

The problem of investigation of temporal and/or spatial behavior of highly nonlinear or complex natural systems is of old fundamental scientific interest. At the same time it becomes presently well understood that identification of dynamics of processes in complex natural systems, through their qualitative description and quantitative evaluation, is far from a purely academic question and has an essential practical importance. This is quite understandable as far as systems with complex dynamics are abound in nature and examples can be found in very different areas such as medicine and biology (rhythms, physiological cycles, epidemics), atmosphere (climate and weather change), geophysics (tides, earthquakes, volcanoes, magnetic field variations), economy (financial markets behavior, exchange rates), engineering (friction, fracturing), communication (electronic networks, Internet packet dynamics) etc.

The past two decades of research on qualitative and especially quantitative investigations of dynamics of real processes of different origin, though brought a significant progress in the understanding the behavior of natural processes, at the same time reveal also serious related drawbacks. This is why exhaustive investigation of dynamical properties of complex processes for scientific, engineering or practical purposes is now recognized as one of the main scientific challenges. Much scientific attention is paid to elaboration of appropriate methods aiming to resolution of the problem of measuring the complexity of both global and local dynamical behaviors from the observed data sets - time series.

The lecture presents the short overview of the modern methods of qualitative and quantitative evaluation of dynamics of complex natural processes such as calculation of Lyapunov exponents and fractal dimensions, recurrence plots and recurrence quantification analysis; other related methods are also described. The traditional approach to studying nonlinear dynamical behavior is to reconstruct from observation scalar time series phase space graph how the systems behavior changes over time. Therefore, we mainly focus on methods of identification and quantitative evaluation of complex dynamics that based on the testing of evolutionary and geometric properties of phase space graphs or

images of investigated complex dynamics.

As practical examples of application of mentioned nonlinear methods for identification of complex natural processes, our results on medical, geophysical, atmospheric, linguistic, stick-slip time series will be presented. It will be shown how useful can be modern phase space structure testing methods in identification of dynamics of complex natural processes from different field and laboratory experiments when we deal with finite-length noisy measured data sets.