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PROGNOSIS OF QUALITATIVE BEHAVIOR OF A DYNAMIC SYSTEM BY THE OBSERVED CHAOTIC TIME SERIES

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An approach to the long-term prognosis of qualitative behavior of a dynamic system (DS) is proposed, which is based on the nonlinear-dynamical analysis of a weakly nonstationary chaotic time series (TS). A method for constructing prognostic models using the observed evolution of a single dynamic variable is described, which employs the proposed approach for prediction of bifurcations of low-dimensional DSs. The method is applied to analyze the TS generated by the Rössler system and the system of equations modeling photochemical processes in the mesosphere. The analysis is performed for a TS calculated in the case of a slow variation in the control parameter of the system. The duration of the "observed" TS is limited such that the system demonstrates only one, chaotic, type of behavior without any bifurcations during the observed TS. The proposed algorithm allows us to predict correctly the bifurcation sequences for both systems at times much longer than the duration of the observed TS, to point out the expected instants of specific bifurcation transitions and accuracy of determining these instants, as well as to calculate the probabilities to observe the predicted regimes of the system's behavior at the time of interest.

1. INTRODUCTION

1.1. Methods of analysis of chaotic time series (TS) were developed in the recent twenty years in several hundred works (see, e.g., the book [1] and the references therein). Such an analysis is aimed at reconstruction of the phase space in which the observed system evolves and finding the characteristics of this evolution, such as the range of Lyapunov exponents and attractor dimensions. These studies are based on the Takens theorems [2] stating that the topological structure of a phase-space region and the above-mentioned quantitative characteristics can be reconstructed rigorously using the corresponding single infinite and stationary observable. In real life, however, the observed TS are always finite in time, which leads to errors in reconstructing an attractor and in determining its characteristics. Nevertheless, available algorithms allow one to retrieve quite accurately the dynamic properties of a broad class of systems using a finite stationary [1] time series. In particular, it is possible to make a quantitative ("local") prognosis, namely, to predict future evolution of the system within the basin of the observed chaotic attractor [3].

1.2. In many cases, the observed dynamic process is nonstationary.[2] It was shown in [8] that the Takens theorems can be extended to include the case of nonstationary TSs, i.e., in principle, nonstationarity does not impose principal constraints on reconstructing the observed attractor.[3] This paper is aimed at

[1] With an accuracy of finite duration of the time series.

[2] Several methods for revealing the nonstationarity of a TS were proposed (see, e.g., [4–7]. The algorithm described in this paper includes one more way to diagnose nonstationarity.

[3] Or attractors if bifurcations occur during the observations. One method of estimating the characteristics of observed attractors was described, e.g., in [7].

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