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Stochastic sensitivity of the closed invariant curves for discrete-time systems

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Abstract

Discrete-time nonlinear systems with invariant closed smooth curves forced by random disturbances are studied. Constructive approximations of the corresponding probabilistic distributions near these curves based on stochastic sensitivity functions are suggested. For stochastic sensitivity matrix functions, the linear equations are obtained. For descriptive visualization of this technique, a method of confidence domains is used. The elaborated theory is illustrated on the example of the two-dimensional model.

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Keywords. Discrete system; Stochastic disturbances; Invariant curves; Stochastic sensitivity functions

1 Introduction

Random disturbances in nonlinear systems can generate various phenomena such as noise-induced transitions [1, 2], stochastic resonance [3, 4, 5], noise-induced excitement [6], noise-induced order [7, 8] and chaos [9, 10]. Initially, these phenomena have been found by direct numerical simulation of the solutions of nonlinear stochastic systems. Nowadays, for profound understanding of the underlying probabilistic mechanisms of these phenomena, the analytical methods are required.

A probabilistic analysis of the noise-induced phenomena based on the investigation of corresponding stochastic attractors is a challenging problem of the modern nonlinear dynamics. An exhaustive mathematical description of stochastic attractors for continuous-time systems is given by the Kolmogorov-Fokker-Planck equation [11]. For discrete-time systems, such description is given by the Frobenius-Perron integral equation [12, 13]. However, a direct using of these equations is very difficult technically even for the simplest cases. To avoid this complexity, various asymptotics and approximations can be considered [14, 15, 16].

In this paper, we focus on the study of the stochastically forced discrete-time systems. Even in one-dimensional deterministic case, such systems exhibit a wide variety of regimes