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PARAMETER DETERMINATION OF DYNAMICAL SYSTEMS USING CHAOTIC ORBITS

Abstract

The goal of this paper is to show that chaotic orbits of a dynamical system are advantageous (compared with regular ones) to determine the characteristic parameters of the system, and to give an estimate about the behaviour of the error as a function of the number of observations.

Consider, for instance, the problem of determining the physical characteristics of a celestial body placing one or more satellites in orbit around it. In this paper, we have used as reference example a spacecraft following different kinds of orbits around a binary system, where the larger primary is modeled as a tri-axial ellipsoid with constant density, and the smaller one as point mass sphere; the purpose is to determine the four parameters that define the binary system: the mass parameter μ, and the length of the ellipsoid axes: a, b, and c.

There are several ways to measure the "degree" of chaoticity of an orbit (its sensitivity to initial conditions and parameters), most of them based on the computation and use of Lyapunov exponents, or a set of basic frequencies determined by means of accurate Fourier analysis. In this study we have used two: finite time Lyapunov exponents and Pesin's entropy, which give similar and reliable values providing redundancy and robustness to the procedure.

For the determination of parameters we have developed a procedure, based on least squares approximations, that determines how much the uncertainty in the parameter determination of the system decreases as more measurements are taken. There is a strong correlation between the error in the parameter determination and the length of the trajectory, obviously, the error is reduced as more measurements are taken. If N denotes the number of measurements, for a regular orbit the uncertainty in the determination behaves as $N^{-1/2}$. For chaotic orbits we have found scalings of up to N^{-3}, which are better than the scalings found in previous works for simple systems, which were between N^{-1} and N^{-2}.