Numerical analysis and forecasting nonlinear dynamics of chaotic systems using a chaos theory methods (application to neurophysiology and econophysics)

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Nonlinear modeling of chaotic processes is based on the concept of a compact geometric attractor, which evolve with measurements. We present an advanced approach to analysis and forecasting nonlinear dynamics of chaotic systems, based on conceptions of chaos and recurrence plots method. As example, a few geophysical systems are studied. Since the orbit is continuously rolled on itself due to the action of dissipative forces and the nonlinear part of the dynamics can be found in the neighborhood of any point of the orbit y (n) other points of the orbit yr(n), r = 1, 2, ..., N, that arrive neighborhood y (n) in a completely different times than n. Then you can build different types of interpolation functions that take into account all the neighborhoods of the phase space, and explain how these neighborhoods evolve from y (n) to a whole family of points about y(n+1). Use of the information about the phase space in the simulation of the evolution of the physical process in time can be considered as a major innovation in the modeling of chaotic processes. This concept can be achieved by constructing a parameterized non-linear function F (x, a), which transform y (n) to y(n+1) = F[y(n),a], and then use different criteria for determining the parameters a . Further, since there is the notion of local neighborhoods, we can create a model of the process occurring in the neighborhood, at the neighborhood and by combining together these local models to construct a global non-linear model to describe most of the structure of the attractor. In finding the coefficients of a there is a possible encounter a few problems, which at first glance seem to be purely technical, but are related to the nonlinear properties of the system. If the low-dimensional chaotic system, the data that can be used for fitting, normally cover any available locally dimension, but only a certain subspace. Therefore, the linear system of equations to be solved by fitting is “ill-conditioned”. However, if the system noise is present, the equations formally are not ill-conditioned, but part of the decision relating to the "direction" of noise points to the future, is not having a sense. As an application we employ a variety of techniques (in versions [1-3]) for characterizing dynamics of the nonlinear econophysical and neuro-physiological systems identifying the presence of chaotic elements. As example, let us underline that an ability to provide interaction between the different areas of the brain by using a multichannel electro- entselophalogrmams helps determine the location of the foci of abnormal activity in brain of patients with epilepsy. Many diseases of the brain, including epilepsy, Parkinson's disease, are associated with abnormal synchronization large groups of neurons in the brain. Particular attention is paid to a non-linear signals as obvious is a typicality of a chaotic behavior of nonlinear systems. To analyze measured time histories of the neuro-physiological system responses with the use of the recurrence plots method the phase space of these systems was reconstructed by delay embedding. The mutual information approach, correlation integral analysis, false nearest neighbour algorithm, Lyapunov exponent’s analysis, and surrogate data method are used for comprehensive characterization. The correlation dimension method provided a low fractal-dimensional attractor thus suggesting a possibility of the existence of chaotic behaviour. Statistical significance of the results was confirmed by testing for a surrogate data. We also present the concrete numerical results regarding the ensembles fluctuations of spontaneous Parkinsonian tremor of a few patients.

References

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