World Academy of Science, Engineering and Technology
International Journal of Mechanical and Materials Engineering
Vol:12, No:08, 2018

Generalized Synchronization in Systems with a Complex Topology of Attractor

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Abstract : Generalized synchronization is one of the most intricate phenomena in nonlinear science. It can be observed both in systems with a unidirectional and mutual type of coupling including the complex networks. Such a phenomenon has a number of practical applications, for example, for the secure information transmission through the communication channel with a high level of noise. Known methods for the secure information transmission needs in the increase of the privacy of data transmission that arises a question about the observation of such phenomenon in systems with a complex topology of chaotic attractor possessing two or more positive Lyapunov exponents. The present report is devoted to the study of such phenomenon in two unidirectionally and mutually coupled dynamical systems being in chaotic (with one positive Lyapunov exponent) and hyperchaotic (with two or more positive Lyapunov exponents) regimes, respectively. As the systems under study, we have used two mutually coupled modified Lorenz oscillators and two unidirectionally coupled time-delayed generators. We have shown that in both cases the generalized synchronization regime can be detected by means of the calculation of Lyapunov exponents and phase tube approach whereas due to the complex topology of attractor the nearest neighbor method is misleading. Moreover, the auxiliary system approaches being the standard method for the synchronous regime observation, for the mutual type of coupling results in incorrect results. To calculate the Lyapunov exponents in time-delayed systems we have proposed an approach based on the modification of Gram-Schmidt orthogonalization procedure in the context of the time-delayed system. We have studied in detail the mechanisms resulting in the generalized synchronization regime onset paying a great attention to the field where one positive Lyapunov exponent has already been become negative whereas the second one is a positive yet. We have found the intermittency here and studied its characteristics. To detect the laminar phase lengths the method based on a calculation of local Lyapunov exponents has been proposed. The efficiency of the method has been verified using the example of two unidirectionally coupled Rössler systems being in the band chaos regime. We have revealed the main characteristics of intermittency, i.e. the distribution of the laminar phase lengths and dependence of the mean length of the laminar phases on the criticality parameter, for all systems studied in the report. This work has been supported by the Russian President's Council grant for the state support of young Russian scientists (project MK-531.2018.2).
Keywords : complex topology of attractor, generalized synchronization, hyperchaos, Lyapunov exponents
Conference Title : ICSNDD 2018 : International Conference on Structural Nonlinear Dynamics and Diagnosis
Conference Location : Barcelona, Spain
Conference Dates : August 20-21, 2018