The Center for Control, Dynamical Systems, and Computation
University of California at Santa Barbara
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Presents

Information Technology Applications of Statistical Nonlinear Dynamics

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Abstract:

Recent developments have highlighted that a statistical approach may greatly benefit the study of discrete-time chaotic system (maps). In this case, in fact, critical dependence on initial condition, probably the widest known feature of chaotic behavior, prevents the study of single trajectories from giving information which are globally valid. On the contrary, a highly regular behaviour exists for the distribution of the points describing the evolution of a set of trajectories at each iteration step. We will formalize this approach by introducing a theoretical framework that is based on the classical Perron-Frobenius Operator (PFO), which accounts for the evolution of the probability densities describing the distribution of the system state variable at each iteration step. We then focus on Piecewise Affine Markov (PWAM) maps, and by specializing the set of theoretical tools that we have introduced, we will show how such maps can be considered as stochastic processes generators with tunable statistical features. Such a well-developed theoretical framework can be applied to several topics related to IT, such as

1 - Spreading sequence design for Direct Sequences Code Division
Multiple Access (DS-CDMA)
2 - EMI (Electro-Magnetic Interference) reduction
3- True random number generation

Among them, we will mainly focus on the optimization of DS-CDMA system in an asynchronous environment. The first aim is to ground the theoretical characterization of the performance achievable in a asynchronous DS-CDMA system when chaos-based spreading sequences are substituted for classical Gold or m-sequences. A first advantage of this method for sequence generation is that all the limitations on sequence number and/or length which are intrinsic in discrete-math shift-register based approaches.
Additionally and more important, it can be also proved that chaos-based spreading is able to achieve the absolute minimum multiple-access interference (MAI). Hence, when multiple-access interference is the main cause of errors in the communication, chaos-based spreading allows obtaining the optimum system which can be computed to have an average 15.47% increase in capacity with respect to systems adopting random or pseudo-random spreading. Non-average performance can be optimized to obtain peak of more than 60% increase in capacity. Theoretical predictions have been also confirmed by a prototype system including 8 transmitters and a receiver matched with one of the transmitters. Chaos-based spreading has also been tested against other typical problems in the design of DS-CDMA systems and has been proved to enhance the system performance in terms of lost-bits in the sequence acquisition phase at link startup, reduced bit-error probability in certain multipath propagation scenarios, and Shannon Capacity.

About the Speaker:

Gianluca Setti received a Dr. Eng. degree (with honors) in Electronic Engineering and a Ph.D. degree in Electronic Engineering and Computer Science from the University of Bologna, Bologna in 1992 and in 1997, respectively, for his contribution to the study of neural networks and chaotic systems. From May 1994 to July 1995 he was with the Laboratory of Nonlinear Systems (LANOS) of the Swiss Federal Institute of Technology in Lausanne (EPFL) as visiting researcher. Since 1997 is has been with the School of Engineering at the University of Ferrara, Italy, where he is currently an Associate Professor of Circuit Theory and Analog Electronics. His research interests include nonlinear circuits, recurrent neural networks, implementation and application of chaotic circuits and systems, statistical signal processing, EMI reduction, wireless communication and sensor networks.