Simultaneous amplitude and frequency noise analysis in Chua's circuit – neural network based prediction and analysis.

J.-M. Friedt[1], O. Teytaud[2], D. Gillet[1], M. Planat[1]
friedt@lpmo.univ-fcomte.fr, oteytaud@univ-lyon2.fr
[1]: *Laboratoire de Physique et Métrologie des Oscillateurs (LPMO, CNRS)*
32, avenue de l'observatoire, 25044 Besançon Cedex, FRANCE
[2]: *Laboratoire ERIC - Université Lyon II*
4, avenue Pierre Mendes France, 69676 BRON Cedex, FRANCE

Chua's circuit is a non-linear electronic circuit reduced to its minimal components: a parallel LC circuit and a parallel CN circuit, connected by a resistor, N being a piecewise linear negative resistor.

We have experimentally studied the Chua's circuit from the aspects of frequency and amplitude. We have simultaneously measured the instantaneous period and amplitude while varying the inductor's value L (bifurcation parameter). We used an operational amplifier based simulated inductor [1] whose value is defined by a digitally set variable resistor to completely automate the experiment and gather a large number of data.

The original aspect of our experiment is the development of the electronic circuits allowing the isolation and analysis of the amplitude and the frequency of one and the same period (hence the denomination "instantaneous"). It is mainly composed of a peak holder circuit followed by a 12 bits analog to digital converter while a custom made frequency counter measures with 0.5 Hz resolution the frequency of the oscillation after an appropriate analog signal processing.

We studied the bifurcation diagrams, the evolution of the transfer function (amplitude *v.s* frequency), return maps for the instantaneous amplitude and frequency, and established the evolution of the Allan deviation during the bifurcation process in order to characterize the frequency fluctuations evolution.

In parallel with these statistical studies, we study the efficiency of different learning algorithms for one or many steps prediction of time series. Different strategies are compared, direct long term predictions, iterated methods. Different criterions are used and compared.

Simulated "perfect" data, simulated "noisy" data, and real-world measured data are used and compared. We use many different algorithms: classical ones, like back-propagation, radial basis functions, and k-nearest neighbors, but more recent ones too, like support vector machines, even used for chaotic time series by Mukherjee, Osuna and Girosi [2]. We evaluate the efficiency of regularization. All these methods are combined to give an algorithm of computation of the order of chaotic time series.

[1] Thomas P. Weldon, *An inductorless double scroll chaotic circuit*, Am. J. Phys **58** (10), October 1990

[2] S. Mukherjee, E. Osuna and F. Girosi, *Non Linear Prediction of chaotic time series using support vector machines*, Proc. of IEEE NNSP'97, Amelia Island, FL, 24-26 Sept, 1997