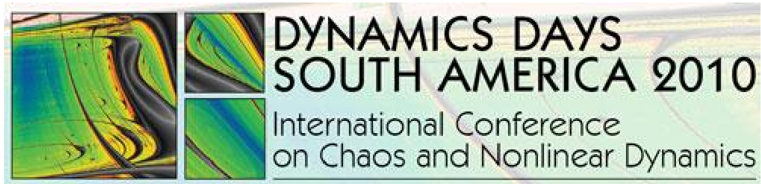

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AUTOMATIC OPTIMIZATION OF AN EXPERIMENT IN NOISE-ENHANCED PROPAGATION

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The phenomenon of *noise-enhanced propagation* [1] is closely related to that of *array-enhanced stochastic resonance* [2], namely the enhancement of individual response through collective synchronization. In [3] the former phenomenon was addressed, with focus on the system's fault-tolerant behavior. A chain of N damped bistable (double-well potential) oscillators were coupled *unidirectionally*. A low-frequency signal was fed at the input of the first unit, and the $(i-1)$th oscillator's output fed (with coupling intensity ϵ') as input to the ith one, also injecting *independent* additive Gaussian white noises (with common intensity D) in all the elements, as in Fig. 1. The cascade, representative of a noisy transmission line, was regarded as a mock-up of synaptic transmission.

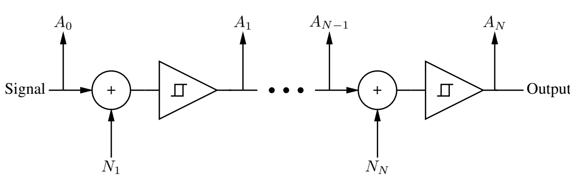

Figure 1 – Block diagram of the experiment

As customary in stochastic resonance and related phenomena, the theory was formulated within an analogical framework[1], and the quality measure was the output signal-to-noise ratio (SNR) of the last unit. Figure 2 shows that the lower right region in the parameter plane (ϵ', D)—high coupling and not too high noise—has the largest output SNR (measured in dB).

An important prediction made in [3] is that the system exhibits fault-tolerant behavior—namely under optimal conditions, the signal reaches the end of the chain even when noise is not fed at every node. As a step towards the experimental verification of this property, we have built a chain of Schmitt triggers, namely positively fedback op amps with a threshold that confers them some noise immunity. Although the system is still analogical, the conditions are those of digital gates and thus, the digital abstraction [5] is operative. Hence the measure of interest is not anymore the SNR (related to the signal's *amplitude*), but rather a measure of *coherence* or survival of the signal in the system. Here, the Hamming distance between the response of the last element and the input signal is used as an indicator.

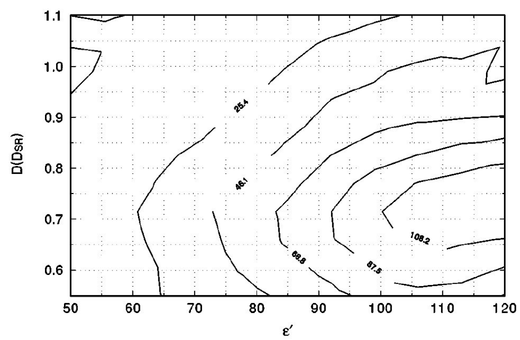

Figure 2 – Level curves of the chain's output SNR, in the parameter plane (ϵ', D).

As a consequence of our experimental need, a data acquisition and control system was built [6]. It composes essentially of a software that communicates through a USB concentrator with independent modules that allow to configure the levels of the signals and to acquire the states of the bistable elements. Its main characteristics are:

- 8 digital channels and 4 Mbits of data per module.
- Up to 255 independent modules per USB concentrator ⇒ maximum 2040 channels ≈1 GByte of data.
- Acquisition speed configurable by the user, up to 450 ksamples per second.

This amply scalable and low cost system allows to carry out variety of experiments, controlling all the variables digitally from a single computer, and implementing control algorithms and automatic optimization. Altogether it is a hybrid system, or an analog–digital computer that allow to study a distributed nonlinear system in an intensive way. Using this system it is possible to configure the experiment, execute it,

[1]Although the standard expression of the SNR assumes the two-state approximation [4].

analyze the results, modify the configuration, and to execute it again in an automatic way as many times as needed. This philosophy of work allows to carry out *real* experiments in a way that parallels a computer simulation, since once the system is wired, one can alter the characteristics of the experiment by just modifying parameters from a software. Here, the input noise intensity in each element can be controlled independently by means of a proprietary code that commands a set of digital potentiometers (Fig. 3), to allow the optimization of the coherence.

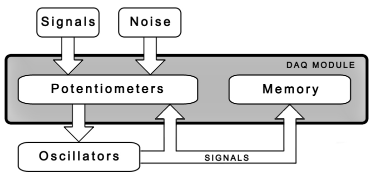

Figure 3 – Conceptual scheme of the experiment.

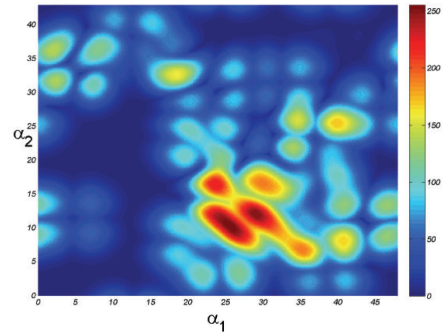

Figure 4 – Color-map graph of the coherence between the response of the last element and the signal, in the plane of the parameters α_1, α_2 of the proposed circuit.

The process of parameter adjustment is automated through a genetic algorithm [7], that carries out the search of an optimal set of noise intensities maximizing the output's coherence with the input signal. For illustration purposes, in this experiment we take $N = 2$. The result is shown in Fig. 4, where parameter α_i refers to the potentiometer set at the input of unit i. Their meanings are roughly the same as those of ϵ' and D, and the graph exhibits the same qualitative features.

The next steps are (1) to implement a user `html` interface based on web servers so to have remote access to the acquired data in real time, without requiring the presence of an observer during the experiment, (2) to verify the fault-tolerant behavior in this system, (3) to study related physical systems as the one in [8] with the same control system.

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