Noise-induced excitability and associative memory in neuron-astrocyte networks

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Introduction

Recently, modelling neuron-astocyte networks attracted a lot of interest because of the variety of research questions linked to this system. These research questions included understanding human brain, artificial intelligence, neural dynamics and noise-induced phenomena in physics of nonequilibrium systems. In the present proposal, the aim is to investigate how astrocytes will affect information processing in the system of excitable neurons if this excitability is induced by noise. The modelling may lead to very interesting and unexpected results, because one can research a combination of two nontrivial effects: noise-induced excitability and astrocyte organised associative memory.

Specific problem

Recently we have shown that multiplicative noise and coupling, if introduced in the lattice of the FitzHugh-Nagumo elements, can change a behaviour of the system from oscillatory to excitable one [1], see the figure. On the other hand, recently we have shown that astrocytes organise an associative memory if coupled to the neural network. Hence, it would be very interesting to investigate whether such an associative memory is possible in a neural network with a noise-induced excitability.

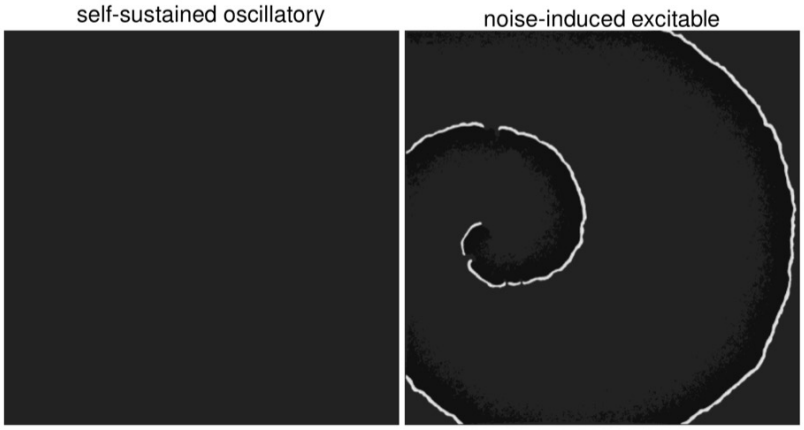

Figure 1. A lattice of oscillatory elements (left) without noise vs a lattice with noise-induced excitability (right), where one can observe propagation of spirals.

Work plan

The numerical modelling should include the following steps:

1. Write the code to solve stochastic differential equations describing behaviour of the elements on the lattice of the size 40x40, and to display the colour encoded visualization of the lattice as in the figure 1. Show that a system can transmit plane or spiral waves.
2. Add astrocytes as in [2] and investigate whether astrocytes enable organization of an associative memory able to store, e.g., two patterns "1" and "0".

Recommended literature

1. E. Ullner, A. Zaikin, J. Garcia-Ojalvo, and J. Kurths, “Noise-Induced Excitability in Oscillatory Media”, **Phys. Rev. Lett**. 91, 180601 (2003).
2. S. Gordleeva, Y. Lotareva, M. Krivonosov, A. Zaikin, M. Ivanchenko, and A. Gorban, "Astrocyte organize associative memory", in "Advances in Neural Computation, Machine Learning, and Cognitive Research III", Springer Nature p. 384 (2019).

Pre-requisites

No specific prior knowledge is required in addition to some understanding of ordinary and stochastic differential equations (SDEs) and its numerical solution. Instructions how to solve SDEs numerically will be provided. One should also be able to visualise 2D lattices.