Exploring long range interactions in neural networks

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Complex networks have attracted more and more interest during recent years. They have been used to describe a wide spectrum of physical processes (from gene manifestation [1] to power grid optimization [2]), human interactions (social networks [3], for example) or to describe the brain, among many other applications.

Usually, there are two main ingredients when working with complex networks: the structural part -and the graph theory-based tools used to describe them- and the dynamical part -usually studied by means of statistics and nonlinear dynamics. When studying the temporal dynamics of a network's nodes, the paradigm is to account for the interactions among closest-neighbours (meaning, only directly structurally connected nodes are able to interact).

A recent novel approach, proposed by Estrada *et al.* [4] was to characterize the dynamics in complex networks taking into account more subtle interactions (they propose the term 'indirect peer pressure' when dealing with social networks, for example). This is not only revolutionary because of the technique they introduced but also due to the paradigm shift it would imply.

Following his insights, we have delved into the study of a well known single cell model, the Morris-Lecar neuron [5]

$$C\dot{V_i} = \sum_j g_j \cdot f(V_j - E_{\text{ion}}) + I_{\text{syn},i} + D\xi, \qquad \text{(1a)}$$

$$\dot{W_i} = \phi\,\tau_w(V_i)\cdot\Big[W_\infty(V_i) - W_i\Big], \qquad \text{(1b)}$$

where V_i is the main variable (it represents the membrane potential of the cell) and W_i is the recovery one (taking into account that there is a refractary period for the neuron to spike after having done so). This model is used to reproduce the variety of oscillatory behavior in relation to different conductances (for different ions) in the membrane potential of a neuron. Specifically, we compare the results we have already attained with the classical (short range) interactions [6] with these obtained when introducing higher order functional links.

This work is a pioneering one because it is a potential solution to the irreconcilable problem of not modelling the role of glia cells (in particular, astrocytes) in neuronal activity. As different physiological measures have shown [7], these cells not only serve as glue and maintenance cells for neurons but they also participate in the modulation and release of neurontransmitters.

The first promising results in this line of research are that we can achieve a greater synchronization (Fig. 1) when using higher-order interactions than when we don't, a possible –and suggestive– explanation for this being that astrocytes make the neuronal signal more synchronous with less coupling strength (i.e., neurons need less neurotransmitter release to achieve synchronization).

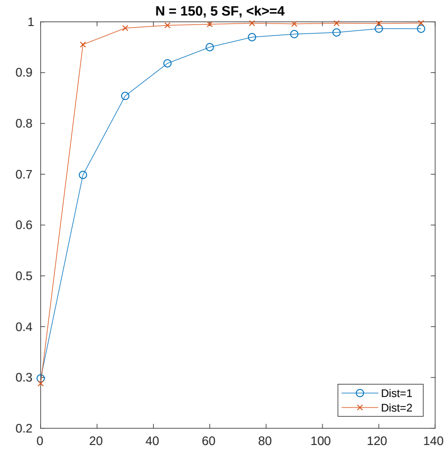

Fig. 1. Synchronization values for different coupling strengths. This is the result of averaging five different realizations of a Scale-Free network of 150 nodes with $\langle k \rangle = 4$. We see that a greater synchronizations is achieved before in the case that we let higher-order interactions take place.

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