Burst syncrhonisation in scale-free network

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1st Perspectives on Oscillation Control

Introdução

The construction of the neuronal model will be done using a network of networks, developed by a real human connectivity matrix, obtained trough experimental methods. The neuronal dynamics will be studied by the two-dimensional Rulkov's map. We also studied the synchronisation in the neural network by application of an external signal on Rulkov's map so that all neurons could start a bursts at the same time. Neuronal synchronisation sometimes is related to abnormal cerebral rhythms that in general, refers to the presence of some neurodegenerative disease, like epilepsy, Parkinson's disease and essential tremors. In this sense, the synchronisation suppression technique was used through the application of a delay field in the neural network.

Resultados e Discussões

To study the dynamics of a neural network we use the Rulkov map

$$x_{n+1}^{(l,p)} = \frac{\alpha}{1+x_n^2} + y_n^{(l,p)} + \frac{\varepsilon_c}{C^{(l,p)}} \sum_{d=1}^{Q} \sum_{f=1}^{P} WH\left(x_n^{(d,f)} - \theta\right)\left(x_n^{(l,p)} - V_s^{(l,p),(d,f)}\right)$$

$$y_{n+1}^{(l,p)} = y_n^{(l,p)} - \sigma\left(x_n^{(l,p)} - \rho\right),$$

H is the Heaviside function, W is the connectivity matrix, f and p denote the cortical networks, d and i denote the neurons within the cortical network.

Chemical synapses were chosen to be 25% inhibitory and 75% excitatory.

$$C^{(l,p)} = C_{out} + C_{ins} \qquad W = W_{(l,p),(d,f)}$$

$$V_s = 1 (excitatory) \qquad \sigma = 0.001$$

$$V_s = -0.5 (inhibitory) \qquad \rho = \theta = -1$$

$$4.1 \leqslant \alpha \leqslant 4.3 \qquad Q = 200, P = 78$$

The 78 subnetworks are generating following the Barabási-Albert procedure. The scale-free networks are characterised by a degree distribution that follows a power-law: $P(k) \propto K^{-\gamma}$

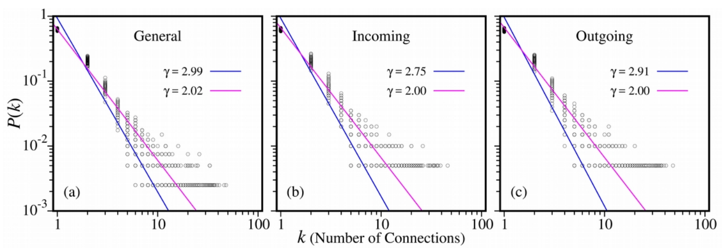

Figure: Power-law fit for a scale-free network with 200 neurons for general, incoming and outgoing connections.

The coupling term is responsable for synchronise the neurons in this network mode.

We measure Kuramoto order parameter by:

$$r_n = \frac{1}{K}\left|\sum_{k=1}^{K} e^{\phi_n^k}\right|$$

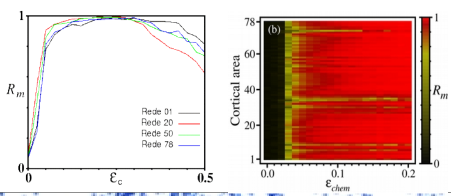

Figure:Kuramoto order parameter (left) for networks 01, 20, 50 and 78. Order parameter for the cortical areas as a function of the chemical coupling (rigth).

The relieve the symptoms of synchonisation we are apply a delayed feedback signal in the cortical areas to suppress the synchronisation.

$$S = \sqrt{\frac{Var(M)}{Var(M(\tau,p))}} \longrightarrow S \gg 1$$

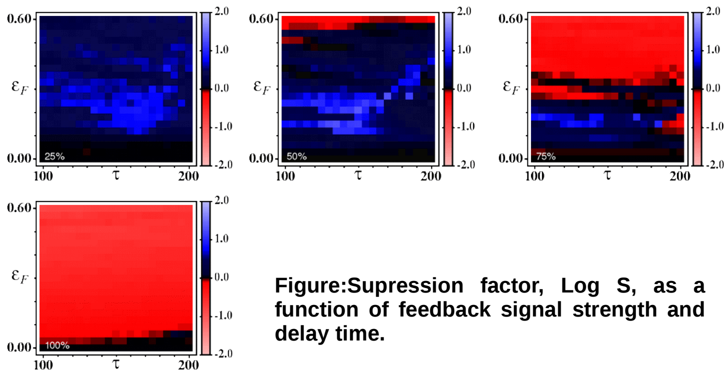

Figure:Supression factor, Log S, as a function of feedback signal strength and delay time.

Conclusões

We show that the coupling of chemical synapses term can synchronise the network. The results for the average Kuramoto order parameter showed that not only all networks synchronise at the same time, but also some regions can be internally more synchronised than others. We also see that as the number of disturbed cortical regions increases, the size of the suppression region decreases, giving rise to a stimulus region of synchronisation, and the suppression factor increases.

Referências

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CAPES