Modelling the Brain with Complex Networks

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Abstract

The complexity of the brain structure is astounding: in plain figures, it contains more than 10^{10} neurons with an average of 10000 axonal projections to other neurons each. This is the case of the human brain. Understanding how this highly sophisticated organ evolved from more elementary forms of life, and how their functional abilities arise from its structure, is the challenge of computational neuroscience.

In this paper we consider a cellular automata model of the brain defined upon a complex network substrate. We consider $1,000,000$ nodes with three possible states: firing, resting or refractory and define the transitions among them according to the SIRS epidemiological model rules. These neurons can also be of two types: excitatory (which induce the excitation of their neighbouring resting neurons when they are firing) and inhibitory (which prevent resting neurons from firing and induce transitions of their neighbouring firing neurons to the refractory state).

The average number of neurons in the brain of a bee is, approximately, $960,000$ and, consequently, our model qualitatively resembles an insect brain. It is known that in the mini-brains of insects neural oscillations appear correlated to odour stimuli [1,2]. These oscillations are also observed in the brains of higher order animals, although their purpose is different. This implies that evolution have shaped the role of neural oscillations since the first insect appeared in the early Devonian, 400 million years ago.

Here we show that, in a random network model for neural activity, self-sustained oscillations appear in a restricted parameter region of the transition probabilities. This could explain the role of synchronized oscillations as a discriminant process for internal or external stimuli in brain dynamics.

Key words: Electroencephalography, Epidemic models, Complex Networks

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