Firing Pattern of Default Mode Brain Network with Spiking Neuron Model

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Abstract. Recently, analyses of fMRI data have revealed functionally connected and interacting spontaneous active regions in the brain, which are referred as "Default Mode Brain Network". The fluctuations on BOLD signals of the default mode brain network have shown spatiotemporally correlated synchronization at a rate lower than 0.1 Hz in contrast to signals under concrete tasks like high frequency rhythms. Here we construct the default mode brain network by functionally connecting a neural network using functional correlation factors. For numerical simulations with Izhikevich’s spiking neuron model, the condition on the slow synchronization of this network model is fixed, and the network dynamics is analyzed.

Keywords: spiking neuron model, default mode brain network, spontaneous activity, firing rate, synchronization.

1 Introduction

The functional magnetic resonance imaging (fMRI) has been yielding substantial results for the brain science. The visualization of active regions in the brain by fMRI is expected to unravel not only functions of the brain but also relations between the brain and the mind. For instance, how does one make a choice when two thoughts emerge? fMRI implied that both regions involved in abstract reasoning and those that process emotions get active in the brain under this situation. Greene and his group found using fMRI that if the dilemma is not so personal, the reasoning part of the brain is dominant when processing a difficult and personal moral dilemma [1].

Thus fMRI makes regions corresponding to any task light up, and also one more possible of fMRI on analyzing the brain is recently presented. It is observation for the slow fluctuations in the blood oxygen level dependent (BOLD) signal in the default or resting state of the brain for dozing situation [2]-[5]. The default or resting state means that someone does not focus on the external environment, namely be in the absence of an explicit task. The fluctuations have shown spatiotemporally correlated synchronization at a rate lower than 0.1 Hz.
These analyses of fMRI have revealed functionally connected and interacting spontaneous active regions in cerebral cortex, which is so-called ”Default Mode Brain Network” and distinct from other systems within the brain. Being the activity in the default, the default mode brain network is a brain system much like the motor or visual systems and/or is associated with the ability of cognitive processing, development, aging, consciousness and psychiatric/neurological diseases. Then, some regions of the brain are in a system that has the spontaneous cognition and other memory-related functions from evidences in brain imaging of fMRI and anatomy [5]. The resting state, but these regions are active, is regarded to be related to the psychological function of the brain such as autobiographical memory. Integration of the neural activities on two states, namely the resting and the task-induced, tells us the entire story of the intrinsic organization of the dynamic networks of the brain that is formulated by anti-correlated signals [2]. Considering the fact that the brain is regarded as a dynamical system, the resting state of the brain is defined as the baseline. Therefore, the resting state is used as a condition of experiments compared with the task positive state, and the knowledge on the default mode brain network from multiple disciplines ranging from psychology to brain imaging technique is important for us to completely understand the brain’s function at a systematical level.

2 Default Mode Brain Network and Its Modeling

The default mode brain network has been established as a new field highlighted in recent years though its history is short – just about a decade [5]. Of course, the related fundamentals in neuroscience leading to the advances of the default mode brain network research can be traced to 1970s [5]. In the early era of the fundamental research, the form of the image is rCBF (regional cerebral blood flow) that is obtained by using the nitrous oxide technique. The signals in this kind of images reflect the neural activity of the frontal area of the brain [5]. Later, other brain imaging techniques including PET (positron emission tomography), fMRI and other techniques are used, and the resolution of the obtained images becomes higher.

In informatics, the correlation network of the default mode brain network is verified by the evidences in neuroscience. The graphical representation of the default mode brain network consists of different nodes of the regions of the brain that are functionally connected and is formulated as an interaction of sub-systems. This kind of structure is expected to help us to explain how different parts of the brain perform a cooperated function. The intrinsic (spontaneous) activity of the resting state of the brain measured from BOLD signals demonstrates the brain’s doing without any input/output. Table[1] is functional connecting core regions suggested as architectonics of the default mode brain network.

Currently, two aspects – the functions of the default mode brain network in neuroscience (e.g., neurophysiology) and pattern analyses of correlated signals (e.g., BOLD) [4] supported by related means of signal processing and data analysis (e.g., handing the noisy case [6]) - are the main streams of the research on