Influence of external input and relative weight of inhibitory connections on the balance of a sparsely connected network of Leaky integrate-and-fire neurons.

Introduction

Neurons in the human cortical brain show an irregular firing pattern. One explanation is that the timing of the input is synchronized enough to evoke action potentials, as there is summation of input signals (Softky & Koch, 1993). A contradictory explanation says that not the timing but the frequency of the input is relevant (Shadlen & Newsome, 1998). The average input is subthreshold and because of the stochastic input it is possible to evoke spikes even though there is no synchrony.

In order to examine the hypotheses it is very useful to perform simulations on computational models of the human cortex. In computational neuroscience there are numerous neuron and network models, all of them having advantages and disadvantages. Mostly the consideration is based on the computational performance versus biological plausibility. Usually, one chooses the simplest model which still contains the minimal features to be able to answer the research question.

When examining the network dynamics of the cortex, simple neuron models are preferred, as the focus is more on the behavior of the network than on that of the single neurons. Moreover, for the examination of cortical networks the connections should be recurrent as in the human brain. Thus a commonly used network is the sparsely connected Balanced random network (Brunel, 2000; Remme & Wadman, 2012; Yger & Harris, 2013).

The balanced random network, also called balanced network, is a large scale network of sparsely connected Leaky integrate-and-fire neurons (LIF). LIF neurons only take a few parameters in account, and it is more a description of how neurons behave than what causes this behavior. The behavior of a balanced network of the simplest LIF neurons is extensively examined, both analytically and computationally (Brunel, 2000). This research showed that the balanced network could settle in four different states, based on synchrony and regularity. The key parameters in the differentiation between these four states are the amount of external input (each neuron receives stochastic background input) and the ratio between the conductance of excitatory versus inhibitory synapses.

Other studies showed that network models with more biological plausible LIF neurons can reach balanced states as well (Yger & Harris, 2013). However, it is still unknown if these networks can reach the different states of synchrony and regularity as well, and whether the transitions between these states are similar to those of the simpler neuron model. It is therefore examined whether the LIF neuron model with more biological plausible characteristics can reach balanced states which differentiate between synchrony and regularity. It is hypothesized that a balanced state will be reached, and that it is possible to differentiate between the different states, although the transitions will differ from simpler models.

This is examined by implementing a balanced network of LIF neurons and systematically quantifying the regularity and synchrony of different combinations of the external input and relative strength of inhibitory synapses. It is expected that it is possible to differentiate between the four states bases on the quantification. Whether these transitions will be nominal or continuously is unknown, as the involved parameters are not linearly correlated to one another.

Materials and Methods

**Neuron model**

Simulations of the spiking neurons were performed using the BRIAN 2 simulator (Goodman & Brette, 2009).