Stimulation strategies for neurons and fibres Connecting biological and artificial neural networks

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Connecting biological and artificial neural networks

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Abstract

Electrical stimulation of nerve tissue and recording of neural electrical activity are the basis of emerging prostheses and treatments for many neurological disorders. Here we present an attempt to connect an *in vitro* Biological Neuronal Network (BNN) with an Artificial Neural Network (ANN) implemented in a neuromorphic board. This work can be seen as the first step towards the realization of an innovative brain-prostheses.

Introduction

Neurological disorders can disrupt connections among different brain regions, resulting in severe damage to cognitive and motor capabilities [1]. In the near future, neural stimulators and implantable systems represent one of the most promising technologies to reduce those impairments [2]. This work is part of the European project BRAIN BOW (www.brainbowproject.eu) whose purpose was to build a test-bed for the development and the study of a new generation of neuro-prostheses capable to restore the communication between neuronal circuitries lost because of a neural lesion, such as a traumatic brain injury [3].

Material and Methods

The biological element used in this study is constituted by dissociated cortical rat neurons plated over Micro-Electrode Arrays (MEAs). We adopted a neuromorphic board which is able to perform real-time event detection and trigger an electrical stimulation of the Biological Neural Network (BNN). The board (figure 1) embeds an Artificial Neural Network (ANN) [4], based on Izhikevich neurons [5] which can be put in uni- and bi-directional communication with the BNN. The ANN used in the following experiments was made up of 100 neurons (80 excitatory, 20 inhibitory) randomly connected with an average degree of 45.

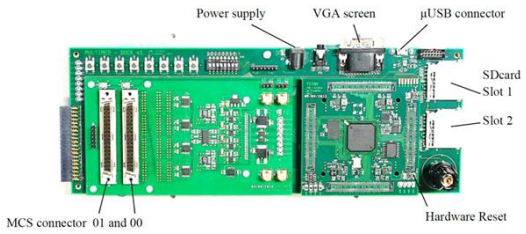

Figure 1: Picture of the neuromorphic board used for this study.

Results

We tested the effect of stimulation from the BNN delivered to the first 1-2-5-10 excitatory

neurons in the ANN. The ANN receives stimulation each time a spike is detected on a channel of the BNN. In figure 2 we show the probability of observing a spike on one of the target channels of the ANN as a function of time occurring since a stimulus was delivered to it. It is possible to note how this graph presents two well-distinct 'bumps'. The highest is almost overlapping in all curves and spans between 5 and 15 ms after stimulus delivery. This peak is likely caused by the stimulated neurons responding with a spike to the external stimulation directly. A delayed 'bump' is present only when 10 excitatory neurons are stimulated, clearly visible in the 20-40 ms time interval after stimulation. This peak is caused by the fact that if a large enough number of excitatory neurons is firing at the same time, the network generate a self-sustaining barrage of activity. Both these peaks are typically observed in biological cultures undergoing electrical stimulation, with similar time profiles (even though evoked bursts tend to last longer, up to hundreds of ms [6]).

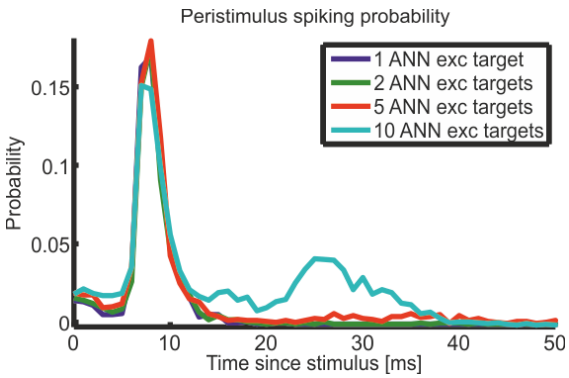

Figure 2: Peristimulus spiking probability on one of the target channels of the ANN as a function of time occurring since a stimulus was delivered to it.

As expected, when inhibitory rather than excitatory neurons are used as stimulation targets, the only macroscopic difference is the lack of the rightmost peak, i.e. the network responses evoked by stimulation (data not shown).

Conclusion

Here we show that the activity of the ANN, implemented into a neuromorphic board, can be influenced by the BNN. With this particular configuration of ANN, we have to stimulate at least 10 artificial excitatory neurons in order to cause a network response. The unidirectional stimulation from BNN to ANN can be seen as a preliminary test for the bidirectional stimulation. During bidirectional stimulation, we expect that time profile of stimulation and the number of stimuli delivered between ANN and BNN can have a profound effect on the information exchange between networks.

Indeed, the results (although preliminary) of this work demonstrate that the board is able to put in communication a biological and an artificial neural network.

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