BIO-HYBRID EXPERIMENTS USING TUNABLE REAL-TIME BIOMIMETIC NEURAL NETWORK

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INTRODUCTION

Neuroscience has been the object of many studies and new fields these last decades leading to an era where technology and biology could be mixed in order to find advanced solutions for curing diseases. Neuroprosthesis require to take into consideration the biological activity of the cells and the connection between machines and biological cells. Understanding the mechanism underlying of affected cells also require to use a tunable and real time system such as a Field Programmable Gate Array (FPGA) to explore different conditions and parameters. Here, we propose to study neurological diseases by using digital hardware system reproducing the spike activity of Fast Spiking (FS), Regular Spiking (RS), Intrinsically Bursting (IB) and Low-Threshold Spiking (LTS) class of cortical neurons [1]. We use Hodgkin and Huxley (HH) [2] which is the most bio-plausible model.

METHODS

Mathematical statements using HH paradigm are complex but it is possible to reduce them by using mathematical and numerical functions like COordinate Rotation DIgital Computer (CORDIC) to perform hyperbolic functions, Euler methods to solve derivative functions and non-restoring divisions. The more the equations are reduced, the more the speed and space are increased. Thus, implementing other biological parameters like axonal delay, synaptic noise is possible. Synapses and short-term plasticity have also been implemented and allow the chip to compute biomimetic locomotion with Central Patter Generator (CPG). The integrated system is fully pipelined and is composed of a main unit managing RAM, computation units and the Digital to Analog Converter (DAC) which is used to output the APs. Moreover, Real-time modification of biological parameters like reversal potential, ionic conductance or membrane capacitance is allowed. The results have been verified by comparing biological data in [2] and electrical activities from the FPGA. Then, cross-correlation equations have been used to evaluate the proximity rate of the results.

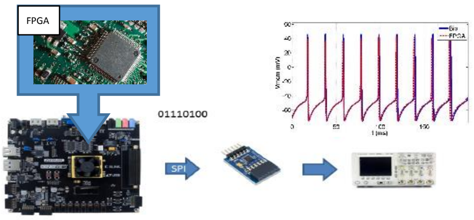

Figure 1: Set-up to observe the FPGA output

RESULTS

Mathematical equations have been significantly simplified. Resources are reduced by 80% from original model. Regular and simplified equations of biomimetic neural network are implemented on a FPGA. Electrical activities of different classes of cortical neurons can be simulated in biological time scale. Mathematical tools show strong correlation between hardware simulations and biological recordings (see figure 1). This biomimetic system is ready for bio-hybrid experiments with 'in vitro' neuron culture.

CONCLUSION

A biomimetic chip has been designed using mathematical and numerical technics for bio-hybrid experiments. The simplification of the equations allow future work on the implementation of multi-compartmental model which takes account of different part of cells, characterization of disorders effect on a neural networks. This system can be connected to an in-vitro culture with a pattern using a microfluidic technic (see figure 2).

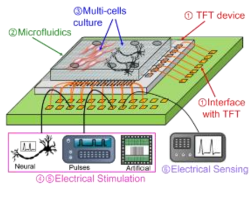

Figure 2: In-vitro culture using microfluidics technic stimulated by electrical system

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KEYWORDS: Biomimetic, Neural Network, Hodgkin-Huxley, FPGA, Bio-hybrid Experiments