# Learning Through Reward In Self-Organized Balanced Networks

Maria Kesa[1] and Marta Castellano[1]
[1]Starlab Barcleona SL, Av Tibidabo 47 bis, Barcelona
maria.kesa@starlab.es, marta.castellano@starlab.es

**[Introduction/Motivation:]**

The molecular machinery in neural circuits implement various forms of plasticity that are of intense interest to the neuroscience community. A particularly challenging problem is understanding how different forms of plasticity conspire to endow living beings with the abilities that they exhibit. Computer simulations provide an avenue for testing mechanistic models of circuit function. Here we propose to study how a spiking neural network with inhibitory and reward-modulated plasticity learns complex movements, mimicking the function of the motor cortex. Our aim is to investigate whether there is cooperativity between these two forms of plasticity that is necessary for performing a simulation of a task.

In particular, we plan to extend the work in [1]. They showed that networks optimized for excitation-inhibition balance through control theory can reproduce transient activity patterns before the initiation of movement, as observed in motor cortex experiments. However, a biologically plausible way for tuning the weights for balance was not investigated. We propose to investigate the self-organization of balance through inhibitory plasticity [2]. Excitation and inhibition balance has been hypothesized to play a role in making population codes efficient [3] and it would be of interest to see whether it is necessary for or improves learning in cortical spiking neural network simulations. Inhibitory plasticity can also play a homeostatic role to counteract run-away excitation stemming from the instability of STDP at excitatory synapses.

**[Methods:]**

In our experiments, we take inspiration from studies of songbird song learning. Zebra finches learn to sing by imitating their father [4]. We want to train a network of spiking neural networks to control simulated muscles to perform pre-defined movement patterns. The read-out from the spiking neural networks to the muscles will be a linear decoder, as in [1]. During learning a reward signal is fed back into the network, to instruct the network how well it is doing and to shape the learning. We plan to use the reward-modulated STDP rule from [5] on the excitatory-to-excitatory synapses. Concurrently, the network will incorporate inhibitory plasticity on inhibitory-to-excitatory synapses.

**[Results and Discussion:]**

In summary, we plan to implement a spiking neural network model with reward-modulated STDP and inhibitory plasticity and train it to learn complex movements. We tutor the network as songbirds such as finches tutor their children. We want to investigate what interesting phenomena arise in simulations through the interplay of reward-modulated plasticity and inhibitory plasticity. For example, in [4] the authors observed that in zebra finch song-learning inhibition selectively silenced responses in the pre-motor areas in response to sub-sequences in the song that had already been mastered by the bird. We are curious whether a similar phenomenon can be observed in our simulations and what other interesting observations we can make.

**References:**


[1] G. Hennequin, T.P. Vogels, W. Gerstner. Optimal Control of Transient Dynamics in Balanced Networks Supports Generation of Complex Movements. *Neuron* 82, p. 1394-1406. 2014.

[2] T.P. Vogels, H. Sprekeler, F. Zenke, C. Clopath, W. Gerstner. Inhibitory Plasticity Balances Excitation and Inhibition in Sensory Pathways and Memory Networks. *Science*, VOL 334, 2011.

[3] S. Deneve, C. K. Machens. Efficient Codes and Balanced Networks. *Nature Neuroscience* 19, p. 375-382, 2016.

[4] D. Vallentin, G. Kosche, D. Lipkind, M. A. Long. Inhibition Protects Acquired Song Segments During Vocal Learning in Zebra Finches. *Science,* VOL 351, p. 267-271, 2016.

[5] R. Legenstein, D. Pecevski, W. Maass. A Learning Theory for Reward-Modulated Spike-Timing-Dependent Plasticity with Application to Biofeedback. *PLOS Computational Biology,* 2008.