Adding new models of synaptic plasticity

August 28, 2015

Contents of package

examples/stdp_triplet.py PyNN script that reproduces experimental protocol developed by Sjöström et al. [2].

neural_modelling/src/neuron/Makefile Makefile which lists all the neuron models defined in this module.

neural_modelling/src/neuron/builds/Makefile.common Makefile which lists new STDP components defined by this module.

neural_modelling/src/neuron/builds/IF_curr_exp_stdp_mad_pair_additive/Makefile Makefile to build SpiNNaker executable with spike-pair STDP rule.

neural_modelling/src/neuron/builds/IF_curr_exp_stdp_mad_triplet_additive/Makefile Makefile to build SpiNNaker executable with Pfister and Gerstner [1] spike-triplet STDP rule.

neural_modelling/src/neuron/plasticity/stdp/timing_dependence/timing_pair_impl.c C source file containing setup code for spike-pair STDP timing dependence.

neural_modelling/src/neuron/plasticity/stdp/timing_dependence/timing_pair_impl.h C header file containing implementation of spike-pair STDP timing dependence discussed in presentation.

neural_modelling/src/neuron/plasticity/stdp/timing_dependence/timing_triplet_impl.c C source file containing setup code for spike-triplet STDP timing dependence.

neural_modelling/src/neuron/plasticity/stdp/timing_dependence/timing_triplet_impl.h C header file containing implementation of spike-triplet STDP rule discussed in presentation.

workshop_2015_adding_synaptic_plasticity/__init__.py Python module entry point containing code to hook module into sPyNNaker and import timing dependences sub-module.

workshop_2015_adding_synaptic_plasticity/spike_pair_time_dependency.py
Python class to instantiate and configure spike-pair timing dependence from PyNN.

workshop_2015_adding_synaptic_plasticity/spike_triplet_time_dependency.py
Python class to instantiate and configure spike-triplet timing dependence from PyNN.

Additional code changes

My presentation covered the code changes that are required to implement the behaviour spike-triplet rule on SpiNNaker. However there are some other, less interesting changes that are also required to build a functioning learning rule. Remaining changes to Python and C are discussed in comments at the following URL `http://tinyurl.com/ouk2gj2`.

Exercises

These are all more suggestions than anything else, I'd be interested to help with any triplet-rule based experimentation.

Exercise 1

As mentioned in the presentation, the SpiNNaker package already comes with an implementation of the full spike-triplet rule developed by Pfister and Gerstner [1]. This is more computationally expensive than the version developed in this workshop session, but the extra parameters may potentially allow it to better fit experimental data. Try switching the stdp_triplet.py example in the package to use this rule, configured with the parameters fitted by Pfister and Gerstner:

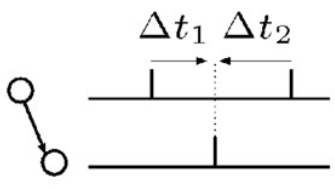
```
timing_dependence = sim.PfisterSpikeTripletRule(
        tau_plus=16.8, tau_minus=33.7,
        tau_x=101, tau_y=114)

weight_dependence = sim.AdditiveWeightDependence(
        w_min=0.0, w_max=max_weight,
        A_plus=5E-10 * start_w, A_minus=7E-3 * start_w,
        A3_plus=6.2e-3 * start_w, A3_minus=2.3E-4 * start_w)
```

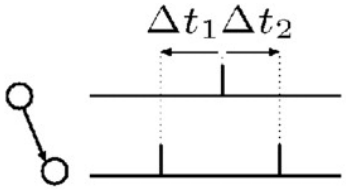
Does this actually reduce the error compared to the version developed in this workshop? Why might this be? The talk this morning on 'Maths & fixed point libraries' may give you some clues!

Exercise 2

Pfister and Gerstner [1] also fitted their model to some experimental data by Wang et al. [3]. These follow the spike-triplet protocol shown in figure 1 which



(a) Pre-post-pre triplet



(b) Post-pre-post triplet

Figure 1: Wang et al. [3] triplet protocol. Each experiment consists of 60 triplets of spikes, one second apart.

Δw	Δt_1	Δt_2
-0.01 ± 0.04	5	-5
0.03 ± 0.04	10	-10
0.01 ± 0.03	15	-5
0.24 ± 0.06	5	-15

(a) Pre-post-pre triplets

Δw	Δt_1	Δt_2
0.33 ± 0.04	-5	5
0.34 ± 0.04	-10	10
0.22 ± 0.08	-15	-5
0.29 ± 0.05	-5	15

(b) Post-pre-post triple

Table 1: Weight changes induced by Wang et al. [3] triplet protocol.

resulted in the weight changes shown in table 1. Can you make a version of stdp_triplet.py that reproduces this protocol?

References

[1] Jean-Pascal Pfister and Wulfram Gerstner. Triplets of spikes in a model of spike timing-dependent plasticity. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, 26(38):9673–82, September 2006. ISSN 1529-2401. doi: 10.1523/JNEUROSCI.1425-06.2006. URL `http://www.ncbi.nlm.nih.gov/pubmed/16988038`.

[2] P J Sjöström, G G Turrigiano, and S B Nelson. Rate, timing, and cooperativity jointly determine cortical synaptic plasticity. *Neuron*, 32(6):1149–64, December 2001. ISSN 0896-6273. URL `http://www.ncbi.nlm.nih.gov/pubmed/11754844`.

[3] Huai-Xing Wang, Richard C Gerkin, David W Nauen, and Guo-Qiang Bi. Coactivation and timing-dependent integration of synaptic potentiation and depression. *Nature neuroscience*, 8(2):187–93, February 2005. ISSN 1097-6256. doi: 10.1038/nn1387. URL `http://www.ncbi.nlm.nih.gov/pubmed/15657596`.