Overview

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2. Different STDP rules
   - STDP rule of excitatory synapses
   - STDP of excitatory synapses onto inhibitory neurons
   - STDP of GABAergic synapses

3. Simulated Motifs using inhibitory STDP rules

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Motivation

Spike timing-dependent plasticity (STDP) have aroused interest among experimentalists and theorists.

STDP helps in understanding information coding and circuit plasticity.

Questions?

- What mechanisms underlie the cell type-specific temporal windows for LTP/LTD?
- Does activity-induced modification of GABAergic synapses influence neuronal networks?
Cellular Mechanisms

STDP is dependent on the temporal order of pre/post spiking.
→ What cellular mechanisms underlie this temporal specificity?

- Many spike timing-dependent LTP and LTD requires activation of the NMDA subtype of glutamate receptors (NMDARs)

Explanation for the temporally asymmetric STDP:
- Pre before post spiking lead to the opening of NMDARs via depolarization-induced of a block which results in a high-level calcium influx.
- Post before pre leads to a limited NMDAR activation resulting from opening voltage-dependent calcium channels.
Inhibitory postsynaptic potential

- Inhibitory postsynaptic potential short IPSP is a synaptic potential which decreases the chance that a future action potential will occur.
- IPSP is the opposite of EPSP.
- Inhibitory presynaptic neurons release neurotransmitters which bind the postsynaptic receptors.
- Ion channels open or close.
- Changes postsynaptic membrane potential and create more negative postsynaptic potentials.
GABA receptors

- *GABA* is the main inhibitory neurotransmitter in the central nervous system ([JOHNSTON et al., 2006])
- $GABA_a$, $GABA_b$ and $GABA_C$ are three different types of neurotransmitter -> What are their different characteristics?
- $GABA_a$ mediate fast inhibition and have a wide distribution throughout the central nervous system
- In contrast to the fast and transient responses from $GABA_a$ receptors, $GABA_C$ receptors mediate slow and sustained responses
- $GABA_C$ receptors are expressed in many brain regions, mostly found on retinal neurons.
Schematic STDP learning rule from excitatory synapses to excitatory neurons.
- LTP is induced whenever pre- before postsynaptic spiking post- before prepairing leads to LTD.
STDP of excitatory synapses onto inhibitory neurons

**Figure:** (From [Bell et al., 1997])

- Schematic STDP learning rule found by Bell and colleagues.
- LTD is induced whenever pre- before postsynaptic spiking
- post- before prepairing leads to LTP.
- LTD/LTP occur within a 60 ms window.
Inhibitory STDP rules

- Schematic STDP window from inhibitory to excitatory neurons found by Holmgren.
- LTP takes place whenever a post- before presynaptic spike pattern occurs within a 100 ms time window.
- Overlapping pre- and postsynaptic spiking leads to LTD.

**Figure:** (From [Holmgren and Zilberter, 2001])
Inhibitory STDP rules

Figure: (From [Woodin and Ganguly, 2003])

- STDP of GABAergic synapses found by Woodin.
- LTP takes place whenever a pre- and postsynaptic spike occur within a 20 ms time window.
- Pairing within 50 ms without consideration of the order leads to LTD.
**Inhibitory STDP rules**

- STDP window from of inhibitory synapses connected to excitatory neurons reported by Haas
- STDP rule acts similarly to the excitatory-excitatory STDP rule.

**Figure:** (From [Haas et al., 2006])

- STDP window from of inhibitory synapses connected to excitatory neurons reported by Haas
- STDP rule acts similarly to the excitatory-excitatory STDP rule.
There are many patterns which could appear in the network, one of them is the feed-forward loop.

Feed-forward loop is more likely in transcription networks compare to a random network → it is called a motif.

8 possible feed forward motifs, two are very abundant.
Feed-forward motif network

- 2 excitatory and 1 inhibitory pool
- Each pool contains 100 neurons
- 10 percent connection between each pool and 10 percent recursive connection within each pool
- Different inputs were given to one excitatory pool
- Rate based outputs were taken from the second excitatory pool
Results from simulating feed forward motif

- Rate based output (blue) and target (green) signals
- Correlation coefficient between target and output signal was $0.6516 \pm 0.0442$ without STDP rule
- Correlation coefficient between target and output signal was $0.77 \pm 0.0423$ using STDP learning (Figure 6).
STDP models

Classification of different model types by Pfister:
- phenomenological models
- biophysical models
- optimal models
Future work

- How can we use the different characteristics of GABA receptors?
- Understanding the roles of different inhibitory STDP rules
- Theoretical analyze of ideal networks (like Pfister and Gestner)
- Starting: Understanding the role of diverse inhibitory STDP rules in WTA-circuits
Discussion

- Which additional aspects would be interesting about STDP rules of inhibitory synapses?
- Where else could STDP rules improve network behavior?
- ...

Further question and future work

Simulated Motifs using inhibitory STDP rules

Different STDP rules

Motivation
Thanks for your attention
References

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