Research Project (2003-2006)

Slow feature analysis and spike timing dependent plasticity

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Slow Feature Analysis (SFA) is an abstract algorithm based on slowness as a learning principle. The objective is to minimize the variance of the time derivative of the normalized output signals. It has proven a powerful tool for modeling the unsupervised learning of complex cell receptive fields, visual invariances, and place cells in the hippocampus. However, the algorithm is far from being physiologically plausible, because it is based on a generalized eigenvalue problem on a covariance and a time-derivative covariance matrix. In this project we have started investigating whether SFA can be implemented with spiking model neurons.

The first conceptual step in this direction is to realize that for continuous signals instead of minimizing the time derivative one can also maximize the variance of the low-pass-filtered normalized output-signal, which can be done with a modified Hebbian learning rule. If one uses a low-pass filter with a power spectrum of an upside-down parabola, the results are identical, see Figure 1. A different type of low-pass filter reproduces the closely related trace rule [Földiák, 1991].

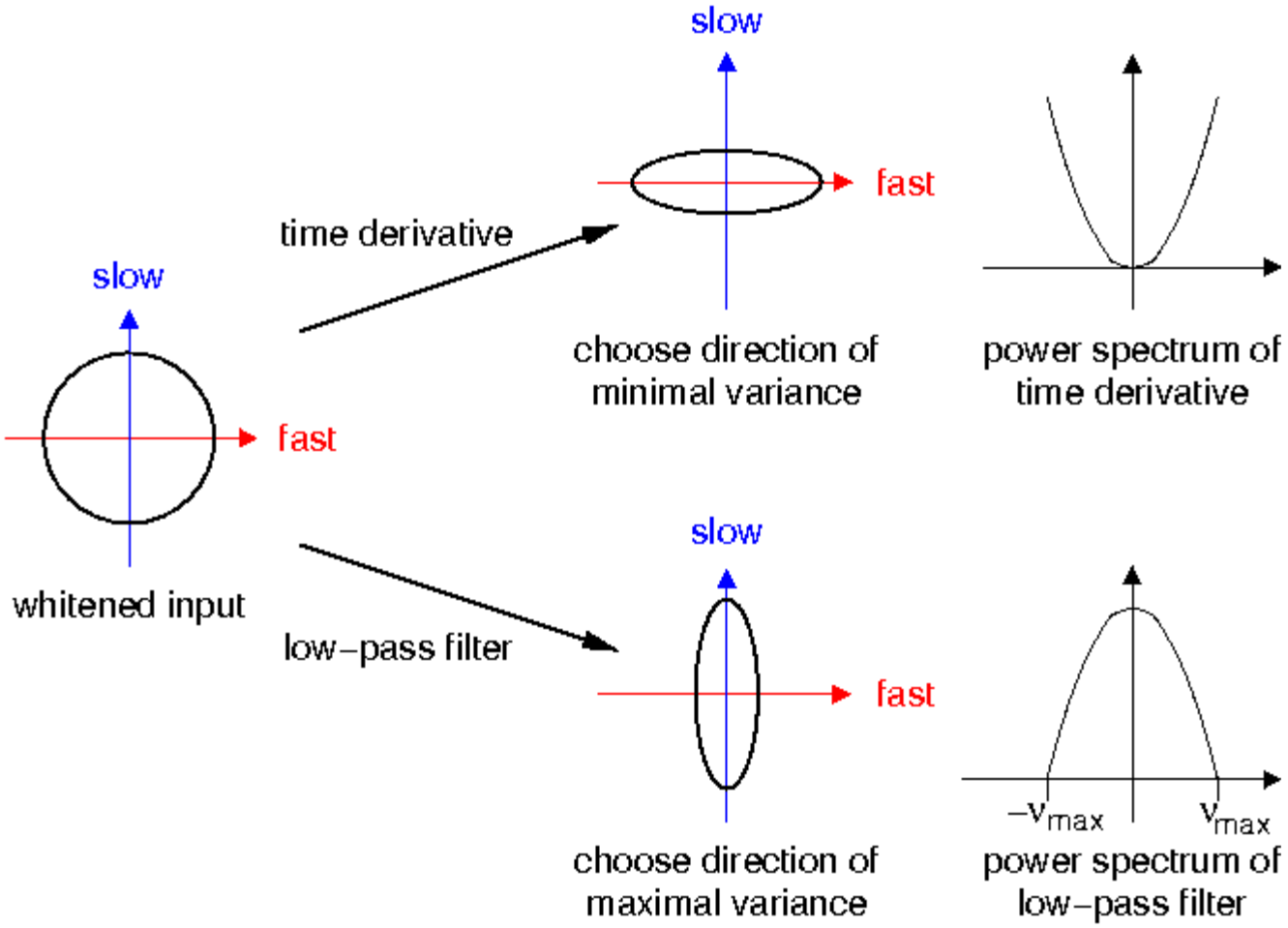

Figure 1: Maximizing the variance of the low-pass filtered signal is equivalent to minimizing the variance of the time-derivative.

The next step is to translate the modified Hebbian learning rule into an STDP learning rule for spiking Poisson units. Interestingly, for the low-pass filter of the trace rule the resulting learning window reproduces precisely the kind of learning windows measured experimentally, see Figure 2.

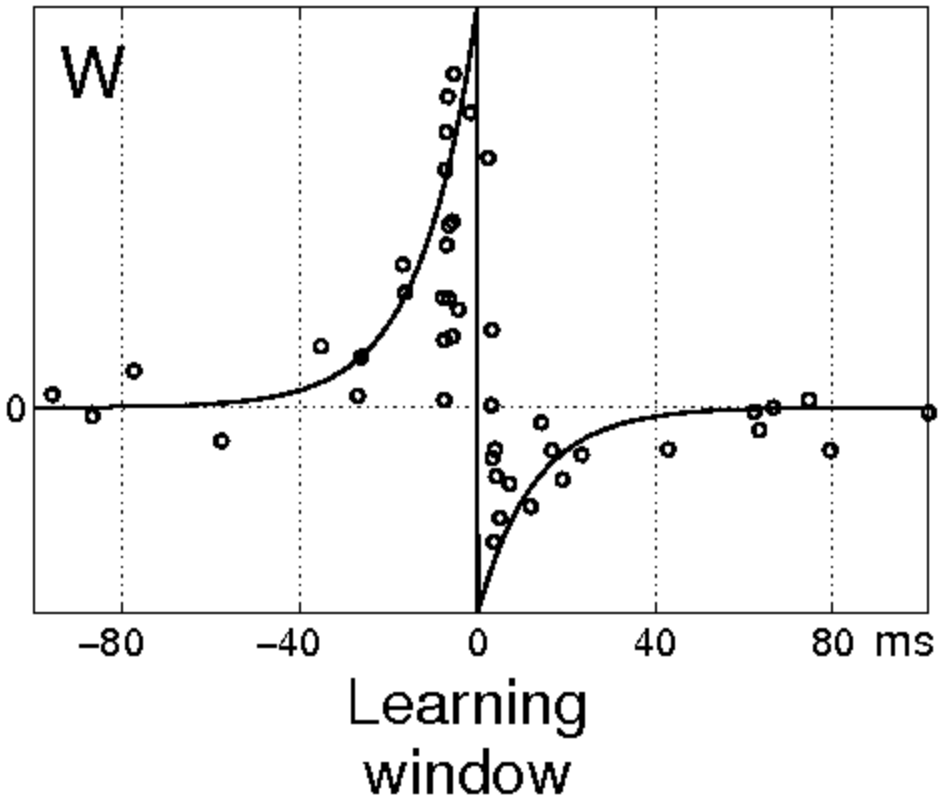

Figure 2: Comparison between theoretical (solid line) and experimental (circles) STDP learning window. Data taken from [Bi & Poo, 1998].

Interestingly, it turns out that it is not the learning window per se that is of functional relevance but the learning window convolved with the EPSP. According to our theory the asymmetric shape of the standard STDP learning window has nothing to do with any causality issues but with the fact that the low-pass filtering effect of the EPSP has to be compensated. The functionally relevant learning window is actually symmetric. Thus, our analysis offers a completely novel interpretation for the asymmetric shape of the standard STDP learning window.

Relevant Publications:

Black colored reference are the principal ones. Gray colored references are listed for the sake of completeness only. They contain little additional information. .ps-files are optimized for printing; .pdf-files are optimized for viewing at the computer.

5. Sprekeler, H. and Wiskott, L. (7. July 2007).
Spike-timing-dependent plasticity and temporal input statistics.
Proc. *16th Annual Computational Neuroscience Meeting, CNS 2007*, Toronto, Canada, July 7-12, (abstract).
(bibtex, abstract.html)

4. Sprekeler, H., Michaelis, C., and Wiskott, L. (29. June 2007).
Slowness: An Objective for Spike-Timing-Dependent Plasticity?
PLoS Computational Biology 3(6):e112, doi:10.1371/journal.pcbi.0030112.

(bibtex, abstract.html, paper.pdf, paper.pdf)

3. Sprekeler, H., Michaelis, C., and Wiskott, L. (29. March 2007).
Slowness: an objective for spike timing-dependent plasticity?
Proc. *7th Meeting of the German Neuroscience Society - 31st Göttingen Neurobiology Conference*, Göttingen, March 29 - April 1, T27-3A (abstract).
(bibtex, abstract.html)

2. Sprekeler, H., Michaelis, C., and Wiskott, L. (12. December 2006).
Slowness: An Objective for Spike-Timing-Dependent Plasticity?
Cognitive Sciences EPrint Archive (CogPrints) 5281, http://cogprints.org/5281/.
(bibtex, abstract.html, paper.pdf, paper.ps)

1. Sprekeler, H., Michaelis, C., and Wiskott, L. (1. October 2006).
Slowness: An Objective for Spike-Timing Dependent Plasticity?
Proc. *2nd Bernstein Symposium for Computational Neuroscience 2006*, Berlin, October 1-3, publ. Bernstein Center for Computational Neuroscience (BCCN) Berlin, p. 24, (abstract).
(bibtex, abstract.html)

Related Project:

- SFA: Unsupervised learning of invariances I (about Slow Feature Analysis (SFA))

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