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Letter of recommendation for Claudia Clopath

Claudia Clopath has been working in my team as a post-doctoral associate from November 2009 to November 2011. I recruited her, out of many potential candidates, since she seemed to have the ideal background: undergraduate studies in physics, followed by a PhD in one of the leading labs in computational neuroscience (Wulfram Gerstner's lab). I have not been disappointed.

She has been working on a project focusing on learning in cerebellum. This project was part of a collaboration with experimentalists in Ecole Normale Supérieure (Boris Barbour, Mariano Casado, Clément Léna). The project followed a first study in which we computed analytically the optimal distribution of synaptic weights in a perceptron, and found that the distribution fits very well paired recording data (Granule cell- Purkinje cell connections) from Boris Barbour lab. In particular, the calculation predicted a finite and large fraction of zero-weight synapses (silent synapses) at the optimal storage level (and/or optimal robustness) which fits well with their experimental data. The goals of Claudia's project were two-fold: (1) generalize the theory to more realistic situations (graded inputs and outputs, rather than binary; temporal correlations in inputs and outputs; presence of bistability in Purkinje cells); (2) derive learning rules that are both consistent with in vitro data and can be shown to converge to optimal storage level, and then apply these learning rules to a particular learning task for which comparisons can be made to in vivo data.

She made very good progress on both fronts. Goal (1) involved two components: involved analytical calculations using statistical mechanics techniques (replica method, cavity method); and numerical simulations. She has considered three different variants of the basic perceptron:

- A perceptron storing temporally correlated input/output associations (with both inputs and outputs modeled as Markov chains). She showed that the capacity diverges when both input and output correlations tend to one, and found a simple formula that allows to fit the simulation data for all levels of correlations. She also found that the distribution at maximal capacity is independent on correlations.
- A bistable perceptron storing again temporally correlated input/output

associations. She found that whenever the output correlation is larger than the input correlation, there is an optimal size of the bistability range that maximizes capacity. Again, the distribution of weights was found to be independent on parameters of the model.

- A linear perceptron, with analog inputs and outputs. In this case, one can compute the distribution of inputs and outputs that maximize capacity. Interestingly, the distribution of inputs that maximizes capacity is a sparse binary distribution, consistent with in vivo electrophysiological recordings of granule cells which show very low firing rates, but a tendency to fire in bursts. Again, the distribution of weights is the same as in the binary perceptron

Overall, all this work suggests the shape of the optimal weights distribution is a universal feature of neural systems with excitatory weights, storing information close to their capacity.

Regarding Goal (2), Claudia quickly derived a family of learning rules that optimize capacity, and mapped out the connection with published data on cerebellar plasticity. The next step was to focus on one particular learning task. One of the obvious candidates was VOR adaptation, for which a lot of experimental data exists. To get access to data, we started a collaboration with Chris de Zeeuw (Amsterdam and Rotterdam), who has collected an impressive amount of data over the years, both electrophysiological and behavioral, and in both wild-type and transgenic animals. Claudia quickly mastered the literature on the topic and produced a series of increasingly detailed models of the system. First, she focused on the granule cell - Purkinke cell pathway and showed that the learning rule produces a time course of learning which is of the same order of magnitude as seen in the data. Furthermore, when a delay is added to the 'error signal' provided by the climbing fiber input, the rule produces a dynamics of the phase shift of the behavioral response in striking agreement with the data. Second, she added the medial vestibular nuclei in the model, and showed how consolidation occurs in this system, on longer time scales. She is now exploring learning in a system in which interneurons in the molecular layer are added explicitly, to be able to compare the model with transgenic animals that lack inhibition in Purkinje cells. Overall, I have been very impressed by how she dealt with this project, and by the progress she made in just a few months.

As far as publications are concerned, I expect at least three papers to come out of the projects we have been working with. The first paper, on the storage of temporally correlated patterns in Purkinje cells, will be published soon in PLOS Comp Biol. A second paper on the linear perceptron will be submitted soon to Physical Review Letters. Last, the results on VOR adaptation are very promising and in my view could lead to a publication in a high profile neuroscience journal.

Overall, I am very happy to have spent two years working with her as a post-doc. She is now a very mature scientist, and is able to work autonomously. She has a very broad knowledge of computational neuroscience. She is also a great person to interact with - always happy, dynamic and willing to help others. I recommend her without any reservation.

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