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Preface

# Methods for computational neuroscience

Computational neuroscience, and more generally theoretical neuroscience, has traditionally been looked at with some scepticism by the experimental neuroscience community. One of the reasons for this scepticism was that models were often disconnected from reality, describing situations that were too idealized compared to the actual biological complexity. However, this situation changed following the emergence of computational studies that were tightly based on experimental data, as exemplified by the Hodgkin and Huxley model of the action potential. Models began to be considered as useful tools to understand physiological recordings. Since then, computational neuroscience has experienced a tremendous growth, and more rarely triggers scepticism. Computational methods now not only aim at explaining or predicting experimental observations, but they also provide tools to manipulate and analyze experimental data. They may even interact directly with living neurons, a fact that may have been unimaginable a few decades ago.

The goal of this Special Issue on "Methods for Computational Neuroscience" is precisely to overview such computational methods that are directly applicable to experimental data. The first type of application is one that allows models to interact directly with living neurons. This so-called "dynamic-clamp" or "conductance-injection" technique consists of injecting – via the intracellular electrode – conductances in the recorded neuron. Because the current injected in the neuron necessarily depends on the instantaneous value of the membrane potential, a real-time interaction between the computer-generated conductances and the living neuron is necessary. Several papers in this issue directly or indirectly deal with these issues. Robinson describes a new DSP-based system to perform "conductance-injection" experiments, which is programmable and enables a wide range of applications. Bettencourt and co-workers compare real and simulated "dynamic-clamp" experiments, and examine artefacts that arise from this technique and possible ways to correct them. Hughes and co-workers introduce a new simulation system called NeuReal which is capable of simulating artificial dendrites and creating hybrid networks with real and simulated neurons, as well as other applications. Piwkowska and co-workers describe a number of methods to analyze intracellular recordings and extract conductances. They use a "dynamic-clamp" system based on the NEURON simulator to test these methods in controlled situations. These papers depict some of the latest developments in the "dynamic-clamp" technique, which remains one of the closest type of possible interactions between models and experiments.

Another theme well represented in this issue is the design and use of computational methods to analyze experimental data. Computational methods are of great value for analyzing data from intracellular experiments, as mentioned above for conductance analysis (Piwkowska and co-workers). The extraction of conductance patterns from intracellular data is reviewed in great detail by Monier and co-workers, in particular with the aim of comparing different methods to extract conductances from intracellular recordings *in vivo*. Cox proposes a computer-based technique to correct for space clamp errors, as typically seen in voltage-clamp experiments. These methods typically apply to intracellular or patch-clamp experiments and illustrate that computational models can help us to obtain reliable measurements of physiological variables.

Computational methods can also be of invaluable help in the analysis of extracellular recordings of neuronal activity. Nawrot and co-workers described methods to measure the dynamics of variability extracellularly recorded spike trains. Part of this paper originality is that the authors test some of the assumptions of such measures on real neurons recorded *in vitro*. Gordon and co-workers use mutual information and Fischer information techniques to analyze spike trains recorded in the auditory system. They show how such measures can be used to reconstruct discriminability close to behavioural performance. In these cases, computational methods help the experimentalist to extract "hidden" variables and components from the recorded data. This theme is also followed at another level by Stewart and Plenz. By using more global measurements, such as extracellular field potentials, these authors aim at finding signatures of self-organized dynamical regimes giving rise to the recorded signals. In particular, the dynamics of "neuronal avalanches" is analyzed using specific methods.

Computational models can also be directly deduced from the data using sophisticated fitting techniques. This is the approach followed by Jolivet and co-workers who propose benchmarks to evaluate simple neuron models. Finally, Hines and Carnevale describe an extension of their NEURON simulator to simulate large-scale models on parallel hardware. This example illustrates that not only new models and theories are needed, but

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that we must also care about adapting the simulation tools to the new parallel computing architectures that are available at present.

In conclusion, by compiling such a series of articles, we hope to provide a good representation of the current and future trends in computational neuroscience. From reading this material, one gets the definite impression that computational methods are getting closer and closer to experiments, as exemplified by the dynamic-clamp technique, in which models and living neurons interact in real-time. This illustrates the fact that solving many of the open questions in neuroscience is only possible through a tight association between experimental and theoretical methods.

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