Probabilistic structures of the brain.

Jeudi 13 décembre 2012 (*)

09h30-10h00 Accueil / Café.

10h00-10h50 **Roberto Fernández (Utrecht)**
Gibbsian descriptions : meaning, limitations and relevance for neural systems – or : All you wanted to know about Gibbs states but were afraid to ask.

11h00-11h50 **Michèle Thieullen (UPMC, Paris)**
Limit Theorems for a family of Piecewise Deterministic Markov models. Application to neuronal electrical activity.

12h15-14h00 Repas au Campanile. [Nécessite inscription .. ! (**)]

14h00-14h50 **Reinhard Höpfner (Mainz)**
Some problems related to modelization of membrane potentials and information transmission in large systems of neurons.

15h00-15h50 **Adeline Samson (Université Paris Descartes)**
Parameter estimation in the stochastic Morris-Lecar neuronal model with particle filter methods.

16h00-16h30 Café

16h30-17h20 **Gilles Wainrib (Paris 13)**
Relative entropy, synaptic plasticity and learning.

Organisateur : Eva Löcherbach

(*) Amphi Colloque. St Martin 2.
2, Avenue Adolphe Chauvin, 95302 Cergy-Pontoise.
Comment venir : **http://agm.u-cergy.fr/venir.html**

(**) Inscription : **http://www.u-cergy.fr/fr/laboratoires/agm/actualites-du-laboratoire/prob-str-brain-dec12.html**

Vendredi 14 décembre 2012 (*)

09h30-10h20 **Bruno Cessac (Inria, Sophia Antipolis)**
Dynamics and spike trains statistics in conductance-based Integrate-and-Fire neural networks with chemical and electric synapses.

10h30-10h45 Café

10h45-11h25 **Antonio Galves & Eva Löcherbach (Numec, Sao Paulo and Cergy-Pontoise)**
Infinite systems of interacting chains with memory of variable length - a stochastic model for biological neural nets.

11h30-12h20 **Alexandre Gramfort (Télécom, Paris)**
Functional brain imaging : how to use MEG and fMRI to know the "where" and "when".

12h30-14h00 Repas au Campanile. [Nécessite inscription .. ! (**)]

14h00-14h45 **Rune W. Berg (Copenhagen)**
Motor activity of populations of spinal neurons is both highly stochastic yet deterministic.

14h45-15h30 **Susanne Ditlevsen (Copenhagen)**
Motoneuron Membrane Potentials Follow a Time Inhomogeneous Jump Diffusion Process.

15h30-15h45 Café

15h45-16h35 **Claudia Vargas (Rio de Janeiro)**
Electrophysiological Correlates of Motor Cognition.

16h45-17h30 **Final Discussion : Probabilistic and statistical challenges in neuroscience**
Chairman : Eric Moulines (Télécom Paris)

Abstracts

Rune W. Berg, Copenhagen : Motor activity of populations of spinal neurons is both highly stochastic yet deterministic.

One of the biggest unresolved questions in neuroscience is how the central nervous system can be so reliable yet seem to be ruled by stochasticity. This is particularly transparent in the motor system, where movement can be reproduced almost exactly again and again, like a clock without ever failing, for instance running a marathon of thousands and thousands of steps without ever falling. Yet if we record any of the underlying electrical activity (spike timing, membrane potentials, electromyographs etc) it is packed with signs of randomness. In this talk I will address this open question and expose the stochasticity in our own data and compare it with the conventional wisdom about how the motor function works. We base our experimental research on electrophysiological recordings from the spinal cord of turtles, who are able to perform stereotypical though complicated motor patterns and is therefore a suitable experimental model.

Bruno Cessac, INRIA, Sophia-Antipolis : Dynamics and spike trains statistics in conductance-based Integrate-and-Fire neural networks with chemical and electric synapses.

We investigate the effect of electric synapses (gap junctions) on col- lective neuronal dynamics and spike statistics in a conductance-based Integrate-and-Fire neural network, driven by a Brownian noise, where conductances depend upon spike history. We compute explicitly the time evolution operator and show that, given the spike-history of the network and the membrane potentials at a given time, the further dynamical evo- lution can be written in a closed form. We show that spike train statistics is described by a Gibbs distribution whose potential can be approximated with an explicit formula, when the noise is weak. This potential form encompasses existing models for spike trains statistics analysis such as maximum entropy models or Generalized Linear Models (GLM).

Susanne Ditlevsesen, Copenhagen : Motoneuron Membrane Potentials Follow a Time Inhomogeneous Jump Diffusion Process.

Stochastic leaky integrate-and-fire models are popular due to their simplicity and statistical tractability. They have been widely applied to gain understanding of the underlying mechanisms for spike timing in neurons, and have served as building blocks for more elaborate models. Especially the Ornstein-Uhlenbeck process is popular to describe the stochastic fluctuations in the membrane potential of a neuron, but also other models like the square-root model or models with a non-linear drift are sometimes applied. Data that can be described by such models have to be stationary and thus, the simple models can only be applied over short time windows. However, experimental data show varying time constants, state dependent noise, a graded firing threshold and time-inhomogeneous input. In the present study we build a jump diffusion model that incorporates these features, and introduce a firing mechanism with a state dependent intensity. In addition, we suggest statistical methods to estimate all unknown quantities and apply these to analyze turtle motoneuron membrane potentials. Finally, simulated and real data are compared and discussed.

We find that a square-root diffusion describes the data much better than an Ornstein-Uhlenbeck process. Further, the membrane time constant decreases with increasing depolarization, as expected from the increase in synaptic conductance. The network activity, which the neuron is exposed to, can be reasonably estimated to be a threshold version of the nerve output from the network. Moreover, the spiking characteristics are well described by a Poisson spike train with an intensity depending exponentially on the membrane potential.

Joint work with Patrick Jahn, Rune W. Berg and Jorn Hounsgaard.

Roberto Fernández, Utrecht :Gibbsian descriptions : meaning, limitations and relevance for neural systems – or : All you wanted to know about Gibbs states but were afraid to ask.

Antonio Galves, Numec, Sao Paulo, and Eva Löcherbach, UCP, Cergy-Pontoise : Infinite systems of interacting chains with memory of variable length - a stochastic model for biological neural nets.

We consider a new class of non Markovian processes with a countable number of interacting components. At each time unit, each component can take two values, indicating if it has a spike or not at this precise moment. The system evolves as follows. For each component, the probability of having a spike at the next time unit depends on the entire time evolution of the system after the last spike time of the component. This class of systems extends in a non trivial way both the interacting particle systems, which are Markovian, and the stochastic chains with memory of variable length which have finite state space. These features make it suitable to describe the time evolution of biological neural systems. We construct a stationary version of the process by using a probabilistic tool which is a Kalikow-type decomposition either in random environment or in space-time. This construction implies uniqueness of the stationary process. Finally we consider the case where the interactions between components are given by an directed critical Erdös-Rényi-type random graph with a large but finite number of components. In this framework we obtain an explicit upper-bound for the correlation between successive inter-spike intervals which is compatible with previous empirical findings.

Alexandre Gramfort, Télécom Paris : Functional brain imaging : how to use MEG and fMRI to know the "where" and "when".

Electroencephalography (EEG), Magnetoencephalography (MEG) and functional MRI (fMRI) are techniques that allow to image brain activations. While MEG/EEG measure outside of the head the electro-magnetic fields induced by cortical activations, fMRI measures the magnetic distortions due to the change in blood oxygenation near the foci of neural activations. In this talk I will review the physics of both acquisition techniques as well as explain some of their benefits for cognitive neurosciences and clinical applications. I will then focus on some recent work on source localization with MEG/EEG using sparse time-frequency analysis, and pattern recognition on fMRI data, also called "brain reading".

Reinhard Höpfner, Mainz : Some problems related to modelization of membrane potentials and information transmission in large systems of neurons.

We start with a probabilistic toy model for information transmission in large systems of neurons. The mem- brane potential in the single neuron is modelled as a Cox-Ingersoll-Ross type jump diffusion with explicit time dependence in the drift, and spike generation is conditionally Poisson. We give a limit theorem which shows how a large system of neurons processing the same signal can transmit this signal up to some small deformation of its shape.

Then we look into sets of neuronal data where the membrane potential in one pyramidal neuron – belonging to an active network in a cortical slice observed in vitro – has been recorded as a function of time, under different experimental conditions which create different levels of network activity. First, assuming that the membrane potential between successive spikes should be well modelled by a time homogeneous diffusion, nonparametric estimates for diffusion coefficient and drift make appear three relevant classes of diffusion models. Second, we consider $p-$variations for different values of p. With reference to Ait- Sahalia and Jacod (2009) we ask the question to which extent an Ito semimartingale model can be adaequate for the membrane potential between successive spikes : in our data, an intriguing difference appears – in the same neuron – between spiking and non-spiking regimes. Hodgkin-Huxley-like systems of differential equations can model fast ionic currents through the membrane, present in the spiking regimes, and absent in the non-spiking regimes, and the time scale for these currents is comparable to the time resolution in our data.

Adeline Samson, Université Paris Descartes : Parameter estimation in the stochastic Morris-Lecar neuronal model with particle filter methods.

Parameter estimation in two-dimensional diffusion models with only one coordinate observed is highly relevant in many biological applications, but a statistically difficult problem.

The membrane potential evolution in single neurons can be measured at high frequency, but biophysical realistic models have to include the unobserved dynamics of ion channels. One such model is the stochastic Morris-Lecar model, where random fluctuations in conductance and synaptic input are specifically accounted for by the diffusion terms. It is defined through a non-linear two-dimensional stochastic differential equation with only one coordinate observed. We aim at estimating the parameters of this stochastic Morris-Lecar model. We propose a sequential Monte Carlo particle filter algorithm to impute the unobserved coordinate, and then estimate parameters maximizing a pseudo-likelihood through a stochastic version of the Expectation-Maximization algorithm. Performance on simulated data and real data are very encouraging. Joint work with Susanne Ditlevsen.

Michèle Thieullen, UPMC, Paris : Limit Theorems for a family of Piecewise Deterministic Markov models. Application to neuronal electrical activity.

In this talk I will present a family of stochastic models which are relevant in order to describe the electrical activity at the level of a single neuron as well as of populations. These models are Piecewise Deterministic Markov Processes and are sometimes called hybrid models since they contain a mixture of deterministic and stochastic evolution. The first motivation is to model a neuron with a finite number of channels displaying a stochastic gating mechanism. This naturally requires to prove limit theorems for a sequence of such models such as Law of Large Numbers and Central Limit Theorems. In the framework of spiking neurons, we are also interested in related results for hitting times and in approximations. The finite dimensional case of a point model as well as the infinite dimensional one describing propagation along the axon can be dealt with in this framework. The material of this talk is based on collaboration with A. Genadot (UPMC), K. Pakdaman (Univ. Paris Diderot), M. Riedler (Univ. Linz), G. Wainrib (Univ. Paris 13).

Claudia Vargas, Rio de Janeiro : Electrophysiological Correlates of Motor Cognition.

In this colloquium I explore cortical networks associated with the viewing of point light displays depicting human locomotion (biological movement, BM) as opposed to scrambled motion (SM), as measured by means of event-related potentials (ERPs). Employing a random graph approach I show that brain network signatures extracted from electroencephalographic signals (EEG) change in fast scale. Furthermore, global and local network measures (average path length, clustering coefficient, degree and betweenness) extracted from BM and SM and compared as a function of time reveal that whereas global measures do not discriminate BM from SM, local node properties do so. Results are discussed in terms of BM vs. SM coding in the brain. Work in collaboration with Daniel Fraiman and Ghislain Saunier.

Gilles Weinrib, Paris 13 : Relative entropy, synaptic plasticity and learning.

We introduce a general learning principle designed to capture the dynamics of an input into a recurrent neural network. By minimizing the relative entropy between a given input dynamical system and the spontaneous activity of the neural network, we derive a new unsupervised learning rule. This learning rule can be interpreted in terms of biologically relevant synaptic plasticity mechanisms, such as spike-timing dependent plasticity and synaptic scaling. Joint work with Mathieu Galtier.