Solving Partial Differential Equations and variational problems with networks of spiking neurons

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In the framework of an EU FET-Proactive FP7 grant BrainScaleS, we are developing mean-field models of populations of neurons in order to come up with rigorous multiscale representations of such populations. The neuronal models are either rate or spiking models.

Many problems in computational and scientific disciplines can be represented as optimization problems and/or by partial differential equations. Partial differential equations contain both spatial and temporal derivatives and arise in physics, chemistry, fluid dynamics, weather maps, seismology, computer vision, often in the context of complex optimization problems. The spatial derivatives correspond to, and can be implemented by, local interacting units. Based on this insight, a large body of literature has appeared that tries to find solutions of partial differential equations by implementation in a neural network with a high degree of local connectivity [1, 2].

The main objective of this Postdoc proposal is to develop general rules of how to translate optimization problems and/or partial differential equations into interacting spiking neurons of the type used in BrainScaleS (see [4] for an attempt in this direction with non-spiking neurons). This objective will be achieved by exploiting the relation between large networks of spiking neurons and their mean-field descriptions as neural fields whose dynamics is defined by integro-differential equations [3], and by exploiting the relation between some classes of such equations and a variety of PDEs and optimization problems. These algorithms will be implemented in large-scale networks on the Hybrid Multiscale Facility developed in BrainScaleS.

As a result, this is a very different type of computational paradigm from the usual von Neumann one in which the network is in effect solving a computational problem “on average”, its solution being read from its mesoscopic descriptions.

The candidate should have a strong background in the area of numerical techniques, in particular particle methods, for solving Partial Differential Equations and be interested in exploring new, unconventional, ways of implementing them with networks of spiking neurons.

The position is for two years in the NeuroMathComp group located in Sophia-Antipolis between Nice and Cannes on the French Riviera.

Applications should be sent to Olivier Faugeras who is the principal investigator. Pierre Kornprobst will also be involved in the project.

References

[1] G. Cottet and S. Mas-Gallic:. A particle method to solve the navier-stokes system. *Numer. Math.*, 57, 1990.

[2] G.-H. Cottet. Neural networks: continuous approach and applications to image processing. *J. Biological Systems*, 3, 1995.

[3] Olivier Faugeras, Jonathan Touboul, and Bruno Cessac. A constructive mean field analysis of multi population neural networks with random synaptic weights and stochastic inputs. *Frontiers in Computational Neuroscience*, 3(1), 2009.

[4] T. Viéville, S. Chemla, and P. Kornprobst. How do high-level specifications of the brain relate to variational approaches? *Journal of Physiology - Paris*, 101(1-3):118–135, 2007.