Ph.D. position

Topic: "Bayesian Inference of Geophysical Dynamical Models by Image Assimilation"

Institute: Research Center of INRIA Rennes - Bretagne Atlantique (France)

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Project description:

This PhD is motivated by the need of inference tools for modeling multi-scale non-linear dynamics in meteorology, oceanography, or in the field of experimental turbulence. The complexity of the fundamental law governing these chaotic flows, the Navier-Stokes equations, prevents the use of a unique model for the description of the great variety of turbulent phenomena. When properly chosen, some simplified model can however constitute relevant approximations. Nevertheless, the crucial issue remains: how to decide which simplification to do?

Image sequences represent an important source of information since they characterize dynamics on a large range of scales in comparison to sparse information contained in "in situ" data. Moreover, the volume of remote sensing image sequences has drastically increases these last years. Such image data can in principle enable the adjustment and the choice of the most relevant models for local geophysics dynamics [2].

Therefore, the goal of the PhD is to devise proper mathematical tools for selecting and fitting dynamical models of fluid flows by inverse modeling of image sequences.

Theoretical background will rely on a Bayesian approach for decision, using a marginalized *a posteriori* sense [3]. To enable the optimization of this criterion, a special attention will be devoted to Expectation-Maximization algorithm [4], mean-field approaches [5], optimal-control strategies [1] and stochastic filtering. The theoretical background will also strongly rely on the physics of fluid. In particular, either deterministic or stochastic fluid models will be considered as physical priors.

One of the goal of the PhD will be to propose proper methods to estimate hyper-parameters and models in variational image assimilation approaches. In particular, research will focus on the estimation of the covariance matrix, the selection of optic-flow priors and sub-grid models in Large-eddy simulation approaches.

An important axis of research will concern the estimation guided by the image data of a proper adaptive representation in time, scale and space of the flow. The goal will be here to choose the most likely low-order dynamical models for fluid dynamics observing some image data. Because of their sparse representation and their scale-space localization, wavelet-based models constitute in this context an interesting perspective [6].

This PhD will take place in the context of the "FLUMINANCE" team of the research center of INRIA Rennes - Bretagne Atlantique (France). Close collaborations are expected with national and international (UBA Argentina) academic partners.

Keywords: Bayesian modeling, optimal control, stochastic filtering, geophysical dynamics, image analysis, differential equations.

Candidate Profile:

Candidates must have a strong background in applied mathematics, with emphasis on Statistics, signal processing and/or numerical methods. Additional expertise in the fields of physics would be welcome. Proficient programming in C/C++ and Matlab is an asset.

References :

[1] N. Papadakis, E. Memin. Variational assimilation of fluid motion from image sequences. SIAM Journal on Imaging Science, 1(4):343-363, 2008.

[2] M. Bocquet. Towards optimal choices of control space representation for geophysical data assimilation. *Monthly Weather Review*, 137(7):2331-2348, July 2009.

[3] S. Kay. Fundamentals of Statistical Signal Processing: Estimation Theory. Prentice Hall, New Jersey, USA, 1993.

[4] A. P. Dempster, N. M. Laird, and D. B. Rubin. Maximum-likelihood from incomplete data via the EM algorithm. J. Roy. Stat. Soc., 39(1):1–38, Jan. 1977.

[5] M. J. Beal and Z. Ghahramani. The variational Bayesian EM algorithm for incomplete data: with application to scoring graphical model structures. Bayesian Statistics, 2003.

[6] S. Mallat. A wavelet tour of signal processing: the sparse way. Elsevier, 3rd edition, 2009.