Assimilation techniques for the estimation of 2D and 3D features from images sequences

PhD in mathematics applied to geosciences – Grenoble, France

Advisors

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Geophysical framework

In the coming years, an increasing number of Earth Observation missions will complement the existing data stream to provide an unprecedented capacity to observe the ocean and the atmosphere. Consequently, it is mandatory to accelerate the development of robust dedicated processing strategies to devise global and regional products combining these new observations capabilities and modeling systems through improved data assimilation capabilities.

Highly dynamical flows abound in nature. In environmental sciences such as oceanography and meteorology, flows control the transport of energy and matter within the atmosphere, in oceans and ashore. The dynamic these flows are undergoing is due to complex physical interactions, almost impossible to describe through affordable computational models. Intricate boundary conditions, interacting multiphase fluids and fully developed turbulence characterize these flows.

The ability to analyze in detail such flows has large implications for numerous scientific studies such as weather forecast.

Mathematical framework

Taken separately models and observations do not permit for a deterministic reconstruction of real geophysical flows. Therefore it is necessary to use these heterogeneous but complementary sources of information simultaneously through so called Data Assimilation methods. These are inverse modelling techniques based on the mathematical theory of statistical estimation and/or optimal control. Their aim is to combine observations and prior model estimates, taking into account their respective statistical accuracies, in such a way that the combined estimate is more accurate than either source of information taken individually. In variational data assimilation, the *analysis problem* is defined by the minimisation of a cost function that measures the statistically weighted squared differences between the observational information and their model counterpart. The cost function is minimised with respect to the control variables and this is done iteratively using a gradient-type descent method.

This kind of application spans a large spectrum of applied mathematics domains, such as scientific computing, optimal control of partial differential equations, wavelets and curvelets, optimal transport theory, data assimilation, ...

Work description

One of the prerequisites for performing data assimilation is the ability to compare model output and observed data through the so-called Observation Operator. For the direct assimilation of image sequences one of the main difficulties is to define a space and a proper norm to perform this comparison. Such a comparison usually takes place either at the pixel level or at the analysis level. In the former a pseudo image is generated from the model output and is compared pixel-by-pixel with the observation, while in the latter structures from both model and image are compared. In this PhD thesis, we would like to explore new ways of designing the observation operator, using sophisticated norms between images and to extend image assimilation techniques to relevant models of geophysical flow dynamics and applications.

The following directions could be followed:

1. New distances based on optimal transport theory. The objective of this work is to explore new ways of defining the distance between two images, in order to perform direct assimilation of images sequences. Optimal transport theory defines the best (in a sense to be specified) velocity field transporting the image luminance function, or image probability distributions related to specific objects or situations. This velocity field could then be used to define a better distance notion between two images, which would take a better care of features displacement, and improve the observation operator and therefore the assimilation results. This approach will be compared to more classical approaches of direct assimilation.

2. Assimilation technique for the tracking of structures. The goal of this work is to provide efficient and robust assimilation techniques for the tracking from

satellite images of geometric elements such as curves or fronts transported by oceanic or atmospheric flows. The definition of meaningful evolution laws and their related uncertainties will be carefully studied. The question of adequate representations for these features (implicit surface, curvelets, bi-orthogonal complex valued wavelet) will be also tackled. The proposed techniques will take into account the problem of tracking when facing occlusion situation due to the cloud cover.

Work environment

The student will benefit from INRIA work status (see e.g. http://www.inria.fr/travailler) and ANR-GEOFLUIDS grant, from the regional graduate courses (thanks to the graduate school), could attend national and international summer schools and conferences, and will have substantial computing resources (personal computer, access to local, regional and national computing centres).

Required background

The ideal candidate will have a master degree in pure or applied mathematics with strong interest in scientific computing for partial differential equations or vice versa. Outstanding applications from mechanical engineering will also be considered. The candidate should also be interested in geophysics and geosciences. Experience in Fortran would be greatly appreciated.