Advanced turbulence models for the assimilation of flows from image sequences

Key Words

Turbulence models (LES, REDLES, Subgrid modeling), data assimilation, fluid motion, image analysis

Description of the project

Context

Complex fluid flows that appear in various applications (oceanography, meteorology, climatology, medical imaging, experimental fluid mechanics, ...) result from different physical interactions that yield very difficult the design of exact mathematical models to predict their evolution. On the other hand, image analysis provide a powerful tool to extract in detail some information at various scales that can complement the errors on the mathematical models. However, due to 3D-2D projection, difficult visualization processes, ..., the inverse problem of estimating a system state (the motion field for instance) directly from an image sequence involving fluid flows can hardly be managed without introducing some physical knowledge. In the recent years, data assimilation techniques [7] have successfully been developed to estimate some physical parameters from image observations, using various Navier-Stokes representations as a dynamical modeling (see [2] for instance).

Nevertheless despite the global accuracy, it has been observed on some applications that such techniques are likely to exhibit errors mainly concentrated on the fine scale structures. These latter are however crucial for the flow analysis. In addition, due to inverse-cascade effects, these poorly-estimation of fine scales (unresolved subgrid-scales) disturb the accuracy of the estimation on the larger structures of the flow. The aim of this work is to define some assimilation tools exploiting dynamical models that directly deal with the different scales of the flow.

Description of the project

This PhD will focus on the use of turbulence models based on 2-point statistical turbulence modeling for the assimilation of the flow. Unlike classical Large Eddy Simulation (LES) techniques that filter out the small scales of the flow to model the largest ones, the Reynolds Decomposition Large Eddy Simulation (REDLES) approach distinguish the physical effects of mean (in the sense of statistical average) and fluctuating fields to provide specific models. The two-point techniques have been largely used to gain understanding of homogeneous turbulence [5] and have been recently applied for subgrid-scale modeling.

The goal of this PhD is to assimilate image of fluid flows under the dynamical models mentioned above. To that end, the student will have:

1. to explore the two-point closures techniques for subgrid-scale modeling developped in REDLES approach [4, 6]
2. to compare with classical subgrid-scale models [8]
3. to explore the way one can represent a velocity field (classical components (u, v) are scale-based representations) and observe it from image sequences [1, 3]

It is expected that the final techniques of analyzing fluid flows under the prior of such dynamical models will constitute unique and powerful tools for fluid image analysis.

Profil

Candidates should have a background in fluid mechanics and applied mathematics (partial differential equations in particular). From a practical point of view, existing softwares of motion estimation and data assimilation are in C and/or matlab.

Contact & Location

This PhD will be supervised by Thomas Corpetti (`tcorpetti@gmail.com`) and Liang Shao (`Liang.Shao@ec-lyon.fr`). Please send us an email before June 30th, 2010.

This work will take place at Beijing ("LIAMA" –Sino-French laboratory on Informatics, Automatic and Applied Mathematics– and " LIA2MCIS " –Ecole Centrale Pékin, Beihang University–) and Lyon ("LMFA" –Laboratoire de Mécanique des Fluides et Acoustique, Ecole Centrale).

References

[1] C. Cassisa, V. Prinet, L. Shao, S. Simoens, and C.-L. Liu. Optical flow robust estimation in a hybrid multi-resolution MRF framework. In *IEEE International Conference on Accoustics, Speech and Signal Processing, ICASSP'08*, pages 793–796, Las Vegas, USA, 2008.

[2] T. Corpetti, P. Heas, E. Mémin, and N. Papadakis. Pressure image assimilation for atmospheric motion estimation. *Tellus Series A: Dynamic Meteorology and Oceanography*, In Press, 2008.

[3] T. Corpetti, E. Mémin, and P. Pérez. Dense estimation of fluid flows. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 24(3):365–380, March 2002.

[4] G. Cui, C. Xu, L. Fang, L. Shao, and Z. Zhang. A new subgrid eddy-viscosity model for large-eddy simulation of anisotropic turbulence. *Journal of Fluid Mechanics*, 582:377–397, 2007.

[5] R. H. Kraichnan. Eddy viscosity in two and three dimensions. *Journal of the Atmospheric Sciences*, 33:1521–1536, 1976.

[6] E. Lévêque, F. Toschi, L. Shao, and J. Bertoglio. Shear-improved Smagorinsky model for large-eddy simulation of wall-bounded turbulent flows. *Journal of Fluid Mechanics*, 570:491–502, 2007.

[7] J. Lions. *Optimal control of systems governed by PDEs.* Springer-Verlag, 1971.

[8] J. Smagorinsky. General circulation experiments with primitive equation. *Monthly Weather Review*, 91:99, 1963.