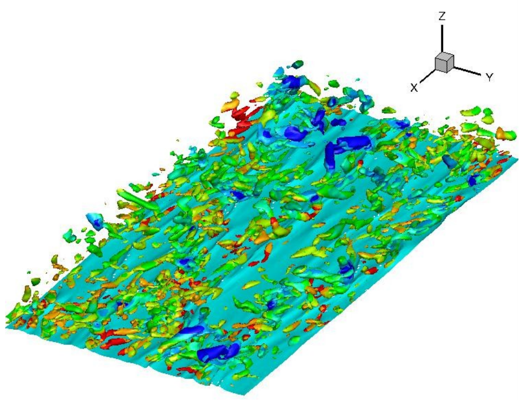
POST-DOCTORAL POSITION

DECODING AND RECODING WALL TURBULENCE

The project is funded by the Center for Data Science of the Paris-Saclay University. The goal of the project is to develop and implement statistical methods for the analysis and reconstruction of wall turbulence.



Vorticity (Q-criterion colored by pressure) and velocity streaks in a subdomain of turbulent channel flow (simulation results from Y. Fraigneau – LIMSI)

Understanding and modeling turbulent phenomena in Fluid Mechanics is pivotal in many areas of science, ranging from life and environmental sciences to engineering applications. As numerical simulations and experimental techniques have developed in recent years, extensive databases are now available, providing opportunities for testing and developing new theories and methodologies. However, numerical simulations are limited in time-span, laboratory experiments only provide sparse spatio-temporal measurements and the fluid mechanics parameters describing a real-life problem may be unknown or cannot be accurately determined. The challenge is to overcome these limitations in order to provide (*i*) **efficient and relevant characterization of the turbulent phenomena**, (*ii*) **reconstruction of missing data and/or generation of virtual data in a realistic context**.

Another motivation for this work is the control of complex physical systems such as turbulent flows (see illustration to the left). This class of systems comprises very high-dimensional objects while being observed only via scarce sensors. Since most efficient control methods require knowledge of the state of the system, controlling a turbulent flow is a grand challenge. To address this issue, the relationship between actuation, sensor measurements and an approximation of the state vector will be learned from the system in a data-driven model-free approach.

The project is divided into the following connected tasks:

1) Kernel-learning for sparse representation: Development of the methodology to learn a suitable kernel and low-dimensional map from the measurements to the state vector approximation. The candidate will build up from early work of ours in the linear case [1].

2) Decoding task: Analysis of Fluid Mechanics databases using application-tailored data science analysis tools (including clustering and graph analysis in a network-theoretic framework),

3) Recoding task: Reconstruction/ Generation of data in a missing information context using statistical methods (such as compressed sensing and deep learning), with a view to emulate a full information context [2].

The methods will be developed for and applied to the existing database of a turbulent channel flow, which has been generated with the code SUNFLUIDH (Y. Fraigneau). The database consists of a large number of flow realizations, well sampled in time, currently stored at the IDRIS facility. Interaction with the CHM department of LIMSI on visualization and learning aspects is planned.

The candidate will have a strong background in one or more of the following areas: Applied Mathematics, Signal Processing, Fluid Mechanics, Computational Mathematics, Statistics. Proficiency in programming and writing is required.

Duration: 12 Months.

Location: LIMSI Laboratory, rue Von Neumann, Université Paris-Sud, Orsay, France.

Contact: Bérengère Podvin podvin@limsi.fr ou Lionel Mathelin mathelin@limsi.fr.

[1] Mathelin L., Kasper K. & Abou-Kandil H. (2017) 'Observable dictionary learning for high-dimensional statistical inference', *Archives of Computational Methods in Engineering*, In Press. Available on ArXiv: *https://arxiv.org/abs/1702.05289*.

[2] Podvin B., Fraigneau Y., (2017) 'A few thoughts on Proper Orthogonal Decomposition in Turbulence', Physics of Fluids, 29, 020709.