Research Area : Numerical Analysis of Flow Phenomena

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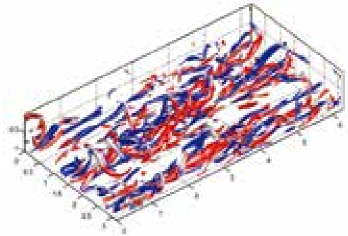
Data-driven computing for prediction and control of wall-bounded turbulence

Wall-bounded turbulence significantly contributes to heat transfer and drag on a wall surface, and the prediction and control of turbulent phenomena leads to the efficient use of energy, and the time-series data of turbulent flow fields have been obtained by the numerical simulation. In the future, it is necessary to develop the data-driven prediction and control technique based on a deep understanding of the turbulent flow for the wide application in engineering.

We will carry out numerical calculations for various engineering problems and challenge the turbulent flow problem, which is so-called the final problem of classical mechanics, using new techniques of information science such as machine learning in addition to statistical analysis and dynamic system theory.



The coherent vortical structures in turbulent plane Poiseuille flow. Flow is from left to right. (red) cloclwise, (blue) anti-clockwise vortices.

Data-driven dynamical system for modeling and optimization of nonlinear phenomena

We can consider turbulent flow as a vector with a large dimension of freedom and a dynamical system, then we can numerically find invariant solutions such as equilibrium solutions and periodic orbits of Navier-Stokes equations or turbulence model equations. Understanding the role of invariant solutions in the turbulent flow phenomenon would provide some insights into the development of turbulence models and flow control techniques. The dynamical system approach can also be applied for the understanding of the mathematical model itself obtained by machine learning such as deep learning, since it must be common for the phenomenon with strong nonlinearity.

Our research aims are following:

development of simulation technique of the complicated process in which we can obtain the data of real phenomena, such as multiphase flow, chemical reaction, combustion, mixing of various particles, separation and aggregation processes, although the knowledge of macroscopic or statistical behavior is limited or the detailed simulation is not realistic; and then, development of the technique of optimization and control method which can be applied in a wide range of the engineering field.

The stratified homogeneous shear turbulence. (Red, blue), low and high density fluctuation, (gray) vortical structures.