［様式一学 5］

Abstract of Main Thesis

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Title of Thesis

Proper Orthogonal Decomposition based Measurement Models for Engineering Flows

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Abstract on the Content of the Applicant's Thesis

The current work aims to build flow measurement models to estimate the hydrodynamic states of complex turbulent flows. A potential application is to "nowcasting" of river flows. Nowcasting incorporates the most recent meteorological or oceanographic measurements to estimate the current state of the atmosphere and/or ocean. Such systems are starting to be developed for estuaries, and one can anticipate growing demand for nowcasting systems to estimate the detailed states of river and estuary flows, including flowfield, water level, suspended sediment, dissolved oxygen, and bacterial levels, in real time.

Such nowcasting systems include of a "state model", *i.e.* a numerical model for the physical system. In addition, a "measurement model", or "estimation model", is necessary to relate the available data to the current values of variables in the state model. The present work develops measurement models based on proper orthogonal decomposition (POD) analysis that relate measurement events to low-order POD coefficients of the velocity field under consideration. To evaluate the estimation models, I used data from both Stereo PIV and Large Eddy Simulation of open-channel flow past a backward-facing step, a complex, three-dimensional recirculating flow, at a bulk Reynolds number of 2800 and 4400 respectively based on step height. The tested POD-based estimation models, Principal Component Regression (PCR)-POD and Kernel Ridge Regression (KRR)-POD, use spatially distributed measurements, in particular wall shear gradient or free-surface velocity in our applications, to estimate the flowfield. In the experiments, three components of velocity were measured by stereo PIV at 15 Hz. Additionally, special image processing was developed to simultaneously measure two components of velocity gradient at the wall. First, the (PCR)-POD and (KRR)-POD estimation models were compared with previously developed approaches such as linear stochastic estimation, (LSE)-POD, and quadratic stochastic estimation, (QSE)-POD. In addition, we have introduced and tested multi-time PCR-POD and KRR-POD estimations, in which past and/or future information from spatially distributed measurements is used. The results show that our proposed multi-time approaches can improve the prediction process as compared to instantaneous estimates. Finally, we have used numerical data from the backstep flow to successfully test a real-time estimation model that uses free-surface velocity measurements to estimate subsurface flow. This represents a promising approach for measurement models to incorporate in nowcasting systems for rivers or estuaries.