Data Assimilation for Shallow Water Flows using Lagrangian Sensing

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The goal of this project is to design, implement and test data assimilation algorithms which can reconstruct two dimensional shallow water flows using Lagrangian (mobile) and Eulerian (static) measurements. Special attention has been paid to the requirements of practical implementation of data assimilation methods. The project also includes an experimental component with hardware – software development and deployment as part of field operational tests in the San Joaquin-Sacramento Delta.

The main objective of this project is to create a set of hardware and software tools which can be deployed quickly in a flexible manner to perform Lagrangian measurements in the Sacramento – San Joaquin Delta. Our group is working on the development of a hardware platform (drifters), which can measure velocity, transmit data in real time to a base station using GSM modules, and perform onboard computing (using a Linux gumstix). Additional sensors can easily be added to the hardware platform developed for the project. The floaters have an underwater sail to capture subsurface currents should that information be desired. Based on measurements provided by the drifters, we are interested in developing data assimilation to reconstruct currents and other features, such as salinity, in real time.

Our data assimilation algorithms seek to incorporate all the possible measurement information available to a flow model of the river. The result is an estimate of the state of the river.

To increase the performance of the data assimilation algorithm with real data collected from the Sacramento River, so called modeling error needs to be taken into account. Modeling error arises from the use of a lightweight computational model to approximate the true river flow. This approximation, however, is necessary for computational efficiency of the algorithm. The modeling error was characterized using a three-dimensional flow model (MIKE3 from DHI Software) as a ground truth. The results show that modeling error is captured and it

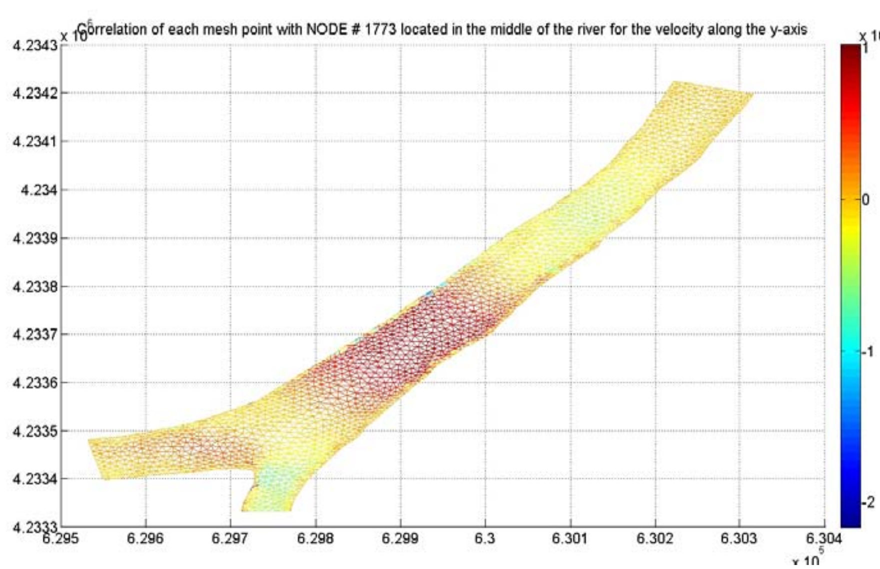

Figure 1: distribution of the modeling error for the model used with the Ensemble Kalman Filtering data assimilation technique, shown here for the Georgianna Slough.

enables the use of real data without any additional tuning of the data assimilation algorithm. The results in Figure 1 show that the characteristics of the error are nontrivial and have to be obtained through extensive modeling. Especially, the correlations between different parts of the river play a significant role. (Velocity units are in m/s.)

Algorithms developed as part of this work are tested in deployments, which for the Sacramento Delta are performed in the Georgianna Slough and the Grant Line Canal. Additional deployments have included the Federal Agriculture Department's Hydrologic Engineering Research Unit, Stillwater, OK, in a joint operation with the US Army Corps of Engineers, and the Department of Homeland Security.

The project has so far developed three generations of drifters, which started with purely passive data logging drifters. This was expanded to communication and control enabled drifters (Figure 2). The third generation drifter also includes motors and a buoyancy control mechanism.

Publications

Issam Strub, J. Percelay, O.-P. Tossavainen, A. Bayen, Comparison of two data assimilation algorithms for shallow water flows, *Networks and Heterogeneous Media,* 2009*,* (4)2, pp. 409-430.

Issam Strub, J. Percelay, M. Stacey, A. Bayen, Inverse estimation of open boundary conditions in tidal channels, *Ocean Modelling*, 2009, 29(1), pp. 85-93.

Qingfang Wu, X. Litrico, A. Bayen, Data reconciliation of an open channel flow network using modal decomposition, *Advances in Water Resources*, 2009, 32(2), pp. 193–204.

Professional Presentations

Olli-Pekka Tossavainen, Ensemble Kalman filter based state estimation in 2D shallow water equations using Lagrangian sensing and state augmentation, *2008 IEEE Conference on Decision and Control*, Cancun, Mexico, Dec. 2008

Qingfang Wu, X. Litrico and A. Bayen, Data reconciliation of an open channel flow network using modal decomposition, *47th IEEE Conference on Decision and Control*, pp. 3903-3910, Cancun, Mexico, Dec. 2008

Collaborative Efforts

The research performed as part of this project is a joint collaboration with Professor Mark Stacey, CEE, UC Berkeley, Dr. Peter Schwartz, Lawrence Berkeley National Laboratories, and Dr. Eli Ateljevich, California Department of Water Resources. Some of the deployments performed as part of this work are jointly done with the US Army Corps of Engineers, and the Department of Homeland Security.

Figure 2: EECS Ph.D. student Andrew Tinka demonstrates the capabilities of the UC Berkeley drifters prior to their deployment, Stillwater, OK.

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