Data Assimilation for Shallow Water Flows using Lagrangian Sensing

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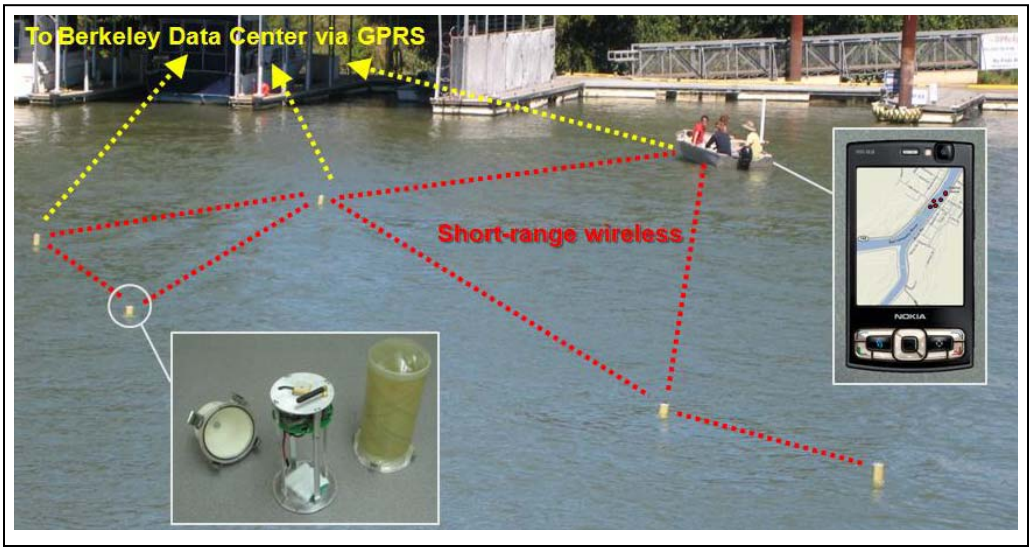
The goal of this project is to design, implement and test algorithms to be able to reconstruct two dimensional shallow water flows using Lagrangian (mobile) sensors. The project also includes an experimental component with hardware – software development and deployment as part of field operational tests 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 inverse modeling algorithms to reconstruct currents and other features, such as salinity, in real time. This relies on an accurate modeling of the deployment areas (using Shallow Water Equations), on which we can add additional one way coupled models. The inverse modeling algorithms under development for the project rely on a proper discretization of the flow equations, and the formulation of an optimization program in which we try to minimize discrepancy between measured and estimated quantities. In the case of the full nonlinear problem, we solve the data assimilation problem using Ensemble Kalman Filtering, a technique capable of handling the nonlinearity of the equation. Under specific assumptions relevant for the Sacramento Delta, we are able to simplify the equations and use either spectral methods (directly applicable to data reconciliation) or quadratic programming.

We implement our algorithms directly in twin simulations, using shallow water solvers such as Mike and Telemac. These twin experiments are used to assess the accuracy and the efficiency of the proposed



methods. The hardware platform deployed in the study is used to gather Lagrangian data in the Georgianna Slough (Walnut Grove), which serves as a testbed for this study. This area is of particular interest due to the tidal inversion it exhibits. The data collected from GPS is fused with additional data available to us through the USGS sensors already deployed in the Delta, or through Eulerian sensors available to us from other grants. Recently, we have started exploring active sensing by adding self propelled drifters and a submarine to our fleet.

Publications

Olli-Pekka Tossavainen, J. Percelay, A. Tinka, Q. Wu and A. M. Bayen, 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, *2008 IEEE Conference on Decision and Control*, Cancun, Mexico, Dec. 2008.

Simon Munier, Q. Wu, S. Amin, A. Bayen, X. Litrico and G. Belaud, Parameter identification for the shallow water equations using modal decomposition, *2007 IEEE Conference on Decision and Control*, New Orleans, LA, Dec. 2007.

Qingfang Wu, X. Litrico and A. Bayen, Data Reconciliation of an Open Channel Flow Network using Modal Decomposition, *Advances in Water Resources,* In Press (available online Nov. 2008).

Professional Presentations

Alexandre Bayen, Data Assimilation for two dimensional shallow water flows using Lagrangian Sensing, Workshop on Networks of Irrigation Channels, Maiori, Italy, October 2008.

Andrew Tinka, Development, testing and prototyping of a Lagrangian sensor platform, Center for Entrepreneurship, March 2008.

Alexandre Bayen, Motion tracking in large scale infrastructure systems using smartphones, CITRIS research exchange, UC Berkeley, May 2008.

Qingfang Wu, Parameter identification for the shallow water equations using modal decomposition, 2007 IEEE Conference on Decision and Control, New Orleans, LA, Dec. 2007.

Collaborative Efforts

Through the France Berkeley Fund, Dr. Xavier Litrico, from the CEMAGREF Agricultural Agency in France spent one year at Berkeley working on the modeling of the water channels under tidal forcing. PhD student Tarek Rabbani worked in France for a month at CEMAGREF to pursue this effort.

The Laboratory of Aquatic Technologies at the University of Porto in Portugal brought a light autonomous underwater vehicle to Berkeley in the fall of 2008 to perform some autonomous navigation and sensing experiments with us in the Georgianna Slough in Walnut Grove. This interaction will continue in Fall 2009.

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