Physical modeling and software synthesis for self-reconfigurable sensors in river environments

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Our work examines the role of software synthesis for monitoring and planning of autonomous sensors evolving on tidally forced rivers. The goal of the sensors is the coordinated sampling of currents and salinity to reconstruct the distributed state of the river and detect salinity intrusion. Solutions to problems such as this require an approach that considers reliable sensing, fast computation and safety verification. Our approach utilizes low-level event based control to avoid collision with river banks [3], Kalman filter based localization algorithms to facilitate the calculation of Voronoi partitions and autonomous sensor deployments (for example, for detecting salinity intrusion [1] while taking energy consumption into account [2]). Model transformations can be used to modify controller models to ensure that behaviors lie within the safety range [4].

More specifically, we have studied the problem of detecting salinity intrusion while minimizing the energy consumption. Due to a reduction in the supply of freshwater in estuaries, saltwater can intrude deeply into river channels. We design algorithms to autonomously deploy sensors to the river environment and adaptively sample the river to determine the degree of salinity intrusion. The results can be used to operate large control structures (e.g., Hiram M. Chittenden Locks in Salmon Bay, Washington) in response to salinity changes in river environments. Since mobile sensors are powered by batteries, we design optimal minimum energy control algorithms for sensor movements by approximating river flows via quadratic functions. We also introduce energy metrics that have potential applications in task assignments and distributed coverage control problems.

Our future work on this front will be dedicated to the development of new metrics and strategies that can help us deal with the uncertainty in the river state (which we would like to reconstruct) and (moderately) dynamic scenarios.

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2. Yu Ru and Sonia Martinez. “Freshwater-Saltwater Boundary Detection Using Mobile Sensors Part II: Drifter Movement”, to appear in Proc. of IEEE Conf. on Decision and Control, 2011
3. Kevin Weekly, Leah Anderson, Andrew Tinka, and Alexandre M. Bayen. “Autonomous River Navigations using the Hamilton-Jacobi Framework for Underactuated Vehicles“, in Proc. of IEEE Conf. on Robotics and Automation, pp. 828-833, May 2011
4. Maribel Hudson and Jonathan Sprinkle. "Simplification of Semantically-Rich Model Transformations Through Generated Transformation Blocks“, in Proc. of 8th IEEE Workshop on Model-Based Development for Computer-Based Systems, pp. 260-268, April 2011