CPS: Medium: Enabling Real-time Dynamic Control and Adaptation of Networked Robots in Resource-constrained and Uncertain Environments

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Project Details

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Institution(s):	Rutgers University New Brunswick
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Abstract: Near-real-time water-quality monitoring in rivers, lakes, and water reservoirs of different physical variables is critical to prevent contaminated water from reaching the civilian population and to deploy timely solutions, or at least to issue early warnings so as to prevent damage to human and aquatic life. In order to make optimal decisions and "close the loop" promptly, it is necessary to collect, aggregate, and process water data in real time. Therefore, the goal of this project is to design a Cyber Physical System (CPS) where drones such as the Rutgers multi-medium Naviator, a Hybrid Unmanned Air/Underwater Vehicle (HUA/UV), and autonomous underwater robots (e.g., modified BlueROVs) can (i) first identify Regions of Interest (RoIs) and take measurements and well as, if needed, collect biosamples from them; (ii) and then, through collaborative information fusion and integration, perform in-situ transformation of these measurements/raw data into valuable information and, finally, into knowledge. To achieve the above goal, this project will need to solve the problem of uncertainties that arise in in-situ processing of data from sensors in any CPS. This project will provide greater autonomy and cooperation in CPSs and, at the same time, will improve scalability, reliability, and timeliness in comparison to traditional sensing systems. The challenges to achieve dynamic collaboration between local and cloud resources will be handled in Task 1, in which novel adaptive-sampling solutions that minimize the sampling cost of a RoI (in terms of time or energy expenditure) will also be developed. In Task 2, novel solutions will be designed to handle model uncertainties in the local resources due to the unpredictable behavior of computational models to input data and resources'

availability. In Task 3, the project aims at developing a biosampler, i.e., "lab-on-robot", that uses in-situ measurements and communicates with the cloud resources to give results in real time on the water quality; also, new solutions to optimize the Naviator's current hybrid air/water multirotor platform/propulsion system will be designed in order for it to be able to carry and perform testing with the biosampler while also increasing its endurance. Finally, in Task 4, integrated field testing on the Raritan River, NJ, will be performed so as to validate the algorithms as well as to analyze their scalability (from an economical and feasibility perspective) and confidence/accuracy performance. Specifically, the Naviators will identify the RoIs via multimodal operations, i.e., in water and air; and then the BlueROVs (which, during the course of the project, will be made autonomous and will be modified to carry on-board water-quality sensors) will perform underwater adaptive sampling in each of those RoIs using the algorithms designed in Task 1. In terms of broader impacts, the collaboration between cloud and local resources can benefit any CPS in the following ways: (i) outsourcing computation to the cloud will allow resource-constrained vehicles (in terms of computational capability) to meet mission deadlines, and (ii) using clouds comes at a price, hence, in order to accomplish the mission goals within budget constraints, the computational tasks composing a workflow should be migrated from the local network to the cloud only when the former does not have enough computational resources to execute successfully the tasks (outbursting). In terms of outreach, this project will develop a pipeline of diverse and computer literate engineers who will be able to solve self-management CPS problems. The PIs will 1) create a course on real-time in-situ distributed computing (for graduate computer engineering and undergraduate non-engineering majors); 2) develop teaching modules for incorporation into key high-school activities; 3) leverage existing minority student outreach programs and networks at Rutgers; 4) incorporate exchange programs and team-teaching approaches; and 5) utilize distributed education technologies with application to robotics and networking. Our electrical/computer and mechanical engineering team has the theoretical and system-level skills, cross-disciplinary expertise, as well as a verifiable history of fruitful collaboration to exploit fully this project's research and educational potential.

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