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Near-real-time Water-quality Monitoring in the Raritan River using a Hybrid Network of Autonomous Vehicles and Static Stations

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I. Motivation and Goal

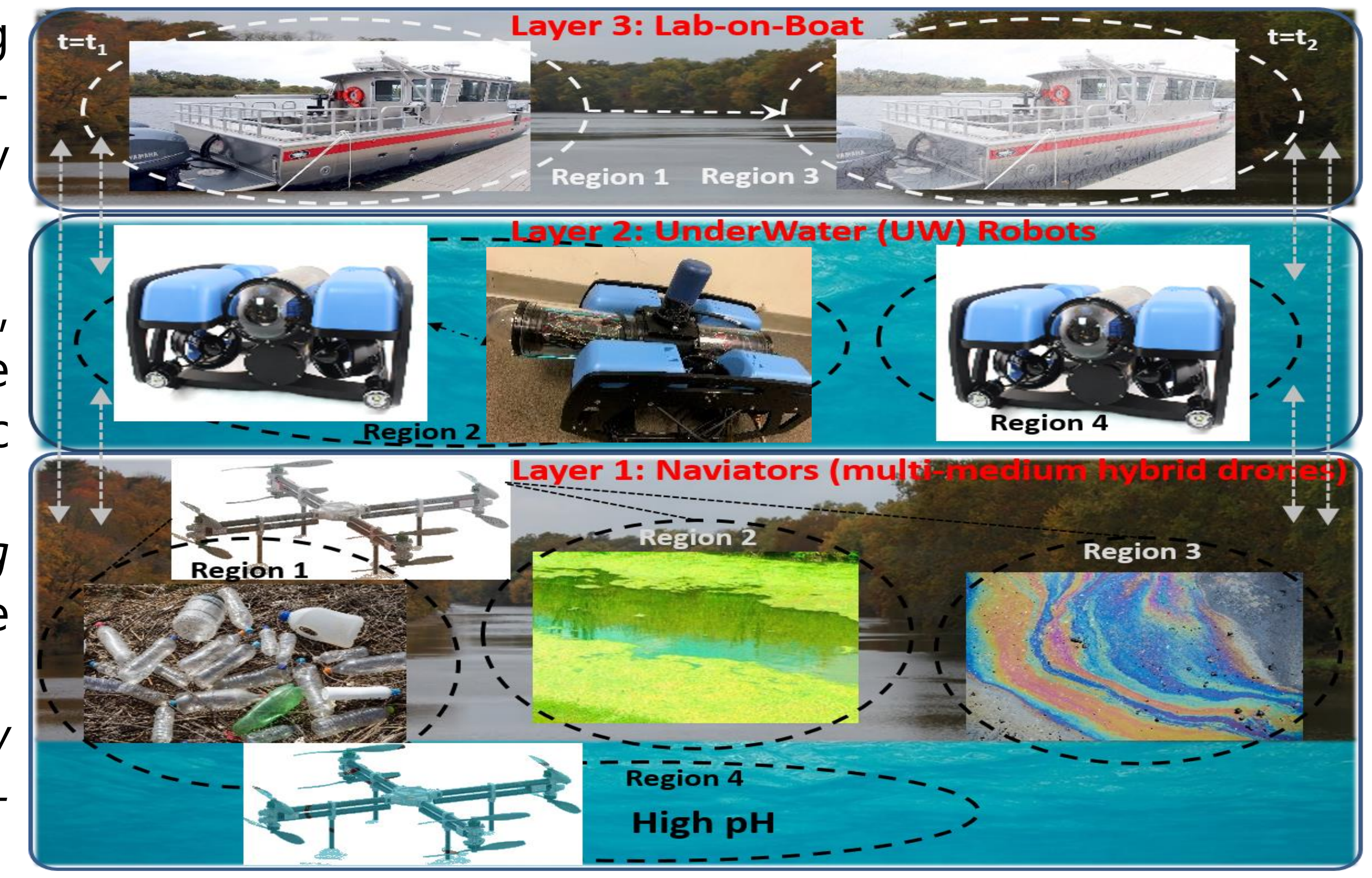
- **Near-real-time water-quality monitoring of physical variables** in the Raritan river is critical since contaminated water should be prevented from reaching the civilian population
- **Optimal decisions and timely closed-loop solutions** should be deployed, or at least early warnings should be issued, so as to prevent damage to human and aquatic life
- The project goal is to **design a Cyber-Physical System (CPS)** where drones and autonomous underwater robots can identify in near real time *Regions of Interest (RoIs)* and collect (bio)samples from them
- **Create a network of hybrid vehicular-static stations in the Raritan river** instead of using only fixed stations with predefined configurations; instead of waiting for the pollution to reach the stations, a team of underwater/surface vehicles chase the phenomenon of interest and collect data
- Provide autonomy, robustness, and cooperation in collecting data in an adaptive and smart way while guaranteeing scalability, reliability, and timeliness in comparison to traditional sensing systems

II. Methodology: A Three-layer CPS Sensing Architecture

- **Three-layer CPS sensing architecture** using heterogeneous and autonomous mobile sensors for real-time, energy-, and time-efficient water-quality monitoring *over time and space*
- **Physical variables of interests** are pH, temperature, dissolved oxygen and metals, (micro)plastic, algae concentration, turbidity, chlorophyll, pathogenic microorganisms, etc.

➢**Layer 1:** drones with *narrow-spectrum sensing* capabilities but with *fast-moving* and quick triage capabilities

➢**Layer 2:** autonomous underwater robots with *narrow spectrum sensing* but with *high temporal- and spatial-resolution* capabilities

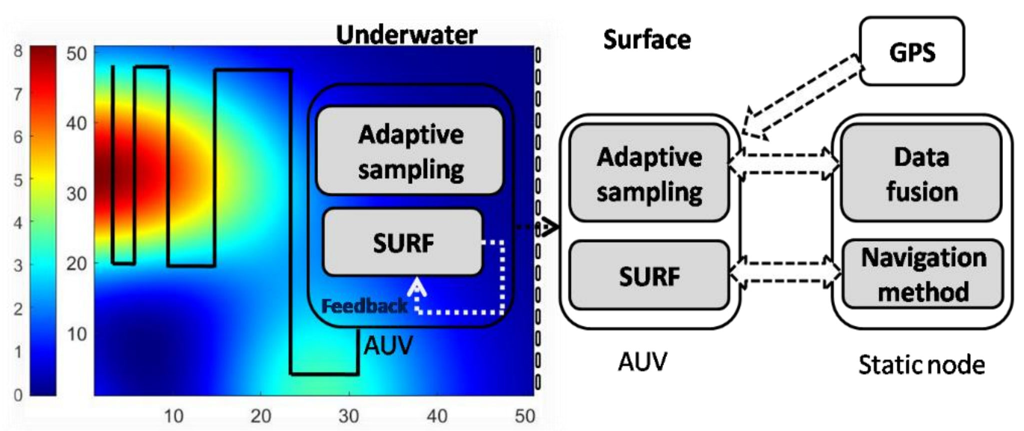


➢**Layer 3:** few Lab-on-Boats with broad and accurate spectrum sensing capability but slow moving and with low spatial- and temporal-sensing resolution

- **Handling CPS model uncertainty** via *distributed multi-scale computing* with transformation of computational workflow [2]

III. On-going Research Directions

- **SLAM-based adaptive sampling.** Entails the conversion of an existing ROV to an AUV so as to be able to navigate and carry environmental sensing autonomously

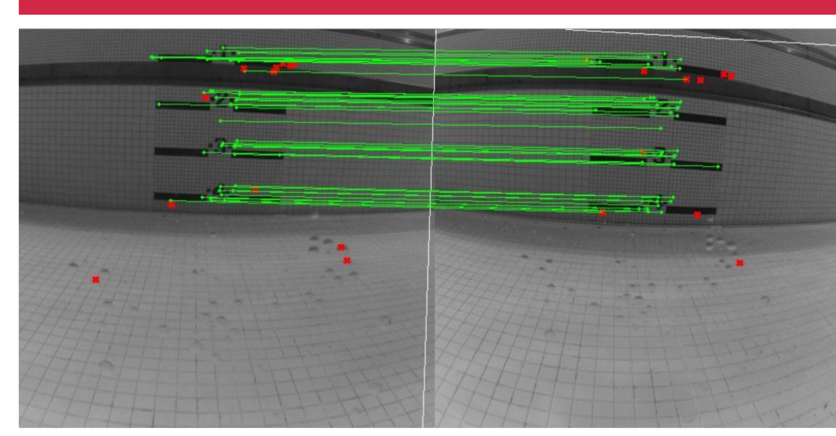


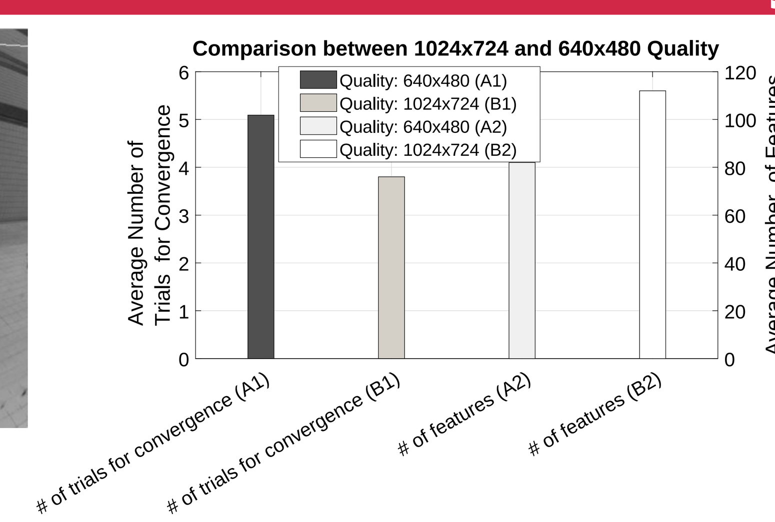
Framework of the adaptive sampling method

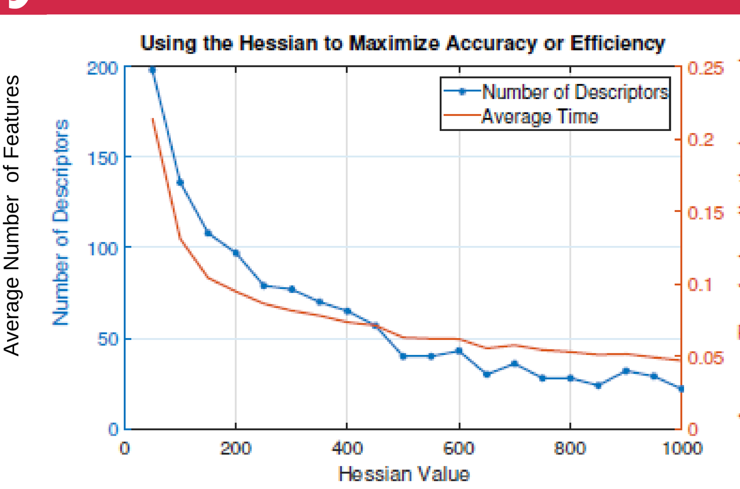
AUVs must be able to travel between waypoints as determined by a path-planning algorithm [3,4], where the spatial distribution of the manifestations in the field is captured with the help of SLAM algorithm for navigation [5]

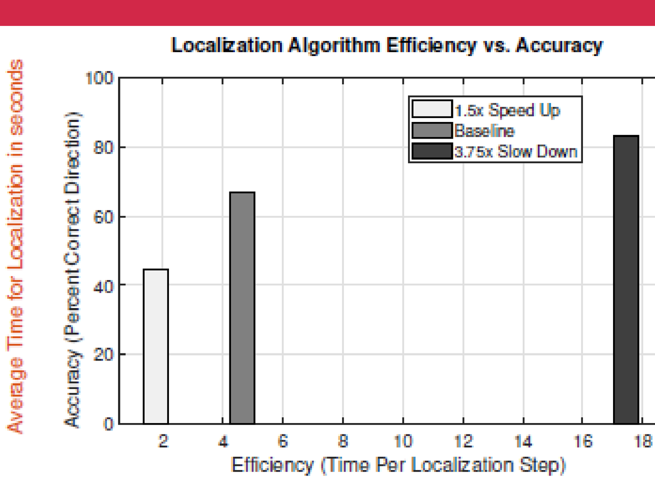
- **Distributed and energy-efficient adaptive sampling for networked AUVs.** A distributed adaptive sampling algorithm for connected AUVs is designed under the system constraints while ensuring accuracy of measurement within RoIs
- **Navigation using image processing/machine learning in muddy water.** Vision-based navigation techniques fail to work underwater when the water is not clear and visibility is low. Image restoration consists in recovering a degraded image using a model of the degradation and of the original image formation, while image enhancement uses qualitative subjective criteria to produce a more visually detectable image. Field testing on the Raritan River, NJ are being performed to validate the feasibility of the proposed algorithms

IV. Preliminary Results

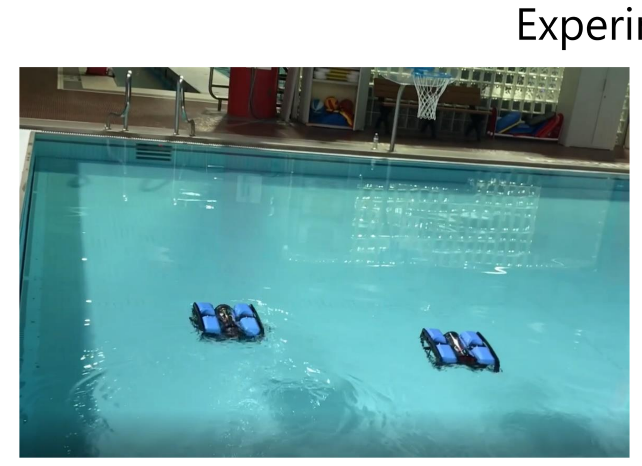








Experiments at Sonny Werblin Recreation Center, Rutgers University; Speed of the algorithm vs. accuracy



Experiments for AUV coordination

Experiments in the Raritan Canal

Bottom video recording in the Raritan Canal

References

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