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MBARI
MONTEREY BAY AQUARIUM RESEARCH INSTITUTE

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1. Core research themes and interests

The Autonomous Systems group at MBARI has two primary goals. One to advance the state of the art and practice in marine robotics using techniques pioneered in the Artificial Intelligence community. And second, to work closely with ocean scientists to ensure such techniques are grounded in reality and are useful for marine science and exploration. Our core area of interest is in using AI Planning/Execution coupled with Machine Learning techniques for sampling, mapping and characterizing upper water column features. These techniques can be onboard mobile robotic vehicles or on shore guiding vehicles to return high-quality data in the most cost-effective manner. Our long-term vision is to have a hybrid distributed goal-oriented autonomy architecture that can (with or without a human-in-the-loop) task robots at sea to adaptively sample a dynamic coastal field such
as Harmful Algal Blooms, anoxic zones, plumes (oil, nutrient laden riverine etc). Such a task would require complex coordination between heterogenous assets, but also deliberation onboard to dynamically and opportunistically task a vehicle on when and where to take water samples and data. Doing so would not only provide a valuable tool for ocean science, but push the state of the art and practice in marine robotics, AI and adaptive sampling. We anticipate it will result in new ways to sample adaptively, redefine how mobile robots are designed in the future, alter the way sensor payloads are constructed and instantiated and effectively change the way science is done.

2. Current maturity of our technology (is it pure research/in simulation/deployed)

We have designed, tested, built and deployed an onboard adaptive system called the Teleo-Reactive EXecutive (or TREX) which synthesizes plans onboard and opportunistically collects water samples based on statistical Machine Learned data on shore. An onboard Hidden Markov Model (HMM) is interfaced to the planner, which triggers a water sampler. Joint work with UC3M, Madrid (S. Jimenez and A. Olaya) has shown how these techniques can be extended to build HMMs that are less reactive and can project further, and to use a more nuanced approach to sampling based on spatiotemporal scales which the planner can reason in-situ. While the latter have yet to be routinely be used at sea, TREX is an operational system (we believe the first in the marine robotics domain) and is Open Source and available for anyone to use (it is however non-trivial to use). TREX has been used to control a terrestrial personal robot, the PR2, from a Silicon Valley startup, WillowGarage to
coordinate different planners (kinematic, path, motion simulators) and is being used as the core system to control a rover for a European Space Agency rover testbed jointly with colleagues at GMV (Madrid, prime), IP-CNR (Rome), LAAS (Toulouse) and Verimag (Grenoble).
As noted above, the multi-vehicle domain is where we believe the challenge lies. However the coastal ocean is a challenging place to be, both for testing and deployment and for actual science. At MBARI we are working closely within the framework of the CANON (Controlled Agile and Novel Observation Network http://www.mbari.org/canon/) as an initial step to build a portable mobile observatory. This is a 5 year internal program with substantial participation by researchers outside MBARI for science and engineering. Our contribution to CANON is expected to be along the following fronts:

- Building a Decision Support System (DSS http://www.mbari.org/canon/DSS.htm) which will provide for situational awareness, data visualization, remote collaboration, archival/retrieval, event detection and planning. A prototype DSS is available at http://dss.mbari.org/DSS/ and is being currently used for a 3 week October 2010 CANON field program in collaboration with Naval Research Lab, UC Santa Cruz, USC, Liquid Robotics, Naval Postgraduate School, UC San Diego and others The DSS is expected to provide the "infrastructure" for doing multi-vehicle sampling with a human-in-loop scenario. The associated shows an example of the vision behind CANON as well as the shoreside DSS.
- Real-time event detection based on incoming data stream which can be filtered and analyzed with statistically important biogeochemical signals for signs of interesting and opportunistic scientific activity.
- Adaptively sampling the dynamic feature of interested which has been detected and obtaining water samples for control as well as within biological hotspots and the features boundary. The criteria for sampling is expected to be driven by science needs and potentially dynamically targeted from shore to assets at sea.
- Multi-vehicle adaptation and control driven by scientists and dynamically varying needs from shore. Since communication and power are key drivers for observability and dynamic coordination, key algorithms will have to leverage human expertise on shore as well as deal with adaptation onboard vehicles.
- A final desire is to be driven by and drive shore side synthetic ocean models such as ROMS as a way to demonstrate a path where information acquisition driven by uncertainty also drives down the uncertainty in prediction especially for exploration of the upper water column in coastal waters.

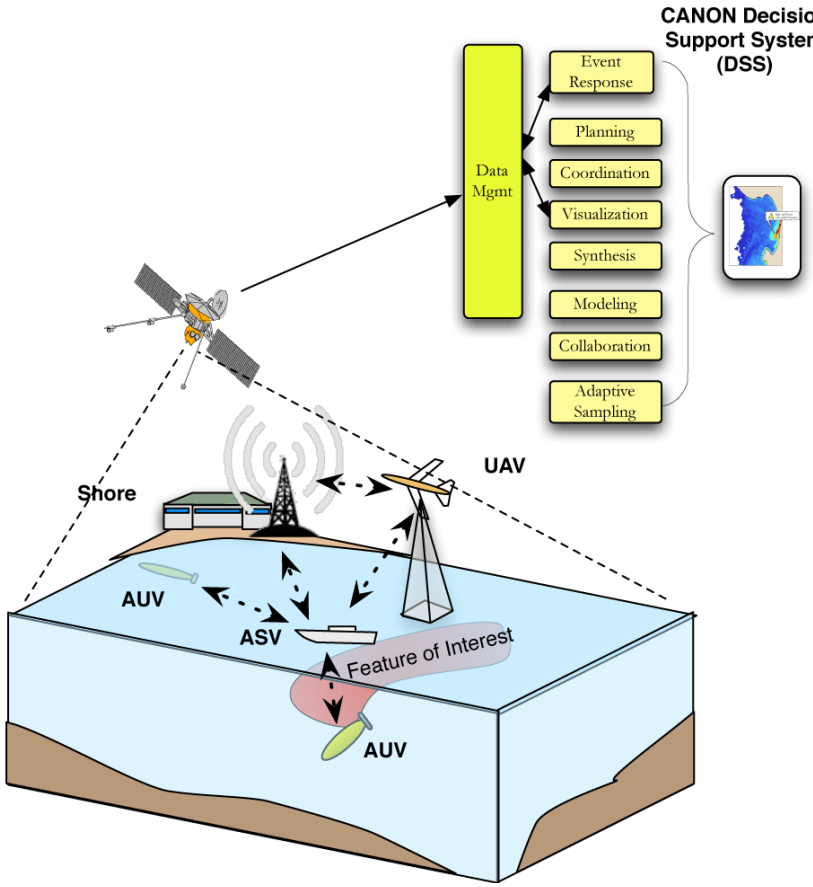
3. Projects and funding

All our work has been provided by the David and Lucile Packard Foundation as a block grant toMBARI. Proposals to US NSF for joint work with USC/Robotics are pending. Our principle projectto date has been to deploy TREX. In this context we have tracked riverine plumes, Intermediate Nephaloid Layers and dynamically targeted thermal fronts from shore targeted by a scientist from his desktop. More recently we've used TREX for drifter tracking providing a Lagrangian context (based on a reference frame centered on the drifter) in various geometries which requires dynamic tracking and updates with all waypoints generated onboard our Dorado AUV.

4 .Most relevant citations

All our publications relevant for marine science/engineering are available at

http://www.mbari.org/autonomy/Publications/index.htm



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below:

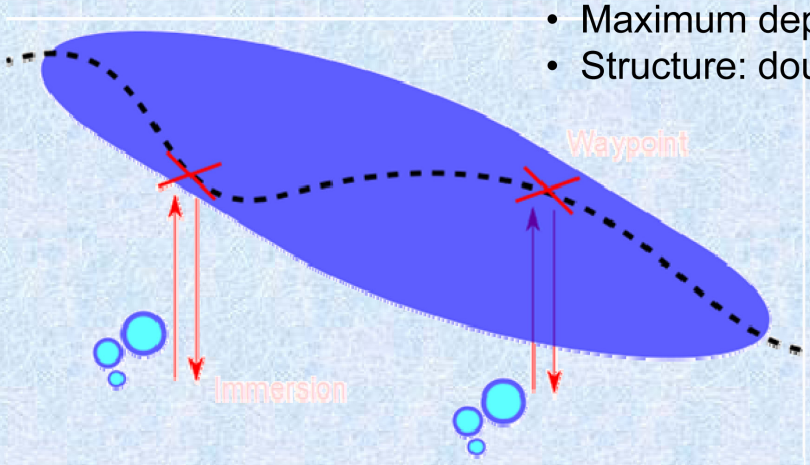
CENTRE DE SISTEMES D'ADQUISICIÓ REMOTA I TRACTAMENT DE LA INFORMACIÓ, Universitat Politécnica de Catalunya

GUANAY II
Underwater Autonomous Vehicle

GUANAY II

The vehicle moves over the surface and can do immersions in pre-established points.

- Dimensions: 2300 x 320 mm.
- Weight: 85kg.
- Maximum depth: up to 30m.
- Structure: double hull.



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