A Modular Autonomous Distributed Ocean Sensor Network

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Idea in a Nutshell

A modular, multi-domain autonomous ocean sensor network based on fixed and mobile sensor platforms, coupled with machine-learning based analysis of data would be valuable in improving modeling and prediction of coastal phenomena, and providing real-time decision-making capability.

Recommendations

Advances in sensor and computer technologies, in robotics, in communication bandwidth, Internet resources, miniaturization and data management provide the impetus for consideration of improved distributed sensor networks that are modular, nimble and adaptive, enabling real-time predictions. In particular, advances in computer technologies has brought resurgent interest in application of machine learning in analyzing acquired data to provide continuously improving models and significant compression of data. The Pioneer Array in the OOI, which involves fixed moorings, gliders and AUVs, represents a step in this direction. Building on this, it would be desirable to have such a modular autonomous ocean sensor network that can address a range of coastal needs.

To obtain the envisioned benefits, the modeling of the proposed sensor network architecture shall meet a series of requirements, driven by associated engineering challenges and stakeholder requirements. First, the network shall be autonomous and self-sustained from the operational perspective, being powered by renewable energy (solar/wave/currents) with micro-grids and/or inductive coupling. Then, it is intended that the network covers air, sea surface, and underwater domains.

From the data collection perspective, the system architecture should be adaptive, enabling routine and event-based sampling, and involving fixed and mobile sensor platforms. Lastly, but not the least important, the system, including the network of sensors and data collection devices and all communication across the network and with the data hubs, must be secure

from any cyber vulnerabilities. It cannot be afforded to be forced to add security to the system after the fact, as many times has happened in the past.

From the data processing perspective, the acquired data shall be processed and analyzed using machine-learning algorithms, in real-time for efficient feedback and data compression. The miniaturized computation power and storage permits including distributed processing and analysis of data on the sensor nodes, and other network devices.

Impact and Value

A modular, multi-domain autonomous ocean sensor network could deliver a number of great impacts and values. They can be listed as follows:

1) Reliable, secure, purposeful, and sustainable sensor networks would result through commercialization.

2) The effort would lead to improved protection of ecosystems, coastline, and coastal infrastructure. The sensor network can measure several variables simultaneously and monitor the coastal areas for long periods of time. The mobile devices can offer long-range communications and enable the possibility of monitoring hard to reach areas with relative ease to greatly improve the protection of coastline and coastal infrastructure.

3) The sensor network will result in improved modeling and prediction. The larger coverage of sensors could provide more useful data and information. In addition, with the advancement of technologies, the sensor network could provide the data with higher spatial resolution, temporal resolution, and spectral resolution. As a result, the modeling and prediction could be greatly improved.

4) The sensor network would help development of early detection and warning systems for coastal hazards. Because of climate change, there are more and more coastal hazards such as hurricanes, tropical storms, wild fires and earthquakes. The sensor network could sense temperature, relative humidity, smoke, and wind, which are all helpful for early detection and warning of coastal hazards.

5) The sensor network would help development of plans for preparedness and real-time decision-making. Besides the real-time data stream, the sensor network can also provide strong analysis functions such as where the flooding area is and where to evacuate. The decision makers could use these results and suggestions to prepare and make decisions.

Justification for the Proposed Idea

Coastal areas are complex environments that include fragile ecosystems, many times highly populated areas, and sought-after touristic destinations. At the same time, they are prone to natural hazards and subject to the consequences of urban development on larger areas. One example for an

environment that includes all these characteristics are the barrier islands that can be found on the east coast of the United States. Given these characteristics, research has been extensively conducted to address these challenges.

NSF sponsors the Ocean Observatory Initiative (OOI), a network of worldwide geographically distributed networks that provide ocean monitoring for a spectrum of research initiatives. There are two research arrays of the OOI that have a close architecture with the one outlined in this proposal: Coastal Pioneer located off the New England coast, and Coastal Endurance located off Oregon and Washington state coasts. Both these arrays collect data related to ocean currents and other specific area data. However, both networks are mostly fixed with data collection gathered from the fixed sensors by autonomous underwater vehicles.

This proposed idea adds agility, modularity, and mobility to the existing OOI arrays concepts. A nimble, modular, and adaptive network, to result from this work, will complement cable-based OOI connected arrays and other fixed networks. The distributed ocean sensor network will be designed to be structured and located as and where needed, thus adding needed mobility to the current fixed ones. Moreover, using machine learning capabilities, the sensor network can be optimized in terms of judiciously gathering and storing data. The recent advances in unmanned systems, computing and sensor technologies will make possible accurate and timely data collection, processing, and communication. Data analytics and compression algorithms will be designed, used, and deployed on network nodes, while unmanned aerial and underwater vehicles will collect the data and send it to designated data hubs.