Sensor Web Position Paper
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AIST-05-0086
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Jan. 29, 2007

This position paper first gives brief answers to the questions posed about sensor webs in the preparatory emails for the February 2007 NASA AIST Sensor Web PI meeting, then briefly describes the approach to creating a particular sensor web taken by our Telesupervised Adaptive Ocean Sensor Fleet project.

1) What is a sensor web?

A sensor web is a group of potentially multi-modal data-gathering devices coupled with computational intelligence and communications such that the overall system capabilities transcend those provided by a group of isolated sensors.

2) What factors or features distinguish a sensor web from data collection scenarios in use today?

The key thing that differentiates a sensor web from most data collection scenarios in use today is communications. Although there has been work in this area over the past several years, most installed sensors, whether individual or in groups, are not networked. Key potential additional features that arise from the existence of communications among sensors are data fusion and adaptivity. Adaptivity can take various forms, including power management such that power is respectively conserved or used among sensors in currently uninteresting or interesting areas, and adaptive mobility such that sensors cooperatively adapt coverage in order to optimize criteria such as information content.

3) What is the scope of a sensor web?

Sensor webs could have an essentially unlimited geographical or spatial scope. Examples in order of increasing scope are a group of moisture and pH sensors for a multi-acre agricultural expanse on the Earth's surface; a group of satellites monitoring the Earth's global weather phenomena; and a group of satellites distributed throughout the solar system monitoring solar radiation patterns. It seems reasonable to restrict the scope of a particular sensor web to a group of sensors monitoring a coherent and inter-related set of physical phenomena, along with the communications and computational intelligence to aggregate and analyze the resultant data and potentially to make decisions on adaptive coverage. The higher-level informational fusion among multiple sensor webs defined in this way would then be distinct from the sensor web concept, since its lower-level components would be the outputs of various sensor webs, rather than a group of physical sensors and accompanying platforms.

4) What are the components or elements of a sensor web?

The basic components are those mentioned above in answer to the first question: a group of sensors coupled with communications and computational intelligence. Additional important components involve the human interface: content-rich and convenient display, data manipulation, and analysis capabilities; and provision for human tasking and interaction via a multi-platform telesupervision architecture.

5) What other systems might interact with the sensor web?
If the more restrictive definition of a sensor web given in item 3 above is used, the outputs of multiple sensor webs must be assembled by an information fusion process that is at a higher level of abstraction than that of an individual sensor web. If, on the other hand, these multiple webs are regarded as "sub-webs", and "sensor web" refers to the monolithic system of all networked sensors in existence, in order to serve the uses outlined by Mike Griffin in May 2005, it would need to interact with various existing national information systems, including historical weather databases, historical agricultural and oceanographic databases, intelligence analysis tools, etc. It is also essential to connect the sensor web to the Internet in order to use the rich array of tools available there for display and data-sharing and to make the science data resulting from sensor web discovery as widely available as possible.

6) What is the benefit of a sensor web approach? Where or how would it be used?
The key benefit is the simultaneous presence within a single information system of a geographically and temporally wide array of sensory data. This is useful in itself by providing a snapshot of physical phenomena that can otherwise only be arrived at by laborious data collection and collation. The benefit increases as computational intelligence to fuse, analyze, and predict, and mobility to adaptively sense, are added. The number of potential applications is virtually endless. The sequel summarizes one of these by describing our project.

Telesupervised Adaptive Ocean Sensor Fleet
Earth science research must bridge the gap between the atmosphere and the ocean to foster understanding of Earth's climate and ecology. Typical ocean sensing is done with satellites or in-situ buoys and research ships which are slow to reposition. Cloud cover inhibits study of localized transient phenomena such as a Harmful Algal Bloom (HAB).

A fleet of extended-deployment surface autonomous vehicles will enable in-situ study of surface and sub-surface characteristics of HABs, coastal pollutants, oil spills, and hurricane factors. To enhance the value of these assets, we propose a telesupervision architecture that supports adaptive reconfiguration based on environmental sensor inputs ("smart" sensing), increasing data-gathering effectiveness and science return while reducing demands on scientists for tasking, control, and monitoring.
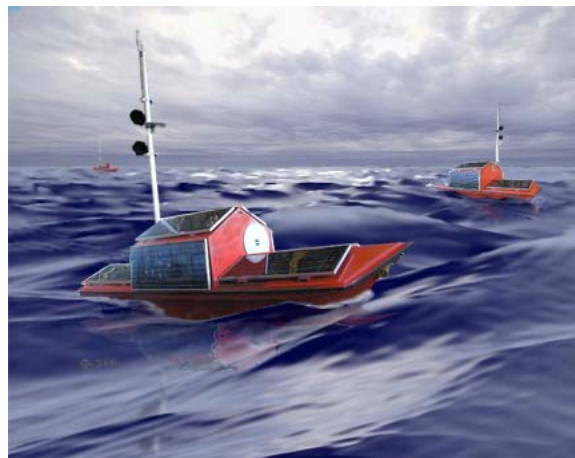

Figure 1. Ocean-Atmosphere Sensor Integration System (OASIS)

We will autonomously reposition smart sensors for HAB study (initially simulated with rhodamine dye) by networking a fleet of NOAA surface autonomous vehicles called OASIS (Ocean Atmosphere Sensor Integration System), shown in Figure 1. In-situ measurements will intelligently modify the search for areas of high concentration. Inference Grid techniques will support sensor fusion and analysis. Telesupervision will support sliding autonomy from high-level mission tasking, through vehicle and data monitoring, to teleoperation when direct human interaction is appropriate.

By extending the capabilities of OASIS to include a telesupervision software architecture, adaptive autonomous fleet control, and HAB-specific sensors, our system will provide:

- Dynamic taskability and adaptation;
- Higher resolution and greater insensitivity to weather than current satellite systems;
- Greater agility in and access to coastal waters;
- Centralized and sophisticated analysis of collected data;
- Real-time multipoint observation by remote oceanographers.

We will conduct extensive end-to-end tests in the Chesapeake Bay area, initially using rhodamine dye as a HAB surrogate in calm water, and moving by Year 3 to adaptively cooperating OASIS platforms performing HAB characterization cued by MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data. The system architecture is broadly applicable to ecological forecasting, water management, carbon management, disaster management, coastal management, homeland security, and planetary exploration.