SESSION 4

DATA ANALYSIS AND MANAGEMENT FOR BIOSENSOR NETWORKS

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CORE ISSUES

Intelligent data acquisition and analysis is a critical challenge as novel biosensors are developed and deployed. Classical sensing models assume that a person gathers and analyzes samples. Emerging models require revolutionary improvements in human productivity, meaning that sensors must be substantially more autonomous. This document briefly summarizes issues arising in the deployment of autonomous sensor networks. Core issues include sampling geometry (how many sensors should be deployed and where should they be placed?), sensor management (what should sensing infrastructure be?), epidemiology (how should data from distributed sensor resources be analyzed?) and response strategies.

These disparate issues are the focus of disparate communities in the United States. Response strategies are developed at the Centers for Disease Control has detailed strategies for bioterror response (http://www.bt.cdc.gov/) and the National Institutes of Health is pursuing sensor and response programs as part of the national biodefense initiative (http://www.niaid.nih.gov/biodefense/about/nbe.htm). Sensor network deployment and management strategies are being explored in DARPA [1], NSF [2] and NIH [3] programs. Wireless network infrastructure, which is critical to rapid and low-cost deployment strategies, is being developed by a variety of telecommunications and computing companies.

DEPLOYMENT AND MANAGEMENT

Integrated sensing, computation and communications platforms are the most developed component of biosensor networks in the United States. See [4] for an review of recent research in this area. Sensor platforms and networks are the focus of the Center for Embedded Network Sensing, a National Science Foundation Science and Technology Center led by UCLA (http://cens.ucla.edu/). Environmetnal and habitat monitoring is a primary focus of this program [5, 6]. Several environmental monitoring networks are underdevelopment in the US, such as the Great Duck Island deployment by UC Berkeley and the Intel Laboratory at Berkeley (http://www.greatduckisland.net/) and the Zebranet deployment underdevelopment at Princeton by Margaret Martonosi (http://www.ee.princeton.edu/~mrm/zebranet.html)

Critical issues in sensor platform development and deployment include power efficiency [7] and utlization, network interfaces and bandwidth [8-11], data processing and computational complexity and deployment topologies [4].

Sensor networks are also underdevelopment in specific applications contexts. Telecommunications companies are actively pursuing both wide-area third generation wireless systems and local area ad hoc networks (such as Bluetooth and WiFi systems). Third generation cellular is more advanced in Europe and Asia than in the US, but network interface cards are on the market in most markets. Cellular coverage is not at a level of ubiquity and service models are not sufficient to support large scale biosensor deployment, however.

Both in the U.S. and foreign providers are developing wireless telemedicine technologies for clinical, home and roaming use [12-17]. These systems share many charcteristics with biosensor networks, especially in their biological focus and urban deployment. Typical biosensor requirements might be considered as an intersection of habitat monitoring and telemedicine networks.

SAMPLING GEOMETRY

Sensor systems are based on spatial models for the source distribution, signal propagation and sensor response. Geometric models are needed to integrate and manage these issues [18]. The field of computational geometry has developed over the past decade [19, 20] around a few canonical problems, such as art gallery and search light problems for searching and monitoring spaces [21, 22]. Recently, DARPA and NSF have supported computational geometry for geospatial and geopotential modeling (http://www.darpa.mil/dso/future/geo/index.htm).

From a biosensor network perspective, critical geometric problems include how to distribute sensors such that events of interest are captured, how to localize events recorded on ad hoc sensor networks and how to predict future sampling requirements based on current data. In cases where one seeks to exclude objects from secure areas, perimeter sampling may be appropraite, in other cases full grid sampling may be required.

While considerable research in geometric models and geometric understanding is being pursued, geometric models have not yet been integrated with sensor platforms or networks.

EPIDEMIOLOGY

As is the case with geometry, mathematical models of epidemiological analysis are under active development in the United States. For example, DARPA's ENCOMPASS biosurveillance system provides a software interface for biosensor data integration (http://www.darpa.mil/body/newsitems/wordfiles/encompass_release.doc). Epidemology as a means of managing and responding to sensor network management will be a critical need as advanced hetergeneous sensor systems are deployed.

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