1 General Information

Title: A General Framework for Wireless Smart Distributed Sensors

People: Rob Armstrong, Nina Berry, Ron Kyker, Carmen Pancerella, Christine Yang (Sandia National Laboratories, Livermore, CA), Katie Moor (University of Notre Dame), Alicia (Pippin) Wolfe (University of Mass, Amherst), Eric Burns (Rutgers University), Brian Lambert (University of North Carolina at Charlotte), Stephen Elliott (Yale University), Tony Fan (RPI), Chris Kershaw (University of California, Santa Cruz), Hillary Davis (Sierra High School, Manteca, CA)

2 The Problem:

When tragedy strikes an environment, group of people, or even an individual, many will stand around saying, "If we only knew ___ earlier." What if one could be alerted of a chemical spill in an environment before it was too large to contain? What if one could identify in real time if a person's health was in distress? These are just some situations that could benefit from sensors monitoring physiological and environmental data, intelligent agents analyzing the data, and a distributed wireless network to communicate this information to others.

The Embedded Reasoning Institute (ERI) at Sandia National Laboratories/CA is designing and developing a hardware/software framework for deploying sensors in a distributed wireless environment.

Designing a useful sensor-based distributed wireless environment comes along with a myriad of challenges. One such issue is where the sensor data should be processed - either on a processor near the sensor or on a centralized processor. In order to avoid bottlenecks and to affect local decisions, the ERI processes data on a personal processor, near the sensors. This information is then forwarded to a centralized processor for more complex reasoning. One of the most important considerations when creating the sensor environment was to develop a reusable platform that would be generic enough to support a variety of applications and allow for new software and/or hardware components to be incorporated easily.

3 The Approach:

Rather than write a custom software and hardware platform for each situation, our approach is to use a generic framework which can be configured by developers of different applications. The framework is constructed of standard off-the-shelf hardware and underlying software (Linux is the operating system and ANSI C and Java are used for the software framework).

The hardware infrastructure is simple and flexible. It consists of sensors, small personal processors (less than 3 X 2 X 1 in), and larger group processors. Sensors of any type may be connected to a personal processor with the addition of a program to convert the sensor output into a standard ASCII data format. Personal processors are located at or near the sensors, and use a wireless network to communicate with one or more group processors. Group processors have more computational power and agents executing on group processors may reason about sensor data from multiple personal processors.

The software on the personal processor provides a data pipeline that takes data from the sensors, processes the data, and makes it available to user-defined agents. Agents may be implemented to analyze, learn from and/or react to data (for example, our Self-Organizing Map agent analyzes and categorizes data, sending high level state labels on to the group processor). Although the personal processors are smaller and less powerful than the group processor, their power lies in the fact that as a group they are able to process and react to data from all sensors in parallel.

Each group processor is wirelessly connected to a set of personal processors, and higher-level reasoning agents execute on the group processors. These agents can analyze patterns in data across many personal processors, can use past data and simulations in order to recognize scenarios, and can archive data for future use.

Our system provides a lightweight, easily configurable, and intelligent solution to a variety of distributed sensing problems. Nonetheless, we are currently working to further improve our framework. Integrating Bluetooth into the wireless network should enable true peer-to-peer communication among the personal processors, as well as improving the security of the network. We also plan to expand our set of intelligent agents on both the personal processors and group processors.

Within the last five years, researchers have acknowledged the emerging importance of wireless networked sensors. TinyOS, developed by Jason Hill et. al. at Berkeley, and the Land Warrior system created by the Integrated Research Team in the United States Army Medical Research and Materiel Command (USAMRMC) are just a couple of good examples of pervasive computing. TinyOS is an optimized operating system for distributed sensors, however, ERI chose to use a standard operating system for which software is more easily developed. The USAMRMC has done similar work but does not use intelligent agents to locally process the data and support situational awareness.

4 Impact, Importance, etc:

This work provides a framework for connecting sensors over a wireless network (or Ethernet). Possible applications are continuous monitoring of health of individuals in a home or assisted-living environment, chemical composition of air/water, and decision support for a team of soldiers or first responders working in emergency situations.

As handheld devices become more powerful, this architecture provides an impressive, (non-traditional) distributed computing cluster for mobile applications and pervasive computing. Large amounts of sensor data can be processed and complex intelligent algorithms can be executed on these small devices, and distributed algorithms can run on these wireless networks.

For those interested in sensor networks (wireless networks, sensors, personal networks) this framework provides an easy and practical solution to the general problem of gathering data from wireless distributed sensors. Processing can be done in parallel, at each sensor location, and all the data can be collated and processed at group processors. The system is general enough to be configured for numerous applications.

The Embedded Reasoning Institute at Sandia National Laboratories/CA is of interest to educators and students who wish to pursue research in this and related areas. The ERI offers qualified upper-level undergraduates and graduate students an opportunity to do ground-breaking, hands-on research. Our institute is always looking to forge new relationships with university researchers.

5 Visual:

We will present a color poster describing the role of the ERI at Sandia National Laboratories, our current and future goals, and overall software and hardware design. The hardware design will describe and show color pictures of the devices used (i.e. Motorola GPS, Nonin Pulseoximeter, wireless modems, etc.) as well as devices we will use in the future (Intrinsyc Strongarm Cerfboard, Bluetooth Modules, etc.). A brief description of the software used in interfacing the sensors to the personal processor and wireless networking devices will also be addressed.

The software design will be broken up into two parts: the Personal Processor software and the Group Processor software. Each section will be accompanied with a color diagram of the software described in the section. For instance, the Personal Processor software will show pictures of initialized and organized Self Organizing Maps. The Group Processor overview will fully explain the code design by providing a diagram of how Point to Point Protocol, Remote Method Invocation, and database functions are interlaced together.

In addition to presenting our poster, we would like to demonstrate our software and hardware if given sufficient set-up time. We feel that although our poster speaks for it self in terms of ingenuity, nothing makes more of an impression than a hands on example of our work.