Works in Progress

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Sensor Networks, Wearable Computing, and Healthcare Applications

EDITOR'S INTRODUCTION

This issue's Works in Progress department includes five submissions covering a variety of research topics. The first two projects are sensor network oriented: a Java MIDP-based sensor network platform that's being offered as an open source development environment and a platform for monitoring and controlling distributed power generation systems. The third is a wearable computing application for optimizing the circuit-training process for a group of users. The final two projects introduce pervasive computing into medical environments with a combined electronic and paper medical charting system and an interactive, multimodal, haptic-enabled medical training simulator.

—Anthony D. Joseph

OPEN SOURCE MOBILE-CENTRIC WIRELESS SENSING

Dirk Trossen and Dana Pavel,
Nokia Research

The Nokia Remote Sensing platform for mobile-centric wireless sensing exploits ubiquitous mobile devices' intelligence to connect locally to sensors and local sensor networks. It connects geographically dispersed sensor deployments, performing both local and remote sensing experiments with almost any mobile phone. NORS integrates with localized sensing solutions, connecting to a centralized server that hosts the application functionality.

The NORS platform design

- minimizes execution costs through event-based sensor acquisition with local aggregation in the mobile device;
- supports future sensors through a flexible plug-in structure;
- builds on a common data model with the goal of supporting, for example, TinyML;
- enables wide deployment; and
- provides a viable license model for wide acceptance in the research community.

We chose Java Mobile Information Device Profile 2.0 as the execution environment, allowing for a wide range of possible gateway devices. We implemented the server platform in C++ under Windows, with the actual server being implemented using the NORS APIs. The platform is available under the LGPL (Lesser General Public License) at http://sourcefourge.net/projects/nors, facilitating proprietary applications while keeping the middleware open. We're confident that our ecosystem will stimulate research and innovation through open source licensing.

We implemented the platform in an environmental-monitoring scenario with two fixed gateways each monitoring a facility, while a mobile phone monitors the premises' surroundings within a given time (see figure 1). We use environmental sensors for temperature, humidity, pressure, and dew point. The fixed gateways also monitor motion. For the mobile gateway, we use off-the-shelf mobile phones with Bluetooth connectivity. For the fixed gateways, we use an available cellular machine-to-machine product. All gateways use IP to remotely connect to our application server.

All sensors are discovered and presented to the user at the server. The user can issue acquisition queries (including aggregation functionality); they're executed locally at the gateway. So, the information that's transmitted to the remote application server consists of notifications that queries have been triggered. Upon receiving the information, the server simply generates dynamic Web pages of the provided information.

We learned promising lessons from this simple deployment. The platform's stability is good, allowing for long-running experiments using standard mobile devices. We used mobile devices from simple Java-only phones to high-end smart phones.

We intend to create larger testbeds in academic collaborations. Our target is participatory sensing scenarios that exploit the existing base of mobile phones. We also seek to integrate the information gateway into efforts such

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as GENI (Global Environment for Network Innovations) for future sensor network research.

For more information, contact Dirk Trossen at dirk_trossen2000@yahoo.com or Dana Pavel at dana_pavel@yahoo.com or see http://sourceforge.net/projects/nors.

SENSOR NETWORKS FOR DISTRIBUTED ENERGY MANAGEMENT

Glenn Platt, Joshua Wall, and Philip Valencia, CSIRO*, Australia*

Distributed energy is enjoying worldwide interest as a way to address key issues facing the electricity industry, including peak demand, peak pricing, and renewable-energy integration. Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) believes that impending growth in the distributed-energy sector will facilitate numerous opportunities to introduce more intelligent ways of managing electrical loads and generators.

CSIRO's latest work involves applying pervasive computing technology based on wireless sensor networks toward the intelligent operation of distributed-energy systems. CSIRO's smart controller technology (see figure 2) uses multiagent systems science and machine-learning techniques, where individual agents control various loads and generators in a distributed-energy network. We've introduced the concept of *tiny agents*, which extend WSN hardware functionality from sensor-centric behavior to implementing distributed, intelligent control devices deep within a distributed-energy network. Tiny agents facilitate the introduction of low-cost distributed control systems, with no central failure point. They can push a control system's intelligence to the edges of the network, where more localized data is available for making optimal control decisions. They can also exploit some well-established properties of WSN technology (such as low power consumption and the ability to form dynamic communications networks), enabling a highly scalable, robust control network.

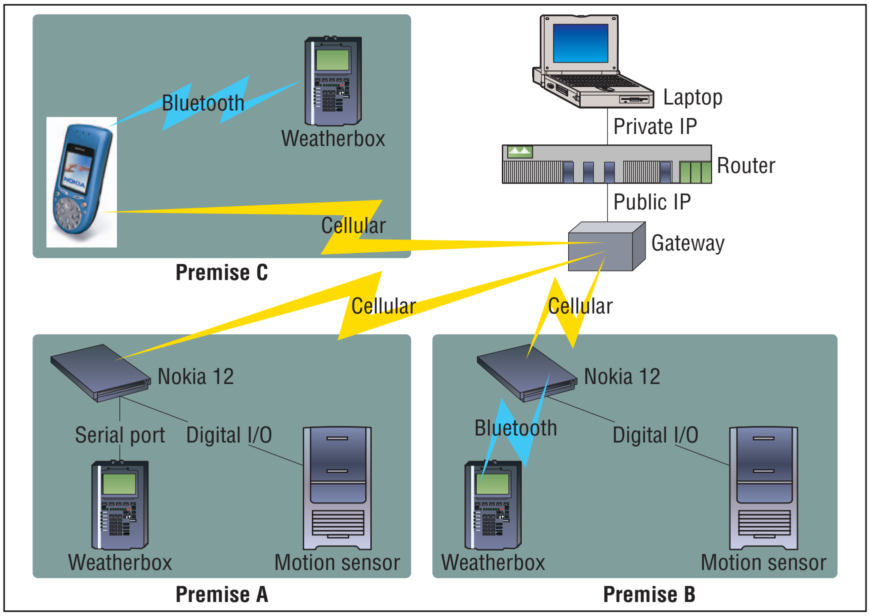


Figure 1. Testbed implementation.

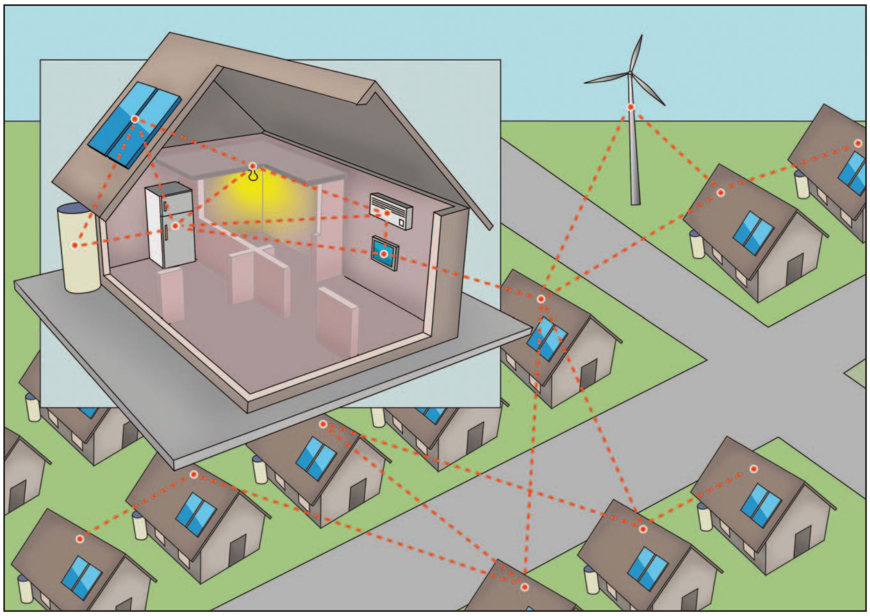
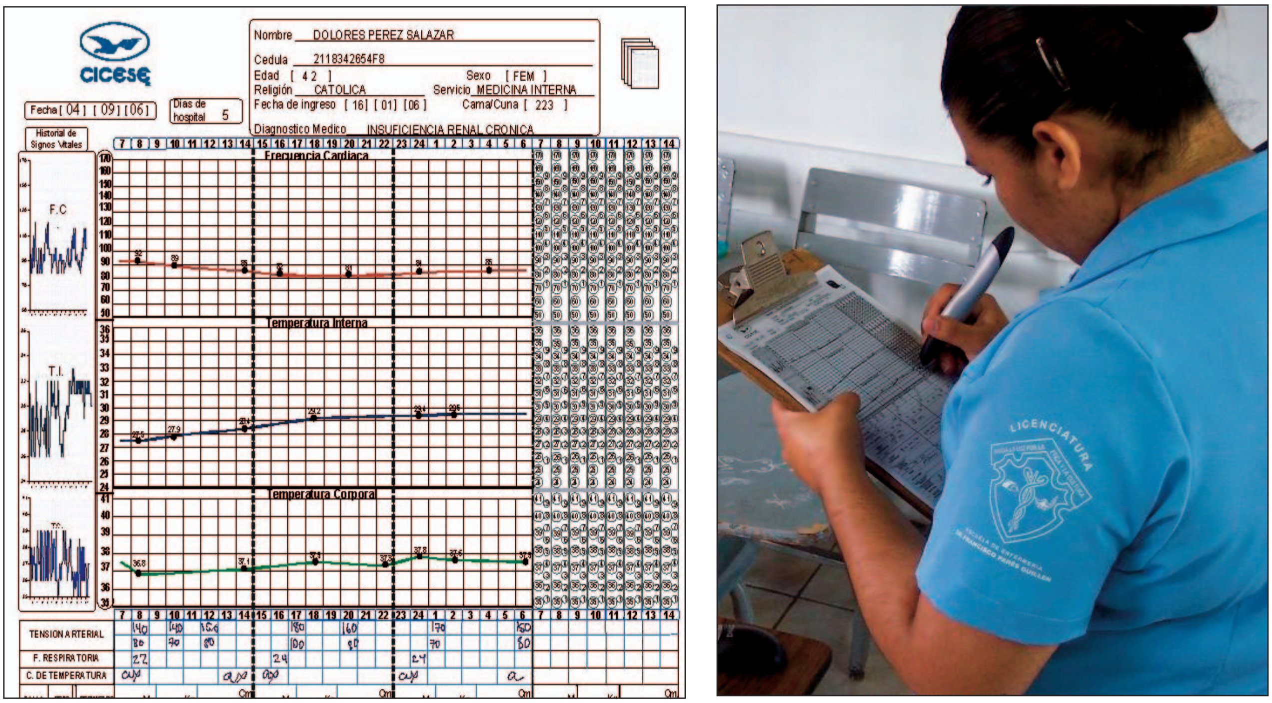


Figure 2. Smart agents manage the energy consumption of a house and surrounding neighborhood.

Realizing tiny agents in the real world presents significant challenges, including applying multiagent systems science concepts, designing low-power application-aware communications protocols, and ensuring communications security in the constrained hardware environment inherent to WSNs. As WSNs increase in performance and decrease in price, the application possibilities for tiny agents will grow dramatically, and we continue to work in this exciting area.

For more information, contact Glenn Platt at glenn.platt@csiro.au or see http://energy.csiro.au.

WORKS IN PROGRESS



(a) (b)

Figure 3. The augmented patient chart system (a) produces a physical-digital nurse's sheet, showing a vital-signs graph, and (b) is evaluated by a nurse.

WEARABLE COMPUTING FOR ENHANCING CIRCUIT TRAINING

Corey A. Graves, *North Carolina Agricultural and Technical State University*

Circuit training is a widely used method of physical conditioning and rehabilitation. The North Carolina Agricultural and Technical State University's Pervasive Systems for Education Enhancement group has developed the Electronic Multiuser Randomized Circuit Training (EMURCT, pronounced "immersed") system to prompt multiple users through a random circuit-training session on multiple exercise stations.

EMURCT addresses two problems:

- a trainee spends too much time on the exercises he or she likes best (the "creature of habit" syndrome), and
- a trainee has to wait idly while another trainee uses a desired piece of equipment.

EMURCT consists of a central control program on a desktop PC and N wearable computers. The EMURCT control program generates N nonoverlapping random sequences involving all of the exercise stations in the circuit. Each trainee is equipped with an EMURCT wearable computer that wirelessly receives (via Bluetooth) the code for the next exercise station to report to. This code (and thus the exercise station) is different for each of the possible trainees. The EMURCT wearable computer audibly and visually prompts the trainee to begin and end the specified exercise. After a rest period, it prompts the trainee to begin another exercise. The exercise time, rest time, and sequence are random. The EMURCT wearable computers also let trainees specify the length of their own workouts.

For more information, contact Corey A. Graves at cag@ncat.edu or see http://eceserver.ncat.edu/faculty/graves/psee.htm.

THE AUGMENTED PATIENT CHART

Myrna S. Zamarripa, *CICESE (Centro de Investigacion Cientifica y de Educacion Superior de Ensenada)*
Victor M. Gonzalez, *University of Manchester*
Jesus Favela, *CISESE*

Despite the introduction of computer technology in hospital settings, paper-based artifacts remain ubiquitous. Manually transferring and updating information from the physical to digital realm is a daily practice among hospital staff, which, although usually well managed, can become a source for errors and inconsistencies. Rather than replacing paper, we aim to use pervasive computing technology to seamlessly integrate paper into context-aware hospital information systems.

We've developed an augmented patient chart system based on Anoto technology (www.anoto.com). The system lets the staff use paper and also captures information directly to the digital system. This solution replaces manually generated graphs of a patient's vital signs (such as cardiac pulse or internal and external temperature) with widgets to annotate accurate values, which the staff can use to plot graphs when creating a new patient chart. So, a nurse can note the medication, and the user will need to validate this data when transferred to the hospital information system. Staff can also annotate and transfer messages to coworkers electronically.

Twenty-two student nurses evaluated a version of our system (see figure 3). Our results indicate a significant reduction in the number of errors while reading information and less time spent annotating data on the digital paper. We plan to conduct an in situ trial of the system at a local hospital in the near future. The solution preserves all of paper's advantages while making information more available and trustworthy.

For more information, contact Victor M. Gonzalez at vmgonz@manchester.ac.uk.

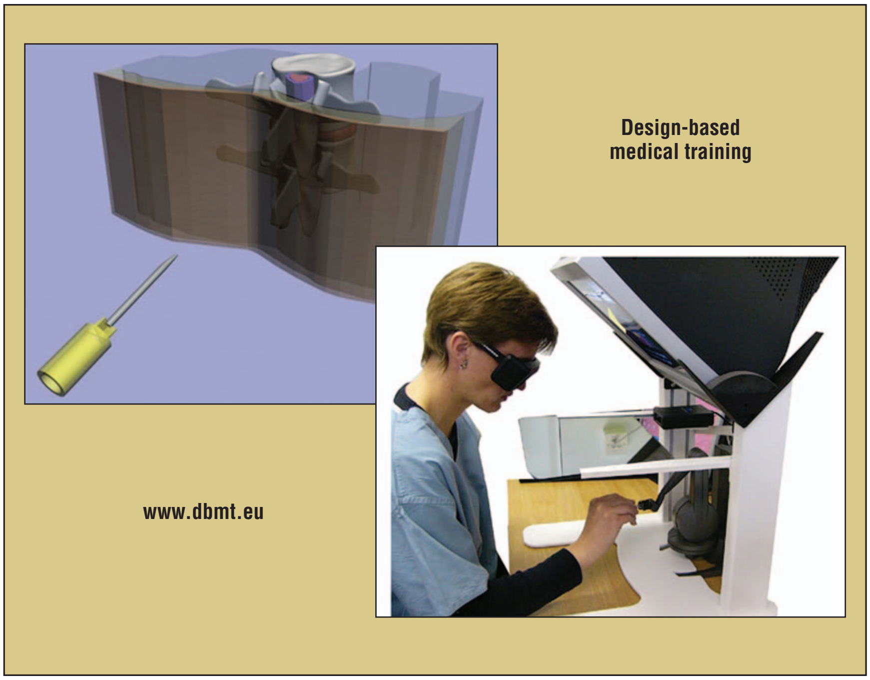


Figure 4. (a) A 3D rendering of the virtual back and (b) an anesthetist using the simulator.

DESIGN-BASED MEDICAL TRAINING

Erik Lövquist, *Interaction Design Centre, University of Limerick*
Zsuzsanna Kulcsár, *Cork University Hospital, Ireland*

Our project addressed how to effectively train health professionals in procedural skills without exposing patients to unnecessary risk. We aimed to build an interactive virtual multimodal learning environment using haptics that medical trainees will use to practice spinal anesthesia. Several existing simulators recreate the experience of performing similar procedures on virtual patients. For example, a 2001 article presents a simulator using a Phantom haptic device[1]—now a commercially available product. Nonetheless, simulators don't seriously address using the simulator as part of an effective training process and creating an intuitive, easy-to-use learning environment.

We use similar technology but focus on issues involved in the teaching and learning processes, including

- transferring understanding and experience of haptic perception to others,
- efficiently using such simulators as training tools, and
- understanding the importance of intuitive interaction between the trainee and the simulated environment.

We've extensively studied 24 experts' tactile perception of simulated tissue sensations using haptics. On the basis of these studies, we've identified critical issues concerning learning-process efficiency while using a haptic simulator. We're using this data to create an immersive, intuitive teaching environment that effectively transfers expert understanding of tactile perception to medical trainees. Figure 4 shows a rendering of the virtual environment and the simulator set-up.

George D. Shorten (Cook University Hospital, Ireland) and Annette Aboulafia, Mikael Fernström, and Liam Bannon (Interaction Design Centre, University of Limerick) also contributed to this project. For more information, contact Erik Lovquist at erik.lovquist@ul.ie or see www.dbmt.eu.

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1. T. Dang, T. Annaswamy, and M.A. Srinivasan, "Development and Evaluation of an Epidural Injection Simulator with Force Feedback for Medical Training," *Proc. Medicine Meets Virtual Reality*, IOS Press, 2001, pp. 97–102.