Using Pervasive Computing to Deliver Elder Care

Vince Stanford

EDITOR'S INTRO

Satya, our Editor in Chief, has characterized pervasive computing as "the creation of environments saturated with computing and wireless communication, yet gracefully integrated with human users." While very much to the point, this high-level statement covers a lot of ground. Many constituent technologies must come together to transform it from dream to usable and productive reality.

Barriers to wider deployment abound, especially in physical and network security, authentication, wireless bandwidth management, multiresolution data rendering, distributed multidevice interfaces, and multimodal user input modes, including speech and pen—problems enough to keep the available engineering talent in the IEEE Computer Society busy for years to come, it would seem.

In each issue of *IEEE Pervasive Computing*, this column will address basic pervasive technical issues in light of case studies of deployed pervasive systems. We'll also explore significant issues that block organizations from deploying pervasive computing applications. Contact me if you have suggestions for future installments.
                                                        —*Vince Stanford*

As an example of an early application that puts pervasive computing technologies directly in the service of improved quality of life for the elderly and that is "gracefully integrated with human users," this inaugural installment looks at the assisted living complex constructed by Elite Care (www. elite-care.com). By building pervasive computing into the environment, Elite Care's Oatfield Estates Cluster (Milwaukie, Oregon) gives residents as much autonomy and even responsibility for themselves and their environment as possible. The company focuses on creating a personalized environment that avoids the traditional institutional care model used in nursing homes for the elderly who can no longer live unassisted.

From the physical setting (see Figure 1), to the language used to set expectations, to the pervasive computing environment, everything about the environment is arranged to serve this goal. Elite Care based the residential setting's layout on an apartment complex rather than a hospital with its hallways and rooms. By using a social care model that has the staff making house calls rather than doctors making rounds, the residents continue to live as normally as they can. In this scheme, pervasive sensors and staff assist residents in maintaining their independence, offering assistance as necessary and using pervasive sensors to monitor vital signs and health indicators.

DEVELOPING THE TECHNOLOGY

Founders Bill Reed and Lydia Lundberg established Elite Care to improve housing and health care for the elderly, evolving the project from their research on elder-care facilities and issues surrounding aging. Experience with their own aging parents helped motivate their efforts. Elite Care, a small, family-owned business, developed all aspects of the technology, including construction, care giving, and pervasive computing, without venture funding and on a limited budget. Design goals included low-cost integration of technologies, unobtrusiveness, and an elder-friendly software interface. The company's advisory committee included representatives from the Mayo Clinic, Harvard University, Providence Health System, Intel, University of Michigan, University of Wisconsin, Oregon Health Sciences University, Eindhoven University of Technology, and Sandia National Laboratory.

Six primary stakeholder groups at Elite Care, each with its own set of needs and responsibilities, use the computing environments:

- The elderly residents
- Families of the residents
- Physicians and health care providers
- Staff caregivers
- The Elite Care management team that monitors the staff and residents
- A community of researchers who are

engaged in determining how to best use the pervasive computing environment to improve the quality and efficiency of care delivery.

The facility's networked sensors let staff identify residents who might need immediate care. Databases that monitor trends over time also reduce stress on staff members who must track the details of vital signs and medication status in delivering quality care. These sensors and databases also help residents integrate into the cluster's social environment. The environment includes actuators that can respond to the activities and whereabouts of residents, lighting the way to the bathroom if someone gets out of bed late at night and recording the period of wakefulness for the staff to interpret later, for example.

FRONT-LINE DELIVERY

According to Connie Easter, the cluster's general manager, pervasive computing technologies help her staff provide enhanced residential care in a variety of ways. Easter, who manages the day-to-day delivery of care to the seniors, points especially to the positive impact pervasive computing has had on her staff's ability to respond to the seniors' care needs (see the "Locator System Resolves a Crisis" sidebar).

In particular, the sensors and pervasive computing infrastructure help staff identify when seniors actually need assistance, such as when one becomes disoriented and starts to wonder off campus or is experiencing an unusually restless or wakeful night. This way, staff can concentrate their efforts where they are needed, and the resulting custom care delivery lets the company avoid regimenting the residents according to institutional needs while allocating caregiver resources efficiently. Integrated databases relieve caregivers from extensive manual record keeping, letting them concentrate on person-to-person care delivery, thus increasing overall efficiency.

THE LOCATOR SYSTEM RESOLVES A CRISIS

As an example of the type of advantage pervasive computing technologies can offer in an elder care setting, Elite Care's Connie Easter cites a case of a resident with early Alzheimer's who was becoming disoriented at times and beginning to wander. Easter described the wandering as the person's way of searching for "a time and place where memory and life were still whole."

Because the resident was well-oriented most of the time, Elite Care could rely on the locator badge, or bracelet, to trigger an alarm if he started to leave the facility. One day, he wandered to the entrance where he encountered a stop sign. He stopped and waited for a moment to decide what to do. In that brief interval, the sensor net detected his elopement. Alerted by an alarm, staff came to his assistance and brought him safely back home.

Assisted living that uses the social model of care is becoming increasingly popular as our population ages. To give residents maximum autonomy, Elite Care uses a pervasive computing solution called Creating an Autonomy-Risk Equilibrium, which includes a network of sensors wired unobtrusively into homes and common areas that gathers information on residents in real time. Some sensors use an infrared, radio frequency badge worn by residents, while others, such as motion sensors do not require the badge. Information gathered falls in three care categories:

- Health vitals
- Inputs/outputs
- Movement

This data offers efficient care allocation and prolongs more independent living for the residents.

The sensors and infrastructure also allow easy trend monitoring for each resident, according to Easter. For example, if a resident's blood pressure or weight changes, the resident's physician might need to be called. The same databases let the staff clearly communicate with the resident's adult children about changes

Figure 1. Gardens of the Oatfield residential cluster with pervasive but unobtrusive sensors.
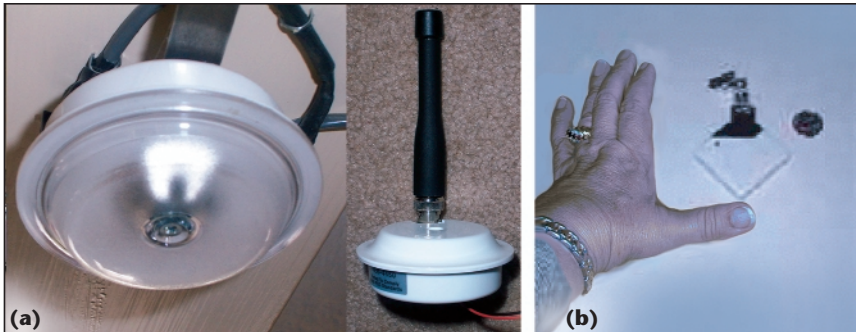
APPLICATIONS

Figure 2. Locator badges: (a) infrared and radio frequency sensors for locator badges reside throughout the Elite Care environment; (b) residents use badges as apartment keys and to locate service or summon help.

in condition such as weight loss, periods of disorientation, or wandering.

Staff quality of life improves as well, dramatically reducing turnover rates in an industry where it can go over 80 percent per year. The facility's residential scale and design attracts many of the staff to live on campus, enabling them to better monitor status using the pervasive computer network from their own apartments. Elite Care supports and encourages this kind of staff living arrangement because it increases familiarity between caregivers and residents and improves the staff's ability to respond rapidly during crucial care situations.

PERVASIVE COMPUTING TECHNOLOGIES

According to Lundberg and Bill Pascoe, a systems engineer, Elite built pervasive computing into the units from the ground up, using up to 30 miles of wiring, 300 or more control relays, 20 control boxes, gigabit Ethernet, and numerous computers and database servers, as well as environmental and personal sensors. Elite Care makes multiple uses of the sensor data streams coming from the apartments and the residence's common areas to maximize the benefits obtained.

Locator badges

Residents each carry a dual-channel infrared radio frequency locator tag that acts as their apartment key and

emits periodic IR pulses to the sensors in each room and in the common areas (see Figure 2a). The pulses are unique to individual badges and support real-time updating of personal location databases. Status bits let residents summon immediate assistance by pressing the proper button and automatically alert the staff when the battery charge gets low (see Figure 2b). The RF component enables location tracking to about a 90-foot radius when a badge is out of sight of an IR sensor, such as when the person wanders.

If triggered, elopement alarms alert staff if a resident prone to disorientation starts to leave the campus. Motion sensors in the rooms enable energy management or convenience functions such as turning on the lights when people enter a space. The locator badge can be deployed in a wristwatch form factor for those who might be prone to misplacing their badges.

Embedded weight sensors

Each apartment bed has a built-in weight sensor. As with locator badges, the pervasive computing infrastructure makes many uses of the signatures obtained from these sensors. For example, a daily weight measurement is taken, but transients during sleep periods can also indicate tossing and turning, which might imply wakefulness, perhaps due to pain or stress caused by illness. Frequent trips to the bathroom might indi-

cate a urinary tract infection, alerting staff to arrange for a checkup. Doctors receive notification of any sudden weight loss, but because some residents might be sensitive about their weight, they can opt out of this measurement.

In-apartment computers

Each apartment has a networked computer with a touch screen interface that provides access to a standard suite of applications residents use to communicate with families and friends. Tools include email, word processing, audio for speech recognition, and video conferencing using Webcams. The applications suite defaults to large fonts for easier viewing. Residents can also communicate with their neighbors and summon staff assistance. Staff can use the consoles in their apartments to monitor the status of residents in their care as well as for personal use. These systems connect to the wired network infrastructure extending across the cluster.

Personalized databases

Elite Care maintains individualized resident databases that enhance care delivery, for example, by documenting vital signs—such as weight and blood pressure changes over time—and activity logs. The caregivers use this data to call for qualified medical attention when needed. Medicine delivery databases let staff know if the residents are current on their prescription medications.

Managers use the databases to monitor staff performance in timely delivery of services and communicate with the residents' adult children. Residents also use the personal histories in the databases to foster social relationships with others who have common points of history, such as having attended the same college or high school.

Most residents do not view these databases as an invasion of privacy and are willing to contribute their data for research in facilitating the design of more effective residential care techniques. Web-based front ends for the databases that will allow staff access

ELITE CARE PERVASIVENESS REPORT

To give readers a quick summary of the deployment discussed in the column, I offer a Pervasiveness Report on each major application. By their nature, pervasive systems are closely integrated to both human activities and conventional systems infrastructure, so they must be characterized along many axes. Table A shows my initial take. I hope to conduct a discussion with our readers on refining this rating report. I would rate systems with an average pervasiveness index of medium or above as significantly pervasive. Smaller, more isolated systems and devices might not address all these axes, but might still be highly pervasive in nature. By contrast, whole systems that facilitate service delivery in the real world will usually score on many or most of the axes. A high rating for a category means that the function is broadly defused or central to the application, while a low rating means that either the function is not present, or is not fully integrated into the application.

Overall, the Elite Care Pervasive Computing Environment seems highly and successfully integrated into the work processes at the Oatfield Cluster, allowing new efficiencies and innovative approaches for meeting the enterprise's mission.

TABLE A
Pervasiveness Report.

Category	Function	Rating
Computing infrastructure and Web servers	Apartment consoles, personalized databases, database	High
Mobile computing devices	Personal badge locators with help functions used by all residents	Medium
Wireless networking	RF and IR locators	Medium
Device discovery	Static configuration	Low
Service discovery	Static configuration	Low
Multimodal user interfaces at apartment consoles	Environmental sensors for location, weight, and speech recognition	High
Pervasive databases	Personalized databases for status and history	High
User authentication	Statically configured	Low
Secure networking	Short range transmission of limited data, relying on the facility's physical security.	Low

from multiple locations are currently under development.

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As we've seen, the Elite Care information technology group has deployed a system with many elements of pervasive computing, including portable and wearable devices and wireless networking, to create intelligent and responsive work and living spaces. It has harnessed the technology in direct and important ways to construct a more humane and human world for its residents and staff. Founders Reed and Lundberg recently received a 2001 Computerworld 21st-Century Achievement Award for their work. P

COMING NEXT COMING NEXT

Pervasive Computing in Health Care

In the US, the Health Insurance Portability and Accountability Act of 1996 makes it a felony to be negligent in protecting medical history data. Health care is a huge potential market for pervasive solutions, but these legal concerns create a significant barrier to deployment. In our next installment, we'll talk to Brent Lowensohn of Kaiser Permanente Research as well as representatives from leading computer software and hardware manufacturers attempting to develop systems to improve health care.