UBIQUITOUS COMPUTING_HOMES

As We May Live

Computer scientists build a dream house to test their vision of our future

ATLANTA—To pedestrians walking past in the muggy summer heat, the green house at the corner of 10th and Center streets looks very much like any of the other two-story homes in this quiet neighborhood a block north of the **Georgia Institute of Technology**. Only the loud whir of two commercial-size heat pumps in the side yard hints at the fact that the house is infested with network cables threaded through the floorboards, video cameras staring from the ceiling, sensors tucked into kitchen cabinets, workstations stacked in the basement, and computer scientists bustling from room to room.

Inside the house, some passing student has arranged toy magnetic letters on the refrigerator door to spell out the purpose of this odd combination: "Aware Home of the Futur," a laboratory in the shape of a house where humans can try out living in more intimate contact with computers. There's a piece missing from the message, but the project itself has many gaps to fill. Construction wrapped up only a few months ago, and seven faculty members from Georgia Tech's computer science department are still working with a battalion of students to get the house's sensory systems online.

This house does all the light-switching, stereo-piping tricks of "smart" homes that provide technophiles with electronic convenience, but here that is just a starting point. The goal is to make this place the most ambitious incarnation yet of ideas that have been fermenting in computer research labs for a decade, ever since Mark Weiser launched the first "ubiquitous computing" project at the **Xerox Palo Alto Research Center** (PARC) in the late 1980s. In a seminal 1991 article in *Scientific American,* Weiser predicted that human use of computers would in the early 21st century go through a transition comparable to the shift from shared mainframe machines to personally owned workstations, laptops and handhelds. The third generation of "UCs," he argued, should look like everyday objects—name tags, books, jewelry, appliances, walls—but should be highly interconnected and able to adapt their behavior to different users, locations and situations. In this vision, we will share many kinds of UCs, and the devices will share us.

IT'S AWARE: a new computer science lab will monitor its live-in test subjects.

A decade's work on UbiComp, as it is known in the field, has produced a zoo of ideas and many demos but few real-world tests. **NCR** unveiled a microwave oven that could support e-mail and electronic banking in 1998 and last year demonstrated a trash bin that can use a bar-code scanner on its lid to track the contents of the pantry. Neither has made it beyond prototypes. On a quick stop at the **IBM Almaden Research Center,** Cameron Miner shows me a glass case full of digital jewelry: a tie-bar microphone, earring earphones, a ring with a multicolored LED. "It might flash when you get an incoming call," Miner suggests. But these are mock-ups; they do not actually connect to anything.

No one knows yet what kind of infrastructure is needed to support a UbiComp world, so the designers of 479 10th Street took no chances. Every wall has at least six high-speed jacks to the internal Ethernet network. Cordless devices communicate through a house-wide wireless net. A radio-locating system can pinpoint any tagged object to within 10 feet. The two-gigabit-per-second connection to the university and the Internet is fast enough to transmit several channels of full-screen video and audio. And with some 25 cameras and almost as many microphones trained on the first floor alone, there is plenty of audio and video to go around.

Aaron Bobick, who specializes in computer vision, gives me the grand tour. "Everybody in our department thought building this must be a good thing to do," he says, "although we didn't really have a clear vision of why." The research team eventually decided that those who most need the home of the future are people of the past—not the rich gadget nuts who typically purchase smart homes but rather marginally infirm seniors. "If technology could help you be certain that your parent maintains social contact, takes her medicine, moves around okay, and that means she can stay another 18 months in her own home, then that's a slam-dunk motivator," Bobick

says. "When we told that to the people from Intel, they just loved it." **Intel** is now one of the project's corporate sponsors, along with **Motorola Labs, Andersen Consulting** and **Mitsubishi Electric Research Lab.**

Two engineers from **Sprint,** which is interested in the project, arrive on a fact-finding mission and join us as we resume the tour. "On the surface, this could look like *Big Brother* or *The Truman Show,*" Bobick concedes, gesturing to the video cameras aimed at us from several directions. Our images pour through wires onto the hard disks of computers in the basement. "But it is important to realize that we want to process video data at the spot where it is collected," he continues. "Then these won't really be video cameras but sensors that simply detect people's location or the direction of their gaze. I want to put cameras in the bathrooms, to make that distinction clear. Suppose your shower could detect melanoma? That's something people are working on." Behind Bobick, Elizabeth D. Mynatt grimaces.

Mynatt, the only woman on the team and the one who suggested the focus on the aged, spends half her time working with caregivers and anthropologists to figure out what problems tend to force seniors from their homes and what annoyances and invasions of privacy they might trade to postpone that. This approach sometimes conflicts with the more typical technocentric style of her colleagues. "I call it the 'boys with toys' phenomenon," she says. "Someone builds a hammer and then looks around for something to bang on."

Mynatt does not want cameras in the bathrooms. She used to work with Mark Weiser at Xerox PARC, and she remembers the lessons of his first experiments with ubiquitous computers. "Xerox tried to make everyone in the building wear these active name badges that we had developed," recalls Dan Russell, who worked in Weiser's group at PARC for several years before moving to IBM Almaden. The idea was to let anyone see where anyone else was at any time. "About half the people said, 'No way.' We also tried to put a Web cam in the coffee room, but again there was a huge backlash." This was at the lab where UbiComp was born.

"Still, I feel uncomfortable about focusing too much on the social implications," says Gregory D. Abowd, co-director of the Aware Home Research Initiative. Abowd is designing software that will automatically construct family albums from the video streams collected by the house—the same streams that Bobick claims he wants to distill at each source. Abowd is also trying to build an intercom system that will allow one person to speak with another simply by saying the person's name. And he enthusiastically describes his idea for a program that would automatically place a phone call to your mother when you talk to her picture—but only after checking with her house to make certain she is awake. "I'm under no illusion about the potential this creates for major privacy problems," he says. "But I'm one of 12 children. I'd rather push the boundary of privacy than cower from it."

Just over Abowd's head, a digital photograph of someone's grandmother sits on the mantle. The photo is bordered by pastel butterflies of various shapes and hues. It is a prototype of a device that one might place on an office desk to keep track of a distant relative living in an "aware" home. Every day the photo would contact the house for a status report from the system that tracks Grandmom's physical movement and social interaction; more activity would add a larger butterfly to the history. The idea, suggests Mynatt, who designed the device, is to find calming technology that helps family members feel close and in control without being invasive.

She describes another active project over lunch: "We know that kitchens are hot spots of activity and that older people suffer some cognitive declines that make it difficult for them to deal with interruptions." So she is designing a reminder program that will use the kitchen cameras and sensors to assemble a running montage of snapshots that can remind people what they were doing just before they were interrupted. She is similarly trying to come up with subtle sounds or images that the house can emit to help inhabitants remember important times of day, such as for appointments or medication. Other researchers want to stick small radio-tracking tags on easily misplaced objects such as keys and remote controls. The list of ideas seems to change weekly, reflecting the enormous uncertainties in the UbiComp field about what society needs and what people will accept.

In a year or so, test subjects will help answer that question as they move into the second story of the house and judge whether all this complex infrastructure and software does in fact simplify and enrich daily life. The project has its skeptics. There is no way to know what Weiser would think, unfortunately, because he died suddenly last year from liver cancer at the age of 46. But his colleague Rich Gold worries that the occupants of a UbiComp house may feel it controls them rather than the other way around. In an essay on "intelligent" houses several years ago, Gold wondered: "How smart does the bed in your house have to be before you are afraid to go to sleep at night?" —*W. Wayt Gibbs*

A Machine for Living In

The four-bedroom, four-bath Broadband Institute Residential Laboratory built by Georgia Tech has more cameras than windows. Amenities include:

- Computers: at least 60
- Video cameras: 25 (first floor only)
- Microphones: at least 1 per room
- Cabinet sensors: 40 (first floor only)
- Televisions (for fun, not research): 60-inch upstairs, 8-by-12-foot projection system in basement
- Network outlets: 48 (at least one per wall)
- Connections per outlet: 2 Ethernet; 2 coaxial; 2 optical fiber
- Internet bandwidth: 2 gigabits per second (via 4 DSL lines and an optical-fiber link)
- Internal wireless network bandwidth: 11 megabits per second
- Construction cost: at least $750,000, not including computer equipment

NETWORK CABLE: about 10 miles' worth in total.