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Ambient Intelligence

Films portraying the future often contain visions of homes of the future. Fitted out with an array of intelligent devices, these homes can anticipate your every need. They are usually depicted as existing within wider smart infrastructures. These infrastructures boast intelligent transportation systems and seamlessly integrate services from health to shopping and from entertainment to law enforcement. This probably differs just a little from our everyday experience of public services. But help is at hand—numerous research efforts are underway that aim to deliver environments rich in what the Europeans call *ambient intelligence*.

Computational convergence

Ambient intelligence involves the convergence of several computing areas. The first is ubiquitous or pervasive computing. Its major contribution is the development of various ad hoc networking capabilities that exploit highly portable or else numerous, very-low-cost computing devices. The second key area is intelligent systems research, which provides learning algorithms and pattern matchers, speech recognition and language translators, and gesture classification and situation assessment. A third element is context awareness; research on this problem lets us track and position objects of all types and represent objects' interactions with their environments. Finally, an appreciation of the social interactions of objects in environments is essential.

The European program that coined the term "ambient intelligence" also developed several scenarios that attempt to give substance to what this research might produce. These scenarios, like all suggested futures, are intended to provoke the imagination. In one, we encounter a woman who is clearly a member of a new business elite. She is operating in a number of pools of ambient intelligence—airports, hotels, conference centers, automobiles, and highways. In each setting, highly discrete devices deliver just-in-time services—whether clearing her way through customs, dealing with tolls and traffic congestion, or storing secure content and customizing it for local cultural norms. A second scenario presents an individual who via his digital avatar can filter the avalanche of information directed at him and respond to it in various ways. The real intelligence in this example is to know that eventually he must respond to that telephone call from his wife. Yet another scenario draws on the intelligent infrastructure to support a whole range of efficient provision of services. In this scenario, transportation is optimized through car sharing, and the infrastructure ensures your journey is routed as efficiently as possible. The same scenario shows how your shopping list can be inferred from your fridge state together with the fact that you have invited friends over for dinner.

Coming soon to a context near you

These scenarios are quite engaging, but are they in the faintest bit likely? Given the underlying technologies' speed of development, perhaps they are. It's easy to forget how fast things have changed and are changing. In "Disappearing Hardware" (*IEEE Pervasive Computing*, Jan.–Mar. 2002), Roy Want and his colleagues pointed out that in 1990, no Wireless Local Area Network standards existed, mobile devices had to put up with processors running at a few tens of megahertz, PDAs had tiny amounts of memory, and PCs could boast only 30-Mbyte discs. The past decade has seen fantastic improvements in wireless networking, processor speed, and storage and display technologies. These technologies will continue to improve and provide an underpinning fabric for much of the ambient-intelligence vision. With a lot of processing power and with devices drawing less power, we can do more and more. We can build chips to solve complex but specific tasks—whether face or voice recognition, route planning, or constraint solving. More memory means we don't have to worry about what we cache, image, or mirror, at least from a technological stance.

These developments applied to office, home, and automobile contexts are the first portents of ambient intelligence. Many of us work in offices and attend conferences and meetings where wireless connectivity is the norm. This means that we carry a whole slew of tasks around with us,

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often to the extreme annoyance of others who would rather we paid attention to the meeting than catching up on email.

At home, we can look at any number of homes of the future via our always-on broadband connections. Whether it is MIT's House_*n*, Georgia Tech's Aware House, or Ericsson's intelligent condominiums, each offers compelling glimpses of what's being researched now and what's around the corner. (The sidebar lists URLs for these and other items of interest.)

In the automobile, we see some of the most complete examples of nascent ambient intelligence. Driving to work, we have systems that provide positional information and advice on avoiding traffic snarls or where to find various services, engine-monitoring systems to maintain optimum vehicle performance, maintenance prediction systems to anticipate any problems that might arise, and fault diagnosis systems for when they do occur. Vehicles incorporate features to effect safe braking, reversing, and parking. Speech synthesis systems and varieties of advanced displays are common. This has happened partly because the automobile manufacturers control the building and integration of the subsystems; they can mandate communication protocols and insist on suppliers building to particular requirements. The cost of running all these systems is small compared to the cost of running the vehicle overall.

Power, empowerment, and possibilities

It turns out that one of the real challenges for ambient intelligence is the perennial problem of power. How do you keep the myriad devices and the ever-present ubiquitous and pervasive infrastructure powered up?

Aside from prosaic but fundamental problems of power, what about the users? What does the home dweller, for example, actually want? Systems that can recognize a friendly face or, more important, recognize an unfriendly face, determine an unwanted intrusion, and inform the appropriate authorities seem compelling. Systems that adjust power and light levels according to external environmental conditions or the number, location, and activities of users sound good too. Smart controllers and knowledge-based systems can do all this now. Devices exist that can observe our TV viewing patterns and recommend or record the programs that are assumed to appeal to us. We can arrange for our refrigerator to know its contents and order items as we run low. All these elements will be getting smarter and are deployable in contexts wider than the home. But will these digital environments really empower people?

It turns out that people don't want to ring up and switch on the oven or log on and set the heating and lighting levels for their arrival home. A real challenge is to understand how people live their lives and to understand how they use the spaces in which they live. For example, people at the forefront of interior design are noticing that the kitchen is evolving into a much more complex living space, where we entertain, eat, cook, watch TV, have phone conversations, and sometimes place a play area for the kids. This life in one room is an ancient model and one that, because of time constraints, is now convenient and sociable to adopt. Surveys indicate that while the kitchen's size is expanding, the cooking area itself is not. Such changes in living style will profoundly influence how we support lifestyles through technology. But the real issue is to understand what the person at home wants at all.

Of course, hard technical problems remain. How do you construct a digital network throughout a home or any environment and ensure its privacy while preventing its interference with other networks? How do you set up an integrated home-networking architecture such that a builder could attach a switch to a wall and it would wirelessly form the appropriate controlling functions over a range of devices? How do you ensure that voice recognition works reliably and in all domestic conditions?

The challenge and promise of ambient intelligence and the continuing development of pervasive and ubiquitous computing contain rich opportunities for our discipline. As technology disappears into the background, we need to identify, compose, configure, and maintain a multitude of interconnected embedded systems, each with different capabilities. To be aware, such systems will have to locate and recognize objects and people, to infer intentions. They will also have to analyze the context, adapt, and learn from the users around them.

Ubiquitous clutter

All this sounds great, but the reality of my existence is that right now the intelligent home is on a par with those other futuristic ideas—we'll all go to work in our own private airplanes or eat a pill for breakfast, lunch, and dinner. I don't know about your house, but mine and those of most of my friends are exhibiting alarming amounts of technological clutter. Rather than the disappearing computer, our homes have grown lumps of plastic or metal containing a PC or three, a specialized games box, a wide-screen TV, a lot of small-screen TVs, a stereo, a VCR, a DVD player, a lot of cordless phones, fixed phones, satellite set-top boxes, and on and on. Far from having the technology disappearing, I've got more chips in more boxes, each with incompatible interfaces and an endless array of charging devices. I can't wait for the day when all these functions have happily receded into the background and I am living Mark Weiser's vision of ubiquitous-but-calm computing. ■

Useful URLs

The European Union report, *Scenarios for Ambient Intelligence in 2010*
ftp://ftp.cordis.lu/pub/ist/docs/istagscenarios2010.pdf

e2 Home, a joint venture between Electrolux and Ericsson to build smart condominiums
www.e2-home.com

Georgia Tech's Aware Home
www.cc.gatech.edu/fce/ahri

MIT's House_*n*
http://architecture.mit.edu/house_n

MIT's Oxygen project for pervasive human-centered computing
http://oxygen.lcs.mit.edu/Overview.html

Philips' vision of ambient intelligence
www.philips.com/research/ami