Ubiquitous Computing: Are We There Yet?

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Computing has for many of us become an integral part of our world. During a short trip some weeks ago, I used three GPS receivers without thinking much about it: one in my phone providing my social network with my location, one in my car navigation system, and one in my camera bag to geotag my photos.

Reflecting on my casual use of this technology, I recalled the words of Xerox PARC scientist Mark Weiser, regarded as the father of ubiquitous computing. “The most profound technologies are those that disappear,” he observed in “The Computer for the Twenty-First Century” (Scientific American, Sept. 1991, pp. 94-104). “They weave themselves into the fabric of everyday life until they are indistinguishable from it.” In this sense GPS has become invisible, as have many other technologies embedded in devices I use, including my phone, music player, and TV.

An implication of Moore’s law is that the cost of a device with certain functionality, like a GPS receiver, will fall precipitously if it can be realized as a digital circuit. This transformation of conventional technologies into digital systems is in full swing, ranging from vehicles to industrial automation to home entertainment.

Does this mean that the vision of invisible computing has been realized and we can move on? Looking back at Bill Schilit’s introductory Invisible Computing column (“Mega-Utilities Drive Invisible Technologies,” Feb. 2003, pp. 97-99), some of the challenges he laid out have been met. Wireless communication is ubiquitous in most developed countries, and mobile devices provide access anytime and nearly everywhere. Smart environments and smart homes, however, remain an open research area, with the technology’s impact on people’s lives much less prevalent than in the domain of mobile and personal devices.

Invisible computing has come a long way, but we’re not there yet. The widespread deployment of technologies like mobile phones continues to drive new applications and to provide research opportunities. For example, public-sensing applications are exploiting mobile social networking platforms. globally networked digital displays are replacing printed signage, and capturing and sharing experiences via mobile devices is becoming commonplace.

As the new editor of this column, I invite researchers to highlight these and other trends by describing leading-edge findings on technologies that will transform the way we understand and interact with computing in the future.

Computing for All

Mobile phones provide computing and communication capability to much of the world. In many developed countries there are already more phones than people, and emerging economies are not far behind. Such devices have rapidly accelerated the pace of technological progress, and the effects are especially profound in developing countries. For example, mobile payment systems, which are just taking off in the West, are already rapidly changing the way money is used in less developed regions. People there are directly making the leap from hard currency to mobile banking, bypassing conventional accounts and credit cards.

Researchers must consider the socioeconomic implications as well as technological challenges of invisible computing. Mobile computing and communication technologies could lead to stark changes in exist-
ing power structures by providing ordinary people with real-time access to information and facilitating the formation of what critic and writer Howard Rheingold refers to as “smart mobs” (www.smartmobs.com). It’s not hard to imagine the revolutionary potential of such technologies in the hands of the impoverished or oppressed.

SENSING AND COMMUNITIES

Sensing, social networking, computing, and communication technologies are becoming increasingly intertwined. System designers now realize that many functionalities can be provided easily and reliably by the collective activity of other humans rather than by traditional artificial intelligence.

For example, suppose we want to design a mobile application that predicts how long it will take to walk from point A to point B. Instead of trying to devise a complex algorithm that considers any number of factors that might influence a user’s walking time, the system could instead simply base a prediction on the average time it takes others to cover the same distance. The focus thus becomes how to use computing technologies deployed to a large number of people that are part of a social structure.


LOOK AROUND

As the cost of display technologies shrinks, digital displays are replacing traditional billboards, posters, and signs. These digital displays are based on different technologies, including projections, LCD screens, and e-ink.

Currently, public digital displays are mostly standalone or connected to a simple content distribution network. In the e-Campus project at Lancaster University in the UK, researchers are investigating the potential of networked displays that can sense their environment (http://ecampus.lancs.ac.uk). Project founder Nigel Davies envisions that globally networked displays will become the dominant public communication media, providing information and communication services well beyond advertising.

Applications for display networks include personal messaging—for example, your friend can send a thank-you note with a photo of flowers to the display at your bus stop—to public service warnings to leave the area in case of danger.

Lancaster’s Firefly project (www.comp.lancs.ac.uk/firefly) explores the possibility of networking individual LEDs rather than screens. Each LED element has its own processor and is an addressable and controllable node. Much like Christmas or fairy lights, the LEDs can be wrapped around trees or buildings, as Figure 1 shows. Once set up and visually calibrated, they display static or dynamic images. According to Joe Finney, one of the system’s inventors, each light bulb could have its own IPv6 address and be controlled over the Internet.
In a similar vein, Project Blinkenlights (www.blinkenlights.net) uses large computer-controlled lights to form stunning artistic displays. The project team has created several interactive, building-scale installations like that shown in Figure 2. As each light can be individually controlled, rooms become pixels and the city the canvas.

Networked displays, small and large, are designed to be visually dominant but are clearly a branch of invisible computing.

**CAPTURING AND SHARING**

With cameras and microphones available on many mobile devices, few events go undocumented. In recent years, it has become commonplace for users to record everything from accidents to parties to political demonstrations and quickly distribute them afterwards via the Internet. Capturing and sharing are becoming ubiquitous.

At Microsoft Research Cambridge, UK, the SenseCam project (http://research.microsoft.com/en-us/um/cambridge/projects/sensecam) has developed a wearable digital camera with sensors and a wide-angle lens that continuously captures still images. Their investigations show that such a device can be an effective memory aid. As technologies become pervasive, competing for user attention, memory aids will be in greater demand.

Researchers have explored how to create life logs, comprehensive collections of media that capture a person’s experiences. In their book *Total Recall: How the E-Memory Revolution Will Change Everything* (http://totalrecallbook.com), Gordon Bell and Gim Gemmell discuss the vision and implications of electronic memory. Ubiquitous computing technology theoretically makes it possible, for the first time, to remember everything.

In the not-too-distant future, users could have real-time access to a large number of cameras integrated into other users’ glasses (perhaps indexed by wearer location), with businesses dedicated to the storage and distribution of captured content. The rapid evolution of mobile social networking shows that many people are eager to share what they see and do.

Ubiquitous capturing and sharing on such a massive scale portends a very different world, with important ethical and social implications.

**Pervasive computing technologies are transparent to users until the system malfunctions. Minor breakdowns are common, and people get used to them. No one is surprised to see a bluescreen with an error message instead of a timetable on a public display or to be denied access to an area because of a faulty ID card reader. However, when breakdowns affect ubiquitous systems that have evolved into megaurities, like mobile communication and data networks, we realize just how dependent we have become on the technology. Some months ago, a major mobile phone network in Germany went down for several hours, disrupting business across the country and creating widespread anxiety among people suddenly “cut off from the world.” And all this over a service that was hardly used 15 years ago.

The incident highlighted another issue about pervasive technologies: It is difficult for the end user to identify where a problem lies. I experienced this uncertainty myself during a meeting when the German network failed and I tried to fix the problem by rebooting my computer several times. It took me a while to consider that the problem was in the infrastructure and not in my device. This begs the question: How invisible should ubiquitous computing be?**

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