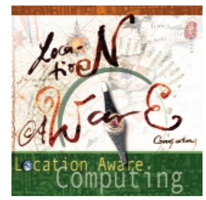
Expanding the Horizons of Location-Aware Computing



Thanks to technical progress on many fronts, we now have location-aware computer applications that sense their location and modify their settings, user interface, and functions accordingly.

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Watching the fast pace of technology growth first-hand is one of the most rewarding aspects of being a part of the computer industry. Ideas considered science fiction only a few years ago now appear in products. Today, thanks to technical progress on many fronts, digital location information is available to software applications running on many different mobile computing platforms. This new type of location-aware or location-based computing has made possible applications with the capability to sense their location and modify their settings, user interface, and functions accordingly.

ORIGINS

When we began working on location-based computing in the late 1980s, even mobile computing was a stretch because most so-called portable computers weighed many pounds. At that time, PDAs were quite basic, mostly providing a simple address book used by a few enthusiasts. Digital cellular telephone networks had yet to arrive in the US: The TDMA Interim Standard was released in early 1991. Our own R&D work attempted to time-travel into a world in which computer mobility was commonplace and computers were ubiquitously connected through wireless networks. With mobility and location in mind, we initiated two research projects: the Active Badge project at Olivetti Research and, later, the PARCTab project at Xerox Palo Alto Research Center.

Active Badge

To experiment with location data before the advent of today's commercial technology, we had to build our own—which usually involved making many design compromises. In the case of Active Badge, you carried an electronic badge—rather than a computer—that informed the computer infrastructure where you were. The infrastructure in turn used your location data to modify the behavior of programs running on nearby workstations. These were the first location-based applications reported in the computer science literature. Despite the Active Badge's limitations, we identified many intriguing applications that captured the imagination of others who began working in this area.

Surprisingly, we originally intended that the Active Badge simply route telephone calls arriving at the office PBX to the telephone extension nearest the intended recipient. Only when we built the system at Olivetti Research in the UK did we begin to understand the utility of a person's location. Another surprise was the newfound use of a test button mounted prominently on the badge's front: Users could test the badge by seeing if sensor indicators around the room flashed when they pressed the button. However, we found that the system could differentiate between a button press and the normal operation of the badge, which meant the test button could also be used to send commands to the system.

At first, one button and one command may not seem very useful. However, the command can have a personalized meaning for each user and can be interpreted differently in each location. The command's interpretation is further extended because each combination of people wearing badges could cause the command to be modified uniquely. In practice, only a few commands at key locations are useful—my office, a conference room, a lab, or the boss's office—and more options might complicate user interaction. But this simple but-

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ton illuminated the implications for location and the first notions of context-aware computing.

PARCTab

The PARCTab, shown in Figure 1, took this simple idea to the next level by using a true palm-sized tablet computer with a pen interface linked to a diffuse microcellular infrared network. Limited by the technology of the time, the tab commanded the applications, but they were executed in the computer infrastructure—the results displayed on the screen of a tab, transmitted over the diffuse IR network. The microcellular property provided location information on a room-by-room basis. The resulting PARCTab applications became the first location-based applications on a PDA-class device.

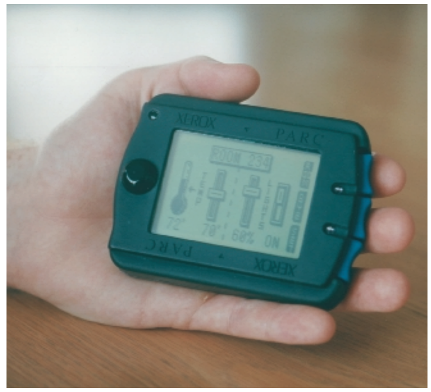

Figure 1. Xerox PARCTab, the first context-aware personal digital assistant.

Now that technology has caught up with the ideas, and wireless data has come of age, the commercial world can test these theories in real products. Many companies now have development efforts that involve location-based computing: IBM's Pervasive Computing Division; ubiquitous computing programs at Microsoft, Intel, and Xerox; AT&T's Sentient Computing R&D, which evolved from the original Active Badge work; and HP's CoolTown project; along with numerous university research programs. Location-based computing is about to come of age.

KILLER APPS

To date, the most successful commercial mobile computers have been laptops and PDAs such as Palm and the Compaq iPAQ. When combined with wireless networks, these devices become a powerful asset useful in both recreational and professional activities. Cell phones have begun to play a role in this space now that PDA capabilities are being integrated with handsets and Internet access is possible through protocols such as WAP and i-mode. The 500 million cell phones currently in use worldwide may all have Internet connectivity in a few years, approximately tripling the current 250 million wired Internet users. The use of mobile devices in the future clearly has the potential to make a huge impact on the applications available on the Internet.

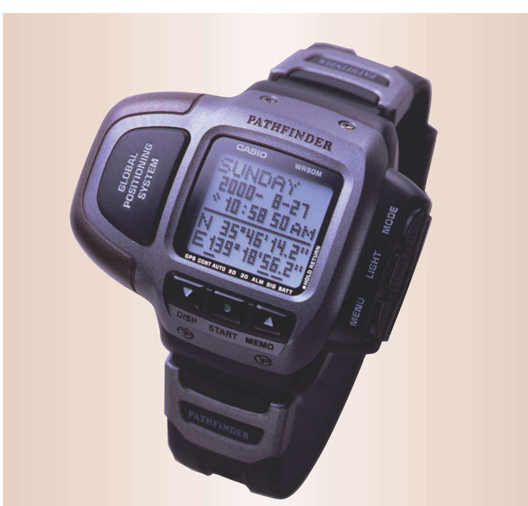

Figure 2. The Casio Pathfinder GPS watch.

Modern mobile computers can now take advantage of context in the same way as Active Badges and the PARCTab, but with a far richer user interface that can access high-resolution color displays, pen input, and tactile buttons. The most powerful facet of context is location, which in many cases can be used to select and filter information, distilling it to the essential components for the task at hand. For example, in answering the command "recommend a restaurant," the most useful response to a computer query about restaurants is not just a good restaurant reference but an establishment nearby. To date, this type of location-based service has not been deployed on a large scale, but its time is close.

LOCATION-AWARE DESIGN

Many research initiatives have examined location-aware design topics. One article in this issue, Nigel Davies and colleagues' "Using and Determining Location in a Context-Sensitive Tour Guide," examines how to make best use of location information and discusses the many issues that must be taken into account to provide a first-class user experience for mobile applications.

E911

The new e911 requirements effective in the US as of 1 October 2001 require that 95 percent of emergency-services calls made from mobile handsets be locatable to within 150 meters. The same mechanisms that enable emergency services to respond to the location of a caller will likely be made available to higher-level services, which in turn will provide an API for developers. Application writers can use this interface to augment existing applications or invent entirely new ones. It will be interesting to see if the users who have been so reluctant to buy Internet content will consider location-based services worth paying for.

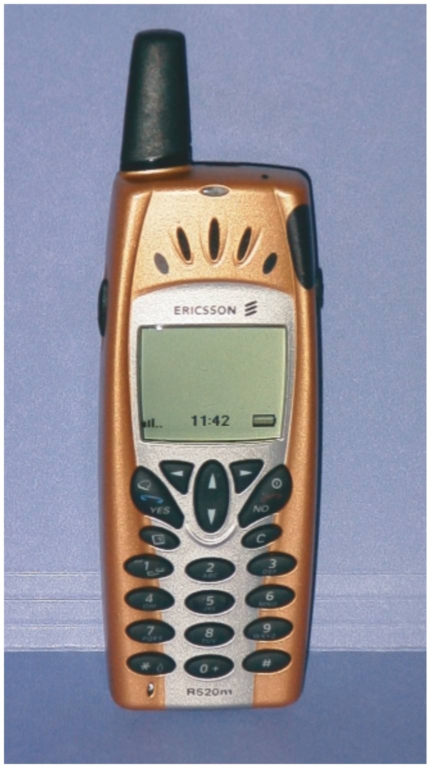

Figure 3. Ericsson's R520M Bluetooth-enabled cell phone, one of the many Bluetooth products that can take advantage of data localization.

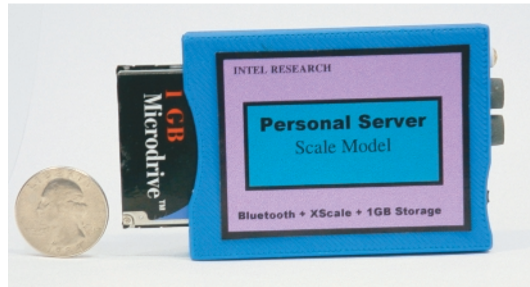

Figure 4. Intel Research's Personal Server, a prototype system that combines powerful processing, high-density storage, and a Bluetooth radio.

GPS

Another technology readily available since the late 1980s, the Global Positioning System lets suitably equipped receivers determine their position within 10 meters. The original GPS equipment was bulky and unsuitable for integration with small mobile computers. The remarkable improvement in this space has been the miniaturization of receivers and antennas.

Two chipset solutions—now available from Philips, STMicroelectronics, and others—allow installing GPS as a low-cost add-on to many portable devices. SnapTrack has made large strides with its server-aided GPS, which is being integrated onto Qualcomm's CDMA chipset. Casio even sells a GPS receiver built into an admittedly bulky wristwatch, as Figure 2 shows.

GPS solves the problem of determining location in most outdoor situations. Another article, Salil Pradhan and colleagues' "Websigns: Hyperlinking Physical Locations to the Web," takes a close look at the problem of using GPS to provide information about specific things and places when navigating with a handheld device. However, GPS information by itself is not sufficient to provide useful information about your locality unless it is augmented by information about the direction in which you are currently looking. The article describes how the HP CoolTown group solves this problem by using an electronic compass to augment data displayed on a handheld device using a labeled, visual representation of the currently viewed direction.

Short-range radio

The Bluetooth short-range radio standard might be particularly well suited to the creation of location-based services. Already, several companies have announced Bluetooth location-based services and positioning technology (for example, Bluesoft Inc.), and a Local Positioning Working Group of the Bluetooth SIG has been charged with providing interoperability among devices from different suppliers. Figure 3 shows a Bluetooth-enabled cell phone, now available commercially from Ericsson, that will be able to take advantage of localization data while connecting to the cellular network.

At Intel Research, the Ubiquity project has begun to push the limits of location-based computing. The project is centered on a concept called the Personal Server shown in Figure 4, which is the ultimate minimal PC, with no display, keyboard, or mouse. To enable user interaction, a powerful processor in combination with high-density storage and a Bluetooth radio connects wirelessly to displays and other resources in the local environment. Standardized short-range wireless connectivity, which inherently uses the property of location, will thus enable new models of personal computation.

Mobile systems that operate outdoors are useful for many work activities. There are, however, many tasks in the IT world that can benefit from indoor location systems. Our third application article, Mike Addlesee and colleagues' "Implementing a Sentient Computing System," describes the AT&T sentient computing project. This project uses a combination of ultrasonic and radio technology to locate objects, not only to the nearest room, but also in 3D space within that room. The project explores the many uses of location-based computing at a fine spatial granularity and demonstrates how systems can learn about a user's intent from this detailed contextual information.

For those of you who have been intrigued by location-based computing, but have not worked in this field, we have included a survey article, Jeffrey Hightower's and Gaetano Borriello's "Location Systems for Ubiquitous Computing," that compares the pros and cons of the various positioning systems. To date, no one technology operates in all locales and satisfies the power consumption and form factor constraints of all mobile devices. As with many technologies, there are trade-offs to be made. This article provides a comparison of the technologies underlying most of the location-based computer systems in use today.

The response we received to our call for papers was considerable and ranged from diverse academic organizations to various branches of industry. In this special issue, we have only a limited opportunity to whet your appetite for location-based computing's potential and have thus chosen the four articles that best convey the underlying principles and the future potential of location-aware technologies. Enjoy! ✷

Acknowledgments

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