# Survey on Information Appliances

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**Information appliances take computing off the desktop and into our everyday world. This survey reviews current applications and predicts where they will lead in the near future.**

An appliance is a tool or machine adapted for a special purpose. Our retail stores are full of traditional appliances that attempt to improve our lives by making an activity less unpleasant. Appliances may provide an increase in efficiency that liberates personal time, such as a washing machine or dishwasher. Or they may perform a task that users couldn't carry out to a high standard by hand alone, such as a vacuum cleaner or a label maker. If a task must be performed frequently, it often becomes worth the investment to spend money on a specialized appliance for the job.

Since their invention, computers have changed dramatically in their capability, size, and form factor. The original computers filled an entire room and led to the mainframe concept. Only large organizations with considerable financial resources could consider applying these machines to everyday problems. The trend from mainframe to desktop to palmtop computer highlights an increasing performance versus cost curve, thereby presenting a clear opportunity for computational appliances. Once the cost fell below the point at which the industry could justify dedicating computers to a particular task, and thus creating a simple model for user interaction in comparison to the original model of a general-purpose machine, then a computational appliance could be born.

Dedicated computers can be used to build control systems, but control applications alone do not take advantage of a computer's unique ability to communicate, process information, and display it. The intimate connection of a computer with the information economy creates the demand for an appliance that can provide specialized access to information—hence the name "information appliance."

The continuous improvement of low-power, high-performance CPUs is only one of many trends that have enabled the development of information appliances. A single technology trend by itself would not have been sufficient. For information appliances to make their debut as a recognized class of device, low-power displays, rechargeable batteries, and miniature radios all needed to be developed in parallel. In addition, the information infrastructure plays a significant role in enabling the usefulness of an information appliance. Key infrastructural communication technologies relevant to this discussion include the digital cellular telephone network, Digital Subscriber Lines (DSL), cable modems, and advanced services such as the Global Positioning System (GPS).

We classify the use of information appliances into the following four categories:

- Home use
- Office use
- Mobile professionals
- Specialist occupations

Common to all these categories is the importance of wireless communication. The real value of an information appliance is the ability to connect to the global flow of information, which currently means the Internet and the World Wide Web. Information appliances serve as filtering mechanisms for the presentation of a narrow range of data. This is the equivalent of the specialist information tool in our traditional thinking about appliances.

The following list provides some good examples of both typical information appliances and systems that use them. In the remaining sections we'll discuss these types of information appliances in more detail:

- Electronic books
- Portable global positioning devices
- Internet-enabled cellular phones
- WebTV and home entertainment
- PDAs enabled with wireless connectivity
- Embedded Web servers
- Smart rooms
- Wearable computers



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## Electronic books

Since the invention of the first computer, computer scientists have dreamed about the paperless office. Electronic books, or e-books, have been a key component in this vision, providing a replacement for the paper-based book, but until recently an effective implementation has not been possible.[1] For a long time people realized that although documents and books can be mastered on a desktop computer, it is nevertheless an unattractive machine to read from. Despite improving screen resolutions, color, and the ability to display text alongside graphics and images, the PC is still not the reading medium of choice for most people. A book is inherently attractive in its size, weight, and robustness. It has the ability to be read in bright sunlight or by a dim lamp. It has affordances that allow somebody to read on a couch or in bed. Modern e-books sold today attempt to match these benefits with a computer dedicated in both form and function to the reading experience.

The resulting specialization of transforming the computer to an electronic book (see Figure 1) makes an e-book a true information appliance. Interestingly, it doesn't have to be wirelessly connected to be effective, since large memory capacity suffices. However, the ability to easily connect with an information source proves essential if users continue to use this medium after they've read the initial material. It's not uncommon for electronic devices to be purchased for home or office use, then filed away in a drawer never to see the light of day again. Current e-book pioneers have elected a phone line as the primary method for downloading content. This approach has the advantage of using the ubiquitous phone network as the accessible and familiar mechanism for a user to connect to a content server. However, even the phone network cannot compete with the ease and ubiquity that a wireless link can bring to bear on the problem. We believe that a wirelessly connected e-book will be the ultimate form of this information appliance, eventually replacing the traditional paper stronghold. However, this can only happen when the display, batteries, processor capability, and total weight of the device cross a threshold equaling the affordances provided by paper, but with all the advantages of searching, cross-referencing, and hyperlinking that a computer-controlled information appliance makes possible.

**1 SoftBook Reader by SoftBook Press.**

Courtesy of SoftBook Press

**2 A Trimble handheld GPS receiver.**

Courtesy of Trimble Navigation

## Portable global positioning devices

GPS provides a mechanism by which a portable commercial receiver can locate itself to an accuracy of 100m in three dimensions.[2] The system, originally designed and deployed by the US military, consists of a constellation of low-earth orbit (LEO) satellites such that at least four or more satellites can be seen from any point on the earth with a reasonable fraction of the sky in view. Each satellite transmits its position and the current time, which are synchronized across all the satellites. A receiving system can establish the arrival times of these various signals and, through a series of simultaneous equations, determine its own position.

The intriguing thing about a GPS receiver designed with today's technology is that it can be made remarkably small (see Figure 2). In fact, the electronics can be assembled from two core integrated circuits. The largest size-limiting additional component is the satellite antenna. Fortunately, new antenna designs have shrunk further to a couple of square inches, which will soon be commercially available.

From a technical standpoint, carrying a small piece of electronics and being able to determine its current latitude and longitude is remarkable in itself. From the point of view of the average consumer, though, it's nothing more than a curiosity. Only when linked with other technologies and combined in the same physical package does a positioning system have real commercial value. Trimble Navigation specializes in navigation aids for boats, aircraft, cars, and hikers. Their products use the basic GPS data and apply it to the presentation of suitably annotated electronic maps. Even on the smaller models, basic route finding becomes possible by simply entering the destination coordinate or a place name that defines that coordinate. Conveniently, a hiker may also use this feature to retrace a route back to the original starting point. The devices Trimble sells go beyond the traditional map and compass. By using GPS data in combination with computation, the resulting capability is considerably more powerful than the traditional mapping tools. Furthermore, the accuracy that can be achieved under any weather condition in any part of the world is far greater than any of the earlier navigation techniques.

By examining traditional specialist tools and then adding computation, we can predict many classes of information appliances. However, some new appliances could not have been imagined before an enabling technology arrived. Consider the problem of locating your car in a large, open-air parking lot or if it had just been stolen. A car fitted with a GPS receiver combined with a cell phone and linked by a computation component can provide you with a device that solves this problem. The cell phone can now be used when these situations arise and information


**3 Cell phone connected to the Internet via i-mode.**

exchanged about the car's current position (the GPS coordinates). In some senses the locating device on the car is the information appliance, but a user may not see it that way. From the perspective of somebody trying to find his or her car, the device used to access the location information will be seen as the appliance technology. This could easily be a computer with a modem running a locator program or a Web site offering a location service. Or, it could be a standalone unit combining a map database, a cell phone, a display, and, of course, computation. A user would perceive the latter device as an information appliance, although in reality the component on the car is as much a part of the appliance as the handheld unit.

This brings up an interesting philosophical point. Where does an information appliance begin and end? For example, in the case of an Internet-enabled phone displaying stock quotes, the information appliance is the end user's equipment—it clearly doesn't include the trading computers and servers distributing the data. However, in the case of the car locator, the end user purchased the component attached to the car and the system for displaying its location. The information appliance in this case is the combination of the two.

## Internet-enabled cell phones

The hottest information appliance on the market at this moment is the Internet-enabled cell phone. In the US, Sprint PCS offers a phone combined with an Internet microbrowser that interprets the Wireless Markup Language (WML) and communicates with a gateway server via the Wireless Application Protocol (WAP).[3] A derivative of Hypertext Markup Language (HTML), WML was honed for small devices with a small amount of display real estate. WAP was recently adopted as the standard for communication between Internet services and cellular phones, and is expected to be deployed universally across the US and Europe.

Currently, WAP-enabled phones are relatively uncommon in the US. Nonetheless, it's unclear whether browsing the Web with a display that's a poor substitute for a high-resolution monitor will be of any real value. Perhaps the answer lies across the Pacific. Last year DoCoMo in Japan (a company mainly owned by telecommunication giant NTT) rolled out an Internet service called i-mode that's available for a few hundred yen per month. Users pay a small additional cost for each service they access. The i-mode service has been astoundingly successful. The small size (see Figure 3) and range of colors also makes these information appliances a "must have" among the younger generation. Our own experience when visiting Tokyo is that a large percentage of the crowd actively uses these phones. More than 4 million people subscribe to i-mode with an adoption rate of about 25,000 new customers per day. Despite the relatively crude display used in the telephone handset, users still find enough value to persevere.

In parts of Europe the cellular phone has taken on an even more powerful role. Some companies would like the cell phone to replace the credit card and, eventually, your entire wallet. For example, in Finland you can call a vending machine to dispense a drink and automatically add the charge to your phone bill. The Internet-enabled cell phone is clearly an evolving information appliance and one that may look very different in a few years' time.

## WebTV and home entertainment

A television in itself is not a true information appliance. It's a specialized tool that we use to entertain and inform ourselves. Even universities, such as the Open University in the UK, take advantage of television for broadcasting lectures. However, a true information appliance is interactive to some degree. It must provide us with information in response to a command or query. A television is a receiver of a broadcast medium and as such—in its traditional form—we have no control.

A few years ago WebTV Networks (now a subsidiary of Microsoft) invented a new kind of product called WebTV (see Figure 4). It combined the traditional entertainment focus of television with the ability to search the World Wide Web interactively. Adding a set-top box, a phone line, and an infrared-linked keyboard makes it possible to surf the Web or watch TV as before, since their content isn't directly linked. To make these two worlds share a single output device, the Web content needed to be reformatted through the WebTV Web site (accessible by telephone). This allowed Web pages to be reorganized and more effectively presented on a low-resolution TV screen. The set-top box also lets users pan and zoom a Web page to effectively display small fonts and detailed graphics. This is a very compelling extension of an existing mode of entertainment enjoyed by millions of people, and so far the company has had good success.

Recently, the TV set and the WebTV interface have integrated further to allow the creation of interactive TV—this is a new product called WebTV Plus. When watching a program using this system, a TV show capable of being interactive will (via the box) display an "I" in the top-right corner of the screen. If viewers select a green button on the remote, they can choose to participate in the show. Now it's possible to vote, participate in game shows, buy advertised products, and find out additional information (such as sports scores) while watching TV. WebTV Plus leverages the connectivity of the Web to let users acquire and interact with information sources while simultaneously preserving the basic product concept. WebTV Plus is an information appliance in the full sense of the definition we've used in this article.

## Wirelessly connected PDAs

Personal digital assistants (PDAs) are one of the great success stories of task-specific devices. They're ideally suited in terms of their form factor and application software to actually replace paper-and-pencil calendars for a large number of users. The reasons for this are threefold: a long battery life, a pen-based user input, and connectivity to the PC.

A PDA that must be recharged nightly quickly proves cumbersome. Frequent travelers must pack a charger or spare batteries every time they're away from work or home for a prolonged period of time. If a rechargeable battery can last several days or even weeks, the PDA that uses it becomes an easy-to-tote device. Pen-based input eliminates the need for a bulky keyboard and makes it possible to fit the device into a pocket or purse easily. Also, it mimics the paper-and-pencil interface that has been so hard to displace. Finally, easy connectivity to the PC lets users back up their data and export it to a larger database or to more elaborate applications on the PC (such as Microsoft's Outlook).

Wireless connectivity, now an affordable reality for PDAs, has caused another giant leap in their appeal (see Figure 5). The first advantage is that special cables and cradles are no longer needed to connect the device to the PC or laptop. Synchronization can be achieved through an infrared port or new radio technologies such as Bluetooth. Users can now easily exchange information such as address book entries, e-mail messages, or appointments just by pointing the devices at each other or bringing them into physical proximity. This removes two more hurdles to acceptance: no more cables to carry and easy exchange of data with others. In fact, young people are enabling a large market for various wireless messagers. These devices have the ability to send sketches, e-mail, or voice-mail messages and are embodied in form factors varying from small calculators to pagers and pens.[4]

Wireless capabilities with longer range enabled by cellular digital packet data (CDPD) modems, wireless local-area networks (LANs), and/or pager transceivers will permit users to access and update information from anywhere and make a whole new set of applications possible. Some examples already introduced in the marketplace include remote synchronization of data, access to Web content appropriately rendered for a PDA's small screen, e-mail, and paging. These capabilities make it possible for many professionals to do without many of their electronic gadgets. With paging and e-mail consolidated into a PDA, there's less of a need to lug around laptops and to even think about carrying an additional pager. The most novel applications enabled by this connectivity include access to real-time data. An example is the availability of data relating to the current locations of transit vehicles so that users can make educated choices about the schedule of buses or trains. Already we're seeing this kind of system deployed in some cities. For those driving cars, calendar alarms can now be made to integrate current traffic conditions and sound at an appropriately adjusted time. Another example is the specialized user interfaces used to access stock trading and auction services on the Web.

In the UK, Safeway and IBM have partnered to provide grocery-shopping services integrated with the physical store and provide special promotions that target user profiles.[5] Users use a PDA to develop shopping lists, place orders, and navigate supermarkets. New services that will soon emerge include remote control of home appliances (from outside the home via the Web and within the home through infrared) and integration with other devices such as vehicles (cars for maintenance data, gym equipment for a training and exercise regime). The future is likely to bring voice-enabled PDAs in order to make the user interface even more flexible. Also, the functions of PDAs and cell phones are likely to merge, as already evidenced by the Qualcomm (now Kyocera-Wireless) pdQ phone that includes a 3Com Pilot as a subsystem (see Figure 6). This demonstrates an interesting countercurrent to increas-

Courtesy of Microsoft

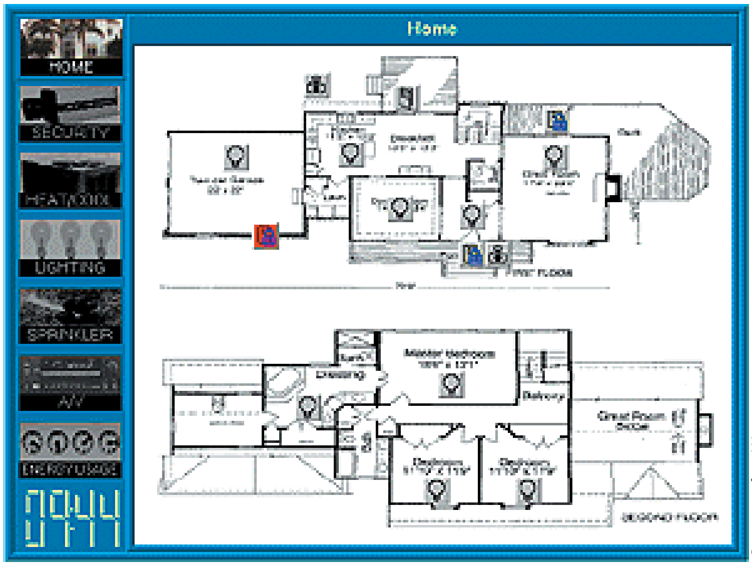
**4** Components of WebTV (from top to bottom): a TV set, a set-top box, a keyboard, and an input-control device.

Courtesy of Palm Corp.

**5** Palm VII with wireless data connectivity.

Courtesy of Kyocera-Wireless

**6** pdQ phone from Kyocera-Wireless integrated with a Palm PDA.




Courtesy of emWare

**7** **A browser showing a plan of a smart house controlled using emWare technology.**

ing task-specificity. Since some sets of applications are commonly used in tandem or by the same people, those functions will merge into single devices.

## Embedded Web servers

Connectivity is an important first step to realizing high-value information appliances. However, physical interconnection is only a prerequisite. The use of standard protocols for the transfer of information proves even more important. The emergence of the Web was made possible by an easily implemented hypertext transfer protocol (HTTP) that could be used to transfer an arbitrary amount of data in a standard format. Web servers have proliferated not only as suppliers of data but also as a new form of database entry through their ability to execute arbitrary code on user-supplied input. We now have the ability to search, order merchandise, trade stocks, participate in auctions, and view a scene through cameras, all through the standard interface of the Web browser (see Figure 7).

The next step is to bring Web server technology into the home and office, maybe even to devices we wear. This will empower our appliances with the same level of interoperability as networked PCs, causing the further proliferation of e-commerce. Several companies have already begun this process in industry. Most notably, emWare developed a Web server for a standard PC that can "serve" appliances connected to that computer via serial lines onto the Web. The appliance implements only a very simple agent that interacts with the server running on the PC. Thus, it doesn't burden the appliance manufacturer—a simple microcontroller (usually already present in most modern appliances) is all that's needed besides a connection to the PC server, and this can be achieved using wireless technologies. One of the first application areas for this kind of server is the vending machine industry, for which inventory control is a difficult problem. By having the information from a vending machine available on the Web, delivery personnel can optimize the restocking process by arriving with exactly the items needed.

Soon, such capability will reach the home.[6] We won't use it to turn on our dishwasher remotely, as satirized by Dave Barry, but instead to enable our homes to use resources efficiently.[7] For example, connecting our lawn sprinklers to the Web may seem a bit frivolous until you consider that weather information is also readily available on the Web. Now imagine a system that, cognizant that the weather forecast is for rain, chooses to postpone watering at the preset time. In fact, the system can be made even more intelligent by actually measuring rainfall and soil humidity so that water need only be expended when truly necessary. We can go further and connect our sprinklers to our Web-based calendar so that we can avoid a muddy lawn on the day of the backyard barbeque.

In the office, embedded Web servers can achieve similar efficiency gains by controlling lights and power to individual offices. Using simple sensors such as motion detectors and light meters, our Web servers can detect the presence or absence of an individual and provide us with services such as maintaining a fixed light level and temperature according to a user profile (turning lights on and off based on external light levels). Building-level services can be further optimized for both activities and environmental conditions.

## Smart rooms

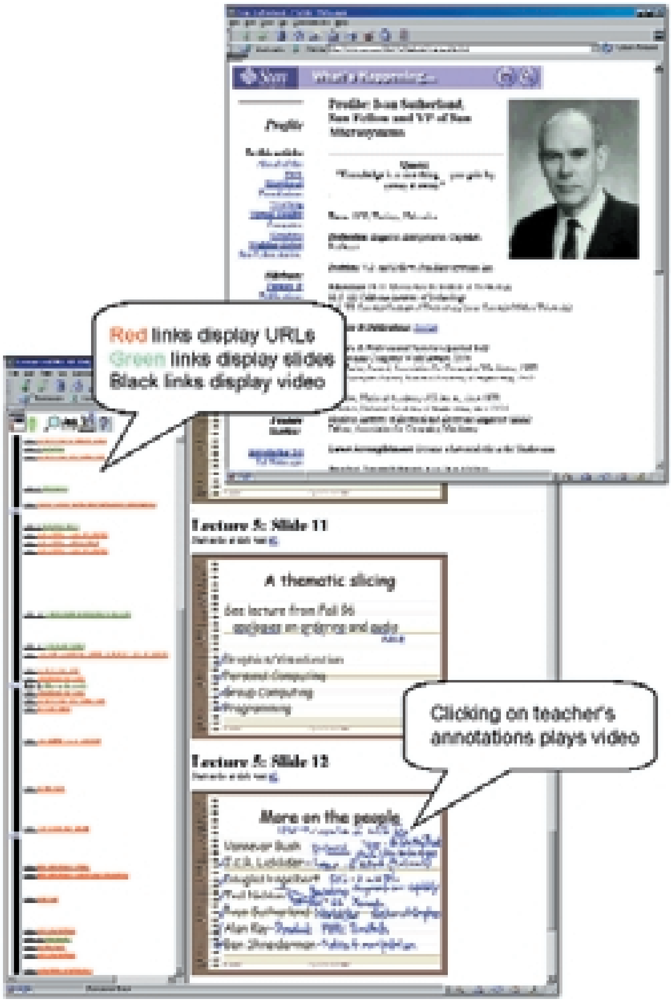
Many types of smart rooms have been described and built over the past 20 years. Usually, these are smart only in a very limited sense. That is, they have some sense of who might be in the room and where. Optimized controls are provided for a variety of audio-visual equipment installed in the room, usually used for advanced teleconferencing and presentations. Smart rooms have often been the subject of humorous stories about how speakers can become befuddled in the unfamiliar and opaque environments they provide. In fact, they're an excellent example of a unified user interface design for a collection of appliances.

Smart rooms, viewed as a unit, are an example of a very large information appliance. They collect audio-visual streams from sources external and internal to the room and display them locally or remotely. Two very interesting projects in smart room technology are being carried out at the Georgia Institute of Technology and Xerox PARC.

The College of Computing at Georgia Tech has constructed several smart classrooms as part of their Classroom 2000 project (recently renamed eClass).[8] The objective was to create a room in which lectures could be captured in their multifaceted entirety for later review by the students. The equipment installed in the room includes multiple data projectors, active whiteboards, video cameras, audio capture, and stylus-based tablets for each student. The instructor displays presentation graphics on the whiteboards where they can be annotated on the fly. The images are captured, time-stamped, and entered in a database for the lecture. Similarly, students can annotate the same slides on their tablets. The use of multiple layers for instructor and student annotations lets students adjust the position of their comments so that they are all clearly legible. Student annotations are also entered into the database. In addition, audio and video for the lecture can be captured and indexed with time and slide transitions.

When students want to review a lecture, they now have a resource they can search that contains the content of the slides and the translated audio. Although speech-to-text translation leaves much to be desired in accuracy, the Classroom 2000 approach uses the translated text only for search purposes. Once students find the right point in the lecture, they can hear the captured speech directly and not rely on the translation. Since all slide transitions and annotations are time-stamped, students can replay the lecture exactly as it happened. The search capability provides excellent performance, since it's just as likely that a spoken phrase is remembered, as with the content of a visual slide. Furthermore, this system captures students' remarks and notes at the same time, not just the instructor's (see Figure 8). Handwriting recognition can also be used to make the annotations searchable in a way similar to that described for speech.

Xerox PARC is tackling the problem of improved user interfaces for smart rooms. Their approach uses physical icons for equipment in the room using infrared beacons.[9] A charge-coupled device (CCD) video camera can see the infrared transmission from the beacon and translate the modulated signal into an identifier associated with the icon. When these beacons are arranged on a whiteboard with links drawn between them, the system can infer the types of devices and the connections needed between them. For example, a user could decide to change the connection to the data projector to the VCR instead of the computer by simply redrawing a line on the whiteboard. This is a much more natural interface, with embodied manipulation of the devices themselves rather than a complex series of buttons and screens on a touch panel (the common implementation we find today).




Courtesy of J. Brotherton, Georgia Inst. of Technology

**8** Viewer for data captured by Classroom 2000 (now called eClass).


Courtesy of Xenote

**9** Xenote keychain fob.

## Wearable computers

Two interesting new companies are leveraging wearable computers in a highly portable form factor to provide a new kind of connectivity. Xenote creates devices that let users collect bookmarks in the physical world and later use them to connect to Web-based information about their experience. Charmed Technology will be marketing a variety of wearable computers in different fashion-conscious form factors, permitting users to carry their own information (and computing) everywhere they go.

The first device from Xenote creates a new application for radio. The device only costs $5 and fits on a key chain (see Figure 9). When listening to a radio station's music or advertising (the company is marketing the fobs as promotional items for radio stations), users can choose to "capture" that item in the key chain fob by pressing a button and thus recording a time stamp. Later, they connect the fob to their PC.

Courtesy of IBM

**10** **IBM's prototype wristpad computers.**

The PC converts the time stamps to URLs. For a song, it may be its title, author, and purchasing instructions. For an ad, it may be a direct link to the advertiser's Web site along with special promotions that may have been advertised especially for listeners of that radio station. Xenote plans to make money not from selling the device, but from a share of the purchase price of the products the device helps sell, such as CDs. This approach represents the new model of information appliances. The devices themselves have too small a profit margin for success and need to reach the hands of as many users as possible very quickly. It's better to make profits from the services provided, which are continuously used, as opposed to a one-time purchase. Eventually, Xenote hopes to be able to put "tags" on a much wider variety of objects in the physical world, for example, to recall a particular meal in a restaurant or to recall an item seen while window shopping.

Charmed Technologies' first product is a smart badge for conference attendees.[10] The appliance is worn on a jacket or belt and can be used to link up with other attendees. Users (or conference registrars) can initially load the badge with business card information and a description of the person's interests. As people (and their badges) walk by each other, interest matches can be signaled. After meeting a person, users can exchange business cards electronically. Before leaving the conference hall, users can have the data they've collected e-mailed to them. Charmed Technologies' longer range goal is to create the personal information appliance that's worn all day long and can serve as a general-purpose device not unlike today's PC, including playing music MP3 files and providing basic applications such as word processing through an audio interface and a head-mounted display. A person's wearable computer can then interact with all the other devices it encounters, including the conference badge and eventually wearable health monitors. It could also serve as a universal remote control for the home, office, and car.

Both of these companies point to the most interesting trends in information appliances: connectivity, task-specificity, and a service-oriented profit model rather than one based on devices.

## Future expectations

Information appliances are evolving rapidly. Clearly, it's a time of experimentation and increasing diversity. An analogy can be drawn to those times in the history of life on this planet when vast new niches opened up because of important changes in the biosphere (due to mass extinctions or new capabilities such as flowering plants). Life quickly evolved into a myriad of different species that then were slowly refined by the evolutionary process.

The new technologies enabled by Moore's Law and the advances in wireless communication are the primary forces responsible for the explosion of different forms of information appliances. A winnowing out will inevitably follow this phase, as in the case of biological life forms. Some forms will eventually dominate because they strike a resonant chord with consumers, who ultimately apply "natural selection." Of course, it's too early to tell who the winners will be or how many more forms will evolve.

However, some clear properties of those winners are becoming clear. First, a few devices will be general-purpose (such as the PDA), although even these will deliberately limit their scope. The majority will be task-specific with optimized interfaces that will make them nearly effortless to use. The ideal of the successful appliance will be for it to achieve a level of invisibility for its user, that is, it will blend into the task rather than require a mental effort that distracts the user.

Second, devices will be interconnected using one of many possible wireless technologies. Note that in many of the examples in this article true value comes when the appliance can take advantage of the resources the Web offers. This is true both in terms of access to data but also to off-load functions that don't necessarily have to be performed by the device itself, yet burden its size and power requirements. Web-based services, connected to a user's information appliances, will be the locus for the lion's share of the business activity.

Third, new technologies will create more new niches for new appliance forms to occupy. Cheaper, more power-efficient, color, high-contrast displays will make the display of information truly ubiquitous. This will range from large wall panels to wristwatches to displays in eyeglasses (see Figure 10). Improvements in IC technologies and power harvesting techniques will permit devices that don't have large batteries to survive on kinetic or electrostatic energy and last for years rather than days or weeks.

Finally, there will always be the surprises presented by completely new ideas that provide new services previously not possible. A simple example is a parking spot navigation tool that references the Web for the position of empty parking spots (provided by sensors in the parking meters or pavement), navigates the user to the spot using the on-board GPS system, and automatically deducts a charge from the user's e-wallet.

We're at a juncture in the history of our computing technology. Previous episodes of explosive diversity have occurred (mainframe, PC, and PDA eras), but the era of information appliances promises to greatly overshadow those events. ■


## Acknowledgments

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## Web Sites

Charmed Technology
http://www.charmedtechnology.com/

E-books.org
http://www.e-books.org

emWare
http://www.emware.com

Georgia Institute of Technology
http://www.cc.gatech.edu/fce/eclass

IBM
http://www.ibm.com

Kyocera-Wireless
http://www.kyocera-wireless.com

NTT Mobile Communications Network
http://www.nttdocomo.com

Palm
http://www.palm.com

Phone.com
http://www.phone.com

Trimble Navigation
http://www.trimble.com

WAP Forum
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WebTV
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Xenote
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