Find New Markets,
Create Better Businesses,
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Around The World 24-7-365

Ubiquitous Computing for Business

Bo Begole

Praise for *Ubiquitous Computing for Business*

"Distilling research over a score of years, Bo nicely describes Ubiquitous Computing's tremendous business potential."

—**Gordon Bell**, author of *Total Recall: How the E-Memory Revolution Will Change Everything*; former Vice President of R&D at Digital Equipment Corporation

"In a field where there remains a surprising paucity of authoritative reference works in print, Bo Begole's detailed and comprehensive overview stands out. Alongside Kuniavsky's *Smart Things*, his book should form the core of any serious working library on Ubiquitous Computing and will challenge preconceptions of this technology's place in business for years to come."

—**Adam Greenfield**, Managing Director of Urbanscale; author of *Everyware: The Dawning Age of Ubiquitous Computing*

"Finally, a comprehensive and wonderfully clear articulation of Ubiquitous Computing—one that goes to the heart of Mark Weiser's original vision and explains just how powerful this vision was and still is. Indeed, this vision goes to the root of why we still feel so frustrated by today's technology, but also why the Ubiquitous Computing perspective will bring less stress and more productivity to us all."

—**John Seely Brown**, Former Chief Scientist of Xerox Corp. and Director of Xerox PARC; co-author of *A New Culture of Learning: Cultivating the Imagination for a World of Constant Change*

"*Ubiquitous Computing for Business* provides a blueprint for anybody in management who seeks better intelligence on the market, more actionable information without the overload, and instantaneous data for fast decisions. For innovating in an ever more uncertain world, Bo Begole shows us that computing power everywhere has emerged as the essential foundation."

—**Michael Useem**, Professor of Management and Director of the Leadership Center, Wharton School, University of Pennsylvania; author of *The Go Point: When It's Time to Decide*

"Few people on the planet know more about Ubiquitous Computing and context awareness than Bo Begole. Applying these two technologies to improve the way businesses interact with their customer is sure to be transformative."

—**Justin Rattner**, Intel Chief Technology Officer and Director of Intel Labs

"Ubiquitous Computing was coined at PARC decades ago, and the vision has continued to evolve here since. So it's wonderfully appropriate that Bo Begole, the current manager of this technology area for PARC and its clients, has authored a book that helps strategists—from CTOs to inventors—understand and exploit its disruptive business possibilities. This book will not only help readers map the various technologies to corresponding trends, but more importantly, help them sort hype from real value. The most valuable part, after all, isn't just ideas about what the future will hold, but actionable plans for turning these opportunities into products and services that people use."

—**Teresa Lunt**, Director of Computer Science Laboratory,
Palo Alto Research Center

"Coming from the birthplace of Ubiquitous Computing at PARC, Dr. Begole's excellent introduction to this growing technology is approachable, interesting, well-informed, and humorous. His insightful treatment of the connection between Ubiquitous Computing and business is one of the few I have seen anywhere, and it goes deeply into what's coming and how businesses will be affected."

—**John Krumm**, Microsoft Research;
Editor of *Ubiquitous Computing Fundamentals*

"*Ubiquitous Computing for Business* takes the potential value in Ubicomp technology and makes its value real. Its straightforward approach distills the experience of two decades of research and innovation to help executives and managers understand the business impact of pervasive computing technology in a way that no other business and technology book has tried. Every chapter is full of great ideas and practical advice from the thought leaders in the field."

—**Mike Kuniavsky**, author of
Smart Things: Ubiquitous Computing User Experience Design

"On par with the business impact of laser printing, the Ethernet, and personal computing, this new paradigm of Ubiquitous Computing is revolutionizing the ways businesses exchange information and interact with customers. This book provides a practical view into the business opportunities enabled by embracing Ubiquitous Computing's capabilities."

—**Sophie Vandebroek**, Xerox Chief Technology Officer and
President of the Xerox Innovation Group

Ubiquitous Computing for Business

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To Florence

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Acknowledgments

Most of the concepts here come from conversations and experiences I've had with many, many colleagues over the years. I rarely work alone, and I am always bugging other people about what they think about this or that.

I would like to thank a number of my collaborators with and from whom I first learned the concepts in this book: all current and past employees of the Palo Alto Research Center, particularly the Ubiquitous Computing researchers in the Computer Science Laboratory; colleagues at the former Sun Microsystems Laboratories in the Network Communities research group; and my dissertation advisor, Cliff Shaffer, who opened this marvelous field to me.

I would also like to thank my parents: my mom for teaching me adequate English in spite of my attempts to thwart her; and my dad for giving me a need to create.

I would also like to thank my children, who remind me daily of why I love life. It is my wife who has really made this book possible and has *always* been supportive of any endeavor. To her, I offer particular gratitude.

About the Author

Bo Begole is a Principal Scientist at the Palo Alto Research Center, the famed innovation center credited with inventing and commercializing many core information technologies, including laser printing, Ethernet, graphical user interfaces, the laptop, and more. He currently manages the Ubiquitous Computing Area at PARC, a computer science team that invents and commercializes novel technologies like those in this book. Before joining PARC, he worked at Sun Microsystems Laboratories, where he created systems to facilitate global collaboration and sensor networks. Dr. Begole habitually collaborates with social scientists and others to create innovations that help people work together remotely, find information more rapidly with less effort, communicate more efficiently, and increase the performance of people using information technologies.

Dr. Begole has chaired committees of several research conferences crossing the fields of human–computer interaction and computer-supported cooperative work, and he has participated on organizing and program committees in Ubiquitous Computing, intelligent user interfaces, user interface software and technology, and pervasive computing. With colleagues, he has written dozens of papers that have appeared in peer-reviewed scientific conferences and journals. He holds several patents. He also hosts and participates in several Silicon Valley business technology special-interest groups and has spoken at several business and technology conferences.

Dr. Begole received a B.S. degree in Mathematics (*summa cum laude*) in 1992 from Virginia Commonwealth University, an M.S. degree in 1994, and a Ph.D. in 1998 in Computer Science from Virginia Tech. Before earning his degrees, he served in the U.S. Army from 1981-89 and during the Gulf War in 1991 as an Arabic language translator. He lives in Los Altos, California, with his wife, Florence, and three children, Brighton, Aiden, and Annecy.

3

Harmless if Used as Directed

Perk up pouting household surfaces with new miracle Ubik, the easy-to-apply, extra-shiny, non-stick plastic coating. Entirely harmless if used as directed. Saves endless scrubbing, glides you right out of the kitchen.

—Philip K. Dick, *Ubik*[1]

By this point, it may have occurred to you that Ubicomp is simply a description of the state of information technology today: Computing is *everywhere*, *all the time*. How is Ubicomp different from other computing paradigms? This question reminds me of the metamorphic product at the center of Philip K. Dick's 1969 novel *Ubik*, which showed up as a different product for each chapter ranging from an electric vehicle to a pain reliever. Ubik was advertised as a cure for any and all ills (when used as directed), and its value was derived through the consumer's simple faith in its effectiveness. In some ways, a new computing paradigm can have a similar feel to Ubik: It can be anything you want it to be and can seem to solve any problem, yet it may actually be simply repackaging an existing set of capabilities (can you say "cloud computing"). Is Ubicomp (or should we say *Ubik*comp[2]) really a distinct category of information technology, a different paradigm for interacting with information systems?

Yes. A distinction exists between the ubiquity of information technology and the paradigm of Ubiquitous Computing. A Ubiquitous Computing system is generally one that interleaves information from physical and digital worlds. Desktop, mobile, web, and embedded computers are all examples of digital systems on one side of the information stream. The other side contains the physical elements:

location, paper, images, audio, or tactile information. In most cases, the person is trying to achieve a goal (which may be simply entertainment), and the Ubiquitous Computing system provides *assistance* or *knowledge* that the user needs, if not proactively, then at least conveniently.

Figure 3-1 shows the three key pillars of a Ubiquitous Computing system: *ubiquitous interoperation* among devices, information, and networks to create *interactive and proactive services* for *personal assistance and knowledge.* A successful Ubicomp system combines all three of these to serve the user's needs.

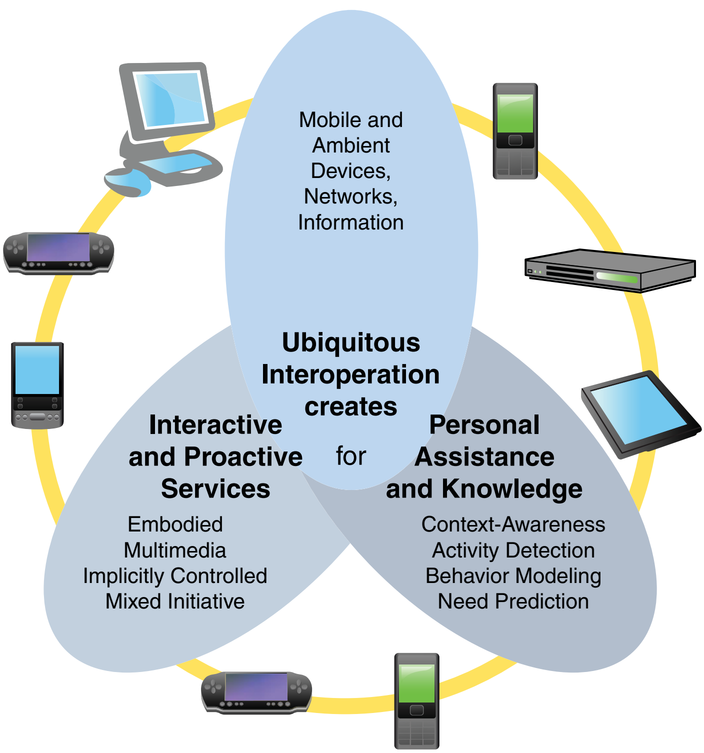


Figure 3-1 Ubiquitous Computing innovation focuses on new technologies and practices to interweave digital and physical information sources when working toward an objective.

What Did the Car Say to the Home Heating System?

Nothing. And that's the problem. Why doesn't your vehicle tell your home heating system when you are headed home so that it can preheat the home? Why doesn't your thermostat setting at home get used to set the temperature in the car? Why don't all of my devices share the information that I enter into them?

The first dimension of advances in Ubiquitous Computing has focused on leveraging the increasing miniaturization of computation and proliferation of devices throughout our lives. At the inception of the field, research and invention centered on creating the hardware devices and software infrastructures for exchanging information that would be needed to realize the vision.

In the previous discussion of the history of the field, I described some of the early prototype devices and networks developed by researchers at Xerox PARC and elsewhere, such as the PARC Tab, PARC Pad, the Tab Network, and Liveboard. At the time (late 1980s, early '90s), wireless battery-operated computing devices were not commercially available, so researchers were required to implement the hardware. Today, of course, wireless battery-operated devices are common in the form of laptops, e-readers, tablets, and smartphones. Until recently, the research community focused on the integration of sensors with the devices, but even that has become commercially common, with examples such as accelerometers, GPS, gyroscopes, and digital compasses on more handheld computers. Certainly, Ubiquitous Computing will continue to advance the field of hardware devices, but at this point, we can be assured that the critical mass of pervasive devices, networks, and information does exist. The larger questions to address today involve leveraging this ubiquity into new services.

The Interoperability Barrier

Increasing computational power on personal computers has expanded what we conceive of as "information." Early business computers were able to handle information in the form of simple text and numbers, but new digital recording devices are generating multiple forms of media: still images, audio, and video. Today documents on the web and word processors can readily handle image, audio, and video media, so the focus of investigation in media technologies has shifted to issues related to the digital delivery of media content for consumer entertainment rather than to business users in the workplace. The same problems exist for consumers as they grapple with understanding how to compose a wide assortment of devices from multiple manufacturers that generate and consume multiple media types (text, photos, video, animations, music, and voice). It's easy to understand that technical difficulties would arise in translating from one media type to another, such as speech to text, but it's hard to understand why so much complexity surrounds the seemingly simple problem of encoding and transcoding content across the dizzying array of "standard" formats (JPG, RAW, WindowsMedia, Quicktime, RealMedia, DVD, Blu-ray, and MVI DVD), as well as exchange protocols (Universal Plug and Play, Digital Living Network Alliance) and media networking technologies (HDVI, Bluetooth, WiFi, and proprietary network protocols). The diversity and complexity is feeding a large segment of the media industry to help consumers understand the various tradeoffs to optimize fidelity, cost, and performance. This confusing array of formats, along with the risk that any new standard might become quickly obsolete, slows adoption of new technical capabilities The wise consumer waits for the standards wars to run their course before making a purchase.

The problems with multimedia are not entirely technological, of course. Some of the "standards" are owned by businesses that aim to optimize commercial benefit by exploiting some proprietary advantage or consumer lock-in to a standard that they own or control. The complexity of standards can keep small players out of a market. Even for the large companies that can afford to participate in standards consortia, the agreements require time-consuming negotiation and fail to accommodate unforeseen technical advances. A recent example is the unexpected growth in 3D video that the recently adopted video standard, H.264, does not cover. The limitations of existing standards give rise to new standards, but the fundamental problem with standards approach remains: standards lag innovation.

Despite the fact that the problem is not wholly based on technological issues, Ubiquitous Computing research has investigated solutions to these sets of problems, such as dynamic transcoding of media formats to match the rendering device's capabilities.[3] In a recent example, researchers at PARC (see sidebar PARC Today) devised technologies for "recombinant computing," called the Obje™ interoperability framework,[4] which uses the approach of dynamically transferring a media codec from a media source (such as a video library server) to a media renderer (such as a digital display). This approach not only solves the core problem of interoperability, but also enables new models of device interoperability, such as "recombinant" device networks,[5] in which end users can co-opt a device designed for one purpose to be used for a different objective (such as using an off-the-shelf digital camera as a page scanner to send a fax through a networked computer).

Under the Obje framework, a flexible security mechanism allows devices to alert each other of their presence and allow safe interconnectivity of trusted and untrusted devices all under the user's direct control. With this and similar approaches to interoperation, consumers can remain confident that their new and existing products will work together. Manufacturers also are free to introduce new and innovative devices, media formats, and networking options without depending on the sluggish creation of standards. As time-to-market cycles shrink, the need for faster iteration of interoperation is increasingly necessary.

PARC Today

Xerox's Palo Alto Research Center, founded in 1970, recently celebrated its 40th birthday. In 2002, Xerox PARC was transformed from a division of Xerox into an independent company. In its new form, PARC, Inc. is still owned by Xerox and now has the flexibility to create technologies with commercial impact outside of Xerox's traditional business domains (which itself has broadened from document scanning and copying into information services and business process outsourcing). Historically, some of Xerox PARC's technologies were inadvertently commercialized by companies other than Xerox. Today PARC deliberately commercializes technologies with partners across various industries, including solar energy, natural language search, biology, retail shopping, and water filtration. In addition to technology innovation, today's PARC is innovating in the business of doing research.

Keeping Control

Even if the problem of various digital media formats and protocols went away, we would still have two problems: making sense of what kinds of interconnections are possible, and then controlling the connections. Think about a typical home media system: The possible connections between TV, video library, music, speakers, and satellite or cable feed are endless—just look at the back of your components at home to see the tangle of complexity there from wires and terminals.

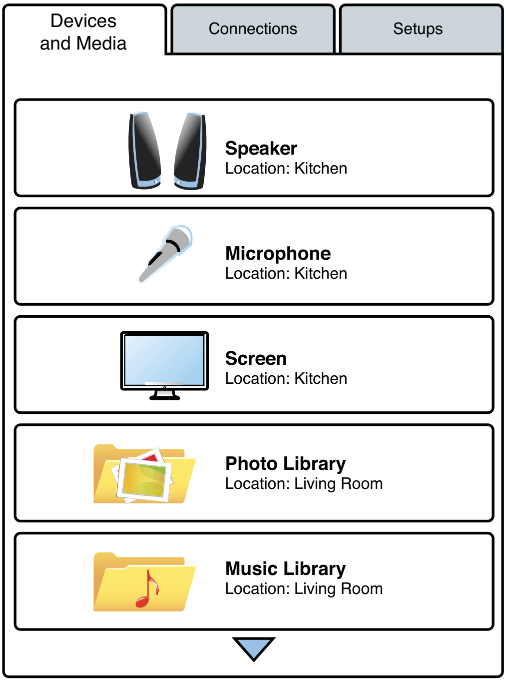
At least today you can see the wires that define the connections. Those wires are disappearing; wireless digital networks are supplanting wires throughout our environments. Sure, the wires are annoying and we will all be better off with fewer. On the other hand, the existence of a physical wire between two connected devices leaves no uncertainty that they are connected. When no wires exist, how will you know whether the media server in your living room is connected to the speakers in the kitchen (or the neighbor's speakers)?

Today's home media entertainment systems come with a remote controller for each device, each using the specific control codes and protocols for that model device from that particular manufacturer. These remote controllers quickly add up to too many to keep track of. A common solution is to use a "universal controller" that is capable of talking to several models of devices from several manufacturers. Thus, we might imagine extending the capabilities of such devices to include the ability to define the logical connections between media servers and players in a wireless network. However, today's universal controllers can control only a device that has been physically connected to another device; universal controllers are not currently capable of making connections, just controlling existing ones.

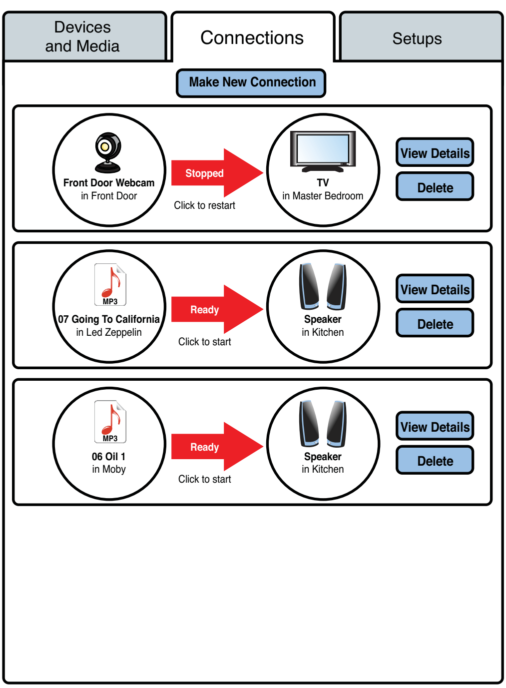
Let's think of the extension of universal controller as a kind of "universal connector." What would that look like? First, it would need to show a representation of all the media devices or services (sources of content and destinations for playback) that it knows about and allow direct control of each. Second, it would need to provide a way to define that two (or perhaps more) media endpoints should be connected without physical "hardwiring." These connection configurations should sometimes include simple instructions of what to do when some event occurs, such as to turn down the volume when the telephone rings. Finally, it should make the connections semi-permanent by recording the connection. Figure 3-2 shows an example of such an interface based on the Obje framework described earlier.[6]

The first market entry point for this capability is consumer media devices in the home, but it could expand to include interoperation with other electronics in the environment, such as smart conference rooms, smart stores, and others.

This first dimension of Ubiquitous Computing has become a reality. The devices that once required research scientists to construct can now be purchased at electronics stores. In this sense, Ubiquitous Computing is already upon us. As we have seen, however, users continue to struggle with how to make sense of the richness of technologies available to them, so the full vision of Ubiquitous Computing has not yet been realized. Fortunately, the continuing adoption of mobile and embedded devices and networks opens up two new capabilities that reduce user confusion and propel us toward the ultimate vision of technologies that weave themselves seamlessly into the fabric of our everyday lives: *interactive and proactive services* that address the needs of *personal assistance and knowledge*.



Discover and control devices and services



Connect devices and services

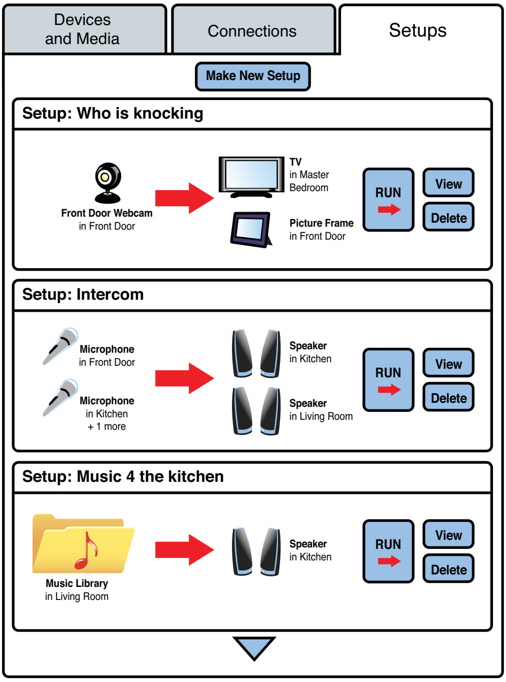


Figure 3-2 Obje Universal Connector simplifies defining connections in the absence of physical wires. The Universal Connector can dynamically learn about the existence and operation of a device/service because the control interfaces are served up by the devices themselves. (Figure credit: Mark Newman)

Proactive Interaction

> *But if you're proactive, you don't have to wait for circumstances or other people to create perspective expanding experiences. You can consciously create your own.*
>
> Stephen Covey, *The 7 Habits of Highly Effective People*

It often seems that the world of electronic information is separate from our own; our PCs, handheld computers, and mobile phones provide tiny portals where people can peer through the screen at a sliver of the info-verse. People manipulate information and devices by poking buttons and pushing a mouse. Ubiquitous Computing adopts the philosophy that no distinction should exist between information space and physical reality, and that we shouldn't have to be trained on how to input data into a computer. Just as we are able to exchange information with humans without necessarily using a text-entry keyboard or mouse, we should have natural ways to interact with computers as well. The keyboard and mouse are recent inventions, but our bodies long ago mastered touching, grasping, speaking, moving, hearing, and interacting naturally with the world.

Act Naturally

Generally, a human operator *explicitly* directs what functions the system should take by deliberately generating commands that direct the operation of the system. Why is it necessary for us to direct every single operation of the computer? Human coworkers don't tell each other explicitly what to do (for the most part). Furthermore, why do we have to manipulate information by poking buttons, pushing pucks, touching graphics, and occasionally speaking to devices? Ubiquitous Computing adopts the philosophy that, just as we don't have to use a keyboard to talk to other humans (though my wife just sent me an email from the kitchen!), we should have *natural* ways to interact with computers as well.

What qualifies as "natural" interaction? *Natural* is a subjective term based on the perception and experience of each individual. A number of metrics are used in the field of human–computer interaction to evaluate the effectiveness of interactive systems: performance speed, number of errors, time on task, perceptions of quality, simplicity, and others. Perhaps the closest metric to the notion of "natural" interaction is ease of learning. A system that is simple to learn seems more natural. The simplicity of learning, however, depends on the skills of the person using the system: Someone who has not yet learned to use a mouse will find even the simplest graphical user interface difficult to use.

Let's use "natural interaction" in an extreme sense: An interactive system is natural if *any* human in the targeted user demographic (age, gender, education level, work type, and so on) will be able to use the system with absolutely no prior training. Examples of purely naturally interactive systems include automatic doors, motion-sensing light switches, antilock brakes, and traction control in automobiles. Anyone who functions normally in the world can use these systems with no training whatsoever.

Computer Perception

The oldest medium for exchanging information is speech. Despite ambiguities and imprecision, human language is the richest form in which to express concepts. Computers in the dawn of Ubiquitous Computing had some ability to recognize human speech, but researchers realized that wasn't enough. Speech is not the only means by which we interact; we point, gesture, draw, emote, write, gaze, and use other external cues to indicate meaning. Each of these communication modalities is better at communicating some types of information than another. Humans often combine modalities to emphasize and reinforce meaning. Similarly, human–machine interaction benefits from the use of multiple input/output modalities: text, mouse, voice, gesture, vision, and touch. Researchers have even done experiments with interaction technologies based on olfactory and taste sensing. The goal is to enrich human–machine interaction beyond the use of one or even two input mechanisms (keyboard and mouse) so that people can use the best communication modality to express their intent.

Touching, Moving, Grasping

"Direct manipulation" is a commonly used computer-interaction paradigm in which users "touch," "move," "select," and in other ways interact with objects that they want to perform operations on—physical objects or abstract objects such as information files and documents can be represented for users to manipulate. Direct manipulation is a more "natural" interaction style than the command-line interfaces that preceded it. On the other hand, direct manipulation interfaces are actually somewhat *indirectly* controlled through the movement of a mouse on a surface that moves a corresponding pointer on a screen. Modern touchscreens get closer to the intent of direct manipulation, but there again, the icons on the screen are usually indirect representations of objects.

An even more direct form of manipulation is present in tangible user interfaces (TUI), such as those created by the Tangible Media Group at MIT since 1996, in which the physical space where information is represented is also what the user manipulates.[7] One example of this approach is Illuminating Clay, a system that allows a landscape designer to manipulate a flexible clay landscape model. The system laser-scans the clay model and calculates heights, contours, water flow, and slopes; those are then projected onto the clay model in near–real time. The clay, a traditional tool for landscape designers, is used as both the input and output medium, providing direct support for the iterative process of design.[8] Certainly, such interfaces are quite "natural" to use, but most TUI-based applications require some user training to understand what actions can be performed on the tangible objects and what information will be delivered as a result of actions. TUI-based systems are easy to use after this information has been conveyed, but some amount of training is definitely required.

Natural interaction is one among a superset of interaction paradigms that has been referred to as Reality-Based Interaction (RBI).[9] This set covers a broad range of interaction styles "that diverge from the 'window, icon, menu, pointing device' (WIMP) or Direct Manipulation" interaction, including virtual, mixed, and augmented reality; tangible interaction; Ubiquitous Computing; context-aware computing; handheld interaction; and perceptual and implicit interaction styles, such as natural interaction. All of these interaction paradigms utilize people's tacit knowledge in the following four categories: simple physics (gravity, friction, persistence of objects, relative scale), body awareness (proprioception, range of motion, two-handed coordination, and whole-body interaction), environment awareness (navigation, depth perception, distance between objects), and social awareness and skills (presence of others, verbal and nonverbal communication). Systems that embody the paradigm of natural interaction leverage the user's knowledge in all four of these categories.

The same kinds of technologies that enable multimodal interaction can also detect user actions that *implicitly* indicate the user's goals and intentions without requiring deliberate direction from the user. A recent example of such a system is the PARC Responsive Mirror,[10] shown in Figure 3-3 and described in more detail in Chapter 11, "Clear Sailing." This is an implicitly controlled video technology for clothes fitting rooms that allows a shopper to directly compare a currently worn garment with images from the previously worn garment, matching the shopper's pose as she moves. When a shopper turns to look at herself in the mirror, she is indicating a need for information about how she looks from that angle. A camera detects the

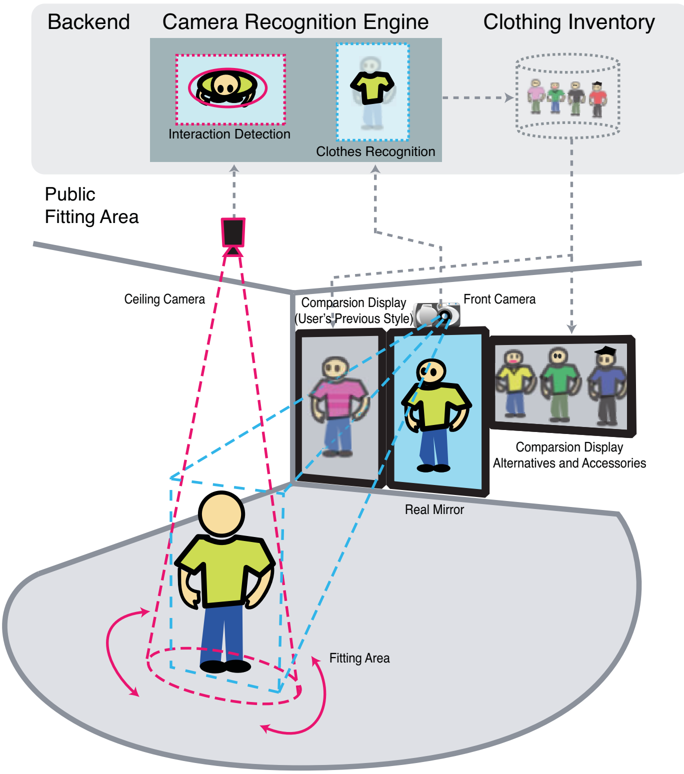


Figure 3-3 The responsive mirror is implicitly controlled: Images in the electronic display on the left match the angle of the user's view in the conventional mirror in the center. (Figure credit: Takashi Matsumoto)

shopper's orientation, and an electronic display shows images of previously worn garments in the matching orientation, providing the information that the shopper desires (how she looks in multiple garments from the same angle). People exhibit many other behaviors in retail settings that indicate their information needs: picking up and examining objects, searching for assistance, comparing products side by side, and more. As machine perception becomes more reliable and less costly to deploy, we will see the ability to deliver information based on implicit behaviors in other domains. Think about all the situations in which you can pretty much tell just by looking what people are trying to do at work, at home, or in kitchens, schools, airports, shopping districts, theaters, hospitals, and more.

Proactive Systems

Proactive systems span a spectrum from ones that automatically take anticipatory action to ones that merely detect and facilitate a potential need for action but that wait for the user to take action. The degree of proactivity depends largely on the appropriateness of taking action and the severity of being wrong. For example, automatic doors sometimes open incorrectly, but the cost of this error is low because little harm results if no one goes through an open door. On the other hand, although automatically printing to the nearest printer *usually* is the right thing to do, possible exceptions make it more prudent to ask the user which printer to use. It is safe and still helpful to sort a printer list according to the proximity to the user, allowing the user to quickly select the nearest printer but still search for others when desired.

Assistance and Knowledge

The main objective of Ubiquitous Computing is not any particular technology or interaction mode. Instead, it is to *assist* users in achieving their objectives with the most appropriate technology at hand. Certain aspects of Ubicomp systems make them particularly suited for such assistance.

Context-Aware Systems

Computing devices seem oblivious of the environment in which they are being used: mobile phones ring in the middle of meetings, email notifications pop up in the middle of presentations, speech-enabled navigation systems interrupt conversations in automobiles, and users cannot simply state that they want to connect to the "nearest" printer, display, or speaker, they have to pick it from a list. In the Ubiquitous Computing paradigm, devices are aware of the context in which they are being used and behave appropriately. Context includes the state of the physical environment (location, time, and weather), the state of the electronic environment (calendar appointments, contents of recently viewed documents and emails, phone calls) and the state of the people involved in the situation (talking, concentrating, laughing).

Context-awareness allows systems not only to react appropriately to the situation, but also to anticipate user needs and behave proactively *when appropriate*. It's not enough to simply have access to contextual information; effective proactivity requires understanding what the situation *means* to the person and what actions are appropriate and will be helpful. Some categories of proactive assistance are almost trivial to implement, requiring little or no analysis of tradeoffs or innovation. Automatic door openers are context-aware, proactive, and easy to implement—for example, a switch or motion sensor rigged to a door-opening actuator is all it takes (but do take care to design the passageway so that the door won't strike a person as it opens).

A grand challenge in artificial intelligence is that of a digital personal assistant. Although prototypes of such have been developed in laboratories, we are only now seeing the emergence of commercial products in this category. The ultimate personal assistant is one that knows your personal preferences, can tell how you would react in any given situation, adjusts for social/political objectives, and behaves proactively only when you would want it to. A combination of a Radar O'Reilly who presciently knows what you want done, a Passpartout who smoothes the way on your journeys, and a Jeeves who deftly extricates you from a jam—the ultimate executive assistant for us all! Between these two extremes lie a broad range of personal services requiring different levels of complexity and innovation to make them real.

The vision of intelligent agents is marvelous and shares many objectives with Ubicomp but takes the approach of doing as much as possible without you (see the accompanying sidebar for more). Do you really want something else to do the work for you? Have we not learned that a sedentary life is not healthy? Will our abilities to learn and think for ourselves atrophy? Ubicomp has publicized the notion of calm computing, but the calmness is intended to be with respect to how one thinks about the computers being used, not that the person is necessarily calmly, lazily existing but not achieving. In fact, while the early visions of Ubicomp espouse systems that anticipate and proactively satisfy needs, they just as equally describe people actively engaged in their lives and work.

Limitations of Agent-Based Interaction Metaphor

The notion of using computer intelligence in the service of users is also at the heart of a subdiscipline of artificial intelligence known as Agent-based Interaction. For the most part, Ubicomp and Agents are complementary notions that enable each other—the ubiquity of systems allows them to be more intelligent, which, in turn, spreads the systems ever more ubiquitously. However, the two have one fundamental difference. An intelligent agent is modeled after a human co-pilot and intended to be a centralized locus of control, handling all your needs in one place. Ask, and it responds. Command, and it performs. Relax, and it will alert you when trouble arises.

To get any particular job done, the agent may have to call on others to perform subtasks, usually in a hierarchically structured organization. Unfortunately, this mode of commanding an agent boils down to essentially the same problem as in using any single point of control. First, you have to be able to communicate what you want. However, we humans do not always have a clear idea of what we want—when we do, by the time we've articulated clearly the goals and the constraints, we might as well have done it ourselves. Speech recognition may help but is not a complete solution, either, as there is inherent ambiguity in human speech. How many times have you seen people in a conversation come away with different interpretations of the discussion? Text input is nearly error free, but does that make keyboard-based user interfaces easy? Second, as a single locus of control, an intelligent agent needs to be able to utilize other services to accomplish goals. Somehow, the agent will have to preserve your intention as commands are dispersed to other systems and actions are taken on your behalf. Generally, intentions blur and become reinterpreted with each link in a communication chain, resulting in inefficient iterations of command-response cycles and outright unintended results.

The Ubicomp paradigm is modeled after a flat business organization in which the leader connects directly with frontline employees and customers. Ubicomp systems are intended to work in the mold of artisanal tools that become extensions of the artisan's body.

Today, though, instead of using physical tools to construct physical artifacts, modern work involves complex information gathering, planning, and communication. Instead of subcontracting the work out to an agent, Ubicomp systems consist of controls, displays, workplaces, communication channels, authentication protocols, and other information tools arranged to facilitate the direct achievement of knowledge-oriented tasks.

At a symposium on User Interface Agents in 1992, Mark Weiser used a version of the following table to contrast the two philosophies.

TABLE 3-1 Distinctions between Intelligent Agents and Ubiquitous Computing Systems

Intelligent Agent	Ubiquitous Computing
Single locus of information about me	Distributed, partial information by place, time, and situation
Command the computer	What computer?
Personal, intimate computer	Personal, intimate people (whom I happen to access through a computer)
Filtering, blocking, re-routing	Breathing, living, strolling, engaging
User interface between person and computer	No boundary between you and the machine
DWIM (do what I mean)	WIWYHIAFI (when I want your help, I'll ask for it)
I interact with an agent. You reach me through my agent.	I interact with the world. You reach me.

To be fair, the idealized visions of personal assistants in fiction (Radar, Passpartout, and Jeeves) know when it is appropriate to intervene and when to get out of the way. The vision of humanlike interaction with an intelligent agent is not inconsistent with Ubicomp; it's just that the emphasis differs. An intelligent agent would do the work for you, calling on you only in extreme circumstances. In a Ubicomp system, you still do the work and conduct the interactions, but you have at your disposal a broad set of well-designed tools that extend and augment your own inherent personal abilities.

The concept of location-based services and context-aware systems began at PARC with the deployment of Olivetti's Active Badge and the PARC Tab, which were able to detect the room in which a person was located in the building. Although these prototype devices proved the viability and value of the concept, commercial success depended on the availability of location-tagged information and reached critical mass in the early 2000s with web-based mapping systems. Since then, a wide range of location-based services has emerged in the form of a variety of GPS-enabled navigation devices and smartphones.

Figure 3-4 shows that the time between the research concepts of context-aware services and the onset of commercial services was roughly ten years. Widespread adoption of location-based service did not occur until around 2007, largely due to the lack of commercial infrastructure for location awareness. Now that the infrastructure exists, the subsequent advances in research labs will become commercially viable at a *much* faster pace. As an example, prototypes of the grand vision of a digital personal assistant existed only as research projects starting around 2005 with the Cognitive Assistant that Learns and Organizes (CALO), funded by the Defense Advanced Research Projects Agency (DARPA) and developed jointly by many

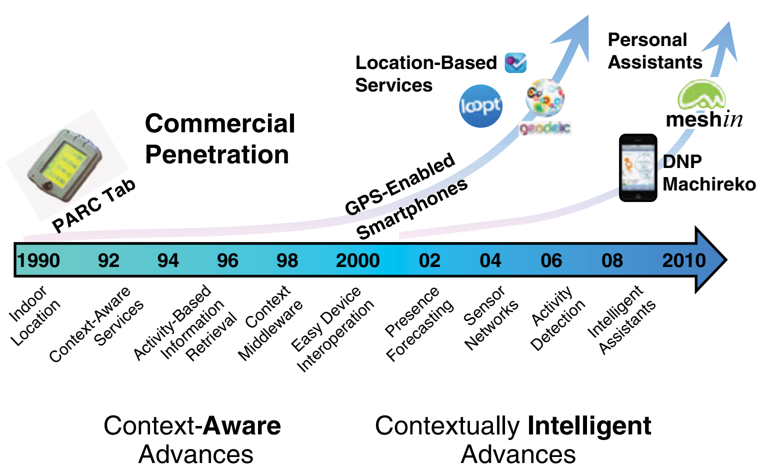


Figure 3-4 Timeline from research to commercial adoption of context-aware services. The adoption rate is accelerating now that critical mass of wireless networking, handheld computers, sensors, and networked information services exists.

academic and commercial research firms. Later advances included a mobile phone prototype codenamed Magitti for providing personalized recommendations of restaurants and stores (described in more detail in Chapter 8, "Breaking Out of the Supply Chain Gang"). It was developed by PARC and Dai Nippon Printing (DNP) in 2007[11] and commercially released for the iPhone in 2010.[12] A subsequent prototype system called Ubidocs combined content-analysis along with digital context to find and present the people, events, and pieces of information related to your email. It was prototyped at PARC between 2008 and 2009 and was commercially released as Meshin in 2010. These early digital personal assistants do not have the full power of a competent human assistant, and research and innovation are still needed to achieve that vision. The take-away message is that commercialization of research in context-aware services will be *much* faster-paced now than ever before.

What Are You Trying to Achieve?

The ultimate goal of context-aware systems is not simply to know the state of the environment, but to have insight into the intentions and goals of people acting in the environment. This is largely determined by a person's tasks and activities, which can be partially inferred by combining inputs from multiple sensor types, as well as content of electronic data that the person has generated or accessed. For example, if the system observes people entering a conference room, combined with the fact that a meeting is scheduled in that room, the system may infer that the activity of the people is a *meeting*. The system may even know the topic of the meeting and information related to the meeting, from information associated with this location and collection of people. This concept formed the premise of the Activity-based Information Retrieval (AIR) in the early 1990s. Since then, we have seen considerable advances in activity detection, to the point that systems are able to detect activities at multiple levels of granularity: from mechanical actions (walking, biking, brushing teeth, and so on) to longer-lasting and cognitive levels of activity (playing football, eating in a restaurant, compiling a report, planning an outing, socializing, preparing a meal, and more). Activity detection provides insight into a person's state of mind. As an example, researchers have demonstrated that people are less mentally receptive to an interruption when a system detects that they are actively involved in conversation or work tasks (explored in more depth in Chapter 10, "Coordination") .

Summary

In contrast to the early days of Ubicomp research, mobile wireless devices are common today in the form of smartphones, laptops, and embedded sensors. Ubicomp innovation is now centered on reducing some of the complexity in our pervasively connected lives: information overload, device management, social connectivity, and network bridging. The Ubicomp field today can be described as pursuing the use of *ubiquitous interoperation* of devices, networks, and services for the creation of *interactive and proactive services* that provide *personal assistance and knowledge.*

Ubicomp systems have several characteristic technologies:

- **Ubiquitous interoperation** is the exchange of information and commands among all systems to perform a task. Ubicomp systems must interoperate with a wide range of system types, including web services, sensors, digital media, phones, building control, medical equipment, games, transaction services, and social network services—any and all encodings of information across all types of technology.
- **Natural interaction** allows humans to use their anatomy and cultural history of interacting with people, objects, and information in the physical world.
- **Multimodal interaction** allows the use of multiple forms of input simultaneously: speech, text, vision, touch, and so on.
- **Physical and embodied interaction** (also called tangible user interface) allows people to directly manipulate physical objects to perform digital tasks.
- **Implicit interaction** occurs when systems automatically perform tasks without requiring directive commands. Automatic door openers are a simple example.

- **Context-aware systems** use the state of the physical and electronic environment (location, nearby objects, people, recently exchanged email, calendar appointments, and so on) as factors in performing an information service.
- **Activity detection** is the use of sensors to identify the physical or cognitive activities of people.
- **Proactive systems** anticipate the user's goals and suggest or perform actions to facilitate their accomplishment.

Although Ubicomp systems employ intelligence and personalization, they fundamentally differ from the notion of an intelligent agent that provides a single locus of control with the world, letting the user specify rules and policies that the agent performs. In a Ubicomp system, the user performs the work and engages with the world through the use of well-designed tools that extend the user's inherent personal abilities.

These capabilities create new classes of applications and services that will have increasing business relevance. The remainder of this book outlines some of the major classes of new services, illustrated with case studies of their applications in business.

Endnotes

[1]Philip K. Dick, *Ubik* (New York: Random House, Vintage Books, 1969).

[2] Mark Weiser may have been aware of this irony when he used the domain name ubiq.com for the initial website of PARC's Ubiquitous Computing research group (archived by PARC at www.ubiq.com/).

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[4]M. Newman, S. Izadi, W. K. Edwards, J. Sedivy, and T. Smith, "User Interfaces When and Where They Are Needed: An Infrastructure for Recombinant Computing," *Proceedings of the 15th Annual ACM Symposium on User Interface Software and Technology* (UIST '02), Paris, 30 October 2002, 171–180.

[5]K. Edwards, K. Newman, and J. Sedivy, "The Case for Recombinant Computing," Xerox PARC Technical Report CSL 01-1, 2001.

[6]See also M. W. Newman, A. Elliott, and T. F. Smith, "Providing an Integrated User Experience of Networked Media, Devices, and Services Through End-User Composition," In *Proceedings of the 6th International Conference on Pervasive Computing (PERVASIVE '08),* Sydney, Australia, 2008: 213–227.

[7]H. Ishii and B. Ullmer, "Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms," *Proceedings of the ACM Conference on Human Factors in Computing Systems* (CHI '97), Atlanta, March 1997, 234–241.

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[11]DNP News Release, "DNP, PARC Jointly Develop Recommender System for Mobile Terminals," 26 September 2007, www.dnp.co.jp/eng/news/2007/070926.html.

[12]DNP News Release, "'Downtown,' an Information Distribution Service Machireko Guide, iPhone for Field Trials Starting in Ginza and Yurakucho" (in Japanese), 25 March 2010, www.dnp.co.jp/news/1213051_2482.html.

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