A1 • UP-FRONT VALUE PROPOSITION

Figure 1. TrafficGauge offers a PDA that provides up-to-date traffic information for the Seattle area. This is a clear and compelling value proposition for users.

• BACKGROUND

An application needs to communicate its purpose immediately and clearly. This pattern describes how to come up with that message, and can be applied to any application, including PERSONAL UBIQUITOUS COMPUTING (A2), UBIQUITOUS COMPUTING FOR GROUPS (A3), and UBIQUITOUS COMPUTING FOR PLACES (A4).

• PROBLEM

Some applications do not make it obvious what they offer users. This is critically important for ubiquitous computing applications, since there are many fears that emerging applications will be used to track users and invade their privacy.

• SOLUTION

Each application needs to offer a clear value proposition that states how it can help users. The value proposition can be a persuasive promise or a unique benefit that can greatly help the user in some way. Here are some hypothetical value propositions:

- Emerging cell phone services offer ACTIVE MAPS (B1) of your current location, promising that you will never be lost again.
- Motion sensors connected to the heating and ventilation systems in SMART HOMES (A8) offer energy efficiency for home owners.
- An electronic message board can be set up in SMART HOMES (A8), making it easy for family and friends to share photos and scribble messages to one another.
- Key chains will act as PERSONAL MEMORY AIDS (A7), recording their current location when you lock your car doors so you will always be able to find where you parked.
- Location-tracking systems for hospitals can make it easier for nurses and doctors to find each other and help ensure high-quality patient care.

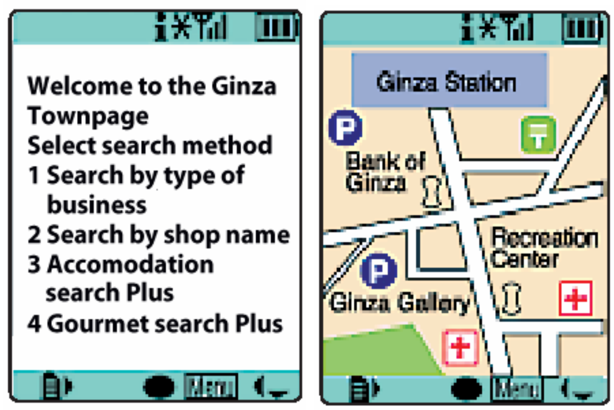

Figure 2. Emerging cell-phone applications let people search for nearby businesses and restaurants, and provide maps of how to get there from one's current location. This is a simple but persuasive value proposition: "never get lost again."

These applications offer solutions to a wide range of needs, from safety to convenience, from efficiency to making it easier to stay in touch with family and friends. *The key here is that they can be quickly and easily explained.*

The last example, location-tracking for hospitals, is an especially important one, as it is in a workplace setting. There are many legitimate fears that such a location-tracking system could also be abused by management, for example by monitoring how often nurses go to the bathroom and by checking how long they spend with each patient.

We have examined people's attitudes toward location-tracking systems in the workplace through a survey, interviews with firefighters, and an analysis of message board for nurses, and have found that the value proposition is a key factor in the success or failure of these systems.

For firefighters, location-tracking leads to ENHANCED EMERGENCY RESPONSE (A6). There is a clear and immediate benefit to location tracking for firefighters, and since they work in emergency situations and completely trust each other, they had no privacy concerns.

For the nurses, if the location tracking was seen and used as something that could help them provide better patient care, then it was accepted. On the other hand, if it was seen and used as something that would primarily help management, then they almost universally disliked it, and in some cases, outright rejected it.

The danger here is making the value proposition a matter of marketing or spin. Your users will be able to sense if there is no real underlying value, and will be even more likely to balk at using the system. Again, the key here is to *focus on real value for users*.

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Grudin, J. Groupware and Social Dynamics: Eight Challenges for Developers. Communications of the ACM, 37(1), 92-105, 1994. http://www.ics.uci.edu/~grudin/Papers/CACM94/cacm94.html. This paper describes what is known as Grudin's Law: "When those who benefit are not those who do the work, then the technology is likely to fail or, at least, be subverted."

van Duyne, D., Landay, J., and Hong, J. The Design of Sites: Patterns, Principles, and Processes for Crafting a Customer-Centered Web Experience. Addison-Wesley, 2002. This book looks at web design patterns, and includes exercises that you can do to help figure out your value proposition.

A2 • PERSONAL UBIQUITOUS COMPUTING

Figure 1. Advances in miniaturization, sensors, wireless networking, and devices of all form factors are driving the shift towards *ubiquitous computing*, where computing and communication are dispersed into our everyday environment to support us in nearly every task imaginable.

• BACKGROUND

This pattern, along with UBIQUITOUS COMPUTING FOR GROUPS (A3) and UBIQUITOUS COMPUTING FOR PLACES (A4), forms the core of ubiquitous computing genres. This pattern should be used with an UP-FRONT VALUE PROPOSITION (A1) to provide meaningful and compelling user experiences for individuals.

• PROBLEM

How can we use progress in sensors, devices, and wireless networking to help individuals be more aware of what is around them, be more effective, or have more fun?

• SOLUTION

The possibilities for computing are becoming wider as the capabilities of sensors, devices, and wireless networking are improved, and as their prices plummet. *Ubiquitous computing* is the term commonly used to describe the vision of what the world will be like as it is filled with these technologies, as the physical world we live in and the virtual worlds of computers are slowly merged together.

There are many examples of ubiquitous computing applications for individuals. Most of these applications tend to be on PDAs, digital cameras, and cell phones, though some can also be worn. In general, this class of applications also has relatively few privacy concerns because the data is not being shared with anyone else.

Below are just a few examples of personal ubiquitous computing. This list is by no means complete, but is meant to give you a flavor of what ideas are out there:

- Emerging cell phone services are providing FIND A FRIEND (B6) services, making it easy to find friends for impromptu meetings.
- New location-based services are enabling FIND A PLACE (B5) services, letting you search for things like the nearest gas station or nearby Chinese restaurants, or see when the next bus is arriving.
- Future PDAs will have CONTEXT-SENSITIVE INPUT AND OUTPUT (D6), using speech when your hands are full but switching to visual displays in noisy situations.
- Mobile GUIDES FOR EXPLORATION AND NAVIGATION (A5) will help people explore new areas that they have never been in.
- Wirelessly connected PDAs can provide TOPICAL INFORMATION (B2), such as reviews on items before you buy them in stores.
- Digital cameras will help people explore the environment by recognizing what kind of tree or animal is in the picture.
- Key chains will act as PERSONAL MEMORY AIDS (A7), recording your current location when you lock your car doors, so you will always be able to find where you parked.
- Cars will provide real-time driving directions to help you avoid traffic jams.

• REFERENCES

Weiser, M. The Computer for the 21st Century. Scientific American 265(3): 66-75, 1991. http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html. This paper describes the driving vision of ubiquitous computing, where sensors, devices of all sizes, and wireless networking will converge and become an invisible part of our everyday lives.

A3 • UBIQUITOUS COMPUTING FOR GROUPS

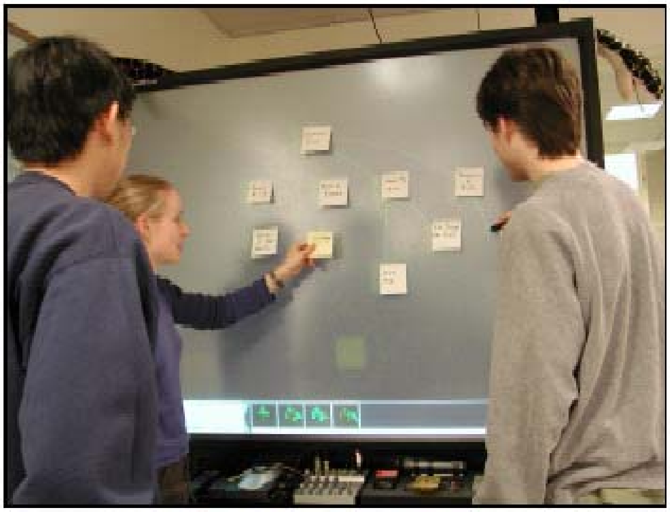

Figure 1. Ubiquitous computing technologies can also help groups in many ways, such as collaborating more effectively or simply making it easier to stay in touch. This picture shows a large electronic whiteboard used for web design. The system senses post-it notes on the board and makes electronic versions of them, making it easier to collaborate across long distances.

• BACKGROUND

This pattern, along with PERSONAL UBIQUITOUS COMPUTING (A2) and UBIQUITOUS COMPUTING FOR PLACES (A4), forms the foundation for this pattern group, ubiquitous computing genres. This pattern should be used with an UP-FRONT VALUE PROPOSITION (A1) to provide meaningful and compelling user experiences for groups.

• PROBLEM

How can we use progress in sensors, devices, and wireless networking to help small groups be more effective, keep in touch better, or have more fun?

• SOLUTION

Advances in computer and communication technologies are driving the push towards ubiquitous computing. One area where ubiquitous computing can help is for groups. Some of these applications use PDAs, but others use large shared displays like the one shown in Figure 1 for collocated groups.

Depending on the level of trust and the nature of the group, there may be few or many privacy concerns. RESPECTING SOCIAL ORGANIZATIONS (C2) is important in designing technologies so that all users of the system, whether they are in an employee-employer or a parent-child relationship, will feel empowered.

Here are some examples of ubiquitous computing for groups:

- Location-tracking systems for hospitals will make it easier for nurses and doctors to find each other and help ensure high-quality patient care.
- An electronic message board can be set up in multiple SMART HOMES (A8), making it easy for family and friends to share photos and scribble messages to one another.
- ACTIVE MAPS (B1) can be used for ENHANCED EMERGENCY RESPONSE (A6), helping improve the overall coordination of responders.
- Small groups of friends can use GUIDES FOR EXPLORATION AND NAVIGATION (A5) to travel around an area together.
- Large electronic whiteboards like the one shown in Figure 1 can help in small group meetings.

• REFERENCES

Weiser, M. The Computer for the 21st Century. Scientific American 265(3): 66-75, 1991. http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html. This paper describes the driving vision of ubiquitous computing, where sensors, devices of all sizes, and wireless networking will converge and become an invisible part of our everyday lives.

A4 • UBIQUITOUS COMPUTING FOR PLACES

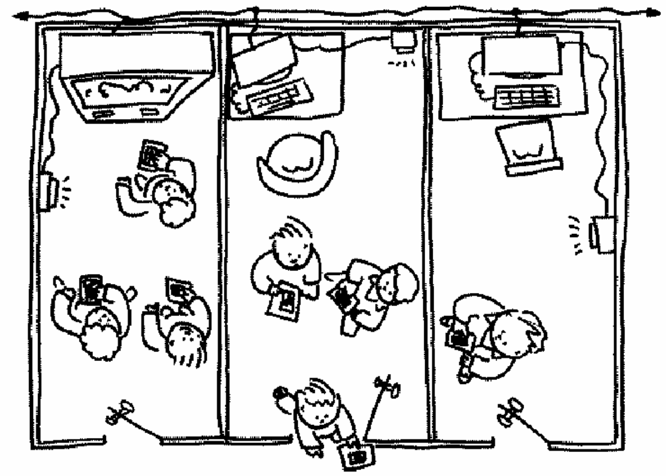

Figure 1. Sensors, devices of all form factors, and wireless networking can be used to make places more efficient to work, more fun to play in, and safer to be in.

• BACKGROUND

This pattern, along with PERSONAL UBIQUITOUS COMPUTING (A2) and UBIQUITOUS COMPUTING FOR GROUPS (A3), forms the foundation for this pattern group, ubiquitous computing genres. This pattern should be used with an UP-FRONT VALUE PROPOSITION (A1) in designing and deploying applications that are embedded in a single place, such as within a building, at home, or on a piece of land.

• PROBLEM

How can we use progress in sensors, devices, and wireless networking to help make places safer, more useful, or more pleasant?

• SOLUTION

Part of the vision of ubiquitous computing is that sensors can be embedded in everyday places to make our lives safer and easier. Here are some examples of ubiquitous computing for places:

- Simple motion sensors connected to the heating and ventilation systems in SMART HOMES (A8) and offices offer better energy efficiency.
- Sensors installed in homes can help STREAMLINE REPETITIVE TASKS (D3) such as monitoring for damage due to termites or water.
- Humidity sensors are dispersed in farms, helping farmers ensure that just the right amount water is distributed to the areas that need it.
- Traffic sensors are embedded into roads, helping traffic engineers monitor the flow of automobiles and helping highway police find accidents faster.
- Sensors are installed in critical structural points in buildings and bridges, letting civil engineers assess structural damage faster, cheaper, and more safely.

One potential danger here is privacy. The concerns are different than for PERSONAL UBIQUITOUS COMPUTING (A2) and UBIQUITOUS COMPUTING FOR GROUPS (A3) because it is not always clear who can see collected sensor data. One way of addressing this is to provide a REASONABLE LEVEL OF CONTROL (C4) and APPROPRIATE PRIVACY FEEDBACK (C5). PARTIAL IDENTIFICATION (C7) is also useful, since most of these applications only need to know that there is someone there rather than a specific person.

• REFERENCES

Weiser, M. The Computer for the 21st Century. Scientific American 265(3): 66-75, 1991. http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html. This paper describes the driving vision of ubiquitous computing, where sensors, devices of all sizes, and wireless networking will converge and become an invisible part of our everyday lives.

Schilit, B.N., Adams, N.I., and Want, R. Context-Aware Computing Applications. In *Proceedings of the Workshop on Mobile Computing Systems and Applications*, Santa Cruz, CA, December 1994. Pages 85-90. IEEE Computer Society. This paper describes several ideas for ubiquitous computing, and is the source of the image used in Figure 1.

A5 • GUIDES FOR EXPLORATION AND NAVIGATION

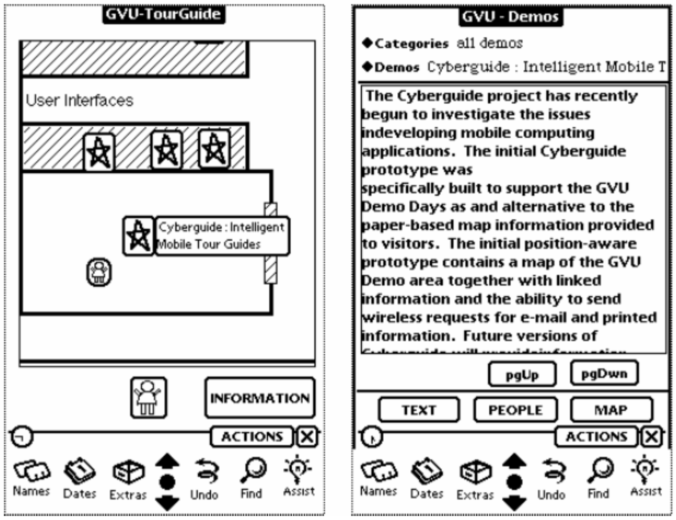

Figure 1. Portable tour guides can help users explore new areas that they have never been in. The pictures above are two screenshots from CyberGuide, a project that has an ACTIVE MAP (B1) that shows people where they currently are, and what points of TOPICAL INFORMATION (B2) are nearby.

• BACKGROUND

This pattern describes portable tour guides that can help people explore spaces they are unfamiliar with. This pattern is an example of PERSONAL UBIQUITOUS COMPUTING (A2) and can be used with an UP-FRONT VALUE PROPOSITION (A1) to create useful and compelling guides.

• PROBLEM

People exploring new areas often face the same kinds of questions. Where am I right now? Where are my friends? What else interesting is nearby? How do I get there? What events are happening later? What is the bus schedule?

• SOLUTION

Guides for exploration and navigation are typically built using small mobile devices like PDAs and mobile phones. Here are some features that users have found useful in tour guides:

Provide active maps of the area • ACTIVE MAPS (B1) are dynamically updated displays that show where the user currently is, and optionally, what friends and points of TOPICAL INFORMATION (B2) are nearby. Figure 1 depicts an active map that shows nearby points of interest (denoted by a star). Figure 2 shows an example of a point of topical information for a castle gateway.

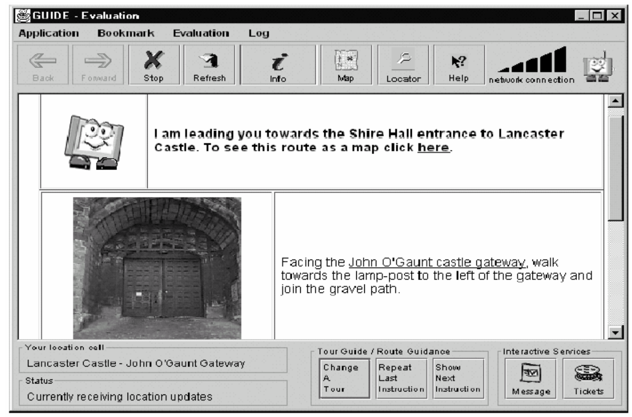

Figure 2. A point of TOPICAL INFORMATION (B2), which is activated when a person walks near a certain castle gateway.

Consider searches for places and for friends • With the emergence of location-based capabilities, guides can also provide FIND A PLACE (B5) services, letting users search for nearby restaurants, businesses, hotels, gas stations, or tourist attractions. Figure 3 shows an example search on cell phones, ensuring that users will never get lost again. A variation of this is FIND A FRIEND (B6), which let you search for nearby friends.

Let people explore • There are also people that dislike pre-planned tours or personal planning. One alternative is to provide SERENDIPITY IN EXPLORATION (D5) by letting users freely explore. For example, rather than providing an omniscient overhead map, a conceptual design called the (De)Tour Guide lets people discover districts and landmarks "only upon approach, as if by chance." It also lets people "get lost on purpose, or to follow the idiosyncratic paths of unusual strangers." This topic is also discussed in KEEPING USERS IN CONTROL (D4).

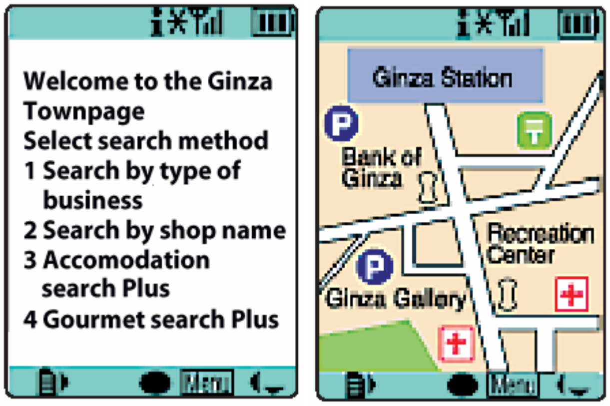

Figure 3. Emerging cell-phone applications let people search for nearby businesses and restaurants, and provide maps of how to get there from one's current location. These services offer simple but compelling UP-FRONT VALUE PROPOSITIONS (A1): "find where you want to go" and "never get lost again."

Consider letting users create content • Rather than just being consumers of content, consider supporting USER-CREATED CONTENT (B4). For example, one idea is to let users post and share virtual "post-it" notes that can be attached to places.

Consider translation services • People visiting foreign countries may not be fluent in the vernacular language there. One idea is to provide sign translators that let people take pictures of signs and translate them (see Figure 4). Another idea is to provide basic phrases to help people in tight situations.

Figure 4. This screenshot shows a Chinese sign translator developed at Carnegie-Mellon University.

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Interactive Systems Laboratories, Carnegie Mellon University, Sign Translation. http://www.is.cs.cmu.edu/signtranslation/

A6 • ENHANCED EMERGENCY RESPONSE

Figure 1. Ubiquitous computing technologies can be used to help prevent or minimize the effect of disasters, as well as assisting responders during a disaster.

• BACKGROUND

This pattern is an example of UBIQUITOUS COMPUTING FOR GROUPS (A3) as well as UBIQUITOUS COMPUTING FOR PLACES (A4). This pattern should be used with an UP-FRONT VALUE PROPOSITION (A1) in designing appropriate technologies that can assist in preventing and assisting during emergencies such as earthquakes and fires.

• PROBLEM

Immediate and effective responses to natural or man-made emergencies are critical to saving lives and minimizing property damages.

• SOLUTION

Ubiquitous computing for emergency response is still an emerging area, one with many possibilities for improving our capabilities in preventing and assisting during emergencies. Here are some topics that researchers are currently looking at:

Continuously measuring the stability of buildings and bridges • Some civil engineers are looking at how to use small sensors to continuously gather data about buildings and bridges, ensuring that structural strength is maintained. This kind of data is useful because it is currently time consuming to gather, and potentially dangerous after incidents such as earthquakes and fires.

Detecting hazardous materials • Some researchers are also looking at portable and embedded sensors for detecting hazardous materials, such as biological weapons or radioactive material.

Finding victims • There are also emerging technologies designed to help find victims of disasters. For example, some firefighters have thermal imagers that can help them see in the dark and through smoke (see Figure 2). One wireless technology still in development, ultra-wideband, promises to help responders find moving people through walls and debris.

Figure 2. Thermal imagers help firefighters see in the dark and through smoke.

Tracking location and status of responders • Tracking the location of responders on an ACTIVE MAP (B1) can help incident commanders know what responders are there and what they are doing.

Large displays for coordinating responders • Large electronic displays can also help incident commanders visualize and coordinate all of the responders.

A7 • PERSONAL MEMORY AIDS

Figure 1. Personal memory aids can help people remember where commonly misplaced items are or interrupted tasks. This picture shows a wearable computer that also acts as a memory aid.

• BACKGROUND

An example of PERSONAL UBIQUITOUS COMPUTING (A2) and UBIQUITOUS COMPUTING FOR PLACES (A4), personal memory aids can help people remember things, such as where they put something or what they were doing.

• PROBLEM

People forget things for a variety of reasons, such as being interrupted, old age, or an overwhelming number of things to recall.

• SOLUTION

Memory aids can be used to help people with common tasks, such as finding lost items or continuing interrupted tasks.

One way of doing this is by creating personal aids that can be carried or worn by people. One example is to include locator systems on key chains that can record your current location when you lock your car doors. Another example is to add tags to your keys so that your house can physically search for them.

Personal memory aids can also be deployed in places to foster SUCCESSFUL EXPERIENCE CAPTURE (B3). One example is to have homes check if the oven is still on when the last person leaves, and reminding them that they may want to turn off the oven. Figure 2 shows another example, which is a display that shows people what steps they have done while cooking, to help them in case they are interrupted.

Figure 2. The prototype above, called "What was I cooking?" uses cameras under the kitchen cabinets to display what people were doing, helping people in case they are interrupted.

NOTIFIERS (B7) are another simple form of personal memory aids. A common example is the calendar alarm on PDAs, which remind people of meetings and other events. More sophisticated examples using wireless networking are emerging which are pushing beyond simple reminders. For example, some airline services are using short messaging service (SMS) to remind customers of flights and to notify them of any delays hours before they arrive at the airport.

A8 • SMART HOMES

Figure 1. Homes of the future face many unique design challenges. This is a picture of Georgia Tech's Aware Home, which is looking at assisted living for elderly people.

• BACKGROUND

One kind of UBIQUITOUS COMPUTING FOR PLACES (A4) that many people have been looking at is the home environment. This pattern looks at what kinds of applications and issues there are in designing for smart homes.

• PROBLEM

Designing and deploying ubiquitous computing applications for homes is very different than at work or in public places, since the home is a special place for families. What kinds of applications are useful, and what are some of the issues involved in the home?

• SOLUTION

Smart homes are still an active area of research. Here are just some of the topics that people are currently looking at:

Energy Efficiency • A large area that many people are examining is how to make more energy efficient homes. One simple idea is to have motion sensors linked to lights, automatically turning them off if no one is around. A related idea is to have sensors linked to heating and ventilation, minimizing their use when people are not around.

An alternative is to empower users to make the best of the current environment. For example, Figure 2 shows a mockup of a user interface that provides useful suggestions on what doors and windows to open to make the house more pleasant. This is an example of ACTIVE TEACHING (D7), where the house teaches the user how to make things better rather than the house proactively making changes itself.

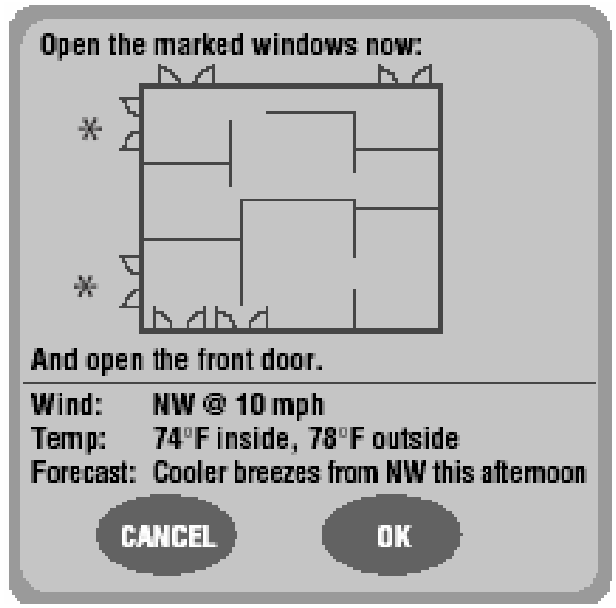

Figure 2. This is a mockup of a Smart Home providing suggestions on what doors and windows to open to make it more pleasant.

Home Maintenance • A smart house can also help automate mundane and difficult tasks, such as detecting water damage or termite damage early on.

Connections with Family and Friends • Homes can also be decorated with devices that help connect family and close friends together. Figure 3 shows a prototype of a Scanboard, which is a shared message board between homes. Figure 4 shows an Intentional Presence Curtain, which allows individuals to easily let family and friends know that they are home. The key here is to have lightweight and simple interactions that are fun and do not entail additional social obligations.

Figure 3. This is a prototype of Scanboard, a message board that can be shared with several families. People can scribble messages to each other, as well as scan in photos and news clips.

Figure 4. This is a prototype of the Intentional Presence Curtain. People can open up the curtain to let their friends and family know that they are at home.

Assisted Living • Some researchers are looking at how smart homes can help elderly people live on their own longer. Ideas include detecting if the person is injured, helping them remember with PERSONAL MEMORY AIDS (A7), and helping them keep in contact with their friends and family. Another idea is to give other family members some notion of how active other family members are (see Figure 5).

Figure 5. A family portrait that helps to show the daily activity of a person. The butterflies represent the level of activity, letting family members see how a person is doing without an intrusive level of monitoring.

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Edwards, W. K., Grinter, R.E. At Home with Ubiquitous Computing: Seven Challenges. Ubicomp 2001. p. 256-272. This paper looks at several challenges that designers and systems builders will face, such as "accidentally" smart homes, lack of interoperability, lack of system administrators, and reliability.

Hindus, D., Mainwaring, S.D., Leduc, N., Hagström, A.E., and Bayley, O. Casablanca: Designing Social Communication Devices for the Home. Proceedings of CHI 2001, pp 325-332. This paper looks at prototype devices for home use, meant to connect friends and families together. Some examples include presence lamps, which can let others know you are home, and shared message boards that let you share photos and scribble messages.

Intille, S.S. Designing a Home of the Future. *IEEE Pervasive Computing*, April-June 2002, pp. 80-86. This paper describes some of the ongoing work at MIT on smart homes, including how to empower people, and subtle reminders for people.

A9 • ENRICHING EDUCATIONAL EXPERIENCES

Figure 1. Ubiquitous computing technologies can be used to enhance educational experiences. This is a figure of eClass, a project looking at classrooms of the future. Large electronic displays are used for viewing and interacting with slides. There is also audio and video capture, so students can always go see lectures again.

• BACKGROUND

An example of PERSONAL UBIQUITOUS COMPUTING (A2), UBIQUITOUS COMPUTING FOR GROUPS (A3), and UBIQUITOUS COMPUTING FOR PLACES (A4), this pattern can be used with an UP-FRONT VALUE PROPOSITION (A1) to create compelling experiences for learning.

• PROBLEM

How can advances in sensors, devices, and wireless networking technologies enhance the educational experiences of learners?

• SOLUTION

Researchers have recently begun to look at applying ubiquitous computing technologies for education. Here, we describe some of the projects that people are doing, to give you a flavor of what the possibilities are.

Classrooms can use SUCCESSFUL EXPERIENCE CAPTURE (B3) to provide PERSONAL MEMORY AIDS (A7) for people, making it easier to focus on the content and on discussion rather than on taking notes.

Schools can provide local FIND A FRIEND (B6) services, making it easier for project teammates to coordinate with one another (see Figure 2).

Museums can provide GUIDES FOR EXPLORATION AND NAVIGATION (A5), giving extra information about exhibits, letting visitors take photographs, and creating a diary of their visit (see Figure 3).

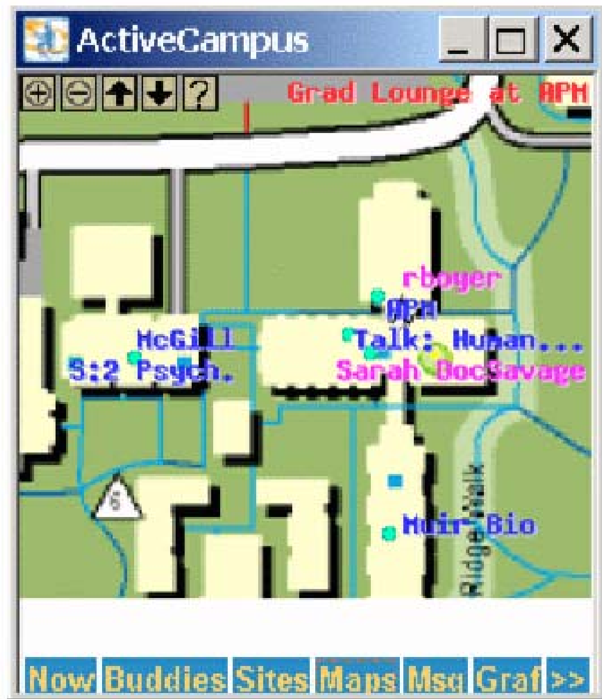

Figure 2. UC San Diego's ActiveCampus provides the location of your friends, making it easier to coordinate meetings.

Figure 3. The Electronic Guidebook in San Francisco's Exploratorium museum lets kids learn more about the exhibits.

A10 • AUGMENTED REALITY GAMES

Figure 1. In the Pirates game, people take on the role of pirates searching for treasure. Players can walk around and find “virtual islands”, search for treasure, and fight other pirates.

• BACKGROUND

An example of PERSONAL UBIQUITOUS COMPUTING (A2) as well as UBIQUITOUS COMPUTING FOR GROUPS (A3), this pattern looks at entertainment aspects of ubiquitous computing.

• PROBLEM

Sometimes people just want to have fun.

• SOLUTION

The convergence of small devices, sensors, wireless networking, and digital cameras has opened up new possibilities for gaming. People are no longer confined to sedentary desktop games, using mouse and keyboard. With ubiquitous computing, the real world can be part of the game itself!

One example of this is The Go Game, an adventure set up in urban areas (see Figure 2). According to its web site, small teams are assigned creative tasks, such as finding “a note written under a park bench, a spur-of-the moment sidewalk bowling game, or the vision of your best friend going undercover as a fry-cook at KFC”. Each team is also given a small wireless device that gives hints and confirms that tasks are completed successfully.

Another example of this is geocaching, a game where people hide small caches of goodies and post the GPS location of the cache on a well-known web site (see Figure 3). These caches are often placed in scenic areas, and some caches are virtual ones, meant to guide people to see a beautiful site. Geocaching is an example of USER-CREATED CONTENT (B4), where it is the users that drive new innovations and new adventures.

Figure 2. The Go Game is an urban adventure game where hints are placed throughout a city for players to find.

Figure 3. In geocaching, people hide small “treasures” for others to find.

There are also games being developed for smaller settings. Pirates is a game developed by the PLAY group in Sweden. It used wirelessly networked devices to create a virtual world of islands, pirates, and treasure overlaid on top of the physical world. People could wander around with these devices, be notified when the area they had walked into contained an island, search for treasure, and fight other pirates (i.e., other players) when they came near each other.

Many single player games are also beginning to use sensors in creative ways, letting people use a greater range of physical motions to play. Figure 4 shows a picture of Dance Dance Revolution, a game where people can actually dance on the mat to a tune played by the machine. Some versions of the game also help people keep track of the number of calories burned.

Figure 5 shows a boxing game, where people have to actually punch small bags on the machine to fight. There are also sensors along the top that detect if a person moves left, right, or ducks. These natural motions translate into the virtual boxer dodging and weaving as well.

Figure 4. Dance Dance Revolution is a dancing game popular among teens. Players dance on the mat according to a pattern and to music set by the machine.

Figure 5. Boxing Mania is a boxing video game that lets people punch bags to hit opponents, as well as physically ducking and dodging to avoid attacks.

A11 • STREAMLINING BUSINESS OPERATIONS

Figure 1. Ubiquitous computing technologies can help businesses streamline their operations, such as managing and routing fleets of delivery vehicles.

• BACKGROUND

This pattern describes how businesses can use ubiquitous computing technologies to streamline their daily processes and operations. It is an example of PERSONAL UBIQUITOUS COMPUTING (A2), UBIQUITOUS COMPUTING FOR GROUPS (A3) and UBIQUITOUS COMPUTING FOR PLACES (A4), and should be used with an UP-FRONT VALUE PROPOSITION (A1).

• PROBLEM

How can businesses make use of improvements in sensors, devices, and wireless networking to make their processes and operations more efficient and make their employees more productive?

• SOLUTION

By using ubiquitous computing technologies, businesses can potentially become more streamlined. Here are some examples:

- ACTIVE MAPS (B1) that display the location of delivery trucks outfitted with GPS sensors can help you with fleet management, tracking where all vehicles are at all times, and routing the nearest one to the next pick-up or delivery.
- UBIQUITOUS COMPUTING FOR GROUPS (A3) such as large electronic whiteboards allow teams of people to collaborate more effectively.
- Barcodes and RFIDs (radio frequency identification tags) can be used to track shipments from factories to warehouses to stores.
- RFIDs can also be used to streamline supply chains, helping to ensure that there is always enough of a product available at all times.

Privacy is an especially important concern here, especially if the sensors and devices are spread out over many people, places, and things. It becomes unclear who can see which collected data. For example, while RFIDs can be used to track a product from a warehouse to a store, it can also be used to track the product all the way to a customer's home if the RFID is not disabled when the customer buys it.

One way of addressing this is to provide a REASONABLE LEVEL OF CONTROL (C4) and APPROPRIATE PRIVACY FEEDBACK (C5). PARTIAL IDENTIFICATION (C7) is also useful, since most of these applications only need to know that there is someone there rather than a specific person.

A12 • ENABLING MOBILE COMMERCE

Figure 1. Progress in sensors, small devices, and wireless networking is enabling new kinds of mobile commerce. This figure shows a small PDA with a barcode scanner. One could imagine using a system like this to get product reviews while out shopping, as well as recommendations and price comparisons.

• BACKGROUND

This pattern describes how businesses can use ubiquitous computing technologies to enable shoppers. It is an example of PERSONAL UBIQUITOUS COMPUTING (A2) and UBIQUITOUS COMPUTING FOR PLACES (A4) and should be used with an UP-FRONT VALUE PROPOSITION (A1).

• PROBLEM

How can businesses, both small and large, make use of improvements in sensors, devices, and wireless networking to make shopping more effective, more fun, and more enjoyable for their customers?

• SOLUTION

Businesses can provide mobile commerce services to their customers to make shopping easier, faster, and more fun. These kinds of services are slowly emerging. Here, we describe some innovative ideas that are being rolled out.

One idea is to make it easy to find more information about products before you buy them. Figure 1 shows a small wirelessly-networked PDA that also has a barcode scanner. People can scan in barcodes to immediately find reviews, making them more confident about their purchases. Such a service could also provide recommendations (and depending on who offers the service and what their business model is, possibly price comparisons as well).

Figure 2 shows FastFrog, an idea tried out in several metropolitan areas in late 2000. Shoppers could use a small handheld to create wish lists that could be shared with friends and family.

Figure 2. FastFrog lets people build a wish list by scanning items in stores using a handheld. This wish list can be viewed on the FastFrog web site, and can be emailed to friends and family for birthdays, anniversaries, and other occasions.

As location-based services are slowly rolled out, mobile commerce GUIDES FOR EXPLORATION AND NAVIGATION (A5) will likely become prevalent. Figure 3 shows a small PDA application that presents an ACTIVE MAP (B1) of a shopping mall. This map could show where the user currently is, make it easy to FIND A FRIEND (B6), as well as interesting stores and sales.

Figure 3. PDAs could also have GUIDES FOR EXPLORATION AND NAVIGATION (A5), showing where you currently are in a shopping area, plus providing suggestions of places to go. The guide could also provide information about what stores have sales today.

As more and more mobile services are deployed, it is likely that we will see retail stores offering physical search engines (see Figure 4). People will be able to use their phones and PDAs to easily and quickly answer questions like "What jeans do you have that fit me?" and "What aisle are showerheads sold?"

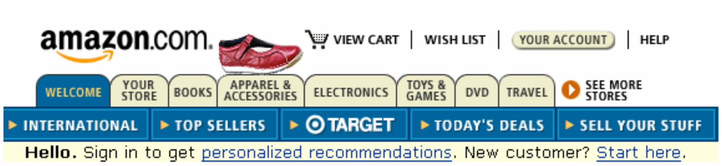

Figure 4. A few years down the road it is likely we will see *physical search engines* for stores. Individual stores will be able to make their inventory available in real time, letting people find answers to questions like "What size 3 dresses do you have?" and "Where are the J.D. Salinger books?"

Moving away from shopping, other possibilities include more streamlined transactions. Figure 5 shows how some companies are using barcodes on phones in place of paper tickets, letting people make completely paperless transactions.

Figure 5. FreedomPass is a security system that uses barcode scanning and voiceprint verification for check-ins on planes. Other companies are looking at using barcodes on phones as replacements for tickets to movies and baseball games. People can purchase tickets using their phone and then use their phone as the ticket.

Although there are many possibilities here, privacy will be a concern that must be addressed for mobile commerce to succeed. The most important thing to do here is to provide a clear UP-FRONT VALUE PROPOSITION (A1), follow the FAIR INFORMATION PRACTICES (C1), and provide a REASONABLE LEVEL OF CONTROL (C4).

B1 • ACTIVE MAP

Figure 1. Active Maps are dynamically updated maps of the nearby environment. This figure from the Sentient Computing project shows where people are in an office.

• BACKGROUND

This pattern focuses on the active map, a common and useful way of organizing people, places, things, and services in a physical space. This pattern is also useful in supporting GUIDES FOR EXPLORATION AND NAVIGATION (A5).

• PROBLEM

Context information such as location of objects, people, and spaces gives users fast and clear information on what options and capabilities are available to them. Such information needs to be made easily understood and read by users.

• SOLUTION

Many applications employ *active maps*, usually a two-dimensional display of a user's surrounding environment. This map usually contains basic information such as physical layout, location information, people, and active objects in the environment.

Active maps can be used to identify nearby resources, such as the nearest printer or the closest gas station. Such displays should provide easy visuals for describing such objects and individuals. For example, Figure 2 shows Cyberguide, a tour guide showing the inside of a research lab and what projects are where. Figure 3 is a screenshot of UC San Diego's Active Campus, which can show you where your friends are. This use of active maps can also benefit from the FIND A PLACE (B5) and FIND A FRIEND (B6) patterns.

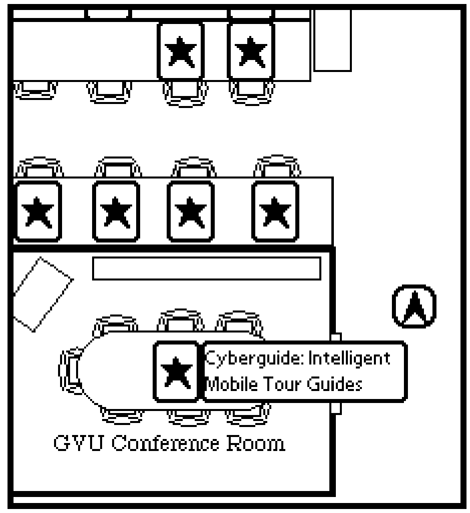

Figure 2. Cyberguide's active map shows where different projects are in a lab.

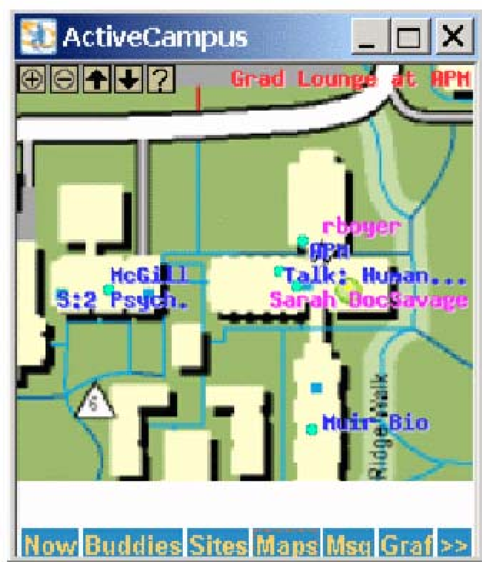

Figure 3. UC San Diego's Active Campus can show where your friends are in real time.

Another use of active maps is to show the status of your surroundings. For example, Figure 4 shows an active map that displays real-time traffic conditions. One could also imagine an active map that shows nearby parking spots.

Figure 4. TrafficGauge provides mobile real-time traffic maps around Seattle.

Figure 5. An In/Out board can be thought of as a very simple active map that only shows whether a person is "in" or "out".

Active maps should have an appropriate rate of update. For example, a person's location should be updated at a different rate if he or she is in a vehicle versus walking in a museum. Similarly, if a map shows a nearby printer, there is no need to continuously poll for the location of the printer, since it is unlikely to be changing.

In some cases, the rate of update can influence privacy. For example, most users would feel comfortable with a simple electronic In/Out board that indicates whether a user is in or out of their offices, updated once every 30 minutes (see Figure 5). However, a service that tracks everyone's movements every second may run into objections. To address these concerns, consider including features such as PARTIAL IDENTIFICATION (C7), INVISIBLE MODE (C11), and BLURRED PERSONAL DATA (C9).

Active maps should vary in fidelity based on the application's needs and sensitivity to privacy. An active map may want to include options to zoom in and out of a physical-virtual space as well as the ability to show and hide details.

An active map should scale according to the application it serves. For example, a fieldworker's tool should support very accurate details by providing detailed geographical data as well as fieldworkers' notes, while one describing traffic conditions can show a large-scale overview of the city.

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B2 • TOPICAL INFORMATION

Figure 1. Topical information associates virtual information with people, places, things, and activities. This picture is from the Exploratorium museum, which is using handhelds to let children learn more about exhibits and to create diaries of their visit.

• BACKGROUND

This pattern describes one way of linking the physical world with the virtual world, by providing useful and topical information about nearby people, places, and things. This pattern is often used as part of GUIDES FOR EXPLORATION AND NAVIGATION (A5), and can be combined with SERENDIPITY IN EXPLORATION (D5).

• PROBLEM

Keeping users informed, educated, and aware of their options in physical spaces can make things more efficient, more useful, and more enjoyable. The challenge is accomplishing this unobtrusively while maximizing knowledge.

• SOLUTION

Having topical information appear unobtrusively while the user is performing tasks can help educate and inform the user while minimizing the amount of distraction. One way of doing this is by *pushing* out useful information to people. For example, Figure 1 shows a museum setting that pushes out information about what exhibit you are near. One can imagine many kinds of useful information that can be pushed out. For example, a smart refrigerator could recommend healthy eating tips and recipes based on its contents, or a SMART HOME (A8) could suggest what windows to open to maintain a pleasant room temperature.

One way of creating push applications is through small beacons that broadcast information, such as the one shown in Figure 2.

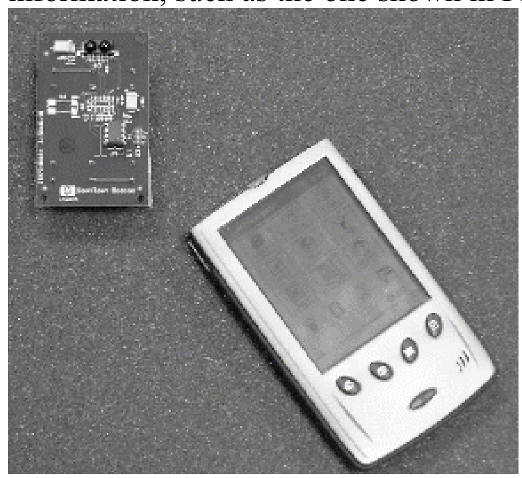

Figure 2. Small beacons can broadcast information. Above is a small beacon used by CoolTown to broadcast the address of a web page. People walking nearby would automatically see those web pages.

Another way is to make it easy for people to *pull* topical information. For example, Figure 3 shows how a small tag embedded in an everyday object can be used to retrieve useful information, in this case, a person's home page. Figure 4 shows how tags also can be used to retrieve product information, in this case, a web page from Amazon. One could easily imagine retrieving product reviews and price comparisons as well.

Topical information can also be USER-CREATED CONTENT (B4). Figure 5 shows post-it notes augmented with barcodes. These post-it notes can then be associated with specific web pages, completing the physical/virtual link. Figure 6 shows how people can add virtual post-it notes to places, sharing them with other visitors that walk through the same place.

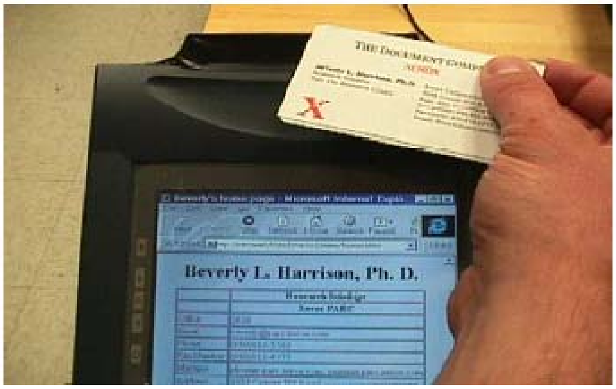

Figure 3. Small tags in business cards can be used to bring up appropriate web pages, in this case, a person's home page.

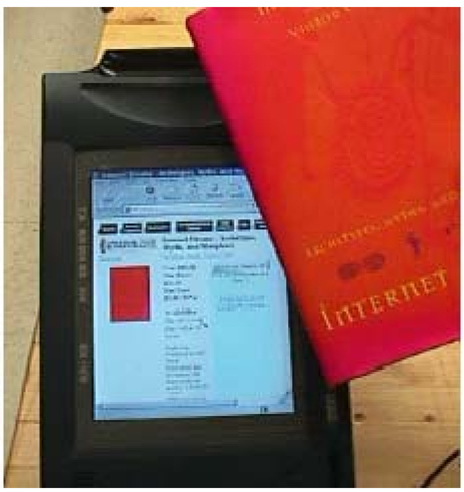

Figure 4. A tag in this book brings a web page in Amazon. One could imagine bringing up reviews for products in stores, such as CDs, books, electronics, and so on.

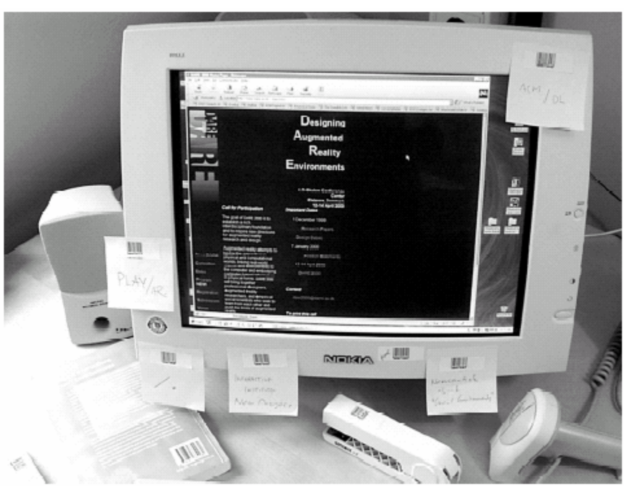

Figure 5. The PLAY group in Sweden has experimented with binding barcodes on post-it notes to web pages.

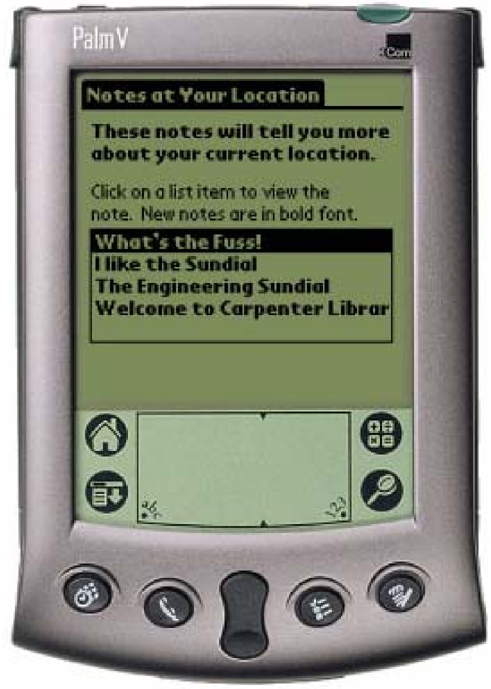

Figure 6. Cornell's e-graffiti project lets people create virtual post-it notes that can be attached to places. This screen shows what notes are at the current location.

• REFERENCES

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B3 • SUCCESSFUL EXPERIENCE CAPTURE

Figure 1. Experience capture is becoming more feasible as microphones and cameras become cheaper. Some people have even talked about recording everything a person experiences in their lifetime.

• BACKGROUND

This pattern is an example of a PERSONAL MEMORY AID (A7), and focuses on capturing experiences to augment human memory, as well as capturing more structured information that is specifically related to ongoing active tasks.

• PROBLEM

While people are good at making creative leaps of intuition and making connections between things, our memories are sometimes unreliable.

• SOLUTION

Experience capture is one way of helping people remember important memories. Cameras are the simplest form of experience capture, but technologies like microphones and video cameras are becoming cheaper and embedded in places, letting people record audio, video, and other forms of input.

Figure 2. Cameras are the simplest form of experience capture.

One problem is that with so much data being captured, it becomes difficult to find anything afterwards. One way of managing this problem is to link all of the different streams of data together. For example, Figure 3 shows the Audio Notebook, a research project at the MIT Media Lab. The Audio Notebook links written notes with captured speech, letting people ask things like "what was the person saying when I drew this diagram?"

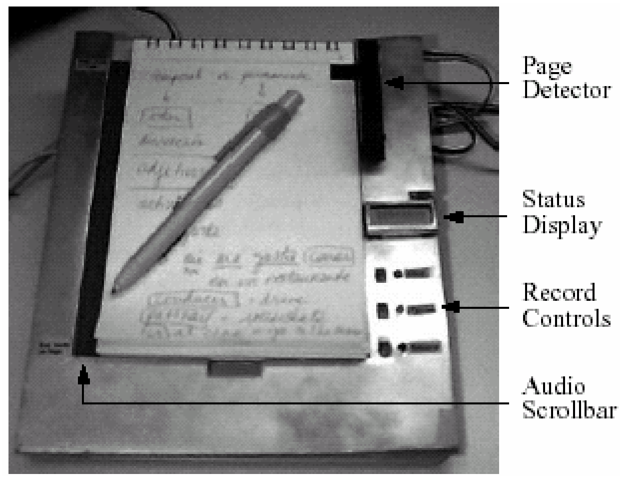

Figure 3. The Audio Notebook captures and links notes with recorded speech.

Another way of helping people find useful data is to capture additional data, such as where the user was and who else was nearby. Figure 4 shows a screen from the Forget-me-not, a PDA-based automatically generated diary. Icons represent people and places. The first line shows that Mike was in the kitchen at 10:37. Afterwards, Mike received mail from Grouch.

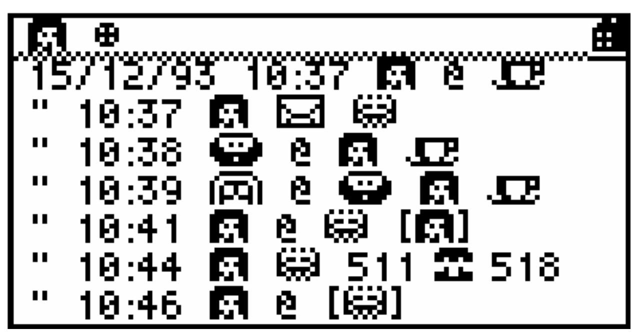

Figure 4. The Forget-me-not is an automatically generated diary.

When designing for experience capture, some of these questions should be asked:

Who are the users during capture and access? It is important to identify how many users are supported and whether captured records are public, private or a mixture.

What is captured and accessed? Which artifacts and streams of information are important to review later on, and what level of fidelity is required between the live experience and the playback of the captured experience?

When does capture and access occur? How much time lag is there between the live experience and the expected time of access? How long do captured artifacts need to persist?

Where does capture and access occur? Does capture or access occur in a well-defined location or set of locations? Is mobility during capture or access important?

How is capture and access performed? Are capture and access services provided by the environment or on devices the users carry? What devices and tools must be instrumented in order to facilitate capture of activity and to provide access to a past experience?

Here are some other examples of successful experience capture:

Mobile Web Logging (Moblogging) • Moblogging services let people capture their lives using cameras on mobile phones. People can upload photos to create blog entries anywhere and anytime. Several moblogs document the 2003 blackout that affected the northeastern United States and part of Canada.

StartleCam • The StartleCam is a wearable video camera and sensing system. When the sensors detect a change in skin conductivity indicating that the wearer was "startled," the video camera uploads the last few seconds to a remote server for later review.

Personal Audio Loop • Conversations are often interrupted, causing the participants to wonder what they were just talking about. The Personal Audio Loop is a mobile device that continuously records the last fifteen minutes, allowing people to easily access what they were just talking about without too much overhead.

Remeberer • The Rememberer is a GUIDE FOR NAVIGATION AND EXPLORATION (A5) for museums. Visitors can keep a record of what exhibits they visited as well as any photographs taken.

eClass • eClass, an example of an ENRICHING EDUCATIONAL EXPERIENCE (A9), provides live capture of the classroom experience, including note-taking, video and audio capture, and information made available on the web.

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Khai N. Truong, Gregory D. Abowd (2002). Personal Audio Loop: Reminders from a PAL. Atlanta, Georgia Institute of Technology. This paper discusses the five W questions posed above.

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Elizabeth D. Mynatt (1999). Everyday Computing. Atlanta, GVU Center and College of Computing, Georgia Tech.

Margaret Fleck, Marcos Frid, Tim Kindberg, Eamonn O'Brien-Strain, Rakhi Rajani, Mirjana Spasojevic (2002). Rememberer: A Tool for Capturing Museum Visits, Mobile Systems and Services Laboratory, HP Laboratories Palo Alto.

Jennifer Healey and Rosalind Picard (1998). "StartleCam: A Cybernetic Wearable Camera." Proceedings of the Second International Symposium on Wearable Computers.

B4 • USER-CREATED CONTENT

Figure 1. E-Graffiti lets users post virtual notes around the Cornell campus.

• BACKGROUND

This pattern looks at content that people can create and provide as a service for other users. This pattern can be incorporated into GUIDES FOR EXPLORATION AND NAVIGATION (A5), SUCCESSFUL EXPERIENCE CAPTURE (B3), AUGMENTED REALITY GAMES (A10), and SERENDIPITY IN EXPLORATION (D5).

• PROBLEM

People do not always want to be just consumers of content.

• SOLUTION

Let your users create content that others can see. One idea is to let people leave virtual notes at physical places, leaving tips or humorous messages to other people visiting the same place. Figure 1 shows a screenshot of Campus-Aware, a college-campus tour guide that detects a user's location and provides relevant information. Users can view content, as well as create it by leaving text.

User-created content is an integral part of many AUGMENTED REALITY GAMES (A10). For example, in geocaching, people hide "treasures" and post the cache's GPS location to a well-known web page (see Figure 2). The creator of the geocache often leaves a booklet and disposable camera for people to sign and take photos. Geocache finders are also encouraged to take an item from the cache (typically an inexpensive item like a small toy) and leave an item as well.

Figure 2. In geocaching, people hide small "treasures" for others to find.

People have also recently started to create moblogs, or mobile web logs (see Figure 3). This form of SUCCESSFUL EXPERIENCE CAPTURE (B3) looks at making it easier for people to take pictures and write up their thoughts while on the move.

Figure 3. An example moblog.

One potential danger that is inherent in any community is bad content. This includes content that is inaccurate, inappropriate, or even slanderous to individuals or organizations. One way of managing this issue is by making it easy for users to report bad content so that it can be reviewed.

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B5 • FIND A PLACE

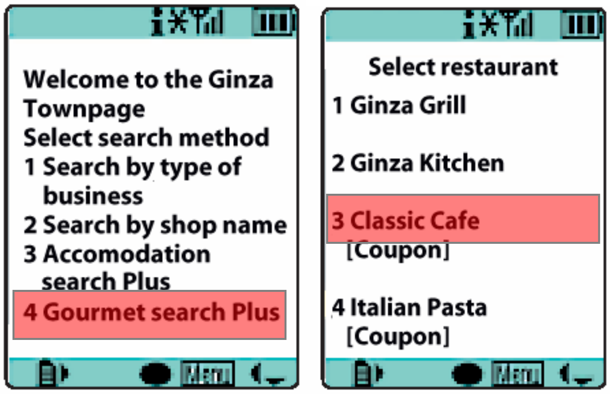

Figure 1. Emerging location-based services let users search for nearby tourist attractions, businesses, restaurants, and gas stations. This figure shows two screens from a search service offered in Japan.

• BACKGROUND

This pattern supports searches for places. This pattern is useful for GUIDES FOR EXPLORATION AND NAVIGATION (A5), ENABLING MOBILE COMMERCE (A12), and ACTIVE MAPS (B1).

• PROBLEM

How can people find things that are nearby and interesting, especially if they are lost?

• SOLUTION

Location-based services should provide a flexible search mechanism that allows users to search for services or TOPICAL INFORMATION (B2) using criteria they have in mind. In some cases, it may be useful to show the information and directions on top of an ACTIVE MAP (B1).

For example, Figure 1 shows two different screens from a search service offered on cell phones in Japan. People can ask questions like "Find me the nearest sushi restaurant," or "How do I get to the nearest train station?" Note that the user interface does not support asking these kinds of questions directly, but instead provides information that can answer these kinds of questions.

Figure 2 shows Vindigo, a PDA application that makes it easy to find nearby places to eat, shop, and play. It groups these places into several useful and meaningful categories, and then presents a map of how to get to the destination the user has selected (see Figure 3).

Figure 2. Vindigo is a PDA application that lets users find nearby points of interest. The current version of Vindigo does not take into account one's current location, but one could easily imagine a version that does.

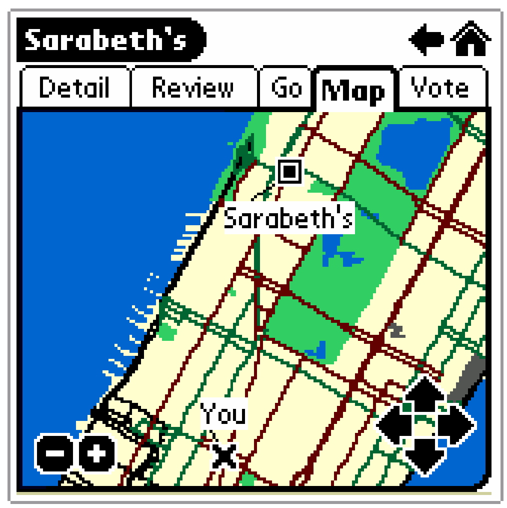

Figure 3. Vindigo presents directions on how to get to a place.

There possibilities here are wide open. One emerging idea for ENABLING MOBILE COMMERCE (A12) is physical search engines, helping people answer questions like, "What kinds of size 3 dresses do they have in this store?" and "Where are the books by J.D. Salinger?"

• REFERENCES

Kaasinen, E. (2003). "User needs for location aware mobile services." Personal Ubiquitous Computing(7): 70-79.

B6 • FIND A FRIEND

Figure 1. AT&T Wireless' mMode service allows customers to add friends to a friend list, find out who is nearby, and call or send messages to them. Users can make themselves invisible whenever they want.

• BACKGROUND

This pattern discusses services that allow people to find where their friends are while allowing those friends some level of privacy. This pattern is useful for GUIDES FOR EXPLORATION AND NAVIGATION (A5).

• PROBLEM

People would like to know where their friends are, for impromptu communication and gatherings. At the same time, those people may not always want to be tracked.

• SOLUTION

Finding friends can be useful in many situations, such as coordinating at conferences, finding lost friends in large crowds, or making sure someone got home safely.

There are two primary design issues when designing find-a-friend services: how to display friends' locations, and how to manage people's privacy concerns.

Displaying people's location • There are several different ways of displaying a person's location. A straightforward approach is to simply show the location in text, for example "near corner of Euclid Ave and Hearst Ave" or "in Soda Hall". Another approach is to show the data on a map, or possibly even an ACTIVE MAP (B1) that is constantly updated.

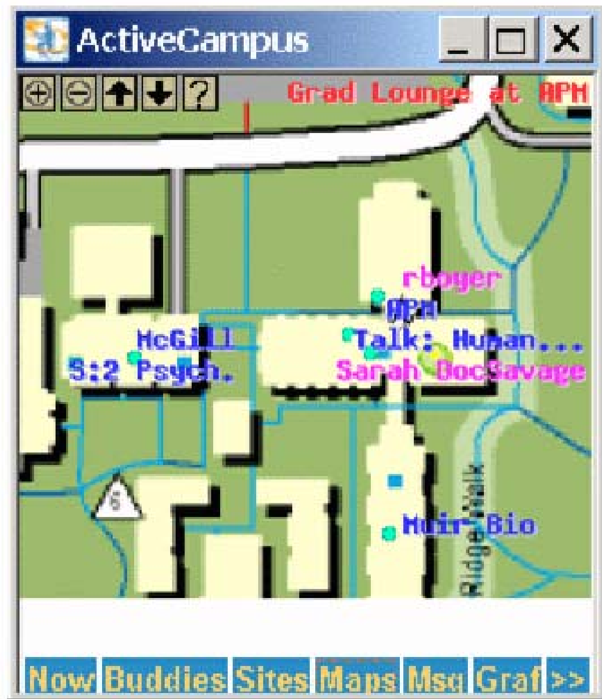

Figure 2. UC San Diego's ActiveCampus project shows your friends' location in real time. While useful, this visualization raises many privacy concerns.

Managing privacy concerns • There are many privacy concerns about find-a-friend applications due to the potential for abuse. This is not just the fear of "Big Brother," but also so-called "Little Brothers," including phone companies, friends, parents, and jealous boyfriends and girlfriends.

One way of managing these concerns is by giving users the ability to LIMIT ACCESS TO PERSONAL DATA (C10). The most common approach here is to have a buddy list that lists which friends can see your current location.

Each friend has one of two settings. The first is call access, where the user must accept or reject each request. The second is full access, where the friend can see the user's location anytime. The user can also use INVISIBLE MODE (C11), so that no friends can see where they currently are.

Another way of managing privacy concerns is providing APPROPRIATE PRIVACY FEEDBACK (C5). A simple form of feedback is NOTIFICATION ON ACCESS OF PERSONAL DATA (C13), where people whose location is requested get a message letting them know which friend asked for it. This lets people know if certain friends are continuously asking for their location.

These control and feedback mechanisms combine into three useful categories (see Table 1). Every person requesting a user's location would fall into one of these categories.

Control	Feedback
No access	None
Call access by friends	None
Full access by friends	Notification

Table 1. This table summarizes how the control and feedback mechanisms described above can be combined.

The first category is *no access*. This is because the requestor is not on the user's buddy list, or because the user is in invisible mode.

The second is *call access*. The requestor is on the user's buddy list, and the user approves or rejects requests as they happen, similar to accepting or rejecting phone calls. Here, no extra notification is needed since the user sees all requests as they happen.

The third is *full access*. The requestor has pre-approved the friend's requests. In turn, the user sees a notification specifying which friend has requested his location.

B7 • NOTIFIER

Figure 1. Notifiers notify people of new events and information, and remind people of tasks they need to do.

• BACKGROUND

One way of providing PERSONAL MEMORY AIDS (A7) is to notify people of new events and information, reminding them of things they need to do.

• PROBLEM

People want to be notified about new information and events that they are interested in, such as a new sports score or that an apartment is available, and they want to be reminded of things they need to, such as taking medication at a certain time, no matter where they are.

• SOLUTION

Provide a notification service where people can sign up to be alerted whenever something of interest happens. Allow the notifications to be sent via a variety of media, such as e-mail, instant messaging, or short message service (SMS). Let subscribers set up new notifications either through the web or on a mobile device. If you would like to target a broad audience, be sure to allow setting up and receiving alerts through SMS, since more people have access to mobile phones than to computers.

Make the notification service engaging so that subscribers stay interested. For example, an SMS service that reminds people to take their medications throughout the day added facts about their disease, trivia, and a weekly joke so that its subscribers were more likely to pay attention to the messages and take their medication.

Here are some examples of how notifiers are being used today:

Children missing from school • Several schools in Ireland and France alert parents via SMS if their children were missing from school. (http://www.textually.org/textually/archives/000578.htm)

Medication reminders • A service in South Africa reminds tuberculosis patients to take their medicine at particular times throughout the day. (http://news.bbc.co.uk/1/hi/technology/2698533.stm)

Real estate notifications • A real estate agency in the United Kingdom sends an SMS message when a new house for sale, and when a tenant has paid a landlord. (http://news.bbc.co.uk/1/hi/uk/916337.stm)

Reminders of payment overdue • A local government council in Scotland sends SMS messages to tenants of public housing whose rent payments are overdue (Figure 1). (http://news.bbc.co.uk/2/hi/uk_news/scotland/3187703.stm)

Breaking news • BBC offers a service to send news via SMS to mobile phone users in India. (http://news.bbc.co.uk/1/hi/technology/2680917.stm)

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Kaasinen, E. (2003). "User needs for location aware mobile services." Personal Ubiquitous Computing(7): 70-79.

C1 • FAIR INFORMATION PRACTICES

Figure 1. The Fair Information Practices are a set of privacy guidelines for companies and organizations for managing the personal information of individuals.

• BACKGROUND

It's not always clear how a company or large organization should handle the personal information of its users. This pattern, in conjunction with RESPECTING SOCIAL ORGANIZATIONS (C2) and BUILDING TRUST AND CREDIBILITY (C3), forms the core policies for privacy in ubiquitous computing systems.

• PROBLEM

Privacy is a serious concern for many people, especially given the sensitive nature of data collected by ubiquitous computing systems. However, it is not always clear what policies and procedures should be in place for collecting and handling personal information in a fair and secure manner.

• SOLUTION

Privacy is the most often cited criticism of ubiquitous computing, primarily because such systems tend to collect sensitive and personal data such as one's location and activity. There are a myriad of complex issues that need to be handled, such as what information can be collected, as well as how and from whom. Furthermore, telecommunications and privacy laws vary from country to country. The best thing to do here is to get legal expertise to help guide you through this rapidly changing area. This pattern is meant simply to give you a flavor of what is required.

The Fair Information Practices are a generally agreed-upon framework for large organizations handling personal information of individuals. The practices were created in the early 1970s and are the basis for many privacy laws today. The practices are as follows:

1. **Notice.** Organizations must notify individuals about the purposes for which they collect and use information about them. This includes contact information for inquiries or complaints, as well as with which third parties personal information is shared.

2. **Choice.** Organizations must give individuals the opportunity to choose (i.e., opt out) whether their personal information will be disclosed to a third party or used for a purpose other than for which it was originally collected. For sensitive information, this choice should be opt-in.

3. **Onward transfer (transfers to third parties).** Organizations should apply notice and choice before disclosing personal information to a third party.

4. **Access.** Individuals must have access to personal information about them and be able to correct that information where it is inaccurate, except where the burden of providing access is far greater than the risks to an individual's privacy or where the rights of other individuals would be violated.

5. **Security.** Organizations must take reasonable precautions to protect personal information from loss, misuse and unauthorized access, disclosure, alteration and destruction. One way of doing this is with a PRIVACY-SENSITIVE ARCHITECTURE (C6).

6. **Data integrity.** Organizations should take reasonable steps to ensure that personal information is relevant, reliable, and accurate for its intended use. One way of doing this is to have LIMITED DATA RETENTION (C12).

7. **Enforcement.** There must be a) procedures for verifying that organizations are adhering to these fair information practices, and b) independent mechanisms for recourse so that an individual's complaints and disputes can be resolved.

• RELATED PATTERNS

The Fair Information Practices look at privacy from an organization's point of view. Just as important is looking at privacy from the individual's perspective. One way of doing this is with LIMITED ACCESS TO PERSONAL DATA (C10), empowering users to choose who they share their data with. Another way of doing this is with PRIVACY-SENSITIVE ARCHITECTURES (C6), where only the user's computer stores and processes the user's personal information.

• REFERENCES

As of this writing, the Location Privacy Protection Act is still being debated in the United States Congress. For the most part, this act can be thought of as Fair Information Practices for location data. The original draft of this act can be downloaded at http://www.techlawjournal.com/cong107/privacy/location/s1164is.asp

Langheinrich, M. Privacy by Design - Principles of Privacy-Aware Ubiquitous Systems. In the Proceedings of Ubicomp 2001, pp. 273-291, 2001. http://www.inf.ethz.ch/~langhein/. This paper introduced the notion of Fair Information Practices to the ubiquitous computing research community. Langheinrich describes how these practices can be applied to such systems.

C2 • RESPECTING SOCIAL ORGANIZATIONS

Figure 1. If the organization, whether it is a family or a workplace, does not trust and respect one another, then the more intimate the technology, the more problems there will likely be.

• BACKGROUND

This pattern, in conjunction with FAIR INFORMATION PRACTICES (C1) and BUILDING TRUST AND CREDIBILITY (C3), forms the core policies for privacy in ubiquitous computing systems.

• PROBLEM

People in different organizations have very different reactions to the same technology, primarily due to reasons of trust. If people in the organization do not trust and respect each other, and if there is an imbalance in power, then systems that push on privacy will likely exacerbate existing problems.

• SOLUTION

This is one of the most difficult issues in privacy, as it cannot be easily addressed no matter how good the user interface and underlying technology.

We examined threads on a message board for nurses, who were discussing locator systems installed in hospitals. By and large, if the nurses already distrusted their management, they were far more predisposed to reject any system that could be seen as infringing on their privacy.

We believe there are five things that can be done to legitimately address privacy concerns.

Clear Value • Provide a clear, UP-FRONT VALUE PROPOSITION (A1). Focusing on how systems can help users is the key here.

Fair Use of Data • Provide clear policies based on the FAIR INFORMATION PRACTICES (C1), describing how data will and will not be used. Transparency is essential here, as many people are justifiably concerned about how sensitive data such as their location or activity will be used.

Participatory Design • Involve users throughout the design process, to ensure that their concerns are addressed in the design and deployment of the system.

Safe Zones • Consider PHYSICAL PRIVACY ZONES (C8) where people are aware of what is being sensed and what is not. For example, it does not make sense to track the location of employees in the bathroom or in lounges if they are on break.

Enforcing Architectures • Consider a PRIVACY-SENSITIVE ARCHITECTURE (C6) that ensures that only authorized people can access sensitive personal information. Other architectural approaches include having REASONABLE LEVELS OF CONTROL (C4) and APPROPRIATE PRIVACY FEEDBACK (C5) that cannot be circumvented by others.

C3 • BUILDING TRUST AND CREDIBILITY

Figure 1. Trust and credibility are the foundation for an ongoing relationship.

• BACKGROUND

This pattern, in conjunction with FAIR INFORMATION PRACTICES (C1) and RESPECTING SOCIAL ORGANIZATIONS (C2), forms the core policies for privacy in ubiquitous computing systems.

• PROBLEM

Trust is an essential element in building privacy-sensitive systems. How should ubiquitous computing systems be built to help foster trust and credibility?

• SOLUTION

Here, we discuss two different aspects of trust and credibility. The first is trust between individuals and companies or large organizations. An example application here is sharing your location with a company that provides real-time directions adjusted for traffic.

Surveys since the early 1990s indicate that the U.S. population can be categorized as *fundamentalists* that do not trust companies with respect to privacy and want stronger privacy laws, *pragmatists* that balance cost to benefit and favor self-regulation, and *unconcerned* (see Figure 2).

One step towards establishing a trusted relationship with all of these groups is to follow the FAIR INFORMATION PRACTICES (C1). However, these are only a start. Other factors that must be designed into systems include 1) significant value for users, so that they see they are getting tangible benefits for sharing their personal information with you; and 2) transparency in terms of REASONABLE LEVEL OF CONTROL (C4) and APPROPRIATE PRIVACY FEEDBACK (C5) over their personal information.

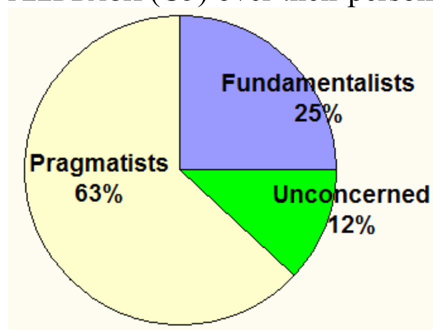

Figure 2. Surveys since the early 1990s show that, for commercial interests, the US population can be separated into *fundamentalists* that do not want to share their data, *pragmatists* that require tangible benefit, and *unconcerned*.

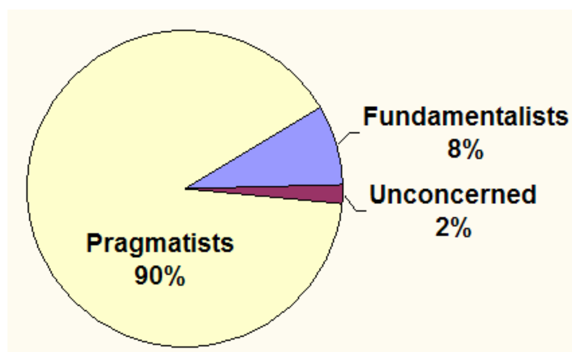

Figure 3. Our preliminary work suggests that the numbers shift significantly for personal relationships between individuals.

The second aspect of trust and credibility is between two individuals. An example application here is sharing your current location with your family and close friends.

What is different in this case is that these individuals already have an established social relationship, and can trust others to be discreet (see Figure 3). A REASONABLE LEVEL OF CONTROL (C4) and APPROPRIATE PRIVACY

FEEDBACK (C5) are still needed, but not at the same level as for companies.

• REFERENCES

Westin, A. Prepared Witness Testimony, The House Committee on Energy and Commerce. 2001. http://energycommerce.house.gov/107/hearings/05082001Hearing209/Westin309.htm. Dr. Westin has been running the surveys gauging the American public's attitudes towards privacy and commercial interests. This web page describes his testimony to a Congressional committee.

Testimony of Lee Rainie to the Subcommittee on Commerce, Trade, and Consumer Protection of the House Committee on Energy and Commerce. 2001. http://www.pewinternet.org/reports/toc.asp?Report=34. Rainie heads up the Pew Internet and Public Life Project. This web page describes the results of some of his groups studies on people's attitudes toward Internet privacy.

C4 • REASONABLE LEVEL OF CONTROL

Figure 1. Curtains provide a simple form of control for maintaining one's privacy while at home. Ubiquitous computing systems should provide similar easy-to-use mechanisms for keeping users in control of how their personal information is shared.

• BACKGROUND

FAIR INFORMATION PRACTICES (C1), RESPECTING SOCIAL ORGANIZATIONS (C2), and BUILDING TRUST AND CREDIBILITY (C3) establish core privacy policies. This pattern, together with APPROPRIATE PRIVACY FEEDBACK (C5) and PRIVACY-SENSITIVE ARCHITECTURES (C6) form the basis for designing and building privacy-sensitive systems.

• PROBLEM

What kinds of mechanisms are needed to put users in control of their personal information in ubiquitous computing systems?

• SOLUTION

In general, users can *push* their data to others, for example, sending their current location to a map service, or let others *pull* data, such as letting family members check your current location.

Users have the greatest level of control when they are pushing their data to others. In many cases, it can be useful to BLUR PERSONAL DATA (C9). Rather than providing precise data, users can share less precise data. For example, a service that told you when the next bus is coming would need to know that you are currently at "the corner of Euclid Ave and Hearst St", while a geographic search for local events would only need to know that you are in "Berkeley, CA". Furthermore, neither of these services needs to know who you are, so PARTIAL IDENTIFICATION (C7) is sufficient here.

When letting others pull data, it is useful to let users LIMIT ACCESS TO PERSONAL DATA (C10). Users should be able to choose who can access their data and under what conditions.

• RELATED PATTERNS

Reasonable level of control should be combined with APPROPRIATE PRIVACY FEEDBACK (C5) to give users a greater understanding of what data is being collected about them.

Systems should also have LIMITED DATA RETENTION (C12), so that personal information is stored only for long as it is needed. Limited retention is also one of the FAIR INFORMATION PRACTICES (C1).

Lastly, control is only useful if there is a PRIVACY-SENSITIVE ARCHITECTURE (C6) backing it up, ensuring that users really do have control and that eavesdroppers are shut out.

• REFERENCES

Weiser, M., Gold, R., and Brown, J.S. The Origins of Ubiquitous Computing Research at PARC in the late 1980s. In IBM Systems Journal 38(4), 1999. http://www.research.ibm.com/journal/sj/384/weiser.html. This short paper looks at the original motivations behind ubiquitous computing, as well as outlining some of the issues in invisible computing, notably privacy.

C5 • APPROPRIATE PRIVACY FEEDBACK

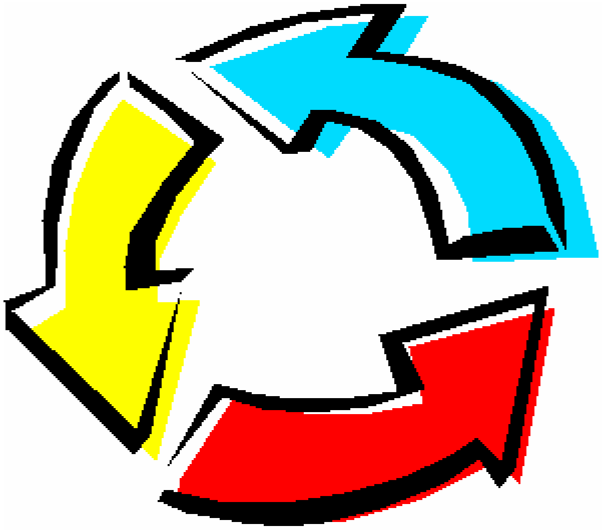

Figure 1. Appropriate feedback loops are needed to help ensure people understand what data is being collected and who can see that data.

• BACKGROUND

FAIR INFORMATION PRACTICES (C1), RESPECTING SOCIAL ORGANIZATIONS (C2), and BUILDING TRUST AND CREDIBILITY (C3) establish core privacy policies. This pattern, together with PRIVACY-SENSITIVE ARCHITECTURES (C6) and REASONABLE LEVEL OF CONTROL (C4), forms the basis for designing and building privacy-sensitive systems.

• PROBLEM

One of the goals of ubiquitous computing is to make computers invisible and unremarkable, making them disappear into the background of everyday life. However, if a system is invisible, how can users understand what personal information is being collected and where that information flows?

• SOLUTION

Ubiquitous computing systems should provide appropriate feedback about who can see your personal information and how that information is used. PRIVACY MIRRORS (C14) are one way of doing this. They display how the system is tracking the user and what information the system currently knows about the user.

Another example of appropriate privacy feedback is NOTIFICATION ON ACCESS OF PERSONAL DATA (C13). Users should be notified when sensitive personal data is accessed by others. This approach lets users see if others are repeatedly requesting personal information, and helps them apply social pressure to protect privacy.

Lastly, feedback is only useful if there is a PRIVACY-SENSITIVE ARCHITECTURE (C6) backing it up, ensuring that the feedback provided is accurate and up-to-date.

• REFERENCES

Weiser, M., Gold, R., and Brown, J.S. The Origins of Ubiquitous Computing Research at PARC in the late 1980s. In IBM Systems Journal 38(4), 1999. http://www.research.ibm.com/journal/sj/384/weiser.html. This short paper looks at the original motivations behind ubiquitous computing, as well as outlining some of the issues in invisible computing, notably privacy.

C6 • PRIVACY-SENSITIVE ARCHITECTURES

Figure 1. Just as the architecture of a building can influence how it is perceived and used, the architecture of a ubiquitous computing system can influence how people's perceptions of privacy, and consequently, how they use the system.

• BACKGROUND

FAIR INFORMATION PRACTICES (C1), RESPECTING SOCIAL ORGANIZATIONS (C2), and BUILDING TRUST AND CREDIBILITY (C3). This pattern, together with REASONABLE LEVEL OF CONTROL (C4) and APPROPRIATE PRIVACY FEEDBACK (C5), forms the basis for designing and building privacy-sensitive systems.

• PROBLEM

How should ubiquitous computing systems be built to ensure that a reasonable level of privacy is maintained?

• SOLUTION

One way of building a privacy-sensitive architecture is KEEPING PERSONAL DATA ON PERSONAL DEVICES (C15). This way, only the user's personal device contains personal information. This is a decentralized approach that often requires an infrastructure that supports this kind of architecture, such as a *location-support* system with beacons that can tell individual devices where they are. (This is in contrast to *location-tracking* systems where the user's device chirps out its location to others.)

Encryption is another way to ensure that no eavesdroppers can see data they are not authorized to see. A trusted computing base can also be used to make sure that data is handled properly, though there are few established standards in this area yet. A trusted computing base can be useful in guaranteeing that any mechanisms developed for a REASONABLE LEVEL OF CONTROL (C4) and for APPROPRIATE PRIVACY FEEDBACK (C5) are correct and have not been circumvented.

Privacy can also be implemented in the physical layer, by deploying sensors only in places that are appropriate. Doing so creates PHYSICAL PRIVACY ZONES (C8) separating where people are being monitored from where they are not.

• RELATED PATTERNS

Some of the control and feedback mechanisms that need software and hardware support for privacy include LIMITED ACCESS TO PERSONAL DATA (C10), LIMITED DATA RETENTION (C12), NOTIFICATION ON ACCESS OF PERSONAL DATA (C13), and PARTIAL IDENTIFICATION (C7).

C7 • PARTIAL IDENTIFICATION

Figure 1. Rather than requiring precise identity, systems could just know that there is "a person" or "a person that has used this system before."

• BACKGROUND

One way of maintaining privacy is to build PRIVACY-SENSITIVE ARCHITECTURES (C6) that do not require the full identity of a person. This pattern looks at different aspects of identity.

• PROBLEM

People may not always fully trust a system to handle their personal information properly. One way of addressing this is by building systems that do not require full identity to work properly. What alternatives are there to full identity, and how can they be applied?

• SOLUTION

An alternative to requiring full identity is to use partial identity. One approach here is knowing that there is simply "a person" there. For example, motion detectors could be used to activate lighting systems as well as heating, ventilation, and air conditioning systems. There is no need to know who specifically is there. Another example is to use proximity sensors with kiosks, activating the kiosk when it detects that someone is nearby. The advantage here is that no authentication or other forms of identification are needed.

A related approach is to use some physical characteristic. For example, one could imagine a smart bathroom that unlocks the medicine cabinet only if the person in front of the mirror weighs more than a certain threshold. This approach avoids the problem of having to define all of the semantics of what a "child" is, or having to grant explicit access to specific people (and thus is more likely to scale better). On the other hand, this approach is also easy to circumvent.

Another approach is using some key, ticket, or password. For example, many mass transit systems require tickets that have enough money on them rather than requiring the identity of the person using the ticket. Some clubs check identification at the door and provide bracelets for people that are old enough to drink. The key here is separating identity from the actual characteristics that are needed, and checking only the aspects of identity that are required.

Partial identification can also be combined with BLURRED PERSONAL DATA (C9) to limit what is known about a person. Partial identification can also be used to LIMIT ACCESS TO PERSONAL DATA (C10).

• REFERENCES

Marx, G. Identity and Anonymity: Some Conceptual Distinctions and Issues for Research. In J. Caplan and J. Torpey, Documenting Individual Identity. Princeton University Press, 2001. http://web.mit.edu/gtmarx/www/identity.html. This paper looks at different meanings of anonymity and why they are important.

Marx, G. What's in a Name? Some Reflections on the Sociology of Anonymity. *The Information Society,* vol. 15, no. 2, pp. 99-112, 1999. http://web.mit.edu/gtmarx/www/anon.html. This paper looks at different meanings of identity, from legal identification to symbols to addresses to appearance.

C8 • PHYSICAL PRIVACY ZONES

Figure 1. People need places where they feel that they are free from being monitored.

• BACKGROUND

An example of a PRIVACY-SENSITIVE ARCHITECTURE (C6), this pattern focuses one of the most concentrated areas in ubiquitous computing: privacy. Use this pattern to consider how physical privacy zones can help build a secure and private ubiquitous computing environment.

• PROBLEM

How can people know what in what areas information is being collected about them and what areas are not?

• SOLUTION

Privacy zones allow users to know what areas can or cannot be considered "privacy safe." Letting users know what information about them will be captured and used is a step towards creating a socially acceptable ubiquitous computing environment.

As an analog to the desktop environment, for example, users who type in search queries often receive messages that indicate that the information being sent is not secure. Similarly, users in ubiquitous computing environments might notice that certain public or private areas have different zones of privacy.

For example, in a corporate building one might implicitly understand that certain information about them will be captured but not be disseminated outside the corporate environment.

A user who enters an "insecure" privacy zone might consider being more discreet or conservative about their behavior (as in any normal public setting). However, a home might represent the maximum amount of privacy, since almost no information should leave that privacy zone, if any.

As a practical example of use, many hospitals that use locator systems for finding doctors and nurses do not have the system installed in lounges, bathrooms, cafeterias, or outside of the building. This allows people not to be found if they are taking a break or doing private activities.

C9 • BLURRED PERSONAL DATA

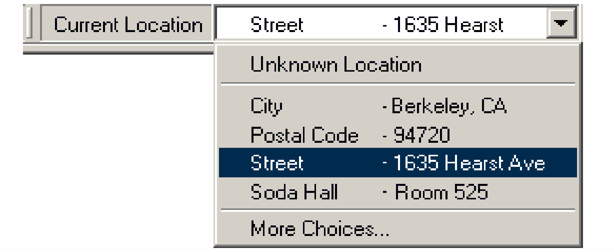

Figure 1. This mockup of the *Place Bar* browser component would let users select the level of location information disclosed to web sites, potentially on a page by page basis, as part of their browsing activity.

• BACKGROUND

One aspect of making people feel that their privacy is being preserved is by providing a REASONABLE LEVEL OF CONTROL (C4) over one's personal information. This pattern looks at how blurring personal data can give users control.

• PROBLEM

How can people share personal information such as location and activity without revealing all of the details?

• SOLUTION

Here we describe two different ways for blurring data, removing details while preserving some level of utility.

Blur individual pieces of data • One way of sharing dynamic personal information such as location and activity is to provide a *blurred* version of it, which is still accurate but at a coarser granularity. Figure 1 shows a mockup of the Place Bar, a component for web browsers that would let end-users share their current location with web services at a level they are comfortable with. The finest level of detail is Soda Hall room 525, while the coarsest level of detail is the city of Berkeley, California.

Figure 2 shows how blurring can be applied to streaming video to preserve privacy. There is enough information to see that there are people, but not necessarily who those people are.

Figure 2. Blurring can also be applied to video to de-identify individuals and to mask activities.

Blur by aggregating multiple pieces of data • Data can also be blurred by aggregating it with similar data. For example, location data for a single individual can be aggregated spatially ("You have been to this restaurant five times this past year, most recently on November 7") or temporally ("You were around San Francisco on November 7" rather than keeping exact location data for each hour).

Data can also be aggregated by combining the data of several individuals, making it harder to identify the activities of any single person. For example, this is often done with medical records, providing analysts statistical data about patients without revealing precise data about any individual.

• REFERENCES

Boyle, M., Edwards, C., and Greenberg, S. The Effects of Filtered Video on Awareness and Privacy. In the Proceedings of CSCW 2000.
http://www.cpsc.ucalgary.ca/grouplab/papers/2000/00-Filtered-Video-CSCW/00-filtered-video-CSCW00.pdf. This paper discusses how effective different filters were in providing awareness while preserving privacy.

Hong, J. I., Boriello, G., Landay, J.A., McDonald, D., Schilit, B., and Tygar, D. Privacy and Security in the Location-enhanced World Wide Web. In Ubicomp 2003 (Workshop on Ubicomp Communities: Privacy as Boundary Negotiation). http://www.cs.berkeley.edu/~jasonh/publications/ubicomp2003-privacy-placelab.pdf. This workshop paper looks at a way of providing global location data in a simple, inexpensive, and privacy-sensitive manner. It also describes the Place Bar, shown in Figure 1.

Sweeney, L. Guaranteeing anonymity when sharing medical data, the datafly system. Proceedings, *Journal of the American Medical Informatics Association*. Washington, DC: Hanley & Belfus, Inc, 1997.
http://lab.privacy.cs.cmu.edu/people/sweeney/people/sweeney/datafly.html. This system looks at how to share aggregated medical data.

C10 • LIMITED ACCESS TO PERSONAL DATA

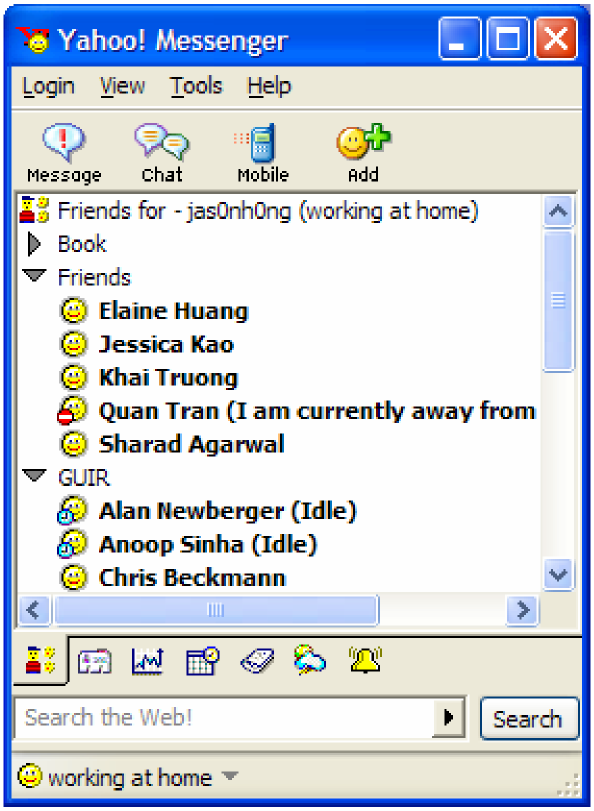

Figure 1. One way of managing your privacy with others is by limiting who can see what about you. Yahoo! Instant Messenger lets you see what your current status is and add and remove friends who can easily contact you.

• BACKGROUND

Building privacy-sensitive applications requires that users have a REASONABLE LEVEL OF CONTROL (C4). Giving users the choice over who sees their data and under what conditions is one way of limiting access to personal data.

• PROBLEM

There are many times when people want to share information with others, such as letting their family or close friends know where they are right now. How can systems be designed to make it so that users can share the information with the right people?

• SOLUTION

There are at least three different forms of access control that can be useful for limiting access to one's personal data. The first is *identity access control*, where access is allowed or denied based on who the person is. Yahoo! Instant Messenger, shown in Figure 1, is a good example of this.

The second is *spatial access control*, where access is limited based on where a person is. An example of this would be "only let people that are in this building see if I am in the office or not". To a large extent, this reflects how people interact outside of the virtual world of computers. Only a person that is physically near you can actually see what you are doing. Currently, this is difficult to do, given that location systems are not widely deployed. This will also be difficult due to a lack of conventions in the identification of places: it is easy to say "work" or "home", but translating these concepts into a form that computers can process is currently unsolved.

The third is *temporal access control*, where access is restricted based on the current time, such as "let my co-workers see my location only between 9 AM and 5 PM". This is also an example of combining different forms of access control, in this case, identity along with time. Access control can also be combined with other forms of control, such as BLURRED PERSONAL DATA (C9), to further restrict the quantity and quality of outgoing data.

Preliminary studies by Lederer et. al. suggest that identity is the most important form of access control, and so should be the starting point of any ubiquitous computing system.

Also see PARTIAL IDENTIFICATION (C7), which looks at how to identify people besides name.

• REFERENCES

Lederer, S, Mankoff, J, and Dey, A.K. Who Wants to Know What When? Privacy Preference Determinants in Ubiquitous Computing. In Extended Abstracts of CHI 2003, ACM Conference on Human Factors in Computing Systems, pp. 724-725. 2003. http://guir.berkeley.edu/pubs/chi2k3/lederer-chi03.pdf. This paper describes the results of a survey that indicates that "who" was requesting one's data was the most important factor in determining whether personal information should be disclosed.

C11 • INVISIBLE MODE

Figure 1. Invisible mode is a simple and useful interaction for hiding from all others.

• BACKGROUND

One aspect of privacy is providing a REASONABLE LEVEL OF CONTROL (C4). This pattern looks at a simple form of control for stopping flows of data to others and hiding from people.

• PROBLEM

People do not always want to be found. It can be for many reasons, from being busy and not wanting any distractions, to experiencing strains in relationships.

• SOLUTION

Provide an invisible mode that lets users stop the flow of data to others. In some cases, the invisible mode makes it look like you are not connected, when in reality you actually are. For example, the invisible mode in many instant messenger clients make it look like the person is not logged in; however, users can still see others and receive messages (see Figure 2).

In some cases, the invisible mode is a more implicit action rather than an explicit feature provided. For example, cell phones do not have an explicit invisible mode feature. Rather, the user can turn off the device and check any missed messages later.

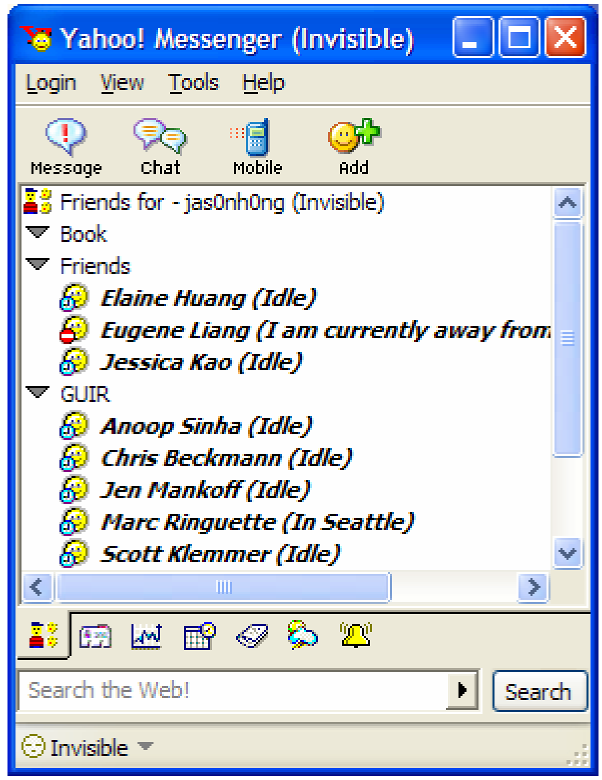

Figure 2. Many instant messenger clients let users mask their presence with an invisible mode, while letting them see others and send or receive messages.

Figure 3. Turning devices off is the simplest form of invisible mode.

C12 • LIMITED DATA RETENTION

Figure 1. Sensitive personal information, such as one's location and activity, should only be kept as long as needed and no longer.

• BACKGROUND

One of the FAIR INFORMATION PRACTICES (C1) is data integrity, where data should be accurate and up to date. This pattern describes why data should be kept for limited periods of time, balancing utility with privacy.

• PROBLEM

One of the dangers of collecting too much data about individuals is that the data may be inaccurate, potentially embarrassing, or can reveal patterns of behavior that individuals may not wish to disclose to others. How can we balance the utility of collecting and using this data with the need for individual privacy?

• SOLUTION

One approach for collecting dynamic data such as location and activity is to keep that data only for a limited period of time. For example, a PDA could keep track of a person's location only for the past week. This is similar to how mobile phones only keep a limited number of entries in the call history (see Figure 2).

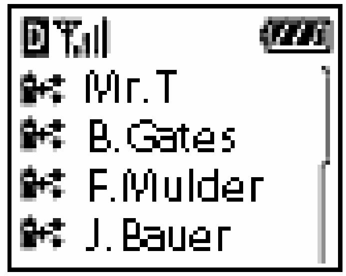

Figure 2. Most mobile phones keep a call history, but limit the number of entries, for example, to the last twenty calls.

Another way of limiting data retention is to store only the last known entry. For example, Figure 3 shows the history screen in the Mozilla web browser. Rather than keeping track of every single time a person visited a web site, only the last time is shown, in addition to how many times the site was visited. This is an example of how limited data retention can be combined with BLURRED PERSONAL DATA (C9) to help preserve privacy.

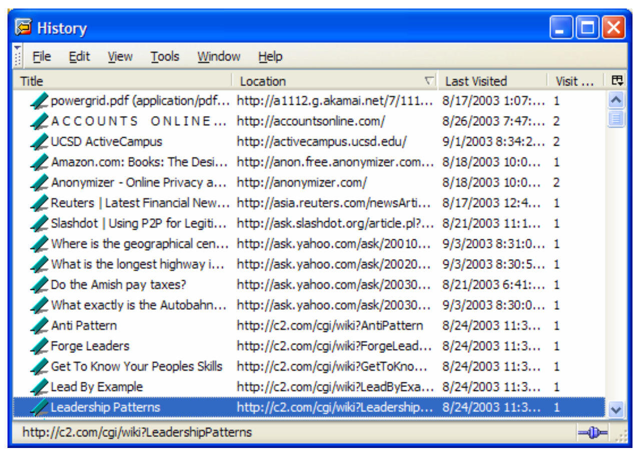

Figure 3. The Mozilla web browser only keeps track of the last time a site was visited and the number of times that site was visited. It does not store every single time the site was visited. Furthermore, older entries are deleted over time. All of these combine to provide utility while providing a useful level of privacy for users.

C13 • NOTIFICATION ON ACCESS OF PERSONAL DATA

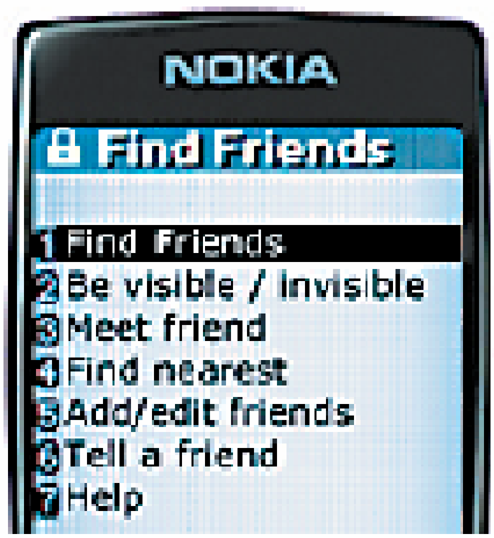

Figure 1. AT&T Wireless' Find Friends service notifies your friend if you ask for his or her location.

• BACKGROUND

This pattern is one part of providing APPROPRIATE PRIVACY FEEDBACK (C5) to individuals.

• PROBLEM

How can systems provide feedback about what is being monitored, as well as the current state of the system?

• SOLUTION

There at least two different times that notification can be used, during an access and afterwards.

Notification during an access means that users are notified as an access occurs. Figure 1 shows an example of AT&T Wireless' Find Friends service, which sends a notification to your friend whenever you ask for his or her location. Depending on how the service is built, the user can choose to accept or deny the request, or is simply notified that a request has occurred.

Notification after an access means that users see a log of what accesses have occurred. This is useful for seeing who has asked for your information in the past. Both of these types of notification can be used in conjunction with one another.

A key design decision here is whether the person is simply notified or has choice over whether information is disclosed. There are plausible cases for each. For example, "always let my family know where I am", but "let me choose whether to reveal my current location if a co-worker asks". This is primarily an issue of trust and boundaries with other individuals.

PRIVACY MIRRORS (C14) also act as a form of notification. Notification can also be combined with unobtrusive displays to provide constant feedback.

C14 • PRIVACY MIRRORS

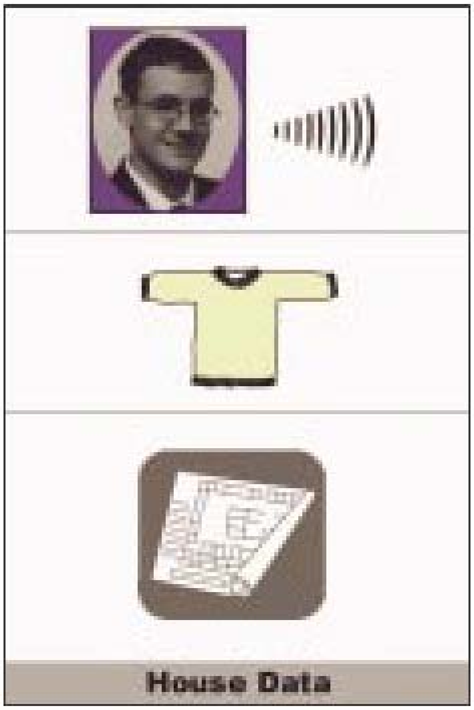

Figure 1. Privacy mirrors provide useful feedback to users by reflecting what the system currently knows about them. The portrait at the top signifies that the system is following that specific person. The audio icon signifies that the system can identify the user's voice. The shirt in the middle means that sensors track that color. The map on the bottom shows that the system also tracks the person's location.

• BACKGROUND

One part of making people feel in control of a ubiquitous computing system is providing APPROPRIATE PRIVACY FEEDBACK (C5). This pattern looks at one way of revealing how the system is actually working and what it knows about users. This pattern is useful for UBIQUITOUS COMPUTING FOR PLACES (A4), especially in SMART HOMES (A8).

• PROBLEM

How can systems provide feedback about what is being monitored, as well as the current state of the system?

• SOLUTION

Privacy mirrors are one way of providing unobtrusive feedback about ubiquitous computing systems. Figure 1 shows a screenshot from an example privacy mirror, which reveals who the system is monitoring, what it is monitoring (people and audio), how it is monitoring (color), and what pieces of information the system knows (location of people).

Figure 2 shows another privacy mirror that displays the number of people the system thinks is currently in the kitchen.

Privacy mirrors can be used as ambient displays, providing useful information without taking up too much of the user's attention.

Figure 2. This Privacy mirror shows that the system detects two people in the kitchen. The more people there are, the more coffee pots are shown.

• REFERENCES

Mynatt, E.D, and Nguyen, D. Making Ubiquitous Computing Visible. Position paper ACM CHI 2001 Conference Workshop: Building the Ubiquitous Computing User Experience. http://quixotic.cc.gt.atl.ga.us/~dnguyen/writings/chi2001Position.pdf

C15 • KEEPING PERSONAL DATA ON PERSONAL DEVICES

Figure 1. One way of managing privacy concerns is to store and present personal data on a personal device owned by the user. Personal data never leaves the device unless it is explicitly shared with others.

• BACKGROUND

One way of ensuring effective privacy is to have PRIVACY-SENSITIVE ARCHITECTURES (C6). This pattern looks at one such architecture, where sensitive information is stored, processed, and presented entirely on personal devices.

• PROBLEM

Some users feel uncomfortable sending sensitive personal information across public networks, or trusting companies to manage their personal data properly. How can users benefit from the benefits of ubiquitous computing while completely ensuring some aspects of privacy?

• SOLUTION

One way of completely ensuring that some aspects of privacy are preserved is to store, process, and present sensitive information on personal devices such as PDAs, mobile phones, or even wearable computers.

One way of implementing this pattern is to have autonomous personal devices that can collect all of the information it needs without any external support. For example, a PDA could have a motion sensor that detects when the user is moving or not.

Another way of implementing this pattern is to have an infrastructure explicitly designed to support semi-autonomous devices. For example, *location-support* systems are comprised of beacons that can tell your PDA where you are. This is in contrast to *location tracking*, where your PDA tells the system where you currently are. End-users tend to have less control in location-tracking systems.

In some cases, users may wish to share their data with selected individuals. In this case, LIMITED ACCESS TO PERSONAL DATA (C10) and BLURRED PERSONAL DATA (C9) are useful techniques to ensure that the right people get to see the right level of information.

• REFERENCES

Trevor, J., D. M. Hilbert, et al. (2002). Issues in Personalizing Shared Ubiquitous Devices. Ubicomp 2002, Göteborg, Sweden.

Abowd, G. D., C. G. Atkeson, et al. (1997). "Cyberguide: A Mobile Context-Aware Tour Guide." Baltzer/ACM Wireless Networks **3**: 421-433. This paper looks at the design of a mobile, location-aware tour guide.

[Reference to the Follow-Me Display]

Hong, J. I., Boriello, G., Landay, J.A., McDonald, D., Schilit, B., and Tygar, D. Privacy and Security in the Location-enhanced World Wide Web. In Ubicomp 2003 (Workshop on Ubicomp Communities: Privacy as Boundary Negotiation). http://www.cs.berkeley.edu/~jasonh/publications/ubicomp2003-privacy-placelab.pdf. This workshop paper looks at a way of providing global location data in a simple, inexpensive, and privacy-sensitive manner. It also describes the Place Bar, shown in Figure 1.

D1 • SCALE OF INTERACTION

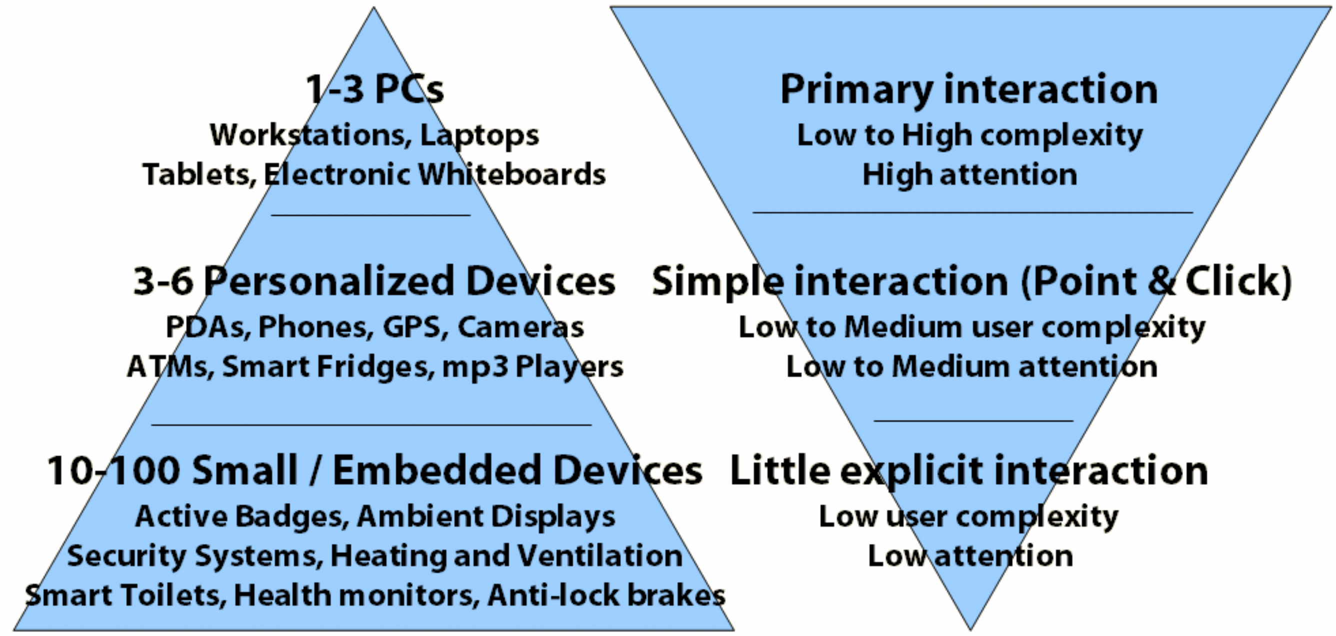

Figure 1. This scale of interaction depicts the different classes of devices that people will likely interact with in the future, as well as how they will interact with them. People are likely to interact with a few personal computers, which will be their main form of explicit interaction; several small personal devices, which will be used from time to time; and many small and often invisible devices that will be used often but have little or no explicit interaction.

• BACKGROUND

This pattern, along with SENSEMAKING OF SERVICES AND DEVICES (D2), STREAMLINING REPETITIVE TASKS (D3), and KEEPING USERS IN CONTROL (D4), looks at interaction in ubiquitous computing from a very broad perspective. This pattern looks specifically at interaction at various scales of complexity and attention.

• PROBLEM

In the envisioned world of ubiquitous computing, there will be dozens or even hundreds of computers per person. How can any person be able to use so many computers?

• SOLUTION

This is still an active research area, and so there are currently few practical design guidelines. However, it is very likely that as devices and applications are created, they will fall into one of three general classes. In the future, we predict that people will interact with:

Few personal computers • Most people will interact with a few personal computers on a daily basis. This will be what people think of when they think of "computer." There will continue to be many kinds of applications, from word processing to spreadsheets to web browsers. The key point here is that personal computers and their applications will be the focus of attention for users, and will range in complexity from being simple to complex.

Several personalized devices • Most people will interact with several personalized devices on a daily basis. These devices might be owned by the user (for example, a PDA or a phone) or might be part of the environment (for example, an automatic teller machine or a kiosk).

Since users will be interacting with several of these devices, and mostly for short periods of time, they will not be willing to learn how to use them. The large majority of devices and applications in this class should not be more difficult to use than pointing and clicking. If it is more complex, there must be a significant UP-FRONT VALUE PROPOSITION (A1) to entice people to learn how to use it.

Many small or embedded devices • Most people will interact with many small or embedded devices on a daily basis. Most of these will be installed in everyday things, such as toilets, cars, walls, and tables. Since there will be so many applications and devices that fall into this category, it is extremely unlikely that people will want to learn how to use each individual one.

The best strategy here is to have extremely simple interactions that fit as naturally as possible into existing tasks. For example, anti-lock brakes were designed to augment drivers without them even having to know that it is there. It takes no attention and, from the user's point of view, is no more complex than what they already do when driving.

• REFERENCES

Weiser, M., Gold, R., and Brown, J.S. The origins of ubiquitous computing research at PARC in the late 1980s. IBM Systems Journal 38(4), 1999. http://www.research.ibm.com/journal/sj/384/weiser.html. This paper looks at how ubiquitous computing research began at PARC.

Weiser, M. The Computer for the 21st Century. Scientific American 265(3): 66-75, 1991. http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html. This paper describes the driving vision of ubiquitous computing, where sensors, devices of all sizes, and wireless networking will converge and become an invisible part of our everyday lives.

D2 • SENSEMAKING OF SERVICES AND DEVICES

Figure 1. How can people understand and make sense of what services and devices are available and active in any given place? Without this capability people will end up confused and frustrated.

• BACKGROUND

This pattern, along with SCALE OF INTERACTION (D1), STREAMLINING OF REPETITIVE TASKS (D3), and KEEPING USERS IN CONTROL (D4), looks at interaction in ubiquitous computing from a very broad perspective. This pattern looks specifically at one of the key issues in ubiquitous computing, understanding what one can and cannot do.

• PROBLEM

How can one make sense of what kinds of services and devices are available, and which are active, when they walk into a room?

• SOLUTION

When a person walks into a room, the light switch is almost always right next to the entrance. Lighting is a standard service provided in nearly every modern room, and having the light switch next to the entrance is a nearly universal standard.

However, the same cannot be said of ubiquitous computing. Currently, we do not know what future standard services for rooms and other places will be, nor what conventions will be developed. Instead of describing solutions in this pattern, we describe some emerging ideas as well as some of the issues that will need to be addressed in the future.

One idea is to make services available regardless of place. This is the approach that cell phone services are taking. There is also a signal strength bar that indicates how well the service will work (see Figure 2).

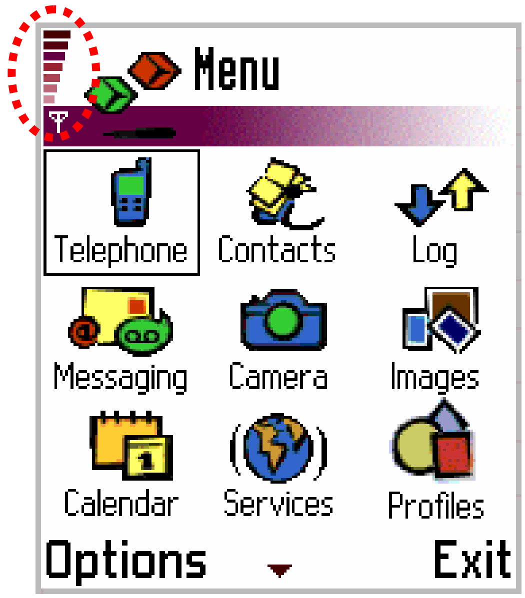

Figure 2. Mobile phones provide indicators of signal strength (in this case, the upper left-hand corner), letting users know about how well the service will work.

However, this approach has two problems. First, it does not scale to dozens or even hundreds of devices and services. Second, it does not work for services that are active or meaningful in local areas, such as an ACTIVE MAP (B1) of a building.

Another idea is to make all of these services discoverable through the network. For example, when a person walks into a room, he would see all of the services available in that room. This is the main approach taken by Speakeasy, a research project at PARC (see Figure 3). The key idea here is that all of these services and devices are represented in a standard digital format that can then use a browser to explore. One could also imagine overlaying these services and devices on an ACTIVE MAP (B1), viewing all of the services and devices on a floor or in a building at once.

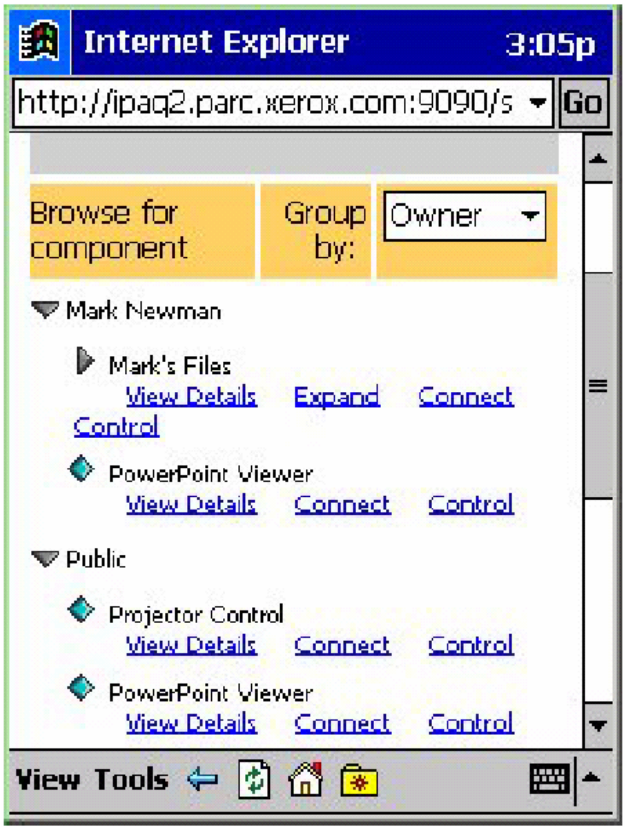

Figure 3. Speakeasy provides a browser that lets people view and control arbitrary devices and services.

A third idea is to try to minimize the amount of devices and services a person would need to explicitly be aware of. For example, most modern computers run dozens of services in the background, of which the user needs to know very little about, if at all. One could imagine a similar approach for future small devices and services, where the large majority of them are autonomous and maintenance free.

Again, this area is wide open to possibilities. Whatever the eventual solution, it will depend on a convergence of insight, ingenuity, technology, great design, and a lot of luck.

• REFERENCES

Newman, M.W., J.Z. Sedivy, W.K. Edwards, T. Smith, K. Marcelo, C.M. Neuwirth, J.I. Hong, and S. Izadi. Designing for Serendipity: Supporting End-User Configuration of Ubiquitous Computing Environments. In Proceedings of Designing Interactive Systems: DIS2002. This paper describes the design of the SpeakEasy browser.

D3 • STREAMLINING REPETITIVE TASKS

Figure 1. Services should be designed so that boring and repetitive tasks can be automated.

• BACKGROUND

This pattern, along with SCALE OF INTERACTION (D1), SENSEMAKING OF SERVICES AND DEVICES (D2), and KEEPING USERS IN CONTROL (D4), looks at interaction in ubiquitous computing from a very broad perspective. This pattern looks specifically at interaction in applications that are designed to streamline or reduce the amount of daily repetitious tasks a user encounters.

• PROBLEM

Many mundane or simple tasks are performed on a daily basis. Individuals could be spending more time on creative and productive duties by streamlining or automating these tasks.

• SOLUTION

Streamline repetitive tasks in your application when personalized conditions are met. Actions should generally minimize the need for human intervention concerning mundane or simple tasks on a day-to-day basis. In general, repetitive tasks can be grouped into three categories:

- **Reminder tasks**, such as reminding anxious people to turn the oven off when they leave the house (or alternatively, a small screen next to the keyhole on a door that displays a small message if the oven is still on). These tasks are often handled by NOTIFIERS (B7).
- **Setup tasks**, such as automatically setting a device's time to the current local time rather than blinking 12:00
- **Correlated tasks**, such as automatically lowering the volume of nearby radios and televisions when using a mobile phone, or automatically switching a television to use DVD input when someone hits "Play" on a DVD player

The challenge in streamlining repetitive tasks is KEEPING USERS IN CONTROL (D4). People want to feel that they are in control, but errors and unexpected results may make people feel helpless. To minimize this, there are two different design issues that must be addressed.

The first is that the tasks must be highly predictable. Current computer systems are not very good at predicting human behavior and adapting to those behaviors. One way of addressing this is for designers to predict common tasks and try to optimize those. However, it is not always possible for designers to predict what tasks will be common for all people. Another way of addressing this problem is to empower people so that they can streamline *their* repetitive tasks. For example, a user may wish to have his coffee made the moment his alarm clock goes off every day. How to do this is still ongoing research, but the key here is to make it easy for users to link devices together.

The second design issue is to handle exception conditions. For example, what happens if the person is not there but forgot to turn off their alarm clock? Or if the coffee pot is already full? Or if the person forgot to put coffee in? When people are taken out of the loop, exception cases like these must be addressed.

One constraint in streamlining tasks is accountability. Who is responsible (and thus liable) for tasks that a computer does? For example, this is an issue that so-called smart cars are facing. What happens if a smart car that is driving itself crashes into another? Currently, it is not clear.

One alternative to streamlining repetitive tasks is ACTIVE TEACHING (D7). Rather than trying to automate tasks, systems could try to teach people how to do things better. Also, people may not always like to have tasks streamlined. Sometimes people enjoy SERENDIPITY IN EXPLORATION (D5).

• REFERENCES

Jurgen Bohn, V. C., Marc Langheinrich, Friedemann Mattern, Michael Rohs (2003). Disappearing Computers Everywhere - Living in a World of Smart Everyday Objects. Proc. of New Media, Technology and Everyday Life in Europe Conference., London, UK.

Intille, S. S. (2002). "Designing a Home of the Future." IEEE Pervasive Computing **1**(2): 76-82.

D4 • KEEPING USERS IN CONTROL

Figure 1. Services should guide users but allow them to stay in control.

• BACKGROUND

This pattern, along with SCALE OF INTERACTION (D1), SENSEMAKING OF SERVICES AND DEVICES (D2), and STREAMLINING OF REPETITIVE TASKS (D3), looks at interaction in ubiquitous computing from a very broad perspective. This pattern looks at a key issue in ubiquitous computing, how to empower people rather than making them feel helpless.

• PROBLEM

Users may fear that services that circumvent or act against their decisions. Services that are too restrictive can result in alarming or even alienating users.

• SOLUTION

Keeping users in control is difficult in interaction design and will be even more difficult in ubiquitous computing, with sensors and devices every invisibly connected by wireless networks.

People feel helpless when they encounter errors that they cannot understand or correct. Although predicting all of the possible errors in advance is difficult, it is still possible to predict the most common and most difficult ones when STREAMLINING REPETITIVE TASKS (D3).

Another design strategy is to use ACTIVE TEACHING (D7) instead of STREAMLINING REPETITIVE TASKS (D3). With active teaching, the computer makes suggestions to people rather than proactively taking any actions. Thus, people make the final decision as to whether to do something or not.

Sometimes people feel constrained by computers. They feel that the computer is guiding them, rather then allowing them the freedom to explore for themselves. Designing for SERENDIPITY OF EXPLORATION (D5) will put users back in control.

A last idea is to help manage the flow of information so that people do not feel overloaded. This is something that AMBIENT DISPLAYS (D9) can help address.

D5 • SERENDIPITY IN EXPLORATION

Figure 1. Design for serendipity when users want to be spontaneous.

• BACKGROUND

An example of KEEPING USERS IN CONTROL (D4), serendipity in exploration is often used in touring and guidance applications, where services like USER-CREATED CONTENT (B4), and FIND A FRIEND (B6) can enhance such services.

• PROBLEM

Some people enjoy directed tours, but others like to just explore freely. Applications that are constrained to pre-determined courses may make people feel that they are not in control and end up being frustrated.

• SOLUTION

Design your applications to be flexible and controllable. Allow users to be spontaneous in their decisions. They may sometimes wish to end up in a specific location but want to be flexible in the path they take to get there.

For example, rather than providing an omniscient overhead map, a conceptual design called the (De)Tour Guide lets people discover districts and landmarks "only upon approach, as if by chance." It also lets people "get lost on purpose, or to follow the idiosyncratic paths of unusual strangers."

Another way of designing for serendipity is to empower users with USER-CREATED CONTENT (B4). Rather than being just consumers of content, they can also be creators of TOPICAL INFORMATION (B2).

• REFERENCES

Kaasinen, E. (2003). "User needs for location-aware mobile services." *Personal Ubiquitous Computing* **7**: 70–79.

D6 • CONTEXT-SENSITIVE I/O

Figure 1. Input and output need to adapt to dynamic situations. For example, a device could switch from using speech I/O to visual text in very loud situations.

• BACKGROUND

This pattern considers how input and output modalities should adapt to a user's context. This pattern applies at all levels in the SCALE OF INTERACTION (D1), and is one potential idea for SENSEMAKING OF SERVICES AND DEVICES (D2).

• PROBLEM

Devices will be used in a variety of locations and situations, from quiet to noisy, from solitary to large groups of people, from sitting down to walking around. How can devices be designed so that the input and output are appropriate in different circumstances, and do not interrupt users or other people nearby?

• SOLUTION

Input and output modalities should adapt to a user's current context. Below, we describe some scenarios to give you a flavor of what kinds of possibilities there are:

- As a user enters a movie theater, his cell phone reconfigures itself to only display text and vibrate when receiving a call.
- A user's device switches from visual input and output to speech-based when his hands are full, such as when carrying groceries or children.
- Output is restricted to using visual displays when in large meetings to minimize distractions.
- A PDA automatically adjusts its backlighting to maximize visibility while minimizing energy use.

While context-sensitive I/O is possible in theory, it is still an ongoing research problem in terms of 1) the best way of implementing it, 2) how to make it predictable, and 3) how to make it so that users can override wrong decisions.

For predictability, the main issue here is how to make devices fit people's expectations. This is partly a matter of learning the particular quirks of a system, but it is still an open research question as to what kinds of feedback are useful to signal that a switch has occurred.

For overriding, the key issue is in KEEPING USERS IN CONTROL (D4). For example, some cars automatically lower the stereo volume when there is an incoming cell phone call. This is the right thing to do in the majority of situations, but causes problems if the user wanted to share a radio broadcast. A simple way to keep users in control is to do "the right thing" in the large majority of cases, but also let users manually override incorrect actions, in this case, raising the volume.

• REFERENCES

van Duyne, D. K., J. A. Landay, et al. (2002). *The Design of Sites: Principles, Processes, and Patterns for Crafting a Customer-Centered Web Experience*. Reading, MA, Addison-Wesley.

D7 • ACTIVE TEACHING

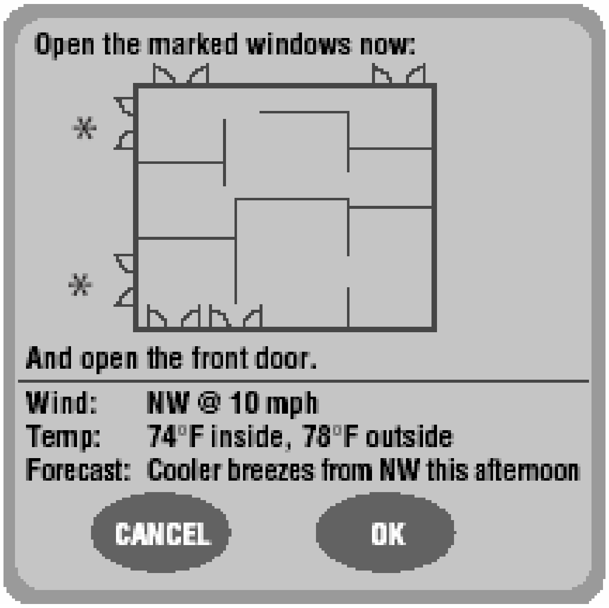

Figure 1. Rather than proactively making decisions for people, systems can instead make suggestions to people. The figure above is a mockup for a smart home that suggests what windows and doors to open to keep the temperature cool.

• BACKGROUND

This pattern looks at how to develop applications that subtly teach users how to do things better. This pattern is an example of KEEPING USERS IN CONTROL (D4), and is in contrast to STREAMLINING REPETITIVE TASKS (D3).

• PROBLEM

Not all tasks can be automated. Computers cannot always adapt to the richness of everyday life. Furthermore, some tasks should not be automated. Applications that are too proactive run the risk of encouraging users to become too dependent or making people feel that they are not in control.

• SOLUTION

One alternative to automating a task is to have applications subtly teach users to become more educated and informed about their decisions and tasks on a day-to-day basis. Applications can also be designed to be non-obtrusive, showing helpful hints when appropriate and useful.

The Smart Home at MIT uses active teaching to help users acquire the information it provides. For example, Figure 1 shows people how to maximize the amount of cross-breeze entering the household. One side benefit of this approach is that people can also use the knowledge learned in other environments that are not covered by ubiquitous computing.

Be sure the suggestions provide TOPICAL INFORMATION (B2). Active teaching is good for cases where people want to be involved. However, for boring or recurring tasks, an alternative is to STREAMLINE REPETITIVE TASKS (D3).

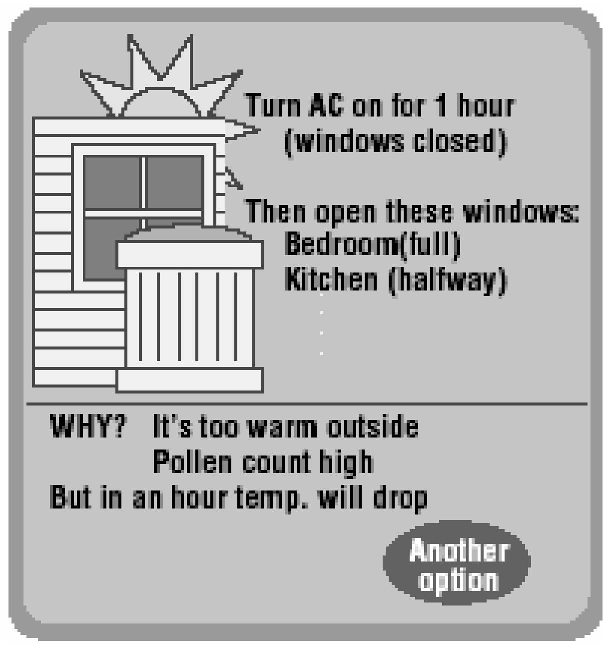

Figure 2. Another mockup that suggests to users what to do and why. The key here is that no action is taken by the system.

• REFERENCES

Intille, S. S. (2002). "Designing a Home of the Future." IEEE Pervasive Computing **1**(2): 76-82.

D8 • RESOLVING AMBIGUITY

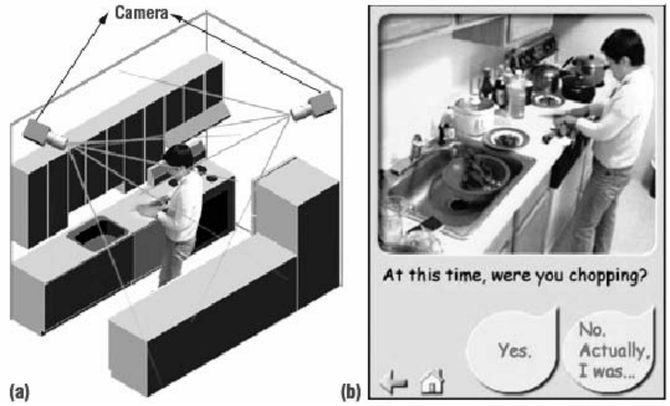

Figure 1. Resolving ambiguity helps systems clarify unclear actions or intentions. The figure on the left shows several video cameras set up in a smart kitchen to monitor users. The video cameras are connected to a computer that tries to infer the activity of users. The figure on the right shows a dialog box that is periodically displayed, asking the user to confirm if the inference was correct or not. With this feedback, the system can make better inferences in the future.

• BACKGROUND

KEEPING USERS IN CONTROL (D4) is essential for successful adoption of products. This pattern addresses a common problem in sensing systems, ambiguity in sensed data and in user intentions.

• PROBLEM

Computer systems do not always make correct inferences.

• SOLUTION

Sometimes, user actions and intentions are unclear, making it difficult for services to work properly. For example, Figure 1 shows a smart kitchen that tries to infer what people are doing. However, this is a very difficult to do even with modern computer vision systems.

One way of addressing this problem is to have these services subtly ask for clarification without annoying users. For example, suppose we have a system that automatically dims lights and turns off stereos and televisions when a person falls asleep. It would obviously be annoying for the computer system to ask people if they are sleeping. One way of managing this problem is to prompt unobtrusively and sparingly. For example, the system could slowly lower the volume and dim the lights before turning everything off.

Figure 2 shows an alternative design for resolving ambiguity from sensor data. Badges, speech, or keyboard is used as alternative input for correcting errors in sensed data for an In/Out board.

Where possible, systems should represent to their users what they know, how they know it, and what actions they are going to perform. Although intended primarily for preserving privacy, PRIVACY MIRRORS (C14) are an effective way of presenting feedback to users.

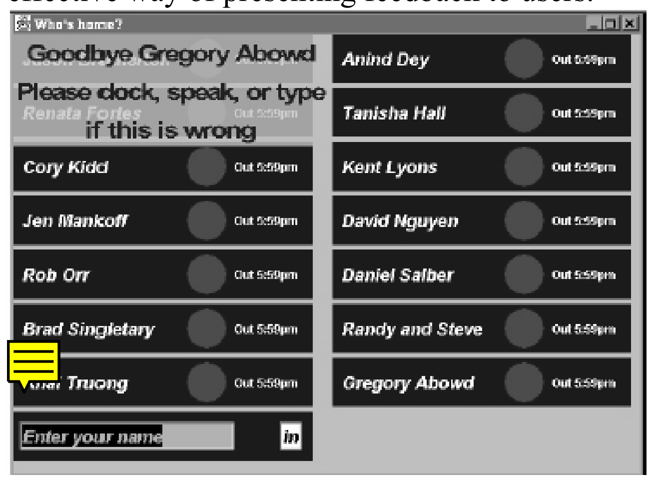

Figure 2. This is an In/Out board that uses simple sensors to resolve sensed ambiguity. When people walk by the system, the board displays a small message (at the top left) stating who it thinks the person is. Users can correct errors by using a docking station (which can read ID badges), by speaking out their name, or by using a keyboard.

• REFERENCES

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Dey, A., Mankoff, J., Abowd, G., and Carter, S. Distributed Mediation of ambiguous context in aware environments. UIST 2002.

D9 • AMBIENT DISPLAYS

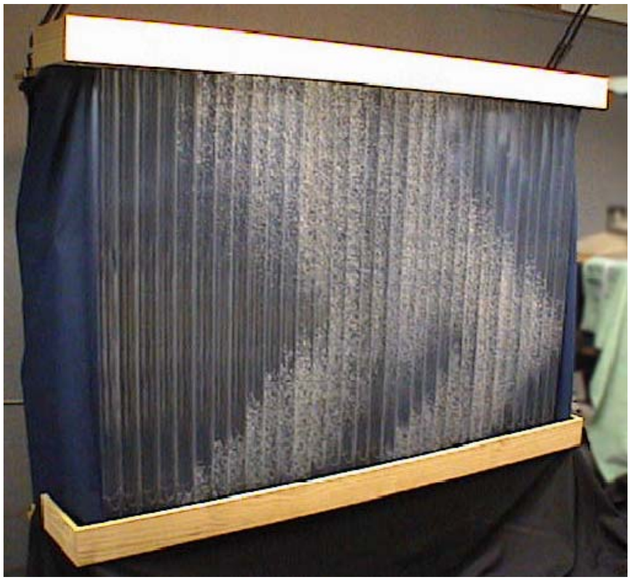

Figure 1. Ambient displays are a lightweight way of showing useful information without requiring people's full attention.

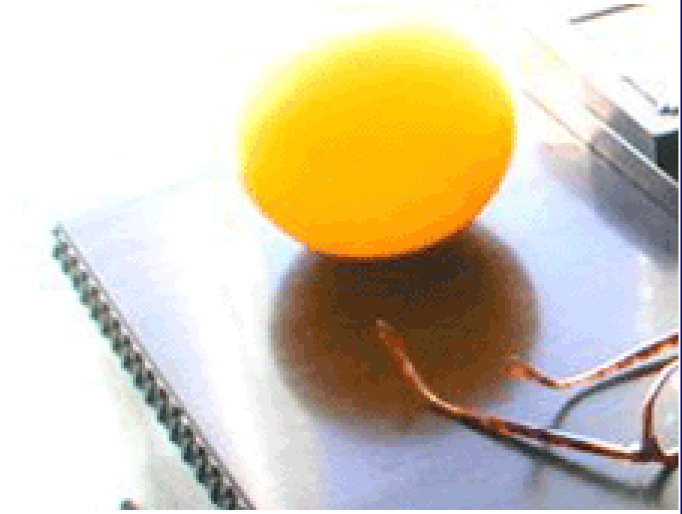

Figure 2. The Ambient Orb is a commercial device that lets people keep track of stock prices. The color shifts to green when the stock market is positive, and red when the stock market is negative.

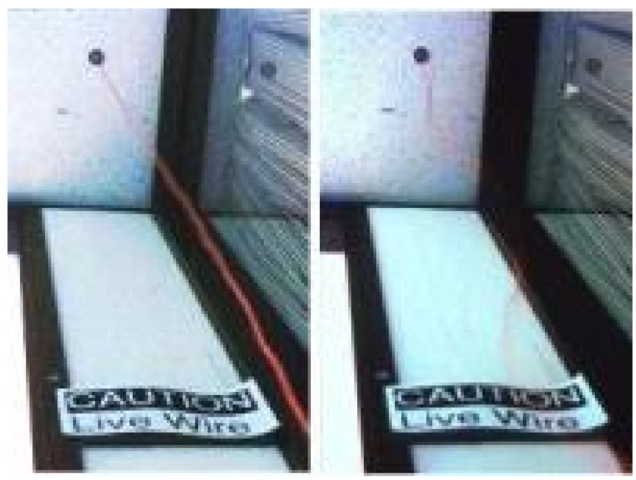

Figure 3. The LiveWire externalizes overall network traffic by shaking a wire. People can easily monitor network traffic conditions by glancing at the wire or by listening to changes in the rhythm of the wire.

• BACKGROUND

Part of KEEPING USERS IN CONTROL (D4), this pattern looks at how to make people aware of relevant information without overwhelming them. As ambient displays are meant to be on the periphery of attention, this pattern is in the middle of the SCALE OF INTERACTION (D1), and is one potential idea for SENSEMAKING OF SERVICES AND DEVICES (D2).

• PROBLEM

With more and more devices gathering more and more data about people, places, and activities, how can people manage the overwhelming flood of information?

• SOLUTION

One solution to managing the flow of information is to use ambient displays that can keep people apprised of changes at the edge of their periphery rather than requiring their full attention. Figure 2 shows the Ambient Orb, which uses a small range of color to let you see about how the stock market is doing at a glance. Figure 3 shows the LiveWire, which lets people monitor network traffic by listening to the rhythm of the wire or by looking at it and seeing how active the wire is.

• REFERENCES

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D10 • FOLLOW-ME DISPLAYS

Figure 1. Follow-me displays help mobile users access their personal workspaces and information wherever they go.

• BACKGROUND

Use this pattern to give users mobility with their workspaces and personal information. This pattern is at the interactive end in the SCALE OF INTERACTION (D1), and is one potential idea for SENSEMAKING OF SERVICES AND DEVICES (D2). This pattern an example of PERSONAL UBIQUITOUS COMPUTING (A2).

• PROBLEM

People who work at different computers at different locations throughout the week can be slowed by down by not being able to access their personal information and workspace settings.

• SOLUTION

Follow-me displays offer personalized information to mobile users. As a person starts to use a particular computer, his or her personal workspace is automatically moved to that computer.

Olivetti's Teleporting System (Bennett et al 1994) was one of the earliest follow-me displays, which added the functionality to existing X Window programs.

FLUMP (FLexible Ubiquitous Monitor Project) is a heterogeneous, ubiquitous, multimedia information system for departmental staff. Collections of computer-monitor pairs are situated throughout a space, supplying users with personal information as they pass.

Many terminals and thin clients, such as Sun's Sun Rays, display the user's workspace when they log in. The workspace is not tied to the thin client and is therefore easily movable from one machine to another.

One of the biggest concerns with this service is privacy; you may not want your information to be displayed on another computer without your knowledge or permission. To make this service privacy-sensitive, consider KEEPING PERSONAL DATA ON PERSONAL DEVICES (C15), BLURRED PERSONAL DATA (C9), and LIMITED ACCESS TO PERSONAL DATA (C10).

• REFERENCES

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D11 • PICK AND DROP

Figure 1. Pick and drop is a simple interaction technique for exchanging data between devices. Currently, it is still a research technique, but one that shows promise.

• BACKGROUND

This pattern describes an interaction technique for sharing data across devices. This pattern is at the interactive end in the SCALE OF INTERACTION (D1), and is one potential idea for SENSEMAKING OF SERVICES AND DEVICES (D2). This pattern can be useful for UBIQUITOUS COMPUTING FOR GROUPS (A3).

• PROBLEM

As more and more devices are deployed, sharing data between computers becomes more and more tedious. What is an easy way to share data in a ubiquitous computing environment?

• SOLUTION

One proposed research solution is to use pick and drop to move and copy data across devices. Pick and drop can be thought of as a multi-device version of drag-and-drop. Users can tap on items on one device to select them ("pick") and then tap on another device to copy or move them over ("drop").

One variation of pick and drop is to use a small device as a palette for a larger device, as shown in Figure 2. One could also imagine a collaborative version that allows multiple people to interact with large electronic whiteboards simultaneously.

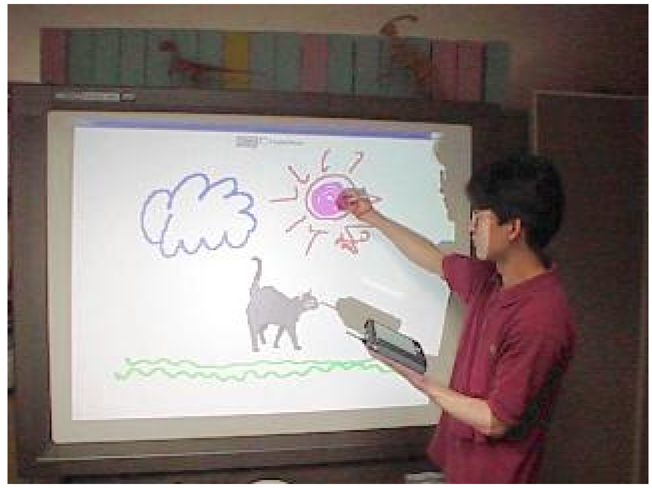

Figure 2. A variation of pick and drop is to use the secondary device (in this case the PDA) as a palette for a larger device (the electronic whiteboard).

• REFERENCES

Rekimoto, J. "Pick-and-Drop: A Direct Manipulation Technique for Multiple Computer Environments," Proceedings of *UIST 97*, pp. 31-39, 1997. This paper describes the original implementation of pick and drop.