

Making Ubiquitous Computing Visible

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An oft-cited feature of ubiquitous computing is its invisibility. When done well, designing for invisibility leads to computing environments that are integrated into people's on-going practices, values, and aesthetic sensibilities. Invisible computing also often leverages implicit input from people, thereby minimizing the threshold of effort required to gain benefits from the system. However, invisible computing has many dangers as well. A worst-case scenario is a system that secretly collects information and disseminates that information inappropriately to others. This "big brother effect" has been the lingering menace for ubicomp work. Clearly such a system is not well-integrated into the social practices of its users.

More subtle dangers of invisible computing are interfaces that do not give people the needed tools of awareness and control to comprehend and shape the behavior of the system. Too often ubicomp designers favor the benefits of implicit input without considering the dangers of invisibility. For example, a system that tracks the location of my cell phone may make it easier for others, including emergency assistance, to find me. However, without reasonable interfaces that convey how this information is disseminated and logged, I am left to trust that the system will "do the right thing."

This lack of awareness and control is not simply a privacy issue, characterized as "Do the wrong people know things about me?", but it strikes fundamental issues in people understanding the capabilities of a system, and then being able to shape that system to meet their particular needs. Without the former (understanding the system), the latter (shaping the system) is impossible.

Cultivating a reasonable user mental model for the behavior of a system is necessary for significant deployment and adoption. The model doesn't have to be correct per se; it must be sufficient. Supporting a reasonable model often requires helping users to understand the limitations and constraints of a system. For example, a kitchen system that helps a person maintain groceries in the house will have sensing limitations, that may be dynamic, based on sensors and situations. Effective use of this tool requires understanding what the sensing system missed so that a person can compensate. As ubicomp systems rely on implicit sensing that is naturally ambiguous or error-prone, it is up to the designer to help users comprehend the, sometimes variable, limitations of the system.

Many proposed ubicomp systems support some form of collaboration, communication, or awareness amongst a group of users. As it is difficult for a designer to match the needs of a particular user, it is almost impossible for a designer to match the needs of a group as those needs will

also shift with the changing social practices of the group. These lessons from CSCW are not new, and point to the need to support flexible adoption of ubicomp systems. Again, for users to shape a system, they must first understand its capabilities and limitations. Additionally an effective design provides controls for shaping the system behavior that are integrated into its feedback. As an example, we are designing software to support informal collaboration utilizing personal calendars typically found on PDAs and location tracking information. Users can shape the behavior of the system by tailoring what information they include in their calendars, and adjusting the reach and precision of the information that is disseminated. However, without feedback about how this information is being read by their colleagues, users have no basis, and therefore little motivation, to tune the system to their advantage.

These observations are best illustrated by examining past work in media spaces. Bellotti [1] and others point to the need for feedback and control for the successful use of this technology. At the simplest level, media space users could see how they were being seen by others. This feedback was accompanied with the ability to control the place of the video camera. These simple affordances allowed users to manipulate the content of information sensed and shared in the media space to meet their needs; for example, including a view into the hallway to include casual passer-byers in the video signal. Note that this feedback and control was not as successfully provided in the case of audio.

The solution to the need for feedback and control is not to provide configuration panels and diagnostic displays. A crucial characteristic for the success of many ubicomp systems is lowering the threshold of effort to achieve benefits from the system. Simply put, no one has the time to actively manage how information about them and their environment is sensed and used. As with the rest of the system, capabilities for feedback and control need to be integrated into the practices surrounding its daily use.

As most ubicomp system designs do not address these issues of feedback and control, we have begun experimenting with interfaces that reflect how information is being sensed and used. We call these interfaces "privacy mirrors," although this name gives too much weight to the privacy issue at the expense of other, equally important concerns. As there is not necessarily a 1-to-1 mapping between sensor and application, our mirrors address a range of information needs, from conveying sensing capabilities in a certain room, to conveying who is reading sensed information.

We believe that these interfaces are a starting point for providing adequate tools for feedback and control in

ubiquitous systems. At this workshop, we welcome the opportunity to discuss the validity of our motivations and the specifics of some of our design concepts. We close this paper with some examples from our work.

The “Sesame Street® Kitchen People Counter”

This prototype simply shows the number of people in a room. However, this and the other prototypes bring to the foreground an essential part of awareness that is missing from a system that does everything in the background. It not only shows the occupants that information is being collected, but that the system is working.

This prototype reminds us of qualities from an American television children's show. So we named it the Sesame Street® Prototype. The visualization uses a Windows CE handheld computer connected to the system using a wireless Ethernet connection. The prototype is placed in a room, for example, the kitchen of the Aware Home[2]. As people enter and leave the kitchen, the Aware Home implicitly collects this information and our prototype visualizes this information. If three people are in the kitchen, our prototype shows the number three on the left side of the 6.5-inch display and three spatulas on the right side of the display. When a person leaves the kitchen, the prototype updates itself and shows the number two on the left side with two coffee pots on the right.

This cue does not demand to be the center of attention; it sits in the periphery. As many get-togethers tend to gather people in the kitchen, it can be a conversation piece for visitors to the home. It is intended to create a light-hearted emotional reaction. Children may be attracted to it and associate people entering and exiting the room with the display. Hence they will begin to learn about the previously invisible sensing mechanisms in their home.



FIGURE 1. The People Counter

What Does the House Know About Me?

Cartoon Parts is another prototype from our collection. The interface has three parts and changes when different occupants of the house look at it. The top part shows a picture of the viewer, indicating that sensors can recognize the viewer's face. It also shows an audio icon, indicating that sensors can identify the viewer's voice. The middle part shows the color that the system is tracking and has assigned to the current viewer. That is, the function of the sensor is only to track blobs of a certain color. This tells the viewer which color the sensor is tracking. The bottom part shows a layout of the environment and specifies where the system thinks the viewer is currently and has been located.

This prototype gathers different information from various sensors and transforms that information into non-technical cartoon illustrations. It is meant to be more playful than technical. This display is one way to aggregate many sensors into one place.

The Calendar Mirror

The Calendar Mirror interface combines a display of the user's calendar with information about how that information has been accessed by others. One difference between this



FIGURE 2. Cartoon Parts

prototype and the others is that this interface displays information that is not physical sensor information. The focus is on the accessing of information and not the sensing of information. However, the same notion of visibility applies. As the day progresses, the calendar bar plus descriptions moves to the right, exposing accesses that occur during the day. Each dash represents an access. In this case, accesses that retrieve the event time and description are indicated above the event line. Anonymous accesses that only receive the event time are located below the event line. By rolling the mouse over the dash, the user can obtain details about the access. A primary goal is to create a simple and aesthetically pleasing design that combines a traditional calendar display with constant and unobtrusive feedback. Then users could make informed interpretations over time without needing to remind themselves to reexamine the access data.

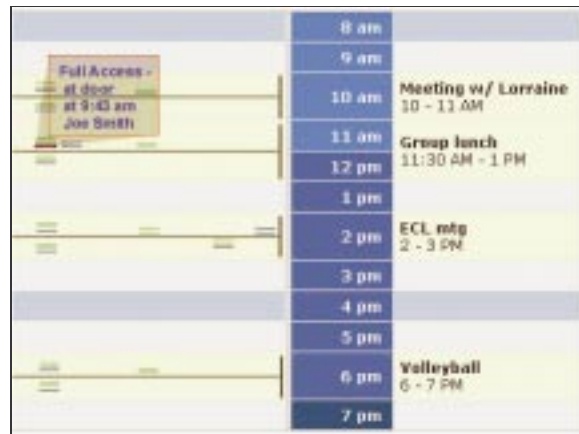


FIGURE 3. The Calendar Mirror

REFERENCES

[1] Bellotti, V. and Sellen, A. “Designing for Privacy in Ubiquitous Computing Environments,” in the *Proceedings of European Conference on Computer-Supported Cooperative Work, ECSCW '93*. Milan, Italy. September 1993.

[2] Kidd, Cory D. et al. “The Aware Home: A living laboratory for ubiquitous computing research.” In the *Proceedings of CoBuild '99*, pp. 191-198.