

Context-Based Systems: Research Challenges

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Mik Lamming and Marge Eldridge
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XEROX RESEARCH CENTRE EUROPE,
61 REGENT STREET, CAMBRIDGE CB2 1AB, UK

Introduction

In the next few years there will be a further explosion in the number of people using the Internet. These people will use small wireless devices: phones, pagers or PDAs. Many of these new users, probably the vast majority, will have little experience of using a WIMPS PC. Thus the challenge for designers is to produce systems with exceptionally high levels of usability. In this position paper we argue that context presents us with a means to dramatically improve many elements of usability. Perhaps more importantly, however, using context information presents us with opportunities to create new classes of application.

Mobile work is special and different (Lamming et al., in press). Some distinctive characteristics of mobile work include:

- *Unfamiliar environments*—in particular the local infrastructure, office equipment and people;
- *Collaboration*—face-to-face meetings, both planned and unplanned, are extremely frequent;
- *Unpredictability*—unexpected encounters, requests for documents, etc.
- *Time-pressures*—heavy schedules, flight connections, etc.

Wireless mobile devices and technology have many unique capabilities. Because the devices are small enough to be taken everywhere, the user may have (nearly) constant access to network-based computing services, and, in turn, networked-based services will have (nearly) constant access to the user. Because mobile devices are personal, they will have a familiar and perhaps personalised user interface. These unique capabilities can potentially be of great benefit to users, but they can also pose problems:

- Users are frequently interrupted by distant people or events. Phones ring or email arrives during meetings, distracting the user's attention away from the work at hand and irritating other people.
- Some users can't stop fiddling. They are simply beguiled by the availability of computers and services.

With few exceptions, mobile technology has not been designed to suit the prevalent activities of mobile users. The user interfaces may be overly complex for the given task, and, in any case, they are small and impoverished. Users fumble around (even more than they would on their PCs) becoming increasingly aware that they are beginning to look incompetent.

We will show that using knowledge of the user's context in unfamiliar, collaborative, unpredictable, time-pressured and often stressful situations offers the prospect of designing applications that are much more usable.

Context to the Rescue

Many wireless devices inherently provide some capability to determine their context by discovering the identity of the other wireless devices with which they are in communication. For example, we developed a system based upon infra-red beacons that enabled the mobile device to determine what room it was in and what other similar wireless devices were present (Lamming & Flynn, 1994.). GSM phones can provide increasingly accurate location information, soon to within a few tens of meters. Once a mobile device knows where it is, a network-based database can be consulted for more information about the location, including information about other nearby devices. Careful processing of this information can provide some understanding of the user's context.

Gathering context information in and of itself is often not enough. Most applications will require these data to be processed into a form that corresponds to the way the user might describe the context. For example,

Pepys processed location data from active badges (Want et al., 1992) and automatically generated a diary of a person's activities during a day (Newman, Eldridge & Laming, 1991). It described events such as "working alone in one's office", "travelling", "in a meeting with X and Y", etc. With this level of context recognition, users can set up context-based reminders expressed in more natural terms, for example: "Remind me to tell the XYZ group about our new product when we next meet."

Pepys used data from active badges to identify people present, but other techniques could also be used. For example, voice recognition technology could be used to identify people present, perhaps even making judgements about the emotional state of the people present by recognising raised voices. Or, video technology could help identify people present, perhaps using sophisticated face recognition software. Video technology could also be used to capture and identify documents on the desk (see, e.g., Newman et al., 1999), using this information to help identify a user's current activity.

Using knowledge about context has the potential to overcome many of the problems of mobile technology that we described earlier. For example, Satchel (Lamming et al., in press) is a system that supports mobile document work. It uses context information from infra-red communications to streamline the user interface. So, for example, when a user requests a service while in front of a printer, a print form specific to that printer appears on the user interface. The user need not fumble around trying to find the printer on the local network, a problem that is often particularly severe in an unfamiliar environment. Or, if a user wants to give an electronic document to someone during a meeting, she can simply "beam" the document to another user over infra-red. Satchel uses context information to streamline the user's interactions by figuring out what the user intends to do in a given situation. If a service is requested in front of a printer, Satchel assumes the user wants to print a document; if a service is requested near another mobile device, it assumes the user wants to pass the document.

Satchel was a simple example of using knowledge about nearby devices to streamline the user's interactions. More sophisticated uses of context are also possible. Forget-Me-Not (Lamming & Flynn, 1994) was a context-sensitive retrieval system using Xerox PARCTabs (Want et al., 1995). It used infra-red communications to detect the presence of other PARC Tabs and devices (e.g., printers) in the same room. It also logged information about telephone calls made, e-mail notes received, and meetings attended. From these context data, it compiled a personal biography of meaningful episodes that could be used to help remember past events. For example, suppose a user wanted to re-read a document he received a while ago; he doesn't remember exactly where it was filed, but he does remember that he printed it just before he had a meeting in his office with his manager. He can enter this remembered information and locate the document.

Many other examples of context-aware applications have been reported in recent conferences and journals. But we are thinking of mobile devices that can act as *mediators*, attempting to reconcile the needs and intentions of the user with the capabilities and constraints of the user's current environment. They could act as *facilitators* by being privy to the user's needs, spotting the user's intentions, and providing non-intrusive and discrete support. Wireless mobile devices have the potential to do all of these things, and by thinking about innovative uses of context data we believe there's an opportunity to design applications that can:

- Automatically collect, maintain and organise information, both shared and private, spotting situations where the information might be useful and making sure it is to hand;
- Automatically spot situations where they can offer help; for example, suggesting that an unfamiliar service might be useful for the current task by correctly guessing the user's intentions;
- Facilitate communications between the user and the organisation in whatever form is most appropriate for the user's social context, physical location and current activity;
- Facilitate interaction with the immediate environment by "impedance matching" the user's intentions to the specific, and possibly unfamiliar, local equipment, services, processes or sources of information; and
- Remember and learn from past events, or recall them for the user.

We believe that capturing and correctly identifying context has a tremendous payoff for wireless applications. It also represents an almost open-ended challenge for the research community.

A Concluding Note on Privacy

We believe that privacy is a major issue in designing context-aware applications. How can users maintain control of their own personal data without giving up their privacy? How do they gather up context data without leaving their own trail in the environment for others to pick up? What are the social expectations about such context-aware applications?

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