Notifications and Information Retrieval in Ubiquitous Environments

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In technology-laden environments, information overload is a serious problem. While information is necessary to perform many tasks, the human mind is limited in terms of how much information it can process at one time. The problem of information management becomes even more difficult and complex in mobile environments. People must juggle a multitude of dynamic sights, sounds, and other stimuli that convey information and compete for their limited attention. One way to reduce information overload is through the use of meta-information, which can require less effort to process and can result in fewer or less severe disruptions. If meta-information is deemed important, the person receiving it can make a decision whether or not to seek additional details. For example, a mobile worker may not need or want the entire contents of a message or an announcement every time one becomes available. It may be too distracting (and perhaps too dangerous) to the worker's primary tasks. However, they may wish to receive a notification that a message is available, along with an indication of how important it is, and its source. That way, the worker can make their own decision, based on their current situation, whether or not to stop their primary task to access the contents of the message. Determining proper notification cues for use in ubiquitous environments can become quite complex, requiring the selection of appropriate delivery channels based on continuously changing contexts and dynamic information needs.

Background

My research can be classified under the field of information science, which combines aspects of both information systems and computer science. I have been studying mobile devices and applications for several years now. Part of my research looks at business and information systems problems, in areas such as mobile commerce (mCommerce) and wireless information systems [1, 2, 3]. My primary research focus, however, is user interface design and usability [4, 5]. In terms of ubiquitous computing, I have been addressing two topics. The first is the design of notification cues. I am presenting a paper at UbiComp 2003 [6] that details the results of a laboratory experiment that measured the performance/size tradeoff of visual displays ranging in size from two LEDs to nine LEDs, while varying a number of display characteristics, such as color and blinking. I am continuing work in this area with a follow-up experiment, and working on notification prototypes including digital jewelry (with Chris Campbell at IBM's Almaden Research Center). The second topic is user

interfaces for ultra-mobile devices (watch-sized and smaller). I have completed several experiments looking at novel thumbwheel text entry methods can be applied to such devices [7, 8], and I plan to perform tests with watch-size PDAs in the near future.

Research Issues

The ultimate goal for any information system is providing access (in some format) to a unified set of information through *any* available device [9]. To achieve this goal, different heterogeneous devices need the ability to communicate with each other. This is an enormous problem that may never be fully solved. The Internet may be a good solution in terms of connecting the multitude of mobile devices that exist, but even this presents challenges because of problems such as connectivity (getting to the Internet), bandwidth limitations, and battery power consumption.

While solving the larger picture of complete "anytime, anywhere" information access from any device is a noble goal, it is probably better in the short term to concentrate on creating personal networks for individual users that consist of their normally used devices (e.g., laptop, PDA, phone, and watch). *How* these devices communicate with each other is not important, but it is critical that they are linked to each other (and with the outside world). Each device should provide input and output functionalities that are best suited to its unique characteristics, and to the environments in which the device can be used.

Assuming that communication between different devices is achieved, another issue that arises is determining which devices are appropriate for performing certain tasks or accessing certain types of information. For example, a watch may be fine for conveying a notification cue, reading small text messages, and identifying one's current location. But a watch is probably not an appropriate platform for composing or viewing lengthy documents or complex diagrams. In certain situations, however, the watch may be the only way (or most readily available way) of accessing information, so the watch should be able to view the information in some (i.e., less detailed) format, perhaps at a summary level. If desired (and if available), the user could then transfer the information retrieval task to another device with better or more appropriate capabilities.

Another interesting problem is automatically determining how to notify or present information to a user, given that several devices may be available. Heuristics could be developed to determine the context of the user, and a decision could be made as to where the information is sent (i.e., to what device) and in what form. For example, if a user is in a meeting, a visual notification cue might be sent to his/her watch rather than forwarding a voice message directly to his/her mobile phone. However, if the message is urgent, then the message might be forwarded directly to the phone.

Notification cues in many cases are the precursors to further information retrieval on other mobile devices. My current and planned research investigates the design of notification cues for the ubiquitous computing environment. Notification cues can be visual, auditory, or tactile in nature, or any combination of these (i.e., multimodal). Cues

can range from subtle and private (e.g., a vibrating cell phone) to loud and public, even intrusive (e.g., a ringing cell phone). To be successful, a cue must 1) get the intended recipient's attention, 2) clearly convey its information to the recipient, 3) minimize the disruption of the recipient's current task(s), and 4) minimize the disruption of other people in the vicinity of the recipient.

1. Getting the Intended Recipient's Attention

Notification cues must safely compete for a user's attention in a world full of distractions. While sensory overload is one concern for notification design, another is subtlety. A flashing light on a person's watch may not be obvious enough to attract a person's attention when driving. There are also risks of a notification cue being ignored because of overuse. The recipient's context affects the appropriateness of a notification cue and the probability of successfully getting the recipient's attention.

2. Clearly Conveying Information to the Recipient

A notification cue must also clearly convey the information it contains to that person. Given that notification cues can take many forms (i.e., visual, audio, tactile), it is necessary to study which forms can be comprehended most easily and consistently by people, in which contexts. Tradeoffs may exist between the amount of information that a notification cue can successfully convey and the context of the intended recipient. Certain contexts may necessitate or favor multi-level cues, where an initial cue conveys a single dimension of information (e.g., priority), and the user can call up additional details (e.g., source) before responding further. While cues can provide multiple levels of information at once, in certain contexts (e.g., high-stress environments) it may be better to convey only part of that information initially.

3. Minimizing the Disruption of the Recipient's Current Task(s)

Notification design must address how to safely and effectively interrupt users. Interrupting people affects their behavior, and how the interruption process works is not always obvious. Notification design should take into account the intended recipient's current task, how that task is being performed, and any cognitive loads currently placed on the intended recipient. For example, if a visual task is being performed, then an audio notification cue (which is dissimilar to the current task) might be best. When current task demands are high, simpler cues that convey only one level of information can be better than more complex cues that convey multiple types of information.

4. Minimizing the Disruption of Other People in the Vicinity of the Recipient

While it is important to convey a notification to its intended recipient, it is also important to minimize the disruption of other people in the vicinity of the recipient, depending on social context (e.g. a party with friends versus a business meeting with colleagues). But it may still be important to let people in the vicinity know about incoming notifications directed to another person (e.g., to avoid perceptions of

rudeness). Guidelines for such notifications will most likely evolve over the years as social situations which involve new technology come to be better understood.

I am performing laboratory research (including prototype work with digital jewelry and other devices) to test notification design fundamentals and usability. In addition to this work, I will continue to investigate input/output methods (primarily text entry) for ultra-mobile devices. One of my longer-term goals is investigating heuristics that take into account context data (including user preferences) to support decision making.

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