Paper or Interactive? A Study of Prototyping Techniques for Ubiquitous Computing Environments

Linchuan Liu, Peter Khooshabeh
Group for User Interface Research
CS Division, EECS Department
University of California at Berkeley
Berkeley, CA 94720-1176, USA
{ lliu, pkhoosh }@cs.berkeley.edu • http://guir.berkeley.edu

ABSTRACT
We studied the effects of varying the fidelity and automation levels of a Ubicomp application prototype. Our results show that the interactive prototype captured the same usability issues that the paper prototype studies did and more. We found that paper prototyping is insufficient for supporting unique Ubicomp requirements, such as scalability, but a prototype with higher fidelity and automation levels can enhance the quality of interaction data available for evaluation.

Keywords
Ubiquitous Computing, Lo-fi Prototyping, Wizard of Oz.

INTRODUCTION
Ubiquitous Computing promises to augment and transform daily tasks by enabling natural interaction with everyday environments. However, there has been little research on the design and evaluation process for Ubicomp applications [1]. Although prototyping has been used with great success in obtaining usability data during the design of traditional UIs [2,3], its use in Ubicomp has not been thoroughly investigated.

We wanted to identify the appropriate level of prototyping fidelity (look and feel) and automation (amount of human intervention) to successfully design Ubicomp applications. To do this, we designed and evaluated Kitchen-Net, a simple Ubicomp application for locating items in industrial-sized kitchens. We evaluated two prototypes of differing fidelity and automation level. Our results showed that prototype fidelity was an important factor in eliciting quality feedback, and automation level was an important factor in uncovering major usability issues.

THE KITCHEN-NET SYSTEM
We ran formative studies at two student cooperatives, looking for tasks that a Ubicomp system could augment. We noticed that cooks had trouble finding the items they needed, given the size of their industrial kitchens. To assist them in locating items, we designed Kitchen-Net.

CHI 2003, April 5–10, 2003, Ft. Lauderdale, Florida, USA.
ACM 1-58113-630-7/03/0004.

Kitchen-Net supports the task of working in an industrial kitchen by responding to spoken queries for items (e.g., "where is…" or "show me…"). Kitchen-Net uses a set of screens placed around the kitchen. The screen nearest the user shows directions to his or her requested item. The level of detail of the directions is proportional to the user's proximity to the item.

To study the effects of varying fidelity and automation levels on usability, we created both a paper and interactive prototype of Kitchen-Net. We employed a Wizard of Oz strategy to simulate a voice-recognition system and a sensor network system for tracking item and user locations. The wizard enters contextual events (e.g., speech or user movement) in real-time to an event logger that we developed.

Paper Prototype
We used paper sketches and Post-It notes to represent Kitchen-Net screens (see Figure 1). There was minimal automation involved in running this prototype. One researcher played the wizard and the other played the "computer." The "computer" manually updated screens in response to spoken queries and user movement events. We implemented the paper prototype in a day and incorporated major implementation changes very quickly.

Interactive Prototype
We replaced the paper "screens" with Vadem Clio Handheld PCs (see Figures 2a and 2b). This prototype automatically responded to events logged by the wizard, removing the need for the human "computer." We needed two weeks to implement this prototype and roughly a day to incorporate each major implementation change.

EXPERIMENT DESIGN
Two sets of studies were conducted with both prototypes on twenty college students. All were cooks for Cloyne Court, a co-op housing 150 people. Eleven females and nine males were all between the ages of 18-25. Their experience cooking meals for the house varied. Participants were asked to consider making spoken queries to Kitchen-Net when looking for any item. The studies ended with a short questionnaire.

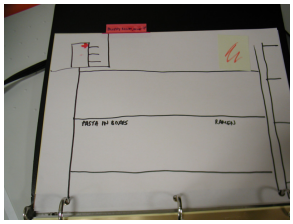

Figure 1. The Kitchen-Net paper prototype. Paper screens show which shelf an item is on, and a Post-It note represents the item's location on the shelf.

Figures 2a and 2b. The Kitchen-Net interactive prototype. PDAs, displaying the Kitchen-Net client program and networked on a wireless LAN, replaced the paper screens.

FINDINGS AND ANALYSIS

Paper prototype studies captured 3 major usability issues: item support, error handling, and ambiguous input handling. The interactive prototype captured the same 3 issues as well as 2 new ones. Additional issues involved problems in how Kitchen-Net displayed directions to items. Effects of fidelity and automation are discussed below.

Fidelity

Interestingly the interactive prototype elicited more comments of all types, although we expected more "fit and finish" remarks [2]. Almost all the participants mentioned the need to support small, highly mobile, and rarely-used items. Furthermore only 1 paper prototype study participant made suggestions for improvements to the interface, while 4 of the interactive prototype study participants made comments. Kitchen-Net was designed to support natural and fluid user interaction by integrating sophisticated technologies that are not yet commonplace. Paper screens were not of sufficiently high fidelity to convince participants that they could really incorporate Kitchen-Net in their lives.

Automation

Since more people are needed to run paper prototype studies, this makes it difficult to obtain realistic interactions of the scale which Ubicomp applications are designed to support. We normally ran hour-long user studies, but that was not long enough to have Kitchen-Net support five hour cooking shifts. To get more interaction data, we ran some paper prototype studies at different times during the dinner cooking process. However, a participant who did not use the system at all explained during the questionnaire period that "it just wasn't there" when she needed it. The increased automation level in the interactive prototype allowed us to run longer studies because fewer people were needed to run the prototype.

We discovered validity issues with the interaction data we gathered from the paper prototype studies. The higher automation level in the interactive prototype uncovered two issues that went unnoticed in the paper prototype studies. Many participants using the interactive prototype either complained about or misinterpreted the overhead floor plan map view. They also had trouble understanding the shelf view (shown in Figures 1 and 2). We had no comments about that display from participants of the paper prototype studies. The presence of the "computer" affected the participants' interaction with Kitchen-Net. With the paper prototype, participants saw that the "computer" only updated a small section of the screen for the overhead view. They would wait until the "computer" updated the screen to quickly figure out where to go. Participants using the interactive prototype had to pay attention to the whole screen, since they did not have any visual cues to the relevant information on screen.

DISCUSSION

From our experience with Kitchen-Net, Ubicomp application designers should carefully choose the fidelity and automation level of their prototypes when evaluating their designs. Paper prototypes give designers more flexibility in the early phases. However, they are insufficient for formal user studies because of their validity issues and need for more staff to support interaction over long periods of time and large locations. Our paper prototype needs more "computers" to handle simultaneous queries from multiple kitchen areas with an acceptable response time, while our interactive prototype does not.

By increasing fidelity and automation, Ubicomp designers can improve the validity of interactions and therefore get better usability data. Using Wizard of Oz, designers can still save a significant amount of time and effort in making these interactive prototypes, although the presence of wizards may also affect study results by affecting the fluidity of interaction.

FUTURE WORK

We plan to hide the wizard in future studies, to increase the believability of Kitchen-Net as a Ubicomp application. We also plan to broaden the scope of our studies to include people working at restaurants or other industrial-sized locations with large inventories. Finally, we hope to generalize our findings by expanding our studies to include the lo-fi prototyping of applications from more domains.

REFERENCES

1. Consolvo, S., et al., User Study Techniques in the Design and Evaluation of a Ubicomp Environment, in *Proceedings of the International Conference on Ubiquitous Computing* (Goteberg Sweden, Ubicomp September 2002).
2. Rettig, M., Prototyping for Tiny Fingers. Communications of the ACM, 1994. 37(4): p. 21-27.
3. Vredenberg, K., et al., A Survey of User Centered Design Practice, in Proceedings of CHI '02 (Minneapolis MN, April 2002).