Position Paper for the SIGCHI 2001 Workshop on:

Distributed and Disappearing User Interfaces in Ubiquitous Computing

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INTRODUCTION

To date, work in ubiquitous computing illustrates a variety of implementation systems, architectures, methods, and prototypes. As this field continues to evolve, we need to develop a larger body of formal studies, analysis and methodologies for ubiquitous computing.

In earlier work at Xerox PARC, we were interested in further pursuing the investigation of ubiquitous computing [10] and extending those original notions. We constructed both physically manipulative user interfaces for portable devices [5] and, through the use of RF tagged objects, we built a system that supported relatively complex task scenarios within a work environment [9]. We designed not only single-user technologies but also collaborative technologies [7], combining white boards, camera systems, and phicons in meeting room scenarios.

At the IBM Almaden Research Center (ARC), there are a number of ongoing ubiquitous computing efforts. The USER lab [14]has developed BlueEyes [13], ISK8TE, WBI [2] (a transcoding infrastructure technology) and Digital Jewelry [12]. We are currently developing a new project, BlueBoard, which deals with improving user interfaces on whiteboard-sized displays. These displays are geared towards supporting more shoulder-to-shoulder collaborative work in public spaces using context-based techniques. We feel that coupling pervasive but stationary components such as BlueBoard with lighter-weight, more mobile components, such as Digital Jewelry and tagged objects will produce a powerful, complimentary system.

THE PAST, PRESENT AND FUTURE

With advances in hardware and software technology, examples of ubiquitous computing are increasing. Considerable work and innovation exist that illustrate *augmented everyday objects*. On a larger scale, research is increasing in the development of entire *augmented environments*. Examples of augmenting everyday objects include wearable computing [e.g.,12, 15], pill bottles, smart staples, kitchen and office appliances [e.g., 3, 6, 9, 11]. Likewise, augmented environments span a range of spaces including cars, offices, art galleries, classrooms, meeting rooms, and entire buildings [1, 4, 7, 8]. We are also seeing the combination of integrating augmented devices/objects with augmented spaces [e.g., 1, 4, 7, 8]. These projects have been ground breaking and fundamental to the development of ubiquitous computing.

As researchers, we will continue to develop and extend these systems and their applications, but we now have sufficient, stable, and interesting base technologies and sufficient fundamental research to start extracting more formal analyses, modeling and methodologies to better understand the design and implications of ubiquitous computing. The goal of this scientific rigor is to support improved work fluency, and produce predictive models useful in the development of seamless physical/virtual environments.

Unfortunately, there is little work to date in formulating design principles that help us predict what works best. There are few frameworks that allow us to systematically compare and contrast projects or to understand what components work or do not work together towards a given task objective with a given group of people. Our interest is to develop further applications, conduct usage studies, and to contribute towards establishing this deeper level of scientific understanding.

CATEGORIZATION

To help make sense of this large research domain, we have identified three investigative categories: *technology*, *people*, and *task*. While no category can be considered in isolation, this separation allows us to see the integration and overlap, the dependencies and relationships between the categories. The Technology category captures those elements related to constructing systems, devices, and making choices about how to configure them. The People category captures elements related to our understanding of human dynamics and capabilities. The Task category captures elements related to the current work/play context and people's goals and objectives within that context. To help illustrate these categories and their possible utility, we list a small subset of elements that fall within each.

Technology

- Components: e.g., pda, cellphone, whiteboard, plasma displays, PCs, etc.
- Communication infrastructure and protocols: e.g., bluetooth, IR, RF, wired LANs, WANs, WAP, 1-way, 2-way, high bandwidth, low bandwidth, etc.
- Software architectures: web-based, peer-to-peer, thin client, broadcast, etc.
- ...

People

•Social: e.g., proxemics (proximity), how different sized groups interact, cultural, etc.
•Cognitive: e.g., learning, high level processing/abstraction, etc.
•Psychophysical: e.g., visual/auditory perception, memory, attention, peripheral-central, etc.
•...

Tasks

•Attributes: degree of formality/rules, format (drawings, speeches, text), tools to execute, processes involved, etc.
•Goals: objectives of task, overall goal, measure of success/failure, etc.
•Participants: e.g., single user versus multi-user, distal vs. proximal (space and time), etc.
•...

BRIDGING THE CATEGORIES

Our design choices largely determine the seemless integration between these three proposed categories. The dimensions that bridge or link these categories bring out difficult challenges and issues and suggest areas for further investigation. We enumerate several (but certainly not all) of the significant design dimensions that we believe require further research:

•Resource management
•Implicit and explicit interaction on the part of the user
•Component connectivity - constant/persistent, intermittent, rare, never
•Open/closed feedback loop between people and the system
•Latency
•Channel modality-visible, audible, vibratory, etc.
•Salience - peripheral, central
•Reliability - (statistical collection from different sensors/emitters)
•Abstraction (higher level processing and representation of system state to user)
•Specialized devices versus general purpose
•Degree of integration, degree of reliance; interdependencies and coupling amongst components
•Extent of presence in physical world and extent of presence in virtual world
•Fidelity of mapping interaction to a real world metaphor - expected interaction method, expected outcome
•Device and environment (device moves from place to place, device locked into one space)
•Transition with the number of people, task, change in environment
•Privacy/security
•Shared space management
•Context
•Diagnostics, errors - logging, analyzing, interpreting (What is undo in a uiquitous environment?)

CONCLUSION

Current research has shown us that ubiquitous computing is a feasible future in terms of technology implementation on a small scale. However, much work remains ahead for us to understand the ramifications of large scale deployment and every day use of such technologies. There are still many unexplored issues and hard problems that the research community needs to address to better understand and hence to design, build and promote such systems.

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