Ubiquitous Computing:
Technical, Psychological, and Value-Sensitive Integrations

Position Paper

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1. Introduction

In recent years, exciting technologies – and challenges – have been emerging in a field that can be referred to as *ubiquitous computing*. The basic idea here is that computation moves out of the "box" (e.g., the PC workstation) and becomes pervasive in our everyday lives. Not only will we be no longer confined to our desktops in order to access information but we will use a larger range of task-specific computing and communication devices that will not distract us from the task at hand. Moreover, in the not too distant future many manufactured goods will not only contain a basic identification capability, but be able to gather data from integrated sensors, monitoring everything from air quality within buildings to physiological responses to medication (Estrin, Govindan, & Heideman, 2000; Want & Borriello, 2000).

Some of the challenges with ubiquitous computing are clearly technical. For example, there are hard problems to solve in designing systems that provide dynamic reconfiguration and allow for heterogeneous intermittent connectivity. Yet equally challenging is to understand how technical advancements can help or hurt human and societal well-being. For example, aggregation of data from remote sensors can lead to greater social communication; but it can also allow organizations to discern more and more about our activity patterns and personal preferences, and thus lead to the invasion of privacy and undermine a climate of trust within social relations, and diminish our social capital (Friedman, Kahn, & Howe, 2000; Nissenbaum, in press).

Till now, most funded research has moved along disciplinary boundaries. Thus technical investigations have largely been separated from investigating the psychological and social effects of the technology. But in our view this separation fundamentally misconstrues the human experience of the world – and to our peril. We would like to take two paragraphs to explain what we mean here, for this interconnectedness motivates our overarching theoretical context, and our resulting research projects.

From an evolutionary standpoint, three features of the human experience are central to the human condition. First, we as humans evolved through daily, intimate contact with the natural world, and thus are favorably predisposed to it today. For example, research shows that even minimal experiences with nature can reduce immediate and long-term stress, reduce sickness of prisoners, calm patients before and during surgery, and promote healing after surgery (Ulrich, 1993). Second, we are social (and moral) beings, and depend on social communication, social interactions, social learning, and reciprocity for our physical survival and in the construction of knowledge (Turiel, 1998). Third, we create and use technologies. We always have. Digging sticks, stone axes, bows and arrows, shovels, tractors, telescopes, electron microscopes, hydroelectric power plants. From an evolutionary standpoint, such technologies presumably have conferred genetic advantages to their creators and users (Wilson, 1998).

Yet here is the rub. In the last 200 years – and especially in the last 20 years – our technology has been developing at a rate that far surpasses anything in our entire evolutionary history. Our mind, evolutionarily speaking, is not a product of this technological age. As a result, it is difficult for the human mind to really understand the larger social implications of our technological advancements. What seems clear to us, however, is that a new research approach is needed that focuses on how to design and deploy technology that integrates these three fundamental features of the human condition.

Thus in our research projects we seek to conduct this form of multidisciplinary research. Specifically, we seek to design and deploy technology that (a) enhances our connection to the natural world, (b) enhances our social (and moral) lives, and (c) furthers our technological advancements themselves.

2. A Collection of Current Projects and Our Integrative Approach

To provide a flavor for our research, we now describe a few newly initiated research projects that fit broadly within ubiquitous computing followed by a brief discussion of how we apply our integrative approach.

2.1 Communicator

We build upon the Star Trek "communicator" concept where a person can easily initiate a conversation with one or more others through the use of microphones and speakers ubiquitously available on the person or in the environment. Connections are initiated through a conversational interface using speech recognition and synthesis. Note that on the television program, no one was ever interrupted at a bad time. The system was clearly intended to be conscious of the context in which the people were operating at the time the call is initiated. Our investigation will focus on how callers can specify how strongly they want to make the connection and how callees can specify in which contexts they are willing to be interrupted. Of particular interest is how the forcefulness of the caller and the interruption threshold of the callee can be negotiated. We are also considering learning algorithms that the system can use to actually predict these levels from past experience with individual users.

2.2 Community Displays

Public spaces provide venues for public displays with highly targeted functions. We are investigating three types of community displays that will be deployed in an academic research setting. The first is a dynamic bulletin board that displays synthesized graphical and video content describing ongoing or upcoming events, visitors, and activities. Our interest here is in determining whether such displays can help students, faculty, and staff be more aware of what is going on. The second is a small touch-sensitive display at users' office doors that can display the occupant's schedule for the day (and next few days) and provides a means for visitors to leave "post-it" notes behind. The interface design issues are in how to make such interaction as close to effortless as possible using automatic user authentication and stylized messages that are integrated with the users' mail system as well. The third is a display of the activities engaged in my individuals and groups at geographically distributed sites. The objective here is to make it easy to establish context in much the same way as walking down a hallway and looking into offices.

2.3 Medical Treatment

One of principal complaints doctors have is in not knowing enough about how their patients have carried out their treatment instructions. We are working with the UW medical school to develop a set of devices, web sites, and databases that will provide doctors and patients with on-going and complete information on chronic conditions such as Type 2 (adult onset) diabetes. Issues of interest include patient privacy, patient well-being and security, and efficiency of treatment.

2.4 Early childhood development

We seek to provide early childhood developmental experts as well as parents with timely and complete information about childrens' activities in a day care center. We will construct an infrastructure that will be able to determine which children played with which others and what activities they were engaged in. This will enable parents to learn information such as who are their children's closest friends and how these may differ depending on the activity. Developmental researchers will be able to follow individual children's

development with various activities and index video records based on interesting events recorded by the sensors and location-tracking system.

In each of the above projects we seek not only to solve the pressing technical problems but also to investigate the psychological and social effects. Toward that end we employ a multi-disciplinary approach called Value-Sensitive Design. Value-Sensitive Design seeks to design technology that accounts for human values in a principled and comprehensive manner throughout the design process. A central tenant of Value-Sensitive Design is that technical mechanisms and designs support (or hinder) particular values and types of human interactions; in turn, values and desired social interactions should help drive the technological innovation.

Prior work (Friedman, Felten, & Nissenbaum, in preparation) in Value-Sensitive design on networked interactions suggests that users of networked systems value the following rights/freedoms:

- Freedom of Speech
- Freedom to Participate and End Participation (Absence of Coercion)
- Freedom to Incur Risk (Implied Consent)
- Freedom to Control Personal Information
    - Gathering of Information
    - Disclosure/Providing of Information
    - Type of Information
    - Use of Information
- Freedom of Access/Exchange of Information
- Right to Property
- Personhood/Human Dignity/Creativity/Growth
- Principles of Democracy

These "rights/freedoms" in turn suggest design constraints. That is, designs should strive to provide mechanisms that would allow users to exercise these "rights/freedoms" should the user wish to. For example, one of the freedoms is the "freedom to initiate and end participation". This freedom suggests the need for technical mechanisms that allow end-users to consent to participate and to withdraw their consent at various times during an interaction.

In our current projects, we explore (a) how each of these rights/freedoms implies design constraints, and (b) what technical mechanisms might be implemented to allow users to exercise these rights/freedoms should they wish to.

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Biographies

Gaetano Borriello is Professor in the Department of Computer Science and Engineering at the University of Washington. He has a BS in EE from the Polytechnic Institute of New York (1979), an MS in EE from Stanford University (1981), and a PhD in CS from the University of California at Berkeley (1988). He also spent four years at the Xerox Palo Alto Research Center from 1980-84. He joined the University of Washington in 1988.

Gaetano Borriello's research interests are in the design, development, and deployment of computing systems with particular emphasis on mobile and ubiquitous devices and their application. He has a wide range of interests that can be classified in embedded system design, development environments, user interfaces, and networking. They are unified by the goal of making new computing and communication devices that make life simpler by being as invisible as possible to their owners, being highly specialized and thus highly efficient for the task at hand, and able to exploit their connections to each other and the greater world-wide networks. He is currently leading the *Portolano Expedition in Invisible Computing*.

Dr. Borriello's mission is to actually make computers useful by abolishing the concepts of installation, configuration, and unifying user interfaces. He just wants them to work. Period.

Batya Friedman is Associate Professor in the School of Library and Information Science and Adjunct Associate Professor in the Department of Computer Science and Engineering at the University of Washington. She received both her B. A. and Ph.D. from the University of California, Berkeley. Her research program has commitments to the areas of Value-Sensitive Design, social-cognitive and cultural aspects of information systems, and human-computer interaction. Her publications have appeared in such journals as *ACM Transactions on Information, Journal of Systems Software, Communications of the ACM*, and *Computers in Human Behavior*. In 1997 she edited *Human Values and the Design of Computer Technology* (Cambridge University Press). She is currently funded by the National Science Foundation for a project titled *Network Browser Security and Human Values: Theory and Practice* and a second project titled *Informed Consent Online: Criteria, Metrics and the Design of Web-Based Programming Languages*. She is also co-Director of The Mina Institute.

Peter H. Kahn, Jr. is Research Associate Professor in the Department of Psychology, University of Washington. He is also Co-Director of The Mina Institute (Covelo, CA), an organization that seeks to promote, from an ethical perspective, the human relationship with nature and technology. He received his Ph.D. from the University of California, Berkeley in 1988. He has taught at the University of California, Davis, the University of Houston, and Colby College. His publications have appeared in such journals as *Child Development, Developmental Psychology, Developmental Review, Human Development, Environmental Values*, and *Journal of Systems Software*. His 1999 book (MIT Press) is titled *The Human Relationship with Nature: Development and Culture*. He is currently editing a volume (MIT Press) titled *Children and Nature: Theoretical, Conceptual, and Empirical Investigations.*