Proxemic Interactions in Ubiquitous Computing Ecologies

Nicolai Marquardt
Interactions Lab, University of Calgary
2500 University Drive NW, Calgary, AB, T2N 1N4, CANADA
nicolai.marquardt@ucalgary.ca

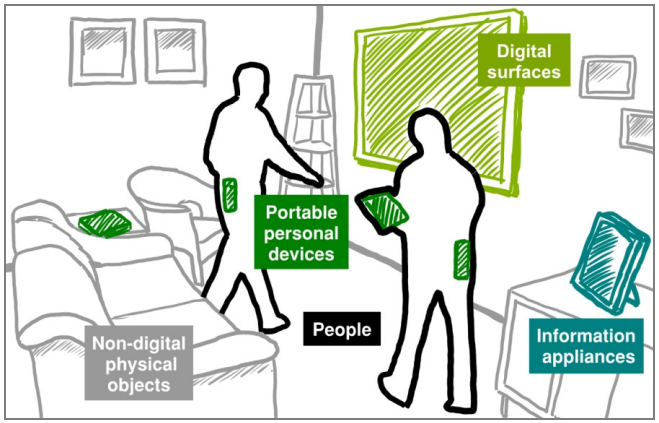

Figure 1. People, digital devices, and non-digital physical objects in a ubiquitous computing ecology.

Abstract
An important challenge in ubiquitous computing (ubicomp) is to create techniques that allow people to seamlessly and naturally connect to and interact with the increasing number of digital devices. I propose to leverage the knowledge of people's and devices' spatial relationships – called proxemics – in ubicomp interaction design. I introduce my work of proxemic interactions that consider fine-grained information of proxemics to mediate people's interactions with digital devices, such as large digital surfaces or portable personal devices. This research includes the design of development tools for programmers creating proxemic-aware systems, and the design and evaluation of such interactive ubicomp systems.

Proc CHI Extended Abstracts 2011, Doctoral Consortium, May 7–12, 2011, Vancouver, BC, Canada. ACM 978-1-4503-0268-5/11/05.

Keywords
Proxemics, interaction, user interfaces, ubiquitous computing, digital interactive surfaces, digital devices

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces: Input devices and strategies.

General Terms
Human Factors, Design

Introduction and Motivation
In everyday life, the interpretation of spatial relationships between ourselves and other people or objects around us is important for how we engage, interact, and communicate. For example, researchers have investigated how we keep certain distances to others depending on familiarity; how we orient towards people when addressing them; how we move closer to objects we are interested in; and how we stand or sit relative to others depending on the task at hand (e.g., [1] [5] [9]). Anthropologist Edward Hall [5] coined the term *proxemics* for a theory of how people use distance, posture, and orientation to mediate relations to other people. Hall correlates physical distance with social distance (in a culturally dependent manner): *intimate 6-18", personal 1.5-4', social 4-12',* and *public 12->25'* distances. As the terms suggest, the distances lend themselves to a progression of interactions ranging from highly intimate to personal, social, and public [5]. Hall also describes people's expectations of space,

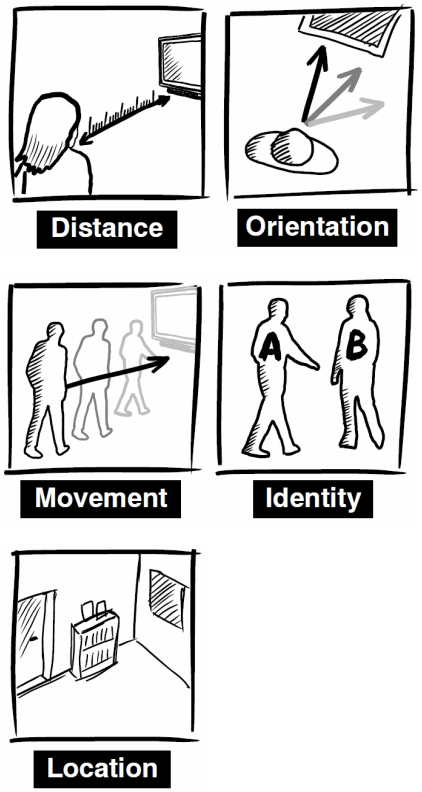

Figure 2. Five essential dimensions for ubicomp systems to determine proxemic relationships: distance, orientation, movement, identity, and location.

including the role of the *fixed* (immobile) and *semi-fixed* (movable) features in their environment. Other researchers added further concepts, such as models describing optimal proxemic distances [10], or considering people's relative orientation [9].

Now consider ubicomp systems in this context. In contrast to desktop computing, ubicomp technology is increasingly integrated into everyday objects and environments [13]. But in spite of the opportunities presented by people's natural understanding of proxemics, ubicomp devices are usually oblivious to their subtle proxemic relationships. Most ubicomp devices – such as those shown in Figure 1 – do not recognize the presence or approach of nearby people, objects, or other devices; or the spatial relationships in between. This is a lost opportunity, since the rules of proxemics would serve as valuable form of input in these situations to mediate people's interaction with these novel computing interfaces. When considering the future proliferation of ubicomp systems accessible in people's everyday life, it is crucial to find techniques that let people seamlessly and naturally connect and interact with the devices around them. Hall emphasized the role of proxemic relationships as a form of people's implicit communication – and this is a form of communication that ubicomp devices have yet to understand.

Planned Research Contributions

In my dissertation I address the research question of how to apply proxemics to inform ubicomp interaction design. I want to understand how ubicomp devices can leverage fine grained knowledge of proxemic relationships to mediate people's interactions in *ubicomp ecologies*. I understand such ubicomp ecologies as composed of the following entities (see Figure 1): large interactive surfaces, information appliances, portable personal devices, and non-digital physical objects. To address this research question, I plan to provide the following three inter-connected contributions:

(1) **Framework of Proxemic Interactions:** Adapting and translating important proxemic theories to inform the design of ubicomp interaction. This includes identifying the essential proxemic dimensions for ubicomp interaction, and the design of concepts for *proxemic interaction* considering these dimensions. My goal is to formulate these in a *conceptual framework of proxemic interactions* in ubicomp ecologies, describing the main design variables, functions of proxemics, and how they relate to ubicomp interaction design.

(2) **Developer tools:** Designing and evaluating tools that make these proxemic relationships accessible to ubicomp system developers.

(3) **Proxemic-aware ubicomp systems:** Designing and evaluating proxemic-aware devices and digital surfaces that understand and interpret the language of proxemics, and react appropriately to people, objects, and devices entering and moving through the space around them. They will be built using the developer tools (Obj. 2) and illustrate the concepts of proxemic interactions (Obj. 1). The evaluation of these systems and a derived set of design guidelines will feed back into the conceptual framework informing the design of future proxemic-aware interfaces.

Related Work of Proxemics in Ubicomp

A few fundamental projects of interactive systems – usually within the area of ubicomp [13] – incorporate spatial relationships of people and devices within interaction design. Some systems trigger activity by detecting the presence of a person within a space [12], or

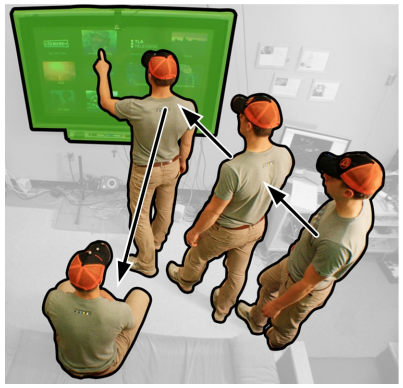

Figure 3. Illustrating proxemic interaction: a large interactive surface reacts to a person's distance, orientation, and approach relative to the display.

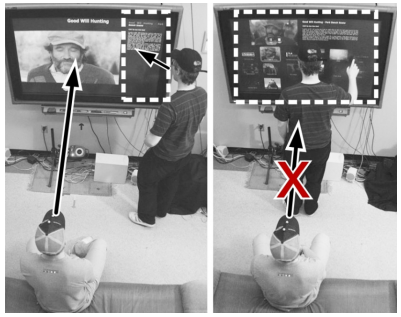

Figure 4. Mediating simultaneous interaction of multiple people.

react to a device within a given range [8]. While powerful, this is only a coarse measurement of proxemics as it only considers distance as a binary value (i.e., in a certain range or not). Other projects considered spatial aware mobile devices interacting in close proximity of a large digital surface. Notably, the Chameleon [4] and M-Pad [8] palmtop computers are aware of their orientation and location to change displayed content.

Researchers also considered vertical surfaces that react to the spatial presence of people. Hello.Wall [7] introduced the notion of *distance-dependent semantics*, where the distance of an individual from the wall defined the interactions offered and the kind of information shown. Vogel [11] took this concept further, where they directly applied Hall's theory to define four proxemic zones of interaction. From far to close, these ranged from ambient display, to implicit, subtle, and finally personal interaction. A major idea in this work – developed even further by Ju [6] – is that interaction from afar is public and implicit, and becomes more private and explicit as people move towards the surface.

Research to Date

To address these research objectives, we began distilling important proxemic theories from the literature and began translating these social theories to inform the design of ubicomp systems. While many dimensions are used by people to mediate their interpersonal proxemic interactions, we identified five essential dimensions for an ubicomp system to determine proxemic relationships: *distance*, *orientation*, *movement*, *identity, and location* (Figure 2). We introduced concepts of *proxemic interaction* that explain how to leverage measured relationships in these five dimensions to drive possible interactions [2].

These concepts of proxemic interactions are illustrated through the design of an interactive vertical display surface that recognizes the proximity of surrounding people, digital devices, and non-digital objects. Here, proxemic information can regulate both *implicit* and *explicit* interaction techniques, either based on continuous movement, or by movement in and out of discrete proxemic zones. For instance, a media player application shown on the large display *implicitly* reacts to the approach and orientation of a person (sequence in Figure 3) and their personal devices by changing information displayed on the screen or triggering application functions. Furthermore, *explicit* interaction (such as pointing) is supported from varying distances to the interactive display surface.

Proxemic interactions also consider aspects of the *fixed* and *semi-fixed feature environment*; for instance, by distinguishing a person sitting from another one standing in front of the screen at the same distance. The simultaneous interaction of multiple people is mediated by considering their precise spatial relationships to the device. For instance, the system can allow simultaneous interaction on a split screen when people approach from different directions (Fig. 4 left), or favor the person that is closest to the screen and that is physically blocking the view of the second person (Fig. 4 right).

Further research

Framework of Proxemic Interaction. I currently translate further proxemic theories to address interactions in ubicomp ecologies; discuss the essential proxemic dimensions and their granularity/fidelity; and explain how measurements of these dimensions can be leveraged in novel interaction techniques for ubicomp systems.

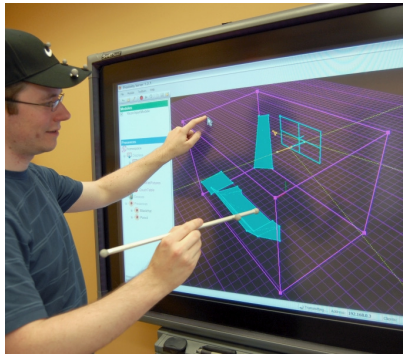

Figure 5. Proxemics toolkit visualization.

Proxemics Toolkit. Based on earlier collaborative work on a sensing toolkit, I currently design the *proxemics toolkit* that facilitates access to proxemic information of tracked entities in small space ubicomp environments (Figure 5). This toolkit provides easy access to fine-grained information of people's and devices' distance, orientation, movement, location, and identity; and the relationships in between. The tracking is implemented through a VICON motion capturing system [www.vicon.com], but the toolkit is designed in a way allowing other sources. The first version of the toolkit will be further refined by evaluating programmer's use of the toolkit to build proxemic-aware applications.

Proxemic-aware systems. In a following step, I will design proxemic-aware systems using the proxemics toolkit. In particular, I will apply proxemic knowledge to mitigate existing interaction problems in ubicomp ecologies, such as the difficulties of addressing a particular device, sharing information between devices, and authorizing access to devices (e.g., summarized in [3]). Here, proxemic information will be used to implicitly offer a person sharing and connection options between digital devices; implicitly establish and break up connections; filter interaction possibilities; and authorize access to devices – all defined as a function of the person's or devices' identity, location, distance, orientation, and movement in space.

Summary

With my dissertation research I will identify ways to leverage the knowledge of proxemic relationships in ubicomp ecologies to mediate interactions. This work extends beyond earlier research by considering fine grained measurements of proxemic relationships, and by introducing novel interaction techniques leveraging this information. The conceptual framework of proxemic interaction and design guidelines will inform future designs of proxemic-aware interfaces that understand and interpret people's use of the space around them.

References

[1] Altman, I. *The Environment and Social Behavior: Privacy, Personal Space, Territory, and Crowding.* Brooks/Cole Publishing, 1975.

[2] Ballendat, T., Marquardt, N., and Greenberg, S. Proxemic Interaction: Designing for a Proximity and Orientation-Aware Environment. *Proc. of ITS '10, ACM,* 2010.

[3] Bellotti, V., et al. Making sense of sensing systems: five questions for designers and researchers. *Proc. of CHI '02*, ACM, 2002.

[4] Fitzmaurice, G.W. Situated information spaces and spatially aware palmtop computers. *Com. ACM 36*, 7, 1993.

[5] Hall, E.T. *The Hidden Dimension*. Doubleday, 1966.

[6] Ju, W., et al. Range: exploring implicit interaction through electronic whiteboard design. *Proc. of CSCW '08, ACM,* 2008, 17-26.

[7] Prante, T., et al. Hello. Wall–Beyond Ambient Displays. *Adj. Proc. of Ubicomp*, 2003.

[8] Rekimoto, J. Pick-and-drop: A Direct Manipulation Technique For Multiple Computer Environments. *Proc. of UIST '97*, ACM, 1997, 31-39.

[9] Sommer, R. *Personal space: the behavioral basis of design.* Prentice-Hall, 1969.

[10] Sundstrom, E. and Altman, I. Interpersonal relationships and personal space: Research review and theoretical model. *Human Eco. 4*, 1 (1976), 47-67.

[11] Vogel, D. and Balakrishnan, R. Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users. *Proc. of UIST '04*, ACM, 2004, 137-146.

[12] Want, R., et al. The Active Badge Location System. *ACM TOIS 10*, 1, 1992, 91–102.

[13] Weiser, M. The Computer for the 21st Century. *Scientific American 265*, (1991), 94.