Applying Proxemics to Mediate People's Interaction with Devices in Ubiquitous Computing Ecologies

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ABSTRACT

Through vastly increasing availability of digital devices in people's everyday life, ubiquitous computing (ubicomp) ecologies are emerging. An important challenge here is the design of adequate techniques that facilitate people's interaction with these ubicomp devices. In my research, I explore how the knowledge of people's and devices' spatial relationships – called *proxemics* – can be applied to interaction design. I introduce concepts 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. In particular, my work considers four dimensions that are essential to determine basic proxemic relationships of people and devices: *position, orientation, movement*, and *identity*. I outline my previous and current work towards a framework of proxemic interaction, the design of adequate development tools, and the implementation and evaluation of applications that illustrate concepts of proxemic interactions.

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General terms: Design**,** Human Factors

Keywords: Proxemics, interaction, ubicomp, surfaces

INTRODUCTION AND BACKGROUND

In our everyday life, the spatial relationships between ourselves and people or objects around us are important for how we engage, interact, and communicate. For instance, we keep certain distances to others depending on familiarity; we orient towards people when addressing them; we move closer to objects we are interested in; and we stand or sit relative to others depending on the task at hand [1] [7] [16]. Anthropologist Edward Hall introduced *proxemics* as a theory for studying these interpersonal spatial relationships [7]. The proxemic theory describes how people perceive, interpret and use distance, posture and orientation to mediate relations to other people, but also the *fixed* (immobile) and *semi-fixed* (movable) features in their environment. Hall also 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, to social and then to public [7]. Proxemics became a widely applied seminal theory of studying people's use and structure of personal space; with others adding further concepts, such as models describing optimal proxemic distances as a function of familiarity and context [17], or people's preference of spatial arrangements and relative orientation depending on the task at hand [16].

Hall emphasized the role of proxemic relationships as a form of people's implicit communication – and this is a form of communication that interactive computing systems yet have learn to understand. However, in spite of the contextually rich information of proxemics and the opportunities presented by people's natural understanding of them, current digital devices in people's everyday environment – such as those shown in Figure 1 – usually neither recognize the presence of nearby people, objects, or other devices, nor the spatial relationships in between. This is a lost opportunity, since the rules of proxemics can serve as valuable form of input in these situations to mediate people's interaction with novel computing interfaces.
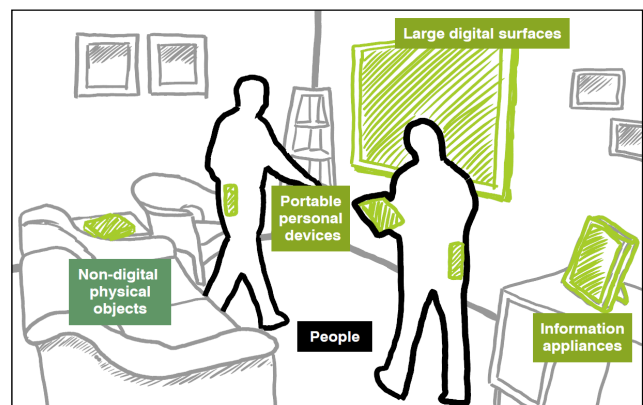

Figure 1. People, devices, and non-digital objects in a ubiquitous computing ecology.

In my dissertation research, I focus on the study of *proxemics* applied to interactions in ecologies of people and devices in ubiquitous computing (ubicomp) environments. In particular, I explore how the fine-grained knowledge of proxemic relationships (i.e., *position, orientation, movement*, and *identity*) between people, objects, devices, and the surrounding environment can mediate the interaction

with ubicomp systems (Figure 1). I design and evaluate devices and digital surfaces that understand and interpret the language of proxemics, and react appropriately and continuously to people, objects, and devices entering and moving in the space around them. Through a framework of proxemic interaction and design guidelines I plan to inform the design of future proxemic-aware interfaces. As in the near future we will likely see an increase of digital devices 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.

Figure 2. Ubicomp ecology: multiple people interacting with personal portable devices, information appliances, large digital surfaces, and non-digital objects.

In the next sections, I briefly review related research that considers spatial relationships in ubicomp. Next, I introduce my dissertation research objectives. Then, I outline my progress in achieving these objectives to date, and provide an overview of ongoing and future research.

RELATED WORK

Only a relatively small number of interactive systems – usually projects within the area of ubicomp [20] – incorporate spatial relationships of people and devices within interaction design.

For example, some systems trigger activity by detecting the presence of a person within a space [5] [19], or react to a device within a given range [14] – often when in direct touch distance [9] [10]. 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 [6] palmtop computer is aware of its orientation and location and changes the displayed content based on this information. Similarly, the M-Pad [14] works as a spatial aware toolglass.

Researchers also designed vertical surfaces that react to the spatial presence of people. For instance, Shoemaker [15] introduced techniques that let a person directly interact with digital content on a vertical wall surface through real or virtual shadows. Hello.Wall [13] 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 [18] took this concept even further, where they directly applied Hall's theory to define four proxemic zones of interaction. From far to close, these ranged from ambient display of information, to implicit, then subtle, and finally personal interaction. A major idea in this work – developed even further by Ju [11] – is that interaction from afar is public and implicit,
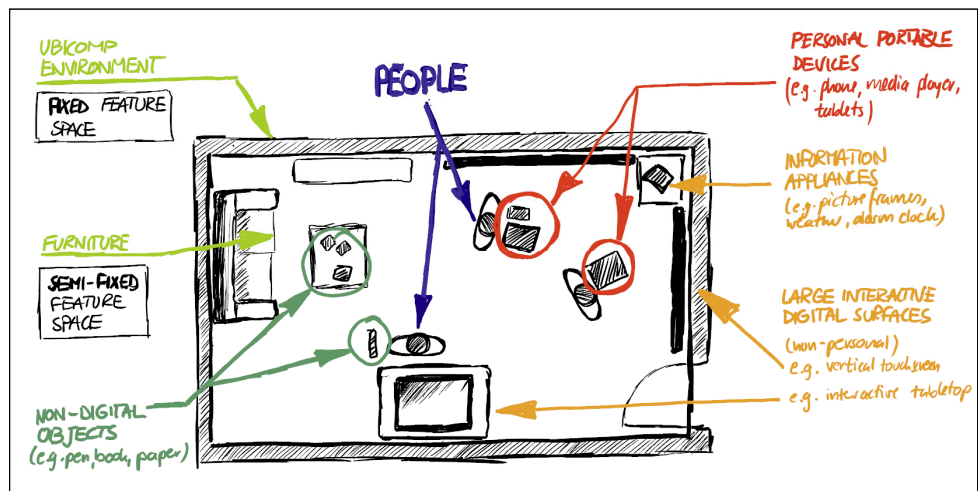
and becomes more private and explicit as people move towards the surface.

In my research, I will extend this prior work by exploiting continuous distance, orientation, movement and identity to tune device and surface interaction, where I also incorporate multiple people and features of the fixed and semi-fixed environment as a complete ecology.

RESEARCH OBJECTIVES

My dissertation objectives address the research question of how to apply the knowledge of proxemics to inform interaction design. My goal is to understand how to leverage fine grained knowledge of proxemic relationships to mediate interactions in complete ubicomp ecologies, composed of the following entities (see Figures 1 and 2):

- **People** (single person to small groups, i.e., 1-4 people)
- **Large interactive digital surfaces** (e.g., vertical screen, horizontal tabletop)
- **Information appliances** (e.g., digital picture frames)
- **Personal portable devices** (e.g., phone, media player)
- **Non-digital physical objects** in the environment (e.g., furniture, books)
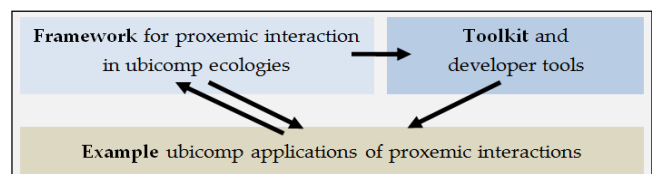

Figure 3. Overview of the inter-connected research objectives.

In particular, I am working towards the following three inter-connected research objectives (illustrated in Figure 3).

1. **Framework of Proxemic Interaction.** I distil important proxemic theories to apply to the design of ubicomp applications; adapt and transform these theories to address the essential dimensions of proxemic relationships in ubicomp ecologies; and develop a conceptual framework of people's proxemic interactions in ubicomp ecologies.

2. **Developer tools for rapidly prototyping proxemic-aware applications.** This includes the exploration of adequate technologies for sensing proxemic relationships in ubicomp ecologies and the design of development tools that make these proxemic relationships accessible for developers. While earlier toolkits allow access to ubicomp sensor data (e.g., [8] [12]), none of these specifically addresses the development requirements of proxemic-aware applications in ubicomp ecologies: the easy access to position, orientation, identity, and movement of entities; the definition of features of the fixed and semi-fixed feature space, and the relationships between these entities.

3. **Design and evaluation of Proxemic Interaction applications.** I develop and evaluate proxemic-aware systems illustrating both the application of proxemic interaction concepts and the use of the provided developer tools. These applications will apply proxemic knowledge to mitigate common 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., [3][4]). The evaluation of these applications will further inform the extension and refinement of the conceptual framework and lead to a set of guidelines informing the design of future proxemic-aware interfaces.

PROXEMIC INTERACTIONS IN UBICOMP ECOLOGIES

To move towards achieving my research objectives, I (in collaboration with members of my research group) began distilling important proxemic theories from the literature, identifying essential dimensions to incorporate proxemics in ubicomp interfaces, defined an extended
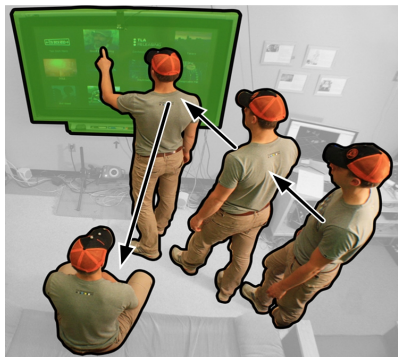

Figure 4. Illustrating proxemic interactions: a media player application reacts to a person approaching the display.

notion of proxemics in regards to ubicomp interaction, and introduced concepts for proxemic interaction [2]. In this first step, these concepts address in particular the relationship of people and devices in regards to a large interactive vertical surface.

While many dimensions are used by people to mediate their interpersonal proxemic interactions, we identified four dimensions essential for a system to determine the basic proxemic relationships between entities (people, digital devices, and non-digital objects): *position*, *orientation*, *movement*, and *identity*. Our concepts of proxemic interaction explain how to leverage information about these four dimensions to drive possible interactions [2]. These concepts are illustrated with the design of an interactive vertic-
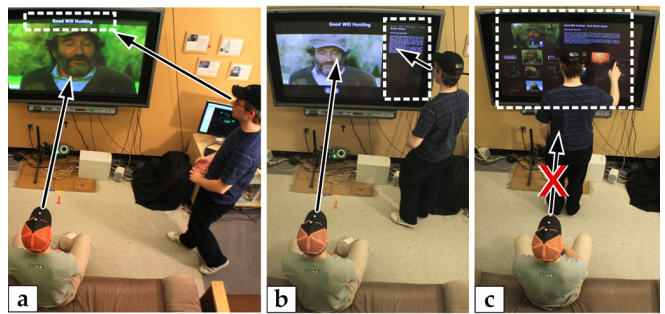

Figure 5. Mediating simultaneous interaction of multiple people.

al display surface that recognizes the proximity of surrounding people, digital devices, and non-digital objects. The example application is an interactive home video media player centered around a vertical surface in a living room (Figure 4). Building upon Vogel's [18] and Ju's [11] work, we demonstrate how 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, the media player application *implicitly* reacts to the approach and orientation of people (Figure 4), and their personal devices and objects. Depending on the distance of people to the display and their movements, the application implicitly changes information displayed on the screen, and reacts by implicitly triggering application functions. Furthermore, we explain how *explicit* interaction is supported from these varying distances to the interactive display surface.

Proxemic interactions also consider aspects of the *fixed* and *semifixed feature environment* (e.g., distinguish a person sitting or standing in front of the screen at the same distance), and extend attentive interfaces. These concepts extend beyond pairwise interaction and consider one person or multiple people in relation to an *ecology* of multiple devices and objects in their nearby environment. For instance, we introduce techniques of how to mediate the simultaneous interaction of multiple people (illustrated in Figure 5).

FURTHER RESEARCH

I am currently working on further projects to continue this research, extend the concepts, and address the aforementioned research objectives.

Towards objective 1. In the next step, I will further extend, complement, and refine the concepts of proxemic interaction. I will bring together proxemic theories and ubicomp interaction design in a conceptual framework of proxemic interaction. In particular, I will discuss the extension and transformation of proxemic theories to address interactions in ubicomp ecologies, leading to an extended notion of proxemics. The refinement of this conceptual framework will also be informed through the further design and evaluation of proxemic-aware applications.

Towards objective 2. I am currently involved in the design of the *proximity toolkit* that facilitates access to proxemic information of tracked entities (currently implemented through the VICON motion capturing system

[www.vicon.com], but designed in a way that allows diverse data providers). The toolkit will be further refined by evaluating the developers' use of the toolkit to build proxemic aware applications.

Towards objective 3. Further, I am currently working on applications using concepts of proxemic interactions to mediate people's simultaneous interactions with a large number of devices. Here, proxemic information is used to implicitly offer a person sharing and connection options between digital devices; implicitly establish and break connections; filter interaction possibilities; and authorize access to devices – all defined as a function of the person's or devices' identity, location, orientation, and movement in space.

CONCLUSION

In my dissertation research, I plan to identify techniques of how to leverage the knowledge of proxemic relationships between people, digital devices, non-digital objects, and the environment to inform the design of interactive ubicomp systems. This work extends beyond earlier research in this area by considering fine-grained measurements of proxemic relationships in the complete ubicomp ecology, and by introducing novel interaction techniques to leverage these proxemic dimensions. By providing adequate developer tools, a conceptual framework of proxemic interaction, and design guidelines, I want to inform future designs of interfaces that understand and interpret people's use of the space around them. Such novel ways of supporting people's seamless and natural interaction with devices around them are becoming even more important in the near future, as it can be expected that the number of available digital devices in people's everyday environment will increase continuously in the years to come.

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