Report from Dagstuhl Seminar 13452

Proxemics in Human-Computer Interaction

Edited by

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Abstract

In 1966, anthropologist Edward Hall coined the term "proxemics." Proxemics is an area of study that identifies the culturally dependent ways in which people use interpersonal distance to understand and mediate their interactions with others [1]. Recent research has demonstrated the use of proxemics in human-computer interaction (HCI) for supporting users' explicit and implicit interactions in a range of uses, including remote office collaboration, home entertainment, and games. One promise of proxemics is the realization of context-aware environments, which have been extensively pursued since Mark Weiser's seminal paper, "The computer for the 21st century," written in 1991. However, the potential of proxemics in HCI is still underexplored and many research questions remain unanswered.

With the growing interest in using proxemics, we organized the Dagstuhl Seminar 13452 on the topic. "Proxemics in Human-Computer Interaction," was held from November 3–8, 2013, and it brought together established experts and young researchers from fields particularly relevant to Proxemic Interactions, including computer science, social science, cognitive science, and design. Through an open keynote, mini talks, brainstorming, and discussion in breakout sessions, seminar attendees identified and discussed challenges and developed directions for future research of proxemics in HCI.

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1 Executive Summary

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Introduction

Over time, people encounter different dimensions of proxemics in everyday life, such as in face-to-face communication while discussing ongoing work with colleagues, in an elevator with strangers as private space is suspended, or at home with their families. In disciplines like architecture and interior design, knowledge about proxemics has been used for decades to model use of space for face-to-face interactions, urban planning, and environmental design. In human-computer interaction (HCI) and human-robot interaction (HRI), the use of proxemics is fairly new, and both disciplines recently began employing proxemics and related theories and models (e.g., Hall's theory of proxemics in his book, "The Hidden Dimension" [2]) to design new interaction concepts that act on proxemics features. Several recent designs explore the use of human body position, orientation, and movement for implicit interaction with large displays, supporting collaboration, and to control and communicate with robots. This research is facilitated by the operationalization of proxemics for ubiquitous computing [16], toolkits to track proxemics [7, 8, 9], and new paradigms such as reality-based interaction (RBI) [4] or Blended Interaction [6] that take a fresh look at the role of the user's body and the environment in HCI. However, work on understanding how proxemics can be used for HCI (and HRI) has only just begun (e.g., Proxemic Interactions [1]).

Goals and Structure

In the seminar, we used Greenberg et al.'s dimensions on Proxemic Interactions [1] and Pedersen et al.'s Egocentric Interaction Paradigm [11] as starting points. These theories are based on findings regarding how humans perceive proxemics; therefore, they might be incomplete, particularly since human perception is much more subtle, gradual, and less discrete than illustrated in Hall's reaction bubbles (proxemic zones [2]). In addition, these discrete zones cope with only the physical features (perception of interpersonal distance). Other features, such as psychological and psychophysical features, have not yet been considered in HCI. However, these features are perceptible by human sensors (olfaction, equilibrioception, and thermoception). Current theories neither give guidelines nor provide sufficient methods for "good" or "bad" designs for systems employing proxemics.

We thought the time was right for bringing researchers with different backgrounds and experiences together to map out the important questions that remain unanswered and to generate ideas for developing an agenda for future research on proxemics in HCI.

The structure of the seminar was based on the four pillars technology, application, vision, and theory that were equally exposed in seminar activities. The forum held 29 attendees with multidisciplinary backgrounds from research institutes in Canada, Denmark, England, Switzerland, Australia, France, Belgium, and Germany. We achieved productive and critical reflections and prospects on proxemics in HCI by letting experts from their respective fields work on a shared vision and theory. We selected the attendees to ensure an equal distribution of expertise across the four pillars.

The diversified program allowed attendees to introduce themselves and their work in brief presentations and offered one impulse keynote given by Saul Greenberg and Nicolai Marquardt. Greenberg and Marquardt coined the term Proxemic Interactions and decisively influenced the application of proxemics in HCI. We also provided ample time for discussions, breakout sessions, and creative work addressing concepts such as:

- Intelligibility of Proxemic Interactions
- Users' options to opt-in or opt-out
- The "dark side" of Proxemic Interactions
- The meaning of physical space
- How image schemas [3] can be used to brainstorm innovative proxemic systems
- Ad-Hoc proxemics
- Including everyday entities in proxemic systems

Throughout the entire seminar, attendees were encouraged to write down their questions, ideas, and comments. These materials were collected and posted to one of the four pillars on a pin board for the purpose of inspiring breakout groups and ad lib collaboration. The breakout session proposed by the group centered around open problems and challenges within proxemic interactions, which was then discussed in each session.

Technology

In recent years, emerging technology has changed the interaction between human and computer. For instance, smartphones and tablets have entered our daily life. More of such novel post-WIMP[1] technologies will be available in the foreseeable future and ultimately define how we interact in physical spaces. Interaction might take place across device boundaries on (multiple) public [15], large and private, mobile, and tangible displays [13]. It might involve collaboration of co-located users around interactive tabletops [7], in front of large vertical screens [5], or on rollout displays [14]. It might be based on non-traditional, post-WIMP interaction styles, such as pen-based [10], multi-touch, and tangible user interfaces. Or, it might provide new forms of functionality beyond the traditional WIMP model of applications by tracking users' spatial location and movements for navigation within large, digital information spaces [12]. Attendees discussed existing technologies that allow people-to-people, people-to-object, and object-to-object proxemics relations tracking, as well as improvements on tracking reliability using sensor fusion.

Application

Seminar attendees discussed the "light" and "dark" side of Proxemic Interactions. Until now, research has focused on the benefits of these interactions; however, they bear risks. We all can imagine how advertisement would change if it becomes possible to show customized ads according to our online shopping profiles while we are walking on public streets or in shopping malls. During the seminar, participants discussed what types of applications would best showcase the benefit of proxemics and avoid the risks that arise when systems are able to track and identify people. Part of this discussion included brainstorming opt-in or opt-out functions for proxemics-aware systems so that users can remain in control of these systems.

Vision

In its past, HCI has benefited from ambitious visions of future interaction such as Apple's Knowledge Navigator or Mark Weiser's "A day in the life of Sal" [16]. Although visions are not always helpful and can lead in wrong directions, we believe that a new overarching vision of future Proxemic Interactions can help inspire ongoing research and thrive in coming generations. This vision is intended to inform researchers, designers, and laymen alike. For researchers, a vision can serve to illustrate research goals, trigger new research directions, and create awareness for as yet un-reflected assumptions in our field. For designers, visions help to present concepts and technologies as a part of a believable scenario – and not only in the isolation of conference papers. Furthermore, visions serve to fascinate and inspire laymen, who prefer to learn about future technologies from narrations instead of purely technical publications. The seminar aimed at creating a unified vision of Proxemic Interactions based

[1] WIMP stands as an acronym for Windows, Icons, Menus, Pointers

on the individual contributions and experiences of the seminar attendees. Current and past visions have been discussed in plenum and breakout groups.

Theory

In the light of the countless variants and dynamics of post-WIMP interaction, traditional collections of design guidelines or "golden rules" cannot provide enough guidance about "good" or "bad" designs. Instead, we need better theories and models of human cognition to be able to understand and classify designs of Proxemic Interactions and to predict their appropriateness. We wanted to understand how physical, psychological and psychophysical features collate and can be transferred into a coherent theory of proxemics in HCI and how to give guidelines or provide sufficient methods for "good" or "bad" designs. Therefore, we had to:

1. Better understand proxemics in HCI to develop such methods
2. Discuss the open question: to what extent can proxemics leverage or constrain human-computer interaction?

Conclusion

The Dagstuhl Seminar 13452 offered a fantastic forum for established researchers and practitioners at a comfortable place. We framed and discussed research questions and worked together on a unifying theory for Proxemics in Human-Computer Interaction. Applications for Proxemic Interactions were sketched out and critically reflected in the light of the "dark side" of proxemics. We also discussed how we can learn from related fields and how they can profit from proxemics in HCI.

The seminar can be seen as a good starting point to identify the role of Proxemics in Human-Computer Interaction. However, it still remains an open research area and its place in HCI needs to be better understood.

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Working Groups

3 Open Keynote

3.1 Proxemic Interactions

Saul Greenberg (University of Calgary, CA) and Nicolai Marquardt (University College London, UK)

In the everyday world, much of what we do as social beings is dictated by how we interpret spatial relationships. This is called proxemics. What is surprising is how little people's expectations of spatial relationships are used in interaction design, i.e., in terms of mediating people's interactions with surrounding digital devices such as digital surfaces, mobile phones, tablets, and computers. Our interest is in proxemic interaction, which imagines a world of devices that have fine-grained knowledge of nearby people and other devices – how they move into range, their precise distance, their identity and even their orientation – and how such knowledge can be exploited to design interaction techniques. Just as people expect increasing engagement and intimacy as they approach others, so should they naturally expect increasing connectivity and interaction possibilities as they bring themselves and their devices in close proximity to one another and to other things in their everyday ecology. The joint introductory seminar by Greenberg and Marquardt introduced the notion of proxemics. It begins by stepping through a brief history of the evolution of HCI from user-centered design to present-day embodied interaction. It then introduces Hall's social science theory of proxemics, followed by variations of how others have developed this theory of proxemics to both refine and extend what is covered by it. The seminar then turned to proxemic interactions, which applies the theory to system design. It described how proxemics can be operationalized by what can be sensed and stored by computer, and then how a toolkit – the Proximity Toolkit – can simplify how programmers access and use this sensed data to build prototypes. A variety of prototypes are then presented around various proxemic relationships: from person to device and device to device interaction, and from considering factors such as f-formations and micromobility. The talk closed with some brief pointers to related work, and by walking through selected challenges within the area.

4 Overview of Talks

4.1 Investigating the Influence of Culture on Proxemic Behavior for Humanoid Robots

Elisabeth André (Universität Augsburg, DE)

In social robotics, the behavior of humanoid robots is intended to be designed in a way that they behave in a human-like manner and serve as natural interaction partners for human users. Several aspects of human behavior such as speech, gestures, eye-gaze as well as the personal and social background of the user need therefore to be considered. In my talk, I will focus on interpersonal distance as a behavioral aspect that varies with the cultural background of the user. I will present two studies that explore whether users of different cultures (Arabs and Germans) expect robots to behave similar to their own cultural background. The results of the first study reveal that Arabs and Germans have different expectations on the interpersonal distance between themselves and robots in a static setting. In the second study, we use the results of the first study to investigate the users' reactions on robots using the observed interpersonal distances themselves. Although the data of this dynamic setting is not conclusive, it suggests that users prefer robots that show behavior that has been observed for their own cultural background before.

4.2 Virtual Proxemics

Jakob E. Bardram (IT University of Copenhagen, DK)

In this talk I want to discuss the concept of "Virtual Proxemics". I want to base this discussion on an on-going research project and I'm looking for input and options for brainstorming on this case together with the participants of the Dagstuhl seminar. The background for the concept of Virtual Proxemics is a research project on supporting global software development (GSD). Today, GSD is extensively used in all sorts of organizations and for all sorts of software engineering projects. Starting with the outsourcing of more trivial IT tasks like operations, support, and testing, software design, implementation, and engineering is increasingly being outsourced to countries with cheaper labor and a larger resource pool (like India, China, Pakistan, Philippines, Kenya, etc.). It is extremely well documented that GSD comes with a long list of challenges, which are related to the distributed nature of software development. In our project we operate with distance in terms of time, space, and culture. In order to mitigate these challenges and to manage large distributed software engineering projects, many organizations are using more traditional, classic waterfall-like software development methodologies – which have their own set of challenges, and often lead to project that deliver the "wrong" system later and over-budget. Agile software development methods like extreme programming (XP) and scrum have successfully been applied and have mitigated the problems of the classic software engineering problems. At the core of all agile methods is the insistence on working closely together in a collocated team of programmers, testers, product owners, and client representatives. In other words, the engine of agile development is close proximity of team members and the various tools they use. Several researcher and practitioners haves asked the questions if agile methods like scrum could work in a distributed manner in a GSD project and this has been tried out in many research projects and companies. In this project, we have been working with – and studying – a company in Copenhagen that tries to apply scrum in a GSD setup with developers in India. Some of the scrum principles work, but mainly because the remote (seen from Copenhagen) team in India is represented with a local proxy, i.e. a senior lead programmer located in the Danish office. Currently we are engaging in a design process aimed at designing tools for supporting global scrum. In particular we're interested in supporting the proxemics of a local scrum virtually over distance. A concrete design challenge is to provide the feeling of proximity across a team that is spread across (at least) two locations.Specifically we're right now designing a global scrum board. The scrum board is the central artifact in scrum that hold all information on the progress of the project (and the so-called "sprints" in which all the work is done). The scrum board is a very public and very visible board with all sorts of information mostly written on post-it notes that are moved around. The board also work as the central focus point during the daily scrum meetings. We want to design a scrum board that support at least the following three aspects in a virtual setup:

1. Tangible handling of post-it notes (or similar)
2. "Collocated" awareness of the progress of work
3. Ad-hoc meeting support based on the proximity of the (distributed) team in front of the board

As said, we're in the process of designing this, and I would very much like to seek input from the participants on the seminar. I would also like to discuss the concept of "Virtual Proxemics" in greater details.

4.3 Social Interaction in Pallative Care

Susanne Boll (Universität Oldenburg, DE)

Palliative care is taking care of individuals who are in the last year of their life. In this special phase of the life, social contacts are of important relevance for the quality of life. In these days, friends and family are often living at different places and communication is realized by selected explicit communication such as phone calls. In the same way implicit, non-verbal commnication plays an important role to communicate a sense of integration into a social community. One challenge for Prexemics in HCI is to develop a sense of social proximity between geographically distant people through human-computer interaction. In our work we focuse on the revival of social interaction through intuitive implicit communication and fully integrated into everyday activities. Novel multimodal human-computer interaction methods need to be designed to adapt to the individual situations of the interaction partners. I our research, we examine how through different sensory modalities such as light, sound, and by the activation of existing devices in the home people can be in implicit communication. With everyday pervasive interaction devices, which are unobtrusively integrated into the budget, we aim to raise awareness of the situation and activities locally separated but emotionally closely related individuals should be created. Simultaneously simple and intuitive ways to signal situations are recognized, in which an explicit communication channel can be initiated.

4.4 Tangible Views into Rich Information Spaces in Proximity of Large Displays

Raimund Dachselt (TU Dresden, DE)

With regard to large interactive surfaces, such as tabletops and display walls, interaction research mostly focusses on two dominant ways of interaction. On the one hand, this is direct interaction on the surface of the displays, e.g., by means of multi-touch or pen input. On the other hand, it is a remote operation of a large display by users standing or sitting in some distance, e.g., by means of handheld mobile devices or mid-air gestures. We have explicitly investigated the large cubic interaction space in front of a wall display or above a tabletop and the way how rich information spaces can be mapped into this virtual volume. By means of interacting with handheld magic lenses, i.e. tangible displays tracked in space, several users are able to explore 2D or 3D information in a very natural and seamless fashion. The complete unification of output and input space as well as the careful usage of spatial relationships between several users, several tangible displays, large contextual displays, and the virtual information allow for rich and expressive ways of navigating and exploring data spaces.

4.5 The Meaning of Space in Interaction

Joern Hurtienne (Universität Würzburg, DE)

Space means a lot to us humans. In early childhood we have learned important connections between space and abstract concepts. For example, the dimension near-far is loaded with experiences in our everyday lives. We put things near to us when we need to ponder about them and put them further away when we don't (considered-is-near mapping). We group similar things close together and keep dissimilar things separate and further away (similar-is-near mapping). Friends may be physically near, but could be described as being close to us when living several thousand miles away (intimacy-is-closeness mapping). Near objects can exert their influence on us and we can exert influence on them better than on far objects (strength of effect is closeness).

We can extend these observations of so-called primary metaphors to other dimensions of space: centre-periphery, up-down, front-back, left-right, being inside or outside of containers. The questions to be discussed can be of a theoretical nature: Can we enhance Hall's ideas about proxemics with a discussion of primary metaphors? Can playing with primary metaphors in interaction design the source of magic in using technology (e.g. as telematics breaks the everyday experience of strength-of-effect-is-closeness by letting us exert influence on distant objects). The practical goal could be to discuss specific primary metaphors and come up with lo-fi prototypes to study the proxemic effects of technology.

4.6 Hybrid-Image Visualization – or Perception-Based Proxemic Interaction

Petra Isenberg (INRIA Saclay – Île-de-France – Orsay, FR)

At this year's InfoVis conference we presented a first investigation into hybrid-image visualization for data analysis in large-scale viewing environments. Hybrid-image visualizations blend two different visual representations into a single static view, such that each representation can be perceived at a different viewing distance. They can be used, in particular, to enhance overview tasks from a distance and detail-in-context tasks when standing close to the display. As such, the technique allows for proximity-dependent (person to screen) interaction through locomotion and perceptual changes alone – without tracking viewers. One main question that arises is how this affects cognition (i.e. understanding and thinking about the data that is being shown) in scenarios in which people are co-located but actually see different things at the same time.

In this talk I will situate the method within the context of other techniques that show information in the same space for different viewing distances, show examples of hybrid-image visualizations, and discuss the question of cognition in more detail.

4.7 Information Visualization and Proxemics: Design Opportunities and Empirical Findings

Mikkel R. Jakobsen (University of Copenhagen, DK)

People typically interact with information visualizations using a mouse. Their physical movement, orientation, and distance to visualizations are rarely used as input. We explore how to use such spatial relations among people and visualizations (i.e., proxemics) to drive interaction with visualizations, focusing here on the spatial relations between a single user and visualizations on a large display. We implement interaction techniques that zoom and pan, query and relate, and adapt visualizations based on tracking of users' position in relation to a large high-resolution display. Alternative prototypes are tested in three user studies and compared with baseline conditions that use a mouse. Our aim is to gain empirical data on the usefulness of a range of design possibilities and to generate more ideas. Among other things, the results show promise for changing zoom level or visual representation with the user's physical distance to a large display. We discuss possible benefits and potential issues to avoid when designing information visualizations that use proxemics.

4.8 Proxemics for ad-hoc communities of devices

Hans-Christian Jetter (University College London, GB)

My goal is to use proxemic interactions between multiple devices and users to create an ad-hoc community of devices that serves users as a single usable and seamless UI. All devices of the community are aware of each other's presence and contribute their individual input/output capabilities for the common goal of providing users with a seamless, usable, and accessible interface that spans across device boundaries. Ideally, this is achieved by letting the UI's behavior emerge from simple proxemic rules that react to changes in presence, location, distance, orientation, and movement of neighboring devices and users. By using simple rules of proxemic interactions between devices, deterministic preciseness of classic top-down design and modeling is traded in against less controllable, but more adaptable, robust, and scalable bottom-up designs that automatically react to the dynamics of ad-hoc real-world usage. This will lead to self-organizing user interfaces. In this context, I also want to suggest that the more we are talking about device-to-device interactions, the less Hall's theories of proxemics help to describe the nature of interactions. David Kirsh's work on "the intelligent use of space" [1] and distributed cognition might serve as helpful frameworks here.

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4.9 Technical Challenges of Sensing People's and Devices' Proxemic Relationships

Nicolai Marquardt (University College London, UK)

This mini talk reviewed diverse sensing approaches for tracking people's and devices' proxemic relationships in ubicomp environments. The talk began with a summary of the proximity toolkit, which facilitates programming of proxemic interaction systems by providing higher-level programming building blocks. Programmers subscribe for proxemic events they are interested in, and then receive notifications about changes (e.g., a person moves closer to a particular device) through the event-driven architecture. The talk then raised the question of how we can build proxemic-aware systems without relying on high-end motion capturing systems. As one possible solution, a method of hybrid sensing is introduced, that combines (a) tracking data from structured light depth-sensing cameras, (b) radio-signal based distance sensing, and (c) the internal 6-DOF sensors. This hybrid sensing approach provides reliable tracking information; demonstrated with a series of cross-device interaction techniques. Finally, the talk raised a series of possible topics for discussions in the breakout session following the talk: (1) What are new and emerging tracking technologies, (2) what kind of tracking fidelity do we need, (3) what are adequate prototyping building blocks, and (4) what are feasible approaches for sensor fusion.

4.10 Proxemics as Play Resource

Florian Floyd Mueller (RMIT University – Melbourne, AU)

Proxemics thinking has previously been applied to make interactions with computers more efficient. However, from computer games we know that making interactions 'harder' can result in engaging challenges. I propose that we can use proxemics thinking to contribute to our understanding of the design of challenges for digital play. In particular, I propose we can learn from related concepts in sports, where spatial relationships between players such as body contact, can make a core element of an engaging experience. By seeing proxemics as a design resource for digital play, I argue novel user experiences can be created, expanding the range of engaging interactions we experience with technology.

4.11 Situative Space Model – for human-centric ad-hoc smart environments

Thomas Pederson (IT University of Copenhagen, DK)

Joint work of Pederson, Thomas; Janlert, Lars-Erik; Surie, Dipak
Main reference T. Pederson, L.-E. Janlert, D Surie, "A Situative Space Model for Mobile Mixed-Reality Computing,"' IEEE Pervasive Computing Magazine, 10(4):73–83, 2011.
URL http://dx.doi.org/10.1109/MPRV.2010.51

In this talk I will introduce a body-centric modeling approach, the Situative Space Model (SSM), for mobile mixed-reality environments and relate it to the five dimensions of Ubicomp for Proxemics proposed by Greenberg et al. (2011) [1]. The SSM is heavily influenced by proximity and divides the space close to the users into two overlapping regions: the perception space and action space, effectively defining what a human agent can perceive and act on in a given situation. Drawing from the vision of Egocentric Interaction (Pederson et al., 2010) [2] it includes real-world everyday objects (not just interactive devices) and can cope with mobility of human agents better than more device-centric approaches. The model is intended to be used both as a tool for analyzing existing mixed reality settings as well as a tool for design. ment (bibtex-files are not supported):

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4.12 User-Aware Devices: How Do we Gracefully Manage Imperfect Automation?

Stacey D. Scott (University of Waterloo, CA)

A key aspect of the move towards "Proxemic Interactions" is an increasing reliance on "smart" systems to track user's body movement in order to infer user intention, and provide more responsive, and ultimately, more user-friendly systems. The underlying philosophy of this design approach is to create systems that actively collaborate with the user to provide an environment in which the technology adopts common social norms, such as increased engagement as a user approaches the system, to leverage existing knowledge of human-human interaction to improve learnability and usability with such systems. However, currently available automation (e.g., sensing technologies, algorithms for gesture interpretation, etc.) are imperfect, and failures to appropriately infer the user's intention can increase frustration, and degrade the overall user experience. This talk with briefly overview emerging user-aware devices and pose questions for discussion about how we, as technology designers, can design our systems to gracefully handle, and allow the user to gracefully manage, such inevitable automation failures with the aim to improve the overall user experience, and overall utility and acceptability of systems that provide "Proxemics Interactions."

4.13 Resizable Mobile Devices for Ad-Hoc Mobile Meetings

Jürgen Steimle (MPI für Informatik – Saarbrücken, DE)

In this talk I propose a novel class of mobile devices to provide better support of ad-hoc mobile meetings. Advances in flexible displays will make resizable devices possible that are lightweight and have a compact form factor, while providing a quite large interactive surface when unfolded or rolled out. A jointly held large surface will allow for novel collaborative usages in mobile settings. Taking proxemics and F-formations as a conceptual basis, I will explore several dimensions of the design space of such “handheld tabletop” devices. I will illustrate these thoughts by means of a first prototype.

4.14 Opportunities for Intelligibility in Proxemic Interactions

Jo Vermeulen (Hasselt University – Diepenbeek, BE)

In this talk, we discuss opportunities for intelligibility to improve interaction with proximity-aware systems. Intelligibility could help users know how to interact with a system and know what to expect. Systems could inform users of their interactive capabilities, reassure them by highlighting mechanisms to repair mistakes and help them to anticipate the consequences of their actions. We explore possible interaction problems in proxemic interactions and discuss how different types of intelligibility could address these problems.

4.15 Siftor: subtle interaction in an art gallery context

Daniel Vogel (University of Waterloo, CA)

I will describe Siftor, a system that uses subtle body movement to interact with a minimal wall-sized visualization of thousands of two-dimensional art works. Using overhead cameras, the system translates the location and speed of multiple visitors into different individual and collaborative interactions. The visualization and interaction design facilitates the serendipitous discovery of art works in a conventional gallery-viewing context. Siftor was recently exhibited for seven weeks at the Owens Art Gallery in New Brunswick, Canada. The key idea is that Siftor functions as an art installation as well as a longitudinal study of interaction. For example, the simple tracking algorithm is designed to be highly flexible and permissive, making it possible to observe natural styles of body input and different strategies to master the system’s input language. Analysis of the usage logs is ongoing, but I will share initial findings relating to general usage patterns and proxemic interactions between visitors. My experience is that digital art installations in an art gallery context are well suited to conducting research in novel interaction.

Video documentation: http://www.youtube.com/watch?v=b7j_T9xUNNI

5 Working Groups

5.1 Play and Proxemics

Florian Floyd Mueller (RMIT University – Melbourne, AU)

Joint work of Mueller, Florian Floyd; Greenberg, Saul; Dippon, Andreas; Stellmach, Sophie; Boll, Susanne

This working group discussed the topic of "play" in relation to proxemics interactions and what one field can contribute to and benefit from each other.

The session started with the group playing a (non-digital) game in the Dagstuhl environment, using locally available materials, highlighting that opportunities for play exist almost anywhere. With this experience and associated knowledge the group assembled a set of mindmaps on the topic, resulting in a following key themes:

1. How could proxemics be used for gaming?
2. Proxemics appears to have potential to engage people into play: we should envision strategies informed by proxemics
3. Proxemics awareness could trigger curiosity
4. One strategy could be to visualize proxemics, this appears to be affording playfulness
5. Connecting space by play could be another strategy
6. Location-based games seem to focus on absolute distances, proxemics on relative distances
7. Proxemics play is related to new dating apps that take location into account: they often ask "is there a compatible match nearby?"
8. Playing with pictures can also benefit from proxemics: "what pictures have been taking nearby my location?"

1. Proxemics games to help teach social issues
2. Proxemics in games could take on a supportive role to create the possibility to deal with particular problems or issues, such as the fear to interact with strangers, deal with anger when losing, promote more rapid intimacy, teach social behavior, make social behavior more explicit, etc. One example system could be a musical chair or cocktail glasses that function as social mixer.

1. Digitally exaggerating proxemics could be fun we believe
2. Twister has been described as a game where the bodies are the play pieces, this could be inspirational for proxemics play
3. An underexplored area seems to be proxemics $\leq$ 0cm, often called contact sport in sports contexts

1. The "Magic circle of play" (Zimmerman and Salen, 2003) could be a frame for proxemics
2. Interaction designers could play with the social norms and expectations of the magic circle of play by using proxemics as frame

The group decided to work collaboratively on a publication on the topic, with the DIS (Designing Interactive Systems) conference as a possible target conference.

5.2 Intelligibility for Proxemic Interactions

Jo Vermeulen (Hasselt University – Diepenbeek, BE)

Joint work of Boll, Susanne; Boring, Sebastian; Dachselt, Raimund; Dostal, Jakub; Isenberg, Petra; Marquardt, Nicolai; Matulic, Fabrice; Mueller, Florian Floyd; Nicosia, Max; Reiterer, Harald; Scott, Stacey; Vermeulen, Jo; Vogel, Daniel

Introduction

In this breakout group, we wanted to delve deeper into interaction issues of systems that rely on proxemics. While many of the systems described in the literature work well for a specific setting, the implicit nature of proxemic interactions could also cause problems for users. During the introductory talks at the start of the seminar, several of these issues were raised, including: discoverability, providing control, graceful failure and correcting mistakes, correctly detecting users' intentions, how to know what is being tracked by the system, or how to opt-out (and avoid unintentionally interacting with the system). As mentioned by Greenberg et al. [5], many of the suggested interaction techniques assume the existence of a set of rules of behavior that dictate what the different entities should do based on implicit acts. There will be many situations in which applying these rules will be the wrong thing to do [6]. Additionally, Ballendat et al. [1] argue that one of the largest unsolved issues in proxemic interactions is how one can configure the rules of behavior, and how users can repair mistakes when the system gets it wrong.

A number of these problems have been reported earlier and are well known in the area of context-aware computing [4]. One of the major challenges with context-aware systems is making these systems intelligible [2] by informing users about the system's understanding of the world. A proxemic relationship between devices and people is essentially nothing more than a specific type of context information that can be taken into account. The breakout group was interested to see whether existing approaches to address these challenges in context-aware systems (e.g., mediation [3]) could also be applied to systems that take into account proxemics, and possible ways to tackle issues specific to proxemic interactions. For example, Ju et al. [7] propose three interaction techniques that could be used to show users what the system is doing (system demonstration), how the users input is interpreted (user reflection) or to correct the system when it makes a mistake (override).

Purpose of the Breakout Group

We set out to discuss discovery, mediation, intelligibility and visualizations in proxemic interactions. Given time limitations, we decided to focus specifically on the problems of opting in and opting out. We also looked into how the user's level of engagement with the system could help in addressing these challenges. As the group was too large for a single breakout session, we split up in two subgroups: (1) opt-in and (2) opt-out / methods of engagement.

Participants of the Breakout Groups

Contributors to both subgroups are listed below.

Opt-in

- Susanne Boll, Sebastian Boring, Raimund Dachselt, Harald Reiterer, Stacey Scott, Jo Vermeulen, and Daniel Vogel.

- The notes for this subgroup are listed in Appendix 1. Daniel illustrated several ideas using sketches. Jo was the group scribe.

Opt-out / Methods of Engagement

- Jakub Dostal, Petra Isenberg, Nicolai Marquardt, Fabrice Matulic, Florian Floyd Mueller, and Max Nicosia.
- The notes for this subgroup are listed in Appendix 2. Nicolai and Fabrice created sketches to capture the discussion.

Outcome

Both subgroups set out to identify the specific problems that occur when opting in or opting out, propose potential solutions to these problems, and discuss how those solutions would be applied in specific scenarios. Both groups used sketches to capture and illustrate their ideas. The brainstorming resulted in many interesting – although somewhat rough – ideas. In the following, we provide a brief overview of recurring themes and concepts.

Social Protocol. One of the proposals, discussed at length in the opt-in subgroup, was the idea to make systems adhere and respond to a social protocol, just like in human-to-human communication. There are several subtle clues in our day-to-day communication that tell others whether we are approachable or not and allow us to opt-in or opt-out (e.g., a brief nod and smile to someone you recognize at the other end of the room at a reception, looking away to avoid starting a conversation).

Multiple Levels of Opt-in. The opt-in subgroup asked the question whether a single level of opt-in might be insufficient. It could be useful to support several levels of opt-in and opt-out (e.g., depending on distance, eye-contact, orientation). Users familiar with the system could then be automatically opted into a deeper level in the hierarchy.

Opt-out Gestures. The opt-out subgroup brainstormed about different possible gestures to opt-out. Several ideas were proposed, such as a 'stop' gesture, covering your face with your hands, or turning away from the system. Similarly, the opt-in subgroup asked the question what would be the proxemics equivalent of sticking a post-it note over a laptop's webcam to avoid being tracked, and which would be more obtrusive, being filmed or having ones proximity tracked? The use of special clothing to indicate willingness to opt-in (e.g., a shirt in a specific color, wearing a special type of hat or cap) was also discussed, as well as the idea of sensible opt-outs, where a system could, for example, avoid implicitly opting in small children.

Ownership of the Space and Interaction Zones. Both groups discussed issues related to how proxemics-aware systems use the space in which they are deployed. A question raised in the opt-in subgroup was who owns the space surrounding the system, as the deployment of the system could influence how people use that space. Users might, for example, need to walk around a public display to avoid opting in, making the space around it more crowded, which could be problematic at rush hour. The opt-out subgroup proposed using a special entrance to opt-in to the system, instead of using interaction zones defined by distance.

Methods of Engagement. The second subgroup considered how the user's level of engagement with the system could be used. Systems could rely on more implicit or explicit means of interaction. For example, they could react to users' presence when they are just walking by, or might require the user to approach the system as a more explicit signal of intent. Similarly, the opt-in subgroup discussed how interaction with physical props near a public display could be used as an explicit way of opting in. To indicate what is tracked and how the system responds to user input (e.g., distance, eye gaze, orientation), this subgroup proposed the use of specific icons or signs.

User Control. Participants also discussed how users can be allowed to exert control over the system, and in what situations a lack of user control could be problematic. Implicitly tracking proxemic dimensions such as distance, orientation or movement and reacting to changes in these dimensions can have annoying side effects. For example, a public display that uses distance to control the zoom level does not allow users to step closer and get a detailed view of a specific part of its contents, as the display will adjust the zoom level in response to their approach. An idea proposed by the opt-in subgroup was the use of a symmetric opt-in and opt-out process, in which opting out could be done by performing the inverse of the opt-in action (e.g., if users would opt-in by approaching the system, they could opt-out by moving back).

References

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2 Bellotti, V. and Edwards, K. Intelligibility and Accountability: Human Considerations in Context-aware Systems. Hum.-Comput. Interact. 16, 2 (2001), 193–212.

3 Dey, A.K. and Mankoff, J. Designing Mediation for Context-aware Applications. ACM Trans. Comput.-Hum. Interact. 12, 1 (2005), 53–80.

4 Dey, A.K. Understanding and Using Context. Personal Ubiquitous Comput. 5, 1 (2001), 4–7.

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Appendix 1: Notes of Opt-in Subgroup

- Levels of opt-in
  - First level of going into space
  - Delineated space
  - 1 pixel bar Dan
    - Pure opt-in? People might never do it
    - Continuous feedback (something moves when I move)
  - Know about system, context matters
    - Maybe I just want to use the whiteboard in an analog way
- Automatic opt-in for feedback
- Just want to look at the map (work of Mikkel)
- Scenario?
- Tile → floor changes
- Social protocol

  - Compare with human-human behaviour
    * Look at someone, opt-in, to start a conversation
  - Level of invitation (Dan)
    * People that look away
  - Displays always want to invite people in (assumption)
    * Allowing user to quickly figure out if display relevant to them (Stacey)
    * Even advertisers don't want everyone to look at it → targeted
    * Encourage approach
    * Who are we?
  - Act in social way
  - Natural ways of opting-out, by just doing the opposite
  - Different levels, teleportation into deeper level if you're an expert
- Does it have to be implicit or automatic?
  - What can you model, what don't you need to model?
    * Use of physical props, car → when you open door → show display
  - Do we need to use zones? We can't just use zones alone, we need more information
    * But we can't use lots and lots of sensors, some things cannot be modelled
- Physical way to opt-out
  - Sticker on webcam to opt-out
  - Flash camera against pictures
  - What for proximity?
  - How acceptable are different sensors
    * Proximity vs. camera?
- Stacey: overlap with territoriality (who owns the space, you occupy)
  - Primary, secondary, public (degrees of defending territory)
  - In public: explicit opt-in
  - Multiple users: one person opt-in, other one is standing beside them, still interact together
  - Social correctness: moving furniture in people's places, chair, table, etc. different
- Shopping scenario
  - Shelf where you can put products on
  - Display that shows info
  - Shopping cart could be mediator
  - Push information to private display
  - Compare in shopping cart
  - At what point do you identify yourself
    * Opt-in with your position compared to products (passing by with shopping cart)
  - Compared to shopping cart
  - Implicitly opting in
  - Push private info to display
  - Show info on phone
  - Bring products near you (shopping cart)
  - Compare them on shopping cart display
    * Explicitly opting in
  - Social protocol

  - Object flashing, like recognizing you, waving hand
  - Close the flap when you don't want to be bothered
    - Explicit opt out
  - Depending on available time / shopping type
    - Everyday shopping vs. explorative shopping
    - Finding products

Appendix 2: Notes of Opt-out / Methods of Engagement Subgroup

- Novice versus an expert
- Explicit vs. implicit Opting in vs. action Transition between the two
- The environment may offer different levels of engagement
  - Walk in a space and you are immediately being sensed vs.
  - Come near a device and do something more explicit to do something with it
  - Different phases probably have smooth transitions from passing by to direct interaction and back to leaving
- Possible ways to indicate actions
- How to inform the user of what is being tracked
- Opt-out / opt-in
  - What is the default?
  - What is the cost of opting in or opting out
  - Being overwhelmed
  - Continuously increasing actions to opt-out
- Links
  - Tracking customers in stores using WiFi: http://www.washingtonpost.com/blogs/the-switch/wp/2013/10/19/how-stores-use-your-phones-wifi-to-track-your-shopping-habits/
  - Tesco face recognition for targeted ads: http://news.sky.com/story/1163551/tesco-face-scanners-to-target-till-adverts
  - Infrared masks to blind cameras: http://mods-n-hacks.wonderhowto.com/how-to/make-infrared-mask-hide-your-face-from-cameras-201280/
  - Wi-Fi Beacons – Prove request details (Device tracking): http://www.wi-fiplanet.com/tutorials/print.php/1447501/

5.3 Dark Patterns in Proxemic Interactions

Saul Greenberg (University of Calgary, CA)

Joint work of Boring, Sebastian; Dostal, Jakub; Greenberg, Saul; Isenberg, Petra; Matulic, Fabrice; Pederson, Thomas; Scott, Stacey; Vermeulen, Jo

Introduction

Authors of human-computer interaction papers concerning innovative design ideas tend to forward their central idea in a positive – often highly idyllic – light. True critical perspectives are rarely offered. When they are, they tend towards a few cautionary lines in the discussion, or are relegated to future work where its actual use would be examined. The problem is that many of our new innovations involve designing for ubiquitous computing situations that are extremely sensitive to intentional or unintentional abuse (e.g., privacy, distraction and intrusion concerns). Rather than wait until some future field study of our technology (where it may be too late to address emerging concerns), we should consider the 'dark side' of our technologies at the outset.

The particular innovation we are concerned with in this Dagstuhl Workshop is proxemic interactions, which was inspired by Hall's Proxemic theory. The theory explains people's understanding and use of interpersonal distances to mediate their social interactions with others. In proxemic interactions, the intent is to design systems that will let people exploit a similar understanding of their proxemic relations with their nearby digital devices to facilitate more seamless and natural interactions. This is especially important as we become immersed in ubiquitous computing ecologies, i.e., where we carry and are surrounded by myriads of devices, all potentially capable of interacting with one another. Examples include: mobile devices that understand their spatial relations to mediate information exchange between nearby devices; large displays that sense people's position relative to them, where they dynamically adjust what is shown and how people can interact with them; public art installations that respond to the movement and proximity of people within its sphere to affect what is shown; application areas such as home media players that monitor the distance and orientation of its viewers to dictate what is shown, and information visualizations that tune their visuals to people's position relative to them. The literature also includes more general essays about the role of proxemics, such as how it can address well-known challenges in Ubiquitous Computing design.

Yet it is clear, at least intuitively, that there is a dark side to proxemics interactions. For example, the systems above rely on sensing people and their devices within the surrounding environment. We already know that some of the sensed dimensions that would be valuable to proxemic system design include: distance, orientation, and movement of entities relative to one another, the identity of these entities, and contextual information about the location. While the purposes of researchers within this area are honorable, such sensing immediately raises concerns about privacy by experts and non-experts alike. Moreover, dystopian visions of the future hint at abuses of such technologies – a well-known example is the movie Minority Report that illustrates how a character is bombarded by targeted advertisements as he moves through a public hallway, and how his location is revealed to searchers.

The Purpose of the Breakout Group

In this breakout group, we revisited the idea of proxemic interactions, where our goal was to discuss a critical perspective – the dark side – of this technology. Our method was to articulate potential dark patterns indicating how we think this technology can be – and likely will be – abused, and anti-patterns where resulting behavior occurs as an unintended negative side effect. Participants articulated not only possible deceptions and misuses of proxemics interactions (dark patterns), but problems that may appear even when the designer has reasonable intentions (anti-patterns).

Unlike true patterns that are based on analyzing a broad variety of existing solutions, we brainstormed patterns based on several sources. As part of our investigation, we revisited Brignull's dark patterns web site (darkpatterns.org) to see if and how the dark patterns recognized in web browsing systems could be applied to proxemic interactions (possibly as variations). We also considered emerging uses of proxemics in commercial and experimental products as examples, as well as 'thought experiments' of how such systems could be designed with dark patterns in mind. We considered dark portrayals of such technologies foreshadowed in the popular literature and cinema, and our own reflections of where misuses could occur. That is, our patterns are a mix of those that describe existing abuses and that predict possible future ones. We did not differentiate whether a particular pattern is dark vs. anti: our pattern examples suggested that the difference between the two often arise from the designer's intent rather than a feature of a particular design. In our view, the same pattern – depending on the designer's intent – can be viewed as either a dark pattern or an anti-pattern. We believe this approach to be appropriate for forecasting – and ideally mitigating – the dark side of our future technologies before actual deceptive patterns become widespread in practice.

A set of initial patterns and the notes accompanying them are attached as Appendix 1.

Participants of the Breakout Groups

Contributors to the breakout group were:

- Kakub Dostal, Fabrice Matulic, Jo Vermeulen, Petra Isenberg, Saul Greenberg, Sebastian Boring, Stacey Scott, and Thomas Pederson
- Petra Isenberg was the group scribe, where the outcome of her work is listed in Appendix 1.
- Aaron Quigley, while not part of the breakout group, deserves special mention as he primed the group with the dark pattern web site when we initially discussed the dark side of proxemic interactions.

Outcome

During the workshop, there was sufficient interest by attendees to develop this idea as a paper.

In early December, Greenberg developed the framework of a paper and wrote a few sections, along with Boring (who happened to be visiting). He then asked who in the group would be willing to participate in the development of the paper, with the proviso that they would be active authors. This was, in part, because Greenberg and Boring were targeting the ACM DIS 2014 conference, where the paper submission deadline was in mid-January. Of the original participants, Jakub Dostal, Jo Vermeulen, Saul Greenberg and Sebastian Boring agreed to be active authors, and others said they were happy to comment on it. As of time of this writing, a complete draft of a paper has been prepared and is available as a technical report [1].

A paper based on this report has been submitted to a conference. The paper itself is a substantial reworking of the original patterns as brainstormed in Appendix 1. That is, the breakout group was excellent in terms of motivating the theme of Dark Patterns and in brainstorming initial discussion. However, as with the results of most brainstorming exercises, it demanded considerable effort to transform these initial thoughts into a publishable form.

References

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Appendix 1: Initial Patterns brainstormed by the Group

The group brainstormed the following initial set of patterns and notes for each pattern. Design patterns were initially taken from darkpatterns.org and more or less adapted to Proxemics, as well as some new patterns proposed.

Bait and switch
- by approaching something you are automatically opting in (implicit action)
- benevolent solutions: needs to be possible to opt out.
  - 1) Gesture for opting out?
  - 2) if you notice that you are tracked, maybe your reaction can be interpreted as "i don't want to be tracked"
- trust is crucial
- cameras make you think you are tracked even if you are not – changes your behavior
- "for implicit things, only safe actions"
- "we no longer own the space"

Forced behaviour
- people are forced to a certain (embarrassing) behaviour in order to use service
- tricks you into go closer (interesting!) then you are forced to see an ad/pay

Disguised ads (disguised tracking) implicit consent
- ads in a public space
- make you get close enough for a picture, then target your face for future ads

The captive audience
- small display on top of mens urinals (you cannot go somewhere else to avoid watching)
- "black mirror" british tv show, you need to pay to avoid the ads on the display walls
- kinect enters your living room, disguised as an entertainment system, silently tracks everything

Faraway bill
- the proxemics system forces you to go to a location in order to get a service

Forced continuity
- forced to remain and watch an ad before leaving the space or all your data will be deleted from the cloud
- when two devices are brought together they share data with their owners consent. next time they will continue to share data, even without the consent

Forced disclosure
- everything is taken from your mobile device as you approach the system

Friend spam
- a system might automatically connect you to people you happen to be close to
- viral: a "friend virus" that spreads among people you are physically meeting

Hidden costs
- in the last stage of the checkout process unexpected charges occur
- proxemics case: you use the service and then you are asked to pay (somehow), e.g. with time
- might work if the fee is not so big
- like fitbit: when you are synching, you are suddenly asked to pay

Unintended relationships

- just because you pass by someone, you are automatically friended with that person

Misdirection

- animations flashing to attract your attention so that the camera can get a good picture of you
- hide information by placing the legal text in a place that is not possible to read

Privacy zuckering

- making it hard to get full privacy

Roach motel

- move up to a public display. when you leave, you need to pay in order for your private data to not stick to the screen.

Trick question

- if you layered info as you move towards the device, you get a quick question that you can't correctly interpret because you are in motion/you are not oriented correctly

Attention grabbing

- proxemics provides better timing

Midas touch problem exploited

Physical aspect

- lure them into positions
- lure them into getting their finger print

Intentional vs. unintentional dark patterns

5.4 Ad-Hoc Proxemics – Inclusion of everyday entities in proxemics systems

Thomas Pederson (IT University of Copenhagen, DK)

Joint work of Butz, Andreas; Dippon, Andreas; Hurtienne, Jörn; Jetter, Hans-Christian; Sorensen, Henrik; Stellmach, Sophie; Pederson, Thomas; Rädle, Roman

This working group deliberately turned the focus away from what had been a recurring topic at this Dagstuhl seminar: predesigned systems that make use of proximity as a means for interaction (e.g. proximity-aware public displays), and instead discussed the potential role that proximity plays when interacting with physical entities (objects) in everyday life and how designers of proximity-based systems need to take that into account.

The interplay between physical structures and the proximity-based system

Since real world objects and structures seem to influence human agents' interpretation of what can be done (and not done) in a given environment (e.g. few entities and structures in a car garage tell us that we could/should bake a cake there), interactive systems that make use of proximity (both object↔object and human agent↔object)

1. should avoid introducing proxemic behaviour that the physical environment as such does not indicate or afford,
2. should as much as possible leverage on proxemic behaviour that the physical environment indeed is signalling to the human agent as possible or even encouraged.

While the above two reciprocal requirements can be fulfilled when a proxemic-based system is set up in a controlled static environment such as a dedicated room, it becomes a challenge if proxemic behaviour is used in mobile settings where the physical surroundings in which the system operates is different from one time to the next.

The working group also came to the conclusion that even for the design of static proximity-based systems (e.g. a proximity-aware public display), it could be beneficial as system designer to take into account, and influence, the physical structure surrounding the interactive system such as to indicate to the users of the system what can be done, and how.

With respect to individual physical objects/entities, their physical properties (shape, colour, weight, rigidity) might be possible to design in such a way as to indicate if, and how, the specific object reacts on/can be used for proximity-based interaction.

The semantics of inter-object proximity

It is well documented in literature (e.g. Kirsh, 1995) that the organization of physical entities in space is associated with the meaning which the "space organizing human agent" projects onto the objects. The most evident fact is that objects that are related end up close to each other. It was concluded that any interactive system that wants to model the intentions of human agents, could benefit from taking inter-object proximity into account.

Semantics can also be built into the physical environment in such a way that human agents that operate in the environment are consciously or unconsciously led to "do the right thing". Example: Silverware at the dining table might be placed in such a way that the spoon is only reachable when the plate is gone.

Does point of reference matter?

Does it matter whether the proximity-aware system uses the human body as center of reference or the room? It was concluded that for certain system tasks, it might matter. The decision depends on which of the approaches that provides the best view of the situation for the system. Combined viewpoints are also possible (e.g. that devices communicate with each other to better identify the situation).

Important property: Everyday objects are inexpensive and ubiquitous

An inclusion of everyday objects (such as paper documents, pens, cuttlery) in interactive systems would open up for new kinds of interaction over both time and space due to the fact that their situational availability is immensily higher than typical digital devices. Part of Mark Weiser's vision for Ubiquitous Computing relied on spreading out the inexpensive devices everywhere. If the everyday objects, to some degree, can take on the role of such devices, they do not need to be spread out because they already are!

The idea of using everyday objects as controllers for virtual/digital processes is not completely new, see for instance Henderson & Feiner (2008); Corsten et al. (2013); MaKey Makey (http://www.makeymakey.com). The working group identified three important roles that everyday objects could take as part of interactive systems:

- controllers
- modifiers
- mediators

The Danger / Challenges

Integrating everyday objects into interactive systems potentially makes the up until now very predictable real world suddenly much less predictable. The working group acknowledged that special care was needed in particular in environments where spontaneous encounters between human agents and objects occur (public places) whereas more private environments could be less problematic due to the fact that everyone operating in the environment will know what virtual processes are tied to what everyday object; what spatial configuration of objects will initiate what virtual process, etc. etc.

Other topics, conclusions drawn, and ideas

- Absolute proximity vs. relative proximity (object↔object and human agent↔object).
- Fine grained object manipulation doesn't necessarily demand fine grained tracking.
- The idea of virtual mobility: virtual "content" moves towards you instead of the other way round. E.g. information ends up on your personal device instead of a wall-sized display.
- The Reality-Based Interaction Framework (Jacob et al., 2008) is highly relevant to the discussion on relying on everyday proxemics for designing better interactive systems.
- For some tasks, in particular in dedicated places designed for "expert users", a high learning threshold for interacting with a proximity-based interactive system might be fully OK.

Outcome

The participants of the working group are considering to set up a workshop at an upcoming conference (for instance MobileHCI 2014) to dig deeper into some of the topics mentioned above.

5.5 Challenges of Sensing People's and Devices' Proxemic Relationships

Nicolai Marquardt (University College London, UK)

Joint work of Dachselt, Raimund; Jetter, Hans-Christian; Rädle, Roman; Sorensen, Henrik, Dostal, Jakub; Nicosia, Max; Pederson, Thomas, Dippon, Andreas, Bardram, Jakob E.

The theme of this breakout session was the discussion of existing challenges and future technical approaches for sensing people's and devices' proxemic relationships. We began by collecting common tracking technology approaches: vision-based (e.g., structure light cameras, motion capturing systems, thermal cameras), radio-based (e.g., Bluetooth, Wifi, RFID), sensor-based (e.g., infrared, ultrasonic, microphone, magnetometer). We then categorized these approaches along the low-fidelity to high-fidelity spectrum. Next step was to brainstorm characteristics and properties that are important to consider when choosing between different tracking alternatives: precision, power consumption, uncertainty, outdoor vs. indoor use, user preference, weight, cost, scalability, complexity of processing, and others. Finally, as the major part of this breakout session, we discussed strategies for combining different sensing technologies with sensor-fusion approaches. In here, alternative strategies are possible:

multiple technologies can complement each other (e.g., work at different scales) or reinforce the results of another (e.g., all tracking same area but fusion increases resolution). Other aspects important for sensor fusion approaches are: the weighting of sensors, approaches for graceful failure, hierarchical sensing approaches, sensor roaming, and translation of sensor data. As possible future outcomes of the breakout discussion we are considering the setup of a website facilitating the comparison and selection of proxemic tracking technologies (e.g., making suggestions for technology based on set of requirements).

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