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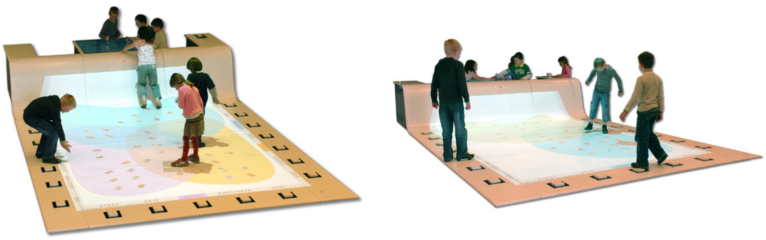

Designing for Spatial Multi-user interaction

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Outline of thesis

This licentiate thesis is conducted within the research area of Interaction Design, and consists of five international peer reviewed full conference papers and one international journal paper, which are co-authored by fellow PhD students, senior researchers and research assistants with related but not identical background and research interests.

The spatial multi-user interaction design program has been presented as a part of a PhD research program. It consists of a theoretical foundation, a design model and research experiments consisting of experimental design projects and experimental design methods.

The thesis aims to present the spatial multi-user interaction design program, consisting of a theoretical foundation, a design model and research experiments consisting of experimental design projects and experimental design methods.

The thesis will cover inspirational work and background to the project, as well as the theory developed from the practical design work in the different projects. First traditional multi-user interaction is discussed, and how spatial multi-user interaction differs from this. It will be presented how the computer form has changed and discuss how the interaction changes as well. After presenting a theoretical base, the concept of spatial multi-user interaction will be presented. The design model will be illustrated by a number of practical examples and design methods. The theory will be concluded by an overall discussion and a conclusion. The papers will be presented briefly, followed by the appended papers.

Appended papers

Journal papers:
E. Eriksson, T.R. Hansen, A. Lykke-Olesen. Movement-Based Interaction in Camera Spaces – A Conceptual Framework (In Press) In the Journal of Personal and Ubiquitous Computing special issue on movement based interaction.

Full Conference Papers:
Hansen, T.R., Eriksson E., Lykke-Olesen, A. Mixed Interaction Spaces – expanding the interaction space with mobile devices. In: Proceedings of British HCI 2005, Edingburgh, UK, Sept. 2005.

Eriksson E., Hansen, T.R., Lykke-Olesen, A. Reclaiming public space – designing for public interaction with private devices. Presented in Proceedings ofTangible and Embedded Interaction '07, Baton Rouge, Louisiana, February 2007. ACM Press.

Eriksson, E, Krogh, PG, Lykke-Olesen, A. Taking the physical aspects serious – A Design Approach to Children's Interactive Library. Manuscript sent for revision.

Eriksson, E, Ludvigsen, M, Lykke-Olesen, A, Nielsen, R. Bthere or be Square: A Method for Extreme Contextualization of Design. In Proceedings of Wonderground 2006 Design Conference, Lisbon, Portugal, Nov 1-4, 2006.

Dindler, C., Eriksson, E., Iversen, O. S., Lykke-Olesen, A., and Ludvigsen, M. 2005. Mission from Mars: a method for exploring user requirements for children in a narrative space. In *Proceeding of the 2005 Conference on interaction Design and Children* (Boulder, Colorado, June 08 - 10, 2005). IDC '05. ACM Press, New York, NY, 40-47. DOI= http://doi.acm.org/10.1145/1109540.1109546

Additional publications

Full Conference Papers:
Lundgren S, Torgersson O, Hallnäs L, Eriksson E, Ljungstrand P. Programming in Design & Designing Programmers – Educating Interaction Design. In Proceedings of Wonderground 2006 Design Conference, Lisbon, Portugal, Nov 1-4, 2006.

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Eriksson, E. Designing Spatial Multi-User Interaction. In the Danish HCI-Research Synposium proceedings. November 15, 2006, Århus, Denmark. ISSN: 0105-8517.

Hansen, T. R., Eriksson, E., and Lykke-Olesen, A. 2005. Mixed interaction space: designing for camera based interaction with mobile devices. In *CHI '05 Extended*

Abstracts on Human Factors in Computing Systems (Portland, OR, USA, April 02 - 07, 2005). CHI '05. ACM Press, New York, NY, 1933-1936. DOI= http://doi.acm.org/10.1145/1056808.1057060

Dalsgaard, P., Eriksson, E., and Hansen, L. K. 2005. Rethinking information handling: designing for information offload. In *Proceedings of the 4th Decennial Conference on Critical Computing: between Sense and Sensibility* (Aarhus, Denmark, August 20 - 24, 2005). O. W. Bertelsen, N. O. Bouvin, P. G. Krogh, and M. Kyng, Eds. CC '05. ACM Press, New York, NY, 161-164. DOI= http://doi.acm.org/10.1145/1094562.1094589

Axelsson, C., Eriksson, E., Lindros, D., and Mattsson, M. 2002. SpringFlow: a digital spring-sign. In Proceedings of the Second Nordic Conference on Human-Computer interaction (Aarhus, Denmark, October 19 - 23, 2002). NordiCHI '02, vol. 31. ACM Press, New York, NY, 297-298. DOI= http://doi.acm.org/10.1145/572020.572073

Hansen, T. R., Eriksson, E., and Lykke-Olesen, A. 2006. Use your head: exploring face tracking for mobile interaction. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems* (Montréal, Québec, Canada, April 22 - 27, 2006). CHI '06. ACM Press, New York, NY, 845-850. DOI= http://doi.acm.org/10.1145/1125451.1125617

T.R. Hansen, E. Eriksson, A. Lykke-Olesen . Mixed Interaction Spaces – a new interaction technique for mobile devices In: Proceedings of The Seventh International Conference on Ubiquitous Computing, Tokyo, Japan, Sept. 2005.

Editor:

Eriksson, E. (Editor) Proceedings The Second Scandinavian Student Interaction Design Research Conference, SIDeR'06. February 24-26, Chalmers University of Technology, Gothenburg, Sweden, 2006.

Workshop Papers:

Hansen, T.R., Eriksson E., Lykke-Olesen, A. Movement and Space – Exploring the Space in Movement based Interaction. In: Workshop Proceedings of "Approaches to Movement-based Interaction", under The Fourth Decennial Aarhus Conference Critical Computing, ISBN 0-9757948-0-9, Aarhus, Denmark, Aug. 2005.

Video:

Hansen, TR, Eriksson, E, Lykke-Olesen, A. Mixed Interaction Space. In: Video Proceedings of The Seventh International Conference on Ubiquitous Computing, Tokyo, Japan, Sept. 2005.

1 Introduction

Now we need to make “computers for the rest of *you.*”
D. O’Sullivan and T. Igoe

Bill Buxton has an exercise he performs with various audiences, where in 15-20 seconds everybody are to draw a computer, and in another 15-20 seconds draw a computer from 1960 (Buxton, 1996). The result of the exercise, after having tried it with over 500 people, is that almost everybody draws a monitor, a keyboard and a mouse in the first part of the exercise, while the second part is more varied and looks more like a collection of refrigerators and washing machines representing keypunch machines, card readers and tape drives. These results show that people do not draw the computer itself (the CPU-unit) but rather the input/output units, meaning what people see and touch, even though the form has changed over the years. As the input and output forms have changed over history, they are therefore candidates to change again, and this simple exercise demonstrates that it is possible, within interaction design, to fundamentally change the perception of computing, especially for entering things into and getting things out of the system.

This thesis contains no ideas that will fundamentally change the perception of computing, rather investigates some different aspects of how the research field of interaction design perhaps can change the way we see computing, especially how we interact simultaneously with several others while being co-located. In line with pervasive and ubiquitous computing, where the traditional computer forms change from keyboard, mouse and display and instead become part of our physical space, here spatial multi-user interaction will be in focus for investigation.

Ubiquitous computing and Interaction design

The quote starting this chapter is an answer to a comment from Steve Jobs, who is the founder of Apple Computer. Jobs sat out to build “computers for the rest of us”, so that non-expert ordinary people could take advantage of the power of computing (O’Sullivan et al, 2004). The quote by O’Sullivan and Igoe, “Now we need to make “computers for the rest of *you.*” means that we need extend this, to build computational things that respond to your body and the world around you, that the computers convey physical expression in addition to information (O’Sullivan.et al, 2004).

Working with computers in the sense that O’Sullivan and Igoe describe has many names, as for instance physical computing (O’Sullivan et al, 2004), ubiquitous computing (Weiser 1991), graspable interfaces (Fitzmaurice et al, 1995), tangible interfaces (Ishii et al, 1997) or pervasive computing (IBM, 1996). Regardless of what name is used, it is basically about moving Human-Computer Interaction from the virtual world of the desktop into the physical real world, meaning extending the design space, which enables new forms of interaction and incorporates the whole body and the context around you. The term ubiquitous computing will be used in this thesis, as Weiser to some people is considered the father of this research field. And the term used for the IT embedded things in focus is here “computational things”, with the same arguments as Hallnäs & Redström; namely: “To point out what they are as we meet them in daily life – what they are in our life worlds – we prefer to mix these two terms (computational artefacts and computer things) and talk about computational things. It is a matter of things that in an essential way are computational in nature”. (Hallnäs & Redström, 2006).

Ubiquitous computing was coined by Mark Weiser at Xerox PARC in 1991, and can very shortly be described by the two words ubiquity and seamlessness (Weiser, 1991). Ubiquity means that each user will have several computers, varied in size, designed for their purpose or task and be connected wirelessly. Seamlessness, or transparency, means that the technology should be incorporated in to our everyday work, live and play environment, so that its presence is transparent and reduces its intrusion into the environment or our activities.

Once, in the mainframe era, there were several users with one computer and computing was isolated from the users. Later in the PC-era there were one user with one computer, and now in the third era of computing one user has several computers. This means that today’s technology has to some extent been incorporated into our everyday life in line with Weiser’s future scenario of ubiquitous computing (Weiser, 1991). Examples of this are for instance the ubiquity of personal technology, such as our use of mobile phones and mp3 players. Interestingly though, the notion of ubiquitous computing also acknowledges the fact that people interact socially and behave differently in different types of situations or contexts, which is so far not really supported by today’s technology. For instance, in augmented reality systems the technology can consist of wearable computers and head worn displays that might be in the way for social interaction between users, and is not very flexible or sensitive to different contexts. Ubiquitous computing can be seen as the opposite of virtual reality; where virtual reality puts people inside a computer-generated world, ubiquitous computing forces the computational thing to live in the real context with people. Ubiquitous computing is about integrating human factors, computer science, engineering, design, and social sciences

An aspect of ubiquitous computing is that it should not be designed in what Buxton names the Henry Ford model for design (“you can have it in any colour you want as long as it is black”) (Buxton, 1996) meaning computing does not have to be so uniformity that it has been so far, with the traditional computer form consisting of mouse, keyboard, display and WIMP interfaces. But information technology (IT) has traditionally been considered a non-spatial and non-physical material for design, since it is constituted by executing program code and thereby primarily temporal. But its expression is manifested both spatially and physically in different ways, and interaction design is to a large extent about designing computational things. However, physical space has not been a major topic in traditional HCI, but its importance has increased with the emergence of research fields such as ubiquitous computing (Dalsgaard et al, 2006).

Context has been a focus in HCI, even though physical space has had no considerable place there, and there are several well-known methods for taking context into account when designing computational things, for instance participatory design (Bødker et al, 1987) and contextual design (Beyer et al, 1998). These methods work well for traditional computer forms and interfaces, but there is a lack of methods that bring space and the physical environment into the design process. The embedding of information systems into our physical surroundings makes an understanding of space in relation to computer mediated activities essential for interaction designers. Inspired by what Winograd (Winograd, 1997) names interspaces, meaning assemblages of interfaces, actors and environments, the challenge for interaction designers is to design mixed spaces for human communication and interaction

As a large part of the HCI community traditionally has been work-practice based, there has not been much room for more playful and leisure based computational things. While first working with computational things focused on aesthetical values (Axelsson et al, 2002), and later developing childrens technology (appended paper 1 & 6), I have come to believe that there has to be another foundation for interaction design than the pure usability and task completion found in HCI. While HCI traditionally has been oriented towards task completion (Winograd, 1997), interaction design can be understood as an activity oriented discipline, since there in interaction design is a focus on ongoing activities and the experience of interacting with the system (Preece, 2002). Further, an important distinction should be made between HCI as empirical science and interaction design as design practice (Hallnäs, 2006). In HCI there is a strong focus on empirical usability studies where design is seen as the mere derivative of analysis. Interaction design investigates some focus by interventions with prototypes, and design is used as a tool for gaining insights. In HCI research, where the leading design process is theory grounding, fieldwork data, user testing and tremendous evaluations, there is a strong focus on usability studies, while there in interaction design is rather an investigation of how to turn the analysis into design. Fällmans asks "where in HCI is design?" (Fällman 2003), and Wolf states that design is the black box art of HCI (Wolf, 2006). In interaction design, experimental design is more common practice, and the research questions rise from design practice.

Spatial multi-user interaction

Mutli-user

In (Haber, 2001) multi-user interaction is defined as interactions where different people take part in the interaction, i.e. either different people work together to trigger the interaction or different people are affected by the interaction. Multi-user interaction is gaining increased interest as larger screens and more personal devices of different sorts start to communicate with each other. Traditionally, multi-user is any system where multiple users can take part in the interaction, passively or actively.

There is a constant struggle to develop new applications and technologies capable of multi-user interaction on shared surfaces. In the beginning the focus was on sharing existing single-user applications across a network, such as for instance the MMM project (Bier et al, 1991). Later the notion of Single Display Groupware (SDG) was introduced (Stewart et al, 1999), and findings such as significant learning improvements (Druin et al, 1997), more motivation (Inkpen, 1995), higher levels of activity and less time off (Inkpen, 1999) are arguments supporting the development of technologies where several people can interact simultaneously on a shared surface.

There are several different technical approaches to how to support several users, and some of them will be mentioned here. The most well-known is pressure sensitive surfaces that track locations of one or several pressures on the surface (i.e. touch-screens). Further, interactive boards, with ultra sound and or infrared sensor technology can track one pen at the time (i.e. Mimio Virual Ink). These techniques do not support several simultaneous user inputs, even though several users can have an individual input device only one is active at the time. More advanced are interactive tables where antennas are built into the surface, and thereby track multiple passive or active objects moving around on the surface (i.e. Sensetable), or even interactive tabletops with built in sensors to track users fingers (i.e. DiamondTouch: Dietz et al, 2001). In common for these techniques is that they are based on expensive special-made hardware, which limits the flexibility and mobility.

Still, far too many multi-user applications are actually single user interfaces with a display and only one or two mice or keyboards can be active at the same time (Johanson et al, 2002). The focus for simultaneous multi-user interaction will in this thesis be on social interaction rather than traditional co-operation and support all actors take active part simultaneously, not take turns.

Interaction

Overbeeke and Wensveen argue that meaning cannot be detached from action, that meaning is in (inter)action (Overbeeke et al, 2003). Dourish agrees in this in his definitions of embodied interaction (Dourish, 2001). Perhaps it is even possible to say that meaning is in the interaction in that it does not limit or is in the way for human behaviour.

Overbeeke and Wensveen further state that design is about people in the first place, that it is about emotion (Overbeeke et al, 2003). In combining this with that meaning is in the (inter)action, then the interaction must support our human behaviour; perhaps spice it a bit, but not to be a hinder of some sort. Interaction styles should follow and meet the way and where we live. By extend the interface and the interaction space out into the spatial reality around us, and support multiple persons interacting simultaneously, then interaction can be part of our every day, supporting human behaviour. An example of this could be the MIXIS multi-user concept where mobile phones and gestures replace any other type of input device and interaction, supporting both the private and the social need and behaviour (appended paper nr 2, 3). “Design is the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes” (Buchanan, 2001)

Spatial

To add spatial aspects to multi-user interaction, inspired by architecture, brings the interface out into the room and increases the social interaction. As mentioned earlier, IT has for long been considered a non-spatial and non-physical material. With pervasive and ubiquitous computing, the number of spatial IT-artefacts has increased and been distributed into the room. Even though physical and spatial issues have not been a major topic within traditional HCI, there have been some indications of the importance of it regarding spatial content. In (Price et al, 2004) Price et al describe an approach for developing digitally augmented physical spaces to facilitate active learning. In (Fails et al, 2005) the merits of desktop and physical environments for young children are considered, by comparing the same content infused game in both contexts. The findings point towards the overall advantages for physical environments over desktop environments. Turning to interaction instead of content, adding spatiality is important, as “our physical bodies play a central role in shaping human experience in the world, understanding of the world, and interactions in the world.” (Klemmer et al, 2006)

Findings from projects within this PhD-project have increased my belief in that there has to be a stronger focus on the physical and spatial aspects in interaction design (appended paper 1) (appended paper 4) (Dalsgaard et al, 2006). In interaction design, it might not be enough to increase focus on simultaneous multi-user interaction to support the users and take a step further from traditional HCI, but rather to emphasis on the physical aspects and introduce spatial multi-user interaction. This is in line with Mark who claims the need for considering physical space in designing pervasive and ubiquitous computing systems: “Physical space rarely matters in current human-computer interaction; but as computational devices becomes part of the furniture, walls, and clothing, physical space becomes a necessary consideration” (Mark, 1999).

Research outline

Buchanan states that "one of the great strengths of design is that we have not settled on a single definition" (Buchanan, 2001). Of course, such a definition will not be defined here either, but as design is central in this work, there is a need to define how design is considered in this thesis.

Design as a word can be both a verb and a noun. In this thesis both notions will be used, but in most cases discussed in terms of activities and processes rather than objects and values. Next to prototype development, the methods and processes will be presented in order to make the process visible for others to repeat and be inspired from. The design experiments are the designs, meaning the prototypes and concepts. The reflections are the design choices and paper writing. The papers are highly communicative, and would not be re-usable if practice was not described.

The basic method through the project is experimental design practice, where prototypes in different stages along with reflections on process and design methods lay the foundation for further directions of research. The intention is to formulate a design program for spatial multi-user interaction, analyse it, perform experiments, reflect upon it and re-formulate the program. The aim of this thesis is two-fold, both to conclude on the included projects so far and to outline future steps. The goal is a research program comprised of theoretical elements informed by practice and analysis. The project will include practical design work in the development of interactive systems and the theoretical understanding of IT as a material of design.

In this thesis, appended papers span over prototypes (appended papers 2, 3 & 4), design methods (appended paper nr 5& 6) and design process (appended paper nr 1). Prototypes, design methods and process reflections are all equally important in the practice based design research work, and interaction design research should contain and present all these parts in the development of computational things, for better understanding, deeper insight, inspiration and for not making the same errors. Therefore, in order to spread the knowledge from the reflections included in this research, it is important not to see the artefacts and systems as the result of the project, rather as parts of the result.

The overall focus for the spatial multi-user interaction design program is to investigate how an increased focus on spatial multi-user interaction changes the way we design and live with computers. While striving to investigate this, several different design experiments have been and will be performed that focus on how spatial multi-user interaction can de designed and what tools there are for this. Presented in this thesis is early design work which has been performed in order to identify and get to know the field. The work to come will hopefully be more focused according the spatial multi-user interaction design program theme.

2 Inspiration

CSCW

Computer Supported Cooperative Work (CSCW) involves workflow technologies and groupware. The term groupware was first defined to refer to a computer-based system and the social group processes (Johnson-Lentz, 1982). Poltrock and Grudin (1998) identify three categories of groupware: communication, cooperation and coordination. Collaborating technology are applications that support groups working together, such as instant messaging, email, e-whiteboards, shared calendars, application sharing and desktop conferencing. One common way of classifying computer-supported cooperation is by characterising according to the time location matrix: distinguishing between synchronous and asynchronous, and between non-distributed and distributed systems (Grudin, 1994). When studying the workflow, the sequences of subtasks in a work process are in focus, but equally important are the roles performed by each individual (Poltrock et al, 1998). The expectation of a new CSCW system is increased efficiency and production by the new technology. The effects are also changes in social behaviours deriving from usage of the new technology. “To design more effective tools and new practices, the key issue is to understand the networks of people, their communication and their networks of actions that connect them” (Flores et al, 1988).

CSCW supports several users, but has traditionally been oriented towards task completion and work practice and most of all desktop based. To move forward in interaction design, CSCW can be used for inspiration, but there is a need to step away from the traditional basic values in CSCW such as efficiency and changes in social behaviours, and to see human practice and spatial aspects as a design resource in work as well as in leisure and play.

‘Third places’

‘Third places’ is a term introduced by Oldenburg (Oldenburg, Web-resource), and is a great inspiration to understanding contexts and what aspects are important in interaction. A third place is defined as follows: “Third places exist on neutral ground and serve to level their guests to a condition of social equality. Within these places, conversation is the primary activity and a major vehicle for the display and appreciation of human personality and individuality. Third places are taken for granted and most have a low profile. The character of a third place is determined most of all by its regular clientele and is marked by a playful mood.” (Oldenburg, Web-resource).

Examples of ‘physical’ third places include pubs, cafes and bookstores. A virtual environment might be considered a third place if it is a shared public space whose primary purpose is social interaction between the people who use the space, such as for instance multi-player role-playing games. 'Third places' has been a great inspiration to developing the spatial multi-user interaction design programme. The democratic values found in third places go hand in hand with the basic values of spatial multi-user interaction, and the context in which several of the experiments have been conducted are either third places from start, or turned into third places by the prototype.

Howard Gardner: Multiple intelligences

Gardner's multiple intelligences have been widely adopted in pedagogy, but can also serve as great inspiration to the designers work. When designers imagine the user, it is important to think of all the intelligences of the human being, and that it might not be sufficient to support one or two of them, but several or all. The intelligences as described by Gardner, are (Gardner, 1993):

- Auditory-musical: listen to music, experiment with sounds, song, dance
- Body-kinaesthetic: physical activity, theatre, dance, creative activities, learning by doing or touching rather than seeing and listening.
- Logical-mathematical: abstractions, numbers, discover and solve problems
- Verbal/linguistic: see and listen to the written word and use the language.
- Visual-spatial: creativity, visual experiences.

1. Interpersonal: communication, understand people, express oneself verbally and bodily, friendship, social experiences.
2. Intrapersonal: self-recognition, self-reflection, originality, self-confidence.

- Naturalist: experiment with and experience nature, create order in chaos

The pedagogical thought of involving several of the intelligences have been a great inspiration to developing the spatial multi-user interaction programme, and goes in line with "designing for the rest of *you*", to build computational things that respond to your body and the world around you, that the computers convey physical expression in addition to information (O'Sullivan et al, 2004). The human body with its multiple intelligences is a given, and the computational things attempts to be designed within the limits of the human body's expression. To support the user in several of her intelligences by exploring both the physical, digital, social and interaction space is taking advantage of the materials potential to a great extent.

Architecture

Architecture concerns the organization of activities and social relations by means of spatial layout, a highly relevant source of inspiration for interaction designers (appended paper nr 1). The nature of a design material is its ability to take up new forms or relate to other materials in new ways shifting its initial function (Löwgren et al, 2004). As touched upon, the primary interaction design material, IT, has been considered as non-physical. However, when designing spatial interfaces, physical materials come into play and designers must understand how the properties of IT relate to spatial properties and boundaries as design materials. There are benefits and drawbacks for IT being non-spatial – likewise there are both things gained and things lost when IT is physically embedded and tied to a particular space. The combination of architecture and interaction design may help in understanding these advantages and disadvantages and open up traditional understandings of space in that with interspaces it becomes a dynamic set of potential functionality open to virtual and interactive augmentation.

A concrete way of seeking inspiration from architecture in the interaction design process, is to work with various spatial design representations throughout the design process. Within the field of architecture, the design process is manifested in models. Such physical and digital models are an embodiment of the design process, where alternative designs and design decisions are represented in different forms. Prototypes in interaction design traditionally demonstrate and explore interaction with a focus on functionality, whereas models in architecture often serve to provide visual overviews and understandings of the entire space in which spatial forms and users will co-exist in the performance of activities.

Architecturally inspired design representations can take on a number of forms, eg. Virual and physical models, static paper sketches, statistically informed renderings of user behaviour, photos combined with imagery etc, and may capture and represent structural aspects as well as aesthetic and affective ones. Physical and design representations may expand the functional focus of traditional prototypes and serve as vehicles for communication, exploration, and understanding. As such, these representations supplement not only prototypes, but also design representations such as mock-ups, storyboards, scenarios etc.

3 Spatial Multi-user Interaction Program Theme

Hallnäs & Redström states that there constantly is a need for new design programs that guide and develop practice by opening up new design spaces (Hallnäs & Redström, 2006). The design space identified and explored in this program is spatial multi-user interaction. Hallnäs & Redström further define a design program as a description of the design intention on a general level, where some position regarding basic approach is stated (Hallnäs & Redström, 2006). In the following sections the general program theme and basic motivations for spatial multi-user interaction will be described, followed by a design model, design experiments, the design model applied to experiments and finally two experimental design methods. The design program has implicitly been the base for design experiments, and the design experiments have explicitly been the foundation for further development of the design program. In future work, the design program will be the foundation for further experiments.

The general program theme

Spatial multi-user interaction refers to the design of computational things with a strong focus on several simultaneous users and spatial aspects, and where a focus on spatial aspects is a central design variable. The central theme is interaction design with a clear focus on the appearance of physicality and several simultaneous users rather than design for efficient use with its focus on digital aspects and single users. It is a program that extends the traditional work practice based HCI into playful and leisure based interaction design. Spatial multi-user interaction supports human communication through computational technology based on democratic values, where several simultaneous users do not have to take turn in being in control and where interaction is based on movements of the human body. As opposed to work practice based technology designed for efficiency, this is technology where the human body in physical space is in focus for playful and leisure based interaction.

Spatial multi-user interaction takes a start in people’s way of expressing themselves physically, both individually and together with others. Here, the human body with its multiple intelligences is a given, and the computational things attempt to be designed within the limits of the human body’s expression. To support the user in several of her intelligences by exploring both the physical, digital, social and interaction space, is taking advantage of the potential of the materials to a great extent.

A designer can discover new design potentials in the existing environment when being in a design situation. A user can re-discover a familiar thing as it suddenly has the potential to perform new things. The interaction comes from human behaviour, and the tools are familiar with built-in technology, which are conscious design intentions, namely that the object has been designed to support the user by explorations in this technology's – this material's – properties, and not changing the user's behaviour.

Basic motivations

As a program for experimental design Spatial multi-user interaction is concerned with the type of dual design that computational technology introduces. The basic characteristics of computational things lie in the fact that their expressiveness, their appearance in use, depend on the execution of programs and its manifestation in a physical material. Design of computational things thus necessarily involves components of spatiality; questions about working models for a design practice where the digital and physical aspects of computational technology as a design material are central issues. This motivates experimental work where special attention is paid to spatiality as a basic design parameter.

Design Model for Spatial Multi-User Interaction

A challenge within ubiquitous computing is to design spaces where people can live, interact and communicate without the technology interfering. To have the environment support human behaviour to such extent that we act without paying that much attention to what we do. This project set out to examine spatial multi-user interaction, spaces where several persons spatially can interact and communicate simultaneously.

Four factors have been identified to focus on and define spatial multi-user interaction, and they are named *space* in the sense of potential design spaces:

The interaction space

The sensor reading space where movement, fix points and inputs can be sensed

The social space

Peoples skills and everyday life, communication, co-operation, attention, activity, intention, understanding, place

The physical space

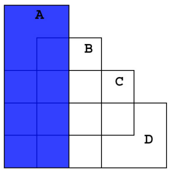
Everything visible, meaning things, environment, personal gadgets, appearances, locations, physical interactions, physical time/space

The digital space

Projections, communication protocols, computer models, infrastructures, relative time/space, augmented space, machine communication

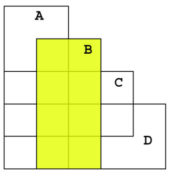
The four spaces have been chosen as they complement each other in covering the context of a computational thing. The four spaces have successfully been used in different projects, and proven helpful for designers. Three of the spaces, the digital, physical and social space have previously been used in the Bthere method (appended paper nr 5). The interaction space was not relevant for in this case architects, but when using it in interaction design the interaction space is lacking. The four design spaces have previously been used in the Missing Link workshop, in interaction design (Web Missing Link, 2004). The workshop aim was to increase the students' awareness of the dual nature of computational things; that the context is both physical and digital, and that interaction can come from both the physical and the digital side. The social space was relevant here even though no users were involved, only other computational things, but the computational things all had different behaviour. The model has evolved from these two workshops, and the four spaces used in Missing Link seemed more complementary than only three spaces.

Below is a more detailed description of what these four design spaces are, but it is important to manifest that there is no clear distinction to what is one or the other. They are all important aspects, and they all both demarcate, intervene, mix and relate to each other, which is discussed and illustrated in Figure 1 below in "Discussion on the design model".



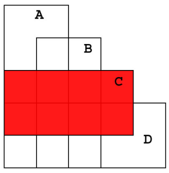
The interaction space

This design space is spanned between the existing technology and the physical human abilities. The interaction space is defined as the sensor reading space where movement, fix points and inputs can be sensed. On the user side, inputs are inspired and constrained by the multiple intelligences and functions of the human body. On the technology side, a sensor reading space can for instance be a microphones ability to take up sound or the camera space, meaning the area where a sensor in this case a camera can see physical input such as movement or appearances. By investigating and knowing the borders and possibilities of this space - static or non-static, aware or unaware - it is possible to use the full potential offered by the sensor and the interaction. There are unlimited mapping combinations between the sensor and the interaction. This can be a huge inspiration to the design process, i.e. trying out different combinations to make less traditional computing and more everyday human action like. The interaction space starts out with the technology and bodies at hand but extends extensively by curious investigations enlarging the possible design space.



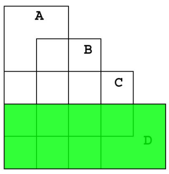
The social space

This is the space where people meet; the social design space includes technology but spans between people. This is where space gets meaning and transforms into places (Harrison et al, 1996). The social space is defined as where humans act, live their everyday lives and co-operate; it includes attention, activity, intention, understanding, communication and place. This is not a space for designing the user or the user's behaviour, this is the space where designers start with the user as a reference point, and support the user on the level of the user.
Here people communicate with several others simultaneously; long distance by technology, and closer by face-to face and with body language and gestures. There are hidden rules, hidden messages, and value signs. Not addressing this design space means missing out on human behaviour and can lead to designing the user, not just the system. This design space can be used as inspiration, for instance to reveal the potential in people's habits and behaviour. The space have a great impact on how people will live and communicate, meaning what relation they will have to the computational thing and to each other using it. To investigate the aspects in the social space, a deep and nuanced analysis is needed, as appearances are deceptive.



The physical space

This design space spans by physical constraints, and contains all types of visible things such as humans and computational things. The physical space is defined as things, context, personal gadgets, appearance, location, physical interaction, physical time/space, or just everything you see in the environment. This is where the system meets the user, and the physical context in which the computational thing will live. See the potential in people's gadgets and behaviour, use that as a base to find new ways of interaction, and design the technology, not the user.
The embedding of information systems into our physical surroundings makes understanding of physical space in relation to computer mediated activities foundational for interaction designers. When designing spatial interfaces, physical materials come into play and designers must understand how the properties of IT relate to spatial properties and boundaries as design materials. Spatial and physical aspects are important in the final system, and must therefore be carefully attended to in the entire design process. It is the responsibility of the interaction designer to care for the physical aspects as well as the interface aspects in design.



The digital space

This is the design space where different computational things communicate with each other and with the users. This design space spans by the communication of the different computational things and their output. The digital space is defined as projections, communication protocols, computer model, infrastructure, relative time/space, augmented space, and machine communication. What is happening in this space can be communicated to the user by various kinds of feedback. For instance, an individual cursor on a shared display can contain information about the input feedback previously provided by the interaction device.
In this space there is dependency on the digital infrastructures, communication protocols and similar devices. We are dependent on that others use the same type of computational objects as we do, and we are dependant on functional communication. Considerations on what communication protocol to use is tightly connected with if the full potential of the computational thing can be used or not; considering communication, how far it reaches, ubiquity, interference and so on. This is highly important when designing for spatial multi-user interaction; since every user is able to communicate with the others, simultaneously.

Discussion on the Design Model

The model presented above is an analytical tool, an attempt to divide the findings and the prototypes into different design spaces. The model can be used as a tool in the data collection phase, in the design phase, for definitions and in discussions. The model is a try to mark out that all the four design spaces are equally important when designing computational things, and especially for spatial multi-user systems. Working with information technology as a material for design means working with software, hardware, traditional physical materials and social aspects. The model aims at making this fact more visible during the entire design process.

To develop inter-spaces where people simultaneously live, communicate and interact, without technology interfering with human behaviour, the four design spaces can be a help, as a mean to design the system, not the user. An analysis of the four spaces can be the foundation for developing spatial multi-user systems, and thereby support human behaviour in both the physical and digital world.

It can be difficult to separate both observations and explorations into any of the four categories, often some aspects fits into several. Rather than to separate them it can be simpler to place them in a graphical representation presenting the entire design universe containing all of the four design spaces without any sharp divisions. A representation for this could for instance be the Venn diagram presented below in Figure 1, which describes all possible mixes of the four design spaces.

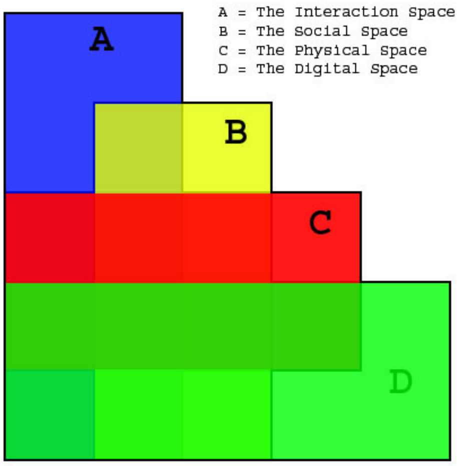


Figure 1. The Venn diagram shows all the logical relations between the sets and the universe.

The design spaces A-D in the Venn diagram contains aspects that are clearly belonging to one of the four categories, as for instance a chair in C; the physical design space. Each space has several shared or common spaces with other design spaces, and example of this could be when a chair provokes social interaction and thereby gives more meaning to itself than just the physical appearance. That specific finding would perhaps be placed in just B; the social design space, or perhaps in the shared space of C; the physical and B; the social design space. If the chair would be responsive and change character in accordance to the number of persons in front of a sensor attached to it, for instance a built in camera, it would perhaps be placed in the space shared between A; the interaction space, B and C. If the persons by the chair are able to control it by their Bluetooth phones, that is adding aspects from D; the digital design space, then it would be more suitable to place the chair in the common space of all the design spaces A, B, C and D.

Actively taking a decision upon where to place the aspect can give rise to very fruitful discussions. The background of the designers and their individual interpretation of findings will have a huge impact on design. This fact can create very interesting discussions, and could be an eye-opener to the design team. Using this picture of the model, the design team can discuss each aspect and compare it to each other while pointing it out. This way, the designers have to argue for why an aspect is weighting in one direction or another.

As interaction design is a very interdisciplinary field, where you work with several other competencies, people come to have very different opinions about what finding is relevant in which category, and the impact of it in other categories. In several projects I have worked with architects, engineers and computer scientist, and there is a constant very fruitful discussion about what is physical or digital, what approach to have in design, and so on.

To further explore the possibilities of combining the four design spaces in designing spatial multi-user interaction, spatial architectural perspectives can be included to enrich the interaction design. Architecture is about organizing social relations by means of spatial layout. By focusing on and understanding information technology in combination with spatial properties and boundaries as design materials we take advantage of what is in the context already, however the nature of a design material is its ability to take up new forms or relate to other materials in new ways shifting its initial function. The focus on these aspects provides designers the basis to rethink the existing elements of the context – the physical as well as virtual elements.

The model has been a tool in the data collection and design phases of several projects, but it has not been used in the evaluation phases within this design programme.

4 Cases

Here, different aspects of the projects are presented divided into the four design spaces. Each space has been separated into observations and explorations, to clarify how it has been useful in the data-collection phase, and how it has been explored in a later implementation phase. The projects in focus are the Interactive Children's Library project and the MIXIS project, and they are both introduced by a short overview of the project.

Finally two different methods for experimental design will be presented, that have been used or been an inspiration to projects where we have designed spatial multi-user systems with respect to the four design spaces described previously.

Case 1: MIXIS – Mixed Interaction Space

Overview of the project

Mobile phones are not just terminals into a virtual world; they are also objects in a physical world. The concept of Mixed Interaction Space (MIXIS) expands the interaction with mobile phones into the physical world (appended papers 2, 3 & 4). MIXIS uses the camera in mobile devices to track a fixed-point and thereby establishes a 3 dimensional interaction space wherein the position and rotation of the phone can be tracked. Mixis supports interaction in 3-dimensions and an object is selected as a reference point by taking a picture of it with the mobile device. The position of the mobile phone in relation to the feature is calculated by analyzing video from the camera. The reference object can be anything that stands out from the surroundings, a colour or pattern, or even the user's face can be used as a reference point .

The PhotoSwapper-application

In this project we investigate if mobile technology can be used to enhance interaction in public places while still being a personal device - to be a facilitator for bringing interaction back into public spaces.

We have introduced the metaphor *market place* to guide the discussion of social interaction in public spaces and we have identified a number of central design issues relating to balancing information push with information dialog, personal spheres in public spaces with social interaction and control versus self-regulated behaviour in the public. These issues relate to how digital technologies can play a role in a more democratized, sporadic, and social experience with digital technology in public spaces. By using interaction technologies such as MIXIS we demonstrate how it is possible to overcome hinders for social interaction. To move focus from the interaction device itself to the public surface, by mapping functionality to hand gestures instead of buttons, is supporting social interaction.

Inspired by the relation between the public space and personal devices we developed a photo viewing and sharing application based on some of the aspects defined in the market place. The users can bring their mobile phones full of personal photos to the application and use the public surfaces to upload, discuss, view and acquire photos.

The Photo-Swapper application (see Fig 2 & 3) is designed around one or more large public surfaces. We call the setup with different projections or displays in the public places *a market place*. When someone brings a mobile device to the application and connect it, we suddenly get a new mixed system consisting of both the public system and the personal device. The system is not limited to one single mobile device - everyone can connect their personal device to the system and change the topology of the system. The constellation mixes both personal and public devices as well as physical spaces with digital spaces.

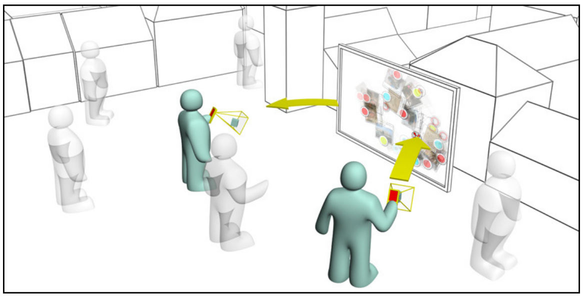


Figure 2: Mixed market place shared display.

Each user is provided with an individual cursor in the colour associated with the user that uploaded the picture. The picture can be dragged, viewed in full resolution on another display, deleted or downloaded to the phone. (See appended paper nr 3 for more information.)

Figure 3: Detail of the Photo-Swapper application.

Interaction Space Observations

An increasing amount of today's mobile devices are equipped with integrated cameras, which can be used to determine how the device is manipulated.

In MIXIS, the field of view of the camera in a mobile phone is in focus in this design space, and especially its possibility to track several different things in different sizes, how far it can reach and its light sensibility.

Related research track computer generated QR codes with the camera of the mobile phone.

Other integrated hardware, such as vibrator and audio alerts within the mobile device, offers the possibility to with tactile feedback indicate when the borders of the mixed interaction space are crossed.

Interaction Space Explorations

Different types of cameras react different to light sensibility. The best way to distinguish colours or icons is normal daylight, or at least relatively light surroundings.

By applying image analysis algorithms on the pictures from the camera, it can track gestures, tilting and movement in 3 dimensions in real-time, rotation and IDs.
Different icons can be displayed in the interface, and indicate where the tracked fixed point is located in relation to the mobile device; if the sensor has lost track of it, if the application is zooming in or out etc. This approach provides the user with little distraction from the main interface, but has the disadvantage that if the device loses track of the fixed point it is difficult to guide the user back into the interaction space.

Different objects to track have been investigated, starting by hand written circles and symbols, and further extended to track faces, fix points and different colours, meaning almost anything.

With the mobile phones used in this project it has not been possible to control the vibrator, but this is promised to appear in later models.

Social Space Observations

Focus on where and how people use mobile phones, and its meaning to us. The mobile phone is a social communication tool, most often used in an individual private situation, even when in a social situation.

In related research there is a tendency to add external technology to existing personal technology, making the user stand out. People using Bluetooth headsets in urban environments tend to be "freaks" to others, as they speak straight out into the air.

Space is turned into place by the meaning, content and use added by the people. Public space in democratic countries is open and free, a space where people can express themselves, for instance through demonstrations.

In public places, there is a strong commercial interest in pushing information to the public which leaves the average person in a public place as a consumer of advertisements.
Within a social group there exist local tacit urban rules, primarily followed by the members of the sub-community, and do not necessarily comply with the law.

A market place is a highly interactive public place. You can bring your own stuff, sell or trade it. Entertainers are highly appreciated. It is also accepted to just *be there*, enjoy the atmosphere and hear other people's opinions.

The border between privacy and public exposure is narrow. The mobile device is besides being always present also a highly personal device where personal information stored and is an interesting gateway between the personal and public domain.

Social Space Explorations

Studying the environment around a user of a mobile phone has been inspiration to the market place metaphor, where there is room for both physical and digital material in a market like interaction situation.

Internal technology of the phone has been explored, to avoid that technology is a load to the user marking her out. MIXIS has a high degree of social acceptability; it is a discrete with small gestures in three dimensions, no noise or light.

Democracy in public places could be manifested by supporting several co-located simultaneous users use the ubiquitous mobile phone as an input / output tool, and support the spatial dimension to multi-user interaction.

We have investigated a more democratic technology design in public places. Users should be able to change the "push" tendency to where the public can form the public space. The users should be able to interact, share, manipulate, and save information around them, and shape the space; not mimicking commercial interests

In PhotoSwapper, the social interaction can take place spontaneously among the visitors of the shared space, but also be mediated and stimulated by objects within it.

Since the mobile phone is a private device in a public setting, it is important to support both private and public material, and have the user in control of what information is exchanged.

Physical Space Observations

The mobile phone and other personal devices have become ubiquitous, appearing everywhere.
Public spaces are filled with different sized screens everywhere.

Physical Space Explorations

The personal camera equipped mobile phone is used for interaction, and different sized screens have been investigated for shared public surfaces. Mixis supports gestures and interaction in 3-dimensions and thereby uses the mobility of the handheld private device. Moving it closer or further away from the tracked object can grab and release photos or interactive icons. Moving the phone moves the cursor. Only one hand is required for operation of the device, so the degree of dexterity is low. MIXIS has a high degree of portability since the mobile device is personal and ubiquitous. Sanitation and physical security aspects with MIXIS are very high since the user never touches any common controls and no maintenance is needed for the input controls.

A mobile device is personal and the user has the possibility to perform private activities in public settings, but so far most of these activities are not exploiting the fact that they are performed in public space, one could say that the mobile device is just extending the office space into the public without engaging in public life.

MIXIS brings the physical world into the digital world. The individual cursors and the uploaded pictures on the shared surface have the same colour as the object being tracked, as an object is selected as a reference point by taking a picture of it. The reference object can be anything that stands out from the surroundings by having a specific colour.

There are commercial interests in being present in public spaces due to the number of people passing. The majority of the visual exposure is pushed and controlled by commercial interests whereas graffiti statements are vandalism and illegal.

As the rules guiding public activity limits the interaction we have investigated novel technology as a design material for reclaiming public interaction.

Place is created from public space in the user's appropriation of space adding content and meaning in this case through the exchange of goods and the social activities this brings along.

In Photo-Swapper the colour of the chosen reference object is transmitted to the interface; it identifies the user on the public display and stems from an object that is present in the context.

Digital Space Observations

The number of digital installations and personal devices present at any time in a public space in a modern western city is overwhelming. Wireless networks cover many city centres and people are becoming increasingly online anywhere through personal mobile devices. The mobile devices contain a range of different communication protocols. Though all these places and devices are connected they are not communicating with each other.

Far too many of today's multi-user applications are actually single user interfaces with a public display and only one or two mice or keyboards can be active at the same time.

In a market place, all activities are based on come and go interaction, where people can join and leave as they wish without interfering with others. But acting in public space there is also always external interruptions affecting the users and contestants just like someone might stand in front you in the queue for the tomatoes.

Digital Space Explorations

The goal is to produce designs that encourage and support social interaction in public places without dictating terms of use. As a large part of physical public space is experienced visually it is a need for moving the bits in mobile devices out in the public. We have explored different communication protocol existing in mobile phones today, such as GPRS and Bluetooth. Bluetooth supports communication to computers, mobile phones, it support sending and receiving data. Bluetooth is used to connect the mobile devices to the application. A program on the phone automatically connects to nearby surfaces when started.

PhotoSwapper supports an unlimited number of simultaneous co-located users. When designing for interaction in public space the application has to support the behaviours of people's multiple simultaneous activities, and support interaction where all users are able to manipulate the interface simultaneously. When a device is connected to the surface the user is given a personal cursor which can be controlled from the mobile phone. The cursor displays information about the input feedback previously provided on the phone.

The application supports input units to disappear during action and can be replaced by a new without interfering. It supports spontaneously joining and leaving the application, and short-term interaction. The information security and privacy is high, only an ID from the specific Bluetooth device is communicated. The user can spontaneously interact by connecting its to the system, and accept the application.

Case 2: The Interactive Children's Library

Overview of the project

Much design research of interactive technologies within libraries has focused on traditional interfaces operated by mouse, keyboard and screen. This project set out to design pervasive computing installations for a children's interactive library, to have the physical space and artefacts in the library becoming the interface for digital material.

There are many challenges and opportunities to consider when designing for children's library domain. The behaviors, skills and needs of the children, the decreasing number of visitors, the massive free information potential of the libraries, the need of a third place, the existing technologies in the library balanced with what is in the pockets of children. With this project, we aim to investigate a stance where we believe that there is a hidden potential in seeing such factors as material for design, and be able to join them in design proposals.
The result became several new design concepts all based on the motto "taking the physical aspects serious"; a new way of thinking within interactive library environments. The project resulted in two fully developed prototypes, StorySurfer and BibPhone. Both mixes the digital and physical to create spatial interfaces for children's multi-user simultaneous interaction and information sharing.

StorySurfer

StorySurfer is an interactive floor application displaying book covers which provide an alternative way for children to browse the library's collection of books. The book covers are evoked by stepping on buttons on the edge of the floor. Each button is associated with a keyword. Hitting a keyword button will evoke a cloud-like shape on the floor containing book covers associated to the selected keyword; overlapping clouds contain book covers associated with several keywords. A cover can be further examined by moving into the floor. Each person entering the floor and the camera space is provided with a cursor in the shape of a "magnifying lens" oriented and positioned in front of the user turning towards the centre of the floor. The "lens" is controlled by the children's body movements. Keeping the lens icon still over a projected book cover causes it to enlarge for better inspection and maintaining the position even a bit longer will cause the image to move across the floor to an interactive table. Figure 4 & 5 shows the StorySurfer prototype and the tracked movements.

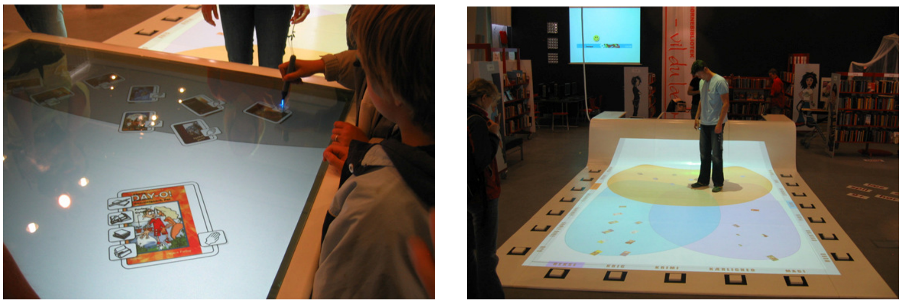


Fig.4: Detail of the table of StorySurfer and the full prototype

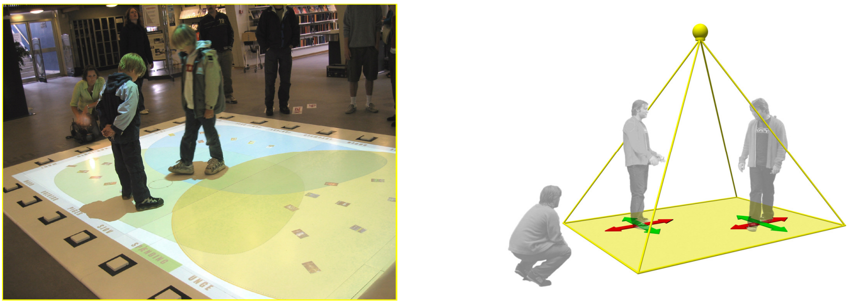


Fig.5: The StorySurfer prototype and a diagram of the tracked movements

Interaction Space Observations

The children's library contains traditional computers that the children use for internet, chat and play games on. Typically one child sits in front of the computer and controls the application, while other children around the child in control are watching, unable to interact. There is a clear need for interaction forms where several children can be in control simultaneously.

The children should be able to engage several senses and even the whole body when experiencing and dealing with information, which opens up for several different types of interaction techniques and sensors. Interaction should be inspired by for instance Gaardners multiple intelligences.

Increasingly number of libraries use RFID-technology and robots to replace the praxis of bar-code use for tracking in and out going books.

Interaction Space Explorations

StorySurfer is divided into two parts, a floor and a table. Both these parts support several simultaneous users. Different types of tracking technologies have been explored to support several simultaneous users, both on the floor and on the table. Retina (Valli, web-resource) is used to separate individuals and track the users on the floor, so there is a web-cam placed above the floor, and. The floor tracks everybody who steps into it, an entire school class or a single individual. Each person gets an individual digital cursor to control, and it moves in the directions that the body moves.

No extra gadgets are needed to interact with the floor, and it responds to body movement. The table has a web-cam inside tracking diod-light. Different interaction techniques have been tried out, but the final choice fell on the in-house developed MultiLightTracker system (Nielsen et al 2006) which supports four different simultaneous users. The home-made pressure sensitive buttons on the rime of the floor have been chosen and tried out to suit the task.

We have investigated RFID as a design material, what type is in use in the library, how far it can reach, how sensitive it is and so on. In the original idea there was a RFID reader on the table of StorySurfer so that information about that book would appear on the table when placing the book there. This idea was put on hold for later prototypes.

Social Space Observations	Social Space Explorations
The children's physical library is a highly social place, either for meeting with friends to play computer games or other typical social encounters such as children meet other children with similar interest where there are books that interest them both. The library is a third place, meaning a place where regular people from all of society can meet in a playful mood.	Being on the floor of the StorySurfer, the children can choose among fifteen different categories and three simultaneous such as for instance "love", "dragons" and "girls". In this way the children can see who chooses what categories, and thereby see who has the same interests as oneself. There is also a bit of a discussion/argumentation going on among the children, if they wish to keep a category search for a longer period of time, which makes the children engage and socialise with each other.
The library has introduced both PC's as well as console games as e.g. Sony Play Stations in striving to both facilitate children in just being there for the entertainment as well as settings for parents playing and aiding their children in PC-based games.	StorySurfer is an installation where both children and adults can browse for materials, alone or together.
There is an increasing awareness and accept of noisy elements such as game playing, and hanging out is an important element in a children's library. The children's library should build upon values appreciated by children and not just a miniature version of the adults library comprised of children targeted materials.	StorySurfer provides an arena for hanging out, tumbling around with friends or discover information. The installation does not make sounds, but the children do while using it.
Alternative information such as for instance what book is most popular is important to the children.	It is possible to see information such as "others that borrowed this book also borrowed:".
Book-droppers are becoming younger and younger	In StorySurfer it is possible for the children to see what the other children are looking at. On the floor it is possible to share curser and thereby investigate the material together. By the table it is possible to share and exchange material with each other.

Physical Space Observations

Shelves are not the preferred ordering and display of books. Books placed together makes the titles hard to separate, hard to estimate which might be interesting. Children perceive it as if the books turn their back to them. In response, librarians pick out books for cover display on special stands. When the cover is turned towards the child, the numbers of borrowers of the book increase dramatically.

Children desire to be listened to and offered a chance to have ideas valued with regard to the development of their library environment. Children desire physical spaces meant for them; spaces supporting living out their social life among friends**.** Children wish to hold on to the physical libraries, but there is a need to add some coolness to them with regard to spatial qualities and appropriate technologies.

Related research either focuses on the physical or digital aspects of the library. The computers are separated as these activities are still regarded to be side-activities to the traditional functions of the library: borrowing materials and reading books.

Little has been done in order to explore and exploit the existing physical information materials in new ways and to emphasize the social qualities of being co-located.

The extensive Internet-based services enable people to do library services from their home. The need to go to the library for collecting information materials is disappearing

Physical Space Explorations

StorySurfer provides the children with an opportunity to search for materials without staring at shelves or trying to use the adult computerised search system. In StorySurfer, the children browse among the covers of books instead of the back of the book, so that the pictures make it easier for them to separate the books from each other.

StorySurfer is a spatial digital installation which creates an arena for children to hang out and meet. Investigating the possibilities of the installation becomes a social activity in the physical library.

A book choice can be printed by the installation, with instructions to how to find it in the physical library and a picture of the cover of the book, so that the children eventually can find the book that interested them and they still remember which one it was.

The interaction is physical, based on body movement. The interaction on the table is with normal-looking physical pens, so when moving the pen the digital material moves as well.

The installation provides the library with a unique thing that has to be experienced in the physical library, and is therefore a mean to attract visitors to the library.

Digital Space Observations

Children see IT services as being a natural and attractive part of a learning environment. RFID-technology and robots to replace the praxis of bar-code use for tracking in and out going books, and this new technology do not stay strange to children for long, but is quickly adopted as an everyday element in the environment.

The library have enormous data bases with many different kinds of information, most data is used internally within the library, or just stored, and they do not know how to get it out to the visitors.

Children do not use computers based services to search for books. The interface of search engines and browsers available today are perceivably more suitable for adults, the children do not use them.

Digital Space Explorations

The floor consists of two projectors, a web-cam, and one computer. The table consists of a projector, a web-cam, a thermal printer, and a computer. The two computers share data-base. The size of the digital surface in the physical room is attractive to children; they are not scare to enter the projection on the floor and do not hesitate to investigate all functionality. To visualise that the table and the floor are connected, the digital material chosen on the floor slowly slide up the "wave" to end up at the table.

The installation is connected to a large database with pictures of children's book covers, categorisation words, content, placing, information about "who borrowed this book also borrowed", and so on. The number of objects is about five thousand.

The book-covers are displayed in a Venn diagram on the floor where each bubble is connected to a certain category. The covers come up from the floor, stay for a while, disappear down into the floor, then changes and another book comes up. In this way it is possible to display many books from the same category. To choose a book on the floor, place a cursor on top of the book so that the picture enlarges. A graphical count-down will appear, and if the cursor stays, the book will be chosen and slide up on the table and disappear on the floor. On the table there are more advanced functions, such as information about the author, the text on the back of the book, "others who borrowed this book also borrowed:" and print information.

5 Experimental Design Methods for Spatial Multi-User Interaction

The experimental design methods presented in this section have not been used as full scale versions in any of the projects described above, but they have been inspiring and parts of them used. The methods are presented here accompanied by inspiration to how they can be useful in designing spatial multi-user systems.

Bthere or be Square - A Method for Extreme Contextualization of Design

The goal for the *Bthere* method is to enhance context-awareness in design, by pushing the design process out into the context, and was developed for a workshop held with architectural students; see appended paper nr 5 for more information. By creating a deep and layered analysis of the context and the inhabitants while being in the context, the identification process of the tasks and behaviours can be adopted immediately in the design ideas. The method has been used in the Interactive children's library project, and has been inspiring when developing the MIXIS Photo-Swapper application.
The four design spaces defined previously in this thesis, or perceptions as they are called in this method, are here three instead of four. This is because the method is not developed specifically for designing computational things, and the interaction space is thereby not included, but can partly be found in the digital space.

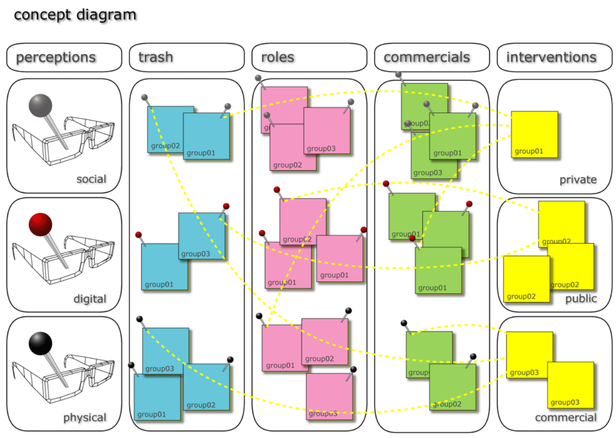


Figure 6. Table of the concept; The perceptions are ways of looking at the site, and used to define data from the three layers; trash, roles and commercials, which will be the base for the final interventions.

The general concept of the method is to divide a site and its surroundings into different layers, and thereby unfold aspects and find depths that are not visible from the surface (see figure 6). *Bthere* aims at focusing on one thing at the time, discuss it from different perspectives, and finally connect them, instead of trying to study and register everything simultaneously.

The *Bthere* method is mainly divided into two phases; the data collection phase, and the design phase. During the data collection phase, three different *perceptions* or ways of looking at the site are to be considered. The perceptions can be: *Social, Digital, and Physical*. The perceptions are ways of looking at the context, and can be compared to wearing three different pairs of glasses. To every data collected, it should to be defined from a personal opinion why it was collected and what perception used.
The perceptions are used during the data collecting phase to look for material in different predefined categories, called *layers*, and these can be: *Trash, Roles, and Commercials.* The layers are used to put words to and define details and aspects in the environment. The layers are revealed one by one, meaning that only one layer is in focus at the time. The layers are not to be presented from only one point of view, the aim is to get into discussions with the people who are in the site using it, to also be able to present their opinions.

The second phase is the design phase, where the findings from the data collection phase are discussed in groups and combined in different constellations to be used as design material. It is a conceptual intervention based on the findings made in the first phase. The groups discuss, augment and intensify three different aspects of the shared design space in the context, i.e.: *Public space, Private space and Commercial space*. The goal of the design phase is to develop ideas that make a significant change to how the site will be perceived in the future, or how life is lived on the site. The collected data will be used to create new technological designs in both the digital, social and physical world.

The common denominator of the three layers is the fact that these are often unnoticeable aspects of the context as for instance urban environments, but at the same time we claim that it is often these aspects, along with a few others, that define a space as urban, bustling and interesting. Combining the three layers with the perceptions forces you to conceive the otherwise well-defined physical space in a new fashion. As an example, it is relatively simple for most architects and designers to analyze a site on the physical level, but when it must be defined according to what roles they play and shape for or dictate to inhabitants of that site, then they will see the space in a new light. We take a range of relatively well-known terms and then combine them to challenge the conception of the participants and to discover new aspects of the city.

Dividing the context into different layers, and at the same time focusing on different perspectives, in order to incorporate tasks and behaviours of users immediately into the design ideas, contributes to many positive aspects of the design process. The information gathering part of the design process becomes more tightened to the analysis process, since it is done simultaneously, both in private, in a smaller group and with the entire group. The proposed method also decreases the load of the designer, when trying to analyze and collect everything in the context and the use of it at the same time.

Mission from Mars – Exploring User Requirements in a Narrative Space

This is a method for how to design for multiple users, and how to divide the context and gather true information from users in a shared narrative context. The method is an inquiry technique which allows designers to ask odd questions about the user's everyday life and everyday artefacts, and the users are encouraged to answer. The method contributes mostly to gaining insight into the structures and experiences of the users practice.

The method introduces data collection in a shared narrative, and it has been used in early phases of the Interactive Children's library project. Findings from the specific case described in appended paper nr 6 have been used in developing the MIXIS project, such as for instance children's relation to their mobile phone.

The method is developed within of a school project named eBag, a software system focused on handling the pupils' electronic school material. The point of departure for designing new artefacts is the current practice of the users, and part of this understanding is rooted in the artefacts that inhabit user context. The Mission from Mars method gain insight to:

- The everyday life of the future users
- The context of the future system
- Social relations and behavior among the future users
- The social relations in the context
- The use of the existing systems today
- The use and extent of personalization and customization of the context, personal objects and existing system
- The future users subjective opinion regarding all the things mentioned above

The basic idea of the MARS-method is to establish a shared narrative in which the users can take part to accomplish the mission stated in a narrative. It is important to go through the introduction of the narrative slowly, to have the users discuss and translate everything. When the story slowly evolves, it becomes apparent that Martians from outer space are interested in how things are on earth and especially the user's everyday life. Due to problems in the Martian space shuttle they can not break through the atmosphere and communication is only possible through a video connection to their orbiting space shuttle. The communication is between the Martian and small groups of users who explain about their things and everyday life. The Martian have audio and visual feedback whereas the users only have audio feedback. To increase the effect of the Martian voice a tin can add a metallic noise (see Figure 7).

Figure 7. The Martian tin can microphone and the setup

The physical representation of the Martian is the DV cam and the audio feedback (see Figure 8). The fact that s/he is not visually presented result in the creation of yet another space, as an imaginative space made by the users. Because a weird unknown voice respond to the things presented for the camera, it again helps keeping focus and interest. The users are kept as experts and focused by the mysterious Martian “eye” with which they engage.

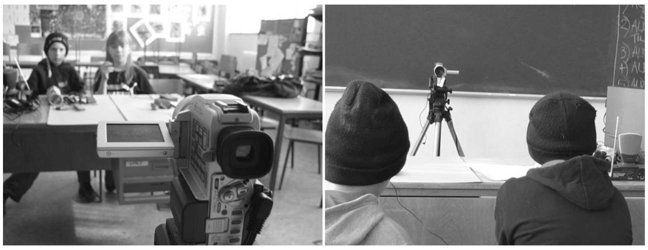


Figure 8. The camera representing the Martian

The Mars-method offers an opportunity for designers to engage with the users, establish the necessary level of confidentiality through role-play, and get requirements for making a design which is meaningful to its users and the context. The Mars-method proved to have its strength in providing a shared narrative space in which questions regarding the everyday life of the users can be asked and answered in an informal way. The Mars-method facilitates the discussion between users, which the researchers mediate through the shared narrative which offers the possibility of posing very “stupid” questions. The Mars-method is established in the user’s own context why it points towards gathering specific user requirements.

The Mission from Mars method is treated as a supplement to the existing repertoire of methods for requirements gathering. The method is inspired by previous work on design games and shared narrative spaces as well as dedicated methods for designing with children. By applying the ‘Mission from Mars’ method it is possible to support the design process in various ways. First, the method provides information on the meaning of things, how the users personalize their things and in which manner this personalization is carried out. Second, the individual structures of the user’s physical things are spelled out as a foundation for structuring the digital material. Finally, the Mission from Mars reveals aspects of the creation of social meaning of artefacts.

6 Discussion

As stated previously in the research outline, the overall focus for the spatial multi-user interaction design program is to investigate how an increased focus on spatial multi-user interaction change the way we design and live with computers. So far there are only small indications for how an increased focus on spatial multi-user interaction change the way we design and live with computers, not enough to conclude on, but enough to say that this research area is interesting to work further with. In a strive to investigate this area, several different design experiments have been and will be performed that focus on how spatial multi-user interaction can de designed and what tools and methods there are for this. As a part of this, the spatial multi-user interaction design program has been developed and consists of a theoretical foundation, a design model and research experiments consisting of experimental design projects and experimental design methods.

The theoretical foundation takes a step from traditional and effective work-practice based HCI to action oriented interaction design with a base in playful and leisure based interaction. The interaction is based on democracy rather than efficiency, the tools are familiar to the user and the user behaviour is supported rather than designed. The theoretical foundation can of course be much larger, which could be work for future directions, but it points out some basic values and differences towards related research.

The experimental design model consists of four different design spaces which can be used for categorising information gathering and prototyping and is basically a design, inspiration and discussion tool for interdisciplinary designers. It is a design model that, when used in experiments, has the potential to reveal hidden problems and forgotten issues, open up new perspectives, ask questions, and define basic concepts. As interaction design is of multi-disciplinary nature, there are many different methods and ways of working deriving from many different fields such as for instance behavioural science and engineering. The experimental design model presented within this design program can be complementary to existing practices and a mean for designers from different fields to meet. It is not a question of how you find your data; it is a question about how this data is treated in the design process, and what values you add to it depending on what background you have. The model is a support to interdisciplinary design teams, a mean to bring democracy to the findings as it is based on equality between the physical, digital, interaction and social aspects.

The experimental design projects demonstrate how this model can be used in the design process, and what result comes out of it. The experiments have been conducted by interdisciplinary design teams, and the prototypes bear signs of this in that aspects new to a certain area of expertise might be equal to foundational aspects of another area. For instance, the weight of the physical aspects in the children's interactive library project is a new architectural complement to existing computer science and interaction design aspects of the project. Here spatial aspects are just as important as information technology itself.

The experimental design methods are suggestions for means on how to gather information in the different design spaces. These methods must be seen as complements to existing practice of information gathering methods, but as they have proven helpful in several projects, they could perhaps serve as inspiration to other designers. The methods claim for dividing the context in smaller chunks, focusing on one thing at the time from different perspectives rather than trying to get it all in simultaneously. The description of the methods is basically general, but they are also highly influenced by how they have been used in the experiments.

Designing by dividing the context into smaller parts and different design spaces has proven helpful in design, and is an area that needs to be further explored. The experimental design model presented here can provide the designer with inspiration from all the four different spaces, as well as it explores the hidden potential in these design spaces.

Hopefully, spatial multi-user interaction is a growing area of interest in interaction design, to meet with the user in the physical world and take a start in people's way of expressing themselves physically, both individually and together with others. To increase the importance of the physical aspects when designing computational things it is important to weight the aspects from the physical design space equal to aspects from the digital, the interaction and the social design space.

Fällman (Fällman, 2003) argues that design involves the designer in a necessary dialogue with the materials of the design situation, from which the problem and the solution are worked out simultaneously. Therefore the role of design in HCI is an unfolding activity which demands deep involvement from the designer. Though, sometimes the designers are not aware of what materials there are in a design situation, or different materials mean different things to the different designers. For a combination of virtual representations and physical artefacts to be successful and truly go beyond what each medium can offer, we first need a thorough understanding what each individual medium can offer to us (Klemmer et al, 2006). The design model and the design methods presented in this experimental design program can be one way of engaging the designer in unfolding the context and materials at hand.

Presented in this thesis is early experimental design work which has been performed in order to identify and get to know the field. The work to come will hopefully be more focused according the spatial multi-user interaction design program theme.

7 Conclusion

The spatial multi-user interaction design program has been presented as a part of a PhD research program. It consists of a theoretical foundation, a design model and research experiments consisting of experimental design projects and experimental design methods.

The theoretical foundation take a step from traditional and effective work-practice based HCI to action oriented interaction design with a base in playful and leisure based interaction. The experimental design model consists of four different design spaces which can be used for information gathering and prototyping and is basically a design, inspiration and discussion tool for interdisciplinary designers. The experimental design projects demonstrate how this model can be used in the design process, and the experimental design methods are suggestions for means how to gather information in the different design spaces.

The basic result of this thesis is the identification of the design space named Spatial multi-user interaction, and the definition of the design program theme and its basic motivations. Other parts of the result is the development of two spatial multi-user interaction prototypes for children’s library context, uses around the MIXIS platform, a framework for camera based interaction, two practical design methods and reflections communicated in several published papers.

Future

So far, the design program has implicitly been the base for design experiments, and the design experiments have explicitly been the foundation for further development of the design program. In future work, the design program will be the foundation for further experiments, with more focus on the basic values in the spatial multi-user interaction design program. Hopefully, those experiments will lead to a re-formulation of the design program, which in addition of the experiments will be the foundation for the doctorial thesis.

At this point, it is not stated that the design model with its four design spaces is the ultimate model for designing spatial multi-user interaction. So far, the general program theme and its motivation has its strength in being identified, and whether the design model is the only or even a good tool to use is still hidden. Designing by dividing the context into different design spaces has proven helpful in design, and is an area that needs to be further explored. The model has been a tool in the data collection and design phases of several projects, but it has not been used in the evaluation phases within this design programme. In future work, further design experiments will hopefully lead to an extended and more complete design program, where its components will not only be identified, but also defined in both a stronger empirical and theoretical way.

8 Summary of Papers

Paper 1

Taking the physical aspects serious – A Design Approach to Children's Interactive Library

This paper reports on a design process of pervasive computing installations for a children's interactive library. The design and research process reported on here involve a wide range of decisive parties of the domain: children, researchers, librarians, library spaces and private companies. The process is designed so that the collectively developed design concepts can suit the needs and interests of the many parties. The design criteria for the pervasive computing concepts are based on the intentions and ambitions of public library services and user studies in children's libraries balanced with the interests of the participating parties. Sketches, concepts and their iterations illustrate the process of design and how the physical qualities of the environment played a central role in the development of concepts.

Paper 2

Mixed Interaction Spaces – expanding the interaction space with mobile devices

Mobile phones are mainly interacted with through buttons, thumbwheels or pens. However, mobile devices are not just terminals into a virtual world; they are objects in a physical world. The concept of Mixed Interaction Space (MIXIS) expands the interaction with mobile phone into the physical world (Hansen et al. 2005). MIXIS uses the camera in mobile devices to track a fixed-point and thereby establishes a 3 dimensional interaction space wherein the position and rotation of the phone can be tracked. In this paper we demonstrate that MIXIS opens up for new flexible ways of interacting with mobile devices. We present a set of novel, flexible applications built with MIXIS and we show that MIXIS is a feasible way of interacting with mobile devices by evaluating a MIXIS application against a traditional mobile interface. Finally, we discuss some design issues with MIXIS.

Paper 3

Reclaiming public space – designing for public interaction with private devices

Public spaces are changing from being ungoverned places for interaction to be more formalized, controlled, less interactive, and designed places aimed at fulfilling a purpose. At the same time personal mobile technology aims at providing private spaces in the public domain. In this paper we explore how technology can be re-thought to not only act as personal devices, but be the tool to reclaim the right and possibility to interact in public spaces. We introduce PhotoSwapper, an application where tangible and pervasive technology is embedded in a public setting with characteristics adopted from a traditional market place. We discuss different design aspects with this approach; information exchange, social support and regulation, inspired by a discussion on public space.

Paper 4

Movement-Based Interaction in Camera Spaces – A Conceptual Framework

In this paper we present three concepts that address movement-based interaction using camera tracking. Based on our work with several movement-based projects we present four selected applications, and use these applications to leverage our discussion, and to describe our three main concepts *space*, *relations,* and *feedback.* We see these as central for describing and analysing movement-based systems using camera tracking and we show how these three concepts can be used to analyse other camera tracking applications.

Paper 5

Bthere or be Square: A Method for Extreme Contextualizing of Design

In this paper we describe the *Bthere* method aiming to increase the context awareness among designers. The paper presents the method and a workshop scenario, as well as the results and evaluation from the workshop. Based upon the methodology from contextual and participatory design, the paper describes a method for dividing the context in different layers, and from different perspectives, reveal hidden structures in the inhabitant's everyday life and the environment among them, meaning a full scale context and user study to use as background material for brainstorming and design choices. The aim of the workshop was to accomplish an expanded notion and awareness of some of the aspects of the city that are invisible or unnoticeable. The method claims for increased full scale context awareness, and for alternative user involvement in the design process.

Paper 6

Mission from Mars – A Method for Exploring User Requirements for Children in a Narrative Space

In this paper a particular design method is propagated as a supplement to existing descriptive approaches to current practice studies especially suitable for gathering requirements for the design of children's technology. The Mission from Mars method was applied during the design of an electronic school bag (eBag). The three-hour collaborative session provides a first-hand insight into children's practice in a fun and intriguing way. The method is proposed as a supplement to existing descriptive design methods for interaction design and children.

9 Illustrations

Figure 1:
Venn diagram from Wikipedia, edited by Eva Eriksson

Figure 2 & 3:
PhotoSwapper by Andres Lykke-Olesen

Figure 4:
StorySurfer by Eva Eriksson

Figure 5:
StorySurfer by Andreas Lykke-Olesen

Figure 6:
Bthere by Andreas Lykke-Olesen

Figure 7:
Mission from Mars by Andreas Lykke-Olesen

Figure 8:
Mission from Mars by Andreas Lykke-Olesen

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Paper 1

Taking the Physical Aspects Serious - A Design Approach to Children's Interactive Library

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ABSTRACT

Much of the research design of interactive technologies within libraries has focused on traditional interfaces operated by mouse, keyboard and screen. This paper reports on a design process of pervasive computing installations for a children's interactive library. The business of developing public institutions is the responsibility and interest of many actors. The design and reseach process reported on here involved a wide range of decisive parties of the domain: children, researchers, librarians, library spaces and private companies. The process was designed so that the collectively developed design concepts could suit the needs and interests of the many parties. The design criteria for the pervasive computing concepts were based on the intentions and ambitions of public library services and user studies in children's libraries balanced with the interests of the participating parties. Sketches, concepts and their iterations illustrate the process of design and how the physical qualities of the environment and the artefacts played a central role in the development of the concepts.

Author Keywords

Sketching, Interaction Design, Children's library, Design process.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

In a children's library a 9-year-old girl, is making a drawing of a moon-rock working as a search tool in Martian libraries. Upon request from a team of researchers doing user studies she is envisioning and sketching what the library on Mars might be like. Like the majority of the children that were subject to user studies with regard to the development of a children's interactive library she imagined physical magical tools that would enable the various intangible tasks in a library e.g. doing searches, engage and participate in the book stories, exchanging opinions etc.

The vast research in children's social and search behaviours in a physical library as well as in digital libraries reveal an interesting area. However, little has been done in trying to combine the two, making the physical space and artefacts in the library the interface for digital material, and shifting the desktop computer to pervasive computing systems. Most literature points toward the need to develop information literacy enabling the children to deal with the increasing range and quality of information in order to make well informed choices. In [17] studies reveal that new tools such as online library catalogues, electronic encyclopaedias, online databases, and digital libraries, bring together children and information. There are several examples on how researchers and libraries try to deal with the decreasing interest for books among children and increased interest for new media. There is also extensive research in various digital services for libraries e.g. library web sites, library search engines, sociable web services based chat rooms connected to the library web site and digital comments on books; services and developments supporting the views of Mackenzie Owen who foresees the future library as digital, virtual and distributed [8].

On the other hand literature such as [13] reveals that children desire for physical spaces in the libraries that are meant for them; spaces supporting them in living out their social life among friends and peers. Along with this there is a desire among children to be listened to and offered a chance to have ideas valued with regard to the development of their environment. The report also identifies a desire among children to exploit new media, as information technology is regarded as a natural learning environment. These findings are in line with [14] where young people and children express their wish to hold on to the libraries, but there is a need to add some coolness to them with regard to spatial qualities and appropriate technologies.

In [16] Price et al describe an approach for developing digitally augmented physical spaces, which they claim do facilitate active learning. Another indication of the importance of the physical environment can be found in [6] where the merits of desktop and physical environments for young children are considered, by comparing the same content infused game in both contexts. The findings point towards the overall advantages for physical environments over desktop environments.

It is generally acknowledged that the physical library has a central cultural and social role in society, democratically accessible to all free of charge and being based on the combination of sociality and collection of information material. What will facilitate and be sufficiently attractive to make children still interested in going to the library?

The current and most prevailing answer to this in many children's libraries has been to set up computers and game consoles in order to make available what presumably is attractive to many children. But little has been done in order to explore and exploit the existing physical information materials in new ways and to emphasize the social qualities of being co-located, promoting the sharing of views and ideas. The latter is the ambition of the library that encouraged our research centre to initiate a project and gather a consortium of interested parties that would stage the political ambitions of how the children's library is to develop.

On the basis of this and the experience from user studies it became the purpose of the project to develop pervasive computing concepts and installations that challenge the traditions of the library with regard to how existing materials are presented, and furthermore how the library offers new activities in the physical spaces of the children's library. The design criteria for the installations was to go beyond existing interaction modalities for computer appliances, involving several senses and the whole body when interacting with computers, and exploring kinaesthetic aspects in learning.

In the following we present a range of design concepts for a children's interactive library and how it was developed and iterated on through a series of workshops involving all the research parties. The design rationale was based on findings from user studies on location in the domain, and the ambitions for development expressed by the librarians.

THE CHILDREN'S LIBRARY DOMAIN

The children's library is typically seen as a library in the library a service on its own rights. Though being an institution on its own rights it is very faithful to the fact that it is grown out of the "adult" library with regard to search facilities and the display of materials. As mentioned in the introduction of this paper the library has introduced both PC's equipped with children appropriate games as well as console games as e.g. Sony Play Stations. These resources both facilitate children in just being there for the entertainment as well as settings for parents playing and aiding their children in PC-based games. Some libraries have established facilities for teenagers. Typically the computers as well as the facilities for the teenagers are separated into rooms and niches in association with the children's library as these activities are still regarded to be side-activities to the traditional functions of the library: borrowing materials and reading books. But there is an increasing awareness and accept of the noisy elements such as game playing, hanging out as teenagers is an important element in what a children's library should offer its users, and that the children's library should build upon values appreciated by children and not just a miniature version of the adults library comprised of children targeted materials. Another initiative taken up by children's libraries reflecting the change of media consumption among children is the many web-based services e.g. forums for Q&A, chat, reviewing and recommending materials that have become available in the last 5 – 10 years contributing to make children aware of the services and many facets of the library.

Generally the library as institution is challenged in many ways these years, among others the extensive Internet-based services provided by libraries enable people to do searches, read reviews, make reservations of physical materials from their home computer. Though many of these services are desirable from an ease of use point of view, they also contribute to the depopulation of the physical library. The actual need to go to the library with regard to collecting information materials is disappearing along with the increase of Internet-based services.

Means for design

There are many challenges and opportunities to consider when designing for children's library domain. The behaviors, skills and needs of the children, the decreasing number of visitors, the massive free information potential of the libraries, the need of a third place, the existing technologies in the library balanced with what is in the pockets of children. With this project, we aim to investigate a stance where we believe that there is a hidden potential in seeing such factors as material for design, and be able to join them in design proposals.

We argue that information technology can be viewed as a material for design for a number of reasons. The material is both abstract and concrete, both imaginary and material, both software and hardware. It allows for communication, controlled dynamic behaviors, as well as adaptation to new or local conditions, and is central to the field of interaction design. However, it is not sufficient for successful interaction design on its own, other materials are needed as well. These "other" materials are primarily physical, such as plastic, metal, glass, wood, textile, even though we also need more abstract things such as ideas, organizations, economy, etc.

To explore the possibilities of the children's library domain, we also include spatial architectural perspectives to enrich the interaction design. Architecture is about organizing social relations by means of spatial layout, the control of natural phenomena such as light, temperature etc. It is about facilitating people in being together and enabling them to separate into groups when this is preferable. Most basically architecture consists of places to stay still and areas for movement and traffic. By focusing on and understanding information technology in combination with spatial properties and boundaries as design materials we take advantage of what already is in the library, however the nature of a design material is its ability to take up new forms or relate to other materials in new ways shifting its initial function. The focus on these aspects of the children's library provided the partners of the design team the basis to rethink the existing elements of the library – the physical as well as virtual elements.

RESEARCH TEAM AND PROJECT SETUP

To meet the challenges experienced in the children's library domain a research consortium was established, comprising competences from the research centre; architecture, interaction design, engineering, and computer science, combined with a set of industrial partners having various interests: a cabinetmaker, a web bureau, a company developing library databases and an architectural office. To facilitate quality and diversity of input from the library domain representatives from five major regional children's libraries were part of the project setup. In order to ensure the relevance of the developed concepts user studies were conducted and the time line and the structure of the project was designed to facilitate several experimental periods involving children in sparking design ideas as well as being test drivers of the installations. Hereby they would also provide valuable input for the iterations on the developed prototypes.

On the basis of these challenges the local library services and key researchers formulated a set of ambitions and facilities to be met in a future interactive children's library:

- The children should be able to engage several senses and even the whole body when experiencing and dealing with information
- Noisy activities are accepted on equal basis with more silent ones as e.g. reading
- Regain the importance of meeting in a physical room emphasizing and staging the social qualities this do enable – the library as a social arena

- Work positively with the fact that children see IT services as being a natural and attractive part of a learning environment.
- The target group of children should be those who had just started reading (approximately 7 – 8 years) but not exclude older nor younger children

Based on the aforementioned selected challenges the project was biased. But not only did the challenges bias the project but the interests of the participating parties also biased the project. In order to ensure the balance of interest in the project a development process was designed. This process is described below.

METHOD

In this section we describe the design process that led to a range of different concepts within the domain of the children's library. The design process covers the project initiation, involvement of parties and development of concepts whereas the implementation is reported on elsewhere [12]. Through this description we wish to emphasize the importance of the different partners being part of the project consortium and further show how ideas got informed and changed through the design iterations. The entire process was highly research driven with respect to the other parties in the consortium. However this influenced the approach and focus throughout the process.

Intro workshop

The Interactive Children's Library project started out with a kick-off workshop that aimed at letting all partners meet up and present themselves to each other. At this stage no one talked about "what to do", but instead what their background and competences was and why they had chosen to participate in the project.

After each participant had presented their perspective on and potential contribution to the project – e.g. furniture manufacturer, interested in new interactive approaches to furniture, contributing with reality checks and know how on production for the specific domain - all participants were divided into smaller workshop groups. In the groups mixed among library, company and research partners we discussed possible ways of progressing the project in such a way that we worked from a common understanding and that every partner could see a useful outcome. The ideas were later presented in plenum and discussed.

User studies

We visited in total three different libraries for field studies; one for observational studies only and two where we did engage the children in activities that would help us understand their perceptions of the current library and what they would like to see happen in the near future. There were four steps in the user studies in the two libraries. Firstly we placed ourselves in the children library department, and started to pack up things that we had brought. The children were curious about us, and approached us to ask what we were doing. We asked them to tell us about the library, what they were doing there, why they were there and what people they would meet there, see figure 1A. We asked the children to make short video films about the library, where they would film each other demonstrating and telling about the library, without us interrupting. Secondly in the middle of the room we had a table which we filled with crayons and papers, and we asked the children coming up or passing by to draw from one of two themes, either how the library will look like in 100 years, or to explain how the library is on the planet Mars. See figure 1B. The idea of taking departure in how the library might be on Mars was inspired by [2] carrying the ambition of creating a shared narrative in which both the children and the researchers could play with ideas that are out side the narrative space staged by the current library. Furthermore this approach could (and did) bring mythical and mystical aspects into the discussion on what the children's library might be like in the future. This discussion happened between the children and the researchers and later within the research team as such.

Figure 1. A member of the research team A) studying children playing a computer game, and B) sketching with a child.

Thirdly we placed out questionnaires in different places in the children's department of the libraries, where the children freely could give criticism to the library and suggest changes. Fourthly and last we did unstructured interviews with interested children while they were demonstrating for instance how a computer game was played or how one returns borrowed books.

Findings

Our findings from the user studies can be divided into three categories:

1. Social and spatial
2. Cognitive and emotional
3. Technological and digital

Social and spatial findings are for instance that many children have a hard time finding a physical location to hang out. In two of the children's libraries we have visited one part was dedicated to infants and pre-school children, and one part to teenagers. Many children do not see them selves as belonging to any of these groups. Experiences from one of the visited libraries show that a nuanced and graded division of the space based on the spatial layout of information facilitate children in finding "their space". Perceivable this can be achieved when the materials are ordered in terms of the age group they appeal to; as expressed by one of the kids: "we meet where I find books that interest me".

With regard to the cognitive and emotional aspects, shelves are not the preferred ordering and display of books seen from a child's perspective. The amount of books placed together makes the titles hard to separate, leaving children with little chance of estimating which book might be of interest to them. Librarians know that the children do perceive it as if the all the books turn their back to them. In response to this librarians pick out books for display on special stands so that the cover becomes visible. As soon as the cover is turned towards the children, the number of borrowers of the book will increase dramatically. As candidly noted by a librarian: "this way we can almost decide which books the children should read!" This is of course not fully true, but the covers of course help the child to visualise if the

book might be of their interest along with the note on the back-cover, and furthermore the children expressed interest in having more info on the story in helping them to decide.
In the Scandinavian countries many libraries are adopting digital technologies for library purposes. Increasingly libraries use RFID-technology and robots to replace the praxis of bar-code use for tracking in and out going books. In our studies we found that this technology do not stay strange to children for long, but is quickly adopted as an everyday element in the environment. Rather than being hesitative the children put their curiosity at work and quickly understands and the use and purpose of the technology. On the other hand we found that children do not use computers to search for books. The interface of search engines and browsers available today are perceivably more suitable for adults, the children do not use them.

Sketching

The findings, design statements and proposals made by the children during the field study was brought back into the research studio and analyzed. We went through the video footage and saw the library presented from the children's own perspective. Together with the children's design ideas for a future library we refined and developed the concepts and visualized them through conceptual drawings.
The purpose of this stage was to be able to present and pass on the most dominant and interesting findings to the rest of the project group making it work as a shared basis for understanding the children's library that we were to design for.
Apart from the ideas directly inspired by children and the existing technology we created a range of drawings, meant to rock all participants' understanding of the children's library, this was inspired by the work of [5]. Deliberately we added a physical approach as the starting point to provoke a discussion on the social aspects of the library space. This was done through 3D computer models of twisted shelves becoming tables, elaborate floors becoming landscapes of secret caves and ponds for knowledge that due to changed scale of furniture would only gain access for children in certain parts of the library. (See figure 2).

Company workshop

The next step in the process was a workshop with the company and research partners. The idea of separating the industrial partners from the library partners at this stage was to have the industrial partners go beyond what might be pleasing to the potential buyers of their products, but also to avoid that a rigid understanding of what the companies were capable of would lock the process. The workshop was lead by a group of researchers and started out with a presentation of the findings and initial concepts, (see figure 2, 3B, 4 and 5 below).
After the presentation all participants were divided into groups doing brainstorms on one or more of the concepts presented earlier. The aim of the workshop was to have the industrial partners to work, contribute to and mould the ideas together with the researchers so that everyone could agree on an interesting way for further development of the concepts. The brainstorm was recorded on post-its and in sketches on regular paper that in the end of the workshop was presented and discussed in plenum.

Sketching

The workshop with industrial partners led to the development of initial concepts as well as a new idea for a piece of interactive furniture called LibBox (see figure 3A). All ideas in this phase were sketched up for presentation at the upcoming workshop with the librarians. All concepts were brought to the same level of completion to be equally treated and evaluated.

Library workshop

The next step in the project was to involve and inform the librarians on the concept developments, challenging their work practice and preconceptions. By excluding the companies from the workshop we hoped for unrestrained ideas that could be blue-sky ideas pointing toward a new children's library despite possible problems in realization. A workshop with librarians from the five participating libraries and the group of researchers was carried out in much the same way as the earlier workshop with the companies. First we presented our findings from the field study and later the design concepts made by children, researchers and companies. The concepts were discussed in smaller groups which led to new concepts inspired from or build on top of the initial ones. In plenum we discussed the new concepts and rated which ones the researchers should develop further for the next plenum meeting.

Sketching

In the weeks after the library workshop the researchers developed the concepts further. We made sure that the design ideas we took further contained the most possible challenges and potentials for all parties in the project team. This was done to assure that the level of engagement and commitment in the later prototyping and implementation phase would be high which the entire project team would benefit from. We the researchers narrowed the number of concepts down to six before the next workshop session. We made small video sketches out of them to visualize the interactive potentials or problems in use.

Common workshop

The purpose of this common workshop which included all project participants was to come down to two or three concepts that we all could agree on should be subject to further development, prototyping and implementation tests in a real children's library environment. The design concepts was presented through sketches and video prototypes as had been the general communication method in the process so far. After a quick round of commenting on the concepts we divided into groups of four-five people all groups having at least one representative from each party. The purpose of this session was to add new aspects and ideas to the presented concepts but most of all it was to rate the design concepts from a personal interest point-of-view being a librarian, researcher or industrial partner. Three different colored post-its represented the three interest groups and each participant had to write pros and cons in relation to each concept. All concepts were displayed on a large white board and added with the colored post-it notes revealing strengths and weaknesses in the concepts in respect to all participants. In plenum we discussed the possibilities for all concepts and it was obvious that everyone had to kill a darling or two if we wanted to proceed with a realistic number of concepts to realize; concepts that contained potential and interest for all participants. We came down to two concepts namely the LibPhone and

CubeSearch, (see figure 7). These were to be developed further by a smaller group representing all parties and then later evaluated in plenum. In the following the concepts developed in the design process are presented.

DESIGN CONCEPTS

Here we will present some of the many concepts that came out of the design process. The concepts are described in order of ideation chronology, the initial provocative concepts first and the refined and altered concepts last. Some design concepts have been left out but the intention is still that these concepts show the development from being thought from one perspective (e.g. information technology) to concepts coupling spatial, social and technological aspects in a children's library environment.

Twisted Shelves

The shelves of the library are rounded to enable the creation of private spaces. This concept was used as a kind of prototype to inspire the participants in the aforementioned workshops. The images question what a shelf is and in particular they should serve to help the participants to go beyond what they knew would work. Furthermore the concept was to encourage daring ideas even if they might seem foolish at a first glance. See figure 2A.

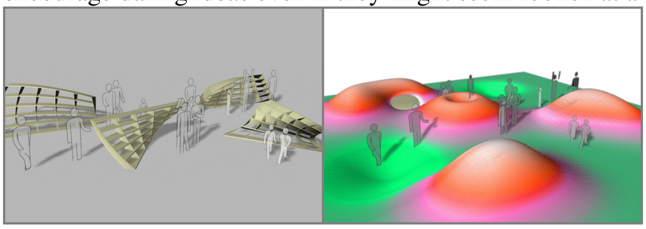

Figure 2. A) Twisted shelves. B) Caves

Caves

The library is turned into a landscape of mountains and caves. This idea supports the children in finding a space for themselves or for them with friends, where they are invisible to others, and takes one step away from today's library. Along with the twisted shelves images these were to promote the blur the potential preconception of what might be realisable within the frame of the project. See figure 2B.

The Egg

This is an interactive 1-4 person room that is responding to the information material that children bring into it. For instance if a book about Antarctic is brought into the Egg, the ambient will be Antarctic-like, with wind sounds, polar bear roars, and a lowered temperature. The concepts originated from the library wanting to provide unique high-quality experiences and installations that children would not find in their private homes. See figure 3B.

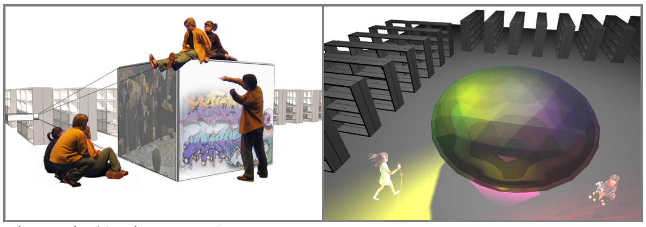

Figure 3. A) Lib-box. B) The Egg.

Lib-Box

The concept consists of a large multi-purpose box. This idea is based on the design intention that the library should be a place for large-scale interactive experiences, and where gadgets are more than welcome to be big and roomy. The box can be used for projections, theatres, games, rooms, stage, sms, or play ground. Furthermore the concept is thought as touring from one library to the other added with new content that expands the use of the lib-box. See figure 3A.

Searching

In this concept a stack of books is read by an RFID-reader. The scanned books can be searched and categorized by attributes that are not usually available when searching books; for instance most popular, amount of pictures, size of letters, number of pages, and so on. The reader becomes a dissection tool to rate physical attributes related to the books but still encouraging the children to pick books from the shelves but then compare and look at them in new ways. The concept originated from our findings that children do not search for books, and that they choose books based on alternative factors not described in the search system as it is.

Tangible Chat

The concept is to connect the emoticons used in chat-rooms to an actuator-enhanced chair translating the emoticons to physical movement. The concept was derived from children's intense use of chat rooms, and the assumption that physically mediated response helps the children in feeling closer connected than what can be experienced in ordinary chat rooms. See figure 4B.

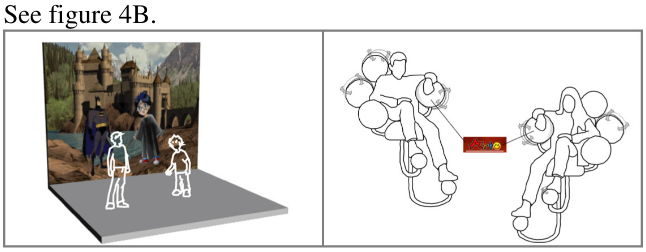

Figure 4. A) Harry and Superman. B) Tangible chat.

Harry and Superman

The idea is based on children's creativity and fantasy, where the children can be their favourite character, as for instance Superman and Harry Potter. By using a tracking technology, the child's movements are direct mapped to the movements of the character on the screen. In this fashion all types of stories can be created, mixing all types of characters. This concept originated from the children's dream to be their hero. See figure 4A.

The Moon-Rock

This is a type of magic large ball-shaped interactive device revealing the content of a book in an explorative way. When putting a selected book into a slot in the "moon-rock", the book is visualised in a peephole manner on small-sized screens showing: the plot, the bad guy, the hero, the main character, the setting, etc. The children get a glimpse of the story inspiring for exploration, the "rock" thereby being a supplement to the narratives about the book to be found on the back cover of the book. The concept originated from children wanting to have explorative glimpses, get snippets of the story to help judge its attractiveness. See figure 5B.

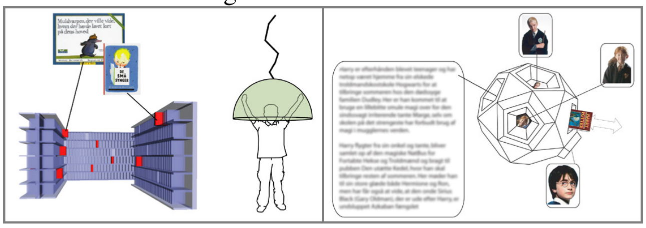

Figure 5. A) The search helmet. B) The moon rock.

The Search-Helmet

This is a large umbrella shaped helmet-like thing that the child holds above the head while moving around in the library. The child can adjust different search criteria focusing the system in relation to the child. When strolling in the library, information derived from the preferences of the child will be displayed on the see-through material of the helmet. Information on books, such as film, info from the web etc. is displayed in relation to the view on the real world books. The concept originated from the observation that children find little interest in the back of the book; to them the attractive part of the book is the cover. Furthermore children do not search for books through the available systems, they browse along the shelves to find material of interest. See figure 5A.

Critique Collector

Here children return their books in the positive or the negative box, and thereby express opinions about the book. Both input and output are instant, and is connected to an act the children will have to do anyway, namely returning the library material. The idea originated from having children informing other children on what to read. Children are reluctant in doing traditional reviews, as these are time consuming. The installation should provide a swift indicative rating of the borrowed material. See figure 6A.

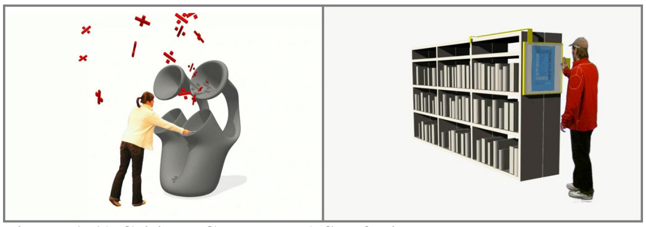

Figure 6. A) Critique Collector. B) Shelf-slider.

Shelf-Slider

This concept supports the children in that they prefer watching book covers instead of the back of the books. By steering a physical slider along a traditional shelf lined up with the back of the books, the covers of the books are displayed on a display next to the user. The interaction should be highly tangible moving the magical section tool through the shelf revealing the must-reads in the otherwise blurry mass of book backs. The idea originated from the fact that shelves are a spatially efficient way of storing books, but inappropriate for children when they browse for books to read. The concept supports the sociality of finding books together as several children can watch simultaneously. See figure 6B.

Lib-Phone

The Lib-phone concept enables children to annotate physical material with digital recordings; children are able to add oral comments to books by placing the Lib-phone over a RFID tag on the book; putting an ear to the book enables hearing the comments recorded by others. Along with the "Critique collector" the concept originated from children's reluctance toward doing written reviews, and the fact that more and more libraries are adopting RFID technology on information material. The lib-phone can be used for "treasure hunting" for messages in books or enabling children to have a secret information layer attached to selected books can also be imagined. Furthermore the concept is not restrained to information materials but could also be used with regard to adding RFID tags to specific elements in the physical environment, enabling new forms of play and information exchange. See figure 7A.

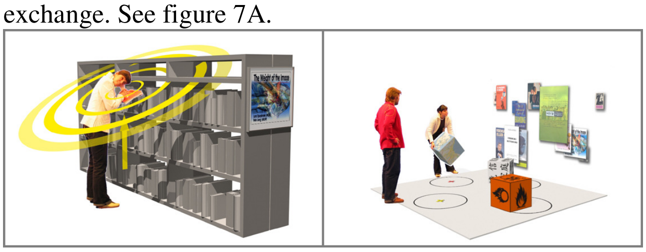

Figure 7. A) Lib-Phone. B) CubeSearch

CubeSearch

The cubeSearch concept is a physical search engine for multiple children. A range of physical cubes represent different keywords or search criteria; by moving the tracked cubes on a floor the connected wall display will visualize book covers matching the position of the different cubes on the floor, e.g. medium horror, some love and large type set. Using the

print and location cube the resulting book covers can be printed for the child to remember what the book looked like along with instructions on how to find it. See figure 7B.
Based on discussions in the project consortium the last two concepts were chosen for realisation. And periods of experimentation will run in the spring of 2006.

DISCUSSION

Based on the presented work we raise two discussions in the following namely: the involvement and role of children in the design process, and how the developed concepts meet the challenges for the children's interactive library as defined by the project team.

The role of the children in the design process

There is a growing acceptance of the stance that new technology for children should be developed according to children's existing practices, and while participatory design is becoming generally accepted, the roles of the children during the design process are ranging from active co-designers [20, 3, 4, 7] to less active informants as advocated in [18] and [19]. These different conceptions of children's role in design have a heavy impact on the way user requirements are gathered during design [5].
Druin [3, 4] has developed a cooperative inquiry framework based on participatory envisioning, contextual inquiry and lab observations to involve children as legitimate co-designers in the design process. During the design process, the children's practice is reflected in their design contributions. The cooperative inquiry framework is indeed a highly useful methodology for gaining access to children's practice; however [11] emphasize the need of time and effort to establish a productive intergenerational design team.
In this project, we have deliberately chosen to exclude the children from large parts of the design process. In our process, the children were involved while performing the initial user studies. After that, the children's views were only involved by reference to the collected data, and by means of the unrecorded experiences from the people involved in doing the user studies. Based on this the design discussions always took point of departure in out understanding of the children. Furthermore it was clear to all project participants that children would be the final judges on the design concepts when involved in the prototyping phase and again in the practical tests and tasks.
We deliberately chose to exclude the active participation of children in the design process, as we regarded our approach to the domain too complex and detached from the real children's library environment in order for it to be meaningful to bring them into our lab. The children's views and wishes are of course the basis for the development but the adult and professional interpretations of these needs to come into play too in order to address intentions beyond the view of the children e.g. "a database is seen as a great potential for a game". We think that the capability of the children to imagine these new types of systems, in addition to imagining being in the context of the library, were not realistic.
During the initial user studies, we did not tell about our project or why we were there, because trying to have children imagine what the library will be in the future would most likely just result in "more computers and more games"-wishes, which was of no use to us. For the purpose of gathering user requirements for this project, we tried alternative ways to establish a common ground, by the mean of narratives.
In recent design projects some of the authors have experimented with shared narrative spaces in various participatory design contexts e.g. [2]. We define a shared narrative space

as a social constructed environment in which conventional cultural expectations are temporarily bypassed, and we believe that the potential of a shared narrative environment might be fruitful when designing with children.

In this project, narratives have been used in two ways, children creating video stories and during sketching what the Martian library might be like. While sketching, the researchers and children sat together in the public library and drew visions, told stories and fantasising on how the library looks like on Mars and how the library looks like in 100 years. Being in the actual environment that we are discussing or designing for made it easy for the children to imagine how things could be different – "look at all the shelves, imagine if they all were placed on top of each other – the library as a shelf tower". This method proved to be a highly successful complement to existing methods for gathering user requirement – a sort of on-site informal brainstorms.

During the initial user studies, we also gave approaching groups of children a video camera to create their own stories about their library. The children shifted between filming and being filmed, and they directed each other to tell an interesting story of what you do where in the library, why they do so and so and what it means to them. We consider this creative study to be a mean for the children to use narratives to make us understand as well as create a common ground. Both in the case of sketching and in video stories, the outcome of the narratives is a straightforward and multi-coloured exploration of user habits and needs.

Instead of establishing an intergenerational design team such as [3] proposes we have established a design consortium with various interests, backgrounds and practice from children. By using informal input from children at an early stage of the design process and in the right context of use, we believe we have been able to create a multi-facetted understanding of the domain, its users and their needs. The time and effort it would have taken for us to create an intergenerational design team, and include children in all parts of the design process, could perhaps have been well invested and perhaps result in different types of concepts. We have chosen to take another approach than [3] in this design process, since we are not convinced that we would profit from that. As it is now, we consider the results to be domain specific and in line with our findings.

Reflection on the design concepts

As described above the developed concepts were designed on the basis of recordings of children's ideas, wishes and associations in context and affected by the members of project team. We will now discuss how the developed concepts correspond to the initial framing of the children's library domain and how a research project consisting of many different partners can work in shared projects with multiple and diverse goals.

To initiate the design process we used blue-sky concepts physical installations for the children's library. Through the workshop sessions all partners improved their understanding of the many aspects and perspectives on the domain, which resulted in increasingly complex concepts that took advantage of the spatial possibilities, the gathered user requirements as well as the expert knowledge of each partner. The Lib-box was initially intended as a piece of furniture supposed to change the physical space but during later discussions it transformed into a multi-functional media box that supported our focus on social activity in physical space as well as containing potentials for both media and furniture partners.

Another example of a progression in the concept development pushed and framed by the project team is the Moon-rock, Search-helmet and Lib-phone. The Moon-rock sketched by a kid had the ability to dissect and present relevant and additional information from a book.

As this concept was related to the library on Mars and in many ways very abstract the idea of an augmented reality-like helmet came up as a more concrete proposal using the existing physical structures but adding new visual layers to the books. Later this concept developed through a discussion on the physical space as interface and the ambition that parts of the children's library can be noisy. This resulted in the Lib-Phone concept exploiting the spatially structured books as the interface for sound interaction while being an invisible system to engage children in exploring the materials in the library.

The guiding principals in the development of the concepts described above have been the findings in the user studies balanced with the ambitions expressed by the participating research parties. Therefore none of the concepts reported on here are associated with computers in a traditional sense. They all explore new ways of taking advantage of the physical environment, children sensor-motor skills and the social qualities in children being co-located. They all try to activate digital information in relation to physical materials, and habits in the physical realm. The concepts presented here focus on supporting existing activities and beyond in the children's library but materialise the ambition to change the children's library through new opportunities for the exchange of information that responds to the interests of the children.

The approach taken and the concepts developed during the initial phase of the interactive children's library project, differs from the stance of other research projects in the domain of children's library. Still, we see the possibility of using other related research as a mean of preliminary concept evaluation, especially from projects such as the International Children's Digital Library (ICDL) [17] saying e.g. that as information seekers, children display evolving information needs and employ iterative search strategies, preferring to browse rather than use keyword searching [1]. Therefore the interface of the ICDL is designed to support alternative ways of searching a collection of digital books such as categories, colour, shape or region of the world. However, since the ICDL is digital, it still support the traditional approach of one user, one computer.

In [10] findings from studies focused on digital libraries are presented, but some of their findings are directly valid also for physical libraries. For instance that children will not use libraries that is uninviting or that do not support their search and retrieval strategies, which is in line with our findings, and mirrored in the furniture concepts e.g. the Egg, the Caves, as well as the physical search concepts, e.g the Shelf-Slider and CubeSearch.

One interesting finding from [10] is what they name sociable literacy, that beyond utilities to support searching and reading activities for individuals, the libraries must support dynamic and sociable functions, for instance functions such as annotating and sharing materials. In [9] Kaplan et al discuss the development and field testing of a "sociable digital library book", an application that provide readers with the ability to leave notes and marks in a digital book and to share notes and marks with others. In these studies, the children's needs for sociability is found in the physical world and is taken one step further into the digital world. The vast research in children's social and search behaviours in a physical library as well as in digital libraries reveals that it is a highly interesting area. However, so far not much have done in order to combine the two, making the physical space in the library the interface for digital material, and shifting the desktop computer to ubiquitous computing systems. When Reuter et al [17] claim that new tools such as online library catalogues, electronic encyclopaedias, online databases, and digital libraries, bring together children and information, we in the Interactive Children's Library project take another approach. We believe that it is true to a certain extent, but we strive to discover if there is a hidden potential in building physical interfaces to explore both physical and digital material in the children's libraries. Our concepts are the result of an effort to try to make a difference, and when finalising the prototyping phase, the judges; meaning the children, will show if we were right or wrong, and if the concepts have the potential to stay sufficiently interesting for continuous use.

CONCLUSION AND FUTURE WORK

In this paper, we have presented the initial findings from the Children's Interactive Library project. The user studies done with children in the context of children's library has led to the design of numerous concepts that exploit the library of today by enhancing the physical and social space with digital properties and resources. Furthermore we suggest that multiple partners should be involved in designing these interactive concepts for the children's library to avoid a narrow perspective on the potentials of the existing elements to form future library environments. So far there has been no user evaluation, as this is planned in the prototyping phase. Currently two concepts are under development, and test periods are planned during 2006.
The contribution in this paper is foremost to present the grounding of this project, and establish the ambition of bringing together children and books, digital material together with physical material, in the context of the physical library.

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Paper 2

Mixed Interaction Space – Expanding the Interaction Space with Mobile Devices

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Mobile phones are mainly interacted with through buttons, thumbwheels or pens. However, mobile devices are not just terminals into a virtual world; they are objects in a physical world. The concept of Mixed Interaction Space (MIXIS) expands the interaction with mobile phone into the physical world [Hansen et al. 2005]. MIXIS uses the camera in mobile devices to track a fixed-point and thereby establishes a 3 dimensional interaction space wherein the position and rotation of the phone can be tracked. In this paper we demonstrate that MIXIS opens up for new flexible ways of interacting with mobile devices. We present a set of novel, flexible applications built with MIXIS and we show that MIXIS is a feasible way of interacting with mobile devices by evaluating a MIXIS application against a traditional mobile interface. Finally, we discuss some design issues with MIXIS.

Keywords: Mixed interaction space, Mixed reality, Mobile HCI, Zoomable interfaces, Mobile computing, Spatial aware displays, Drawable interfaces, Gesture interaction.

1 Introduction

Mobile devices such as mobile phones and PDA's have been adopted into our daily life. Researchers at Nokia have observed that an important factor contributing to this is the personalization of the device, not just the communication possibilities [Vänänen-Vaino-Mattila et al. 2000]. In constant use the mobile device becomes a personal object to such extent that it intensifies the user's feeling of being inseparable from this unique thing. Still, the mobile devices are more and more becoming a personal computer in both functionality and interaction. The most common interaction is through buttons, thumbwheel or pen, and through something that can be characterized as a downscaling of the classic WIMP interface. The mapping of navigation and functionality to buttons, wheels and icons is not flexible and with low degrees of customization. The standard technique to view a large picture or map is scrolling by repeatedly press a button, roll a thumbwheel or drag a pen, and it is impossible to combine the manoeuvre with zoom, since the user has to divert the attention switching button to change function.

Designing for small mobile devices involves the classical problems of limited screen space, mapping functionality to small multifunctional buttons and traditionally a 2D interface. These problems can be reduced by expanding the interaction space outside the limits of the screen and the physical frames, and by using natural body gestures, the interface combine the digital and the physical world in a new 3D interaction space. By transforming the interface of the device into a 3D object it becomes a space belonging to the real world instead of the digital, and therefore reduces the cognitive load on the user

1.1 The concept of Mixed Interaction Space

In this paper we present a set of applications that expand the classical interface and interaction of the mobile device, to create a more natural interaction with a mixed reality interface. The applications are built on mixed interaction space [Hansen et al 2005], and demonstrate a new way to interact with digital information by using the existing camera of a mobile device to extract location and rotation of the device. Independent of the applications, the concept is to expand the interface of the mobile device outside the display by using the space between the front of the camera and a fixed-point, as illustrated in Figure 1a. The space becomes the interaction space for gesture recognition. Moving the phone in the interaction space can be mapped to actions in the graphical user interface shown in the display or an action on a nearby device or display.

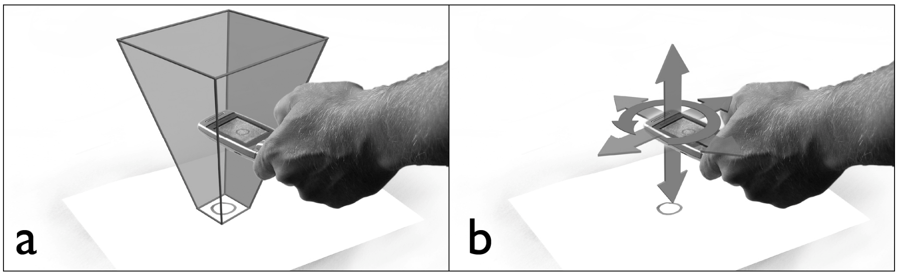

Figure 1: (a) Diagram of the Mixed Interaction Space. (b) Diagram of gestures for interaction.

To interact with the system the user only need one hand for the mobile device, and then use the natural gestures of the body to address the system. Depending on the application the device can be seen as having one to four degrees of freedom [Beaudouin-Lafon 2000]. Figure 1b displays how a four degree of freedom device can be generated by tracking the position and rotation of the device.

The size of the interaction space sets the borders both for the gesture recognition input and for the augmented interface, and is dependent on the size of the circle symbol representing the fixed-point and its distance from the viewpoint of the camera. A larger symbol spans a larger interaction space and therefore the gestures can be coarser. The fact that there is no fixed size opens up for the possibility to have small mixed interaction spaces, where the user have to use fine motor coordination or large spaces that requires the user to use larger movement.

The symbol can be anything as long as the camera can detect it. In the implemented concept a circle is used, it can be drawn or be a part of a decoration of some type and it can consist of different colours. Choosing simple symbols and using tolerant detection algorithms opens up for the possibility of drawable interfaces. The symbol can also be associated with a unique id, and combined with some type of generic protocol to send information, the concept can be used for controlling pervasive devices in the environment.

Even though the interaction is based upon natural body gestures, the concept does not require external sensor technology or specialized hardware. The concept can be implemented on standard mobile phones or PDA's equipped with a camera.

The applications presented in this paper are built upon the principles of direct manipulation [Norman 1999], the actions are rapid, incremental and reversible and whose effect on the object is visible immediately. The users are able to act through gesturing and the display feedback or device functionality occurs immediately which convey the sense of causality.

In this paper we will demonstrate that MIXIS is a new and flexible concept for interacting with mobile devices that combines some of the properties of tangible interfaces with traditional mobile device interaction. We will argue for the novelty and flexibility of the concept by presenting four applications build with the concept. We have discussed several of the applications at small workshops, and we have made a formal evaluation of one of the applications to investigate and demonstrate that MIXIS is also a feasible way of interacting with mobile devices. Finally, we will discuss mapping and identity; two central aspects of MIXIS.

2 Related Work

Beaudouin-Lafon [2004] claims that it is becoming more important to focus on designing interaction rather than interfaces. Inspired by that, we argue that our applications are new compared to related work because: 1) support a high degree of mobility in the sense that it is not depending on any external tracking hardware, 2) are highly flexible because a wide set of different applications can be built by using the mixed interaction space in different ways and 3) provide a natural mapping between gestures and the interface since we are able to get quite precise information about the position of the mobile device in 4 dimensions.

2.1 New interaction techniques for mobile devices

Several projects have explored different new interaction techniques for mobile devices [Fitzmaurice et al. 1993, Yee 2003, Patridge et al. 2002, Fällman et al. 2004, Masui et al. 2004]. Fitzmaurice et al. [1993] uses a 6D input device to navigate in a virtual world, Yee [2003] uses special hardware from Sony to track a PDA and interact with different applications using 3 dimensions and Patridge et al. [2002] have equipped a small portable device with tilt sensors for text entries. These systems use specialized tracking hardware that limits the mobility [Fitzmaurice et al. 1993, Yee 2003, Masui et al 2004] or tracks the device in just two dimensions [Fällman et al 2004, Yee et al. 2003, Masui et al. 2004], constraining the flexibility of the systems.

Accelerometers, can interact with an application by using tilting, rotation and movement of the device as input. The clear advantage of this interaction technique is its independence of the surroundings why it supports mobility very well. It supports new ways of interacting with applications e.g. scrolling in applications by tilting the device [Harrison et al. 1998].

2.2 Using cameras with mobile systems

Other projects have experimented with using the camera on mobile devices for tracking and augmenting reality [Rekimoto et al. 2000, Rohs 2004, SemaCode, SpotCode]. Several of these projects aim at augmenting reality by using bar codes in the environment to impose a 3D digital image on reality [Rekimoto et al. 2000] and do not focus on the interaction. SemaCode [SemaCode] is focusing on how to bridge the gap between digital and physical material. SpotCode [SpotCode] and Rohs [Rohs 2004] focus on the interaction, but both systems relies on tracking two dimensional barcode and e.g. not on drawable symbols.

Interaction techniques that use integrated cameras strongly resemble interactions that can be designed with accelerometers. The movement, rotation and tilting of the device, can partly be extracted from running optical flow algorithms on the camera images. However, the camera images can provide more information than the movement, tilting or rotation vector. It can be used to identify a fixed point, and it can calculate its relative rotation, tilting and position according to this point.

2.3 Physical interfaces

MIXIS is related to tangible user interfaces (TUI) in the sense that both interaction techniques try to bridge the physical with the digital [Ishii et al. 1997]. TUIs focus on hiding the computer and having the interaction mainly in the physical world. This opens up for highly intuitive interfaces, but TUIs are not that suitable for more advanced interfaces with much functionality, because each object or function in the program would have to be associated with a physical representation. MIXIS uses a combination of the physical and digital world. Most of the interaction possibilities are presented in the digital world, but to guide the interaction and to build shortcuts in the navigation a fixed-point is used in the real world.

3 Applications

3.1 Implementation

Based on the conceptual discussion we designed and implemented a component to track the position and rotation of a mobile device within the mixed interaction space and identify a symbol drawn in the centre of the circle. Thereafter four applications based on the concept were implemented.

One of our main design goal was to build a system that everyone could use anywhere without having to acquire any new kind of hardware. Using the camera of mobile devices to track a fixed point fulfilled our requirements.

A circle is chosen as fixed-point in our prototype implementation of MIXIS, and it is appropriated for several reasons: 1) It is a symbol most people recognize and are able to draw. 2) There exists a lightweight algorithm for finding a circle in a picture. 3) The radius of the circle provides information about the distance between the camera and the circle. 4) The circle is suitable as a frame for different icons.

To detect the circle, we implemented the Randomized Hough Circle Detection Algorithm as described by Xu [Xu et al. 1990] on the phone. The main reason for choosing the randomized version is that it is lightweight and much faster than the Non-Randomized Hough Algorithm [Kälviäinen 1995]. We optimized the algorithm for the specific use by e.g. looking for only one circle in the picture.

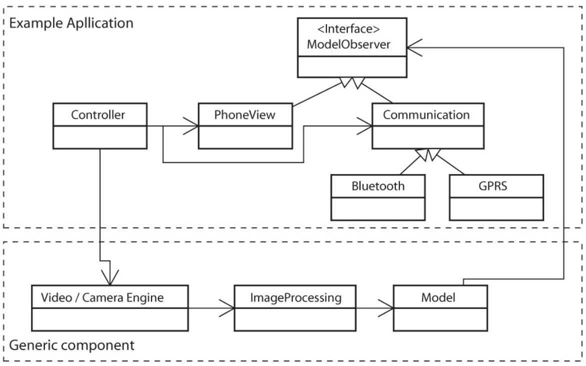

Figure 2: Diagram of the system and how the applications use the generic component. Depending on what application, the communication model is used to communicate with external devices.

The system is implemented in C++ for Symbian OS 7.0s on a Nokia 7610 mobile phone. To keep the interaction fluent and to reduce the memory used, we capture video in a resolution of 160x120 pixels in most of the prototype applications. In some of the applications where an instant response from the program was not required we used 320x240 pixels.

In the current implementation a black circle on a mainly non-black surface is tracked. The circle does not have to be perfect, the algorithm easily recognizes a hand drawn circle and the algorithm is also able to find the circle in different light conditions, which makes it more robust for use in different environments. Figure 2 demonstrates how the applications use the generic component.

3.2 Applications

We have implemented four applications that use the mixed interaction space concept. To test the feasibility of the concept we carried out a formal evaluation of one of the applications and a set of workshops discussing some of the other applications. The conclusions from the evaluation are presented in the next section.

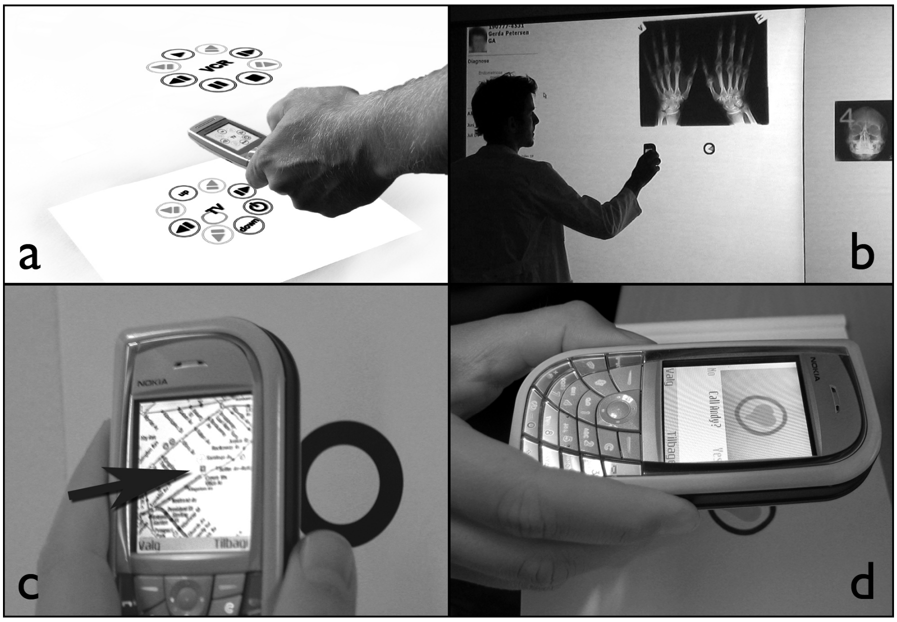

Figure 3: MIXIS applications (a) Diagram of the LayeredPieMenu application. (b) DROZO in use on a wall display. (c) ImageZoomViewer in use. (d) DrawME, “Call Andy?” “no” – left, “yes” – right.

3.2.1 ImageZoomViewer

The first application allows the user to pan and zoom simultaneously on a picture by moving the phone in the mixed interaction space, see Figure 1c. When moving the phone closer to or further away from the circle the application zoom in and out on the image. Moving the phone to the left - right or up - down makes the application pan the image in the direction the phone moved.

We have worked with a basic scenario; navigation on a map. Maps are normally too large to fit on the screen of a mobile device and users need both an overview of the entire map and details like street names. In Figure 3c we demonstrate the use of the ImageZoomViewer for browsing a subway map, here using a printed circle placed on a wall. The arrow points at the visual cue displayed on top of the map that indicated what kind of interaction the user was performing. In the picture the visual cue on the display shows that the user has placed the physical circle slightly to the right of the centre of the camera view why the visible area of the map is panning slowly to the left. The applications resembles the application implemented by [Yee 2003, Fällman et al. 2004], but in our application no specialized tracking equipment is used and we were able to both pan and zoom at the same time.

3.2.2 LayeredPieMenu

In the application called LayeredPieMenus MIXIS is investigated and used to navigate a menu structure. The interaction space can contain numerous menus organized as pie menus [Callahen et al. 1998] on top of each other. When the camera recognizes the circle a pie menu appears and augments the circle on the display. The pie menu consists of up to eight function segments that surround an info text explaining which menu is at hand. The functions in each menu can be selected by panning the phone towards the specific segments and back to the centre. By making a simple gesture towards the circle and back again the next menu is selected and moving the phone away from the circle and back again selects the previous menu. The diagram in Figure 3a demonstrates the principle of the LayeredPieMenu application where virtual pie menus are stacked on top of each other.

3.2.3 DrawME

In the DrawME application the device is, besides from recognizing the clean circle, also able to distinguish between a set of hand drawn symbols within the circle. Like in [Landay et al. 2001] DrawME opens up for the idea of drawable interfaces where the user is able to draw shortcuts, to applications in the real world e.g. on paper, whiteboards and walls. In a sense the user add another layer or functionality to disposable doodling. When the user draws a circle containing a specific symbol the camera recognizes the input and performs the function mapped to the specific symbol. The algorithm stores a set of masks of known symbols and finds the best match between the symbol in the centre of the circle and the known masks. At the moment the mask is hard-coded to the different symbols, but we are working on a user interface for creating and mapping new symbols. In DrawME we mapped different symbols to the single function of calling a certain contact from the address book illustrated in Figure 3d. To either confirm or reject calling the contact appearing on the display the user pan towards the yes and no icons displayed on the phone interface.

3.2.4 DROZO

The application Drag, Rotate and Zoom (DROZO) focus on how the mobile device can be used to interact with pervasive devices in the surroundings equipped with an interactive circle. The commands are sent through a generic protocol, see Figure 2. We enhanced the application by putting a circle underneath an x-ray picture on a large wall display, allowing the user to drag the picture around on the screen using the mobile device. The user is able to zoom in and out on the picture by moving the device closer to or away from the display, and to rotate the picture by rotating the phone. In our first prototype we used GPRS to communicate between the wall and the phone, but in the new version we use Bluetooth to communicate between the device and the screen. To be able to rotate the picture we added a small mark to the circle that allowed us to detect rotation as illustrated in figure 3b.

4 Evaluation

Our main purpose of introducing the MIXIS concept is not to argue that this is necessary a faster way to interact with mobile devices: Our main purpose is to show an alternative and more flexible interaction concept. With the ImageZoomViwer we performed a usability test with fifteen persons to see if it is feasible to use MIXIS as an interaction technique. We have had some preliminary experiences with some of the other applications at a workshop where we invited a group of users and their children to test some of the applications. However, in this paper we will focus mainly on the usability test of ImageZoomViewer.

4.1 Usability test of ImageZoomViewer

We wanted to investigate if users were able to use our interface as efficient as the traditional interface offered by mobile devices, to use the result as guidelines for further development. Therefore a usability study was conducted, comparing the ImageZoomViewer application to a standard application for picture viewing from Nokia. An even more important aspect was to test if MIXIS was perceived as a fun complement to traditional interaction techniques. The participants were 15 in total, and they had various degrees of experience from mobile devices, spanning from not owning one to software developers for mobile phones. None of them had ever before seen or used gesture interaction for mobile devices.

The test was performed in a quiet conference room, a Nokia 7610 mobile phone was used, and there was a drawn circle on a white paper on the table. The two tasks were designed to test map viewing, a typical use case for mobile devices, including shifting degrees of zoom for overview and detail. For each of the two tasks, a conventional Nokia interface for image viewing using buttons was compared to the ImageZoomViewer application. Each participant did both tasks using both interfaces, where half of the participants started out with the conventional interface and half with the new interface and then switched for the second task. Before starting instructions were given in both techniques and both interfaces were practiced on a dummy data set for a few minutes before proceeding with timing tasks. For each task a new data set was used, to reduce learning effects. The order in which the different data sets were used changed for half of the test group.

4.1.1 Task 1

First application: Given a subway map, locate the blue line and follow it from the most southern end station to the most northern end station of that line. Read the names of the end stations out loud.

Second application: Locate the green line and follow it from the most southern to the most northern station. Read the names of the end stations out loud.

4.1.2 Task 2

Second application: Given a second subway map, locate a station in the centre of the map and tell out loud the colour of all the lines that stop there. Follow one of those lines to the two end stations and tell the name of those.
First application: Go to a different centre station and tell what lines stop there. Follow one of those lines to its both end stations, and tell the names of the end stations out loud.

4.2 Result of usability test with ImageZoomViewer

Independent of what data set or interface, the user error rates were not significant, and there was no difference between the two data sets for each task. After the test was over, the participants were asked which application they preferred. The majority of the test persons, 80%, strongly preferred ImageZoomViewer for map viewing. Table 1 and 2 presents a summary of the experimental data.

The conventional interface was 6% faster then ImageZoomViewer in the first test, but in the second test the ImageZoomViewer was 9% faster, as illustrated in Table 1. These results show that gesture interaction with ImageZoomViewer is a quicker method the second time, concluding that with some practice the concept is actually a more effective navigational technique.

During the user tests, it became obvious that the distance between the camera on the mobile device and the circle on the object was very relevant. The female test persons were a bit shorter in height, and the positioning of a circle on the table made the phone end up closer to the face leading to that the interaction was not natural to the same extent as for the men. It was a lack in our test that the test persons were not asked to test different positions of both the circle and of themselves, to find the most comfortable and effective distance.

The most positive comments were about the direct connection between the physical movement and the interface, and also the possibility to pan and zoom simultaneously. The overall experience was that it was intuitive, fun and effective.

The most frequent complaint concerned the refresh rate and the sensitiveness of the system. This problem was due to the size of the circle: we should have chosen a larger circle, since enlarging the circle also enlarges the span of the interaction space and therefore the gestures. The ImageZoomViewer was due to the sensitiveness considered a bit less precise than the conventional interface. In some cases there were comments about the small size of the letters, which was a problem due to the quality of the picture we had chosen.

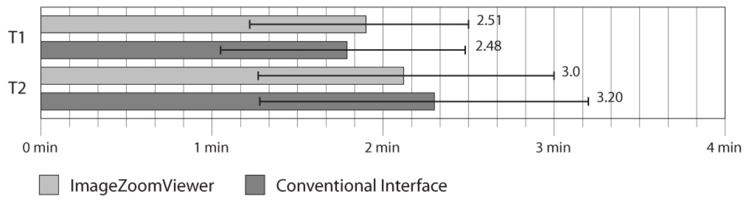

Table 1: Experimental data from the usability test where ImageZoomViewer was tested against a conventional Nokia interface for viewing pictures. The bars represent the time to complete two tasks (T1 and T2) for each interface.

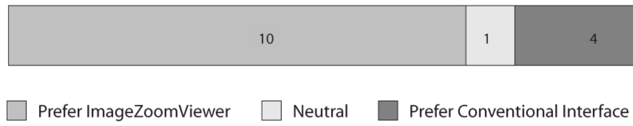

Table 2: Subjective preferences from the usability test.

5 Discussion

The main outputs from the tracking component are the location and rotation of the device in relation to the fixed-point and in some cases information about the symbol inside the circle. Applications can use this information in a number of ways to interact with the device. This flexibility open up for the creation of a wide variety of different types of applications as shown above. We found two aspects relevant in describing the characteristics of the different application. The first was how the movement of the phone in the mixed interaction space was mapped to the application and the second was if the tracked fixed-point was associated with an identity or ID. Below we will thoroughly discuss these two aspects.

5.1 Mapping applications to the Mixed Interaction Space

Basically two different types of mapping were found present in the applications we explored, natural and semantic mapping.

5.1.1 Natural mapping

In the first type of applications we tried to make a tight coupling between the physical movement and the application, trying to accomplish natural mapping introduced by Norman [Norman 1999]. One example of this is in the ImageZoomViewer application, where moving the device to the left, right, up or down makes the application pan the image. Moving the phone closer or further away from the circle the application zoom in and out. Another example is the DROZO application that uses the rotation of the phone to rotate the current picture.

To further discuss mapping we need to introduce a distinction between absolute and relative mapping. In absolute mapping there exists a one to one mapping between a specific position in the mixed interaction space and the application. E.g. each time the phone is in a specific position in the space the application will scroll and zoom to the same position. The project suggested by Yee uses what we call absolute mapping [Yee 2003].

Relative mapping maps a specific position in the space to a movement vector instead of a position. Keeping the device in the centre of the mixed interaction space resembles the movement vector null, which we call the stable zone illustrated in Figure 4. If the device is moved outside the stable zone the position of the device is mapped to a movement vector in the application. E.g. moving the device to the left of the stable zone would be mapped to keep scrolling to the left until the device is moved back into the stable zone. The further away the device is moved from the stable zone the faster the application scrolls. The project suggested by Fällman uses relative mapping [Fällman et al. 2004].

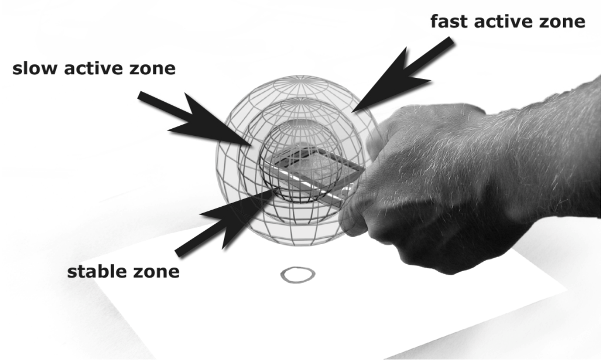

Figure 4: Diagram of the stable zone in relation to the drawn circle.

We explored both relative and absolute mapping in e.g. the ImageZoomViewer application. With absolute mapping moving the phone towards the circle results in a zoomed in picture, moving the phone to the left edge of the space moves the focus to the left edge of the picture and so on. One of the problems with absolute mapping is that the Mixed Interaction space has the form of an inversed pyramid (see Figure 1a), meaning that, if the device is close to the fixed-point, the x, y plane is smaller than when the device is far from the fixed-point. This property makes mixed interaction space unsuitable for absolute mapping or at least absolute mapping on all three axes. It is still possible to use absolute mapping for instance for zooming and then use relative mapping for panning. We found two other problems with absolute mapping. The image captured by the camera has to have similar size as the picture being watched; otherwise a small movement with the device will make the picture jump several pixels. Secondly, because the mechanism for determining the exact position and radius of the circle is not always exact, the picture becomes more vivid than with relative mapping.

Relative mapping is best suited in our applications. As an example, using a circle with a diameter about 2,5cm made a stable zone approximately 10 cm above the circle as illustrated in Figure 4. When the device is within this zone the picture is fixed and when moving the phone forward towards the circle or away from the circle the picture is zoomed in or out with a speed relative to the distance from the stable zone. The same applies for panning. The disadvantage with relative mapping is that it does not provide the same spatial awareness as absolute mapping about the position on the picture. Relative mapping is used in the evaluated applications.

5.1.2 Semantic mapping

The second type of mapping we use is what we call semantic mapping. With semantic mapping moving the phone in a specific direction does not necessarily map to the application moving in the same direction. With semantic mapping a metaphor is used to bridge between the physical movement and the action on the device. For instance moving the phone to the left might correspond to the action play media file and not to move left. This kind of mapping resembles the mapping used in gesture based application where performing a gesture is mapped to a specific function and not the same movement in the interface.

A characteristic of semantic mapping is that it is discrete; the space is divided into different zones that can be mapped to activate different functions. E.g. in the LayeredPieMenu moving the phone down towards the fixed-point and into the stable zone is mapped to the function “go to the next menu”. The semantic mapping between the gesture in the interaction space and the application can be arbitrary which also results in problems with purely gesture based interfaces. How are the gestures the system recognizes visualized and how are these gestures mapped to the different applications? With LayeredPieMenu we use the display of the mobile device to guide the user. By graphically visualize the different menu items in the display the user was helped figuring out e.g. that making a gesture to the left would activate the function displayed to the left on the screen.

5.2 Mixed Interaction Space with or without Identity

One of the main strengths we found of Mixed Interaction Space in comparison to other systems [Rohs 2004, Semacode, Spotcode] is that the system also works with simple symbols e.g. a circle drawn by hand. We found, that a set of very different applications could be designed by giving the circle different types of identity. We made a distinction between interfaces needing solely a simple circle to function (simple fixed-point interfaces), interfaces that uses a simple fixed-point with an associated icon drawn by hand (drawable interfaces) and interfaces that need to associate a unique ID with the fixed-point (identity interfaces).

5.2.1 Simple Fixed-Point Interfaces

The simple circle interface proved to be the most flexible. A simple interface just needs to have the software to recognize a circle to work. The circle could be drawn with a pen, but we also explored how to use different things as a marker like special finger rings or a black watch. The ImageZoomViewer and the LayeredPieMenu are examples of simple interfaces.

5.2.2 Drawable Interfaces

The main characteristic of drawable interfaces is that the system is can recognize different symbols drawn by hand within the circle and provide a set of different mixed interaction spaces on top of each circle, as illustrated in DrawME. Landay et al. [2001] present an application recognizing the widget in a hand drawn interface. We wish to pursue the possibility with drawable interfaces, but in contrast to Landay in our system the drawing is the actual interface.

Instead of squeezing a lot of functionality into a single device, drawable interfaces are able to customize the interface with only the functions required in the given situation. The drawn symbols can be seen as physical shortcuts into the digital world and resemble TUIs that also try to distribute the controls to the real world. One of the problems with TUIs as pointed out by Greenberg [2002] is that you have to carry a lot of special tangible objects with you if you want to use these interfaces in a mobile setting. Greenberg [2002] propose to use easily customizable tangible objects, but still you have to use a set of tangible objects. With drawable interfaces all you need is a drawable surface and a pen, and after use the interface can be wiped out or thrown away.

Another advantage with drawable interfaces is that each circle can be associated with a 4D mixed interaction space with the interaction possibilities demonstrated in e.g. ImageZoomViewer. Furthermore this application can be combined with the LayeredPieMenu concept as a fast physical shortcut to certain predefined functions in the phone e.g. the four most called persons, send/receive mail and so on.

The number of symbols the system recognizes and tracks is dependent on the software, the hardware and the context. Sometimes it is difficult for the application to recognize a colour because the colour seen by the camera depends on the quality of the camera, the lightning, the pen used to draw the colour, and the surface. Therefore a small set of different colours are best suited for drawing the symbols. The same restriction applies for symbols. Because the symbols are hand drawn and not computer generated to symbols never looks exactly the same. Choosing a set of symbols that does not resemble each other works best with drawable applications.

Drawable interfaces opens up for a whole new area of customization and personalization of the interface of the mobile device, which is one important factor contributing to the success of mobile devices. The user is able to adjust the device to recognize new and personal symbols, to make it even more “intelligent” and unique, since the user becomes the interface designer. In the workshop with DrawME, the participants strongly welcomed this possibility to customization, both because it is fun and that it provides the ability to personalize their device. The workshop also taught us the importance of having the user in total control of the mapping, and not have automatic mapping of any kind. We consider that it should be fun to interact with technology, and especially with the mobile and personal devices. Schneiderman [2004] highlights this aspect with a recent question: "Did anyone notice that fun is part of *fun*ctionality?".

5.2.3 Identity Interfaces

In the final type of interfaces the fixed-point is associated with a specific identity or unique ID. The identity can be read by printing a barcode in the circle [Semacode], providing the identity by using short range Bluetooth [Blipnodes] or by RFID tags [Want 1999]. The corresponding mixed interaction space can then be stored in the device, transmitted through for instance Bluetooth or downloaded from the internet. We used identity interfaces in the DROZO application.

Identity interfaces are especially suitable for interacting with external devices or as shortcuts to specific places on the internet. Using MIXIS to interact through identity interfaces can be seen as a possible method to interact with the "invisible computer". When computers get smaller, embedded or even invisible it is becoming more difficult for the user to know how to interact with them. A circle on a wall can be used as a visual cue, signalizing the existence of a hidden MIXIS interface and can at the same time be used as fixed point for the interaction space. In this way, the context can be used to reduce interface complexity.

6. Conclusion

The main contribution of this paper has been to introduce Mixed Interaction Space, a concept that investigate and demonstrate that the interaction with mobile devices is not something that has to be limited to the screen and buttons on the phone. By using the camera of a mobile device we are able to combine the phones abilities with the physical environment and introduce a new interaction concept.

In this paper the main focus has been to introduce MIXIS and demonstrate some novel applications with the concept. The applications use the camera in the mobile device to track a fixed point and thereby establish a 3 dimensional interaction space wherein the position and rotation of the device is calculated. The first application, ImageZoomViewer, allows the user to pan and zoom simultaneously on a picture by moving the phone in the mixed interaction space. In the application called LayeredPieMenu the mixed interaction space is used to navigate a layered menu structure. In the DrawME application the device is able to distinguish between a set of hand drawn symbols within the circle. The application Drag, Rotate and Zoom (DROZO) focus on how the mobile device can be used to interact with pervasive devices in the surroundings equipped with an interactive circle.

Mapping and identity, two central issues with MIXIS have been discussed and some relevant distinctions and design challenges have been pointed out. However, mapping and identity are just two aspects of MIXIS and we can see several other possibilities in combining tangible interfaces and mobile phones. Because the mobile phone is a highly personal device most people have we are e.g. currently looking into how to use the concept to design multi-user applications and so far MIXIS seems to have some interesting properties in this domain.

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Paper 3

Reclaiming Public Space - Designing for Public Interaction with Private Devices

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ABSTRACT

Public spaces are changing from being ungoverned places for interaction to be more formalized, controlled, less interactive, and designed places aimed at fulfilling a purpose. At the same time new personal mobile technology aims at providing private individual spaces in the public domain. In this paper we explore the implications of interacting in public space and how technology can be re-thought to not only act as personal devices, but be the tool to reclaim the right and possibility to interact in public spaces. We introduce information exchange, social support and regulation as three central aspects for reclaiming public space. The PhotoSwapper application is presented where tangible and pervasive technology is embedded in a public setting with characteristics adopted from a traditional market place. Based on the design of the application we discuss four important design challenges when designing for public interaction.

Author Keywords

Interaction design, public space, mobile technology.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

The information technology present in public spaces is increasing drastically. Billboards are replaced with digital displays, the number of portable devices has increased, wireless networks allow internet connection throughout the urban landscape, laptops are a common device in cafes and coffee bars and surveillance cameras monitor and analyze the life unfolding in public spaces. All this technology affects how life unfolds in the public space. Mobile phones and mp3-players are designed to be single user devices that most often create small enclosed personal spheres within the public space. Information displays are mainly designed to distribute advertisement or notification and are with only few exceptions an information push setup, where people's role is to consume messages. Finally, as large parts of public space is occupied by commercial interests new rules both regarding acceptable social behavior as well as use of technology becomes highly regulated

The use of technology in public space for pushing information along with devices for creating personal islands in the public are to some extend the opposite of the notion of public spaces as being interactive, social, democratic and self-organizing. A number of initiatives have hence worked with using technology to reclaim these aspects of the public space [1][5][16][29]. In this paper we follow this line of work and investigate how mobile, pervasive and tangible technology can be used to design more interactive, social and self-regulated systems for use in the public space.

The outset for the discussion is our work with technology in public spaces both indoors and outdoors. To leverage the discussion we present the PhotoSwapper application. The application evolves around a shared interactive surface where pictures from mobile phones can be viewed, shared, explored and interacted with by multiple simultaneous users. Based on this work, we will present a number of design concepts that address design issues relating to balancing *information push* with *information dialog*, *personal spheres* in public spaces with *social interaction* and *control* versus *self-regulated behavior* in the public.

RECLAIMING PUBLIC SPACE

Public space can in general terms be described as a place open to all free of charge. Furthermore public space in democratic countries is considered a space where people can express themselves politically e.g. through demonstrations and live out their lives within the law.

The use of public space is carried out in different ways. In some cities urban planning forces people to use cars or other means of transportation to access public places and some cities are designed to segregate people from different social classes to minimize the "risk" of being confronted with strangers and other people living their public lives. In cities that are not initially planned for cars public spaces often function as an extension of the living room e.g. in Italy where most public life occurs as pedestrians on streets and in public places. As stated by [13] space is turned into place by the meaning, content and use added by the people. Still people's views on public spaces are very different depending on social status, age, political observance and so on. Public space is an amazing physical and social interface between these very different people and a set of urban interests both regarding consumers, suppliers, dwellers and jurisdiction. The ways these interests interrelate has been and is under continuous development and depend on spatial layout, political agendas, climate and culture of use.

However, there seems to be a development in the use of public spaces towards increased centralization and control of the use of these settings. Being engaged in private activities in public is often looked down on and offends a range of other sub-cultures as this behavior ruins their image of the division or gradient between public and private activities as [13] exemplifies through the development of the bedroom since medieval times till today turning from an open social activity to a private concealed activity. A similar tendency can be seen in the development of public space where consuming alcoholic drinks in many public places is becoming illegal, but it is still legitimate on sidewalk cafes, nevertheless it is the same social activity going on (though more uncontrolled in the public setting). A similar change is happening through the arising of malls that are privatizing public space mimicking the spatial structures and the rules of public space, however creating controlled semi-public spaces filtering people, opinions and potential activities.

The design of technology in public spaces is a highly political act that can both enforce the governance and centralization of public space or allow more unstructured social behavior. To discuss these issues we introduce three aspects of technology design in public spaces: *Information Exchange*, *Social Support* and *Regulation*. Figure 1 presents the three design issues. The dotted circles show what technologies for public spaces are mainly designed to support today, and the full circles describe a more balanced use of technology in the public. These aspects will be further presented in the following sections.

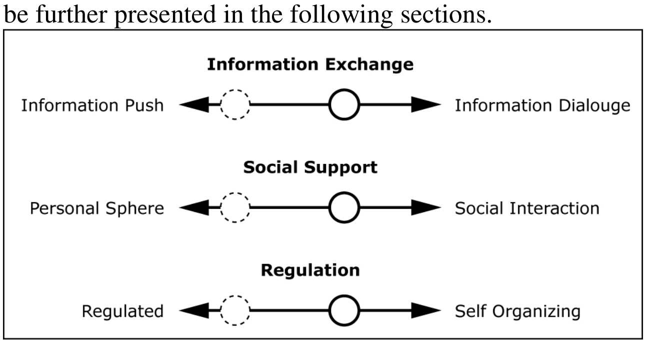

Figure 1: Design aspects for technology in public place

The Push of Information in Public Spaces

As seen with the rise in large malls there is huge commercial interests in controlling or being present in public spaces due to the number of people passing through. We see many examples on how these interests compete for the attention of people present in the public for maximum exposure e.g. on Time Square where the battle

between the different billboards create a massive push of information towards the public. This strong commercial interest in pushing information to the public leaves the average person in a public place as a consumer of advertisements. This is not necessarily negative, but it raises the questions: Is this the only type of information exchange possible in public places? What happens to the interaction between the physical space and the people present or between the people? Is it possible to design technology in public places that is more symmetric and democratic?
Public users should be able to change this "push" tendency towards a situation where the public can expose, comment and edit elements of the public space. Thereby, letting the space be formed and shaped by the people passing by and not only mimicking commercial interests. This leads to the design aspect we define *Information exchange*, meaning turning the tendency from information push towards information dialogue (see Figure 1).

Public Interaction with Pervasive Technology

To understand the activities taking place Gehl [9] defines the use of public space into three categories - necessary activities, optional activities and social activities. These categories are suitable for understanding the different activities and use of the public space both concerning work and leisure activities. In this paper we will mainly look at the social activities in public space, however as Gehl's categories are defined before the emerging pervasive and ubiquitous technologies we will look at how new technology can enhance and facilitate these types of activities in public spaces.
Inspired by [13] we see place as a part of space extended with social and cultural meaning. As the rules guiding public activity limits the interaction we see novel technology as a design material for reclaiming public interaction. The goal is to produce designs that encourage and support social interaction in public places without dictating any terms of use. To establish this design we take departure in the fact that a large part of physical public space is experienced visually and therefore there is a need for moving the bits in mobile devices out in the public. An example is the "Blinkenlights" project [29], where people control the lights in an office building by SMS-technology.
Counting the number of digital installations and adding the number of personal devices present at any time in a public space in a modern western city the technology present is overwhelming. Wireless networks cover many city centers and people are becoming increasingly online anywhere through personal mobile devices. Though all these places and devices are connected they are not communicating with each other. A mobile device is personal and the user has the possibility to perform private activities in public settings e.g. sending love mails, talking on the phone or buying stocks. So far most of these activities are not exploiting the fact that they are performed in public space, one could say that the mobile device is just extending the office space into the public without engaging in public life.
If we imagine using a mobile device for engaging in public activities this changes the device from being an introvert gadget to a gateway to digital interaction and

presence in the public space. Mobile devices are so common that almost everyone carries at least one device. By letting the mobile device be the entry point to an interactive version of the public space the interaction is not limited to the person in control of the joystick, mouse, or control box, but everyone can interact through their mobile device. The mobile device is always present and also a highly personal device where personal information e.g. phone numbers, messages, pictures, music, videos, games, themes, emails are stored. It is hence an interesting gateway between the personal and public domain.

This leads to the design aspect we identify as *social support*, meaning going from the personal sphere created by personal technologies towards social interaction in public places (see Figure 1).

The Control and Governance of Public Spaces

The rules governing the behavior in public spaces need to strike a balance between the fears of exploitation versus the joy of expression. Too much control result in doll predictable public spaces whereas no restrictions can end up in pure anarchy. In [19] the virtual city of Karlskrona2 is managed by a group of people through their virtual avatar citizens. What is interesting about this experiment is that there exist no laws and rules from the beginning – Karlskrona2 is a totally open virtual city platform for discussion and experiments with governance and self organizing planning. During the experiment lots of rules evolved creating a common understanding of the life in Karlskrona2. A similar approach to public spaces is needed to make a stronger potential connection between the public space and its inhabitants, and hereby establishing the ground for place-making [13]. Beliefs that systems to a certain extent will self organize and find a level that is not offensive to the majority of the public is crucial.

The trend is however the opposite, that more and more rules apply (no alcohol, no loud sounds, no skateboarding) as well as more surveillance through video cameras to ensure highly safe and controlled environments. Again safe environments are definitely preferable, but the point is again to strike a balance between freedom of expression and control. Here it is important to remember that any part of public space can be misused and introducing a new channel of expression through technology will not make it better or worse, but maybe different.

Public space has to be able to provoke, inspire and push opinions – think about singing football supporters cheering, carnivals with music and dance or political demonstrations. All these happenings and activities might provoke and offend however they point exactly at the important part of public space - it is alive and partly out of your control.

This leads to the design aspect we identify as *regulation*, meaning going from regulated behaviour into more self organizing (see Figure 1). In the following section we will describe an application aiming to move the design towards the full circle rather than the dotted circle in Figure 1.

THE DESIGN OF PHOTO-SWAPPER

Moving on to design, we wanted to create a design that aimed at balancing the three identified aspects in the public space discussion. We searched for an urban activity which could guide our design. We found the notion of a market place to be a strong metaphor for public space design.

An Interaction Metaphor: Market place

A market place is a highly interactive place where goods are traded and prices negotiated. Small talk with acquaintances and sales persons are the rule, not the exception. In many market places you can bring your own stuff and either sell it or trade it for new items. And if you have got a special talent – being able to perform, draw, play chess, or pretend to be a statue - these types of activities are also highly appreciated at a market place. It is accepted to just *be there* to see what is going on, enjoy the atmosphere and hear other people's opinions.

Overall, a market place is full of atmosphere created not only by the physical space, but more by the people present. It is a place for negotiation and expression. However, as a market place is relatively self-governed there is a risk of being cheated, tricked, offended or pick-pocked. The market place reflects the people there, both the good and the bad sides of life. As described earlier [13] place is created from public space in the user's appropriation of space adding content and meaning, in this case through the exchange of goods and the social activities this brings along.

In the design of an interactive tangible system for public space the market place seemed to be a good metaphor. Users of the system should be able to come to the market with their goods, trade, look around, play games, talk to each other, pick up stuff and leave again.

In this paper we present the PhotoSwapper application as a prototype example, an application for viewing, talking about, playing with and sharing photos. The users can bring their mobile phones full of personal photos to the market place and use a shared public surface to upload, discuss, view and acquire photos.

The PhotoSwapper Application

The PhotoSwapper application is designed around one or several large public surfaces (see Figure 2). We call the setup with different projections or displays in public places a marketplace. The marketplace is alone relatively uninteresting, however, the surfaces become much more interesting when someone brings a mobile device to the market place. By connecting the mobile device to the market place a new mixed system consisting of both the public system and the personal device is created. The system is not limited to one single device - everyone can connect personal devices to the system and change the topology of the system. The constellation mixes personal and public devices as well as physical and digital spaces.

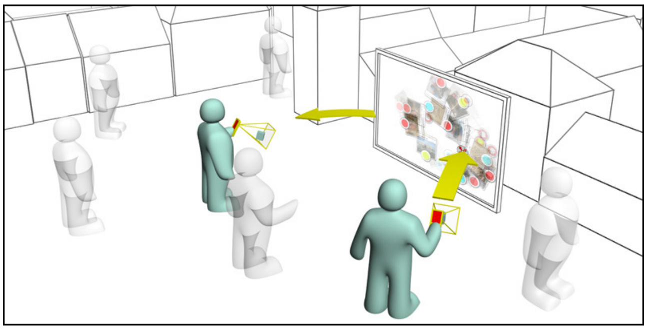

Figure 2: A market place shared display

In the Photo-Swapper application we use Bluetooth to connect the mobile devices to the public surfaces which requires people interacting with the system to be physically present. A small program on the mobile phone automatically connects to nearby surfaces when it is started. As soon as a user is connected to the surface the user is given a personal cursor which can be controlled from the mobile phone e.g. by using the Mixis interaction technique (described in the next section). An important point is that each user is given an individual cursor which allows several users to interact with the display simultaneously and the interaction is not limited to the person controlling the mouse.

By pressing a key on the phone a dialog box is opened where a picture from the mobile phone can be selected and uploaded to the public surface. A thumbnail of the picture is presented on the public surface together with a colored grapping point that links to the user that uploaded the picture (see Figure 3). The picture can be dragged, viewed in full resolution on another display, deleted or downloaded. Viewing photos in full resolution is achieved by dragging the picture to a porthole icon that moves the picture to a separate screen and shows it in full resolution. By pressing a key on the phone the picture can be deleted or downloaded to the phone.

The described application is implemented and the shared display application runs on standard PCs with Bluetooth Dongles. A small C++ program handles the Bluetooth communication whereas the main interface is written in Macromedia Flash. The application for the mobile devices is implemented in Symbian and runs on most never high-end Nokia phones e.g. Nokia 7610, 6630, 6680.

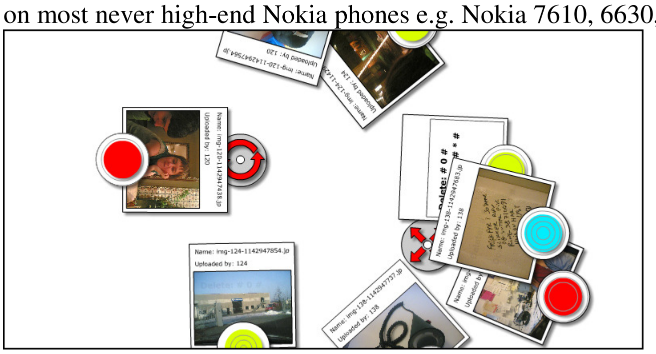

Figure 3: Detail of the PhotoSwapper application demonstrating the individual cursors, photos and porthole.

Using Vision to Interact Through Mobile Devices

For the navigation of the individual cursor we chose to explore an alternative interaction technique called Mixis [10, 11, 12], which support interaction in 3-dimensions and thereby uses the mobility of the handheld private device.

With Mixis an object is selected as a reference point by taking a picture of it with the mobile device. The reference object can be anything that stands out from the surroundings by having a specific color or pattern, e.g. a jewelry, some cloth, or a handwritten symbol, and if no suitable object is found the users face can be used as a reference point [11] (if the mobile device is equipped with a camera pointing towards the user). Video from the camera is analyzed on the mobile device and the position on the mobile device in relation to the feature is calculated.

This vector is then used to control the cursor on the shared display. E.g. moving the mobile device closer or further away from the tracked object can grab and release photos or interactive icons. Moving the phone left, right, forward and backward can be used to move the cursor on the shared surface.

This technique has previously been used in several single user applications, but it turned out to also be highly useful in multi-user applications for one or more shared displays. The advantage of using Mixis is that it allows interaction in three dimensions as well as more precise control than simply up/down/left/right key presses.

Identifying multiple cursors

Another issue with multi-user applications is how to identify which cursor belongs to whom.

In the Photo-Swapper application the color of the chosen reference object for the Mixis interaction technique is transferred to the interface, and this color identifies the user on the public display. The personal cursor is given this color and all uploaded pictures are tagged with this color. In that way the pictures on the shared surfaces are all marked with colors taken from an object that is present or has been present in the context surrounding the interface. Relating to the public space discussion this is analogue to referring to someone in the public as “the girl with the green hat” without knowing her phone number or name.

Test Set-up and Challenges with PhotoSwapper

In a test setup displayed in Figure 4 we used two large surfaces - a floor projection and a large wall back projected screen, but other setups could be used as well, e.g. PC’s, or interactive tables. The floor projection acts as the market place and provides an overview of uploaded pictures from the co-located mobile phones. The pictures can be viewed and dragged around on the floor, and a portal icon allows the pictures on the floor to be viewed on the wall display.

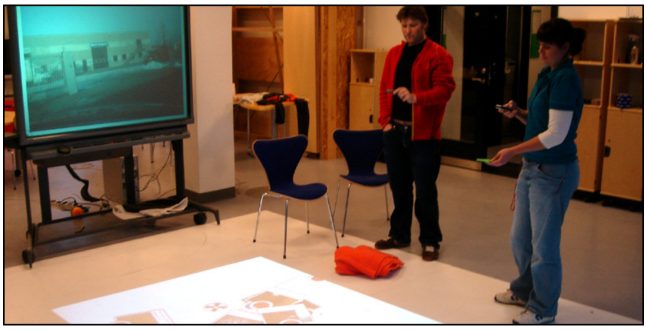

Figure 4: PhotoSwapper using floor and wall

While testing the application, we were able to make a small unstructured test. People involved as test persons were local and familiar with the floor projection as well as the back projected screen, but not in combination and not with this specific application. The setup was placed in the entrance of a research institution.

Due to the test subjects' high technical skills and general interest in technology as well as the semi-public setting these results might far from reflect the lessons learnt from deployment in real public spaces. We are currently working on staging the setup out in the real world, but are faced with a number of technical challenges. Among others one of the challenges is to get the program responsible for connecting to the market place distributed to a large number of phones.

The Potentials of PhotoSwapper

While a substantial amount of work is needed to move this application to a real public place, the prototype directly address the three aspects introduced in the discussion on public space. This is done by supporting social interaction in that multiple users simultaneously can engage in an information dialogue through the shared market place. The governance and regulation of the specific content is laid out to the users.

Being able to upload, download and discuss photos in public places opens up for new ways of influencing the public space. PhotoSwapper builds on the mechanisms of public rules and governance. Everyone can interact through a mobile device and expose statements, happiness or anger by adding content to the shared surface. People can show their holiday pictures to the public or McDonalds can post images of their menu. The only rule is that rules are made up by the users. This openness has the potential for users of public space to appropriate it and turn space into a meaningful place that constantly reflects ongoing discussions, new opinions, joy, and sorrow. We imagine small games, riddles, comic strips, photo competitions and more to evolve in different sub-cultures expressing the diversity of public life.

DISCUSSION

Based on our work with design in public places we suggest four design challenges that need to be considered when designing tangible, interactive, social and self-organizing systems for public spaces:

- How to move from single-user designs to multi-user designs
- How to move from individual to social design
- How to move from closed systems to open and extendable systems
- How to move from regulated to self-organizing and evolving designs

From Single-User to Multi-User Systems

There is a constant struggle to develop new applications and technologies capable of multi-user interaction on shared surfaces. In the beginning the focus was on sharing existing single-user applications across a network, such as for instance the MMM project [2]. Later the notion of Single Display Groupware (SDG) was introduced [23], and findings such as significant learning improvements [7], more motivation [14], higher levels of activity and less time off [15] are arguments supporting the development of technologies where several people can interact simultaneously on a shared surface.

Still, far too many multi-user applications are actually single user interfaces with a public display and only one or two mice or keyboards can be active at the same time [17]. As we are designing for interaction in public space we argue that the application has to support and exploit the behaviors of people in public space, e.g. multiple simultaneous activities in the same place, why we argue for a democratization of the interaction where all users are potentially able to manipulate the interface simultaneously.

PDAs and mobile phones can be used to implement simultaneous inputs. The Web Wall [8] and Digital Graffiti [5], allow users to post comments and to annotate a shared display by constructing the annotation on a PDA or mobile phone and then apply it to the system through a web-based interface. This supports democracy, but it is networked based and not completely simultaneously. An important aspect of the market place metaphor is the possibility of exchange - these systems do not support taking information with you through your interaction device.

Other multi-user systems include capacitive surfaces or devices like the SMART DViT [28] and the MERL DiamondTouch [6] that cope with simultaneous inputs, or active ultrasonic pens such as Mimio Virtual Ink [27]. Even more interesting is the capability of tracking and distinguishing between users actions, such as the Multi-Light Tracking system that allows four users to interact simultaneously on a back-projected display [20]. These techniques are based on direct interaction with the display, but this one-to-one mapping is not a realistic interaction paradigm to use in public spaces, where e.g. scalability, sanitation and physical security are problems [1].

In the PhotoSwapper application multi-user interaction is supported through the Mixis interaction technique. This technique uses people's mobile phones as interaction device and scales to the number of users as long as they carry a mobile device.

To increase the portability of the interaction device and the physical security and sanitation of the system, we find it straight forward to use the personal devices in peoples pockets as interaction tools, for instance mobile phones and PDAs. When using the private device for public interaction with a shared display, it is important to make the user in control of what data is transferred and displayed where, so sensitive data such as name and phone number is kept private. In Photo Swapper the users' privacy is secured by using Bluetooth as communication protocol, as it only transfers the ID of the Bluetooth unit, and not phone number or name.

From Individual Design to Social Design

Nevertheless, only focusing on multi-user design is not enough to build truly public engaging tangible and pervasive systems. They also need to be designed for social interaction.

In today's public spaces, technology has to some extent been incorporated into our everyday life in line with Weiser's vision of ubiquitous computing [25]. Examples of this are our use of mobile phones, and other wearable computing gadgets. The notion of ubiquitous computing also acknowledges the fact that people interact socially and behaves differently in different types of situations or contexts, which are so far not really supported in today's technology.

In a number of augmented reality systems wearable computers, head-worn displays and similar technologies have moved the focus away from the interaction between users. Another approach is to put the support for social interaction first. In e.g. [4] it is not mandated to interact with co-players for the game to proceed, but it encourages social interaction to occur during the play. Since the social interaction is primarily spontaneously the game explores what Zagal et al [26] defines as stimulated social interaction. We believe that when designing for public spaces, the applications and technology need to support spontaneous social interaction, meaning interaction that occurs naturally between the participants [26]. In the notion of market places, the social interaction can take place spontaneously among the visitors of the shared market/screen, but also be mediated and stimulated by objects within it. Inspired by [18], we wish to view social interaction as an entity in itself and not focus on the single user experience of participation.

In the PhotoSwapper application, the users' foci are not on the individual small screens on the private device, but on the shared display. Here, private material can be turned into public material, and it is possible to share information with several other users.

From Closed Systems to Extendable and Open Systems

Most digital systems in public spaces are closed controlled systems. Either they are not interactive at all, or there are some well defined interaction sequences that are supported. To design systems for public information dialog, we argue for making systems that are more social and less restrictive.

In [24] photos taken with a mobile phone is sent as emails and then analyzed by a server to be displayed in one form or another on the public display. In this way the content on the public display will mirror the context, but the interaction is not simultaneous.

In [1][21] visual codes are used for interacting with camera-enabled mobile phones on a large public display. The strength here is that a unique ID can be encoded in the tags; but the limitation is that the interaction technique only can be used in front of a 2D barcode, and the interaction situation is then limited in mobility and scale.
Technology and applications making use of contextual information are generally referred to as context-aware computing [22]. An example of this is location based multi-user games, such as [3]. The game supports multi-user simultaneous gaming, but everybody are occupied with their own personal device, in this case a modified PDA, and the interaction and action all takes place individually on the screen even though the entire city is the game board. In [4] the physical co-location of the players and objects in the world is adopted as important elements of the game mechanics. The game experience in [4] is inspired by traditional board games, and takes place in a social setting, where simultaneous participants play together in a limited physical area, a stage where players and the game can meet. Still, focusing on an individual private screen is a limit in public places, and the common denominator lacks.
In PhotoSwapper we have tried to accomplish this openness by the shared display, the simultaneous interaction, and the possibility to connect and disconnect easily through your personal device.

From Regulated to Evolving Designs

A related issue is how to support open applications that are evolving through peoples use.
One design principle is to support serendipitous or "come and go" interaction. The content of an application and the ongoing activities should not be affected by people joining and leaving the application and the system should support short-term interaction [1]. However as browsing a market place is an intentional activity, joining the interaction in the place requires the user to take action. Still serendipity should be supported in the sense that the user spontaneously can join, meaning without too much effort.
In Dynamo [16] anyone can walk up and use the interface. Users attach multiple USB mice, keyboards, PDA:s or laptops, and Dynamo allows users to claim areas of the surface, place and take information, display information and leave items for others. Here, public interactive surfaces are defined as inside buildings, and it is possible to rely on different external hardware gadgets physically hooked up with the computer. This technique is not possible to support in outdoor public spaces. The Dynamo system introduces the concept of carving out parts of the public screen estate for private use. We find this analogue to the tendency discussed earlier regarding physical public space namely an increased privatization that are expanding private activities to public spaces. However, it does not comply with what we understand as acknowledging the rules and interactions of public space.
Enforcing rules is one way of controlling the use of an application, but for self-organizing systems the rules are made up as the system evolves. Within a social group there exist a range of local tacit urban rules e.g. an unwritten rule for graffiti painters stating that you are not allowed to paint over a piece that you cannot do

better yourself. These rules do not necessarily comply with the law and are primarily followed by the members of the sub-community who have defined the rule implicitly or explicitly. Those kinds of rules are inspiring to the discussion of regulation, since the graffiti world actually is self-regulated in a way, even though it is invisible to people outside that community.

We do not claim that opening up for more uncontrolled interaction in public places is purely a good idea. A controlled environment is much safer since the people passing through are ensured that they do not get bothered by homeless people, racists or provoking statements, or people simply behaving strange. The control aims at making the environment pleasant, nice and secure. Interestingly, sometimes the most innovative and thought provoking ideas appears when something offend you, something unexpected happens. By shielding off public places from uncensored, spontaneous events (while keeping a sense of accountability) the possibilities for being provoked in a positive sense also disappears.

In PhotoSwapper, everybody is offered equal chances of displaying and controlling information. Of course there will certainly be uploaded information offending other people, just like graffiti, but as the system is self-regulated, then people who get offended can easily remove the offending material.

CONCLUSION

In this paper we claim that many public places, though still publicly available, are restricted in their use by a number of rules stating how different groups of people are allowed to behave. That these spaces are designed as being places for information or advertisement and not for personal expression. Further we point to another development that personal technology especially represented by the mobile phone is being used extensively as a private anti-social device in public places. In this paper we ask the question if pervasive and mobile technology can be used the other way around - to enhance interaction in public places while still being a personal device - to be a facilitator for bringing interaction back into public spaces.

We have introduced the metaphor of the market place to guide the discussion of social interaction in public spaces and we have identified a number of central design issues relating to balancing information push with information dialog, personal spheres in public spaces with social interaction and control versus self-regulated behavior in the public. All of the issues relate to how digital technologies can play a role in a more democratized, sporadic, and social experience with digital technology in public spaces.

The PhotoSwapper application represents a project aiming to address some of the issues while not being able to embrace all of them. For instance, by using interaction technologies such as Mixis we demonstrate how it is possible to overcome hinders for social interaction. The PhotoSwapper application shows how multiple users can participate on “equal terms”. The interaction is not controlled by the user with the mouse, but by everyone with a mobile phone acknowledging basic rules of public living.

In the paper we have focused on identifying current problems with public spaces, surveyed and discussed how mobile and pervasive technology can be used to facilitate interaction in public spaces as well as presented a photo-sharing system based on the market place metaphor. We hope that the presented discussions can be used to move the focus from designing private mobile devices to designing new interesting places where mobile devices are integrated to support social interaction.

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30.

Paper 4

Movement-based interaction in camera spaces: a conceptual framework

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Abstract In this paper we present three concepts that address movement-based interaction using camera tracking. Based on our work with several movement-based projects we present four selected applications, and use these applications to leverage our discussion, and to describe our three main concepts *space*, *relations*, and *feedback*. We see these as central for describing and analysing movement-based systems using camera tracking and we show how these three concepts can be used to analyse other camera tracking applications.

Keywords Movement-based interaction - Camera spaces - Mixed interaction spaces - Camera interaction - Mobile phone interaction

1 Introduction

Every interaction is in some sense movement-based: pressing a key, moving the mouse, or uttering a sound. By emphasizing the word *movement* in movement-based interaction though, movement is no longer just the source of interaction; it becomes the central element in the interaction. Movement-based interaction seems to be especially suited for interaction that takes place in a public or social context, and it provides interesting alternatives to traditional interaction techniques within social settings, games, public places, for encouraging exercise, and in mobile settings. Using movement-based interfaces, however, can be strenuous and is thus less suited for continuous e.g. desktop work. Location-aware games [*1*], fitness games [*2*], and interfaces based on accelerometer input [*3*, *4*] are examples of already available systems based on movement-based interaction.

Cameras are a common ubiquitous sensor in movement-based interfaces and the wide-spread use of camera phones and webcams makes camera-based computer vision a feasible platform for novel interfaces. Hence applications that use real-time camera input are already common within the research areas of tangible user interfaces (TUIs), virtual reality, sensor-based computing, ubiquitous computing, pervasive computing, and augmented reality. Within the computer vision community there is thus a great interest in analysing and extracting information from the video stream and use this information to provide new ways of interaction [5, 6]. However, little research has focused on how to actually use vision to design applications and on how to describe, compare, and characterise different approaches towards camera-based interfaces.

In this paper we focus on movement-based interaction that uses cameras to detect movement. Cameras have a limited field of view and the area within the camera's view can be seen as a bounded space. We call this space a *camera space.* It is only within this space movements can be detected and registered. By mapping the movement within a camera space to a virtual space in an application a combined space is obtained. We refer to this type of space as a *mixed interaction space* [7] pointing to the space being both physical and virtual. The mixed interaction space is a subset of the mixed reality concept with a major focus on space.

Based on our work with these types of spaces we present a conceptual framework for movement-based interaction based on camera spaces. The framework is grounded in four projects briefly described and discussed. Due to the spatial nature of camera spaces we have drawn on an architectural understanding of space which will be unfolded later on in this paper. The framework is built around the three central concepts of *space*, *relations*, and *feedback*. The concept of *space* describes properties of the mixed interaction space. The mapping between the captured physical movements and the virtual domain is captured by the concept of *relations.* The concept of *feedback* finally describes how the digital events are visualized to the users. The framework is finally used to present and discuss a number of movement-based interfaces, and hereby we demonstrate how the presented framework provides explanatory power beyond the scope of our own projects.

1.1 Related work

Within several different research fields there are frameworks and taxonomies briefly touching upon the capabilities and aspects of camera sensor technologies. Together these frameworks form an important base, but being too general in their nature none of these go into depth with the specifics and potentials of camera-based interaction technologies and the use of them. As the main contribution of this paper is to present a conceptual framework for movement-based interfaces using camera tracking, we here present a short overview over some of the extensive related work, and use this as a springboard to a more in depth analysis.

In [8] Mackay presents the concept of augmented reality as opposite to the, then, increasing focus on virtual reality. Three basic strategies to augmented reality are presented, where video cameras as tracking sensors are used as examples to augmenting the environment surrounding the user and the object, but not discussed further. In [9] Benford et al. analyse sensor-based interfaces in general, including a discussion of camera-tracking. They point out several problems with camera-tracking, such as the number of cameras needed, the frame rate, the field of view limits the extent of traceable surfaces, and that camera-tracking systems are usually unable to cope with different objects, multiple objects, occlusion, and changes in lightning. The two papers do not further discuss the possibilities with this technology. We take the opposite approach and explore how camera-tracking systems' strengths and weaknesses can be used in the process of developing movement-based interfaces.

In [10], Abowd et al. state that research in ubiquitous computing implicitly requires addressing some notion of scale, whether in the number and type of devices, the physical space of distributed computing, or the number of people using a system. They posit a new area of applications research, everyday computing, focussed on scaling interaction with respect to time. Scale is further discussed by Ullmer and Ishii in the conceptual framework [11], which focuses on the characteristics of TUI. Tangible interfaces are here divided into groups labelled spatial, constructive, relational, and associative. Camera-tracking systems can be found in all of the presented groups. The paper states that several concepts need to be explored further, e.g. physical scale and distance. Our aim is to continue some of these discussions by focusing on e.g. the aspects of space and scale in camera-tracking systems.

In [12] Holmquist et al. strive to create a common vocabulary to systems where a physical object is used to access digital information stored outside the object. In Fishkin's taxonomy for tangible user interfaces [13], categorizations and definitions from previous frameworks are unified, such as the vocabulary of [12] and the classification system from [14]. Fishkin further suggests that tangible user interfaces are leaving the traditional computer-human interfaces into the realm of human interfaces in general, and draws more towards the communities of industrial design, kinesthesiology, architecture, and anthropology. We agree in this change in departure for TUIs in general, and especially for systems based on camera-tracking. In our work we have a base in the conventional computer virtual world, but we use inspiration and relations from the physical world, especially from the fields of architecture and kinesthesiology.

Surely, a lot have been left out, but the frameworks presented here are examples that cover a wide spectrum and involve different general perspectives on camera-tracking systems. These frameworks create a framing to the context of camera-based systems, and they provide tools of how to analyse, define, and re-design different types of systems in this wide context. Still, we stress the need for a more specific tool developed for camera-tracking, since these related frameworks present a too general picture and do not pay enough respect to the specific characteristics of camera spaces.

2 Movement-based applications in camera spaces

To frame and inspire the discussion of the movement-based framework we start out with a brief presentation of four selected movement-based projects. The first two applications are developed around an interactive floor with a ceiling mounted camera-tracking the people within the camera space. The last two applications use the mobile phone's camera to track different features, e.g. circles, coloured objects, or a person's face. The movement passed to the application is either the movement of the camera (the mobile device) or the movement of the tracked objects.

2.1 Application one: iFloor

iFloor is an interactive floor facilitating the exchange of information between users of a public library, as well as bringing some of the services that the library offers on the internet into the physical library. A video tracking system tracks the movements and size of the people present along the edges of the display. A single person or a group of people will attract a circular cursor that expands and highlights the different questions and answers displayed on the floor. As soon as a person is recognized by the camera within the legitimate space a string is drawn from the shared cursor to the person indicating a successful established relation and ongoing interaction. The cursor distributes a string to each person around the floor and calculates the resulting vector which determines the overall movement direction. The cursor is shared between all participants, why a collaborative effort and physical movement is necessary in order to navigate the cursor on the floor [*15*]. The iFloor prototype and the tracked movements are illustrated in Fig. 1.

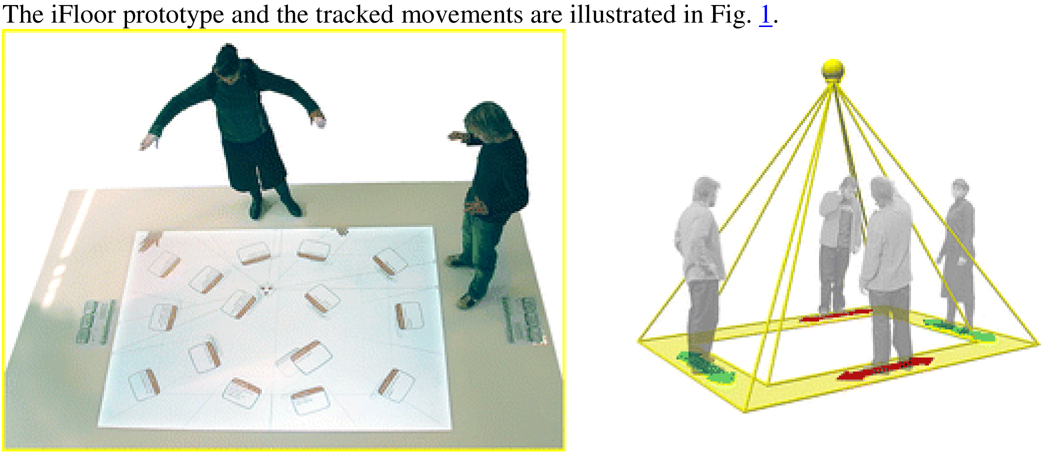

Fig. 1 The iFloor prototype and a diagram of the tracked movements

2.2 Application two: StorySurfer

StorySurfer is an interactive floor application displaying book covers which provide an alternative way for children to browse the library's collection of books. The book covers are evoked by stepping on buttons on the edge of the floor. Each button is associated with a keyword. Hitting a keyword button will evoke a cloud-like shape on the floor containing book covers associated to the selected keyword; overlapping clouds contain book covers associated with several keywords. A cover can be further examined by moving into the floor. Each person entering the floor and the camera space is provided with a cursor in the shape of a "magnifying lens" oriented and positioned in front of the user turning towards the centre of the floor. Thus the "lens" is controlled by the children's body movements. Keeping the lens icon still over a projected book cover causes it to enlarge for better inspection and maintaining the position even a bit longer will cause the image to move across the floor to an interactive table [*16*]. Figure 2 shows the StorySurfer prototype and the tracked movements.

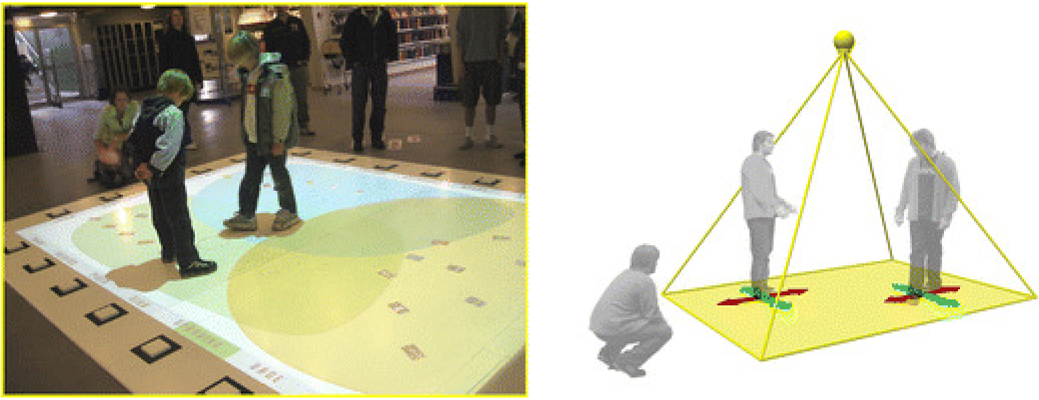

Fig. 2 The StorySurfer prototype and a diagram of the tracked movements

2.3 Application three: ImageZoomViewer

The ImageZoomViewer that is built on the Mixis tracking technique [*17*] is an application for mobile devices. It uses movement-based interaction to navigate in a map or a large image. The mobile device tracks either a hand-drawn circle, any coloured object, or the user's own face if the device is equipped with a second camera pointing towards the user. If the mobile device is close to the feature the application zooms in on the map, if the device is far away from the feature the application zooms out, if the device is to the left, right, up, or down in relation to the tracked feature the application pans accordingly. Figure 3 shows the ImageZoomViewer application running on a mobile phone and a diagram of the tracked movements. [*17*]

Fig. 3 The ImageZoomViewer prototype navigating in a map with gestures and a diagram of the tracked movements

2.4 Application four: Photo-Swapper

The Photo-Swapper is built on the Mixis tracking technique [17]. Photo-Swapper is an application that allows the mobile phone to operate a cursor on a shared display. Several users can connect to the shared display with their own personal device resulting in several simultaneous cursors. The cursor can be moved on the shared display by moving the mobile device in relation to the tracked feature: moving the device closer to the feature results in a pick-up action, while moving the device away from the feature is mapped to a drop action. It is possible for up to seven users to connect to the same shared display, thus operating seven independent camera spaces simultaneously and using them as input in the same application. Figure 4 shows the Photo-Swapper application and a diagram of three camera spaces connected to the shared display. [18]

Fig. 4 The Photo-Swapper prototype and a diagram of the camera spaces and feedback areas

2.5 Application summary

Despite the projects different foci, setups, and use situations we present some recurrent themes binding these projects together. The main findings from the individual projects are presented elsewhere [15, 16, 17, 18].

First, *movement and space* play a central role in the four presented applications, but are used in different ways. In the first two applications the tracked features are human bodies moving around in a large static camera space, whereas in the last two applications it is the entire camera space that moves in relation to a set of tracked features and not the tracked features that move within the camera space.
Second, a special relationship exists between the camera and the features being tracked and used for interacting with the system. In application one and two several features (human shapes) are tracked and all user movements affect the system. In applications three and four a single feature (a symbol, a coloured object, or the user's face) is tracked, where changes in the location of the feature as well as changes in the camera position will affect the interaction. We call the relationship between the camera and a tracked feature a *relation*, because it is the changes in this relationship that trigger the interaction.
Third, these interfaces are not traditional desktop interfaces, why there is a clear need as well as many possibilities for providing user *feedback*. We distinguish between feedback mainly focused on the input system (*input feedback*), and feedback from the application about its state (*application feedback).*
In application one and two the input feedback is provided visually on the floor on top of the application feedback. In application three input feedback is visually overlaid the application feedback but in a very limited screen area. Finally, in application four all feedback is moved from the mobile device onto the shared display, combining input feedback and application feedback on the same display for

multiple users. The feedback used in these applications is purely visual but other types of feedback will also be discussed.
Based on our work with the above described applications we hence find *space*, *relation*, and *feedback* to be central concepts useful for describing, explaining, and comparing movement-based interfaces based on camera spaces. *Relations* describe how users manipulate the system and provide input. *Feedback* describes how the computer system informs the user about its state and provides output, and *space* provides a context for the interaction by constraining and influencing the way in which interaction can take place.

3 Describing movement-based interaction in camera spaces: three central concepts

3.1 Space

A camera space has the shape of a pyramid. Close to a tracked feature the space is small, but expands the further away from the feature the camera is, until it finally blurs out (when a feature is too far away from the camera to be registered). Combined with a digital application the space becomes what we call a mixed interaction space. The mixed interaction space is the combination of a physical camera space and a digital application space, existing within the same setting. The setting can be seen as a physical space containing the mixed interaction space, e.g. a library, a hallway, a street corner, or an office.

Interaction, which results in a division of space between what is interaction sensitive and what is not, can only occur within the camera space. Before the Bauhaus period [19] space was understood and defined as a container that could contain other containers (spaces). During the Bauhaus period space was seen as a continuum where spaces dynamically would intertwine and flow among each other. This continuous space was changed by the observer moving in space. In our work we expand this understanding of space further through ubiquitous computing and virtual augmentations. With the dynamic nature of digital systems and interfaces the perception of space is not only changed by the observers moving point of view, but the space itself is dynamic, both regarding appearance and functionality. We hence see space as being highly defined by the potential functionalities afforded by areas or spaces within a continuous space, and not only as a container defined by a three-dimensional set of physical and virtual boundaries.
We see space and the physical environment as a design resource open to virtual and interactive augmentation. Using camera-based interaction we can design spaces that correspond perfectly with traditional physical spaces, where different connected but

distributed spaces afford different functions and norms for social and working behaviours. An example of this is the kitchen where you cook, compared with the living room where you can crash on the couch and watch TV. As camera spaces are physically constrained they mime the pure physical spaces loaded with a certain functionality, however the augmented digital properties make the nature of these spaces different from traditional spaces for a number of reasons. Camera spaces can afford numerous functionalities depending on the specific user/users, time of day, kind of activity, and so on. This opens up for temporary ownerships of space or situations where different users of the camera space perceive it the space differently in a use perspective, or don't see it at all. Furthermore, functions are usually associated with specific parts of our built environment as e.g. the kitchen or bathroom, but camera spaces can adapt to any space because of its multi-scaled nature, understood in the sense that the kitchen has a scale that is adjusted to the human body, whereas camera spaces can take on any scale. As the camera space is not a physical container but just an area with extra or advanced properties, it can be established, moved, or wiped out instantly, changing the way user and space can engage and interact with the environment. Figure 5 shows how a camera space can be scaled to cover from small objects to several users depending on the distance from the camera to the tracked objects.

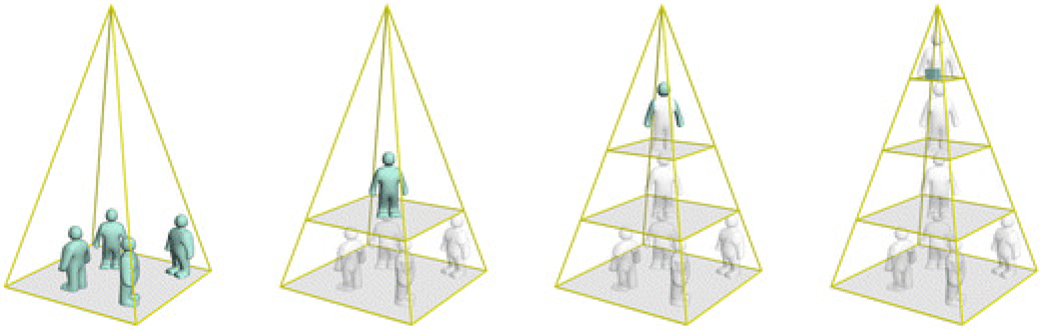

Fig. 5 *Scales* of camera spaces; diagram showing how the same camera space can adapt to different scales of space and feature

As computer systems migrate into our physical environments space becomes an important player in the design of future interactive environments. Therefore we have to accept and play with the properties of physical space and their influences on the types of interactions. We characterize the camera space by a number of properties—type, scale, and orientation. The four above described applications show how the camera space can either be *static* or *dynamic*. In static camera spaces movement occurs when tracked features move in the camera space. In dynamic camera spaces it is the camera space itself that moves in relation to the tracked feature, see Fig. 6.

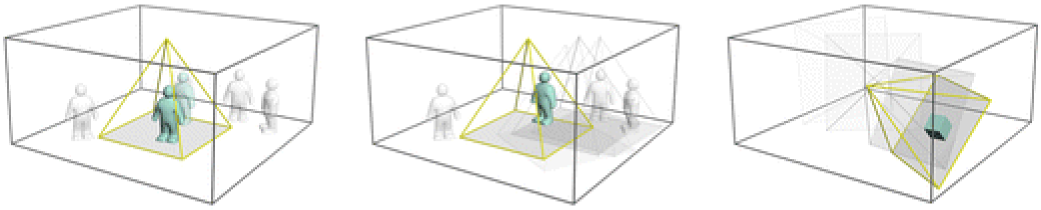

Fig. 6 *Static* and *dynamic* camera spaces; **a** static camera space and dynamic features, **b** 2D dynamic camera space and static feature, **c** 3D dynamic camera space and static feature

In the large scale applications iFloor and StorySurfer the camera space is static and the ceiling-mounted camera tracks the people who, at the same time, are the users of the system. In the small scale applications (ImageZoomViewer and Photo-Swapper) the camera space is dynamic and used to track primarily small static features. The user is in charge of moving and orienting the camera space.

Another property we have identified regarding *space* is the orientation of the camera space. As described earlier the camera space exists within a larger but continuous space. The importance of *orientation* is highly related to *scale*, and the relation between the user and the *space*. If we look at basic architectural elements such as walls, floors, and ceilings taking part in the definition and framing of physical space, we see that the orientation of the camera space influences the way in which a feature, being static or dynamic, can interact with the system. The floor is due to gravity our most shared architectural surface [20], why we as humans are used to act on the horizontal plane, see Fig. 7. As gravity forces objects to the ground, tracked features in a horizontal camera-space will most often exist on the two dimensional ground plan. Trackingwise the horizontal ground plan serves as a two-dimensional coordinate system for measuring positions and movements of tracked features. Orienting the space in the vertical direction, e.g. towards a wall, affords a new set of potential interactions where the feature has to overcome gravity. Most features will not continue to hang in free space, thus this type of space is similar to many situations where gestures and acting are used. Further acting within a vertical camera space the notion of a solid plane is replaced by a more free space in which the z-axis roughly seen as the distance between feature and camera can play a more dominant role in the feature moving away or towards the camera. This difference is most prominent with the larger scale camera spaces, where the users are the features themselves. With dynamic camera spaces orientation becomes less important because of the user's changed role from being a tracked acting feature to controlling the entire camera space. In these setups the focus on physical space diminishes because gravity in some sense has less influence—we are able to move the world.

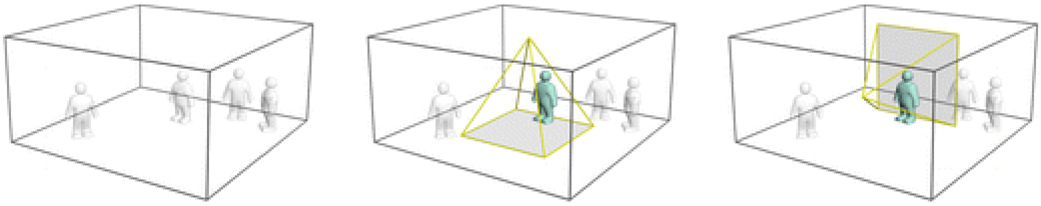

Fig. 7 *Orientation* of camera spaces; **a** none, **b** horizontal, **c** vertical

3.2 Relations

Where space defines the context for movement-based interaction, relations describe the connection between a camera and the tracked features within the camera space.

10.1.1.1 3.2.1 Entities and properties

A relation is an edge between a camera node and a tracked feature node. The edge can have a number of properties, and since vision algorithms are able to track multiple features a single camera can have multiple attached edges connected to the different features. However, a feature can also be tracked by different cameras, implying that also a feature can have multiple edges attached. Figure 8 shows how an interaction relation is created as a feature enters a camera space and how several relations can exist simultaneously.

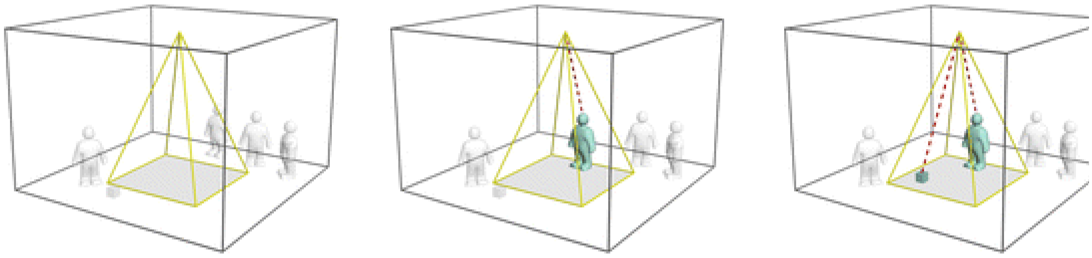

Fig. 8 *Relations* between feature and camera; **a** none, **b** one relation, **c** two relations, **d** movement

The Mixis ImageZoomViewer application only utilizes a single relation between the mobile device's camera and a tracked feature (circle, object or user's face). In the iFloor application multiple features in form of human shapes are tracked within one camera space. Every time a new person enters the camera space a new relation is created, but the relation is not associated with a specific identity and no distinction is made between the different users. The Photo-Swapper application is the opposite case, where multiple camera spaces are facilitated, still with only a single relation associated to each space. The different relations are combined by the shared application where each user is able to manipulate the interface and receive feedback, see Fig. 4.

A relation can be described by a set of properties that defines the potential interaction inputs. The number of properties depends on the algorithm used to analyse the input from the camera. The presence of a feature (on/off), the position of the feature in 1D, 2D or 3D space, rotation of the feature, the feature's size, its state, identity, or information about uncertainty, are examples of properties associated with a relation. Interaction is triggered by mapping a different action to changes in a relation's property.

The number of relations and the number of properties associated with each relation greatly determine the complexity of the interaction. With a complex setup there is a great need to visualize the way in which the user is actually able to influence the application through feedback. The iFloor application directly visualizes the relations present by drawing a line between the cursor and each user (tracked feature). Furthermore, each relation contains a 2D location and a size property based on the volume of the tracked object. Changes in the size property control the force associated with each user's pull in the cursor.

The Mixis applications use only a single relation, but this relation has a 3D location property, and can have a 1D rotation property as well. This design space opens up for a 3D spatial interface, and is hence richer compared to both StorySurfer and iFloor. The ImageZoomViewer application maps the movement in the physical space directly to pan and zoom in the application and it is therefore possible to pan and zoom simultaneously.

We found *direct input* and *gesture input* to be two different approaches on how to map changes in a relation's property to actions within an application. Direct input describes a mapping strategy where changes in a relation's properties directly influence the application. E.g. when a feature is positioned to the left in a camera space an application starts scrolling left. Gesture input describes a strategy where changes in a relation's property is monitored over time and matched to predefined patterns.

10.1.1.2 3.2.2 Multi-user interaction

With multi-user systems the relation concept opens up for a discussion about how to map the different relations to the multiple users. In the StorySurfer application each user is given a separate relation associated with an independent cursor. While one user browses the floor content by moving on the floor and hereby invoking a change in the position property, other users can use the magnifying lens to examine a book by standing still, hereby starting a selection timer. The Photo-Swapper also gives each user a separate relation, but in this application each relation is associated with its own camera. In the Photo-Swapper the relations have an extra property where the colour of the tracked feature is transferred to the corresponding cursor on the shared display as a sort of an identity.

3.3 Feedback

Movement-based interaction in camera spaces is problematic in the sense that the interaction tool is invisible to the user. The user cannot see what the camera registers or what the algorithms applied calculate. Feedback is hence important in order to visualize the relations that govern the interaction. Feedback from movement-based systems can be divided into *input feedback* and *application feedback*.

Input feedback focuses on telling the user that the input system is actually working; that a relation exists, and that the user is able to control its properties. Bellotti et al. call it attention and use it to describe the problem of knowing when the system is ready and attending to actions [20].

Application feedback provides feedback about the application and its state. Bellotti et al. call this type of feedback alignment and address how to tell the users that the system does the right thing [21].

In the iFloor application input feedback about the relations is provided by a special cursor with a number of strings to each user. The application feedback is simultaneously provided on the floor in form of pictures, questions, and videos, which are highlighted and expanded as the cursor moves over them.

The four presented applications mainly use visual feedback and during our research it became evident that visual feedback needed to be provided close to the user's focus area. To further analyse feedback we found it useful to study focus shifts inspired by Bødker's work [23]. Bødker differentiates between focus shifts that are deliberate and focus shifts resulting from breakdowns and unsuccessful interaction design.

In the first iteration of Photo-Swapper we had two sources of feedback. The shared display showed information about the cursor and provided application feedback, whereas the display on the mobile device showed information about the position of the feature in the camera space (input feedback). This resulted in a below-average performance and user experience because of constant focus shifts between the mobile device's display and the shared display. We addressed this issue by designing a special cursor on the shared display with information about the input feedback previously provided on the phone. By eliminating a large number of focus shifts we were able to greatly improve the performance of the system. Figure 9 shows the different options for visual feedback in the Photo-Swapper setup.

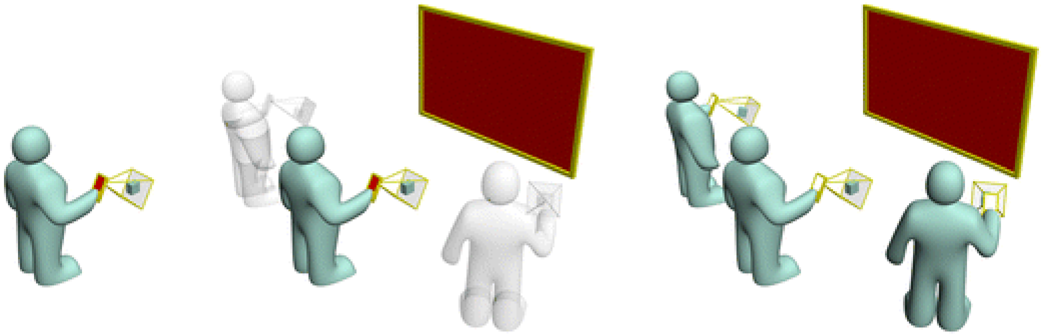

Fig. 9 Options of *input-feedback* and *application-feedback;* **a** local feedback, **b** local and remote feedback, **c** remote feedback

4 Analysis of movement-based interaction systems

In this section we use the presented conceptual framework to analyse other movement-based interaction systems in order to demonstrate the framework's explanatory abilities. Furthermore, we use these systems to clarify our conceptual framework and fill in the gaps of the design space not covered by our own work, for instance non-visual feedback. The systems are selected as prototypes representing a number of different approaches to movement-based camera space interaction.

4.1 A number of movement-based systems

Sony Eyetoy is a motion recognition camera that plugs into a Playstation2 game console. The camera detects movements in the vertical plane from a user, and delimited areas of the screen are able to register input motion during a limited time period. In Beat Freak players are required to move their hands over a speaker in one of the four corners of the screen simultaneously as a CD flies across the speaker [24].

Urp is a tangible interface for urban planning, based on a workbench for simulating the interactions among buildings in an urban environment. The interface combines series of physical building models and interactive tools with an integrated projector/camera/computer node, the "I/O Bulb." [14].
Mouthesizer consists of a miniature head-mounted camera which acquires video input from the region of the mouth. It extracts the shape of the mouth with a computer vision algorithm, and converts shape parameters to MIDI commands, so that the users' facial gestures control a synthesizer or musical effects device. [25]

Kick Ass Kung Fu is a large display martial arts game installation where the player fights virtual enemies with kicks, punches, and acrobatic moves such as cartwheels. With the use of real-time image processing and computer vision the user's video image is embedded inside 3D graphics. By shouting the player can go into a special power mode for a limited time. [*26*]

The ARTennis is a face-to-face collaborative application for mobile phones that use a set of three ARToolkit markers arranged in a line. When the players point the connected camera phones at the markers they can see and play on a virtual tennis court model superimposed over the real world. [*27*]

The above described projects are analysed based on the framework and presented in Table 1.

Table 1 The nine applications arranged after the concept of *space, relation* and *feedback*

	StorySurfer	**iFloor**	**Kick Ass Kung Fu**	**EyeToy beat freak**	**Mouthesizer**	**URP**	**ImageZoomViewer**	**ARTennis**	**Photo-Swapper**
Space									
Type	Static single	Static single	Static single	Static single	Static single	Static single	Dynamic single	Dynamic two	Dynamic multiple
Orientation	Static horizontal	Static horizontal	Static vertical	Static vertical	Static vertical	Static horizontal	Dynamic	Dynamic	Dynamic
Scale	Humans	Humans	Human	Human/limbs	Limbs	Object	Object	Object	Object
Relation									
Feature	Human shape	Human shape	Human shape	Movement Shape	Movement Shape	Color dots	Color/circle object	Tags	Color/circle object
Number	Multiple	Multiple	Single	Multiple	Single	Multiple	Single	Multiple	Single
Presence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Position	2D	2D	2D	2D	2D	2D	3D	3D	3D
Id	No	No	No	No	No	Yes	No	Yes	No
Other		Size			Shape	Rotation		Tilt	Rotation
Feedback									
Type	Visual	Visual	Visual	Visual	Audio	Visual	Visual	Visual	Visual
Input	Looking glass (floor projection)	Strings (floor projection)	Player rep. (wall projection) Sound	Player rep. (TV)	Changes in sound	Overlay e.g. shadows (table projection)	Dynamic cursor (phone display)	Court/racket (phone display)	Dynamic cursor (phone and wall display)
Appli	Visual	Visua	Visua	Visual	Audio	Visua	Visual	Visual,	Visual

	StorySurfer	iFloor	Kick Ass Kung Fu	EyeToy beat freak	Mouthesizer	URP	ImageZoomViewer	ARTennis	Photo-Swapper
cation	(floor projection)	l (floor projection)	l and sound (wall projection)	and sound (TV)	(speakers)	l (table projection)	(phone display)	sound and vibration (phone)	(wall display)

5 Discussion

By using the above described framework to analyse different movement-based interaction applications a picture is starting to form of how these applications relate and differ. By looking at the space property in Table 1 we see that the applications generally fall into two groups; they either use static spaces or dynamic spaces. The applications that use dynamic spaces are generally used to support mobile interaction, while the static spaces are augmentations of specific physical spaces. The Mouthesizer application provides an interesting combination: while the space is static the whole setup is mobile. In the selected projects only applications based on dynamic spaces use multiple spaces, e.g. ARtoolkit tennis and Photo-Swapper; however, applications that combine e.g. two static spaces appear as an uninhabited space open for exploration by new applications.

Looking at the orientation we have three different types represented: horizontal surface, vertical surface, or a dynamic space. Looking at Table 1 scale and orientation seem to be related. To use a horizontal orientation setup tracking human movements requires a large surface to move on, e.g. a floor, whereas if the setup scale is smaller and the tracking objects are e.g. limbs or objects a table top is more suitable (Urp). The applications that use dynamic spaces can potentially be used with large scale spaces, however, most of the applications we have looked at use relatively small spaces (ARTennis, Photo-Swapper and ImageZoomViewer). The applications we have chosen cover the scale from multiple human shapes to small objects, thus since camera spaces can be resized freely (only depending on the optics in the camera) this conceptual framework will also be able to describe and analyse smaller or larger camera spaces, e.g. spaces under a microscope or tracking cars in a parking lot.

With relations, the tracked feature is often closely connected to the scale of the space in use. Many projects use several relations, and in most of the projects a single user is given control of only one relation, and the relation controls a single cursor or object. However, two applications are interesting to point out. In KickAssKungFu one user controls several relations as each limb of the body is used

to control a relation. In iFloor the approach is exactly the opposite since several users are given their own relation, and these relations are coupled to a single cursor.
Concerning feedback, the chosen applications mainly rely on visual feedback, only the Mouthesizer rely purely on auditory feedback. Even though several applications using more ambient feedback can be found and designed, the use of visual feedback seems to be the most common feedback mechanism for movement-based camera-space systems. To minimize focus shifts almost all the discussed applications use overlays or special cursors to present input feedback close to the application feedback.
Since some of these applications rely on complex interaction with multiple relations with many properties a standard cursor provides too little input feedback, hence specially designed cursors or overlays that visualize the properties of the relations need to be considered and designed. In the ImageZoomViewer application the cursor uses colours and changes in its size to visualize the distance to the feature and the presence/non-presence of a feature. In the KickAssKungFu input feedback is addressed by letting the user be the cursor, and all movements are thus mirrored in real time. However, in EyeToy Beat Freak the application feedback is weaker. Tracking the limbs being or not being in the right position of the camera space to intersect with an object in space-time only confirm the user in being right or wrong, the application do not provide the user with any type of information in orientation, for instance if leaning too much to the left. In Larssen et al. [*22*] an evaluation of Sony EyeToy was performed on how movement as input would hold as communication in the interaction. The evaluation highlights how challenging it would be to facilitate the interaction, without the use of a conventional GUI for feedback, even though the interaction is not based on detailed knowledge of orientation.
A further issue to discuss in relation to designing camera spaces is frame rate. All the projects described here are exploiting the maximum possible frame rate for the camera to give instant feedback. The frame rate can be seen as a property that connects the relation between space and feature dealing with the match or mismatch between physical space time and interaction space time, which could inspire to new ways of designing camera space interfaces.

6 Conclusion

Building camera tracking systems is not only about developing technically sound algorithms. Being able to describe and understand the design possibilities and limitations is an equally important factor in the development of a successful system.

With this conceptual framework we have covered some basic concepts relating to movement-based interaction using camera tracking, but there are other important concepts we have left for future work. Mapping, privacy, tracking inaccuracy, ambient feedback, and affordance seem equally relevant, but to focus our discussion we have chosen the space, relation and feedback concepts.

With the space concept, properties of the setting that the system is deployed in are taken into account. Relation describes different approaches for mapping tracked features to interaction, and feedback address how the users are informed about the events taking place within the digital application. These concepts have proven not only to be useful for analysing our own four applications, but also to point out interesting aspects of a number of other very different movement-based camera tracking applications.
We believe the framework and table presented in this article can be used to describe and analyse a wide variety of movement-based applications in camera spaces. The aim has been to present both a general conceptual framework for comparison as well as provide concrete suggestions for the analysis of individual applications. We also hope that this framework will be useful for exploring novel variants and approaches to the design of movement-based applications with camera spaces.

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Paper 5

Bthere or be Square: A Method for Extreme Contextualization of Design

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Abstract

In this paper we describe the Bthere method aiming to increase the context awareness among designers. The method and a workshop scenario will be presented, as well as the results and evaluation from that. Based on the methodology from contextual and participatory design, the paper describes a method for dividing the context in different layers, observed from different perspectives. This reveals hidden structures in the inhabitant's everyday life and the environment among them, using a full scale context and user study as background material for brainstorming and design choices. The aim of the workshop was to accomplish an expanded notion and awareness of some of the aspects of the city environment that are invisible or unnoticeable.
We claim that the Bthere method increases awareness of a richer full scale context, and points to an alternative approach to user involvement in the design process.

Keywords: critical design; design and public; design methods; user-centered design research methods; teaching

INTRODUCTION

The user is in focus in all types of user centred system development, but to what extent the user is involved in the process varies extensively (Preece et al 1994). In various types of design education of today there is often a focus on context awareness, meaning the designer is to become familiar with the user and the environment. In contextual design methodology (Beyer et al 1998) this is performed by user studies within the context, where results from interviews, observations, films and photos are brought back to the studio for analysis. Based on these findings, a user- and task analysis is performed, and requirements are set up in accordance of the information found in this phase. When evaluating, these requirements are used as measurements for success. This process is often iterative, meaning the different phases are done over and over again until the system is satisfying. In professions like architecture the awareness of walls and other physical frames is very high, but that is just one part of the entire context. This fact made us interested in finding a new way for designers to open their minds for more aspects of the context and create a method to find more input to their work. We wanted designers to understand that in many cases appearance is deceptive, that even things perceived as simple and obvious are more complex than you would think from start.

Design work is an unstructured process, since there from the beginning is no well-defined problem, the solutions and the problems are rather developed hand-in-hand (Schön, 1983). This means that the need for having direct contact with the context and its users is important throughout the design process, not only when data is collected or for testing purpose, but also when analyzing and brainstorming.

The goal for the *Bthere* method we propose in this paper is to give birth to new and perhaps controversial design ideas in the area of context-aware computing systems. Developing digital context-aware systems and artefacts has been a major direction for human-computer interaction (HCI), to explore new types of interaction achieved by integrating computer technology with our everyday physical world. The area of interest has over the past decade developed in different directions with different names, but it started when Weiser introduced the notion of ubiquitous computing in 1991 (Weiser, 1991). The central idea is a future with computation embedded into the context around us, not using the classic computer interface, but rather a range of familiar looking devices with added functionality.

This paper describes a method for enhancing the context awareness among all types of designers, suggesting a way to bring the design work into the context, not to bring the users context back to the office. Thus enhancing context awareness in the designers' process as they develop design proposals. Although the method has only been used with architectural and design students, we believe that its applicability is general to most designers dealing with context; industrial designers, urban planners, artists, interaction designers and more.

The paper describes related work, the general concept of the *Bthere* method for designing context-aware computing systems, a workshop setup with architect and design students as participants using this method, and finally a discussion of the method and the results of the workshop.

Definitions in this paper

In this section some definitions used throughout this work will be presented. In the *Bthere* method described below, three different perspectives will be mentioned, physical, digital and social. We define *physical* as appearance, location, physical interaction, and physical time/space. We define *digital* as computer model, infrastructure, protocol, relative time/space. We define *social* as attention, activity, intention, understanding and communication.
In our experimental workshop, the facilitators of the method are referred to as the *workshop leaders*. The students that were participating in the workshop are called *designers* and the people from the context who contributed to the workshop as it progressed are called *contributors – both groups being participants in the design work*. Finally those who only passed by and were in the context are referred to as *inhabitants*.

Related work

Context in its general sense can be defined as something related to, but not within our current focus of attention. The general definition of context and its relationship with computation is a primary concern in HCI research. Dourish claims that the context in which ubiquitous computing systems are embedded into is used in two different ways, a technical and a social notion (Dourish, 2004). The first type encode context along with information to conceptualise human action and the relationship between the action and computational systems to support the technology. The second type dynamically analyzes certain social aspects of the context to have the behaviour of the system respond to patterns of use. Dourish' goal in his paper is to explore the relationship between technical and social aspects, and to examine the mismatch of these two. He does that by separating the context and the content of activities that people might perform. Our primary concern is that systems are responsive to the different social settings in which they are used, but we also claim that the context is more complex, and that there are more and dynamic aspects that the future design should be responsive to. The *Bthere* method is therefore focused on spending the major part of the process in the context of the future design, and to analyse it in small steps.

In the field of participatory design, Mambrey et al (Mambrey et al, 1998) uses the term "osmosis" to refer to the multi-level information that a designer receives by visiting the workplace and having contact with users. They consider that this gives a rich picture of the users' working life which cannot be reproduced in any other form, and that this contact encompass interviews, user workshops, active user services, and simply being present at the workplace. The Bthere method proposed in this paper is based on osmosis, but differs from (Mambrey et al, 1998) in the sense that also the design process is performed in the users context. In their work Mambrey et al describe that designers reported that they felt like a "sponge" soaking up information, while we would like to propose a more active role for the designer. We suggest that the designer should be both a collector and receiver.

Several methods are concerned with finding more aspects of the user and the use of things or environments. "Extreme characters" is a method that helps designers to explore sociocultural aspects of their designs (Djajadiningrat et al, 2000), and "Interaction relabelling" helps designers to understand the richness of actions (Djajadiningrat et al, 2000). Both of these are methods to use when finding inspiration and more aspects in the design process, but they are also trapped in the traditional way of designing in a sense, staying safely in the office or design studio, using their imagination. The *Bthere* method differs from this in the sense that we use the extreme characters from reality, not only providing us the opportunity to observe the phenomena and persons, their use of things and contexts, but also having contact with them and getting their direct input in the data collecting phase.

Gaver et al. (Gaver et al, 1999) present a method in which they use cultural probes that they hand out to the inhabitants of different sites, for them to personalize and then return their personal story to the designers (Dunne et al, 2001). Similar to this approach, the task of our method is to understand the particularities of a site. Both methods aim at providing possibilities to discover new forms of sociability and culture, and to be provocative through design. Furthermore the cultural probes were designed to live their own lives uncontrolled by the designers, as is the aim of our confrontation with the site by placing an open tent on the square. We confront an uncontrollable dynamic environment hoping it will bring us a better understanding of this context.

Just like Gaver et al. we are looking for inspirational data with our method rather than to define a set of problems, and hereby trying to create greater awareness of the complexity of the site. The data collected is inspirational for the design process and also as a way for us to ground designs in the detailed textures of a local site.

The Bthere concept

Context is a central issue in interaction design as well as in architecture, and we propose a method with an increased focus on the context in both the process and in the final proposals. The goal for the *Bthere* method is to enhance the context-awareness in the design, by pushing the design process out into the context. By creating a deep and layered analysis of the context and the inhabitants while being in the context, the identification process of the tasks and behaviours can be adopted immediately in the design ideas.

The general concept of the method is to divide a site and its surroundings into different layers, and thereby unfold aspects and find depths that are not visible from the surface. *Bthere* aims at focusing on one thing at the time, discuss it from different perspectives, and finally connect them, instead of trying to study and register everything simultaneously.

The *Bthere* method is mainly divided into two phases; the data collection phase, and the design phase. During the data collection phase, three different *perceptions* or ways of looking at the city are to be considered during the day. The perceptions could be:

- Social
- Digital
- Physical

The perceptions are ways of looking at the context, and could be compared to wearing three different pairs of glasses. (see Figure 1). To every data collected, it has to be defined from a personal opinion why it was collected and what perception was used.

The perceptions are used during the data collecting phase to look for material in different predefined categories, called *layers*, and these could be:

- Trash
- Roles
- Commercials

The layers are used to put words to and define details and aspects in the environment. The layers are revealed one by one, meaning that only one layer is in focus at the time. The layers are not to be presented from only your own point of view, the aim is to trying to get into discussions with the people who are in the site using it, to also be able to present their opinions. Between each layer, the data collected should be physically presented, discussed and defined from its perception. Each single data should be physically annotated to a large shared surface, e.g. written down on a post-it note, with one colour for each layer. The shared surface should be a representation of the site, so that the data collected can be attached to the exact location of where it was found.

The second phase is the design phase, where the findings from the data collection phase are discussed in groups and combined in different constellations to be used as design material. It is a conceptual intervention based on the findings made in the first phase. The groups shall discuss, augment and intensify three different aspects of the shared design space in the context, i.e.:

- Public space
- Private space
- Commercial space

The goal of the design phase is to develop ideas that make a significant change to how the site will be perceived in the future, or how life is lived on the site. The collected data will be used to create new technological designs in both the digital, social and physical world.

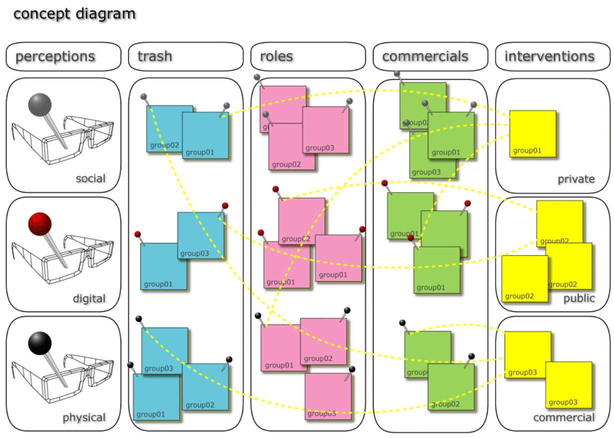

Figure 1. Table of the concept; The perceptions are ways of looking at the site, and used to define data from the three layers; trash, roles and commercials, which will be the base for the final interventions.

The common denominator of the three layers is the fact that these are often unnoticeable aspects of urban environments, but at the same time we claim that it is often these aspects, along with a few others, that define a space as urban, bustling and interesting. Combining the three layers with the perceptions forces you to conceive the otherwise well-defined physical space in a new fashion. As an example, it is relatively simple for most architects and designers to analyze a site on the physical level, but when it must be defined according to what roles they play and shape for or dictate to inhabitants of that site, then they will see the square in a new light. We take a range of relatively well-known terms and then combine them to challenge the conception of the participants and to discover new aspects of the city.

The workshop setup

The *Bthere* method was used in a workshop that took place in Gothenburg, Sweden during one day in late spring, and there were 14 designers from three different architect and design schools. The context in focus was a city square, a bustling urban environment with many different kinds of activities and personalities during the day. It is a centrally located open site with trams, busses, cars and bicycles, a meeting place containing shops, fast food restaurants and open-air cafés. It is a heavily used public space, but still not touristy.

The setup was an open tent serving as a studio, containing a table in the middle. (See Figure 2). The 2,5 x 0,8 m table was partly covered with a large print of the square, which was attached to thick cardboard. A web-camera attached to the ceiling of the tent, documenting the activities on the table during the day, how the original map was covered with observations in layer by layer, how it was growing thicker and richer and finally how physical thread was used to link material from different observations together and outputted scenarios for interventions on the map. (See Figure 3).

Figure 2. The workshop setup with tent, table, posters, designers and inhabitants.

The designers were given the three different *perceptions*, or ways of looking at the city, at the beginning of the day. The three *layers* that the designers were to work with during the day were revealed as the workshop progressed, they were not only to look at them from their own point of view but also trying to get into discussions with the people who were in the site using it.

The designers had to define and relate their observations from each layer to one of the three perceptions, and then place a physical notation of it on the map where they had found it. The template of the notation were post-it notes in different colours describing the specific layer on which they were to write down the things or phenomena they had observed. Attached to the map were also photos shot by digital cameras and printed on the fly in the tent. Finally a coloured pin had to be added and hereby specify the point of the observation on the cartographic table. The colour of the pin defined the perception of the observation; whether if it was considered as physical, digital or social.

In the first part of the data collecting phase the task was to observe and collect things that were categorized as *trash.* During the discussion with the designers, trash was defined as something that had outlived its use or something that was disturbing to the atmosphere of the square, which of course brought forward the differences in opinions of what the designers would then label as trash. Examples of what the workshop labelled as trash was a surveillance camera considered as digital trash for one person, but considered as a security by someone else; an alcoholic could be defined as social trash, and noise from the streets and trams going by were defined as physical trash even though the workshop discussed whether it could be defined as a simple and maybe even appropriate aspect of urban space.

The participants worked in smaller groups of 3-5 persons, and lively discussions took place within that constellation of people, but also when presenting their observations and opinions to the entire group when placing it on the map. At this point, interesting discussions came up, and several aspects that the designers had never considered before were revealed.

During the day two more layers were addressed. These were focusing the designers' attention towards the roles played by people and the aspects of commercials in the urban environment through the way they shape e.g. movement and attention for the inhabitants of the site. Each of these observations were again annotated on their own colour of post-it notes, and defined as digital, social or physical by the pins.

Figure 3. The map after the annotation process in the workshop; the disappearing physical square.

The groups had to discuss the findings during the day, and augment and intensify three different aspects of the shared design space in the context, meaning public, private and commercial space. The three groups had to deal with one type of space each and in their work and presentation be aware of

eventual overlaps, shared interests or conflicts with the other groups. Furthermore we asked the groups to make interventions without relating to the other themes, so that e.g. the group working with commercial spaces did not consider whether or not their idea would be disturbing to the ideas or goals of the group working with public space. In addition to this, the interventions had to activate and combine observations in the different layers. They should investigate how different types of use and phenomenon's of the public space, positive and negative, can work together and thereby enhance the three aspects.
To demonstrate which aspects had been relevant for their ideas, they had to connect the relevant pins with a thread, and hereby illustrate the linking of properties and spatial relation between the observations placed in the different layers. Finally the results from the ideas and prototypes were attached to the map too.

Results from the workshop

The final task was for the three groups to come up with ideas on how to increase the private, public or commercial space within the context, and use the experiences from prior data gathering and analysis phases as a base. As a result from being in the context, the designers used experience prototyping (Buchenau, et al, 2000) when communicating the design proposals to the audience, to some extent while trying to understand the existing context and user experience, and when exploring design ideas within the group.
The ideas varied from pure physical changes to purely digital and from public to private use.

Examples of design proposals to enhance the private space are:

- Install a machine where you can pay to record your own movie and when you leave, you receive the movie on a DVD. The idea is built upon the fear people have for being in the scene when they see a personal or surveillance camera or video camera. When the machine is recording, a red lamp will blink, keeping other people away from that part of the site and thereby create a personal sphere in the public space. (See Figure 4).
- Install live projections on a wall on the opposite side of the street from the entrance of a porno shop. By this the embarrassed customers can enter or leave the shop without being detected, since other inhabitants will study the live and colourful projection and not the door of the porno shop.

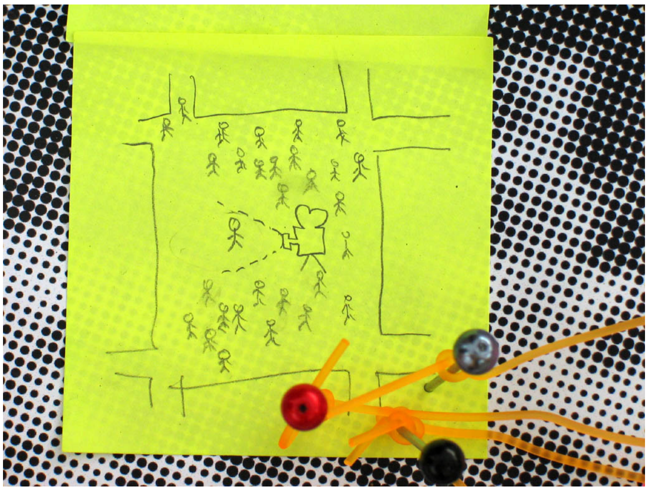

Figure 4. Design proposal from the workshop; A personal sphere is created when the video camera is recording, as people try to avoid exposure to the camera.

Examples of design proposals to enhance the commercial space are:

- An agent checking your personal profile through your phone when entering a certain space, so that when you pass a digital advertisement board, it will be adjusted to your personal needs. Examples of personal ads could be cheap drinks at the nearby bar to a 23 year old guy, or a picture of yourself with much thinner body as an advertisement from a plastic surgery. (See Figure 5).

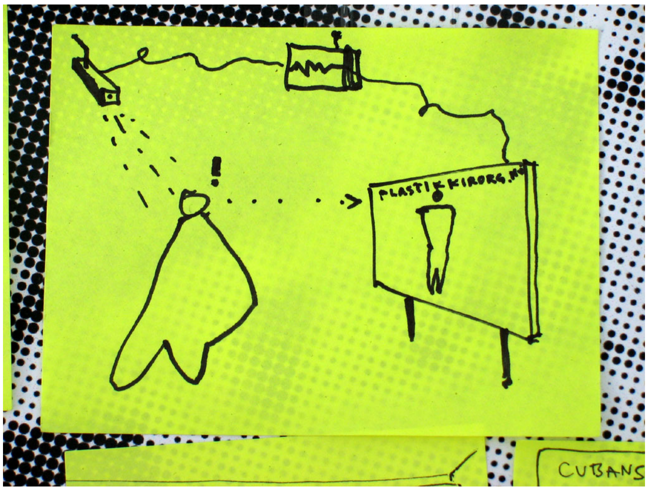

Figure 5. Design proposal from the workshop; Personally directed advertising from a plastic surgery.

- To have advertising from the local shops mixed with the live digital traffic information displays inside the bus stops.
- Have red digital tracks on the ground to lead people in to the fast food restaurant. They should be connected with the local transport system, so that when the bus stopped and the doors opened there would be a red light like a red carpet on the ground leading a potential customer from door to door. (See Figure 6).

Examples of design proposals to enhance the public space are:

- A wide and large staircase up to the rooftops above the public plaza, to expand the public site, and creates a view and overlook over the square and its surroundings.
- A real time guide in your mobile phone, recognizing the surroundings and displays it in the phone with a digital layer of information; what is inside the buildings or the profile of the persons around you.

Figure 6. Design proposal from the workshop; Red digital tracks leading the flow of potential customers into the fast food resturant.

Apart from the actual design proposals, there were a number of interesting findings to be found from the paper representation of the square on the table. The map stores the layers of information, but also information about what was most relevant or inspirational for the ideas. The designers were asked to link the different data they had used in their ideas with a physical thread, so that one would get a visible proof of both the information but also the location of it. There were interestingly two needles that had been used in almost all the projects, and they were an advertisement board and the culture of illegal posters, both located very centrally on the square.

The results were of different quality, but they all had in common that they were pioneering to both the context and to the designers themselves. The sketches and discussions showed that the designers had expanded their view of the city, that they had learned something from observing reality by using different perceptions. During the day their arguments got stronger and stronger, and the designers learnt to discuss and to analyze aspects in a way they had not done before.

DISCUSSION

The tent placed in the middle of an open square drew a lot of attention to the workshop. The inhabitants of the square, meaning the people passing by, people waiting for the bus or friends of the workshop participants, people living or working in the houses, or the people living on the street, all came in to the tent, and some of them contributed to the map with a new and personal aspect of the space, e.g. one person who joined one of the design groups and worked with them for the entire day and even participated in the presentation the following day.

When evaluating the workshop we compared the initial and the final map, and discussed if the final map maybe gave a more correct picture of the square than the original picture did. During the data collection and design process the accumulated design material were slowly obscuring the physical map and thereby redrawing and creating a new understanding of the square from both material and immaterial observations. Being on the site during the design session made it possible to state arguments through the design material and emphasize these by relating them directly to the physical context, due to the short visual distance. In that way the physical context and the new representation of the square began to complement each other in the discussion.

The use of the web-camera for documentation made it possible to have an ongoing discussion and evaluation of the process, meaning which types of data were collected where and by what perception, adding new discussions to the overall understanding of the design space.

The results from the design phase varied a lot, most of them were extreme and daring, and the proof of new thinking and inspiration. Other design suggestions were more careful and classic, but also new in the sense of being based on more untraditional design material. The method seems to succeed in providing an opportunity for the designers of the workshop to successfully focus on new aspects with different perspectives, and also with stronger arguments and provocative design ideas. Ideas that in themselves show new aspects of the context as in parallel with the concept of critical design.

One interesting notion that came out of the workshop was that data collected as trash, meaning as something negative, was applied directly into the design proposals. When these data became the base for their design ideas, the notion changed to positive. An example of this is the porno shop, which was negative trash from start, but turned into something positive and working as a base for a creative design proposal. The same was valid for the surveillance camera and the massive amounts of advertisements. In our experience, to incorporate negative observations into the design is not a common procedure and these are more often used as constrains for the design output.

Another common notion that came out of the discussions was a definition of public space as where a person is opening up to the surroundings either actively or inactively. Furthermore that a person can be in a public physical space, and in there define a private sphere through either social interactions, the use of physical objects, or by being connected through digital infrastructures. As opposed to commercial space, access to the public space is not dependant on social status or potential purchase, it is open to everyone.

This became especially clear during the day as we were approached by several residents of the square, who contributed their views to the data collection, and in one case joined a group and worked with them all day.

The background of the workshop participants had some effect to the outcome of the workshop. The designers came from various architect and design schools, and are therefore creatively minded and open to new perspectives. The major part of them was first or second year students with very little practical training, and none of them had computers as their major design material. Through the deep analyses and discussions in identifying aspects in the data collection phase, they gradually got used to not just the physical, but also the digital layer. When arriving to the design phase, they all adapted easily to using new and technology based design materials that they were not used to. The fact that they were not used to think digital infrastructures as design material was considered as positive, as they did not become limited by what ideas are possible or realistic or not to implement. On the other hand, if they would have had a more technological background, they would have been familiar with more advanced technology, and could have come up with other design ideas. Our conclusion was that for the context in focus, the background of the workshop designers was well suited.

Being on site

It is clear that in a prolonged design assignment it will not be possible to position a group of designers on-site for the entire design process, but confronting the information collection phases of the design process with the creating phase relates the designs strongly to the site. This is a known problem from some specific design fields and has been experimentally supported in e.g. the WorkSPACE project in various ways, where e.g. tabletPC's were used to enable landscape architects to design while being on site (Grönbäk et al, 2001), (Büscher et al, 2003). The method we are proposing here is much more open and therefore confronting towards the social and cultural, urban environment, simply because of the shared surface of the table in the tent is much more open than a tablet PC or any other shared digital device

On the other hand one can argue that the specific setup based on the open tent in a public square might frighten potential contributors among the public by its bare presence and maybe even be misunderstood as a political activity or a place hosting sale etc. To avoid the worst misunderstandings posters were placed out, explaining the project and inviting the citizens to take part in the workshop. Nevertheless the discussions in the tent challenged the contributors in terms of forcing them to argue in public and thus being prepared to defend their ideas and opinions to the other designers as well as bypassing strangers. This invariable openness did on one hand allow the designer to meet unforeseen input in the debate but might as well have limited and in worst case held back shy designers.

The possibility to actually be physically on the site in an open tent can be very dependent on the location, the time of year and the weather. The most important factor is though for the designers to be on the site in one way or the other, it could be a closed tent with windows, or a hired room nearby with windows out to the site, however, this would probably influence the participation from the inhabitants. In cases of rain or snow, the workshop construction could be a shelter for interested contributors and inhabitants.

The general method

We propose a method for the analysis and design process of contextual design in a public place which in this paper is exemplified in a workshop performed in the context of an open public square. The context could be of other kinds, we claim that the method would still give meaning and be highly usable to the data collecting and design process. The digital, physical and social perceptions are relevant and applicable to any type of context, but the layers can change depending on context.

If the context in focus would be e.g. a workplace instead of a public space, the layers of trash, roles and commercials would not have the same relevance. We claim that roles are an applicable and important aspect in all types of environments including people, but that trash and commercials could be changed to e.g. culture and information. In the design phase, the private and public spaces are still relevant, but the commercial space could be changed to e.g. forbidden or invisible space.

The most important aspect of the process is that the method allows one to, step by step and in layers, go through the data in the context. The iterative process of collecting, analysing, presenting, reflecting and discussing step by step, with one layer at the time, provides the designers with time to mature and with arguments to relate to. The perceptions are also very useful in the process of identifying, since you are forced to consider why this data is collected. To be in the context during the entire design process gives the positive outcome that things that were overlooked or forgotten will be updated, and you will always have the "power users" at hand to study, ask questions to or perform tests with. The attitude of the future users for the new design grows more positive as their involvement in the design process increases.

Apart from that the *Bthere* method can be used to identify hidden aspects in a context, and to generate new design ideas, it could also be used as a base for discussions. The data collected and the design ideas deriving from it can be used as a base for creating scenarios, and thereby discuss how the site is being used or misused.

In a prolonged design scenario, it would be interesting to use the *Bthere* method for the major part of a complete design process, so that the user- and task analysis, the data collection and the design phase is conducted in the context. The implementation phase could then be situated back at the office, but after that one returns to the site and places the prototypes into the context to continue testing and conduct user studies there. A one day workshop with relatively inexperienced but very creative designers gave a lot, and we believe that the benefits of this method, when being used for a longer time and with more experienced designers, will grow even more.

CONCLUSION

This paper describes the *Bthere* method which aims to increase context awareness among designers to ensure that the designer is fully aware of the different layers, depths and perspectives within the context. Different design methods claim for increased context awareness, but this is mostly practiced in the data collecting and testing phase. The *Bthere* method places the designer within the context, not only for a limited time or for a certain part of the design process, but for the entire process. The concept of the method is to use different perceptions when collecting data, which is done from different layers in the context. These findings are then used in the design phase to enhance different aspects of the site.

The *Bthere* method is described in a scenario where it was used in a workshop held with architect and design students, and the setup was an open tent in a public square. The results from the workshop demonstrate that increased and active context awareness can be more effective in terms of performance and motivation from the designer's point of view.

Dividing the context into different layers, and at the same time focusing on different perspectives, in order to incorporate tasks and behaviours of users immediately into the design ideas, contributes to many positive aspects of the design process. The information gathering part of the design process becomes more tightened to the analysis process, since it is done simultaneously, both in private, in a smaller group and with the entire group. The proposed method also decreases the load of the designer, when trying to analyze and collect everything in the context and the use of it at the same time.

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Paper 6

Mission from Mars
- A Method for Exploring User Requirements for Children in a Narrative Space

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ABSTRACT

In this paper a particular design method is propagated as a supplement to existing descriptive approaches to current practice studies especially suitable for gathering requirements for the design of children's technology. The Mission from Mars method was applied during the design of an electronic school bag (eBag). The three-hour collaborative session provides a first-hand insight into children's practice in a fun and intriguing way. The method is proposed as a supplement to existing descriptive design methods for interaction design and children.

Keywords

Design method, Mission from Mars method, eBag, requirements for new technology, shared narrative space, participatory design.

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INTRODUCTION

New methods for designing technology for children are constantly emerging, many that encourage children to participate in the design process. In this paper we contribute to these methods by propagating the 'Mission from Mars' workshop as a fruitful method for gathering users requirements among children by establishing a shared narrative among the participants in the design process.

As participatory design methods are becoming increasingly accepted, there is also a growing acceptance of the stance that new technology for children should be developed according to children's existing practices. In spite of the general acknowledgement of user participation, discussions about what roles the children should play during the design process are still sparkling. The roles, ranging from active co-designers [22, 6, 7, 9] to less active informants as advocated in [21] and [20]. These different conceptions of children's role in design have a heavy impact on the way user requirements are gathered during design [8].

Druin [6, 7] has developed a cooperative inquiry framework based on participatory envisioning, contextual inquiry and lab observations to involve children as legitimate co-designers in the design process. During the design process, the children's practice is reflected in their design contributions. The cooperative inquiry framework is indeed a highly useful methodology for gaining access to children's practice, however [16] emphasize the need of time and effort to establish a productive intergenerational design team.

To gain access and insight into the everyday life of children, several methods involving sending out probes to the children have been developed. [19] propagate the use of Photo Diaries as a way to get probes into the process of designing children's technology. This method is further developed by [10] that suggest the use of technology probes as a way to comprehend the needs and desires of users in a real-world setting. [11] experiment with the use of MMS messages to gain access to children's everyday life. In these methods the probes can be seen as static appearance of the designer, and the user and their practice materialized and represented in the probe.

[1] offer the 'KidsReporter' method as a way for children to contribute to a design problem through the making of a newspaper with the children's ideas about a certain topic. [18] provide a similar frame-work in which children's use of mobile technology is investigated and reported during a three-hour workshop in which the children create an internet-based News Portal (www.networkingkids.dk) by means of new mobile technology. Both the KidsReporter and the NetKids.News method provide a framework for gathering user requirements in the geographical and social context of the children. Both methods establish inspiring social settings in which children are encouraged to participate and thereby expose their practice and especially their use of technology for designers. These methods are useful, when conducting open-ended research into children's practice. However neither of the

methods provide a frame-work for questioning specific user requirements according to elements in children's practices.

In resent design projects some of the authors have experimented with shared narrative spaces in various participatory design contexts e.g. [17, 13, 12]. We define a shared narrative space as a social constructed environment in which conventional cultural expectations are temporarily bypassed. Although these experiments were conducted with adult users, they convinced us, that the potential of a shared narrative environment might be fruitful when designing with children.

Inspired by both the KidsReporter and NetKids.News framework and the resent studies of design games this paper propagates a new method for gathering specific user requirements by establishing a shared narrative space in the children's practice. In the following, the Mission from mars method is presented as a supplement to existing methods for gathering user requirement.

Designing an Electronic School Bag

The Mission from Mars workshop was carried out within the context of the iSchool project. The iSchool project is a part of the Center for Interactive Spaces, ISIS Katrinebjerg; an interdisciplinary research centre bringing together as diverse disciplines as architecture, engineering, and computer science with the research mission to create new concepts for future interactive spaces. As one of the application domains, the iSchool project focuses on developing software infrastructure, GUIs and spatial concepts for interactive school environments.

Within the context of the iSchool project, a software system focusing upon handling the pupils' electronic school material is under development. The system is called eBag [2, 3], and is each pupils digital counterpart to the physical schoolbag; a personal digital repository where the pupils may store pictures, videos, music, and documents to be used for school projects or free time. The eBag may exist on several platforms (mobile phones, large displays, PC's) and provides pupils with the ability to seamlessly access and share digital material. The mobile phone acts as each pupil's personal key to opening the eBag. When the pupil approaches a display connected to a Bluetooth unit, the personal eBag will appear on the screen.

We acknowledge that the point of departure for designing new artifacts is the current practice of the users. Part of this understanding is rooted in the artifacts that inhabit user context. In our case the school bag was of particular interest since the concept of the eBag to some extent was coined as the digital counterpart to the traditional school bag. As part of the children's school- and everyday activities the traditional school bag has been appropriated to fit the practice of the children. As part of our efforts to design the eBag we wanted to gain an insight into the traditional school bag as a part of the children's practice, and how it had been appropriated into the activities concerning schoolwork as well as their everyday life. An insight into the qualities that make the traditional school bag a successful part of the children's practice would be a pivotal criteria for succeeding in designing its digital counterpart.

Figure 5. The first prototype of the eBag

With the Mission from Mars method, we wanted to gain insight into:

- The everyday life of the future users
- The context of the future system, in this case the school context
- Social relations and behavior among the future users
- The social relations in the context
- The use of the existing systems today, in this case the physical school bag
- The use and extent of personalization and customization of the context
- The use and extent of personalization and customization of personal objects
- The use and extent of personalization and customization of the existing system
- The future users' attitude to order and sorting
- The future users subjective opinion regarding all the things mentioned above

THE MARS WORKSHOP SETUP

The Mission from mars workshop was conducted in the early phases of the eBag development process in an effort to understand the nature and role of the physical school bag as a point of departure for designing the digital counterpart. In the following we describe the Mission from Mars workshop setup and discuss both how the results informed our design as well as issues relating to the method. Table 1 (next page) provides an overview of the method.

Participants: 7 children aged 10-11, 5 members of the design team. **Setting:** Two classrooms in a lower secondary school. **Duration:** 3 hours total **Equipment:** Video camera, monitor, speakers and equipment connecting the three. **Setup:** In one classroom a member of the design team is located assuming the role of the Martian. A monitor connected to the video camera is placed in this room. The second room (the broadcast room) is equipped with the video camera. **Primary activities:** **1. Establishing the narrative** • A member of the design team introduces the story that will provide the frames for the workshop. • The broadcast setup is introduced – the children must present their material in front of the camera. **2. Preparing for the encounter with the Martian** • The children are divided into three groups. A member of the design team joins each group. • The children prepare what they want to present in the broadcast room. **3. Encountering with the Martian** • The groups take turns presenting their material in the broadcast room. The member of the design team located in the other classroom can ask questions to the pupils regarding the material.

Table 1: Overview of the Mission from Mars workshop

We prepared the workshop by contacting the school for permission, and they appointed a teacher who helped us choose suitable children. We did not take any part in selecting the children who should participate, since we did not have any relation to them at all, and did therefore not know their personalities. The teacher did not take any part in the workshop, she left when we arrived.

The workshop took place in a lower secondary school. The participants in the workshop were seven children between the age of ten to eleven. The workshop leaders were four visible male researchers in their thirties and a fifth invisible female "Martian". There was one researcher per group, and one researcher that helped out where it was needed, and who also wrote/gathered documentation.

The children divided themselves into groups so they worked together with their friend/-s. This was important so they would not be shy in front of each other. The four girls were divided into pairs of two best friends working together. We had planned for four boys to participate, but at the end they were only three, so the three boys worked together as one group. This turned out to be an interesting constellation, since we got a first hand insight into how the children behave towards their best friend but also how they behave to a not so close class mate. The two best friends of the three were more dominant than the third boy, who was much quieter.

Finding common ground

Starting out with an informal introduction we tried to level with the pupils and relate ourselves to them in a different way than if we were teachers. This was accomplished by small-talking around subjects that are important to them, namely soccer, fast food and music. In this way they saw to some extent that we were like them and on common ground, which was a good starting point for introducing the narrative.

Establishing the narrative

Secondly we introduced the narrative of the MARS-workshop. The idea was to establish a story in which the pupils should take part to accomplish the mission stated in the narrative. The story was illustrated by a range of computer renderings (see Figure 2) that was projected on a wall during the introduction.

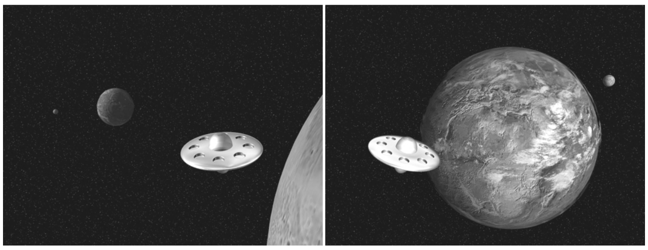

Figure 6. Examples of renderings illustrating the narrative

The start-off was a contact established by Martians to our research center. We received/picked up some signals, and we made our computer scientists call for a translator. We brought the translator to the class room and wanted the pupils to participate in the translation and decoding of the Martian signals. This was done in a very simple, and at the same time convincing, way. We had written all messages as text chunks in our own language and then changed the font type to "symbol". This results in an unintelligible piece of text looking mostly like strange Greek letters. Each chunk was copied to the clipboard of the computer from where we presented the narrative, and pasted it into notepad that was the visual manifestation of our translator. As notepad only works with one text type everything was converted back to normal text with some errors and strange symbols but still possible to read and understand (see Figure 3).

ςι μΣ υνδερσ/γε υνιϖερσετ φορ λιϖ, ογ σε ομ δερ ερ ανδρε μΣδερ ατ γΣ ι σκολε πΣ ενδ ϖορεσ εγεν.....ςι ηΣβερ ατ φΣ κοντακτ μεδ εν ηελτ ανδεν χιϖιλισατιον, σομ λεϖερ πΣ εν ηελτ ανδεν μΣδε ενδ ϖορεσ....	Vi mΣ unders ge universet for liv, og se om der er andre mΣder at gΣ i skole pΣ end vores egen.....Vi hΣber at fΣ kontakt med en helt anden civilisation, som lever pΣ en helt anden mΣde end vores....

Figure 7. Examples of coded and decoded text chunks

Slowly we went through the signals and had the pupils discuss and translate everything. The story evolved, creating the shared narrative space as we see it, and we all understood that the Martians were interested in the way schools function on earth and especially how pupils spend their time during the day. Due to problems in the Martian space shuttle they could not break through the atmosphere and therefore communication with them had to be through a video connection to their orbiting space shuttle.

Preparing for the encounter with the Martian

After we had decoded the signals we divided the pupils into the three groups and distributed them in the classroom. Together with a facilitator from our research center each group had to prepare a short presentation of their school day mainly focusing on their school bag. The reason for the preparation was related directly to the story as the transmission connection was possible when the shuttle was above our part of the world. The session had to inform the facilitator in an informal way and on the other hand prepare the pupils not to expect the Martian to understand any of the content of their school bag. Therefore they had to think thoroughly about each object in the bag and consider whether it would be interesting for the Martian and hereby informing the facilitator (see Figure 4).

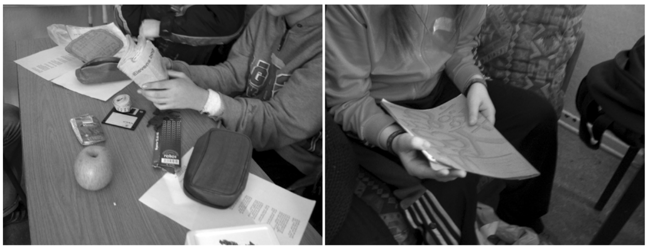

Figure 8. Preparing for the Martian broadcast

The broadcast setup

In two nearby classrooms we established the transmission setup. In the first room we installed the Martian stand-in who was supposed to communicate with the three groups of experts, namely the pupils. Here we installed a TV monitor, loudspeakers and a microphone. In the second room we installed a DV camera connected to the TV monitor in the first room, loudspeakers and a microphone. In this setup the Martian would have audio and visual feedback whereas the pupils would only have audio feedback from the Martian. To increase the effect of the Martian voice we used a foreign researcher as stand-in, who spoke our language with an accent through a tin can to add a metallic noise (see Figure 5). Due to a real-time audio translator "developed" for this mission the Martian could speak our language.

Figure 9. The Martian tin can microphone and the setup

Encountering with the Martian

In turns the groups went into the broadcast room and sat in front the DV camera that was placed behind a desk where the pupils could lay out and show the prepared things for the Martian. The connection got establish by one of the researchers who tested the microphone and got feedback from this strange Martian voice (see Figure 6). After that the communication was between the Martian and the pupils who explained about the content of their bags and how they used it during the day. The Martian could ask very stupid questions and have the pupils putting different props closer to the camera to give a better look at them. As some of the groups had difficulties to understand some of the responses from the Martian the researchers helped to interpret. After about 10-15 minutes the connection was cut and the next group would enter the room to give their story to the Martian.

Figure 10. Pupils broadcasting and the watching Martian

LANDING THE REQUIREMENTS FOR THE EBAG

When returning to our lab at the end of the day, we sat down and shared experiences and impressions from the workshop. Since we all had different roles and locations during the day, it was important to share this information with each other to be able to create the whole picture and see the scope of the results.

The primary source of data from the workshop was the video obtained from the preparation and broadcast. Several methods have been proposed for applying video data within the context of design [15, 4, 5]. In [14] Iversen discusses how video may be used when designing with children. In order to bring the video data into the design of the digital school bag we used the Interaction Analysis Lab method as described by [15]. This method has the advantage of allowing researchers to gain a general overview of large amounts of video data while maintaining the ability to work with specific sequences in a collaborative setting.

The video data from the preparation as well as the broadcast was initially logged into segments, and subsequently specific segments that were deemed particularly relevant for design were chosen for further analysis in the Interaction Analysis Lab. The goal of the analysis was to understand the traditional school bag as a part of the children's practice and to identify how these could be reflected in the eBag. The results from the analysis ranged from concrete design ideas to issues that needed to be addressed in the ongoing process. The key requirements for the eBag exposed in the Mission from Mars workshop are summarized in three categories; personalization, structure, and sociality.

Personalization

The issue of personalization was very central to the workshop and has also pervaded the following design of the electronic school bag. All of the pupils participating in the workshop had given their schoolbag their own personal look. Names of their favorite singer or soccer player were written on the bag. Key chains and other tokens were attached to the bag so that they would be visible to others. When presenting the schoolbag to the Martian the pupils were eager to elaborate on the different ornaments and their significance.

Apart from the schoolbag, their pencil cases, calendars etc. were also given a personal stamp of some sort. Perhaps most striking was the personalization and meticulous customization of the pupils' mobile phones. Almost all of the pupils chose the mobile phone as one of the items that they presented to the Martian. Most of the pupils had custom covers, and some even had different forms of tokens attached to the phone. All of them had carefully chosen a sound for their mobile phone that they found neat or cool. They were all very eager to display and talk about their mobile phones and how they used them.

Structure

As the pupils presented their schoolbag and its content to the Martian it became obvious that they had very different ways of structuring the content. Some had a very explicit and precise system for structuring the content of their schoolbag; the calendar was always in one room while the lunchbox and pencil case were stored in a different compartment. Others had little or no system regarding the structure of the content; the different items were more or less randomly found in different compartments. The tendency was for the girls to have the most explicit systems, while the boys seemed to store their items more randomly. The point of these observations is that it is difficult to formulate a meaningful general structure of a schoolbag. Much in line with the issue of personalization the pupils had appropriated the physical structure of the schoolbag in different ways. In relation to our design of the digital schoolbag it made us aware of the problem and potential counter productiveness of imposing a given structure for the content of the schoolbag.

Apart from calendars, lunchboxes, and pencil cases which were found in all the pupils' schoolbags, other more unlikely items appeared during the session. In one example one of the boys found a small rubber figure in at the bottom of his bag. Apparently this had been put in the bag a long time ago and had been forgotten until now. The boy decided to show this figure to the Martian, telling the story about how he had acquired it and what it was used for. This incident led us to discuss another perspective of the schoolbag, namely as a place where some things are allowed to 'sink to the bottom' and be forgotten until they one day are stumbled upon. Having functional support for serendipidous browsing of content in this way, could lead to a pedagogical potential for training combinatory skills. Most of us have probably had similar experiences stumbling over items that we had long forgotten existed; items that bring back memories of past activities or experiences and gives us input to a current situation. To some extent the example of the small rubber figure in the boy's schoolbag is similar; it displays how the schoolbag mediated an experience of serendipity.

Sociality

The final point that we will discuss concerns the sociality of the schoolbag and its content. When the boy found the small rubber figure (the example from the previous section) he was preparing what he wanted to show to the Martian. He was sitting alone with only a member of the design team in his company. When initially finding the rubber figure by himself he did not pay it much attention. However, when the other two group members joined him the small rubber figure became the centre of attention; they quickly created stories about the figure and played with him. Analysing the video material, it was striking how the small rubber figure gained attention as a social artifact from which the pupils constructed stories and played. In relation to the design of the digital schoolbag this led us to considerations about being able to share material and engage in joint activities.

Much in line with this example the pupils' eagerness to personalize their schoolbag and its contents also touches upon the issue of sociality. The artifacts that were personalized by the pupils were all in some way visible to other students. In many cases the personalization took the form of making one's position visible regarding a given subject e.g. writing 'Arsenal' on your schoolbag not only reveals that you are an Arsenal supporter but it also in some sense distinguishes you from another group in the class who supports Manchester United. Both regarding football and other subjects such as musical orientation there seem to be different fractions within which you may position yourself. The issue of positioning oneself and navigating the social structures of the school context has subsequently been a pervasive issue in our design of the digital school bag.

The above sections summarize the most central results from our workshop. The workshop was conducted as an initial exploration, and many of the points form the workshop were elaborated later on in the process. Some of the results fostered very concrete guidelines for the design of the digital schoolbag while others raised issues for further exploration. A preliminary design of the new eBag, based on these findings is presented in figure 7. The new eBag allows the pupils to personalize the visual appearance and structure of their eBag. Moreover it allows the pupils to make files public accessible or share them with groups of pupils.

Figure 11. The second prototype of the eBag.

Evaluation of the Mars-method

The age of the workshop participants turned out to be in the borderland for buying the Martian story or not. Most of the children were suspicious of the story and did not believe that they were talking to a real Martian. This turned out to be of no matter, since they discussed their discovery with each other, and then they continued to play along in the set -up. One group, however, was convinced of the fact that they actually talked to a real and true Martian, and they even asked for the Martian's email address.

Leveling the playground

However, establishing this kind of narrative between us as outsiders with regards to children's everyday lives, and the children, gave us a common ground we could meet on. The normal relationships between young and adult in the school were changed and we tried to obtain a role that was as uncommon to us as to the kids – communicating with Martians - which in return made a safe space for the children to expose themselves. Kids of the age we approached are particular anxious about looking childish in front of their peers. It is the age where they are becoming more aware of looking adult or like a teenager. The Martian story and the fact that some of the pupils really didn't believe it, but went along with it anyway, made us look a little ridiculous, but we believe that it helped us level the playground and get better input from the kids.

The Mars-method enabled us to get a look into the kids' life-world, and most importantly it allowed us to, in a play-like atmosphere, define a shared envelope in time and space, within their own context, based on a narrative.

Distributed setup

The spatial distributed workshop setup played an important role for the narrative to work. Like actors moving from set to set and thereby getting new feedback and inspiration to the role they are playing, the groups were moved around from "the introduction and decoding" over "preparation of the presentation" to "the encounter", which increased the credibility of the narrative. As mentioned earlier not all groups were convinced about the genuineness of the story, but because we could refer to other yet unknown spaces where the narrative would proceed later the focus and interest were kept intact. The acting part went for the researchers as well, playing or pretending that they did not know the Martian. We had to help translate some of the questions asked by the Martian and could thereby in a legitimate way interpret it in a direction that could give new information that would seem silly or degrading if asked by an adult or researcher outside this temporary narrative context.

The representation of the Martian

The physical representation of the Martian was the DV cam and the audio feedback (see Figure 8). The fact that s/he was not visually presented resulted in the creation of yet another space, as an imaginative space made by the kids. Because a weird unknown voice responded to the things they presented for the camera, it again helped keeping focus and interest. If we instead had tried dressing the Martian stand-in up as a Martian and established a physical face-to-face interview we would most plausible get the same reaction as when kids who are a bit too old to believe in Santa drag in his long white beard when meeting him, which would take the focus away from the narrative. In this setup the kids were kept as experts of being pupils and focused by the mysterious Martian "eye" with which they were engaged. Because of the rather abstract representation of the Martian, we believe that the kids did not dare or wish to insult him/her because after all the story could be true. The group that was most convinced by the story asked the Martian about his/her world and of course if the general Martian skin color was green.

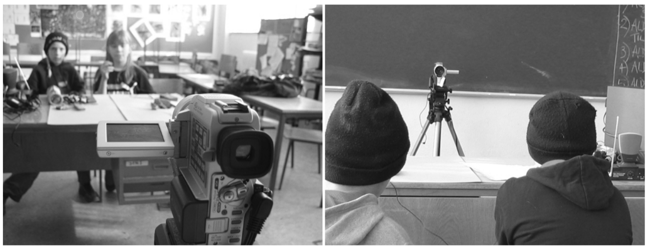

Figure 12. The camera representing the Martian

It would be an obvious critique of the Mars-method, that a really good teacher or pedagogue would be able to establish the same kind of safe space or confidentiality for a specific interaction with the children, either through a narrative or through other means. However we believe that it is of great importance that the people designing the application afterwards are the ones confronted with the children's stories and experiences. So the Mars-method offers an opportunity to the technical developers and designers to engage with the children, establish the necessary level of confidentiality through role-play, and get to the actual requirement for making a design which is meaningful to its users in the context.

Our experiences indicate, however, that it does not really matter if the test subjects believe in the story or not, because when they get excited over the task they play along. This is the positive thing with a workshop set up where we as designers meet with the children within the game, and where we cooperate towards a common goal.

The Mars-method proved to have its strength in providing a shared narrative space in which questions according to the everyday life of the kids could be asked and answered in an informal way. This kind of information would be very difficult to retrieve from e.g. probes [19] where the selection of gathered and documented material lies solely on the user, whereas the Mars-method facilitates the discussion between children, which the researchers mediated through the shared narrative which offers the possibility of posing very "stupid" questions.

Comparing the Mars-method to 'KidsReporter' [1] where the kids are contributing to the design by gathering information on different topics playing the role as journalist, our method tends to extract another kind of information. Both methods work on the basis of a shared narrative or role play, but they relate differently to the context of the children. 'KidsReporter' is set in an unfamiliar contextual setting which encourages the kids to explore, whereas the Mars-method is established in the children's own context why it points more towards gathering specific user requirements.

Conclusion

This paper propagates a design method 'Mission from Mars' for gathering requirements when designing children's technology. The method is inspired by

previous work on design games and shared narrative spaces as well as dedicated methods for designing with children. By applying the 'Mission from Mars' method to the design of the eBag we were able to support the design process in various ways. First, the method provides us with information on how children personalize their stuff and in which manner this personalization is carried out. Second, the individual structures of the children's physical school-bag were spelled out as a foundation for structuring the digital material on the digital eBag. Finally, the Mission from Mars revealed aspects of the creation of social meaning of artifacts. In this way, the method provided a valuable input for the design of the eBag.
As mentioned in the introduction, the Mission from Mars method is treated as a supplement to the existing repertoire of methods for requirements gathering with children. However, when comparing the outcome of the Mission from Mars workshop with other methods, the potential of the method is apparent. The methods main strengths is that it is a playful and motivating framework for both children and designers and the shared narrative space makes it possible to ask questions that would be impossible to raise in a conventional setting. Whether the Mission from Mars method will work as well with other age groups than the children of 10-11 years has not been tested. However, our research experiences with both the Mission from Mars set-up as well as the work with design games indicate that shared narrative spaces are indeed a recommendable setting for the gathering of user requirements.

The methods main strengths is that it is a playful inspiring framework for both children and designers and the narrative shared space makes it possible to ask questions that would be impossible to raise in a conventional setting.

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