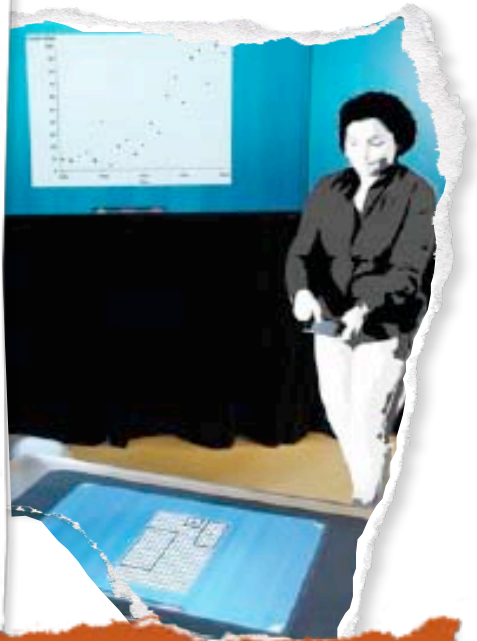
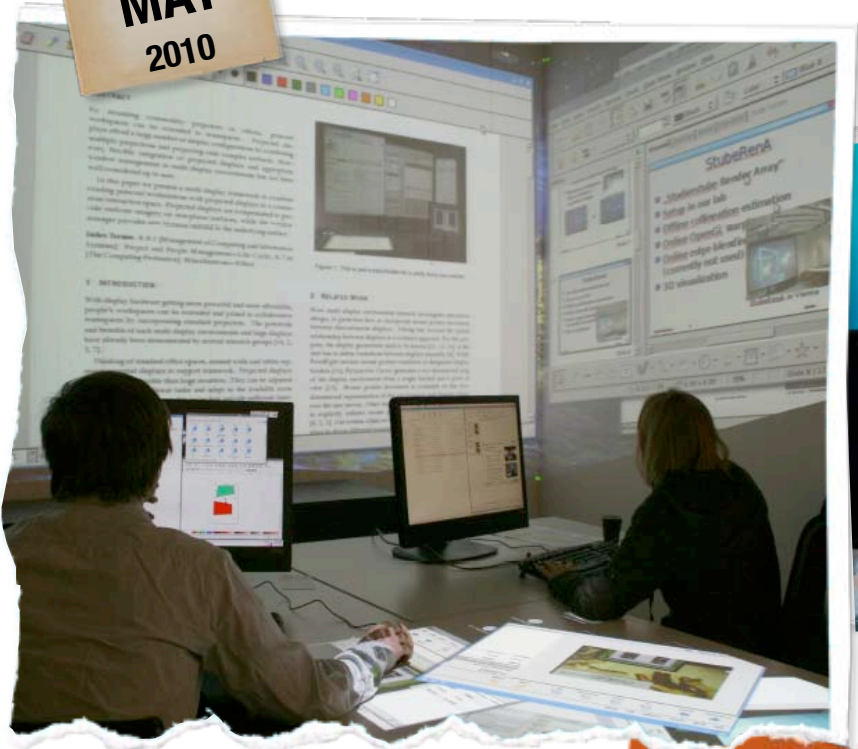


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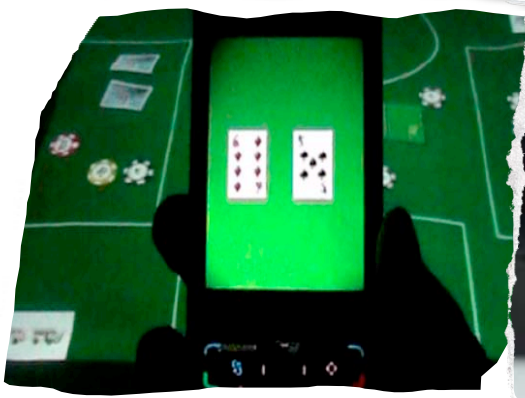


PPD10
WORKSHOP ON
COUPLED DISPLAY
VISUAL INTERFACES
ROME ITALY

IN CONJUNCTION
WITH AVI 2010

WORKSHOP CHAIRS
ALAN DIX
AARON QUIGLEY
SRIRAM SUBRAMANIAN
LUCIA TERRENGHI

WEBSITE
[HTTP://WWW.HITLAB.UTAS.EDU.AU/WIKI/PPD10](http://www.hitlab.utas.edu.au/wiki/ppd10)



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Coupled Display Visual Interfaces

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ABSTRACT

Interactive displays are increasingly distributed in a broad spectrum of everyday life environments: They have very diverse form factors and portability characteristics, support a variety of interaction techniques, and can be used by a variable number of people. The coupling of multiple displays can thus create interactive “ecosystems” which mingle in the social context, and generate novel settings of communication, performance and ownership. The objective of this workshop is to focus on the range of research challenges and opportunities afforded by applications that rely on visual interfaces that can spread across multiple displays. Such displays are physically *decoupled* (i.e. connected to multiple computers) yet are visually *coupled* due to the interfaces and interactions they support. This can range from visual interfaces spread across multiple small private input displays (e.g. information exchange or game play) to small private displays coupled with larger public displays (e.g. public photo sharing).

Categories and Subject Descriptors

B.4.2 [Input/Output and Data Communications]: Input/Output Devices – *Data terminals and printers*. D.2.2 [Software Engineering]: Design Tools and Techniques – *User Interfaces*. H.5.2 [Information Interfaces and Presentation]: User Interfaces – *Input devices and strategies, evaluation/methodology, interaction styles, theory and models*.

Keywords

Gestures, Ubiquitous Computing, Mobile User Interfaces, Interactive Surfaces, Multi-Touch, Tablet, HCI, Multi-display and CSCW.

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1. INTRODUCTION

Recent developments have seen the wide spread proliferation of both large shared displays and small display technologies. In parallel we have seen the emergence of new classes of device, which support both touch and multi-touch interaction. Examples of small touch driven devices include the PDA, Tablet PC, iPad and iPhone. Examples of large interactive surfaces (multi-touch driven displays) include the SMART Table, Circle Twelve/MERL DiamondTouch and Microsoft Surface Computer. Interactive surfaces offer great potential for face-to-face work and social interaction and provide natural ways to directly manipulate virtual objects. Small devices by contrast afford the individual a personal workspace or “scratch space” to formulate ideas before bringing them to a wider audience.

An emerging trend is the research and development of advanced visual interfaces built around a combination of small private displays coupled with larger public ones [2]. Such computer mediated multi-device interaction between personal touch-driven displays and shared public ones presents a number of novel and challenging research problems. This workshop will specifically focus on the research challenges in designing visual interfaces for multi-display ecosystems such as the combination of small touch driven private input displays (e.g. a set of iPhones) coupled with large public displays such as information kiosks, digital notice boards, DiamondTouch or Microsoft Surface. This workshop follows on from the AVI 2008 workshop “PPD 08: Workshop on designing multi-touch interaction techniques for coupled public and private displays” [1] but focuses on a different set of challenges.

1.1 TOPICS OF INTEREST

The following eight topics of interest were specified in our general call for papers for this workshop. These topics include:

- Developing evaluation strategies to cope with the complex nature of multi-display environments
- Ethnography and user studies of visual interfaces relying on coupled displays

- Understanding the design space and identifying factors that influence user interactions in this space
- The impact of social conventions on the design of suitable interaction techniques for shared and private displays
- Exploring interaction techniques that facilitate multi-display interfaces
- Novel interaction techniques for both private and public multi-touch devices as part of multi-display environments
- Techniques for supporting input re-direction and distributing information between displays
- SDK/APIs and IDEs for the development of coupled display visual interfaces

Based on the research described in the accepted position papers, this set was refined into our five workshop themes as described in Section 6.

2. AUDIENCE

This workshop brings together international researchers and practitioners from industry and academia working in the area of coupled multi-display environments and interactive surfaces coupled with private displays. Interested attendees were invited to submit a short position paper. These papers were each peer reviewed by up to four members of our international program committee. The eleven accepted position papers are available from our website <http://www.hitlab.utas.edu.au/wiki/PPD10>.

This workshop is designed for maximum audience participation, interaction and development of ownership of the resultant ideas. We aim to continue the tradition of turnover within the organisation of any workshop outcomes, for example in 2010 two of the four organisers were workshop participants at PPD'08 [2]. Participants this year will be encouraged to take a leading role in activities and ideas formulated during this workshop.

3. Workshop Plan

The PPD'10 workshop on coupled display visual interfaces on May 25th, 2010 is a workshop held in conjunction with AVI 2010, the 10th International Working Conference on Advanced Visual Interfaces. As a full day event it is structured to provide maximum time for group discussion and brainstorming. Each participant is familiar with all eleven position papers accepted prior to the event.

The workshop is structured around four sessions (separated by the morning break, lunch and afternoon break). In the first session the participants briefly introduce themselves and provide a brief presentation highlighting the key points from their position papers. Following this a brainstorming session is employed to develop key discussion topics for the two midday sessions. In the second and third sessions the entire group is divided into sub-groups moderated by the workshop organisers to have focused discussions on some of the key topics identified earlier. In the fourth session the entire group reconvenes to discuss the advances and challenges identified in the breakout discussions.

The workshop concludes with a detailed discussion to define immediate next steps on two fronts. Firstly, the discussion of a

proposed research book drawing on submissions from some of the workshop audience. Our previous workshop resulted in a Special Issue of the Journal of Personal and Ubiquitous Computing in 2009 by Springer-Verlag, entitled "Interaction with coupled and public displays" [1]. Second, we seek discussion and input into the development of a revised European Cooperation in Science and Technology action (COST) proposal entitled "Technologies, Tools and Techniques for the design of coupled display visual interfaces". Such a COST action will be a long lived outcome from this workshop.

4. WORKSHOP ORGANISERS

Alan Dix is Professor of Computing at Lancaster University. He has worked for 25 years in many areas of Human-Computer Interaction and is co-author of one of the principle textbooks in the area. His current interests include the design of interaction with physical devices, techniques and theory of technical creativity, intelligent web interfaces and personal interaction with public displays. Alan has served in various roles for major conferences in HCI including co-organiser of the physicality workshop series. He was a participant at PPD'08 and also co-organiser of the CHI2008 workshop on Designing and Evaluating Mobile Phone-Based Interaction with Public Displays.

Aaron Quigley is the inaugural director of the Human Interface Technology Laboratory Australia and an Associate Professor in the University of Tasmania. From July of 2010 he will be Professor in the Chair of Human Computer Interaction in St. Andrews University Scotland. His research interests include human computer interaction, pervasive computing and information visualisation. He is currently chair of the Pervasive Computing conference series and workshop co-chair for Pervasive 2010. Aaron has served in various roles for leading international conferences and has co-chaired two previous AVI workshops, ITT'04 in Gallipoli, Italy and PPD'08 in Naples, Italy.

Sriram Subramanian is currently a lecturer at the University of Bristol and a visiting staff member at the human-interface engineering lab at the University of Osaka, Japan. Prior to this he has held positions as an Assistant Professor at the Computer Science Department of the University of Saskatchewan in Canada and as a senior scientist at Philips research labs in the Netherlands. His research interests are in human-computer interaction, input devices and interaction techniques for multi display environments and digital tables. He is the general chair for Tabletops and interactive surfaces 2008 and he has served on the program committee for conferences including CHI and GI. He has been co-chair for PPD'08 at AVI.

Lucia Terrenghi is an interaction designer and researcher interested in how technology can enhance people social engagement, self-expression, and creativity. She holds a Master in Industrial Design and a PhD in Computer Sciences, from the LMU University of Munich. Since 2008 she has worked at Vodafone R&D, where she investigates cross-platform user interfaces and the ways in which expressive interaction techniques can enhance inclusivity and sustainability. She has organised a workshop on Information Visualization and Interaction Techniques for Collaboration across Multiple Displays at CHI2006 and was a participant at PPD'08, and recently at the Dagstuhl Seminar on Pervasive Public Displays

5. INTERNATIONAL PROGRAM COMMITTEE

Our international program committee of twenty experts in the field, draws on strengths from pervasive computing, mobile computing, user interface design, hardware design, mobile devices, tabletops, surface computing, human computer interaction, computer vision and ethnography. The program committee included:

- Albrecht Schmidt, Universität Duisburg-Essen, Germany
- Antonio Krüger, Saarland University, Germany
- Carl Gutwin, University of Saskatchewan, Canada
- Christian Kray, University of Newcastle, UK
- Corina Sas, Lancaster University, UK
- Daniel Widgor, Microsoft, USA
- Dima Aliakseyeu, Philips Research Labs, The Netherlands
- Frédéric Vernier, University Paris Sud, LIMS-CNRS labs, France
- Giulio Jacucci, Helsinki Institute for Information Technology, Finland
- Kenton O'Hara, Microsoft Research Cambridge and University of Bristol, UK
- Kevin McCarthy, CLARITY, University College Dublin, Ireland
- Michael Rohs, Deutsche Telekom Laboratories, TU Berlin, Germany
- Miguel Nacenta, University of Calgary, Canada
- Patrick Baudisch, Hasso Plattner Institute, Berlin, Germany
- Umer Rashid, Human Interface Technology Lab, Australia
- Ravin Balakrishnan, University of Toronto, Canada
- Rodger Lea, University of British Columbia, Canada
- Sebastian Boring, University of Munich, Germany
- Stacey Scott, University of Waterloo, Canada
- Tico Ballagas, Nokia Research, USA

We would like to thank all the members of the program committee for their concerted efforts in reviewing the submitted papers.

6. ACCEPTED PAPERS

The full versions of the papers accepted to the workshop are available online at <http://www.hitlab.utas.edu.au/wiki/PPD10>. The abstracts of these papers are described here in sections 6.1 – 6.11. These papers primarily address the following workshop topics.

- Developing evaluation strategies to cope with the complex nature of multi-display environments (see sections 6.7 and 6.9)
- Ethnography and user studies of visual interfaces relying on coupled displays (see sections 6.3, 6.5 and 6.6)
- Understanding the design space and identifying factors that influence user interactions in this space (see sections 6.2, 6.8, 6.10 and 6.11)
- Novel interaction techniques for both private and public multi-touch devices as part of multi-display environments (see sections 6.1 and 6.7)
- Techniques for supporting input re-direction and distributing information between displays (see section 6.3, 6.6, 6.4 and 6.9)

6.1 Experiences with Mouse Control in Multi-Display Environments

Manuela Waldner and Dieter Schmalstieg

Institute for Computer Graphics and Vision, Graz University of Technology, Austria

Abstract: It is now increasingly common to extend private workstations with large public displays into a shared multi-display environment. Mouse-based interaction across multiple displays provides a convenient way to quickly shift between private work on the personal monitor and tightly coupled collaboration on shared display spaces. However, mouse pointer navigation can be negatively influenced by display factors in the environment and thereby limits fluid interaction across displays. In this paper, we present experiences with mouse-controlled multi-display environments. Based on an experiment comparing four mouse pointer navigation techniques, we show limitations of mouse-controlled interaction in multi-display environments and suggest improvements to enhance the user interface experience with low-cost multi-display settings.

6.2 Primitive Interaction Tasks for Multi-Display Environments (PRIME): A Hands-on Approach

Mahsa Jenabi and Harald Reiterer

HCI-Group, University of Konstanz, Germany

Abstract: Cross-display interaction is a challenge for HCI researchers, because a naive adaptation of mechanisms in single-display workspaces might be inappropriate for teamwork in multi-user multi-display environments. In this paper, we identify a set of primitive cross-display interaction tasks, which, so far, have not been addressed in the literature. Additionally, we present our ideas to design a prototype that incorporates the identified primitive tasks, using an iPhone as a mobile input device with an integrated display.

6.3 Investigating Distributed User Interfaces across Interactive Large Displays and Mobile Devices

Matthias Finke, Nima Kaviani, Ivy Wang, Vincent Tsao, Sidney Fels and Rodger Lea

Media And Graphics Interdisciplinary Centre (MAGIC) University of British Columbia, Canada

Abstract: There has been significant research interest over recent years in the use of public digital displays and in particular their capability to offer both interactivity and personalized content. A promising approach is to use cell phones as a means to interact with displays, but also as a small, high quality screen to complement the larger public display. The use of a dual screen approach offers a number of intriguing possibilities including a potential solution to the problem of managing conflicts that arise when a screen is shared in a public setting or providing a means to show targeted and personalized information. However, to date, there has been little investigation into the impact for users of having interfaces distributed across this type of dual screen setup. In this paper, we report on a series of experiments carried out to determine quantitative or qualitative effects on user performance

when interaction is split across large public and smaller private screens. Our position is that using mobile devices as an auxiliary device for interaction can boost user experience when interacting with large displays.

6.4 Partial Web Interface Migration

Giuseppe Ghiani, Fabio Paternò and Carmen Santoro

CNR-ISTI, HIIS Laboratory, Pisa, Italy

Abstract: In this paper we present our solution for partial Web migration from large screens to mobile devices: it is based on the use of multiple abstraction levels for describing UIs and a set of transformations that allow the migration of user interface components selected by the user to another device. This feature is particularly useful in complex Web applications, such as various emerging mash-up applications. We also show an example of applying our solution to a Web social game.

6.5 Fridge Fridge on the Wall: What Can I Cook for Us All?

An HMI study for an intelligent fridge

Manuela Bucci¹, Caterina Calefato², Sergio Colombetti³,
Monica Milani⁴, Roberto Montanari³

¹Centrocittà, Milano, Italy

²Department of Computer Science, University of Turin, Italy

³HMI Group DISMI, University of Modena e Reggio Emilia, Italy

⁴Indesit Company Spa Innovation & Digital Design, Italy

Abstract: New technologies have changed our life, making everyday tasks easier and faster. This new style of living requires a new kind of distribution of cognitive processes, resources and information. Trends in appliance design propose more sophisticated control and networking capabilities. Current white goods may be equipped with complex software and GUIs that may be inputted, by mobile phones. The ZmartFRI project aims at developing a seamless technology with an interactive fridge surface, assuring simplicity and intuitiveness of interaction. The fridge surface equipped with a display and an effective GUI provides more than additional memory device supporting human activities and providing opportunities to reorganise what is known. Thanks to a coupled display system between the fridge and the user mobile device, the fridge is able to alert products expiration date, to suggest recipes, to fill in and send by SMS or email the shopping list, to send and post messages for the house residents.

6.6 WallShare: A Collaborative Multi-pointer System for Portable Devices

Pedro G. Villanueva, José A. Gallud and Ricardo Tesoriero

University of Castilla-La Mancha, Spain

Abstract: WallShare introduces a new system to improve the collaboration possibilities among the participants in face-to-face meetings and working groups. It defines a novel interaction device and platform to develop collaborative applications. The system provides a shared zone displayed by a projector over a wall. In order to collaborate, users move their own cursors in the projected shared zone by performing gestures over their mobile device screens (mobile phones, PDAs, tablet PCs, laptops, etc.). Through

their cursors and mobile devices users are capable of posting notes and messages, and sharing files, such as documents, images, etc. This article also exposes a preliminary usability evaluation of WallShare showing the effectiveness, productivity and satisfaction of users when performing a set of defined tasks with distributed user interfaces.

6.7 Labeling Large Displays for Interaction with Mobile Devices: Recognition of Symbols for Pairing Techniques

Umar Rashid¹, Lucia Terrenghi² and Aaron Quigley³

¹School of Computer Science, University College Dublin, Ireland

²Vodafone Group Service R&D, Munich Germany

³HITLab Australia, School of Computing and Information Systems, University of Tasmania

Abstract: Interactive displays are an effective means to exchange contents with mobile devices for co-located collaboration in offices and schools. It is very important that the users are able to easily comprehend and learn the interaction techniques to pair their mobile devices with large displays. In this paper, we report on the results of an exploratory case study investigating the comprehension and understandability of the labels advertising different interaction techniques for pairing mobile phones with large displays. The results of this case study are discussed and the suggestions to enhance the comprehension level of these labels are provided.

6.8 Projector Phone Interactions: Design Space and Survey

Enrico Rukzio¹ and Paul Holleis²

¹Computing Department, Lancaster University, UK

²DOCOMO Euro-Labs, Germany

Abstract: As projector units become smaller, brighter and more energy conserving, they are bound to become an integral part of many mobile phone models in the future. We layout and discuss the design space of interactions and applications enabled by such devices. Moreover, we focus on the implications of hardware design, discuss possible interaction concepts, describe the most relevant applications areas and give an outlook on future research topics.

6.9 Delegating the visual interface between a Tablet and a TV

Konstantinos Chorianopoulos¹, Francisco Javier², Burón Fernández², Enrique García Salcines² and Carlos de Castro Lozano²

¹Department of Informatics, Ionian University, Greece

²Department of Informatics and Numeric Analysis, Cordoba University, Spain

Abstract: The introduction and wide adoption of small and powerful mobile computers, such as smart phones and tablets, has raised the opportunity of employing them into multi-device scenarios and blending the distinction between input and output devices. In particular, the partnership between a personal device and a shared one provides two possible output screens. Then, one significant research issue is to balance the visual interface between two devices with advanced output abilities. Do the devices compete or cooperate for the

attention and the benefit of the user? Most notably, how multi-device interaction is appreciated in multi-user scenarios? Previous research has raised and considered the above research issues and questions for dual screen set-ups in the work environment. In our research, we are exploring multi-device user interface configurations in the context of a leisure environment and for entertainment applications. Our objective is to provide interaction possibilities that are more than the sum of the parts.

6.10 Exploring Gesture-Based Interaction Techniques in Multi-Display Environments with Mobile Phones and a Multi-Touch Table

Tanja Döring, Alireza Sahami Shirazi and Albrecht Schmidt

Pervasive Computing and User Interface Engineering Group
University of Duisburg-Essen, Germany

Abstract: In this paper, we explore the potential of combining shared and interactive displays (e.g. a multi-touch table) with personal devices (e.g. mobile phones) as an important class of heterogeneous multi-display environments. Within six case studies applications and interactions were invented and implemented that utilize the potential of such heterogeneous multi-display environments. We were in particular interested how to design systems that include interaction across different displays and how to manage public and private information in a group setting. One case study, a digital card game, highlights these design challenges. A player has personal information (her cards), and there is public information (e.g. the cards on the table). Additionally, inherent interaction between both (e.g. transferring cards from the phone to the table and vice versa) is possible. We explore different natural ways of interaction, including touching the table as well as tilting, throwing, and shaking. With this application we provide a use case to discuss gestures combining mobile phones with tabletop surfaces, as well as to explore a private-public display setting. First results showed that combining tables and mobile phones provide a suitable and understandable way for interaction in these settings.

6.11 Digital Hospitality: Expressing hospitality towards guests in smart homes using private and domestic displays

Rasmus Gude

Department of Computer Science, Aarhus University, Denmark

Abstract: For more than a decade the use of ubiquitous computing technologies in the domestic space – the so-called smart homes - has been a subject for research. While research projects and findings has focused on smart homes and its inhabitants in various incarnations, little or no research has been questioning how these smart homes engender hospitality towards guests and how inhabitants in a smart home can express hospitality using ubiquitous technologies. This paper defines the novel notion of “digital hospitality” and proposes an early state system design based on coupled displays. The system called EWIA is designed to facilitate and strengthen the relationship between guest and host by utilizing both private smart phone displays and domestic displays. Preliminary results and topics for discussion are reported.

7. ACKNOWLEDGMENTS

We would like to thank all the authors who submitted to the workshop and all those we had position papers accepted and attended. We would also like to thank the Human Interface Technology Laboratory Australia for hosting our website.

8. REFERENCES

- [1] Quigley, A., Subramanian, S., and Izadi, S. 2009. Special issue on interaction with coupled and public displays, *Personal Ubiquitous Comput.* 13, 8 (Nov. 2009), 549-550. DOI=<http://dx.doi.org/10.1007/s00779-009-0242-7>.
- [2] Terrenghi, L., Quigley, A., and Dix, A. 2009. A taxonomy for and analysis of multi-person-display ecosystems. *Personal Ubiquitous Comput.* 13, 8 (Nov. 2009), 583-598. DOI= <http://dx.doi.org/10.1007/s00779-009-0244-5>

Experiences with Mouse Control in Multi-Display Environments

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ABSTRACT

It is now increasingly common to extend private workstations with large public displays into a shared multi-display environment. Mouse-based interaction across multiple displays provides a convenient way to quickly shift between private work on the personal monitor and tightly coupled collaboration on shared display spaces. However, mouse pointer navigation can be negatively influenced by display factors in the environment and thereby limits fluid interaction across displays. In this paper, we present experiences with mouse-controlled multi-display environments. Based on an experiment comparing four mouse pointer navigation techniques, we show limitations of mouse-controlled interaction in multi-display environments and suggest improvements to enhance the user interface experience with low-cost multi-display settings.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces—*Input devices and strategies (e.g., mouse, touchscreen)*

General Terms

Design, Experimentation, Human Factors

Keywords

multi-display environment, mouse control

1. INTRODUCTION

The availability of affordable display technology has given rise to a wide variety of multi-display environments (MDE). Especially in conventional office and team spaces, users can extend private workspaces with shared interaction spaces by projecting imagery onto unused wall and table spaces (*c.f.*, Figure 1). The resulting combination of private and shared displays has been found to cause a better coordination of distributed work and a more equitable task work load [5].



Figure 1: Public projected displays as extension of private workspaces in an office environment.

Numerous observations have shown that users frequently switch between a tightly and loosely coupled collaboration style (*e.g.*, [11]). In an MDE, this change of collaboration style requires the user to switch between private and shared display spaces to share information, discuss shared information artifacts, or to return to private work. In a conventional office setting, performing these switches by moving the mouse pointer across display boundaries is convenient, as the user does not need to change interaction technique when using the MDE as extension of the personal workspace, and distant displays can be accessed without physically moving [4]. Furthermore, interference of multi-user input is kept to a minimum, as users do not occlude displayed content when interacting on public display space – in contrast to direct input methods. However, previous research has shown that mouse pointer navigation in MDEs is negatively influenced by a number of display factors, such as depth offsets between displays [10], adjacent displays at relative angles higher than 45° [9], physical distance and size-resolution mismatches [2], as well as non-optimal seating arrangements [13].

In this paper we report findings from an experiment comparing four mouse pointer navigation techniques in a heterogeneous multi-display setup [12]. We will discuss limitations of mouse-controlled MDEs and suggest improvements for mouse pointer navigation techniques.

2. COMPARISON OF TECHNIQUES

In conventional multi-monitor systems, adjacent display edges are usually “stitched” to create a seamless interaction area. This approach has also been applied to MDEs with more complex display arrangements, such as in Augmented Surfaces [8] or PointRight [6]. MouseEther [2] additionally incorporates visual discontinuities introduced by monitor bezels and display-size resolution mismatches into the motor space. Perspective Cursor [7] extended this approach by evaluating mouse input events from a tracked user’s perspective of the environment. Thereby, it additionally introduces a non-uniform control/display (C/D) gain when navigating within a single display, caused by perspective foreshortening. Instead of implicitly triggering a transition by crossing connected display edges, pointer warping techniques (*e.g.* [3]) and interactive miniature views (*e.g.* [4]) allow the user to redirect input explicitly to a target display.

From this short overview, it is evident that mouse pointer navigation in MDEs covers a large design space. We grouped the differences between the presented navigation techniques into the following four categories:

Trigger: how input redirection is triggered (implicitly by moving the mouse pointer across a display edge or explicitly by pressing a trigger).

Cross-display movement: how display-less space is bridged (warping the mouse pointer across the gap or continuous movement by considering the physical display-less space).

Outcome: where the mouse pointer re-appears on the target display (*e.g.*, at the display edge or at the center).

C/D gain: how the C/D gain is adjusted when moving within a display (*e.g.*, standard C/D gain or perspective).

We assume that the optimal choice of parameters for navigation techniques is dependent on the individual display geometries (such as differences in size and resolution), the arrangement (such as distance and angle between displays), as well as the individual user preferences.

3. EXPERIMENT

We conducted a single-user experiment with 20 participants. We compared four navigation techniques differing in the above mentioned parameters in a heterogeneous multi-display setup [12]:

Path navigation (*path*) is similar to stitching, as it virtually connects the closest display edges of adjacent display pairs. Paths do not necessarily cover the entire display edges, but are limited to intervals determined from the corner point projections of the adjacent edge. Overlapping paths are prioritized according to their display-to-display proximity. Resulting paths represent point-to-point mapping areas between paired displays. To aid the path-finding process for the user, we visualized connected edge portions with color-coded lines.

Similar to Perspective Cursor [7], free navigation (*free*) takes into account the individual users’ perspectives as pointer movement is adapted to their estimated focal planes. However, instead of letting the mouse pointer continuously move within display-less space, free navigation warps the mouse across display gaps. The outcome position on the target display is determined by extrapolating the last mouse motion

and intersecting the resulting ray with the display boundaries on the user’s focal plane representation of the environment. If no target display was found along the ray, input redirection is not triggered. As we did not employ head-tracking, the perspective representation of the environment does not change when the user moves.

The world-in-miniature (*WIM*) control is a GUI presenting a 3D model of the environment textured with live desktop contents. The view is initialized from the user’s perspective and can be interactively modified. The WIM window is invoked by a shortcut and appears at the current mouse pointer location. To redirect mouse input, the user clicks the desired target location within the miniature view. As a result, the mouse pointer will be redirected to the associated display position in the physical environment.

Pointer warping (*warp*) relocates the mouse pointer to the center of a display with a given ID. Relocation is triggered by pressing a modifier key and the desired target display ID number on the keyboard. Table 1 illustrates the differences of the four employed navigation techniques.

	Path	Free	WIM	Warp
Trigger	implicit (edge interval)	implicit (edge)	explicit (GUI)	explicit (key-press)
Outcome	point-to-point edge-mapping	ray-edge intersection	selected in GUI	display center
C/D gain	standard	perspective	standard	standard

Table 1: The experimental conditions differ in how input redirection is triggered, the outcome position on the target display, and the C/D gain adjustment. All techniques warp the mouse pointer across display-less space.

The display setup was chosen, so that each cross-display transition covered varying display factors, such as change of display size, different display angles, depth disparities, whether displays are placed distant from each other (and thus are not accessible without crossing intermediate displays), and whether one of the displays lies outside the user’s field of view. Figure 2 shows the setup.

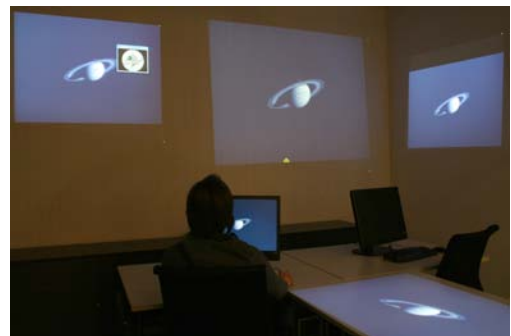


Figure 2: Experimental setup.

For each navigation technique, users had to accomplish a target selection task with targets appearing sequentially at different display locations. After performing the task for each of the four navigation techniques, users were asked to accomplish a combined navigation condition where they could choose between path navigation and free navigation as

mouse-based navigation technique and were free to invoke the WIM control or pointer warping at any time. We collected task completion times between two target selections as performance measures, employed input logging, asked users to fill out a questionnaire rating the four techniques, and conducted a semi-structured interview at the end of the experiment.

3.1 Performance

We measured task completion times between two consecutive target selections and conducted a 4(navigation technique) x 9(transition defined by displays of two subsequent targets) repeated measures ANOVA. WIM was the slowest technique (average completion time across all transitions $t_{wim} = 5.84s$), followed by free navigation ($t_{free} = 4.17s$), which was slower than both, path ($t_{path} = 3.67s$) and warp ($t_{warp} = 3.29s$). Pointer warping had the best performance for navigation between the monitor and the tabletop displays, as well as for navigation from and to the tabletop display, compared to the other navigation techniques. Both mouse-based navigation techniques (path and free) were faster for navigation between the wall displays than WIM and warp. However, performance of path and free differed when more complex transitions than traversing between wall displays had to be accomplished: Free was superior compared to path for navigation between monitor and wall displays, as well as when navigating from the tabletop display to a wall display. However, it suffered from severe performance fallbacks when navigating to the tabletop display and subsequently selecting a target there. WIM and warp had almost uniform task completion times across all display crossings, thus did not seem to be strongly affected by changing display factors, as compared to path and free. Additional information on task completion times outcomes can be found in [12].

3.2 Usage frequencies

When giving our users the choice, eleven out of twenty users decided for path navigation, nine for free navigation as mouse-based navigation techniques. Overall, 64% of all display crossings were performed with the mouse, 27% with pointer warping, and 4% with the WIM control. Usage of mouse-based transitions was high for navigation between wall displays (85% on average for adjacent displays and 75% for jumping between the outermost wall displays). The mouse was also the main choice for navigation between monitor and wall displays (64%). However, pointer warping was employed more often than mouse-based transitions whenever the tabletop display was involved (47% and 29%, respectively).

3.3 Preference and user feedback

After the experiment, users were asked to evaluate the four navigation techniques on a seven-point Likert scale. A one-way repeated measures ANOVA did not reveal any significant differences across the ratings. On average, pointer warping was rated highest ($r_{warp} = 5.55$) and free navigation lowest ($r_{free} = 4.55$). In the interview, most users mentioned they preferred the combined condition.

When interviewing the users, we found that preferences were indeed diverse. Some users appreciated the clear, visualized

structure given by path navigation. Others rated it as “too restrictive”. Similarly, seven users stated they found free navigation “very intuitive” while two users “did not understand the concept at all”. Several users also reported that the mouse pointer speed was too slow with free navigation. Free navigation was the only technique for which the C/D gain was altered from the standard device settings, as it was adjusted for the perspective field of view of the user. One user mentioned that “the display outline is my reference frame”, so he would expect the mouse to move with consistent speed within the individual display boundaries, irrespective of the physical size. The perspective mapping was also the main reason for performance fallbacks of free navigation, as navigation on the tabletop display resulted in a skewed and rotated mouse navigation frame relative to the actual device space. Users mentioned that navigation on the tabletop display was the main reason to rate free navigation low. Another problem with free navigation was that any display border region was potentially connected to a target location. Depending on the current movement direction, the mouse pointer would be warped to a distant location on a remote display when involuntarily touching the display border. We assume that this problem will be even more severe when working with conventional desktop content, where important GUI-elements are often placed at the border of the display.

For the WIM control, users reported that the start-up latency was too high and that “too many mental steps” were involved. Some users also indicated that the window placement at the mouse pointer location was not appropriate. They argued that their focus was already on the target display when the WIM window would appear at the current pointer location, forcing them to look back and identify the target in the miniature view. Thus, some suggested to open the WIM consistently at the private monitor or synchronously on all displays. Pointer warping was generally appreciated by the users as it was perceived as fast option to change displays. Users also reported that pointer warping was convenient when losing track of the mouse pointer, as it would consistently warp the mouse back to a pre-defined location. Considering usage frequencies, these reports are surprising, as pointer warping was less often employed than mouse-based transitions. When asking participants for their strategy when to employ pointer warping or the WIM control instead of mouse-based transitions, they mentioned long distance travels, “not easily accessible” displays, and tabletop display and monitor in particular.

4. DISCUSSION

Based on the findings and observations of the experiment, we will discuss implications and future research directions.

Implicit or explicit trigger? Our study suggests that triggering input redirection through pointer warping techniques leads to increased performance and is appreciated by participants across all experience levels. However, it also indicates that users rarely employ pointer warping when they have the choice. In fact, they choose pointer warping primarily to overcome subjectively complex transitions where extensive movement planning, physical effort, or adaptations of pointer movement directions (as for the tabletop) would be required when using the mouse. Thus, we recommend

to provide pointer warping techniques as additional option when building mouse-controlled MDEs, so users can overcome complex display crossings and quickly relocate their pointer to a known position.

What about tabletop displays? Our initial design approach was to enable consistent navigation and manipulation techniques across all displays in the environment. However, seamless mouse pointer navigation proved to be unsuitable for accessing and manipulating tabletop content in a configuration as employed in our setup. As tabletop displays cannot be controlled from distance in a similar manner as wall displays, users need to gather around the tabletop display to view and manipulate content. It therefore seems reasonable to restrict interaction with tabletop content to direct manipulation techniques, such as touch input. However, to enable spontaneous collaboration, we require flexible user interfaces to relocate content from the remaining workspace to the tabletop display and vice versa. We assume that a world-in-miniature control is a promising tool for moving content across displays with different input capabilities. In a low-cost multi-display setting without touch-capable input devices, we recommend to refrain from seamless mouse-control across tabletop display borders. Instead, it seems more suitable to access tabletop displays by using pointer warping or a WIM control.

How can mouse pointer navigation in MDEs be improved? We will discuss the advantages and limitations of navigation techniques with respect to the navigation parameters introduced in section 2:

Trigger: Path navigation was rated as too restrictive by some users as the display-connecting paths were perceived as too small. On the other hand, the ability to leave the display at any display border position was a major problem for free navigation, as participants often lost their mouse pointer when they involuntarily touched the display border and thereby caused a transition to a remote display. The ideal solution would be to predict whether the user is actually intending to leave the display by analyzing the motion pattern. Thereby, we could preserve the display edges as valuable navigation aid when selecting items located at the boundaries of the displays [1], such as menu bars, while letting the user navigate quickly across display borders.

Outcome position: We observed that users sometimes had difficulties spotting the mouse pointer after performing a transition. We did provide the users with an animated dot to signal the outcome position on the remote display. However, when the target display was not in their field of view, they did not have a visual cue about the current mouse pointer location. It is worth investigating whether more sophisticated visual cues indicating the current mouse pointer location (e.g., a technique like “anchored cursor” [8]) help the users finding their mouse pointer more easily. However, it is also important to find out whether more obtrusive visual cues interfere with collaborative work in a group.

C/D gain: The perspective C/D gain adjustment applied by free navigation caused serious navigation problems, such as targeting difficulties on the tabletop display, as well as low mouse pointer speed. While it seems useful to have a perspective representation of the environment to determine the outcome position on the remote display, having a perspective C/D gain does not seem to bring any advantage. In

the future, we will therefore investigate different combinations of navigation parameters, combining positive aspects of path and free navigation.

5. CONCLUSION

Mouse pointer navigation is universally employable and can provide fine-grained input even on distant displays, while allowing to traverse quickly across multiple display boundaries. It seems to be an ideal choice to extend single-user workspaces with shared wall and tabletop displays. However, our experiment has shown some limitations of mouse-controlled MDEs including the ability to traverse to and from tabletop displays, involuntarily redirecting the mouse pointer, and finding complex paths across multiple displays. We discussed the implications and suggested some improvements for mouse-controlled MDEs. In the future, we will address the raised issues and shift our focus to collaborative settings.

6. ACKNOWLEDGMENTS

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7. REFERENCES

- [1] C. Appert, O. Chapuis, and M. Beaudouin-Lafon. Evaluation of pointing performance on screen edges. In *Proc. AVI 2008*, pages 119–126. ACM, 2008.
- [2] P. Baudisch, E. Cutrell, K. Hinckley, and R. Gruen. Mouse ether: accelerating the acquisition of targets across multi-monitor displays. In *Ext. Abstracts CHI 2004*, pages 1379–1382. ACM, 2004.
- [3] H. Benko and S. Feiner. Multi-monitor mouse. In *Ext. Abstracts CHI 2005*, pages 1208–1211. ACM, 2005.
- [4] J. T. Biehl and B. P. Bailey. ARIS: An Interface for Application Relocation in an Interactive Space. In *Proc. GI 2004*, pages 107–116, 2004.
- [5] K. Inkpen, K. Hawkey, M. Kellar, R. M. K. Parker, D. Reilly, S. Scott, and T. Whalen. Exploring display factors that influence co-located collaboration: angle, size, number, and user arrangement. In *In Proc. HCI International*, 2005.
- [6] B. Johanson, G. Hutchins, T. Winograd, and M. Stone. PointRight: Experience with Flexible Input Redirection in Interactive Workspaces. In *Proc. UIST 2002*, pages 227–234, 2002.
- [7] M. A. Nacenta, S. Sallam, B. Champoux, S. Subramanian, and C. Gutwin. Perspective Cursor: Perspective-Based Interaction for Multi-Display Environments. In *Proc. CHI 2006*, pages 289–298, 2006.
- [8] J. Rekimoto and M. Saitoh. Augmented Surfaces: A Spatially Continuous Workspace for Hybrid Computing Environments. In *Proc. CHI 1999*, pages 378–385, 1999.
- [9] R. Su and B. P. Bailey. Put them where? towards guidelines for positioning large displays in interactive workspaces. In *Proc. GI 2005*, pages 337–349, 2005.
- [10] D. S. Tan and M. Czerwinski. Effects of visual separation and physical discontinuities when distributing information across multiple displays. In *Proc. Interact 2003*, pages 252–255, 2003.

- [11] A. Tang, M. Tory, B. Po, P. Neumann, and S. Carpendale. Collaborative coupling over tabletop displays. In *Proc. CHI 2006*, pages 1181–1190. ACM, 2006.
- [12] M. Waldner, C. Pirchheim, E. Kruijff, and D. Schmalstieg. Automatic configuration of spatially consistent mouse pointer navigation in multi-display environments. In *Proc. IUI 2010*, pages 397–400. ACM, 2010.
- [13] J. R. Wallace, R. L. Mandryk, and K. M. Inkpen. Comparing content and input redirection in mdes. In *Proc. CSCW 2008*, pages 157–166. ACM, 2008.

Primitive Interaction Tasks for Multi-Display Environments (PrIME): A Hands-on Approach

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ABSTRACT

Cross-display interaction is a challenge for HCI researchers, because a naive adaptation of mechanisms in single-display workspaces might be inappropriate for teamwork in multi-user multi-display environments. In this paper, we identify a set of primitive cross-display interaction tasks, which, so far, have not been addressed in the literature. Additionally, we present our ideas to design a prototype that incorporates the identified primitive tasks, using an iPhone as a mobile input device with an integrated display.

Categories and Subject Descriptors

H.5.2 Information Interfaces and Presentation: User interfaces—Input devices and strategies, Interaction styles.

General Terms

Design, Experimentation, Human Factors.

Keywords

Input device, cross-display interaction, multi-display environment.

1. INTRODUCTION

Meeting rooms are nowadays increasingly equipped with many displays in different sizes and with a variety of functionalities (e.g., touch sensitivity). While large displays are suitable for presentation, horizontal touch tables, such as Microsoft Surface, may enhance collaborative work. In addition, people often bring their own tablet PCs and/or mobile phones, which also have integrated displays. This results in “coupled displays” [15] in the room, introducing new challenges for cross-display interaction.

Multiple displays are beneficial in collaborative work, or presentation sessions. For example, in a presentation meeting, one might want to show data about accidents in one particular year and at the same time show the geographical locations of these accidents in Google Earth on another display. Further displays could show a table of accident costs and impacts. Even though in most cases such a multi visualization option is possible when the displays are all connected to the same computer, the configuration of views is time-consuming. An intuitive interaction method is required in these situations.

Interaction in MDEs can be divided into two types: within-display interaction and between-display interaction. Within-display interaction includes the method of interaction well known from single-display workspaces. Users should be able to move and manipulate objects inside the display. A set of primitive

interaction tasks is mentioned in ISO 9241-400 and Foley, et al. [3]. Between-display interaction (also known as cross-display interaction) includes a specific set of interaction tasks that can only be performed when two or more coupled displays are available; for example transferring an object from one display to another.

Between-display interaction is a challenge for HCI researchers and interaction designers. Therefore, this type of interaction is the focus of this research project.

2. RELATED WORK

We are not the first group who is working on interaction for MDE. There are many related works in this field that have inspired us to design our MDE setting. As mentioned in Nacenta et al. [10], a fundamental between-display interaction is moving an object from one display to another. The Crystal project [13] uses a touch table for controlling an interactive room. Simple touch gestures on the table can be used to transfer media data to a TV or even to turn on/off a lamp. Another project that also uses a touch table is WeSpace [17]. The touch table is used to manage the view of different laptop screens on a large vertical display.

IMPROMPTU [1] introduces a framework for multi-display interaction, which also provides object movement, using mouse input. The documents that have to be discussed in a group can be transferred to a large display and users can set their data as sharable with others or have it kept privately.

Dynamo [1] provides a large display that can be controlled via mouse with multiple users. Each user has an individual part of the display, in order to browse the Internet or view multimedia data. Users are able to set security options, for instance, on who is allowed to edit their data.

Stitching [6] allows for the sharing of objects from one display to another. It detects the relationship between pen strokes that are performed across the two displays. The displays can be located directly next to each other or even at a distance.

In addition to the object movement interaction, related works have investigated other applicable prototypes taking advantage of multiple displays. Forlines et al. [4] use a touch table and/or tablet PC for controlling a multi-display setting. They also show different views of Google Earth on different displays (3 wall displays, one touch table, and a tablet PC). On one display users can see a 3D building visualization on the Google application; in parallel a visualization of streets and schools located in that area is displayed on the other vertical displays. Users interact with the geographical interface using their tablet PC or touch table. Users can use their own tablet PC to work privately on the visualization,

and also not to disturb their colleagues. For increasing awareness concerning teamwork, people can use the touch table to interact. This project is an example of how multiple displays can be used for showing different but synchronized views. Another authentic example of such a scenario is the deskothèque [11] project. It uses the Caleydo application [14], a Visual Analysis Framework for Gene Expression Data, in the context of biology, for viewing various synchronized biomedical visualizations in parallel on multiple displays. In this domain, having different biomedical visualizations can help study the interdependencies of the gene products. In the following section we present some of the requirements for MDEs and use the above mentioned projects to discuss these requirements.

Rekimoto et al. [12] also presented the design and implementation of a hybrid workspace that users can move or attach digital data across displays.

TouchProjector [2] is a project that uses video streaming data, which is taken by an iPhone camera to manipulate objects. iPhone is also able to transfer an object from one display to another even remotely. Several other researchers have investigated using hand-held devices for controlling their environment. For example Pebbles project [12] uses PDAs as a universal controller. Some interesting scenarios using PDAs from meeting sessions to military are mentioned in [9]. Semantic Snarfing [8] is a method used to indicate the region of interest on the display using laser pointer, finger tracking or eye tracking and copy this region to the screen of a handheld device.

3. MDE Requirements

The following characteristics are necessary for co-located collaboration in MDEs. We explain each of the requirements and mention different examples from the above-mentioned related work.

3.1 Bi-directional interaction

In order to support an equal participation in the collaboration, we need to give all the users an opportunity to transfer objects from any display to any other display. Therefore, regardless of touch-sensitiveness and other specific features, displays should be controllable *bi-directionally*.

Crystal project [13] is a useful setting as a home application when people want to control the devices in the room, but if one wants to extend the system for collaborative work scenarios this uni-directional control may not allow users at any display to control and manipulate the objects.

WeSpace [17] is also implemented with the purpose of presentations in a meeting room when researchers want to discuss about their results. A touch table is a potential control device in this setting, but in a workshop scenario, where people are divided into sub groups and each sub group collaborates separately in parallel, a bi-directional control is more helpful.

This problem is solved in Stitching [6], since any object can be transferred to another display using a pen.

3.2 Privacy & Awareness

Another important issue in collaboration scenarios is awareness. Crystal [13] and WeSpace [17] increase the level of group awareness by using a touch table, which may not always be desirable in collaborative work. For instance, when users want to enter a keyword for searching, publicly presenting the keyword on the table might be undesirable. Using hand-held devices can help in such settings for performing private actions, for example, as tablet PC is used in Frolines et al. [4].

3.3 Mobility

Mobility is a necessary feature in ubiquitous computing environments, especially in collaborative spaces where people are free to change their position or perspective while performing joint tasks [5]. Users should be able to move around and interact with the surrounding displays. Systems that use a touch table to control the displays, or a mouse have this problem (e.g., Crystal [13], WeSpace [17], IMPROMPTU [1], and Dynamo [10]). Systems that use mobile input devices, such as PDAs, mobile phones, or laser pointer (e.g. TouchProjector [2], tablet PC in [4]) offer a solution to this problem.

3.4 Reachability & Flexibility

Some of the related works present novel solutions for MDEs based on specific features of the displays (e.g., touch sensitiveness). Therefore generalizing the solution for any kind of display is not always straightforward. For example the object transfer technique in Stitching [6] is applicable only for pen-based displays, which is not flexible enough to interact with different kinds of displays. Furthermore this technique cannot be used, if the displays are not reachable due to, for example, a crowd of people in a presentation session. TouchProjector [2] solves this problem by using a mobile phone to transfer the objects.

3.5 Generalization of single-purpose applications

State-of-the-art techniques in cross-display interaction have investigated different prototypes to transfer objects or to distribute different visualizations on displays. Lessons learned from these single-purpose solutions can help in the design of future MDE applications. For example deskothèque [11] and Frolines et al. [4] have shown that enabling users to actively manage visualizations on different displays enhances collaborative work and should be generalized and integrated into cross-display interaction. However, we recognize a number of disadvantages of current systems: uni-directional control, the provision of a stationary controlling mechanism that hinders the freedom of movement in the room, privacy and awareness issues, and finally flexibility of the interaction regardless of specific features of the display (e.g., pen-based or touch-sensitive). We try to solve these problems in our design (see the Approach section). We avail ourselves of the guidelines for using multiple views in information visualization [16] as golden rules for our design. Moreover, we believe that a set of primitive tasks for cross-display interaction is required as a standard basis for interaction design in MDEs. Such a set is unaccounted for in the literature.

4. OUR CONTRIBUTION

As the first part of our research we identify the following primitive kinds of between-display interaction that are inspired by example applications mentioned in related work:

- *Object selection*: Selecting one or more objects from one or more displays (e.g., for collecting objects of interest from different displays to drop them on an individual display for further manipulations)
- *Object transfer*: Moving an object from one display to another (moving object to an individual workspace)
- *View management*: Viewing a selected area on another display as a new workspace (This can be used for task distribution in a workshop scenario)

- *Visualization gallery*: Selecting objects for generating a new visualization of the data set or their metadata on another display (e.g., synchronized geographical or statistical visualizations).

These cross-display interaction primitives are a good basis for interaction designers, especially to design and evaluate a new input device for MDEs.

The second part of our research is to build a prototype that incorporates the interaction primitives in MDEs. This prototype shall account for the problems discussed in the MDE requirements section (e.g., uni-directional control, non-mobile interaction, etc.) and will enable users to have a fluid interaction while collaborating with other team members.

We have selected the iPhone as an input device, because it has the advantage of having an integrated display. Using this display, visual feedbacks can be given to the user especially when the cursor is between displays. In this case, the user obviously does not receive any visual feedback from the displays, since the pointer is locating at the space between them, but the iPhone screen gives continuous feedback to the user. The iPhone can offer different input modalities, such as a virtual keyboard which is considered as a mobile keyboard. Taking advantage of rich integrated sensors like compass, accelerometer, and camera, this device has the potential to enhance user interaction.

Designing and evaluating this prototype helps the HCI community and us to answer the following research question which the state-of-the-art techniques have left unanswered:

Does a mobile input device with an integrated display improve performing cross-display interaction primitives in collaborative work?

The following section presents our assumptions for the target interaction environment.

5. APPROACH

In the contribution section, we have specified cross-display interaction primitives: object selection, object transfer, view management, and visualization gallery. Multi-display settings provide these new opportunities that may enhance collaborative work.

We take a practical approach to answer our research question, which means building and evaluating a working prototype including identified types of interaction. The employed device is an iPhone. Additionally, the system is aware of the orientation of the user (device), using the OptiTrack tracking system with attaching markers to the iPhone. This information is used to control the cursor. We have divided the implementation of this prototype to four phases for each cross-display primitive.

5.1 Object Selection

Before performing any of the next three primitive tasks, users must select the objects of their interest. Object selection is already considered as a single-display primitive task (in ISO 9241-400 and Foley, et al. [3]), however it has to be considered as a primitive task in cross-display interaction as well, since users may want to select different objects from different displays.

Whenever the user takes the device in hand and starts his working, the device will be in a selection mode. There the user sees a subset of objects located under the pointer and around it on the iPhone screen. The limited space on iPhone screen does not allow us to show more objects, but only when we choose methods such as a

cover flow visualization. Therefore in the case that the number of objects on a display is less than 12, we can show all of them on the iPhone as a grid visualization (see fig. 2). The grid is filled with the selected objects from top to down and left to right, without considering the real physical position of the object on each display. If the number of objects is more than 12, they will be shown as a cover flow visualization (see fig. 1).

The orientation of the iPhone is recognized using a tracking system. This enables the system to detect the display in focus, and also to move the pointer. Furthermore the integrated display of the iPhone gives us the possibility to show the last selected objects as a visual feedback.

There are several methods for selecting objects on the screen. For example with the standard keyboard and mouse, users can select one object with a mouse click on that object. Dragging the mouse on the display and drawing a rectangle enable users to select more objects (selection window). Another method is a combination of the shift button and a mouse click (shift + Click). With this method more objects can be selected regardless of their physical position in the display. More research is needed to find out the best selection mechanism that is proper for iPhone screen and also support scalability. Scalability is a challenge in the sense of selecting numerous objects on different displays on the one hand, and the ways the selected objects can be viewed on the small display of iPhone on the other hand.

For the first design iteration of our prototype, we have decided to use the same mechanism as shift + Click with the iPhone to select the objects, since *selection window* mechanisms are less handy for the small screen of iPhone (not more than 12 objects can be shown on iPhone, so it is not much quicker to draw a rectangle with finger gestures than to tap on them). Therefore, when the user takes the iPhone in hand, a simple tap on an object selects that object. A second tap would again deselect the object (fig. 1). This selection procedure continues till the user taps on the icon of the target display. This icon is only shown when the user is facing that display (using the orientation data from the tracking system).



Figure 1. User selects her objects of interest using an iPhone. iPhone shows the selected objects, as well as the current display in focus.

5.2 Bridging the Gap between Displays

In a single-display setting, the graphical representation of the cursor gives users feedback about the current position of the cursor. While moving an object inside the display, the user can always see the visual representation of the object. In multi-display settings, different screens are located physically apart from each other. When the pointer is moved from one display to another, it disappears between the display physical spaces. Our idea is to use an iPhone as an input device to transfer objects or to move the cursor from one display to another. After selecting the objects of interest as mentioned in 5.1, the selected objects are visually shown on the iPhone. Therefore, selected objects move with the user around the room until the user performs the drop action. The iPhone screen constantly shows which display is currently in focus by presenting the icon of that display. Therefore the paste



Figure 2. User turns to the target display. She transfers the selected objects to the target display by tapping on the icon of that display (the icon under the red circle).

action is done by tapping on the icon of the target display (fig. 2).

5.3 View Management

In teamwork scenarios, it is necessary to define individual or subgroup workspaces, e.g., in the case that different groups work simultaneously on different objects using different displays. One interesting question is: how can a user actively manage this workspace view?

Not only the workspace management, but also defining different views/windows over a sub-collection of objects, in general, may be necessary (e.g., for presenting different perspectives of a topic using different sets of data).

The advantage of an iPhone, as an input device, is that it is mobile, which gives users freedom of movement in the room. A laser pointer or similar devices that are mobile could also be suitable for the task. However, since our aim is to take advantage of bridging the visualization gap between displays, we decided to build the workspace definition task also with an iPhone.

The difference between defining a view and transferring objects, mentioned in 4.2, is that when views are defined on the information landscape, manipulations on the objects will be synchronized among all the displays that have defined this object as a part of their view. This synchronization helps when people want to synchronize their work on a specific object. In comparison, object transfer is simply transferring an object to another display. Further manipulations on that object will just be on that specific display, without any synchronization. One can simplify these two interaction types and define them as: object transfer = Paste as independent objects, and view management = paste as linked objects.

5.4 Visualization Gallery

In business group discussions, multiple visualizations may be necessary for presentation issues, or for comparing different results. This different visualization can be a simple visualization of the selected images on a small screen in a bigger size on another display (as also used in Stitching [6]). The visualization could get more complex by showing different diagrams of the same dataset on different displays (e.g., scatter plot, grid, or locations on Google). In multi-display settings one can use an input device with an integrated display, such as an iPhone, to manage and select the desired visualization.

We implement this additional interaction task in our prototype. iPhone is used to select the object/data set and the possible visualization available for that data from a list. One can simplify this interaction type and call it: paste as a new visualization.

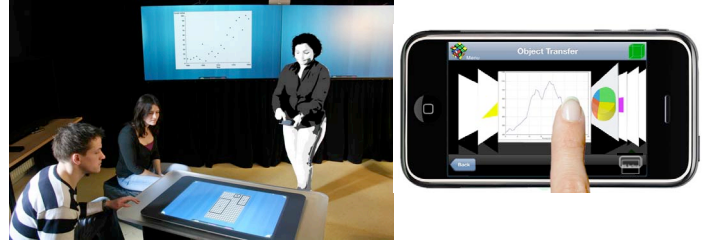


Figure 3. After selecting the objects of interest (fig 1), user can select the type of visualization on the iPhone. Afterwards she taps on the icon of the target display, so that the visualization is shown on that display.

6. CONCLUSIONS

We have identified four types of cross-display interaction primitives. Interaction designers can use these interaction primitives while they are prototyping their multi-display space. We introduced our ideas for a practical prototype that implements these primitive tasks. This prototype solves the problems we recognized in the related works. In addition they shall enable users to have fluid interaction with multiple displays when collaborating with other team members. Lessons learned from design and implementation of this prototype will show the HCI community and us the advantages of using mobile input device with an integrated display for cross-display interaction.

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8. REFERENCES

- [1] J. Biehl, W. Baker, B. Bailey, D. Tan, K. Inkpen, and M. Czerwinski. Impromptu: a new interaction framework for supporting collaboration in multiple display environments and its field evaluation for co-located software development. 2008.
- [2] S., Boring, D., Baur, A., Butz, S., Gustafson, and P., Baudisch. Touch Projector: Mobile Interaction Through Video. In Proceedings of CHI 2010.
- [3] J. D. Foley, V. L. Wallace, and P. Chan. The human factors of computer graphics interaction techniques IEEE Comput. Graph. Appl., 1984.
- [4] C. Forlines, A. Esenther, C. Shen, D. Wigdor, and K. Ryall. Multi-user, multi-display interaction with a single-user, single-display geospatial application. In Proceedings of the 19th Annual ACM Symposium on User interface Software and Technology (Montreux, Switzerland, October 15 - 18, 2006). UIST '06. ACM.
- [5] V. Ha, J. Wallace, R. Ziola, and K. Inkpen, 2006. My MDE: configuring virtual workspaces in multi-display environments. In CHI '06 Extended Abstracts on Human Factors in Computing Systems (Montréal, Québec, Canada, April 22 - 27, 2006).

- [6] K. Hinckley, G. Ramos, F. Guimbretiere, P. Baudisch, and M. Smith. Stitching: pen gestures that span multiple displays. Proceedings of AVI '04 Conference on Advanced Visual interfaces, 23-31. New York: ACM.
- [7] S. Izadi, H. Brignull, T. Rodden, Y. Rogers, and M. Underwood. Dynamo: a public interactive surface supporting the cooperative sharing and exchange of media. In Proceedings of the 16th Annual ACM Symposium on User interface Software and Technology. UIST '03. 2003.
- [8] B. A., Myers, C. H., Peck, J., Nichols, D., Kongand, R., Miller. Interacting at a Distance Using Semantic Snarfing. In Proceedings of the 3rd international Conference on Ubiquitous Computing. G. D. Abowd, B. Brumitt, and S. A. Shafer, Eds. Lecture Notes In Computer Science, vol. 2201. Springer-Verlag, London, 305-314.
- [9] B., Myers, "Using Multiple Devices Simultaneously for Display and Control." IEEE Personal Communications special issue on "Smart Spaces and Environments." vol. 7, no. 5, Oct. 2000. pp. 62-65.
- [10] M. A. Nacenta; C. Gutwin; D. Aliakseyeu; S. Subramanian, There and Back Again: Cross-Display Object Movement in Multi-Display Environments Human-Computer Interaction, 1532-7051, Volume 24, Issue 1, 2009, Pages 170 – 229.
- [11] C. Pirschheim, M. Waldner, and D. Schmalstieg. Deskotheque: Improved spatial awareness in multi-display environments. In Proc. of IEEE VR '09, pages 23–126, March 2009.
- [12] J., Rekimoto, and M., Saitoh. Augmented surfaces: a spatially continuous work space for hybrid computing environments. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: the CHI Is the Limit. CHI '99. ACM.
- [13] T. Seifried, M. Haller, S. D. Scott, F. Perteneder, C. Rendl, D. Sakamoto, and M. Inami, "CRISTAL: Design and Implementation of a Remote Control System Based on a Multi-touch Display," in Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces 2009.
- [14] M. Streit, A. Lex, M. Kalkusch, K. Zatloukal, D. Schmalstieg: Caleydo: Connecting Pathways with Gene Expression Bioinformatics, Oxford Journals, 2009.
- [15] L. Terrenghi, A. Quigley, and A. Dix. A taxonomy for and analysis of multi-person-display ecosystems. Personal Ubiquitous Comput. 2009.
- [16] M. Q. Wang Baldonado, A. Woodruff, and A. Kuchinsky. Guidelines for using multiple views in information visualization. In Proceedings of the Working Conference on Advanced Visual interfaces (Palermo, Italy). AVI '00, 2000.
- [17] D. Wigdor, H. Jiang, C. Forlines, M. Borkin, and C. Shen. Wespace: the design development and deployment of a walk-up and share multi-surface visual collaboration system. Proceedings of the 27th international conference on Human factors in computing systems, pages 1237-1246, 2009.
- [18] <http://www.pebbles.hcii.cmu.edu/puc>

Investigating Distributed User Interfaces across Interactive Large Displays and Mobile Devices

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ABSTRACT

There has been significant research interest over recent years in the use of public digital displays and in particular their capability to offer both interactivity and personalized content. A promising approach is to use cell phones as a means to interact with displays, but also as a small, high quality screen to complement the larger public display. The use of a dual screen approach offers a number of intriguing possibilities including a potential solution to the problem of managing conflicts that arise when a screen is shared in a public setting or providing a means to show targeted and personalized information. However, to date, there has been little investigation into the impact for users of having interfaces distributed across this type of dual screen setup. In this paper, we report on a series of experiments carried out to determine quantitative or qualitative effects on user performance when interaction is split across large public and smaller private screens. Our position is that using mobile devices as an auxiliary device for interaction can boost user experience when interacting with large displays.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *evaluation/methodology, interaction styles, theory and models.*

General Terms

Design, Experimentation, Human Factors, Verification.

Keywords

Interactive large displays, small devices, distributed user interfaces, user study.

1. INTRODUCTION

Large public displays are becoming increasingly prevalent and rapidly replacing conventional static methods of presenting information to the public. The growing use of large public displays is partly driven by the flexibility that digital displays offer, such as dynamic and remote updates using broadband networks [1], and partly by significant price reductions of such

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devices [10][11]. Recent research work has investigated this trend and in particular explored the possibilities afforded by interactive large public displays [11], which can be customized for targeted groups or individual users. This approach offers the opportunity for large public displays to also be considered as *large information scale appliances (LISA)* [1][11], playing an alternative role to PDAs for accessing information. Although a variety of interaction approaches, such as touch-based interaction, gestures and body orientation [11], and user movement [10] has been explored, smart phones are quickly being adopted as the interaction device of choice with large public displays [1].

Extending interactive large public displays (LD) with small devices (SD) such as smart phones has been discussed in earlier research [9]. The main idea behind this *Dual Display* approach [9], is to distribute a user interface across the LD and SD to take advantage of input and output capabilities of both device types. Current research work with large public displays rests on the assumption that interaction feedback and user requested information (output data) can be presented on the LD, SD, or a combination of both. However, to the best of our knowledge, there has been no formal study on how well users respond to the separation of user interface widgets concerning input and output between the LD and SD.

This paper builds on our previous research [6] on the use of dual displays and explores how well users comprehend the nature of interaction in a dual display environment. If we can find evidence for the assumption that there is no significant difference in user performance, user satisfaction, and user preference for both conditions (LD SD, or mixed LD/SD) then, designers can take full advantage of the dual display approach when it comes to designing for such environments [9]. We report on a series of user studies conducted at the University of British Columbia where participants used smart phones to interact with multimedia applications to solve a series of tasks.

2. RELATED WORK

In this section we present a number of research projects that utilize the combination of large displays and small devices. Only a few of these projects have conducted user studies to verify their design concepts.

Jin et al. [5] introduce an approach in which the combination of a handheld device and a large public display is used in order to share and manage the information on the handheld device. The authors use QR-Codes to provide the information for connecting to the display using the PDA. Users can then transfer content between the LD and the SD. Content can be shown on both the LD and the SD based on user's choice. Although this approach

takes advantage of both device types, it has not yet been validated through any formal user study.

Echtler et al. [4] have evaluated collaborative interaction concepts for a game application conducted between touch-based tabletops serving as large displays and small devices such as PDAs. Their user studies results showed that users perform equally when using either the handheld device or the table top. Their users did not show any significant preference in using either the tabletop or the handheld device to interact with their application.

Carter et al. [3] envision a scenario in which users can annotate content shown on a large display in order to encourage collaboration and discussion. Users are able to download content from the LD to the SD, annotate the content, and push it back to the LD to present to others. Based on this design, they conducted a user study in which users indicated interest in receiving and storing the content on the SD so they could preserve a copy when leaving the interaction scene.

As shown in the brief review above, while there have been a number of investigations into the use of dual displays there is limited research into the interaction between large display and small devices. To the best of our knowledge, the examination of input and output capabilities using the LD and SD, which forms the core of our research, is largely unexplored.

3. DISTRIBUTED USER INTERFACE DESIGN

The primary research question in this paper is to verify if users benefit from executing an application across large displays and small devices taking advantage of input and output capabilities of both devices. In other words, we would like to understand if and how splitting interface entities (user interface widgets) across the LD and SD affects user task performance.

According to Norman’s seven stage model [7], different mental activities are associated with the input and output. Therefore, widgets allowing users to enter input might exhibit different design constraints compared to output widgets. Hence, we denote widgets associated with system input as *interactive widgets* and those associated with system output as *non-interactive widgets*. Non-interactive widgets are in general used to present system states to users while interactive widgets are used to accept user input to initiate system state changes. In addition, these widgets often provide instant feedback indicating that an input has been received such as a change in a button widget’s appearance every time a user clicks on it. Such feedback helps users verify the correctness of their inputs, revealing possible mistakes or slips.

There is considerable complexity concerning the placement of non- and interactive widgets when designing a distributed user interface across the LD and SD. Imagine a simple interactive application containing only a *Button* widget that triggers a *Text* widget to print “Hello World”. The *Button*, as an *interactive widget*, can be placed either on the LD, SD or on both. The same holds for the *Text*, as a *non-interactive widget*. Hence, for this very simple application we can already come up with 9 possible settings (see Figure 1). Each setting might provide different solutions for interface issues a designer has to solve.

We can come up with several basic design strategies to address this complexity for distributing interactive and non-interactive widgets across the LD and SD. Two of the prominent design

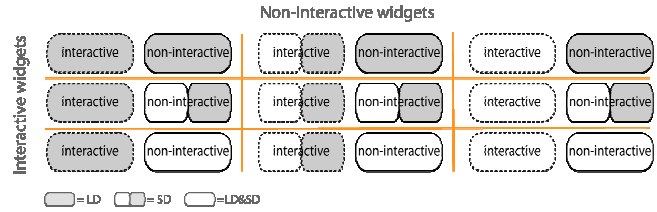


Figure 1: Placement complexity of paired interactive (input, button widget) and non-interactive (output, text widget) widgets across a large display (LD) and small device (SD)

strategies are designing only for the LD or splitting it between the LD and SD.

- **LD mode:** With this design strategy, users employ their smart phone to directly interact with widgets placed only on the large public display. Although simple, in a multi-user scenario, problems can arise where more than one user wants to access the same interactive widget. Furthermore, a sequence of actions might require a user to interact with several widgets over a longer time period and so requires space or 'real estate' on the LD. A designer has to find the correct balance between real estate, and content quantity/quality to properly serve the audience.
- **LD-SD mode:** In this design strategy, some widgets are placed on the LD and some on the SD. The advantage here is that every user interaction has a defined entry point, which is in this case the LD. On the other hand, an interactive widget arrangement that is partly across the LD and SD may cause user confusion. Content that might be interesting to the entire audience can be presented using non-interactive widgets on the LD. Content, which is specific to users who request it and of less interest for the audience can be placed on the SD. Furthermore, even though not directly investigated in this paper, we believe that content presented on the SD provides users with a feeling of privacy that may contribute towards better and more successful interactions with the large display.

To reiterate, if we want to offer designers the flexibility of choosing among these modes, we must first verify that changing from the current strategy (LD mode) to a different mode (LD-SD mode) will not lead to a real and perceived degradation of user performance when executing a sequence of actions. That is, users have to be able to interact with interactive widgets and perceive outputs from the non-interactive widgets in the same manner regardless if we place them on LD or SD.

4. APPLICATIONS

For our user studies we developed three applications whose interfaces were capable of utilizing just the LD or distributing itself across both the LD and SD.

Polar Defense is a game where users begin by placing six defense towers on a 9 x 9 grid. Once the towers have been placed, enemies begin to cross the grid. Depending on the strategic placement of the towers, a number of enemies will be prevented from crossing the field as the towers attack nearby enemies. Users score based on how many enemies they prevented from crossing the field. Figure 2a shows the Polar Defense game.

The Eyeballing Game presents a series of geometric figures that have to be adjusted by the users based on given instructions. In order to do so, users control a pivot point on the geometric object,

which could be a corner, a point along a line, or a point in space near the object. An example instruction is to find the centre of a circle by nudging a point inside the circle that starts off slightly offset from the centre. Users score base on how close they are able to nudge the point to the correct result by “eyeballing” it.

The Interactive Directory Application enables users to browse a set of categories in order to find venues of interest in a city area (e.g.: hotels, restaurants, theatres). Initially a map of the city area is displayed. Users then select a category which triggers the appearance of a set of markers on the map, each one representing a venue in that category. For instance, selecting the category “restaurants” would show all restaurants in the city area and their location on the map. Users can then select a venue and read information and view pictures of that venue (see Figure 2b).

More details on our developed applications can be found in [8].

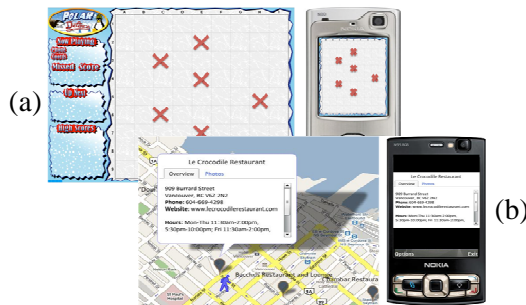


Figure 2: (a) The Polar Defense Game (b) The Interactive Directory Application

5. USER STUDIES

Participants. Using the three applications, we designed three within-subject user studies and recruited 16 participants (12 males and 4 females, aged 18 to 39), including 11 in computer science/engineering, 1 in another engineering area, and 4 in humanities and social sciences. Around 62% of our participants considered a display bigger than 30 inches as a large display, yet only 38% had previous experience interacting with a large display, and their interactions with the large display had happened only by using a remote controller.

Apparatus. We used a projector to create an interactive large display (LD) with a resolution of 1024 x 768. A laptop computer was connected to the projector to run our applications. A Nokia N95 smart phone was used as the small device (SD) with a screen resolution of 320 x 240. The right and left soft keys as well as the phone’s joystick were used to control the applications in both LD and LD-SD modes. In order to obtain a proper proportion for the content shown on LD and SD, we tried to keep the visual angle consistent across both LD and SD designs. The CSS2 reference document on W3C’s website¹ indicates that “for a nominal arm length of 28 inches, the visual angle is 0.0213 degrees”, giving us a pixel size of 0.26mm for our Nokia N95 smart phone with a display resolution of 320 x 240. Considering the size of the room where the user studies were happening, we required the participants to stay 3.5m away from the display, which, taking the visual angle into account, requires us to have a pixel size of 1.3mm for the large display. Considering the resolution for our

projector (i.e. 1024 x 768), we set the height of the projected display equal to 1m (i.e., 768 x 0.0013 = 0.9984m) in order to obtain the pixel size of 1.33mm and guarantee an identical visual angle between our LD and SD experiments. In order to obtain the best reading rate for our participants, we set the font size equal to 12pts or 16pxs across all designs in both LD and SD modes.

Analysis. In all three designs, we measured *error rate* and *time* as quantitative dependent variables, and *user satisfaction* and *personal preference* as qualitative dependent variables. Time and error rate collection were application dependent. User satisfaction in all three designs referred to how much faster or easier it was to interact with the application in either of the two modes; and personal preference referred to which of the LD or SD modes were preferred by the participants when interacting with large displays. User preference and user satisfaction were measured through a post-experiment questionnaire completed at the end of the study based on Likert-Scale responses.

5.1 Experiments

We designed three experiments to evaluate the two design strategies, LD and LD-SD modes. In all three experiments, the LD condition has all the interactive and non-interactive widgets placed on the large display. Subjects interact with the applications using the phone but the changes and feedback all happen on the large display. In the LD-SD condition, some of the widgets are moved to the SD and some remain on the LD. Hence, users will need to switch between SD and LD when interacting with the applications. In this mode, the LD and SD always show distinct widgets.

Our overall hypothesis is that interaction in the LD-SD mode is not significantly different from the widely employed LD mode interaction. More specifically, users perform equally well or even better when some widgets are placed on the SD compared to having everything on the LD.

Experiment 1. Spatial Course Granularity

Polar Defense is used for this within subject experiment where the game interaction for placing towers is the independent variable. The interactive input widget for setting towers was placed either on the LD or SD depending on the condition, while game results are shown on the LD in both conditions. We consider the interaction a spatially coarse granularity interaction model because users have to place towers onto a large grid with defined positions. We asked the participants to write their desired strategy of placing towers on a piece of paper prior to entering it to the game. For *error rate* we measured how many times a participant removes a tower from the game field and repositions it to make it match the strategy written on the paper. For the *time*, the amount of time it takes for a participant to place the proper coordinates for the towers on the game field and send them off to the application during each phase of playing the game was measured.

Experiment 2. Spatial Fine Granularity

We used the Eyeballing Game for this experiment. It is very similar to the first experiment where an interactive widget for manipulating geometric figures is placed either on the LD or SD depending on the condition. Game results are shown on the LD for both conditions. In contrast to the Polar Defense, the movements of a cursor in this game are more fine-grained in that the cursor moves pixel by pixel as opposed to cell by cell, requiring more attention from the users. Thus, we consider interactions for the

¹ <http://www.w3.org/TR/CSS2/syntax.html#length-units>

eyeballing game as spatially fine granularity interactions. For the *error rate*, we measured the rate for how close or far participants were to the actual position of the correct answer and for the *time*, we logged the amount of time it took each participant in each of the LD and LD-SD modes to choose the proper pixel they thought was the answer to the problem from when they were presented with the problem.

Experiment 3. Perception of New System States

The goal of this experiment was to determine where to place output user interface widgets to better allow users to perceive and evaluate new system states using the Interactive Directory. We still focus on two conditions. The research question we try to answer in this experiment is “do users perform better, or at least no worse, in perceiving system state changes when they are presented across LD and SD than if we just use the LD?” In the LD condition, the information window for the venue selected is shown on the LD, while in the LD-SD condition it is shown on the SD. The map navigation and category selection for both conditions are shown on the LD. In each step of the experiment the participants were asked to answer a question regarding the text information shown for a specific venue or to a given picture related to the selected venue. As an example we asked the user to provide us with the operation hours of a museum from its information presented in LD or LD-SD mode or to count certain objects in an image related to the venue. *Error rate* was measured by counting wrong answers to the tasks related to the number of items in a text phrase or a picture or wrongly selected venues when searching for the correct venue. *Time* was measured from the point where a target venue, either correct or incorrect, gets selected up to the point where the participant finds the answer to the task and presses the submit button.

5.2 Results

For the coarse granularity interaction (Polar Defense) our results show that on average there is no significant difference in time error-rate when using the LD for placing tower in the Polar Defense game. Yet, participants had a higher degree of satisfaction when playing the game in the LD-SD mode. In the fine-granularity interaction case of the Eyeballing Game, the exact same results in terms of accuracy and time of interaction between LD and LD-SD modes were obtained (i.e.: no significant difference). However, unlike the case of Polar Defense, users thought they spent more time playing the game in the LD-SD mode compared to the LD mode. Finally, in the last experiment for perceiving the system state, our results show that users perform better in terms of their error rate for differentiating images presented in the LD-SD mode compared to the LD mode. However, the time spent in each of the two modes to go through the experiment was almost the same in both modes of experiment. Overall, our results show that participants preferred to interact with the LD-SD mode (in particular read and scroll text on the phones) rather than the LD display, although time and error rate did not show significant differences in all three experiments.

6. DISCUSSION & CONCLUSION

The main results we found indicate that users can perform equally well whether using large or small displays within our experimental settings. These results hold for user activities that occur within the stages of Norman’s model of interaction [7]. It is interesting to note that phones play a more significant role when more accuracy

or privacy is required. In the case of the Eyeballing Game, users spent more time fine-tuning their game play for finding the answers. Similarly, users spent more time on the phone when it came to understanding information through counting elements or answering questions. Our post-experiment questionnaires show that phones provide users with a stronger feeling of possession allowing them to spend more time perceiving or fine-tuning the answers with less concern for social embarrassment. The demographics of our user study primarily reflect healthy and young adults. Older adults, who haven’t participated in our experiment so far, might perform differently, especially when reading text with smaller fonts on the SD.

In conclusion, our work supports the hypothesis that user interfaces can be distributed on both the LD and SD without a significant effect on user performance. We believe that this allows designers of distributed user interfaces to exploit dual displays (as suggested by Sas and Dix [9]) to improve end-user experience. In the future we plan to run a more diverse population in our user studies and to generalize our work more by investigating more complex widget arrangements across the LD and SD. We also plan to further evaluate and investigate dual display scenarios based on our previous work [6] with a focus on exploring and understanding the dynamics of collaborative work using interactive large public displays [2][9].

7. REFERENCES

- [1] Ballagas, R., Borchers, J., Rohs, M., and Sheridan, J. G. 2006. The Smart Phone: A Ubiquitous Input Device. *IEEE Pervasive Computing* 5, 1 (Jan. 2006), 70.
- [2] Ballagas, R., Rohs, M., and Sheridan, J. G. 2005. Sweep and point and shoot: phonecam-based interactions for large public displays. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems* (Portland, OR, USA, April 02 - 07, 2005). CHI '05. ACM, New York, NY, 1200-1203.
- [3] Carter, S., Churchill, E., Denoue, L., Helfman, J., and Nelson, L. 2004. Digital graffiti: public annotation of multimedia content. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems* (Vienna, Austria, April 24 - 29, 2004). CHI '04. ACM, New York, NY, 1207-1210.
- [4] Ehtler, F., Nestler, S., Dippon, A., and Klinker, G. 2009. Supporting casual interactions between board games on public tabletop displays and mobile devices. *Personal Ubiquitous Comput.* 13, 8 (Nov. 2009), 609-617.
- [5] Jin, C., Takahashi, S., and Tanaka, J., Interaction Between Small Size Device and Large Screen in Public Space. *KES* (3) 2006. pp. 197-204.
- [6] Kaviani, N., Finke, M., Fels, S., Lea, R., and Wang, H. 2009. What goes where?: designing interactive large public display applications for mobile device interaction. In *Proceedings of the First international Conference on internet Multimedia Computing and Service* (Kunming, Yunnan, China, November 23 - 25, 2009). ICIMCS '09. ACM, New York, NY, 129-138.
- [7] Norman, D., "Psychology of Everyday Action". The Design of Everyday Things. New York: Basic Book, 1988. 45-46
- [8] PSPI Web Site: <http://www.magic.ubc.ca/PSPI/pmwiki/>
- [9] Sas, C. and Dix, A. 2008. Designing and evaluating mobile phone-based interaction with public displays. In *CHI '08*

Extended Abstracts on Human Factors in Computing Systems (Florence, Italy, April 05 - 10, 2008). CHI '08. ACM, New York, NY, 3941-3944.

- [10] Shinohara, A. and Tomita, J., Kihara, T., Nakajima, S. and Ogawa, K. A Huge Screen Interactive Public Media System: Mirai-Tube. *HCI* (2), 4551: 936-945, 2007.
- [11] Vogel, D. and Balakrishnan, R. 2004. Interactive public ambient displays: transitioning from implicit to explicit,

public to personal, interaction with multiple users. *In Proceedings of the 17th Annual ACM Symposium on User interface Software and Technology* (Santa Fe, NM, USA, October 24 - 27, 2004). UIST '04. ACM, New York, NY, 137-146.

Partial Web Interface Migration

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ABSTRACT

In this paper we present our solution for partial Web migration from large screens to mobile devices: it is based on the use of multiple abstraction levels for describing UIs and a set of transformations that allow the migration of user interface components selected by the user to another device. This feature is particularly useful in complex Web applications, such as various emerging mash-up applications. We also show an example of applying our solution to a Web social game.

Keywords

Ubiquitous environments, Migratory interfaces, Partial migration.

INTRODUCTION

Nowadays people are ever more exposed to ubiquitous environments, which are characterized by the availability of various interactive devices with different interaction resources. Thus, the possibility to opportunistically exploit the resources that such contexts offer (e.g., moving from stationary to mobile devices) is invaluable for providing an effective interaction experience to the user. In this context, interactive migratory user interfaces offer the added value of enabling users to migrate across various types of devices while preserving the task continuity. This implies that there should be the possibility to select a target device and activate on it a version of the user interface adapted to its features with the same state as on the source device. The state of a user interface includes the values entered or selected by the user, the content, the cookies, etc.

Various types of migration can be identified depending on the number of source and target devices or whether the entire user interface or only a part of it migrates. In particular, *partial* migration is moving only a portion of the

interactive application (namely: some components) to another device in order to better exploit its interactive resources. The typical scenario is a user who is interacting with a desktop or large screen system and then for some reason has to leave, but wants to continue the interaction through a mobile device with only a part of the application. This can be either because of its complexity or limitations in the mobile device (e.g. iPhones do not support Flash applications). This is particularly important with mashup-like applications, which tend to be particularly complex and made up of various perceivable components.

Model-based approaches (see for example [5, 6]) have shown good potential in managing the complexity of multi-device environments. Through the use of abstract and concrete logical descriptions it is possible to better support interoperability across various types of devices and implementation languages.

Our approach aims to provide a general solution for Web applications implemented using (X)HTML, CSS, and Javascripts. It can also support applications based on languages such as JSP, PHP, ASP because it considers one page at a time on the client side. Thus, it adapts only what is actually accessed by the user. Another advantage of the solution proposed is that it makes Web applications migratory regardless of the authoring environments used by the developers. Without requiring the use of any specific tool in the development phase, it enables the applications to migrate, even if the developers never considered migration. This is obtained through the use of reverse engineering techniques that create the logical descriptions of the Web pages accessed on the fly, which are then adapted for the target device. Lastly, an implementation with the state of the source version is dynamically generated.

The subject of partial migration raises a number of issues, which have been addressed from different viewpoints in other work by the research community. Partial migration can be related, to some extent, to the issues connected with Distributed User Interfaces (DUI). In this regard, in [2] a toolkit for deploying distributed graphical UIs is presented. In our solution we opted for a distribution down to the granularity of the single interactor but no deeper, since we judged such fine granularity unimportant for our goals. In addition, this solution requires that the user interface be

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implemented using an extension of the Tcl/Tk toolkit, while we are interested in solutions that allow partially migrating any Web application developed with the standard W3C languages (XHTML, CSS) and Javascripts.

The issue of distributing a user interface onto multiple devices is also analysed in [3], with particular attention to how to leverage legacy applications to attain the new distributable features easily. However, it is worth pointing out that the relations on which this infrastructure is based includes a strong limitation that narrows the set of devices that can be interconnected to each other (only the personal devices of a user). Instead, fully migratable applications should be able to opportunistically exploit the devices in the environment (even the devices not owned by the users but accessible to them).

The study in [1] describes an infrastructure (Objé) that supports building interoperable systems without having prior knowledge about them ahead of time. While the motivation of the Objé architecture was to provide an infrastructure for opportunistic interoperation in device-rich environments (as in migration) this approach basically addresses problems of interoperation rather than migration. In general, we can notice that while a number of model-based approaches have been put forward for the design of multi-device interfaces, and in particular for mobile applications (see for example [6]), none of them has shown a general solution able to work on any Web application implemented according the W3C standards for supporting partial user interface migration from desktop to mobile systems.

In this paper we present a solution supporting partial migration, its main characteristics, the architecture of the migration platform supporting it, and also provide an example of a partial migration for a Web application in the game domain, in order to show its use and potentialities.

THE ARCHITECTURE OF OUR SOLUTION

The starting point for the work presented in this paper was the solution presented in [4], which supports migration of only entire user interfaces (total migration) without providing any possibility to migrate only parts of them. In that work an architecture based on a number of modules was proposed supporting dynamic reverse and forward engineering. The module identified were: the **Reverse Engineering** module builds the logical description of the source page considered; the **Semantic Redesign** transforms the source logical concrete description into another one tailored for the target platform; the **State Mapper** associates the state of the current Web page to the logical description automatically generated for the target device; the **Generator** generates the corresponding implementation. Such implementation is then sent to the target device so that the user can immediately find the adapted page, with the state resulting from the interactions already carried out with the source device; the **Proxy Server** is in charge of serving as an intermediate layer

capturing the interactions between the user browser and the original web site; the **Migration Orchestrator** handles the communications with the different modules involved in the migration.

The Reverse Engineering part is able to build corresponding logical descriptions from (X)HTML, CSS and Javascript implementations. If the Web application contains Flash or Java applets, then the reverse is not able to analyse its code. In this case, the applets are either replaced with alternative content provided by the application developers (such as images) or passed to the target device “as they are”, if the target browser is able to execute them.

The Semantic Redesign module transforms the concrete description (specific for the source platform) to the one that refers to the target platform. The concrete descriptions are independent of the implementation language, while the abstract descriptions are even independent of the interaction modalities. In general, concrete descriptions assume the existence of some interaction modalities but are independent of the implementation language. At the abstract level there are, for example, concepts such as selection, edit, activate while at the concrete level for a graphical device for example the selection object can be refined into a list or a radio-button or a pull-down menu or other similar techniques. Such elements can be implemented in different languages. The abstract and concrete vocabularies contain concepts for structuring the user interface as well, such as grouping and relations. The semantic redesign transformation aims to map source concrete interface elements into ones that are more suitable for the interaction resources of the target device. The semantic redesign uses the abstract level to identify the type of interaction to support and then identify suitable, concrete refinements for them for the target platform. Thus, for example, in a desktop-to-mobile transformation the possible target concrete elements will be characterized by a more limited usage of screen space while preserving their semantics (i.e.: the effect that they have on the interactive application).

The objective of the State Mapper is to update the concrete user interface for the target device (and which has been delivered by the semantic redesign module) with latest information regarding the state of the UI contained in the DOM file of the source page just before migration. After having obtained the new concrete user interface description for the target device (updated with information about the state), the Generator module builds the final user interface specified in an implementation language supported by the target device considered. The Proxy Server module plays a role whenever a browser on a client device requires access to a certain Web page. Indeed, every request to the application server is filtered by this module, which accesses the application server to obtain the page and also annotates it by including scripts, which will enable capturing of the UI state.

The previously described solution was not able to support partial migration because this feature implies the ability to select a subset of features and then migrate them to the target device. In order to obtain this we have again exploited the possibilities offered by the use of logical user interface descriptions. Indeed, in the language that we use (MARIA [5]) it is possible to describe the logical structure of a user interface through interactor composition operators that indicate groups of logically connected elements or relations among such groups (e.g. a set of controls are associated with a certain form). Thus, we want to make this logical structure accessible to the users so that they can interactively select what parts they want to migrate and to which device.

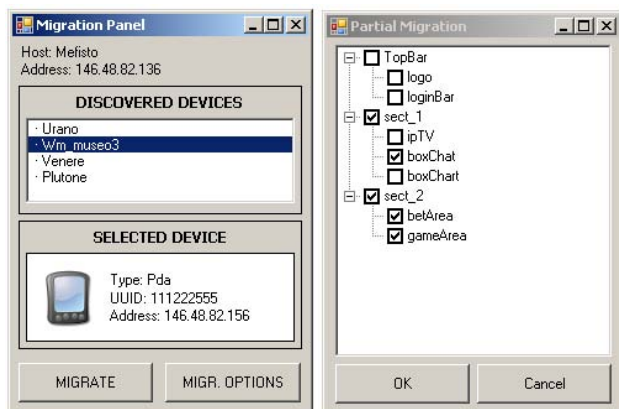


Figure 1: The window displayed for selecting target device (left part) and the components to migrate (right part)

When the user selects the migration options on the client (see Figure 1, left), the migration server Orchestrator communicates with the Reverse module. This is done in order to call the Reverse module functionalities for the analysis of the page. The Reverse produces the Concrete User Interface (CUI) description associated to the current page and passes it on to the Orchestrator. One specific functionality of the Partial Migration module is to parse the CUI provided by the Orchestrator. The result is a list of user interface components according to the hierarchical relations among them. Such list, organised according to the hierarchy of the interactor compositions of the main presentation, is sent by the Orchestrator to the source device, in order to let the migration client display the tree-like view of the page structure. The user is then able to specify which page components to migrate by selecting them in the migration options form (see Figure 1, right).

Automatically generating the list of Web page components names and sending them to the migration client (in the background, since the user is interacting with the browser), allows for hiding the computation and communication latency. When the user pops-up the migration client, s/he will already have the tree view of the page structure in the migration options, thus speeding up the selection of the components to migrate.

If the user triggers a migration request when a subset of the components is selected on the list, then the migration is considered to be partial. In this case, the Orchestrator requests a subset of the CUI from the Partial Migration module, according to the sub list of components selected by the user, and forwards it to the Semantic Redesign, thus skipping the Reverse phase (which, however, had been executed previously to create the original CUI of the entire desktop interface).

AN APPLICATION EXAMPLE OF PARTIAL WEB MIGRATION

In this section an example of partial Web migration is presented. The example considered deals with a gaming application that includes different parts: a chat, a betting part, an IPTV, a racing game, etc. (<http://www.arcadiadesign.it/SocialGameIntegrated/>), and also involves interaction among multiple users (social game). An example user interface can be seen in Figure 3: there is an IPTV in the top-left part, some additional info just beside the IPTV (e.g. live race positions), information on game positions, and a chatting area displaying the buddy list where users can connect and talk. In the bottom (left) part there is a betting area for selecting the driver to bet on as well as the desired amount, while the bottom right part displays the racing game. The goal of the game is to finish a lap in the shortest time.

At a certain moment the user decides to partially migrate the application to a mobile device, since s/he has to go out. Figure 3 shows the tree that summarizes the logical structure of the CUI of the current Web page created by the reverse engineering module. Note that the colours of the nodes in Figure 3 refer to the colours of the squares that highlight the sections in Figure 2. *Grouping* and *Relation* nodes are specific types of interactor compositions. For example, the HTML login form (pink nodes) is identified by a *relation* containing two input interactors and the submit image.

The HTML tag div containing the Betting area composed of the table, section and form at the bottom left is identified by the purple nodes in Figure 3 (which refer to the first yellow grouping node in Figure 2). The server carries out the migration of the selected components to the new device (PDA). Figure 1 shows the migration client interface for selecting both the target device and which components to migrate. More specifically, on the left side you can see that four devices are available in the example scenario. Depending on the device currently selected further information is presented in the bottom part of the user interface.

As soon as the user has selected a particular device s/he can trigger the migration. In the case of partial migration, an additional window shows the list of components that can be migrated. The list is displayed in a tree-like way, reflecting the structure of the original page: groups of components and/or single components can be selected for migration (see Figure 1, right). The representation of the user interface components is a simplified version of the logical structure of the application interface in order to facilitate the choice by the users. For this purpose our platform does not show the groups that correspond to elements without associated functionality. The names that appear in the selectable list are automatically generated from the name attributes used in the corresponding tags at implementation level.

In particular, once the user has selected the components that s/he wants to migrate, a new presentation is generated by

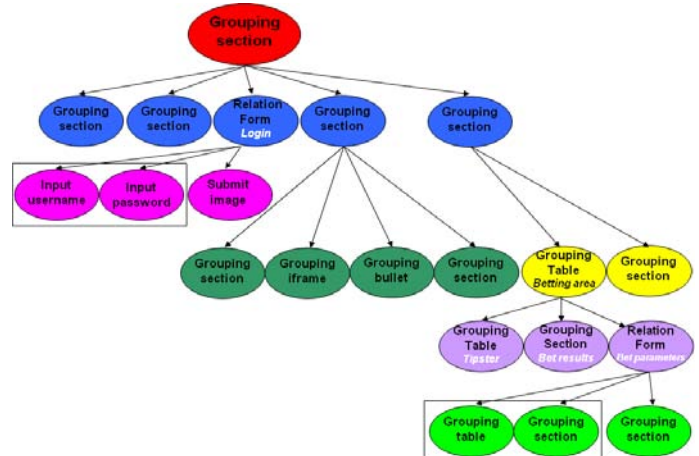


Figure 3: The tree-structure of the Web interface components resulting from the Reverse.

Figure 4 shows some presentations that the user can see after migration. In the adaptation process some interactors can be replaced by others that preserve the same semantics but are better adapted to the current device.



Figure 4: The Betting area (left) and the chat area (right) visualized on the PDA after partial migration



Figure 2: A screenshot of the Web gaming application considered in the example highlighting the groupings.

the migration support. This is done by creating a new presentation consisting of a grouping composition of the selected components at the concrete description level. Such a newly created concrete presentation has to be analysed in order to be semantically redesigned and adapted for the new target device. In this case, since the target device is a mobile one, each of the selected components will be displayed on a separate page.

CONCLUSIONS AND ACKNOWLEDGMENTS

In this paper, we have presented our approach for partial migration of Web applications. An example in the game domain has been described to show how we support the possibility of migrating a subset of the elements shown and running in the source device. In our example, migration from large screen to mobile has been considered.

The described method is based on the use of user interface description languages and automatic reverse engineering tools able to build specification of UIs compliant with such languages, starting from existing desktop Web content. This reverse phase is able to handle all the (X)HTML and CSS tags. In this phase, it is possible to identify the structure of the set of elements currently populating the page, which is a

crucial point for partial migration, in order to be able to present the user with the elements that can be migrated.

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REFERENCES

1. Edwards, W.K., Newman, M.W., Sedivy, J. Z., Smith, T. S., Experiences with Recombinant Computing: Exploring Ad Hoc Interoperability in Evolving Digital Networks, ACM Transactions on Computer-Human Interaction, Vol. 16, No. 1, Article 3, 2009.
2. Melchior, J., Grolaux, D., Vanderdonckt, J., Van Roy, P., A Toolkit for Peer-to-Peer Distributed User Interfaces: Concepts, Implementation, and Applications, pp. 69-78, EICS'09, July 15-17, 2009, Pittsburgh, Pennsylvania, USA.
3. Pierce, J. S., Nichols, J., An infrastructure for extending applications' user experiences across multiple personal devices. UIST 2008: 101-110.
4. Paternò, F., Santoro, C., Scordia, A., Ambient Intelligence for Supporting Task Continuity across Multiple Devices and Implementation Languages, the Computer Journal, the British Computer Society, 2009.
5. Paternò F., Santoro C., Spano L.D., "MARIA: A Universal Language for Service-Oriented Applications in Ubiquitous Environment", ACM Transactions on Computer-Human Interaction, Vol.16, N.4, November 2009, pp.19:1-19:30.
6. Eisenstein J., Vanderdonckt J., Puerta A. R.: Applying model-based techniques to the development of UIs for mobile computers. IUI 2001: 69-76.

Fridge Fridge on the Wall: what Can I Cook for Us All? An HMI study for an intelligent fridge

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ABSTRACT

New technologies have changed our life, making everyday tasks easier and faster. This new style of living requires a new kind of distribution of cognitive processes, resources and information. Trends in appliance design propose more sophisticated control and networking capabilities. Current white goods may be equipped with complex softwares and GUIs, that may be inputted, by mobile phones. The ZmartFRI project aims at developing a seamless technology with an interactive fridge surface, assuring simplicity and intuitiveness of interaction. The fridge surface equipped with a display and an effective GUI provides more than additional memory device supporting human activities and providing opportunities to reorganize what is known. Thanks to a coupled display system between the fridge and the user mobile device, the fridge is able to alert products expiration date, to suggest recipes, to fill in and send by sms or email the shopping list, to send and post messages for the house residents.

Categories and Subject Descriptors

H.4.3 [Information Systems Applications]: Communications Applications – *bulletin boards*.

H 5.2 [Information Interfaces And Presentation]: User Interfaces – *Graphical user interfaces (GUI), Interaction styles, Prototyping, Screen design, User-centered design*

J.7 [Computer applications]: Computers in Other Systems – *command and control, consumer products*

General Terms

Your general terms must be any of the following 16 designated terms: Algorithms, Management, Measurement, Documentation, Performance, Design, Economics, Reliability, Experimentation, Security, Human Factors, Standardization, Languages, Theory, Legal Aspects, Verification.

Keywords

Coupled Display, Ethnographic Analysis, Household Appliance, Human Machine Interface, Intelligent Fridge, Mobile Phone Nomadic Device, Participatory Design, Ubiquitous Computing,

1. INTRODUCTION

Increasingly people work and live on the move. At the same time, companies are producing various portable and embedded information devices, such as personal digital assistants (PDAs), cellular telephones, pagers and active badges [1] which support this mobile lifestyle, especially as work becomes more intensely information-based. In fact, new technologies have changed our life: they improve our life, making everyday tasks easier and faster; providing enjoyment, playfulness, fun and aesthetics. This new style of living and working requires a new kind of distribution of cognitive processes, resources and information.

The wide availability of digital information and services associated to physical objects reinforces the need for a strong link between the digital and physical spheres, in order to allow users to access useful information anywhere and anytime. On the other hand, the rapid growth of enabling technologies offers concrete opportunities to design on-the-move, fluid interactions with computing devices. In fact, nomadic devices are commonly equipped not only with networking technologies at present, but their processor speeds and storage and display capabilities are rapidly growing, too.

Bridge technologies between the physical and digital worlds (such as wireless sensors, microcontrollers, RFID tags and two-dimensional barcodes) are currently available, as well as standards for the representation and communication of structured data (the most notable example is XML) [2]. Designers should assure that people can interact with computing devices in a fluent and natural way, barely being aware of the underlying technology, even if they are accessing interactive displays that very often are widespread in everyday environments, including our kitchen or any household appliance.

Trends in appliance design are towards more sophisticated control and networking capabilities concerning new innovative domestic technology [3]. Current white goods may be equipped with a quite complex software and graphical user interface (GUI), that may be inputted, for example, by mobile phones, allowing the user at creating, modifying or extending the household appliance scope and use.

The idea of inputting and interacting with our kitchen households by any personal nomadic device, leaving a public message on an available display surface, i.e. as the fridge surface, will create an interactive ecosystem supported by the coupling of multiple display. In this way home appliance that were in the past considered plain and utilitarian, become entertainment devices or, as in the case of ZmartFRI, become a family information hub. The house inhabitants may send and receive messages and information from the fridge, that play the role of family totem.

In the ZmartFRI (Zigbee sMART FRidge) project, we aimed at developing a technology that could realize a vision of computation everywhere, where computer technology seamlessly integrates into everyday life, supporting users in their daily tasks. In this way, a common fridge becomes augmented as soft media, therefore it becomes able to enter into dynamic digital relationships with users and with each other, generating novel settings of communication, performance and ownership.

In facts, homes are living spaces that centralize many different activities: housework, entertainment, professional work, information, communication, learning and shopping. The integration of all these activities with the living space model is fundamental to understand how an household appliance as the fridge could become an information hub. The ZmartFRI is designed to play the role of information hub connected to any personal device, making of the fridge the home intersection point of sociology and technology.

Usually fridges aren't of much interest because they are not quite intelligent. In this paper we want to show how it is possible to extend the fridge intelligence, allowing it at becoming a family totem, the preferred place where posting and sending electronic notes [4]. A fridge interactive surfaces offers great potential for social interaction and provides natural ways to directly manipulate virtual objects as electronic post-it, creating a multiple display ecosystems with a combination of small displays belonging to personal mobile devices (i.e. smart phones and mobile phones) coupled with a quite wide public display such as the fridge electronic surface.

The ZmartFRI visual interface lets people maintain existing habits and the desirable characteristics of paper or printed messaging, but also provide easy access to the advantages of the electronic medium. The design of such an interface is part of a longer term research effort to investigate with ethnographic methods applications and interaction techniques about every day home-life and users needs and desires.

Section 2 explains what are the aspects that build in the concept of Intelligent Fridge, starting from some literature considerations and proceeding with the findings of the ethnographic analysis and of the participatory design session. Section 3 shows the ZmartFRI project, its main architecture and its user visual interface. Section 4 reports conclusions and future works.

2. THE 5 W'S OF THE INTELLIGENT FRIDGE

The literature defines the intelligent fridge as follows:

«An “intelligent fridge” could inform its owner when an RFID (Radio Frequency Identification) tagged carton or milk is close to empty or the retailer thereby requesting replenishment» [5]

«The intelligent refrigerator is a relatively new concept. It has the ability to order grocery items that are out of stock or low automatically using RFID technology» [6]. And: «The intelligent fridge that is communicating to the consumer in the supermarket which food is needed to cook a certain dish» [6].

In other words, the intelligent fridge should be able to sense the context and to communicate the user context variations (i.e. approaching expiring dates or close empty cartons) or context implications (i.e. a good recipe to use a product close to expire). Besides these functions, we implemented in ZmartFRI also the ability to automatically fill in a grocery shopping list, that may be communicated to the user via sms or email when s/he is shopping. Moreover it improves its traditional function of showcase for anyone's message with magnets or post-it by sending and posting messages electronically and visualising them on its own display.

In this way context is not only position and identity. The concept of context also incorporates knowledge about time, people's interactions and habits, as well as many other pieces of information often available in our environment. The context is minimally well defined by the “five W's”: Who, What, Where, When and Why.

Whereas the connection between computational devices and the physical world is not new, these simple location-aware applications as ZmartFRI are perhaps the first demonstration of linking implicit human activity with computational services that serve to augment general human activity [7]. Context-aware systems and ubiquitous computing promise more than just infrastructure, suggesting indeed new paradigms of interaction inspired by widespread access to information and computational capabilities.

To attain this aim, the driving design principles for our intelligent fridge were the simplicity of the application and intuitiveness of the interaction. To assure an effective and user friendly interaction among a plethora of purpose-specific information functions, interaction design should make it possible that people can discover, and remember, how to use such appliances without any instruction or explanation, as they did with paper messages, photographs, postcards, shopping lists, in order to leave messages to each other, or reminders for themselves.

In fact, resources and information have three interesting features [8], to be taken into account designing smart or proactive appliances:

1. They are distributed across the members of a social group (i.e. message or reminders);
2. They may involve coordination between internal and external material or environmental structure (i.e. the shopping list);
3. They may be distributed through time in such a way that the products of earlier events can transform the nature of later events (i.e. products approaching expiry date may become ingredients for cooking a certain dish).

In this way the fridge surface equipped with a display and an effective GUI provides more than additional memory device and affordance to support human activities. It also provides opportunities to reorganize what is known using a different set of internal and external processes [8]. Users are expected to benefit from a continuous access to the information and from the

possibility to be informed and/or warned everywhere (i.e. at work or at the supermarket).

ZmartFRI is able at receiving and sending messages to house inhabitants. In order to develop an interaction concept effectively supporting people's needs, we followed three main scenarios, derived from the ethnographic analysis:

- Cooking assistant suggesting useful receipts (see Figure 2)
- Shopping assistant suggesting (and sending) the grocery/shopping list (see Figure 3)
- Family totem receiving and sending messages from an to family members (see Figure 4 e 5)

2.1 The ethnographic analysis

The real expectations and needs of people concerning intelligent home devices are multifaceted and should be carefully researched. To understand in details which functions the user may desire about an intelligent fridge, field methods have been conducted to gather typical users' ideas, expectations, and concerns. The specific goals of this investigation were [6]:

- Define a targeted set of users
- Define features desirable to a user
- Determine the ordering processes surrounding an intelligent fridge
- Determine potential negative issues surrounding the product
- Determine if there is a market for this product

In order to achieve our objectives we set up a short ethnographic research, involving 8 users, which had been requested to fill in a questionnaire about the way they i) leave messages to others residents, ii) check products expiry date, ii) compile the shopping list. We observed the way they write and hang messages up the fridge surface, documenting it with pictures (see Figure 1).

What come out was that a mere surface become an intelligent infrastructure, able to monitor, look and act assuring an appropriate smart home experience, without any high technology.



Figure 1 A and B Some picture of intelligent infrastructure based on fridge surface set up by an end-user.

The findings of the ethnographic study allowed us at designing ZmartFRI for specific needs, but starting from a particular point of view: home is already smart, smart not in terms of technology, but in terms of how people conduct their lives at home. This consideration is also present in human factors literature [10], confirming the approach to augment and support these existing practices, learning from the ways in which people already manage their activities, choosing the most proper device.

We are, of course, not the first to focus on surfaces in the home nor on the potential of digitally augmenting them [10][11], but we

paid attention on the implications of human machine interface in a multiple coupled displays eco-system. In fact surfaces are places in which digital capabilities may appear, but they are also part of an ecology within a household, where the placement of information acts as memory aids. The fridge provides a surface which is "public". The physical form of fridges and the way in which we use it are embedded into a home social organisation. Surfaces on fridges become intelligent surfaces not in what they do, but in the ways they are used.

What makes homes intelligent is how surfaces are used to display material in particular ways. The ZmartFRI aim is to improve what people usually do with particular surfaces, using "low tech" and non-computational artefacts (i.e. paper notes and calendars) [10]. In fact, as our study showed, a note placed on the refrigerator door has implications for who will see it and how it will be used. Further, people make particular decisions about where best to leave a note for someone else. Thus, they are "pushed" to people's attention, confirming that the pervasive computing paradigm has a "technology push" vision and primarily deals with basic next generation computing technologies, differently from emails, sms or phone calls, that are often "pull" rather than "push" methods of communication.

Starting from these considerations we sketched two of the three scenarios presented in the previous paragraph. The use cases we followed took into consideration specific user profiles: young house inhabitants confident with technology or people who usually follow new technology trends and are skilled in using advanced personal devices.

Particularly, the scenarios depicted in Figure and Figure are expression of the "A3 paradigm" which states that information will be available Anytime, Anywhere, and with Any-device [9].



Figure 2 In this scenario the user receives a mail message on her laptop from her fridge, that is suggesting that the milk expiring date is tomorrow and that to cook an omelette for the dinner, eggs are missing.



Figure 3 In this scenario the user is at the supermarket but she forgot the shopping list. She requested a real-time updated list to her fridge and received it by an sms on her mobile.

2.2 The participatory design

In order to design a user-friendly and effective HMI (Human Machine Interface) we set up a participatory design session, with a facilitator, four experts (an ergonomist, a designer, an engineering developer, an user-experience designer) and four target users. The design session took place during evening, at 7 o'clock pm. After the presentation of the meeting aims, a dinner was offered in order to promote the socialization among participants and to create a relaxed and familiar atmosphere. The design session ended at about 11 o'clock pm.

The most important features for an intelligent fridge that come out thanks the facilitator interventions, the participants' open discussion and the hand-made draft of the outcoming ideas were:

1. expiration date alert
2. ability to print the grocery list and sent it by sms or email
3. make remote questions about an item through a touch screen display
4. Write, send and post messages for the house residents (i.e. "I'm coming, put the pasta on")

The design session was really crucial in defining ZmartFRI concept in order to offer a new way to inform house residents about someone's whereabouts or needs.

3. THE ZmartFRI architecture

The ZmartFRI has a RFID antenna and a reader inside to read the goods stored in it. Each product has got a smart label attached to it. The overall architecture works in the following way:

- The fridge communicates via zigbee with the router server of the home
- The house resident register themselves and the fridge to an on-line messaging service
- Anyone can send a message to the on-line service that post it to the home server which sent it to the fridge, in order to be displayed on the TFT display.

The TFT display features are:

- Size 4.7 inch
- Resolution 480(RGB) x 272

- Interface RGB 24 bits
- Color Depth 16.7M
- Measures (W x H x D) (mm) 114.3x72.5x5.0

3.1 The innovative HMI

Thanks to the interaction between the display of a personal device and the fridge display, several actions are possible: i) checking the goods in the fridge, ii) creating a shopping list, iii) sending to a personal device the shopping list if requested iv) being guided on how to prepare a recipe, v) writing and delivering messages, vi) creating, rearranging and deleting notes, vii) mailing a note to one of the family members whose portrait is decorated with a cover icon (see Figure 4 and Figure 5 A and B).



Figure 4 An example of a message sent to the fridge from a personal mobile device ("Hi Mum, put the pasta on, 'cause I'm arriving")



Figure 5 A and B On the left the user interface to add items to the shopping list, that may be updated also by the ZmartFRI. On the right the user interface to write a message for an house resident.

4. CONCLUSIONS AND FUTURE WORKS

The presented ZmartFRI project follow a main design principle: this is the "just use it" requirement. The fridge prototype is still virtual, but it represents a promising start, which we plan to pursue further, implementing a mock up that will be used for usability tests with users. With the adequate improvements we

intend to test its use in a real context, by installing it in the residence of our subjects, and testing its uptake as part of their daily life over some prolonged period, according to the ethnographic approach we undertook. A future challenge will be the design of a wider display that will open new interaction concept and modalities between the family totem (the fridge) and the personal portable devices.

5. REFERENCES

- [1] Mills, K., L., Scholtz, J., 2000, Situated computing: the next frontier for HCI Research, in *ACM Transactions on Computer-Human Interaction*, Vol. 7. No. 1, March 2000, 537-552
- [2] Greenfield A., 2006, *Everyware: The Dawning Age of Ubiquitous Computing*, New Riders, Indianapolis, Indiana, March 2006
- [3] Dutta-Roy A., 1999, Networks for homes. *IEEE Spectrum*, pp 26-33, December.
- [4] Vroubel, M., Markopoulos, P. & Bekker, M.M., 2001, FRIDGE: Exploring intuitive interaction styles for home information appliances. In: J. Jacko and A. Sears (Eds.): *CHI 2001 Extended Abstracts of the Conference on Human Factors in Computing Systems*, Seattle, WA, USA, March 31 – April 5, 2001, 207-208. New York: ACM Press
- [5] Loebbecke C., 2005, *RFID Technology and Application in the Retail Supply Chain: The Early Metro Group Pilot*, 18th Bled conference on eIntegration in action, Bled, Slovenia, June 6-8, 2005
- [6] Genest KL, 2007, *Research and Recommendations for the Intelligent Refrigerator*. Consulted on 19th March 2010, available at: http://kristagenest.com/files/school/hf755_project.pdf
- [7] Abowd, G., D., Mynatt, E., D., 2000, Charting past, present and future research in ubiquitous computing, in *ACM Transactions on Computer-Human Interaction*, Vol. 7. No. 1, March 2000, 513-535
- [8] Hollan, J., Hutchins, E., Kirsh, D., 2000, Distributed Cognition: toward a new foundation for human computer interaction research, in *ACM Transactions on Computer-Human Interaction*, Vol. 7. No. 1, March 2000, 75-94
- [9] Weiser, M., 1991, The computer of the 21st century, *Scientific American*, 265, 3, 66-75.
- [10] . Taylor A. S, Harper R., Swan L., Izadi S., Sellen A., and Perry M., Homes that make us smart. *Personal and Ubiquitous Computing*. Springer London, 2006
- [11] Norman D. A., 2007, *The Design of Future Things*, Basic Books, New York.

WallShare: A Collaborative Multi-pointer System for Portable Devices

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ABSTRACT

WallShare introduces a new system to improve the collaboration possibilities among the participants in face-to-face meetings and working groups. It defines an novel interaction device and platform to develop collaborative applications. The system provides a shared zone displayed by a projector over a wall. In order to collaborate, users move their own cursors in the projected shared zone by performing gestures over their mobile device screens (mobile phone, PDAs, tablet PCs, laptops, etc.). Through their cursors and mobile devices users are capable of post notes and messages, and sharing files, such as documents, images, etc. This article also exposes a preliminary usability evaluation of WallShare showing the effectiveness, productivity and satisfaction of users when performing a set of defined tasks with distributed user interfaces.

Categories and Subject Descriptors

H.5.1 [Information interfaces & presentation]: Multimedia Information System; H.5.2 [Information interfaces & presentation]: User Interfaces; H.5.3 [Information interfaces & presentation]: Group and Organization Interfaces

Keywords

HCI, UI Distribution, Interaction resources, Mobile devices

1. INTRODUCTION

Mobile devices are highly available among users, which has motivated the emergence of novel interaction devices mainly on the entertainment market. Traditional devices such as keyboards, screens and mice seem to belong to an ancient age and they are being gradually substituted by new devices that support ways of interaction such as natural or gestural interaction.

In this paper we present the WallShare application, a new collaborative system that is controlled by portable devices. WallShare allows mobile users to collaborate by means of sharing the same desktop to perform collaborative activities like sharing documents, images or videos in the same place at the same time.

Section 2 describes the related work and WallShare motivation. Section 3 introduces the system from the functionality, architecture and implementation point of views. Section 4 shows a the preliminary usability evaluation performed on the system. Finally, the last section presents the conclusions and future work.

2. RELATED WORK

The related work is centered on: distributed user interfaces, the design of new interaction devices and the design of Groupware applications.

The modeling and design of distributed user interfaces (DIU) is facing the complex and dynamic world of managing users' interaction with heterogeneous devices. The development of new devices supporting DIU models to provide users with a divided interface among different devices introduces new interaction and collaboration possibilities [3, 12, 17].

The distribution of an interface among different platforms can be seen in desktop computers when users employ two or more screens to extend the desktop surface. In [4, 11], authors improve this idea with different proposals that employ simplex screen devices. The Dynamo [6] proposal is similar to WallShare. However, the WallShare approach employs less resources than Dynamo to provide similar functionality due to the use of less access points. Some works employ distributed user interfaces to migrate resources or an entire system among different platforms, as in [1]. Besides, new interaction paradigms, such as the Pick & Drop that offers a way to copy and paste resources between mobile devices using of wireless network [10], are arising to exploit DUIS.

From the design of new interaction device point of view, this work covers both, the software and hardware perspectives. Most relevant works are: (a) the ReacTable presenting a new tangible device based on a tabletop interface to compose mu-

sic [7], (b) the Touchpad Pro [16] allowing users to control a single pointer (no multi-pointer is supported), (c) the Control Mac [2] which uses the iPhone to control presentations remotely and (d) the Microsoft Multipoint [8] allowing users to control a remote pointer using mouse devices.

In [15], an interaction system based on RFID technology allows users with a mobile device to interact with interactive panels. These panels are traditional information panels enriched with RFID tags allowing both, the retrieval and storage of information through user gestures over the panels. The work presented in [14] describes a mobile application to improve the visitor's experience in museums.

From the collaborative system point of view, we have to highlight the design Electronic Meeting Systems (EMS) [9] that allow meeting participants to perform collaborative tasks through electronic devices that are embedded in the room.

3. WALLSHARE SYSTEM DESCRIPTION

Before exposing system characteristics we will define the set of non-functional requirements of the system:

Common mobile devices The system should not require specific or no widely accepted hardware integrated in the users' mobile devices.

Common communications protocol The system should use common or popular communication protocol as can be Wi-Fi or Bluetooth.

Users' actions should influence on the environment the user should be able to interact with other users and to influence in the environment some way.

The system as platform the system should not be an isolated application but a framework to implement different applications.

To satisfy these requirements WallShare defines a client-server application based on a shared zone that is projected on a wall or screen which is clearly visible by all the participants of a meeting. Figure 1 shows the shared zone with the presence of different users. According to [13] WallShare is defined as few-to-few context interaction application belonging to a inch or foot ecosystem scale.

The client application is a mobile application that runs on participants mobile devices to share resources through a shared zone. To access the WallShare system, participants download and install the client application into a mobile device from the WallShare server. This application is automatically updated whenever a new version is released in the server. In order to interact with the system, participants connect their mobile devices to the server application. When participants get connected to WallShare, they receive a double feedback, a sound from the server machine, and a pointer representing each user on the screen.

An interesting aspect of WallShare is the possibility of providing each participant with the ability to control the movement of a cursor that represents him/her on the screen just



Figure 1: The WallShare shared desktop



Figure 2: Samples of chat messages and post-its

by performing dragging gestures on the mobile device screen. Thus, users can use the mobile device as an enhanced X-Pointer device.

Therefore, connected participants are able to download and upload resources from and to the shared zone. To upload a resource, users select resources from the mobile device through the client application and upload them performing a simple gesture. When the resource was uploaded, it is shown on the shared screen. To download resources from the shared zone, a participant points the resource to download with the cursor. Then, the user performs a double click on the mobile device screen to download it to his/her mobile device.

WallShare also allows users to post notes on the shared zone as post-its (see Figure 3 on the right). These post-its are really useful to highlight information that is relevant to the meeting. Post-its are an interesting way to post anonymous information.

A chatting system is provided by the WallShare application to send a messages to all participants (see Figure 3 on the left). Unlike post-its, chat messages are associated to an author and are displayed on the lower left corner of the screen.

When a user logs out from the system, he/she receives a double feedback: a sound from the server machine, and the pointer representing the user disappears from the screen.

The server application provides some functionality that is very useful for the participant leading the meeting to manage the look of the shared zone. This functionality includes:

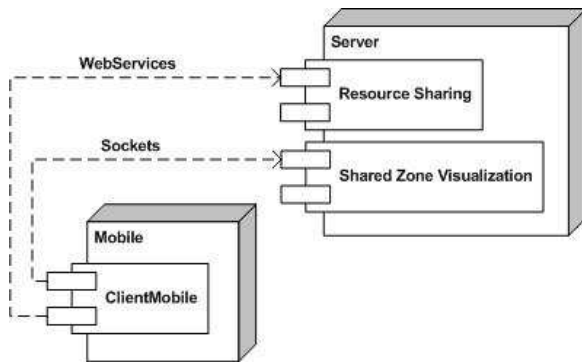


Figure 3: The WallShare UML component diagram

The shared zone wallpaper custom function provides the adaptation of the shared zone to the environment according to, for instance, illumination issues of the meeting room or participants (i.e. color-blindness). It also may be used to distinguish different meetings within a single room.

The chat enabling/disabling function gains some space from the shared zone when this functionality is not required. Besides, it also prevents chat abuse from participants.

The resource relocation function avoids resource overlapping. The resource rearrangement is performed automatically using a random location algorithm in a fashion way.

The shared zone clean function sends shared resources to the recycle bin. This functionality may be useful to set a starting point in the middle of a meeting.

3.1 WallShare architecture

As we have mentioned, WallShare is based on a client-server architecture defined in Figure 3.

The main goal of the Server node is the provision of communication, resource sharing and the coordination services to the Mobile nodes.

The Server node is realized by a desktop computer. It is composed by two basic components: the resource sharing component and the shared zone visualization component. The server is connected to a wireless network via a Wi-Fi or Bluetooth connection. The resource sharing component is in charge of performing resource transferring between the client and the server applications. The resource transference is performed when clients download/upload resources from/to the server. This communication is performed using Web Service technologies. The server is also connected to the visualization system, i.e. a projector or large screen, to support the shared zone visualization. Thus, the shared zone visualization component is in charge of synchronizing and displaying client actions, such as cursor moving the on the shared zone. Besides, it is responsible for displaying resources sent to the resource sharing component on the shared zone. Because of performance issues, we have decided to implement the communication between the clients



Figure 4: The WallShare as an electronic meeting platform

and the shared zone component through sockets (instead of using Web Services).

The main goal of the Mobile node system is providing to the server the participants actions through an easy to use interface in order to share resources during a meeting. It runs on the user mobile device and it is connected to the server application through a wireless network via a Wi-Fi or Bluetooth connection. According to the task to be performed, the client application selects which server component to connect. For instance, to upload or download a file, the client connects to the resource shared component of the server system to transfer the file via Web Services. However, to perform actions of the shared zone (i.e. move the cursor on the wall, post a note, send a chat message, etc.), the client connects to the shared zone visualization component of the server system via a socket based connection to improve system performance.

3.2 Domain specific WallShare applications

WallShare is not an isolated application, instead it can be seen as a set of domain specific applications with similar collaborations needs. This means that WallShare sets a platform beyond the presented application leading the improvement of face-to-face meetings (see Figure 4). Some potential applications of the platform are:

Games WallShare can be easily applied to support collaborative games where several users share common objectives. A puzzle is a good example of a WallShare game. All users see the evolution of the puzzle and collaborate to put the different pieces on the puzzle.

Education A number of different WallShare applications can be defined to support teaching activities. A group of students perform collaboratively a task as associate animal images with description.

Entertainment Restaurants, café or pub can use WallShare to allow customers to share their resources (images or video) while spend time with friends.

Science WallShare can be used in working groups to create documents in brainstorming meetings.

4. EVALUATION

In this section we present the results of the WallShare usability evaluation based on the ISO 9126-4 standard [5]. Specifically, we have focused on the effectiveness, productivity and satisfaction as the main factors that influence in the quality in use concept. Effectiveness has been measured using these three metrics: Effectiveness, Task completion and Error frequency. To measure productivity we have used Task time and Task efficiency. Satisfaction has been measured using a questionnaire based on the SUMI proposal. The experiment was defined as follows. A group of 17 users, range ages from 19 to 47 years old, without technological expertise were asked to perform four specific tasks: (1) Installing the client version of WallShare and login, (2) To share a resource (upload and download), (3) Add a note with a specific text, (4) Send a message to the shared chat with a specific text. Additionally participants were asked to fill the SUMI based satisfaction questionnaire. Satisfaction results showed a 77.4% of users with a positive opinion using WallShare, 15.2% of users feel neutral and 7.4% were not satisfied using WallShare.

5. CONCLUSIONS AND FUTURE WORK

This paper presents a novel alternative of a collaborative system to improve face-to-face meetings or working groups called WallShare. WallShare takes advantage of the distributed user interface paradigm as the users' interactions performed on their mobile devices are shared in the common public interface. By means of WallShare, a group of people participating in a meeting or working group is capable of sharing documents by performing simple gestures on his/her mobile device. WallShare extends the functionality of everyday devices, such as mobile phones or PDAs. WallShare also sets a platform to create domain specific applications in the fields of the entertainment, teaching and so on. WallShare has been tested with a group of non-technical users getting a high degree of satisfaction. Quality in use metrics show us that users can perform common WallShare tasks with effectiveness, productivity and satisfaction.

Future work includes the deployment of a new version for running on other mobile OS platforms.

6. ACKNOWLEDGMENTS

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7. REFERENCES

- [1] K. A. Bharat and L. Cardelli. Migratory applications distributed user interfaces. In *Proceedings of the 8th ACM Conference on User Interface Software Technology*, pages 133–142. ACM Press, 1995.
- [2] Control Mac. Control Mac. <http://www.soydemac.com/2008/03/18/controlar-un-mac-desde-el-iphone/>, 2010.
- [3] J. Coutaz, L. Balme, C. Lachenal, and N. Barralon. N.: Software infrastructure for distributed migratable user interfaces. In *Proceedings of UbiHCISys Workshop on UbiComp*, 2003.
- [4] K. Hinckley, G. Ramos, F. Guimbretiere, P. Baudisch, and M. Smith. Stitching: Pen gestures that span multiple displays. In *Proc. of the working conference on Advanced visual interfaces*, pages 23–31, 2004.
- [5] ISO. ISO/IEC 9126-4: Software engineering - software product quality -part 4: Quality in use metrics, October 2002.
- [6] S. Izadi, H. Brignull, T. Rodden, Y. Rogers, and M. Underwood. Dynamo: a public interactive surface supporting the cooperative sharing and exchange of media. In *Proceedings of the 16th ACM Conference on User Interface Software Technology*, pages 159–168. ACM Press, 2003.
- [7] S. Jordà, G. Geiger, M. Alonso, and M. Kalttenbrunner. The reactable: exploring the synergy between live music performance and tabletop tangible interfaces. In B. Ullmer and A. Schmidt, editors, *Proceedings of the 1st International Conference on Tangible and Embedded Interaction*, pages 139–146. ACM Press, 2007.
- [8] Microsoft. Microsoft Multipoint. <http://www.microsoft.com/unlimitedpotential/TransformingEducation/MultiPoint.aspx>, 2010.
- [9] J. F. Nunamaker, A. R. Dennis, J. S. Valacich, D. Vogel, and J. F. George. Electronic meeting systems. *Commun. ACM*, 34(7):40–61, 1991.
- [10] J. Rekimoto. Pick-and-drop: A direct manipulation technique for multiple computer environments. In *Proceedings of ACM Conference on User Interface Software Technology*, pages 31–39, New York, 1997. ACM Press.
- [11] J. Rekimoto and M. Saitoh. Augmented surfaces: A spatially continuous work space for hybrid computing environments. In *Proceedings of the CHI*, 1999.
- [12] P. Tandler, T. Prante, C. Müller-Tomfelde, N. Streitz, and R. Steinmetz. Connectables: Dynamic coupling of displays for the flexible creation of shared workspaces. In *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology*, pages 11–20, 2001.
- [13] L. Terrenghi, A. Quigley, and A. Dix. A taxonomy for and analysis of multi-person-display ecosystems. *Personal and Ubiquitous Computing*, 13:583–598, 2009.
- [14] R. Tesoriero, J. A. Gallud, M. D. Lozano, and V. M. R. Penichet. A location-aware system using RFID and mobile devices for art museums. In *Proceedings of the 9th Congreso Internacional de Interacción Persona-Ordenador*, pages 76–81. IEEE/CS Press, 2008.
- [15] R. Tesoriero, R. Tébar, J. A. Gallud, V. M. R. Penichet, and M. D. Lozano. Interactive ecopanel: Paneles ecológicos interactivos basados en RFID. In J. A. Gallud and M. D. Lozano, editors, *Proceedings of the 9th Congreso Internacional de Interacción Persona-Ordenador*, pages 155–165, 2008.
- [16] Touchpad. Touchpad Pro. <http://www.touchpadpro.com/>, 2010.
- [17] C. Vandervelpen and K. Coninx. Towards model-based design support for distributed user interface. In *Proceedings of the 3rd Nordic Conference on Human-Computer Interaction*, pages 61–70. ACM Press, 2004.

Labeling Large Displays for Interaction with Mobile Devices: Recognition of Symbols for Pairing Techniques

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ABSTRACT

Interactive displays are an effective means to exchange contents with mobile devices for co-located collaboration in offices and schools. It is very important that the users are able to easily comprehend and learn the interaction techniques to pair their mobile devices with large displays. In this paper, we report on the results of an exploratory case study investigating the comprehension and understandability of the labels advertising different interaction techniques for pairing mobile phones with the large displays. The results of the case study are discussed and the suggestions to enhance the comprehension level of these labels are provided.

Categories and Subject Descriptors

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

General Terms

Design, Experimentation, Human Factors.

Keywords

Communication design, Multi-display systems, Intuitive interfaces.

1. INTRODUCTION

Large interactive displays provide an efficient means to disseminate and manipulate information for co-located collaboration. Increasingly research efforts have focused on the creation of smart meeting rooms that represent multi-display collaborative environments comprising personal computing devices (e.g. laptops, mobile phones) connected to large displays [7]. The emergence of smartphones equipped with advanced features such as Bluetooth, camera and accelerometer, make it feasible to implement interaction techniques that can seamlessly pair them with large displays, hence, bypassing the cumbersome

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process of device discovery and selection process [7].

In order to make the device pairing process intuitive, it is important that the signs and symbols on large displays convey to the users a clear notion of the steps they have to undertake to pair their smartphones. Apart from soliciting the mobile phone users' attention, the labels on the large displays should demonstrate the available pairing techniques in an intelligible way.

Labels with pictorial illustration have been in vogue to convey the information about traffic signs [6], map navigation [1, 2, 3, 4] and usage of medical devices [5]. However, to date, the "communicative efficiency" of labels for pairing of display devices has received little coverage in literature. In this paper, we report on the results of an exploratory case study investigating the comprehension and understandability of the display labels for four pairing techniques i.e. pointing, touching, drawing and typing. Based on these results, we offer recommendations for the re-design of these labels that is compliant with our stated aims of soliciting the user's attention and increasing the comprehension level of these labels.

2. Labeling a Wall-Mounted Display

2.1 Participants

The study involved 14 participants in the age group 22-45; 10 males and 4 females. Among the participants, there were 5 postgraduate students (3 in computer science, 1 in geographical science and 1 in interaction design), 2 human resource (HR) professionals with limited insight into cutting edge research of multi-display interactions, and 7 researchers who have been involved in computer science research for past few years. On average, they had experience of using handheld devices (such as mobile phones, personal digital assistants, smartphones) for more than 5 years.

2.2 Design of Display Labels

For this experiment, we alternately placed each of the 4 labels on a wall-mounted LCD that was about 32" wide and placed about 8 feet above the ground. While designing labels, we considered the two questions in mind:

- *How to solicit user attention to the label?* To make the label stand-out and grab user attention was critical. Hence, we decided to place it on the top middle sidebar of the large display to make it conspicuous.

- *How to make them understandable for the users?*
Picture is said to be worth more than thousand words. We decided to include only pictorial representation of the interaction technique in the label, without any textual description. Each label consisted of two parts:
 1. *Instructive image:* The left-side of the label consisted of illustration of interaction technique. This image was placed with black background.
 2. *Interaction symbol:* The right side of the label consisted of the symbol the user was required to interact with, in order to pair the mobile device with the large display. This symbol was placed in white background.

The labels for the interaction techniques we included in the case study are given below.

2.2.1 Pointing

This technique requires the scanning of a 2-D barcode on the large display using phone camera. The pointing label is shown in Fig. 1.

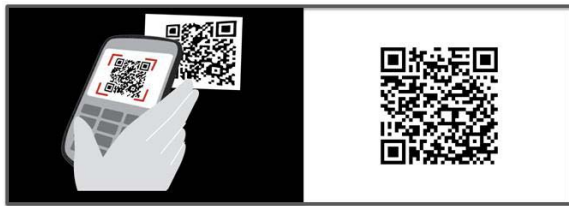


Fig.1. Pointing Label

2.2.2 Drawing

This technique requires the drawing of a symbol on the touch screen of the mobile phone using finger. The drawing symbol is shown below in Fig. 2.

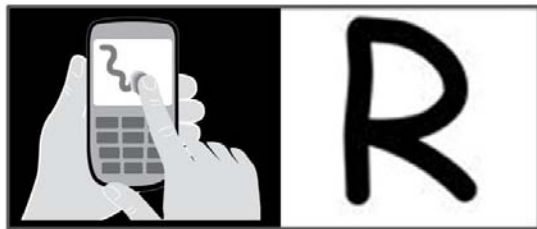


Fig.2. Drawing Label

2.2.3 Touching

This technique requires the touching of a Near Field Communication (NFC) tag on the large display with the NFC reader attached to the mobile phone. The touching symbol is shown in Fig. 3.



Fig.3. Touching Label

2.2.4 Typing

This technique requires the typing of a word (i.e. network name of the large display) on the keypad of the mobile phone. The typing symbol is shown in Fig. 4.

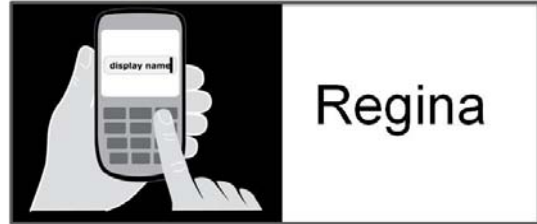


Fig.4. Typing Label

2.3 Study Methodology

At the beginning of the trial session, we provided the participants with an explanation of the whole notion of seamless device pairing as well as the purpose of this experiment. Afterwards, they were shown the label being placed on the top-middle edge of the large display. The participants were asked to think-loud during the experiment and were categorically told that what is at trial is the understandability of the labels, not their observation skills. After they identified a label, they experimented with the corresponding interaction technique using a Wizard-of-Oz application on mobile device. As they performed the action corresponding to each interaction technique, the screen on the large display showed the home screen of mobile phone at greater resolution, hence, giving the impression of mobile display being paired with the large display. After the users performed a pairing technique, they were interviewed about the communicativeness of the display label corresponding to that particular technique. The sequential order of labels to be shown was randomly changed in each trial session to mitigate any biasing effect. On average, each participant spent 20-30 minutes in the whole exercise. All of them were compensated at the end of the experiment.

3. EXPERIMENTAL RESULTS

The responses of the participants with respect to the labels of pairing techniques are explained below.

3.1 Pointing

The results about identification of pointing label are shown in Table 1, while Table 2 shows the user responses about the positioning of pointing symbol on the large display.

Table 1. Identification of pointing symbol

Identification	Participants
Correct Identification	9/14 (65%)
Incorrect Identification	5/14 (35%)

Most participants were able to recognize this symbol because they found it similar to the visual tags on train tickets. Some others got the idea of scanning the 2D barcode but could not get the idea that doing so will connect their mobile device to the large display. One participant was at first confused to see the visual tag in both black

and white background parts, but later understood the idea because of his background in Augmented Reality (AR). Another participant wanted the display label to convey the information how far from the display one has to be to scan the visual tag.

Table 2. Positioning of Pointing symbol on Large Display

Position on Large Display	Participants
Top Middle	2/14 (15%)
Bottom Middle	4/14 (28%)
Bottom Right	7/14 (50%)
Separate from the display	1/14 (7%)

As shown in Table 2, most participants wanted this label to be placed on bottom right corner of the large display as that is the standard position for start button in TV sets. One participant remarked that while in current position, the label was well placed to solicit user’s attention; it becomes distracting once pairing is done and one is interacting with the large display. One participant also suggested the label to be placed separate from, but close, to the large display in order to make it more conspicuous.

3.2 Touching

The results about identification of pointing label are shown in Table 3.

Table 3. Identification of touching symbol

Response	Participants
Correct Identification	2/14 (15%)
Incorrect Identification	12/14 (85%)

Of all the labels, this label was the most confusing and toughest to decode for the participants. Some participants confused it with Bluetooth connection and while others mistook it to be a sound alarm. The participants who correctly identified this label were able to do so because of background in NFC research.

Table 4. Positioning of Touching symbol on Large Display

Position	Participants
Top Middle	2/14 (15%)
Bottom Middle	4/14 (28%)
Bottom Right	7/14 (50%)
Separate from the display	1/14 (7%)

Most participants wanted this label to be placed on the bottom right corner of the display, as shown in Table 4. Since this label requires to be touched with mobile phone, placing it on the bottom of the large display also suits the people who find it inaccessible to reach up to the top corner of the large display.

3.3 Drawing

The results about identification of drawing label are shown in Table 5.

Table 5. Identification of Drawing symbol

Response	Participants
Correct Identification	4/14 (30%)
Incorrect Identification	10/14 (70%)

Some participants misinterpreted the label as typing the letter “R” on mobile phone’s keypad. Other suggested that at least 2/3rd of the letter “R” should be shown drawn with finger to make it more comprehensible.

Table 6. Positioning of Drawing symbol on Large Display

Position	Participants
Top Middle	6/14 (40%)
Bottom Middle	2/14 (15%)
Bottom Right	4/14 (20%)
Separate from the display	2/14 (15%)

As show in Table 6, most participants favored this label to be placed in the top middle corner of the large display.

3.4 Typing

The results about identification of typing label are shown in Table 7.

Table 7. Identification of typing symbol

Response	Participants
Correct Identification	8/14 (65%)
Incorrect Identification	6/14 (35%)

Some participants find it hard to understand what exactly the name “Regina” in the label stands for. Others understood that the symbol meant the name “Regina” to be typed on the mobile’s keypad failed to get the correlation between typing “Regina” and paring with the large display. One participant mistook “Regina” to be the company logo of the large display instead of its network name.

Table 8. Positioning of Typing symbol on Large Display

Position	Participants
Top Middle	8/14 (15%)
Bottom Middle	2/14 (30%)
Bottom Right	4/14 (50%)

As show in Table 8, most participants favored this label to be placed on the bottom right corner of the large display as well.

4. LESSONS LEARNT

According to Zwaga et al. [8], comprehension rate of a good graphic symbol should be above 67%. As we see from our experiment, only the pointing symbol comes close to that score

(65%). Considering the relatively small sample size of our participants and the controlled experiment setting, we are not in a position to generalize the results and come up with an exhaustive list of implications. However, we think some useful insights can be gained for improving the comprehension rate of symbols for pairing techniques. Below we discuss some of the ways we can re-design the labels to solicit attention and enhance their comprehension level.

4.1 Solicit attention towards the label

Most participants wanted the label to be placed on the bottom right corner of the large display as that's where the buttons of TV sets and monitor are usually placed and the users are intuitively inclined to look there at first. One drawback in placing the label on top sidebar of the large display is that it can be distracting for the users if they have to interact and manipulate information on the large display for long. Also it is quite possible to confuse typing label with the company's logo as such logos are usually placed in the middle of the sidebar, thus making the case for right corner position stronger.

One participant suggested these labels to be placed on the eye level. Moreover, the NFC tag on touching symbol has to be physically touched by the NFC reader on mobile phone; hence, this symbol should be placed at bottom margin to make it physically accessible.

Some participants suggested the labels to be enlarged and placed next to (and not on) the large display. They suggested an approach similar to the storyboard sketches that are usually placed next to hand dryers and washing machines.

4.2 Increase the Comprehension Level

We learnt from our experimental results that picture can complement but not override the need for text. Some participants wanted a minimum amount of textual information on these labels such as the distance range of NFC tag reader and 2D barcode scanner.

Some other participants suggested animations to be shown in the main area of the large display to give a visual demonstration of interaction technique.

Overall we think that as the multi-display interfaces become commonplace and more and more people become familiar with

these pairing methods, comprehension level of these labels is likely to rise.

5. CONCLUSIONS

In this paper, we report on the results of an exploratory case study aimed at estimating the comprehension levels of labels for pairing techniques of pointing, touching, drawing and typing. Based on our experimental observation, we presented some suggestions to re-design the labels in order to solicit the users' attention and increase the comprehension level of the labels. In future, we plan to improve the presentation style and comprehension level of these labels and conduct a longitudinal *in situ* evaluation.

6. ACKNOWLEDGMENTS

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7. REFERENCES

- [1] Clarke, L.M. 1989. An experimental investigation of the communicative efficiency of point symbols on tourist maps. *The Cartographic Journal* 26(2): 105-110.
- [2] Dymon, U.J. (2003). An analysis of emergency map symbology. *International Journal of Emergency Management* 1(3): 227-237.
- [3] Forrest, D. and H.W. Castner. 1985. The design and perception of point symbols for tourist maps. *The Cartographic Journal* 22(1): 11-19.
- [4] Kumari, A.M. First Responders and Crisis Map Symbols: Clarifying Communication. 2009. *Cartography and Geographic Information Science*, Volume 36, Number 1, January 2009, 19-28.
- [5] Liu, L., U. Hoelscher, and T. Gruchmann. 2005. Symbol comprehension in different countries: experience gained from medical device area. *Mensch Und Computer*, 81-87.
- [6] Shinar, David; Dewar, Robert E.; Summala, Heikki; Zakowska, Lidia. 2003. Traffic Symbol Comprehension: A Cross-Cultural Study. *Ergonomics* 46(15), 1549-1565.
- [7] Terrenghi, L., Quigley, A., Dix, A. 2009. A taxonomy for and analysis of multi-person-display ecosystems. *Personal and Ubiquitous Computing Journal* 12: 583-598.
- [8] Zwaga, H.J. et al. 1982. Evaluation of a set of graphic symbol. *Applied Ergonomics*, Vol. 14, No. 1, pp. 43-54.

Projector Phone Interactions: Design Space and Survey

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ABSTRACT

As projector units become smaller, brighter and more energy conserving, they are bound to become an integral part of many mobile phone models in the future. We lay out and discuss the design space of interactions and applications enabled by such devices. Moreover, we focus on the implications of hardware design, discuss possible interaction concepts, describe the most relevant applications areas and give an outlook on future research topics.

1. INTRODUCTION

The possibility to display and interact with large high-resolution information everywhere and at any time has always been the dream of interaction and application designers in the pervasive and mobile computing field. Current available solutions are, on the one hand, the augmentation of the environment with fixed public screens or projections and, on the other hand, private mobile devices such as mobile phones, mobile media players and tablet PCs. Augmenting the environment with display technology is very expensive and the currently used solutions focus mainly on broadcasting information to a larger audience. Mobile devices have advanced intensively in the last years, though they still suffer from a rather small screen which makes them especially inappropriate for co-located collaborative interactions.

We currently observe the emergence of pico projectors that are integrated into projector phones, wearable computing devices, and external devices that can be coupled with existing mobile devices. Using such mobile or wearable personal projectors, everybody can project a large high-resolution display everywhere and can potentially interact with them. This enables the development and design of a broad variety of completely new applications and interactions concepts which bridge the gulf between private mobile devices and public displays.

This paper concentrates on projector phones as this device class shows a real potential to bring personal projectors in our everyday lives. The aims of this paper are: to discuss the technology behind pico projectors, to analyze the possibilities of integrating the projector and a camera into a mobile phone, to classify the new interaction concepts that have been presented in the last years in this context, and to discuss application and research areas for projector phones.

2. HARDWARE DESIGN

The section opens with a discussion about the available projector phone hardware. This is followed by an analysis of different possibilities for integrating pico projectors into mobile phones.

2.1 Pico Projector Hardware

Three different technologies are currently available that allow the development of pico projectors: Digital Light Processing (DLP), laser pico projectors and Holographic Laser Projection (HLP).

Digital Light Processing (DLP) technology from Texas Instruments is the most mature technology and is used in the most pico projectors or projector phones currently available on the market or being demonstrated such as the Samsung W9600 / Beam, LG Expo, NTT DOCOMO Keitai F-04B or Optoma PK 102 (see Figure 1). Here, light emitted by Light Emitting Diodes (LED) is sent to a micro mirror array whereby each mirror can be rapidly repositioned in order to control the reflection respective intensity for each pixel. A laser pico projector (as used in SHOWWX from Microvision or the L1 from AAXA technologies) works in principle very similar to a Cathode Ray Tube (CRT) as a single laser beam is steered to sequentially project the pixels respective lines one by one. Holographic Laser Projection (HLP) developed by Light Blue Optics is a further approach where the light is generated by a laser. The difference here is that the light illuminates a micro display which is diffracted in order to reflect the desired image.

All the products currently available have a brightness of up to 20 ANSI-Lumens, a battery lifetime of up to two hours and can easily project images up to a size of 100 inch. The great advantages of the laser based approaches are that the projection is always in focus whereby the focus of the DLP based projectors must be manually controlled. Furthermore, the laser-based approaches are in principle brighter and more energy efficient as they steer light and do not block it as DLP does. The most relevant shortcoming of pico-projectors is battery consumption and their low brightness of currently up to 20 ANSI-Lumens which is just one percent of the brightness a good projector for home cinema has.



Figure 1. Samsung W9600 (dlp.com), LG Expo and Epoq EGP-PP01 (aboutprojectors.com)

2.2 Alignment of Camera and Projector

The location of the pico projector on the mobile phone, its throw angle and the spatial relationship to the camera, input and display affects heavily the possibilities of how to interact with the projection. The aim of this section, which is inspired by the work of Schöning et al. [1], is to explore this design space.

Figure 2 shows the potential locations on which the pico projector and camera could be placed. Figure 3 shows the possible combinations of projector and camera locations. The white marked combinations in Figure 3 indicate settings in which the projector and the camera face in the same direction. This allows

the projection of user interfaces and the simultaneous tracking of the user's fingers which interact with the projection via the camera [2, 3, 4]. Furthermore, it is also possible to build augmented reality applications whereby the camera is responsible for recognizing and tracking a real world object and the projector projects relevant information onto it.

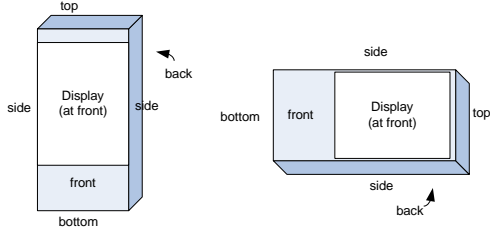


Figure 2. Locations on a phone (portrait and landscape).

A further setting (indicated with black) is when the projector and the camera face in opposite directions. When having, for instance, the projection on the back and the camera on the front, then this can be used for video telephony.

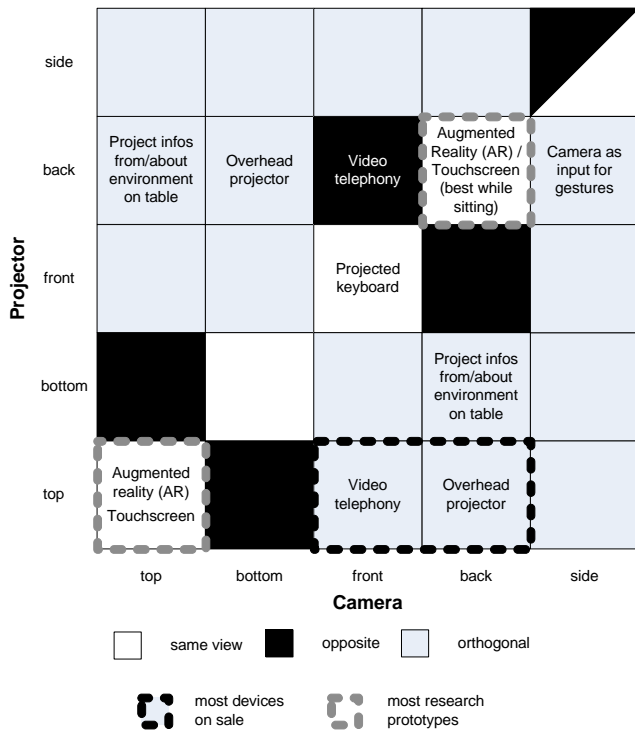


Figure 3. Configurations of projector and camera.

Furthermore, there are many different possibilities for attaching the projector and the camera so they are orthogonal to each other (grey boxes). For instance, when having the projector on the back and the camera on the top then the camera could be used to recognize a product and related information are projected onto a table. When having the projector on the back and the camera at the bottom then the projector phone could be used as an overhead projector. Here, the camera focuses e.g. on a document positioned on a table which is displayed on the wall by the projector. A further option for this orthogonal setting is the use the camera to track finger / hand gestures (e.g. when camera is facing towards

the side) in order to scroll for instance a webpage shown by the projector (e.g. facing towards the back).

Future research will show whether all or which possible combinations will be explored even further and one can assume that certain configurations will be more popular (e.g. camera and projector facing towards the top) than others.

The previously discussed design space could be even extended when considering devices which have more than one projector. This option has been explored by Funai Eco Scan Mini Projector and NEC P-ISM (Pen-style Personal Networking Gadget Package) which are used to create laptop like working environments. Both placed the device on a table whereby one projector was projecting onto the wall behind the table and the second projector projected a touch surface on the table.

Furthermore, one could also consider projector phones which allow changing the direction of the pico projector. Cauchard et al. for instance discuss a projector phone that has a projector on the top which can point towards the top (e.g. for wall projection), towards the back (table projection) and point at an angle between top and back (desk projection) [6]. The Cinemin Swivel from WowWee is shows that it is feasible to develop such adjustable hardware.

A further possibility is to have a modular projector phone such as the NTT DOCOMO Keitai F-04B. Here, the projector unit can be decoupled from the mobile phone unit and can be placed on the table. The mobile phone is able to communicate with the projector unit via Bluetooth and can be used as a remote control.

3. INTERACTION CONCEPTS

This section provides an overview of the different concepts for interaction with projector phones. There are four conceptually different approaches to interact with a projector phone which are illustrated in Figure 4:

- interactions on the projector phone (e.g. by pressing buttons, Figure 4a)
- changing the location and orientation of the projector phone (e.g. pointing somewhere or turning the projector, Figure 4b)
- interactions with the projection (e.g. using it like a touch-screen or drawing on it, Figure 4c)
- interacting with the surface on which the projection is displayed (e.g. by changing its position and orientation, Figure 4d).

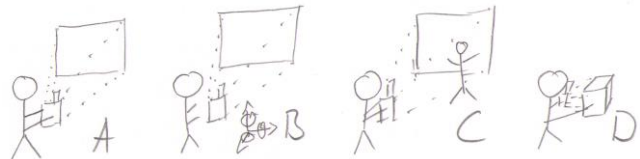


Figure 4. Approaches to interact with a projector phone.

When it comes to the way information is presented by the projector phone, one can distinguish between three different concepts as shown in Figure 5:

- the projection can be just used as a large display that can be projected on any surface (Figure 5a)
- projection could act as a magic lens revealing a part of a virtual information layer which is much bigger than the actual projection (Figure 5b)

- projection could show information related to the object on which the projector currently focuses (augmented reality, Figure 5c).

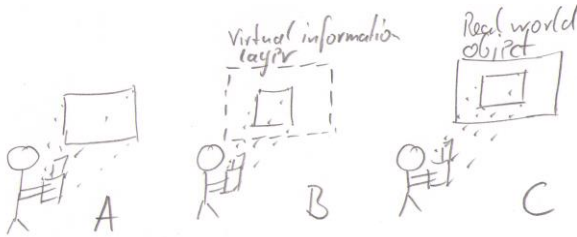


Figure 5. Output concepts of projector phones.

3.1 Input on Projector Phone

Early research focused on one-handed interaction with handheld projectors providing just two buttons operated with the user's thumb [7]. Using this approach, the user was able to focus his/her attention always onto the projection as it's easily possible to locate and press the buttons without looking at them. Current projector phones provide a touch screen (e.g. Samsung W9600) or 12-key keypads (e.g. Epoq EGP-PP01) allowing much richer means of interaction with the projection.

3.2 Position and Orientation of Projector

Especially when the user is holding the projector phone in his/her hands, it is possible to change the position and orientation very easily which could be used as an input for corresponding interactions. Tilting the projector up/down or left/right can be used to pan for instance an image, map or webpage displayed on the projection [8]. When tilting the projector downwards, the web browser would e.g. pan or scroll downwards.

When using the spotlight or magic lens interaction technique, the user reveals always a certain part of a larger virtual layer through changing the orientation and location of the personal projector [9, 10]. This allows the interaction with a large and high-resolution virtual information layer which is e.g. distributed over a large wall and the user is easily able to reveal and find information due to the fact that the user can easily remember which information is located where. Selections can be performed via a cross-hair in the centre of the projection. Once the cross-hair is over the item, in order to select, the user presses a button on the projector phone.

3.3 Direct Interaction with the Projection

The system developed by Karitsuka and Sato was the first one supporting means for direct interaction with the projection itself [4]. The user wears a finger-cap with an IR-LED through which the system can track where the user's fingers is. Through this, it is possible to interact via touch with the projected information. The authors show how the user can interact with projected buttons and sliders or how the user can draw on the projection using his finger.

The concept of direct interaction with the projection was extended by the Wear Ur World (better known as SixthSense) system [2] in which the user was able to interact via in-the-air hand gestures and touching the projection. The discussed projection surfaces are e.g. walls, the user's hands or a newspaper. The Wear Ur World system projects e.g. relevant information onto a product the user

is holding in his/her hands and supports also direct touch-based interaction with the projected information.

Using the hand as the projection surface is also supported by the Brainy Hand [3] prototype which is an ear-worn device with a camera, projector and an earphone which could provide a vision for a future generation of mobile phones (see Figure 5 left). A mobile phone user interface is projected onto the user's hands. The user can interact with it via touching it with the other hand.

3.4 Augmented Reality (AR)

When projecting onto objects, it is also possible to project information about this particular object on it or close to it. Examples being explored so far were visualization on items in a warehouse to show information about their expiration date [5], augmentation of a fuse box showing which fuse belongs to which room [7] and augmentation of a paper showing further information about certain locations on a map [1]. A prerequisite here is that the projector knows which object it currently projects onto. This information can be provided by the object itself by broadcasting its location, shape and information [5], by a room based localization and information system [9] or by a camera focusing onto the augmented object [1].

3.5 Multi-User and Multi-Projector

Projector phones are predestined for co-located collaborative interactions and applications due to the availability of large high resolution projection. The View & Share system allows a group of users to share the projection provided by a projector phone [11]. So it is for instance possible for a group member with a non-projector phone to control what is projected by the projector phone of another user. Cao et al. explored different interaction techniques for a setting where two users have a handheld projector [9, see Figure 5 right]. Concepts being investigated were to combine the two projections side-by-side to create a larger projection area and overlapping the two projections. An example for the latter was a scenario in which user A and user B are both projecting their calendar and once the projections overlap only the free timeslots the two have in common are shown.

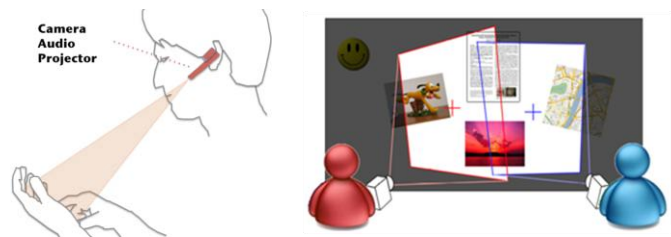


Figure 5. left: projector-camera unit in form of a headset [3], right: overlapping projections both acting as magic lenses [9].

4. APPLICATION AREAS

Recently, some attempts have been made in order to find and classify the most important classes of applications and domains for which projector phones would be most interesting to use. Cao for instance identified three aspects as main application areas [10]: personal information processing, interacting with the physical world, and interpersonal information exchange. In [7], three classes are proposed: projected desktop applications, projected augmented reality, and selecting a physical region of interest. As there have been only few approaches using projector

phones, we also look at general mobile projectors for reference. Interestingly, our survey indicates that the majority of existing and planned projects falls into only four categories.

Games and Entertainment: Projector phones offer interesting opportunities for novel ways of providing entertainment and games for groups of users by adding the environment as interface canvas. The implicit separation of the interface into public and private screens very appropriate for many types of games where some parts are shown to all and some only to its owner. Examples include [1] (combining real world props and drawings to influence a projected character) and [10] (treasure hunt exploiting overlapping projections and jigsaw puzzles emphasizing collaboration).

Augmented Reality (AR): Aligning camera and projector view frustums, AR applications display data in connection with an existing physical item. Examples include [1] (superimposing travel directions on large stationary paper maps) and [5] (including detecting and tracking physical objects).

Data Visualization and Manipulation: Projector phones, in particular, fit the flashlight or magic lens metaphor. One example is [8] (showing stock information). Manipulation of such data is often done by porting interaction techniques from the desktop or using gestures. Examples include [7] (using the projector as a replacement of a mouse) and [3] (using gestures on one's palm to interact with a body-worn prototype).

Collaborative Scenarios: Phones enable and enhance opportunities for remote communication. Adding a projector unit greatly enhances collocated collaboration. Sharing information is simplified by having several people either each using their own personal projector or sharing one projector phone. Examples include [9] (exchanging documents, combining displays, and exploring techniques such as magic lenses) and [11] (enable all members of a group of people to have selective access to one projector phone using their own phones for looking at and sharing pictures).

5. RESEARCH QUESTIONS

When considering the research conducted so far as well as the possibilities given by the hardware design and interaction techniques, one could consider that the following research questions should be addressed in future work:

Context switch: Conventional projector phones suffer from the problem that the input (keys or touch screen) is decoupled from the output (projection). In order to interact, the user has to switch his/her focus constantly between mobile device and projection leading to higher mental demand, task completion time and frustration [12]. Future research could reduce the number of needed context switches (e.g. by the provision of preview information on the projection), help the user to refocus after a switch or through the development of interactions in which the user doesn't has to look at the mobile phone at all.

Public and private display: Projector phones provide two conceptually very different displays: a small private one (mobile phone screen) and a large public one (projection). Currently available or announced projector phones use the projection only to mirror the information shown on the mobile phone screen. Future research should analyze what to shown on the two screens

considering its properties and how interaction techniques could be developed that take advantage of the private and public display.

Further applications and interactions: The applications currently envisioned by industry focus primarily on the projection of pictures, videos, games and presentations onto nearby surfaces. The potential given by the availability of the camera and touch screen for sophisticated input has not been explored in its full extend so far. In particular, when it comes to projector phone games, multiuser applications, and interaction techniques, one can expect many novel ideas to appear.

Social interactions: It is currently unclear which kinds of social interactions and social protocols will emerge or establish once projector phones are pervasively used. Upcoming questions might be related to teenagers projecting inappropriate information onto public spaces or visual pollution generated by a multitude of projections generated by many users at the same location [13].

Technical advances with projections: Future research will focus also on brighter and smaller pico projectors with lower energy consumption and projector phones with new camera- projector-phone configurations.

6. REFERENCES

- [1] Schöning, J., Löchtefeld, M., Rohs, M. and Krüger, A. Projector Phones: A New Class of Interfaces for Augmented Reality. *International Journal of Mobile HCI*. 2010.
- [2] Mistry, P., Maes, P., and Chang, L. WUW – wear Ur world: a wearable gestural interface. In *Proc. CHI EA'09*. 4111-4116.
- [3] Tamaki, E., Miyaki, T., and Rekimoto, J. Brainy hand: an ear-worn hand gesture interaction device. In *Proc. CHI EA'09*. 4255-4260.
- [4] Karitsuka, T. and Sato, K. A Wearable Mixed Reality with an On-Board Projector. In *Proc. ISMAR'03*. 321.
- [5] Raskar, R. et al. RFIG lamps: interacting with a self-describing world via photosensing wireless tags and projectors. In *Proc. SIGGRAPH'04*. 406-415.
- [6] Cauchard, J., Fraser, M. and Subramanian, S. Offsetting Displays on Mobile Projector Phones. In *Proc. Ubiprojection 2010*.
- [7] Beardsley, P., Baar, J. V., Raskar, R., and Forlines, C. Interaction Using a Handheld Projector. *IEEE Computer Graphics and Applications*. 2005, 25(1). 39-43.
- [8] G. Blasko, S. Feiner and F. Coriand. Exploring Interaction with a Simulated Wrist-Worn Projection Display. In *Proc. ISWC 2005*. 2-9.
- [9] Cao, X., Forlines, C., and Balakrishnan, R. Multiuser interaction using handheld projectors. In *Proc. UIST'07*. 43-52.
- [10] Cao, X. *Handheld Projector Interaction*. PhD thesis. University of Toronto. 2009.
- [11] Greaves, A. and Rukzio, E. View & Share: Co-Present Viewing and Sharing of Pictures using Personal Projectors. *International Journal of Mobile HCI*. 2010.
- [12] Greaves, A. and Rukzio, E. Evaluation of Picture Browsing using a Projector Phone. In *Proc. Mobile HCI 2008*. 351-354.
- [13] Intrusion Warning over Mini Projectors. *BBC News*. 26.02. 2008. <http://news.bbc.co.uk/1/hi/technology/7265365.stm>

Delegating the visual interface between a Tablet and a TV

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ABSTRACT

The introduction and wide adoption of small and powerful mobile computers, such as smart phones and tablets, has raised the opportunity of employing them into multi-device scenarios and blending the distinction between input and output devices. In particular, the partnership between a personal device and a shared one provides two possible output screens. Then, one significant research issue is to balance the visual interface between two devices with advanced output abilities. Do the devices compete or cooperate for the attention and the benefit of the user? Most notably, how multi-device interaction is appreciated in multi-user scenarios? Previous research has raised and considered the above research issues and questions for dual screen set-ups in the work environment. In our research, we are exploring multi-device user interface configurations in the context of a leisure environment and for entertainment applications. Our objective is to provide interaction possibilities that are more than the sum of the parts.

Keywords

Tablet, TV, interaction, design, evaluation

1. INTRODUCTION

The majority of contemporary user interface systems consider a clear distinction between the input and the output devices. Indeed, the user interface systems in desktop computers, TVs, telephones, have usually distinguished between the input and the output devices. Smart phones and tablets are devices that don't consider this distinction. Moreover, the plentitude of devices enable the creation of ubiquitous computing scenarios (Weiser, 1993) where the user can interact with two of more devices.

The remote control has been the most common way to interact with iTV. However, the popularity of mobile computers such as smart phones and tablets allow us to leverage the established way of interaction. A second screen could give the user more information and the possibility to interact controlling, enriching or sharing the content (Cesar et al. 2009). In this work, we examine three alternative scenarios for controlling the content in a dual screen set-up and explore the respective evaluation methods.

In the following subsections, we describe previous work that has used dual displays. While there is research that evaluates the usability or performance of the independent displays as a single continuously addressable space, there is also research that employs two synchronized screen devices. Both areas of study are of great interest and influence in our research for both the evaluation of its use and for the development of our prototypes.

2. RELATED WORK

The majority of previous research in dual-screen set-ups has been focused on the effects of increased screen real-estate, which has been considered as a quantitative parameter in performing several user tasks. Indeed, several studies have been performed in a work-setting, which lends itself to performance measurements as efficiency. On the other hand, there are few research efforts in leisure environments that have considered the qualitative effects of secondary screens. The general research area is characterized by the partnership between a personal device and shared screen one. Then, one significant research issue is to balance the visual interface system between two devices with output abilities.

2.1 Multi-device timeline

Since the advent of the PDAs there have been some studies to replace the remote control in the interaction with interactive television. One of the most influential research for this work is the Robertson one (1996), which proposes a prototype for real estate searching by a PDA bidirectionally communicated via infrared with interactive television. The author proposes a design guide remarking the importance of distributing information through appropriate devices. So the right information for display on PDA's is text and some icons, but television is suitable for displaying large images, video or audio. So the nature and quantity of information determines how to display and on which device. This research also gives priority to increase a synchronized cooperation between both devices.

In the design proposed by Sanaz (2005) is established a mobile phone as main element of interaction with the television in order to language learning. This interaction, unlike the previous one, is based on multiclient-server architecture: mobile phones connect through two levels of WAP and SMS to the server, which is accessed via a set top box for the iTV.

Another way to interact is proposed by Yang et al. (2009). In this case a second screen is attached to the mouse showing helpful and contextual information to interact with a PC. Although the interaction is done with a PC (different to a TV in terms of use), the paradigm is quite similar in which the main screen is extended with an Interactive Touch Display. Reducing mouse trips (in our case remote controller trips) and reducing occlusion are some of the advantages that are cited and could have application in our study. Also some released products as RedEye¹ that let the user interacts with TV through a second screen to do some basic

¹ <https://thinkflood.com/products/redeye/what-is-redeye/>

operations of content controlling, however, it works only like Wifi to Infrared traductor in different devices.

Previous iTV research works could be placed within taxonomy of activity that is divided into three categories: Content Control, content editing and content sharing (Cesar and Chorianoopoulos 2009). Pablo Cesar et al. (2009) propose a more complex model architecture. Their work defines taxonomy of global actions with interactive television. This classification is divided into three levels high: content control, content enrichment and content sharing. In this paper we focus our prototypes on content control, covering among other things navigating of content, and the common video controls (Play, Pause, etc). Also we provide some prototypes for enrichment content.

2.2 Dual-screen research

In the study area of multiple-screens we should emphasize the study of Hutchings (2004) where is compared the general use of a single with multiple monitors (2 or 3). To do this, is evaluated how 31 people use different windows on Windows XP operating system. To carry out the evaluation is used a monitoring tool. As highlight features we can observe that the activation of additional screens arises as a consequence of the desire to hide information in the main screen display. Besides it is important to highlight that is not usually interact with the various windows of the same program.

Another study to really consider is from Grundin (2001). It shows that the users do not treat the second monitor as an additional space, so not establish a single window across multiple monitors. In addition users will typically set a monitor for the primary task and other tasks related to but not synchronized. Like other studies confirm the increased usability of multiple monitors in achieving greater satisfaction of users and more productivity. Besides, user satisfaction and efficiency, it is still an open research question whether coupled screens could also facilitate enjoyment. Early examples in the video-game industry have been well received (e.g., Nintendo link between GameBoy Advance and GameCube), but there are no published reports on user behavior in the context of leisure activities.

3. METHODOLOGY

In our research, we are exploring alternative multi-device visual interface configurations in the context of a leisure environment and for entertainment applications. For this purpose, we have developed a flexible experimental set-up, which we plan to employ in several user evaluations. The latter are focused on the actual user behavior in the face of important parameters, such as attention, engagement, and enjoyment.

3.1 Technological Set-up

The system architecture for the experimental set-up consists of:

- A TV connected to a set-top-box based on Linux.
- A tablet with Linux operating system installed (Figure 1)
- A local network that it is connected both devices.
- A remote controller connected to the set-top-box using Bluetooth. The design of the controller is based on a selection system based on six colors (Figure 2). These colors correspond to different options in the menu.



Figure 1 Tablet with SiESTA system

One of the most important settings is the way in which the tablet is connected bidirectionally with the set-top-box. To connect both interfaces we could use Bluetooth, RPC or HTTP-Request. Bluetooth is already used to interact between remote control and iTV. However, it is a better option to use RPC for a complex interaction because it is more scalable and flexible. For some operations and transmission of content is used HTTP-request. So, in the end, we can define the architecture as a double client/server between the tablet and the set-top-box. To implement the interface has been chosen HTML5 for its opened character.



Figure 2 - Current SiESTA remote controller

3.2 User Evaluation

Dual-screen interaction might not be suitable for every type of Television content. Actually, it might be rather suitable for some types of content, but completely irrelevant for other types of content. Although researchers have highlighted some of the benefits (e.g., personalized view of related content), they have not yet coupled them to the respective types of content. Instead, previous efforts have only regarded the technological facts, such as the segmentation of long videos, in shorter clips and providing links to related information. As a matter of fact, obvious choices of dual-screen compatible content include sports, news, documentaries, series, and movies.

This work is focused on the evaluation of a secondary-screen as a control device for TV content. Previous research has regarded the secondary-screen as an editing and a sharing interface, but has neglected the control aspect. Moreover, previous research has only concerned user attitude, but has neglected to employ a methodology that explains actual user behavior. Indeed, Cesar et al. (2008) have focused on the utility and the general acceptance of a dual-screen system, but have not employed any user behavior measurements. In particular, we are seeking to understand the balance between the shared and the personal screen during alternative TV-control scenarios that regard the secondary-screen as a: 1) simple remote control, 2) related information display, 3) mirror of the same TV content.

The main objective in the evaluation of a dual-screen TV set-up is the measurement of actual user behavior rather than just user attitude. For this purpose, we are measuring user attention and engagement with TV content. In contrast to measurements of efficient and effective task completion, which are common in work settings, we are focusing on measurements of user involvement with the TV content, which are common in a leisure setting. Moreover, we are working on measurements that consider the main of benefit of TV, which can be summarized as “a significant shared experience” within smaller or larger social circles, and regardless of the actual or perceived quality of the content.

In particular, we have developed a flexible experimental set-up for testing several hypotheses, such as those developed in previous related research:

- Cesar et al. (2009) ‘argue that secondary screens provide a less obtrusive mechanism for affecting television content than traditional solutions in the form of television overlays.’
- ‘A number of participants did not want to browse while something was already showing’ (Cesar et al. 2008).

3.3 Outline of ongoing research

For our research we consider the following situation: Peter is watching a cooking program on TV on demand and he wants to control the video content (play/pause/stop) and do some interactive actions like: see more information about the video, mark as favorite, share comments and watch related videos. It is worth highlighting that the proposed functionality is a subset of that provided by the API of YouTube, which is a rather diverse and growing pool of video content.

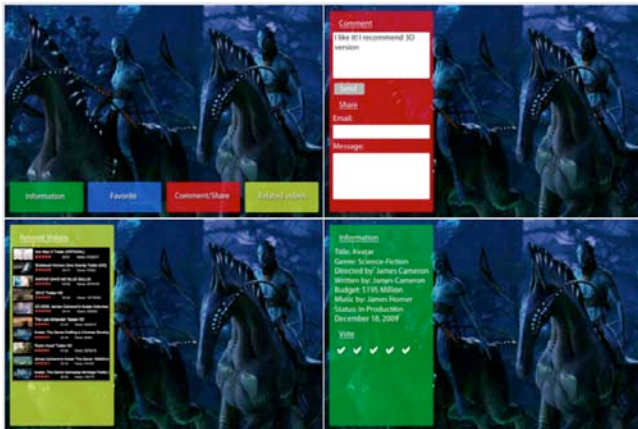


Figure 3 - Scenarios 1 and 3

So far we have developed three scenarios of tablet-TV interaction:

1. To Interact with iTV using a remote control (Figure 3): In this case user interacts with iTV using remote controller (Figure 2). To control the content there is a button in the remote controller to play or pause the video. To use interactive actions: Information, Favorite, Content/Share and Related Videos, the user press the color buttons to access every one. When the user presses one-color button

a bigger rectangle is opened. Now the remote controller is used to move (up or down) the focus into the content. When the user wants to select an option he would press the central button. To introduce text it is necessary an extra keyboard. On the top-left of figure 3 we can see the possible actions: Information, Favorite, Comment and share and Related Videos with different colors to be associated with remote control. On the top-right we can see the dialogue shown when we want to comment or share the video. On the bottom-left is shown a list of related videos and, on the bottom-right, information about the content, ratings and comments.

2. To interact with iTV using a tablet as remote controller (Figure 4): In this case, all the overlay information shown in the first scenario is displayed in the tablet cleaning the first screen of interactive information so it wouldn't disturb other users. On the top-left we can see the main functionality, although the same options are shown, more functionality could be added and access to it with one click or tap on the screen. Basically the figure 4 shows the functionality cited before although now the Play/Pause controls are in the tablet. Now to introduce text is shown a virtual keyboard in the tablet screen. (Figure 5)

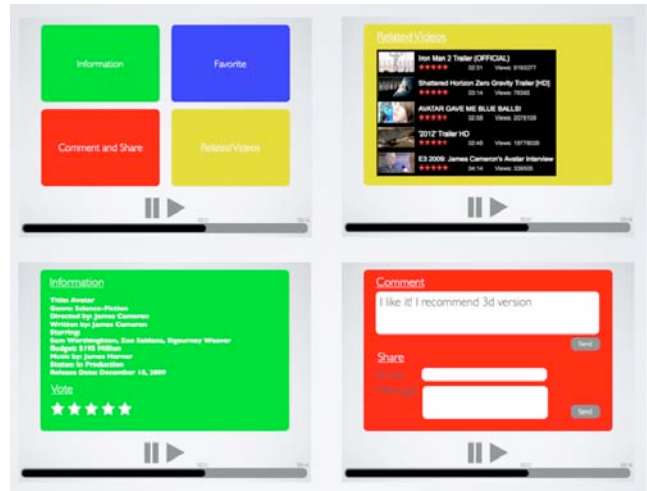


Figure 4 - Scenario 2

3. iTV inside the tablet (Figure 3): This scenario suppose that the user is watching the iTV in the tablet so the prototypes is very similar to the Figure 3 but, in this case, it would be the tablet screen. In this prototype would be necessary to introduce a video control bar similar to the scenario two. (Figure 4).

Although in scenarios 2 and 3 is not necessary, in all prototypes the buttons are differentiated by colors to provide consistency between them.

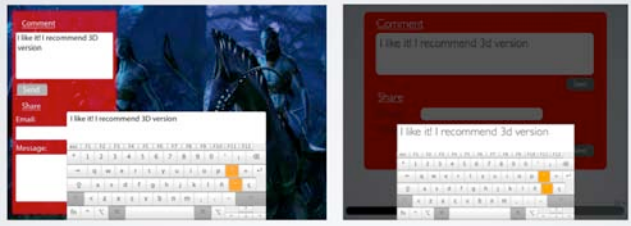


Figure 5 - Virtual keyboards in scenarios 1 and 3 (left) and in scenario 2

4. EXPECTED OUTCOMES

As it has been shown three scenarios include the same options and functionalities. It is important to remark because the more complex are these functionalities the more appropriate it will be the tablet to do that. But when we do common actions that we usually do when we watch videos on Internet is when the advanced visual interfaces in a second screen can affect the user attention in a negative way.

In summary, we are motivated by the introduction and wide adoption of small and powerful mobile computers, such as smart phones and tablets. The latter has raised the opportunity of employing them into multi-device scenarios and blending the distinction between input and output. In particular, we are addressing the following research questions:

- Do the advanced visual interfaces compete or cooperate for the attention and the benefit of the user? We have seen in related work (Hutchings, 2004)(Grundin, 2001)(Yang et al., 2009) how the productivity increases and how the content distortion decreases when we use multiple displays, so the expected results could be a better user experience in scenario 2 for content controlling. It is relevant to indicate, “for content controlling” because the user evaluation in other more complex actions the scenario 3 a better option.
- How coupled-display visual interfaces are appreciated in multi-user scenarios? Scenario 2 let’s separate all the overlay information in the second screen so the rest of user don’t be disturbed. But sometimes it is possible that the users want or need particular information in the main screen so in these cases would be better a new scenario configuration. This scenario would be based on scenario 3, but the tablet user would have the possibility of showing the information that he wants (video, comments, ratings, etc.) in the main screen acting as extended screen and transforming the scenario 3 in scenario 2. For this comment, a hypothetical better user experience could be obtained in a mix between scenario 2 and 3.

Anyway, it is expected that the case study of TV users and TV content could provide complementary evidence for the design of coupled display interfaces in general.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

- [1] Cesar, P., Bulterman, D. C., Geerts, D., Jansen, J., Knoche, H., and Seager, W. 2008. Enhancing social sharing of videos: fragment, annotate, enrich, and share. In Proceeding of the 16th ACM international Conference on Multimedia MM '08. ACM, New York, NY, 11-20.
- [2] Cesar, P., D.C.A. Bulterman, and J. Jansen, 2009. Leveraging the User Impact: An Architecture for Secondary Screens Usage in an Interactive Television Environment. Springer/ACM Multimedia Systems Journal (MSJ), 15(3): 127-142
- [3] Cesar, P. and Chorianopoulos K. (2009). The Evolution of TV Systems, Content, and Users Toward Interactivity. Foundations and Trends in Human-Computer Interaction, 2(4): 279-374.
- [4] Fallahkhair, S., Pemberton, L. and Griffiths, R. 2005. Dual Device User Interface Design for Ubiquitous Language Learning: Mobile Phone and Interactive Television (iTV)
- [5] Grudin, J. 2001. Partitioning digital worlds: focal and peripheral awareness in multiple monitor use. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. CHI '01. ACM, New York, NY, 458-465.
- [6] Hutchings, D. R., Smith, G., Meyers, B., Czerwinski, M., and Robertson, G. 2004. Display space usage and window management operation comparisons between single monitor and multiple monitor users. In Proceedings of the Working Conference on Advanced. Visual interfaces. AVI '04. ACM, New York, NY, 32-39.
- [7] Kang, Y. and Stasko, J. 2008. Lightweight task/application performance using single versus multiple monitors: a comparative study. In Proceedings of Graphics interface 2008. GI, vol. 322. Canadian Information Processing Society, Toronto, Ont., Canada, 17-24
- [8] Robertson, S., Wharton, C., Ashworth, C., and Franzke, M. 1996. Dual device user interface design: PDAs and interactive television. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. CHI '96. ACM, New York, NY, 79-86.
- [9] Weiser, M. Some computer science issues in ubiquitous computing. Communications of the ACM, 36, 7, (July 1993), 75-85. Spector, A. Z. 1989. Achieving application requirements. In *Distributed Systems*, S. Mullender, Ed. ACM Press Frontier Series. ACM, New York, NY, 19-33. DOI= <http://doi.acm.org/10.1145/90417.90738>.
- [10] Yang X., Mak E., McCallum D., Irani P., Cao X., Izadi S.. LensMouse: Augmenting the Mouse with an Interactive. CHI 2010: Displays Where You Least Expect Them April 10-15, 2010, Atlanta, GA, USA
- [11] Brad A., Using handhelds for wireless remote control of PCs and appliances. *Interacting with Computers* 17 (2005) 251-264

Exploring Gesture-Based Interaction Techniques in Multi-Display Environments with Mobile Phones and a Multi-Touch Table

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ABSTRACT

In this paper, we explore the potential of combining shared and interactive displays (e.g. a multi-touch table) with personal devices (e.g. mobile phones) as an important class of heterogeneous multi-display environments. Within six case studies applications and interactions were invented and implemented that utilize the potential of such heterogeneous multi-display environments. We were in particular interested how to design systems that include interaction across different displays and how to manage public and private information in a group setting. One case study, a digital card game, highlights these design challenges. A player has personal information (her cards), and there is public information (e.g. the cards on the table). Additionally, inherent interaction between both (e.g. transferring cards from the phone to the table and vice versa) is possible. We explore different natural ways of interaction, including touching the table as well as tilting, throwing, and shaking. With this application we provide a use case to discuss gestures combining mobile phones with tabletop surfaces, as well as to explore a private-public display setting. First results showed that combining tables and mobile phones provide a suitable and understandable way for interaction in these settings.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *input devices and strategies, interaction styles*

General Terms

Design, Human Factors.

Keywords

Multi-Display Environment, Mobile Phone, Interactive Surface, Gestures, Multi-Touch Table, Card Games

1. INTRODUCTION

Heterogeneous multi-display environments allow the combination of small personal devices (e.g. phones) and larger shared devices like multi-touch tables. The integration of these different devices enables new application scenarios: users can, e.g., connect their mobile phone to a table and share their personal data, save new data, give presentations, order foods, do shopping, or play games. Phone and table are both used as input and output devices. The phone provides means for keyboard and gestural input and it serves as a small display for personal (graphical) information.

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Figure 1: Poker Surface: an example application integrating mobile phone interaction and a multi-touch table.

The table allows multi-touch interaction and a shared visualization on the tabletop. If we look at the integration of multi-touch tables and mobile phones with sensors (in particular accelerometer sensors), a set of different interactions can be combined: (multi-) touch interaction on the table, interaction on the mobile phone, or mobile phone gestures through movement of the phone. For the mentioned scenarios the question arises how the interaction can be designed. Which interaction techniques are useful for what kind of task? For which tasks and how should we interact with the mobile phone? When should we interact directly on the table?

Our research addresses three topics:

- (1.) designing embodied and intuitive interactions for specific tasks combining **mobile phone gestures** and **tabletop interaction**
- (2.) understanding and utilizing the benefits of setups that combine personal **private** and shared **public displays**, and
- (3.) exploring the potential of tabletop and mobile phone interaction for **different types of concrete applications**.

In this paper, we first discuss our design approach for “mobile phone and tabletop settings” and present results from an investigation on the use of mobile phone gesture interaction with interactive tabletops within six case studies. Furthermore, we present one case study in greater detail: a tabletop poker game as an example for a digital card game combining mobile phones and a multi-touch table (see Figure 1). Finally, we discuss the results from first investigations with users, the used interaction techniques, and future work.

2. DESIGN APPROACH

The evolving field of multi-display environments comprises a broad variety of settings with large interactive surfaces (walls and tables) and small displays (e.g., PDAs, tablets, mobile phones) [9]. Terrenghi et al. [12] have structured this design space

into a taxonomy that distinguishes three main factors: the size of the ecosystem, the nature of social interaction, and the type of interaction technique. In this work, we focus on the interaction with mobile phones and a multi-touch table, which can be – according to [12] – classified as “yard size ecosystem”. The social situation that is evoked by the setup can be characterized as “one-few” and “few-few” as data can be either sent from mobile phones to the table (one-few), or it can be manipulated directly and collectively on the tabletop surface (few-few). The coupling between mobile devices and the multi-touch table was initiated explicitly through a request from the mobile device (via key input). We focused on the interaction design and wanted to integrate natural human movement. Thus, we put an emphasis on exploring gesture-based interaction techniques with the mobile phone. What mobile phone gestures could be useful to interact with a digital table? Were users able to grasp the concept? Did they like it? Or did they prefer direct touch interaction on the table?

Nowadays, mobile devices can serve as universal devices for many different applications. When enhanced with accelerometer sensors, they can be used for gesture input [2] and are well suited for novel interactions with large screens, as for example done in [5]. Gestures are a natural way to interact, and we can find unlimited examples in everyday life (e.g., [3]). These can be taken as a starting point for the design of novel interactions with the digital. Through tilt interactions, which have been investigated in various researches (e.g., [8]), gestures can be realized with accelerometer-equipped mobile phones. By using a mobile phone in combination with an interactive table, the concept of private and public display areas can be realized in tabletop applications. The potential of small private screens with large public displays has been examined in previous research, e.g. [6].

To explore this design space, we organized a practical lecture with 13 students (from systems engineering and information systems). We provided a multi-display setting including a multi-touch table with a 100 cm by 80 cm surface (using the FTIR principle, see e.g. [7]) as well as a set of Nokia N95 mobile phones (include accelerometers). The phones and the tabletop could be connected via Bluetooth. The task for the students during the course was to design and develop applications, which used this setting. Visual output should be provided on the table as well as on the display of the mobile phone. Furthermore, interactions should be designed carefully, considering the potential of the mobile phone as a personal device and the tabletop surface as a shared surface. The students also had to come up with a specific use scenario: what interactions would suit their chosen situation?

The students designed and developed in total six different projects (in groups of 2-3 persons). All six applications realized mobile phone gestures combined with multi-touch interaction on the tabletop. While trying out and analyzing these six applications, we came up with a first set of mobile phone gestures for interaction with tabletop surfaces that turned out to be useful and intuitive (see Table 1). We think, being transferred to a more general application context than our first case studies, the gestures have potential to form a first step towards a design space for mobile phone gesture interaction with tabletops.

Overview of the realized projects:

An interactive café table: This application was built for a café scenario, where users can order drinks and food on an interactive table. The menu was displayed on the table and could be browsed

via touch or by a mobile phone gesture (e.g. via a rotate gesture, see Table 1 (3.)). Selections could be entered via touch or by shaking the mobile phone (see Table 1 (4.)).




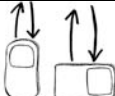

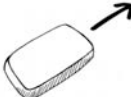
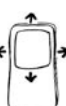

Gesture	Description	Usage in Applications
	(1.) Holding the mobile phone horizontally	Passive mode: personal data is not shown on the mobile phone display; used for playing cards
	(2.) Holding the mobile phone vertically	Active mode: personal data is shown on the mobile phone display; used for playing cards
	(3.) Rotating the mobile phone 90 degrees to the left or right	Scrolling / turning a page of a file (e.g., a menu, a presentation) on the tabletop surface
	(4.) Shaking the mobile phone/ moving it up and down	“Pressing Enter”: e.g, select an item, finish an input
	(5.) Moving the mobile phone with face up horizontally towards the table	“Throwing” data from personal display on the mobile phone onto the tabletop surface (information is shown)
	(6.) Moving the mobile phone with face down horizontally towards the table	“Throwing” data from personal display on the mobile phone onto the tabletop surface (information is hidden)
	(7.) Tilting the mobile phone	1. Navigation in a 2D plane, discrete mapping (e.g. in a control menu) 2. Tilting a digital 3D plane on the tabletop surface, cont. mapping
	(8.) Vibration of the mobile phone (feedback only)	Alerts a user concerning activities on the tabletop surface

Table 1: A set of mobile phone gestures for interaction with a tabletop surface. Subsets of these gestures were applied within six case studies with mobile phone and tabletop surface setting.

A presentation tool: With the presentation tool, users could send presentations from a mobile phone to the table. Navigating the pages in the presentation was done by rotating gestures (see Table 1 (3.)). Additionally, the table provided personal annotation areas for all participants, which were directly editable by touching the surface.

A marble game: The implemented marble game was similar to existing games, where a virtual ball rolls over a plane that can be adjusted in 3D. The game target was to let the ball drop into a certain hole. Here, the orientation of the plane was manipulated by a tilting gesture (see Table 1 (7.2)). Focusing on social aspects, additional to existing games, the layout of the game (e.g., obstacles and holes) could be drawn onto the table through direct touch input in a configuration mode by people standing around the table. The game itself was as well presented on the tabletop display.

A board game: In this project, an existing physical board game was translated into a multi-touch tabletop game with connected mobile phones. Cards that formed the board game background were displayed on the tabletop and could be manipulated via multi-touch interactions. Mobile phones were used to “roll a dice” realized by a shaking gesture (see Table 1 (4.)), as well as to display action cards (see Table 1 (2.)). Furthermore, players were informed that it was their turn via vibration feedback (see Table 1 (8.)).

A memory game: A physical game named “Simon” was translated to a tabletop multiplayer game. The game could be played either using the mobile phone or directly on the table. The aim of the game was to remember and select a sequence of colored areas. The mobile phone was used to navigate in the grid of colored fields by tilting (see Table 1 (7.1)).

A poker game: This version of the poker game used mobile phones to display one player’s cards (see Table 1 (1), (2)) and smoothly integrated the phone and the tabletop display, e.g., via a “throw gesture” cards were digitally sliding onto the table (see Table 1 (5), (6)). Furthermore, a set of direct touch interactions was implemented. We will discuss this case study in greater detail in the following section.

3. CASE STUDY: A DIGITAL CARD GAME

The application area of augmented tabletop gaming is part of the research field “pervasive gaming” [1] that works towards a better integration of the digital into the physical world. First steps have been made to use motion interaction with mobile phones in pervasive games (e.g. [4]). Other related approaches have worked on digitally augmenting card games [10]. In order to explore and evaluate a novel combination of intuitive interaction techniques at the tabletop display, a digital poker game¹ was designed, implemented, and tested. This part of the paper was previously shown and published as a poster at MobileHCI 2009 [11].

3.1 Traditional Interactions in Poker Games

In a poker game players are seated around a table, which is the game field. In addition to playing cards, chips, which are small discs used in lieu of currency, are used as objects in the game. Based on the game’s rules, a player can *fold*, *check*, or continue *betting*. *Folding* may be indicated verbally or by discarding one's cards face up or down into the center of the game field. When a player *checks*, he declines to make a bet. A common way to signify *checking* is to tap the table. For *betting*, players place a stack in front of them using the chips. During the game, players may play tricks (manipulations) with chips.

3.2 Interaction in Poker Surface

The interaction metaphors of the classical Poker game (*folding*, *checking*, and *manipulating chips*) are mapped to the digital domain using a digital tabletop and mobile phones with built-in accelerometer sensor. The following sections describe the setup and the interaction techniques with mobile phones as well as the interaction with the multi-touch table.

¹ A video of the application can be found here: <http://www.youtube.com/watch?v=BgNJv8EKuD0>

3.2.1 General Setup

The multi-touch enabled tabletop surface is used as the game field (see Figure 2). Players can distribute around all four sides of the table. They get their own personal areas for digital cards and digital chips on the table in front of them. Additionally, each player can connect a mobile phone via Bluetooth to the table and use it as additional game console for gesture input and as a private display for showing a player’s cards. Table 2 gives an overview of the different interactions and their realization in classical, multi-touch, and mobile-phone gesture modes.

Classical Poker Interaction	Multi-Touch Table Interaction	Mobile Phone Interaction
Look into cards	Double click on cards	Hold the phone vertically/horizontally
Check (tap table)	Double click on the table	Rotate the phone 90° left or right + shake the phone
Fold with cards face up/down	Drag cards	Phone face up/down + throw gesture
Bet/manipulate chips	Drag chips/double click or long click	(not implemented)
Move/Rotate a card	Select and rotate a card with two fingers (multitouch gesture)	(not implemented)

Table 2: Mapping the interaction from the classical poker game to tabletop and mobile interactions.

3.2.2 Interaction Techniques with the Digital Table

We aimed to design and map similar interactions as in the classical game on the table. Players can drag and move card/s and chip/s for betting as well as knock the table two times as in the classical game for checking. Players can split a big chip into two or more chips with smaller value by double clicking on a chip, or the other way round, group two chips together and make a chip with bigger value by performing a long click (3 seconds) on the top chip. Users have to cover their cards on the table (e.g. with their hand or a sheet) when they want to look at them, in order to make sure that the other players do not see them.



Figure 2: The poker game surface on the multi-touch table.

3.2.3 Interaction Techniques with Mobile Phones

Mobile phones offer further options to play the game. They offer private displays to show a players hand and thus provide a tangible feeling of holding “cards in the hand”. For looking into the cards, we implemented a natural tilting gesture: if the phone is held horizontally or is lying on the table, the faces of the cards are down; if it is tilted vertically the faces are shown (see Figure 3a). Furthermore, we implemented gesture interactions for *folding* the cards, either with cards faces up or down: a quick horizontal movement of the hand towards the table tosses the cards onto the table and they digitally slide into the center of the tabletop (see Figure 3b). The *checking* action can be performed by tilting the

phone 90° to the left or right and by shaking the phone (see Figure 3c). All interactions are shown in Figure 3.

3.2.4 Investigations with Users

To evaluate our system, first investigations were carried out with 20 participants, 18 males and 2 females with an average age of 24 years. All participants were familiar with playing Poker, and 40% of them played Poker at least once per month. The participants were divided into 7 groups (3 persons per group; one participant had to play twice). Each group played the game twice, once directly on the table without the phone and once with the phone as game console. The study took around 30 minutes per group. At the end, participants were asked to fill out a questionnaire in which they ranked how hard or easy the different interactions on the multi-touch table and on the mobile phone were to perform. Further, we asked them how they liked each interaction based on a 1 to 5 point Likert scale.

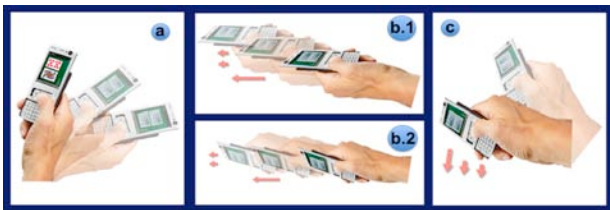


Figure 3: Natural gesture interactions with the mobile phone: (a) look into cards, (b.1) fold with cards open, (b.2) fold with cards closed, and (c) check.

Overall, the players liked the novel interactions we provided in the Poker game: 80 % of the participants stated that they would like to play Poker again in a setting with mobile phone and multi-touch table. The study showed that the chosen setup was feasible and, without long familiarization, easy to use. It allowed fluent interactions and the participants enjoyed playing. It demonstrated that the combination of tabletop UI and mobile phone did not lead to a more complicated interaction – participants did not rate the pure tabletop interaction mode easier to use than the combination of both. This supports our approach of an integration of the different devices. The results show that gestures with mobile phones are appreciated by users. Even those who found gestures difficult to perform still liked them. This indicates that, albeit some gestures seem harder to perform, users are willing to put up with challenges because they enjoy gestures a lot.

4. CONCLUSION AND FUTURE WORK

There are many setups where people sit together around a table, bring additional material and interact. A typical example is a traditional meeting where the participants each bring a stack of papers and discuss them. With tables becoming effectively interactive computers (e.g. multi-touch tables) and the additional material becoming digital (e.g. on a phone or e-book) interesting interactive multi-display environments emerge.

Our research suggests that mobile phone gestures are a promising approach to interact with digital tabletop surfaces. Within six case studies, gesture-based interaction ways were explored, designed, implemented and tested. Overall, we conclude that there is a set of different intuitive gesture interactions that is useful across several application domains. The interaction techniques presented offer a first step towards a design space for mobile phone based gesture interactions with interactive tabletops. Additionally, the combination of a shared table and personal phones gives powerful

design options for creating interactive systems with public and private presentations and shared as well as personal means for interaction. Our initial results show that performing the interactions with mobile phones in combination with tabletop UIs was considered easy by the users. They liked the phone as device for private data and personal interaction. Future work will include further studies on how intuitive users regard the motion gestures as well as research towards a generalisable set of interaction techniques that combine multi-touch and motion gestures.

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6. REFERENCES

1. Benford, S. Magerkurth, C. and Ljungstrand, P. 2005. Bridging the physical and digital in pervasive gaming. In *Communications of the ACM*, 48(3):54–57.
2. Bhandari, S. and Lim, Y. Exploring gestural mode of interaction with mobile phones. 2008. In *Proceedings of CHI EA '08*. ACM, New York, NY, 2979-2984.
3. Brereton, M., Bidwell, N., Donovan, J., Campbell, B., and Buur, J. 2003. Work at hand: an exploration of gesture in the context of work and everyday life to inform the design of gestural input devices. In *Proc. of AUIC 2003. International Conference Proceeding Series*, vol. 18. Australian Computer Society, Darlinghurst, Australia, 1-10.
4. Chehimi, F. Coulton, P. 2008. "Motion Controlled Mobile 3D Multiplayer Gaming", In *Proc. of ACE '08*, Yokohama, Japan, pp. 267-270.
5. Dachsel, R. and Buchholz, R. 2009. Natural throw and tilt interaction between mobile phones and distant displays. In *Proc. of CHI EA '09*. ACM, New York, NY, 3253-3258.
6. De Luca, A. and Frauendienst, B. A privacy-respectful input method for public terminals. 2008. In *Proceedings of NordiCHI '08*, vol. 358. ACM, New York, NY, 455-458.
7. Han, J. Y. 2005. Low-cost multi-touch sensing through frustrated total internal reflection. In *Proceedings of the 18th Annual ACM Symposium on User Interface Software and Technology*. UIST '05. ACM, New York, NY, 115-118.
8. Rahman, M., Gustafson, S., Irani, P., and Subramanian, S. 2009. Tilt techniques: investigating the dexterity of wrist-based input. In *Proc. of CHI '09*. ACM, New York, NY, 1943-1952.
9. Quigley, A., Subramanian, S., and Izadi, S. 2009. Special issue on interaction with coupled and public displays. *Pers. Ubiquitous Comp.* 13, 8 (Nov. 2009), 549-550.
10. Römer, K. and Domnitcheva, S. 2006. Smart Playing Cards: A Ubiquitous Computing Game. In *Pers. Ubiquitous Comp.* 6:371–378.
11. Sahami Shirazi, A., Döring, T., Parvahan, P., Ahrens, B., and Schmidt, A. 2009. Poker surface: combining a multi-touch table and mobile phones in interactive card games. In *Proc. of MobileHCI '09*.
12. Terrenghi, L., Quigley, A., and Dix, A. 2009. A taxonomy for and analysis of multi-person-display ecosystems. In *Pers. Ubiquitous Comp.* 13, 8 (Nov. 2009), 583-598.

Digital Hospitality: Expressing hospitality towards guests in smart homes using private and domestic displays

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ABSTRACT

For more than a decade the use of ubiquitous computing technologies in the domestic space – the so-called smart homes – has been a subject for research. While research projects and findings has focused on smart homes and its inhabitants in various incarnations, little or no research has been questioning how these smart homes engender hospitality towards guests and how inhabitants in a smart home can express hospitality using ubiquitous technologies. This paper defines the novel notion of “digital hospitality” and proposes an early state system design based on coupled displays. The system called EWIA is designed to facilitate and strengthen the relationship between guest and host by utilizing both private smart phone displays and domestic displays. Preliminary results and topics for discussion are reported.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces;

H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces; H.5.2 [User Interfaces]: Theory and Methods; User-centered design.

General Terms

Design, Experimentation, Human Factors, Theory

Keywords

Mobile user interfaces, Group interfaces, Ubiquitous computing technologies, Digital hospitality

1. INTRODUCTION

For more than a decade ubiquitous computing technologies in our homes has been an interesting research topic for researchers.

Integration of ubiquitous computing technologies in domestic settings can in done in various ways ranging from robotic vacuum cleaners to pervasive health care. Most of this research focuses on

how to facilitate the inhabitants of the home and has an overall goal to make their everyday easier and more enjoyable. Less focus is on guests and visitors and the relationship between guest and host. Homely routines, gestures and interactions with domestic technologies might change when having guests, and domestic technologies should adapt to such situations. Based on this assumption the novel notion of “digital hospitality” is defined. “Digital hospitality” is about using technology to make life easier and more enjoyable for both guest and host in domestic settings.

In order to examine the practical and physical properties of “digital hospitality” a simple ubiquitous computing prototype called EWIA is being designed. EWIA is an early state ubiquitous computing prototype using domestic coupled displays to let guests display personal digital photos on e.g. the big screen TV in the living room of the home being visited. EWIA explore concepts and routines such as guests *entering* and *leaving* a home and the opportunity for the guest to give a digital photo to the guest as a *digital gift*.

The results presented in this paper are still work in progress and views on user evaluation and further development is discussed throughout the paper.

2. RELATED WORK

This section covers related research both in terms of domestic technology research and visual display research.

2.1 Technology in the Domestic Space

Back in 2001 Edwards et al [1] compiled a set of seven challenges for designers and researchers to take into consideration when designing ubiquitous computing technologies for the domestic space. The first of these challenges cope with the so-called “accidentally” smart home; the notion of the “accidentally” smart home is a reaction to the holistic, predesigned and purpose build homes that are used for lab testing of “the future smart home” [2] – in the following referred to as “lab homes”. The “accidentally” smart home is a *real* home which contains pieces of different smart technology (e.g. alarm system, wireless speakers ...). These pieces of technology are brought in to the home piece by piece to e.g. entertain the kids (a gaming console) or solve a certain labor task (robotic vacuum cleaner or micro wave oven). These pieces of technology all together potentially make the “accidental” smart home grow smarter over time. The so-called lab homes, on the contrary, are considered smart from the very start [2]. The lab homes already contain all the technologies necessary to make a home smart – all the

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technologies are placed correctly in the domestic space and the different technologies are able to communicate with each other.

An interesting work in progress is presented in [3]. The authors present a digital photo frame called “Cherish”. The “Cherish” system is focusing on how digital photos are organized and displayed. “Cherish” identifies persons on digital photos and store relationships between them. Context aware technologies in “Cherish” detects persons in a room and only display photos related to the persons who are present in the same room or home as “Cherish” (e.g. a father is visiting his son; the “Cherish” picture frame only displays family photos of father and son).

A lot of research has been put into the analysis of routines in the domestic space. Both [4, 5] and [6] analyses the domestic routines and the role of technologies in the home. The result of this research is a set of tools that uncover important physical places of domestic communication. The *sensitising concepts* are an example of this; it is a conceptual framework with which we can talk about ubiquitous computing technologies in the domestic space. In [6] the three *sensitising concepts* (also referred to as *flow of communication*) are:

“ * **Ecological Habitats:** *places where communication media live and where residents go in order to locate particular resources.*

* **Activity Centres:** *places where media are actively produced and consumed and where information is transformed.*

* **Coordinate Displays:** *places where media are displayed and made available to residents to coordinate their activities.*” [6]

The *Ecological Habitats*, *Activity Centres* and *Coordinate Displays* are places in the home that are important to the flow of communication and the domestic routines in the home.

2.2 Visual Displays in Domestic Research

Placing visual displays in domestic settings is of great interest especially in industry and research – and especially with the introduction of Internet connected HD TV’s and digital picture frames. “Cherish” is an example of such a domestic visual display. The same goes for [7] where the authors place different kinds visual displays (augmented picture frame, web page, cell phone) in the homes and every day life of the test subjects. Selected family members have the possibility to display holiday pictures on the display devices. In [8] Taylor et al explores the area of digital photo display through field studies. The paper presents a guideline for designing domestic photo displays and discussions on actual design ideas.

3. DEFINING THE NOTION OF “DIGITAL HOSPITALITY”

While the literature over the last decade has contributed with lots of interesting usages of technology in the domestic space, most of these designs are aimed to facilitate the inhabitants who already live in the home. Not much work has been done to facilitate visitors and guests in smart homes. Sure, guests and visitors are appearing in ubiquitous computing research but mostly as visitors in museums or in design of surveillance systems (where the guests in question are often uninvited). But hospitality towards guest and the act of being a good host/guest have not coursed much attention in the communities of domestic and ubiquitous computing research. For this reason I introduce the novel notion of “digital hospitality” which I define in the following way:

The notion of “Digital Hospitality” covers technologies and methods to enrich the experience and expression of hospitality towards guests in domestic settings using ubiquitous computing technologies. In other words: digital hospitality is about using technology to make life easier and more enjoyable for both guest and host in domestic settings.

The definition raises lots of interesting questions: what kinds of ubiquitous computing technology in the smart home will make things easier or more enjoyable for inhabitants when having visitors – and for the person being a guest in a smart home?

To make things clear I define a *visit* as: 1) *to go or come to see (someone) out of friendship or for social reasons; and/or 2) the act of going to see some person or place or thing for a short time.*¹

A visit has three main actors: 1) the person being visited – called the *host*; 2) the person who is visiting the host – called the *guest*; 3) the place being visited – called the *home*.

3.1 Interesting issues in “Digital Hospitality”

To dig further into “digital hospitality” I have put up three issues that might help to uncover how routines in the home changes when guests are present.

The act of being a good host: How do we define and frame routines involved when an inhabitant wants to be a good host towards a guest and wants to use domestic technologies to enhance this experience?

When guests enter and leave the home: Unlike inhabitants a guest may not come back to the home for a long time and the home is not considered the guest’s private sphere. Because of this the action of *leaving* and *entering* a home is a different routine than it is for the inhabitants of the home. E.g. when guests leave a home after a visit they probably want to make sure they don’t leave anything behind. Furthermore when guests enter a home they might want to announce their presence by approaching the host – and the host wants to welcome the guest.

Using the guest’s private digital media and private mobile device in the home: The home is considered the private sphere and comfort zone of its inhabitants. The guest – on the contrary – does not, by default, have any private sphere in the home he/she is visiting. On the other hand, the guest might be interested in bringing some private digital media into the home being visited; e.g. if the guest wants to – as part of telling a story about a vacation - show a digital photo on the host’s big screen TV as proposed in [9]. This can be done already by existing technology but the technology is not very “host minded”. If the guest wants to show a digital photo he/she can: 1) ask the host to use e.g. the living room computer and then log into a photo sharing website using his personal credentials; 2) another way is for the guest to bring his/her digital camera hoping that he/she has a cable that fits into the host’s TV (or that the host has a converter from the guest’s cable) ; and 3) to show the picture on the built in display of the digital camera or mobile phone. While the last option might be the easiest way – and maybe the most often used – the small display size does not reveal much details in the image, and the fact that at least one of the viewers have to hold the device in the hand for a long time is not an optimal solution. The first two options all have better display configurations and enable the guest

¹ With inspiration from the Princeton University WortNet Web dictionary: <http://wordnet.princeton.edu/>

to tell the story of the digital photos while showing them, but both methods – besides being quite cumbersome – requires the guest to enter the private spheres of the host. In the first case the guest needs to interact with the host's private computer and the guest even has to type credentials to a digital photo website; the second one requires the guest and host to alter the setup of the TV system by connecting cables and changing settings on the TV.

Lastly it is possible to use a wireless media transfer and streaming technologies such as Bluetooth, UPnP A/V or DLNA². These wireless media transfer and streaming (in the following called WMTS) technologies deals with some of the issues from the other possibilities: the wireless nature of the technology makes cables, converters, card readers etc. unnecessary and thereby not necessitating any changes to the physical setup in the home; further more it is possible to present a digital photo without logging into a web service on the hosts computer or showing the photo on the small built-in screen on the digital camera or mobile phone.

While these WMTS technologies at first sight seem to solve all problems involved when using domestic technologies to express hospitality and encourage friendly conversation, they have some pitfalls. In short the pitfalls cover:

1. The first pitfall is that WMTS technologies are, as a rule, not context aware. This means that WMTS technologies does not know if the guest is sitting in the living room and looking at the big screen TV, or if he is sitting in the arm chair in the hall listening to music. All WMTS technologies support some kind of wireless discovery technology. The discovery technologies scans for supported displays within the wireless range and then presents a list of available devices. It is then up to the user to be able to select the device he wants to interact with – e.g. it is possible for a guest using WMTS technologies in a home he/she is visiting to play music on the stereo in the kids room or showing his photos on the picture frame in the kitchen even though he is sitting in the living room. Technologies like “Bluetooth 2.1+EDR”³ tries to cope with the issues of context awareness but technologies like wireless indoor positioning are still under development and too expensive for the ordinary man.
2. The second pitfall is that WMTS technologies do not cope with domestic routines – especially routines involving guests. As mentioned earlier the action of entering and leaving a home is a primary routine for the guest. When leaving a home the guest might want to ‘delete’ or unload some or all of his/her digital media from the displays in the home. E.g. if the guest have been showing some digital photos to the host on the big screen TV in the living room, he might want to remove those pictures from the TV screen when living so that other inhabitants in the home doesn't see them hours after the guest has left the house. On the other hand the guest might want to ‘give’ some digital photos to the host by letting them stay on a display in the home even after he/she leaves. Controlling what to clean up and what not to clean up when leaving is not supported by the WMTS technologies.

4. EWIA: ENRICHING THE EXPERIENCE OF BEING A GUEST AND HOST

In order get a practical and physical view on digital hospitality a simple ubiquitous computing prototype is being designed. EWIA (Express Where I Am) is an early state system design based on coupled displays. With its basic design grounded in the literature EWIA is an effort to design a piece of ubiquitous computing software that implements *digital hospitality*. To make things more graspable I decided to only focus on digital photos; especially EWIA should give the host the ability to let his/her guests use the visual displays in the home during the visit. The guest should – when invited to by the host – be able to display his/her own digital photos on the host's visual displays (e.g. the TV or digital picture frame).

The following illustrative example gives an impression of how EWIA is working:

“Joe is invited to visit Jane in her apartment down town. Joe has just been on a wonderful vacation for two weeks and he is excited to show all his vacation photos to Jane. Joe's photos are stored on his iPhone and he never goes anywhere without his iPhone. Jane knows that Joe likes to talk about his vacations and she wants to give him the best possibilities to do that. When Joe enters Jane's home he instantly takes his iPhone out of his pocket: “I have brought some photos I'll like to show you.” he says. They sit down on the couch in the living room and Jane says: “I'll love to see the photos of your vacation. Please, use my TV!” and she points at the TV. By the TV there is a *connection point*. When Joe touches this connection point with his iPhone an RFID chip in the iPhone tells Jane's home server that Joe is now able to display photos on the big-screen TV in the living room. A dedicated EWIA-app installed on Joe's iPhone lets him browse all photos stored on the iPhone as well as photos stored on Flickr and Facebook. When Joe taps a photo thumbnail on his iPhone, the photo is shown on Jane's big-screen TV. Joe shows a photo of his visit at lake IJsselmeer and Jane says: “I'll like to show that photo to one of my friends some day – he's from Nederland and he was raised near lake IJsselmeer”. “Sure, you can have it” Joe says. Joe walks across the room where the digital picture frame is. A *connection point* is placed at the bottom of the picture frame. Joe touches the connection point with his iPhone and his photo of lake IJsselmeer is instantly transferred to the picture frame. After hours of talking – mostly done by Joe – they decide to call it a day. Joe leaves Jane's home. Just before leaving he scans a connection point placed right next to the door handle. When this point is scanned all the photos displayed on the TV and picture frame are gone; only the photo he gave to Jane is still present on the picture frame.”

The above example illustrates concepts inspired by the previous section on digital hospitality. The first one mentioned is the *connection point*. Connection points are used to initiate the connection between the EWIA-app running on Joe's iPhone and the home server placed at Jane's home. The EWIA-prototype is currently designed to use RFID tags and RFID readers but other contactless techniques could be used as well. The connection points is a way to detect when guests are *entering* or *leaving* a home and well as to detect interaction with *activity centres*[6] in the home.

The next concept is the fact that the digital photos are part of friendly conversation and hospitality. Jane is the host, and to express hospitality towards Joe she encourages him to use her big-screen TV in the living room to display his photos. The way she expresses this kind of hospitality is by handing over a physical artifact - the TV remote - to Joe. Joe accepts Jane's offer by taking the remote and touching it with his iPhone to instantiate connection to the TV.

² <http://www.bluetooth.com>, <http://www.upnp.org/> and <http://www.dlna.org/>

³ <http://www.bluetooth.com/English/Technology/Building/Pages/Specification.aspx>

In [10] the authors sports that mobile devices are strictly personal and that mobile device owners are uncomfortable lending out their device even for a short period of time; to somehow respect this I decided that only the owner of the device is able to browse its content event though it's connected to the TV. Only when Joe explicitly selects a photo on his phone before it is shown on the TV.

The last concept introduced in this illustrative example is the action of *leaving* the home. When Joe leaves Jane's home he scans a connection point by the front door. Doing this states that Joe wants to leave the home and thus removes all photos shown on the TV or any other visual display; the photo on the digital picture frame is a virtual gift from Joe to Jane and thus it remains on the picture frame even after Joe leaves.

4.1 System Setup

In the related work section I referred to the research on flow of communication in the home done in [6]. The concepts of *ecological habitats*, *activity centres* and *coordinate displays* is reflected in the EWIA system design. Figure 1 shows an overview of the EWIA setup. *Activity centres* are places where media are produced and consumed; in the case of EWIA the sofa-and-tv part of the room is an activity centre whereas the picture-frame-and-table part of the room acts as coordinate display. Even though the research in by Crabtree et al in [6] is thorough they don't take guests and visitors into account, likewise they concentrate mostly on the communication flow of the inhabitants in the homes. In the case of EWIA – and digital hospitality in general - the action of guests entering and leaving the home is integrated into the design.

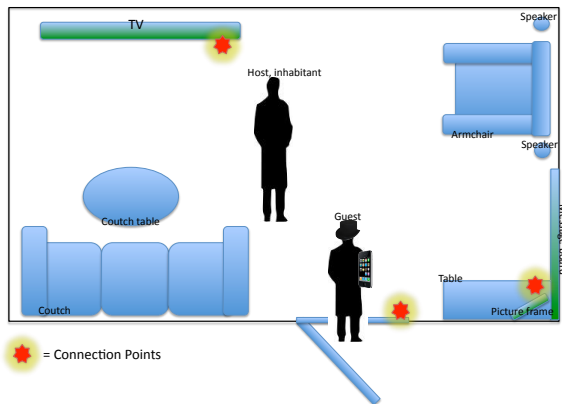


Figure 1 Overview of the EWIA setup.

Figure 1 illustrates how an EWIA setup would look in an actual living room. The red stars represent connection points and the green objects (and the iPhone) represent visual displays. Each of the visual displays has a different role in the home and thus has different user interfaces. Figure 2 shows two displays; the left one is a screenshot from the TV where digital photo gifts are pinned to the screen (image thumbnails at the bottom with red frame); to the right is a screenshot from the EWIA iPhone App – the screenshot shows the picture selection screen displayed when the guest connects to the home.

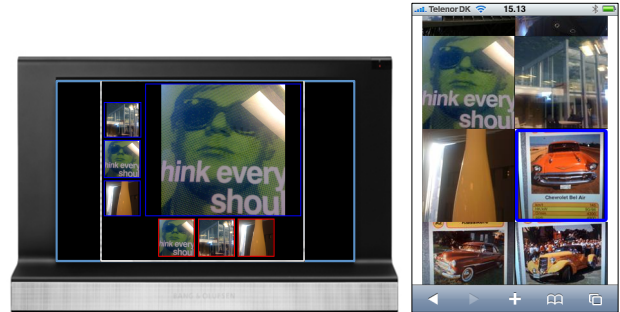


Figure 2 Screenshots of TV and iPhone UI.

5. CONCLUSION AND FUTURE WORK

Throughout this paper the notion of “digital hospitality” is defined and related to existing literature. Development of the EWIA prototype has been done as a way to examine the practical and physical properties of “digital hospitality” using private smart phone displays and domestic visual display like TV and digital picture frames.

The EWIA prototype and the notion of digital hospitality are still under development. At the time of writing the EWIA prototype is implemented as described and the next step is to evaluate the implementation with end users.

6. References

1. Edwards, W. and R. Grinter, *At home with ubiquitous computing: Seven challenges*. Lecture notes in computer science, 2001: p. 256-272.
2. Kidd, C., et al., *The aware home: A living laboratory for ubiquitous computing research*. Lecture notes in computer science, 1999: p. 191-198.
3. Kim, J. and J. Zimmerman. *Cherish: smart digital photo frames for sharing social narratives at home*. 2006: ACM.
4. Hughes, J., J. O'Brien, and T. Rodden, *Understanding Technology in Domestic Environments: lessons for cooperative buildings*. Lecture notes in computer science, 1998. **1370**: p. 248-262.
5. Crabtree, A., et al., *Finding a Place for UbiComp in the Home*. Lecture notes in computer science, 2003: p. 208-226.
6. Crabtree, A. and T. Rodden, *Domestic routines and design for the home*. Computer Supported Cooperative Work (CSCW), 2004. **13**(2): p. 191-220.
7. Petersen, M., et al. *HOMEinTOUCH Designing two-way Ambient Communication*. 2008: Springer-Verlag.
8. Taylor, A., L. Swan, and A. Durrant. *Designing family photo displays*. 2007: Citeseer.
9. Nunes, M., S. Greenberg, and C. Neustaedter, *Using physical memorabilia as opportunities to move into collocated digital photo-sharing*. International Journal of Human-Computer Studies, 2009. **67**(12): p. 1087-1111.
10. Liu, Y., et al. *xShare: supporting impromptu sharing of mobile phones*. 2009: ACM New York, NY, USA.