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 vise 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.

In: PPD'10: Workshop on coupled display visual interfaces
In conjunction with AVI 2010. 2010-05-25.

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.)).

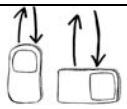
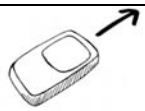
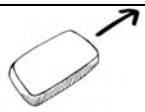
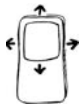
Gesture	Description	Usage in Applications
	(1.) Holding the mobile phone horizontally	Passive mode: personal data is not shown on the mobile phone display; used for playing cards
	(2.) Holding the mobile phone vertically	Active mode: personal data is shown on the mobile phone display; used for playing 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 game[1] 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.

5. Acknowledgements

We thank all the students on the course that explored this new form of interaction. In particular we like to acknowledge the work of Pouyan Parvahan and Bernd Ahrens on the Poker Surface.

The research was partly funded by DFG in the project Embedded Interaction and we are thankful to NOKIA research center for providing us with the N95 mobile devices for the course.

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. Dachselt, 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.