

# Evaluating Interaction Techniques for cross-device data exchange

Evaluierung von Interaktionstechniken für  
den Datenaustausch zwischen Geräten

Diploma Thesis

Hendrik Röllinger

Thesis advisors:

Prof. Dr.-Ing. Til Aach  
Institute of Imaging  
& Computer Vision  
RWTH Aachen University

Prof. Dr. Jan Borchers  
Media Computing  
Group  
RWTH Aachen University

Submission Date:  
September 30, 2011





I hereby declare that I have created this work completely on my own and used no other sources or tools than the ones listed, and that I have marked any citations accordingly.

Hiermit versichere ich, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt sowie Zitate kenntlich gemacht habe.

*Aachen, September 2011*  
*Hendrik Röllinger*



# Contents

<b>Abstract</b>	<b>xv</b>
<b>Überblick</b>	<b>xvii</b>
<b>Acknowledgements</b>	<b>xix</b>
<b>Conventions</b>	<b>xxi</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Research goals . . . . .	2
1.2 Chapter overview . . . . .	3
<b>2 Related work</b>	<b>5</b>
2.1 History of cross-device data exchange . . . . .	5
2.2 Evaluations of cross-device data exchange . . . . .	17
<b>3 Classification and redesign of proposed exchange techniques</b>	<b>21</b>
3.1 Classification by interaction of the common exchange techniques . . . . .	21

---

3.2	Pen related interaction techniques . . . . .	27
3.3	USB flash memory enhancement . . . . .	31
3.4	On-screen exchange methods . . . . .	32
3.5	Techniques and devices excluded from the evaluation . . . . .	34
<b>4</b>	<b>Non-functional prototypes, contextual inquiry and survey</b>	<b>35</b>
4.1	Non-functional prototypes . . . . .	36
4.1.1	Scenarios . . . . .	36
4.1.2	Pipette and pen techniques . . . . .	38
4.1.3	Graphical user interfaces for USB flash drive . . . . .	38
4.1.4	Daily objects for data transport . . . . .	40
4.1.5	On-screen exchange device . . . . .	40
4.2	Contextual inquiry . . . . .	41
4.2.1	Concept of the contextual inquiry . . . . .	41
4.2.2	Results and observations of the Con- textual Inquiry . . . . .	42
	The pipette concepts . . . . .	43
	USB flash drive with GUI support . . . . .	45
	Daily objects for data transportation . . . . .	47
	On-screen exchange device . . . . .	47
	New ideas by the participants . . . . .	48
4.3	User survey . . . . .	48

---

4.3.1	Design of the survey and initial hypotheses . . . . .	48
4.3.2	Results of the survey . . . . .	52
	General findings . . . . .	52
	USB flash drive . . . . .	55
	Data exchange with USB cable and the file system . . . . .	58
	USB cable and synchronization software . . . . .	58
	Cloud services . . . . .	59
	Email . . . . .	61
	Hypotheses and other findings . . . . .	62
4.4	Summary and conclusions . . . . .	67
<b>5</b>	<b>User study</b>	<b>71</b>
5.1	Design of the user study . . . . .	71
5.1.1	Study setup . . . . .	72
5.1.2	Pipette concept . . . . .	73
5.1.3	Exchange dot . . . . .	75
5.1.4	USB flash drive with graphical user interface . . . . .	76
5.1.5	Common data exchange methods . . . . .	77
5.1.6	Study survey . . . . .	78
5.2	Results of the study . . . . .	78
5.2.1	Study statistics . . . . .	78

---

5.2.2	Observations during the study . . . . .	83
5.3	Summary and conclusion . . . . .	84
<b>6</b>	<b>Summary and future work</b>	<b>87</b>
6.1	Summary and contributions . . . . .	87
6.2	Future work . . . . .	90
6.2.1	Get more feedback from users . . . . .	90
6.2.2	Comparison of the cross-device data exchange techniques on other devices	90
6.2.3	Evaluating other exchange methods .	90
<b>A</b>	<b>Summary Forms</b>	<b>93</b>
	<b>Bibliography</b>	<b>99</b>
	<b>Index</b>	<b>103</b>

# List of Figures

1.1	The interaction design process . . . . .	3
2.1	The scheme of picking up data with Pick-and-Drop . . . . .	6
2.2	Design space of the mediaBlocks . . . . .	7
2.3	Concept of the different slots provided in the mediaBlock approach . . . . .	8
2.4	Connecting a passenger with passage and copy data . . . . .	8
2.5	Example for hyperdragging . . . . .	10
2.6	Example for synchronous gestures . . . . .	11
2.7	Transferring a photo with stitching . . . . .	12
2.8	Scheme of the Toss-It data exchange . . . . .	13
2.9	Example how Slurp could work . . . . .	14
2.10	Example for the Through-Body transport presented in LightSpace . . . . .	15
2.11	Example for picking up a digital object in LightSpace . . . . .	15
2.12	The Pipet concept . . . . .	16

2.13	Study setup by Nacenta et al. . . . . .	20
3.1	Classification space for cross-device data exchange techniques . . . . .	24
3.2	Pipette concept for data exchange . . . . .	29
3.3	Concept similar to a pipette . . . . .	30
3.4	Concept of an on-screen exchange device . .	33
4.1	Sketched scenario showing a web browser and files. . . . .	37
4.2	Sketched scenario showing a file manager. . .	37
4.3	Non-functional pipette prototypes. . . . .	39
4.4	Non-functional exchange dot prototypes. . .	41
4.5	Histogram of the survey participants' age. . .	52
4.6	Preferred exchange method for data exchange between computers . . . . .	53
4.7	Preferred exchange method for data exchange between smartphone and computer .	54
4.8	Preferred exchange method for data exchange between tablet computer and computer	55
4.9	Preferred data exchange method for exchange between computers distinguished by the preferred operating system. . . . .	62
4.10	Preferred exchange method for the exchange between smartphone and computer for Android and iOS. . . . .	63
4.11	Distribution of experts over the different operating systems. . . . .	64



---

4.12 Preferred exchange method distinguished between non-experts and experts. . . . .	65
4.13 User satisfaction for data exchange between computers distinguished between experts and non-experts . . . . .	66
4.14 User satisfaction for data exchange between computers and for data exchange between smartphone and computer. . . . .	68
5.1 Functional pipette prototype . . . . .	74
5.2 Exchange dot prototype with GUI. . . . .	76
5.3 USB flash drive with GUI. . . . .	77
5.4 Average time to copy files per exchange method . . . . .	79
5.5 Average time to paste files per exchange method . . . . .	80
5.6 Results of the 5-Likert scale from the study survey. . . . .	84
A.1 First two pages from the online survey. . . . .	94
A.2 Pages three and four from the online survey. . . . .	95
A.3 Page five from the online survey. . . . .	96
A.4 Study survey which was handed out after the study. . . . .	97



## List of Tables

- 3.1 Overview of the different classification attributes for the different HCI approaches . . . 27
- 5.1 The differences between group means for coping the three files . . . . . 81
- 5.2 The differences between group means for pasting the three files . . . . . 82



# Abstract

Today it is common to work with several computers and mobile computing devices. Since there is a need to exchange data between the devices several HCI approaches for cross-device data exchange have been made. However, little is known about the differences in between these techniques. Also little is known about the users' behavior in regard to cross-device data exchange. In this thesis we researched the users behavior in regard to today's common cross-device data exchange methods and discovered that there was room for improvements. Our survey with 140 participants showed there was still the need of improvement, especially for data exchange for mobile devices. We also researched in cross-device data exchange HCI approaches and created a classification by interaction for those techniques. We chose five HCI approaches which we first evaluated with small modifications in a contextual inquiry. Afterwards we compared three of them with today's data exchange methods in a user study and found significant differences in the time participants needed to exchange data.



# Überblick

Heutzutage ist es üblich mit mehreren Computern zu arbeiten und daher ist es notwendig, Daten zwischen den Computern austauschen zu können. Es wurden viele Konzepte vorgestellt um den Datenaustausch zu verbessern und zu erleichtern. Worin sich die unterschiedlichen Konzepte unterscheiden und wo ihre Stärken liegen, wurde bisher nicht erforscht. Ebenso wenig ist bekannt, wie Nutzer heutzutage eigentlich Daten austauschen und warum sie sich für bestimmte Methoden entschieden haben. In dieser Arbeit stellen wir unsere Umfrage mit 140 Teilnehmern über den Datenaustausch zwischen Computern und anderen Geräten vor und zeigen auf, wo es noch Verbesserungsbedarf gibt. Außerdem präsentieren wir unsere Evaluierungen von Interaktionstechniken für den Datenaustausch. Wir haben fünf Interaktionstechniken ausgewählt, die wir Nutzern in einer Befragung präsentiert haben. Die drei vielversprechendsten Interaktionstechniken haben wir dann in einer Nutzerstudie mit zwei herkömmlichen Austauschmethoden verglichen. Dabei haben wir deutliche Unterschiede bezüglich der benötigten Zeit für einen Datenaustausch zwischen den Techniken gefunden.





# Acknowledgements

This work is dedicated to my family who always supported me.

First of all, I would like to thank all persons who participated in the online survey. Thank you for your voluntary participation and the time spent on answering my questions.

Secondly, I would like to thank all persons who participated in the contextual inquiry and the user study. Thank you for all the feedback and the the leisure time you spent helping me.

Special thanks to my supervisors Leonhard Lichtschlag and Simon Völker for their feedback and advice for my thesis.

Finally, I would like to thank Prof. Dr.-Ing. Til Aach. Thank you for supervising my thesis.



# Conventions

Throughout this thesis we use the following conventions.

## *Text conventions*

Definitions of technical terms or short excursus are set off in coloured boxes.

**EXCURSUS:**

Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition:  
*Excursus*

Historical hint are set in blue boxes.

2011: End of diploma thesis

The whole thesis is written in American English.



## Chapter 1

# Introduction

A study from Dearman and Pierce [2008] indicates that today people are interacting in average with 5.96 computing devices. So there is a need to exchange data between the devices, to share them or to continue one's work with another device. Because of this need there were a lot of HCI approaches and commercial products presented over the last decades to solve it. Every two or three years new HCI approaches are presented. Sometimes these got revisited or enhanced but most of them have never been tested in user studies or compared with other exchange techniques. In other parts of HCI there are good evaluations between different interaction techniques but for cross-device data exchange there is only little research that tries to compare and evaluate the different HCI approaches.

There is one paper by Nacenta et al. [2005] that focused on multi display reaching which can be seen as part of cross-device data exchange. However this is only a small aspect of cross-device data exchange because they regard only techniques which support the exchange for two nearby displays. But not all the cross data exchange is nearby and immediate. So all exchange methods which did not support the exchange directly between two displays were not considered.

There exists only one evaluation, yet.

Not only the HCI approaches for cross-device data exchange are quite undiscovered but the users' practices in re-

gard to cross-device data exchange are quite undiscovered, too. There are studies that explore the users' copy&paste behavior within applications [Stolee et al., 2009] and research about how many computing devices users possess and use every day [Dearman and Pierce, 2008] but little is known about how the users exchange data between their devices in practice.

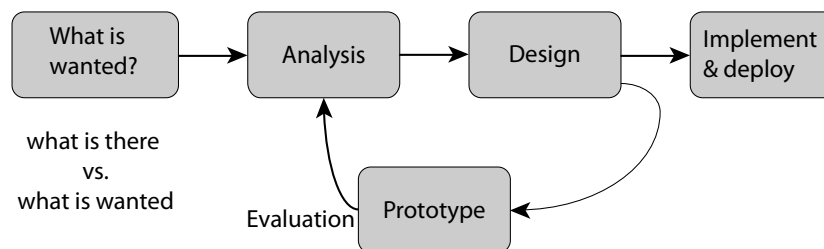
All possible user  
feedback is used.

In this work we want to investigate which cross-device data exchange methods were proposed over the last decades and which of them have already been evaluated. We want to analyze which of the proposed exchange methods are up-to-date and which of them are outdated or need to be changed to fulfill today's requirements. All changes and modifications we test in the interaction design process which was presented by Dix et al. [2004] (Figure 1.1). We will use every cycle of the process to get feedback from the users in regard to the interaction method before we do our final study with the interaction methods that are left.

But we do not only want to focus on the HCI approaches. We also want to discover how the users exchange data today between their devices to get a better understanding how future HCI approaches can satisfy the users' needs. Hence we want to discover which exchange methods users use and why they use them. Understanding the users and how they do their daily tasks is important and needed to understand cross-device data exchange methods. Often HCI approaches are too much focused on proposing something new instead of proposing something that users really want or need.

## 1.1 Research goals

Our research goal is to find out which cross-device data exchange methods have been proposed over the year. We want to analyze and compare the different approaches to see what they have in common and if it is possible to compare them with each other. We will make a study to compare exchange methods which are comparable on an equal level.



**Figure 1.1:** The interaction design process suggested by Dix et al. [2004]

In addition we want to discover how the users exchange their data today. We want to find the reasons why they use certain exchange methods and what they like about these methods. But we also want to discover the weak points which annoy the users to show where there is still need for enhancement and new ideas.

## 1.2 Chapter overview

We structured our work as follows:

**Chapter 2** In this chapter we present the related work. First we present cross-device data exchange techniques in chronological order. We also give hints which commercial products were available at this time to lighten the under-

standing for the HCI approach. We also talk about other evaluations in regard to cross-device data exchange. We present the other evaluations and the aspect they have focused on.

**Chapter 3** In this chapter we classify the different presented HCI approaches and we constrain the list of exchange techniques. We discuss weaknesses of certain exchange techniques and discuss why some of the exchange techniques do not work as the authors have proposed. We also introduce some modifications in regard to some exchange methods so that they fulfill today's requirements or abstract the technique.

**Chapter 4** First we present the contextual inquiry we made to get feedback for the changes we made and to get a first reaction from the users so that we could focus on the most promising cross-device data exchange techniques. We present the observations we made. After this we describe the survey with 140 participants we made. We present the design of the survey before we show the results. Then we discuss our findings and show where is room for improvement.

**Chapter 5** In this chapter we present our study where we compared cross-device data exchange methods with each other. First we talk about the study setup and how we implemented the different exchange methods. Then we show our results and the differences we could find between the different exchange methods. Afterwards we discuss possible reasons for these findings.

**Chapter 6** This is the final chapter of this thesis. We summarize our work and repeat our most important findings. Then we present possible future work and which aspects need to be explored more.



## Chapter 2

# Related work

In this chapter we will first present you the history of cross-device data exchange with the different approaches and ideas developed. We decided for a chronological order because the ideas and trends evolved with the development of technology. In the second part of this chapter we will present previous evaluations about this topic.

### 2.1 History of cross-device data exchange

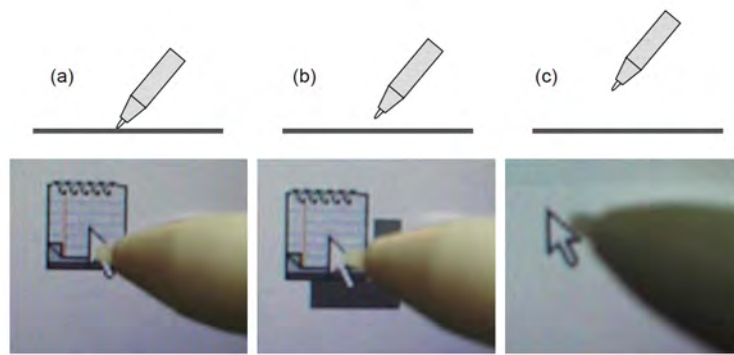
Over the years there were a lot of ideas how to improve cross-device copy and paste. In this chapter we will introduce previous approaches.

1971: First commercial floppy disk available  
1995: First CD Recorder under 1000\$

One of the earliest HCI approaches was developed by Jun Rekimoto [1997]. It is a pen-based direct manipulation technique called “Pick-and-Drop”. This technique is an extrapolation of drag-and-drop, a popular technique to move files and icons on a computer to a pen based interface. To pick up data the user taps with the pen tip on the object and lifts the pen from the surface (Figure 2.1 a). After this the pen tip holds the object which is symbolized by a shadow (Figure

Pick-and-Drop is a pen based exchange method.

2.1 b). The user moves the pen tip to the designated destination and releases the object by tapping the screen again. This gesture could be done within the same screen or between different devices to copy data from one device to another. The user gets the impression to work with real objects which are attached to the pen tip while the data is copied over the network. To differentiate the pens each pen has a unique ID.

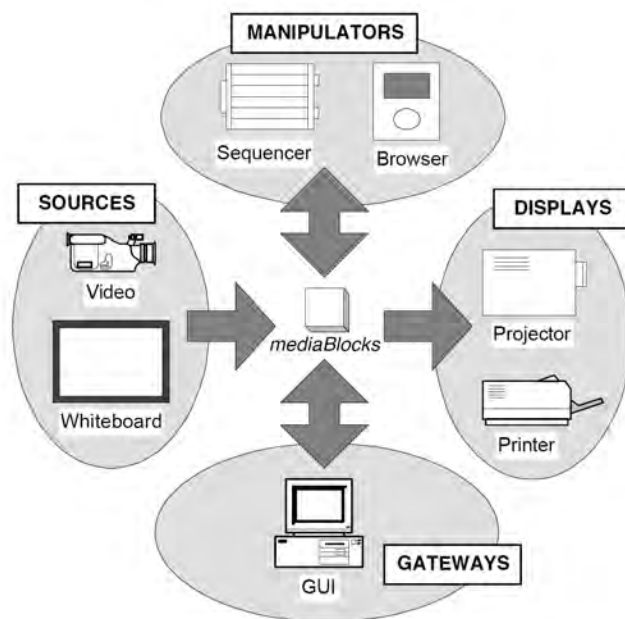


**Figure 2.1:** Scheme of picking data up with Pick-and-Drop: (a) The pen contacts the surface and the icon is selected. (b) Pen is lifted, the icon is attached to the tip and gets raised, symbolized by shadow. (c) Pen is moved away from the surface and the icon disappears. Taken from Rekimoto [1997].

MediaBlocks support  
all kinds of media  
data.

Another concept of sharing multimedia data called “mediaBlocks” was designed at MIT by Ullmer et al. [1998]. MediaBlocks are small wooden blocks with a unique ID which should support the transport and exchange of media between media devices. It supports network printer, projectors, video cameras, digital whiteboards and desktop computers (Figure 2.2). Each device has to be equipped with a slot for recognizing the mediaBlock. When a mediaBlock is put in a slot of a camera the camera starts recording and sends the data to a media server. By removing the mediaBlock the recording stops immediately, by putting the same mediaBlock into a media presentation device like a projector the server starts to playback the recorded media data on the projector. When the block is removed the playback gets halted. If a mediaBlock is put into a slot mounted on a desktop computer a GUI pops up at the position the slot is

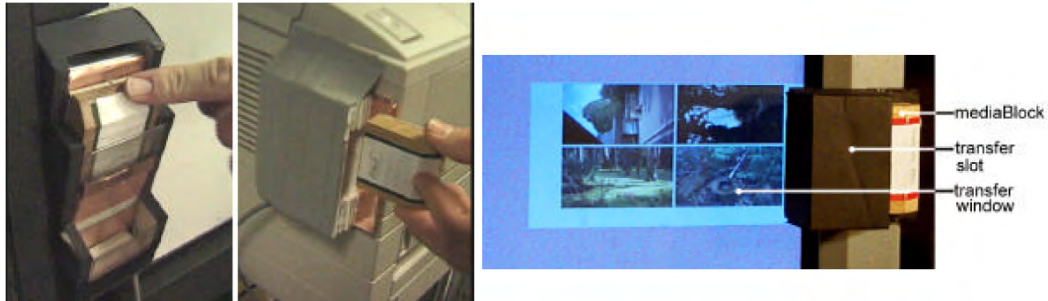
mounted on the display (Figure 2.3). Now the user can add and remove data, regardless which kind it is, from the block by drag and drop. So it is possible to use the mediaBlock for data transportation like today with a USB flash drive, to put any kind of data onto the block and use it to transport data. So the mediaBlocks are able to exchange data between computers, media sources, displays and printers.



**Figure 2.2:** Design space of the mediaBlocks showing the concept of sources, manipulators, displays and gateways. Taken from Ullmer et al. [1998].

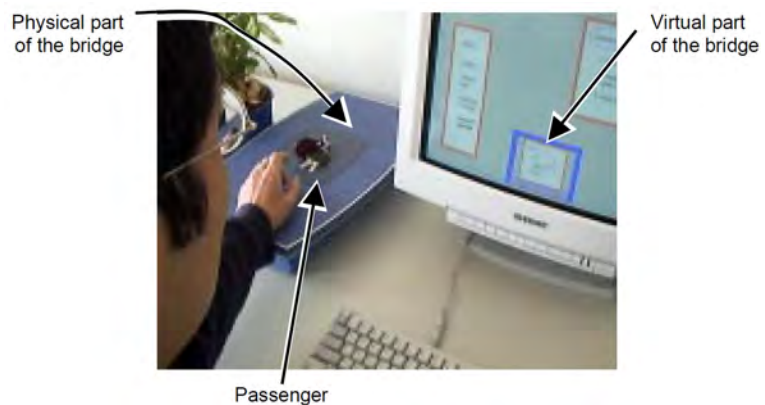
A concept of using daily objects to transport data was made by Konomi et al. [1999]. This concept "passage" is an expansion from the i-LAND [Streitz et al., 1999] concept to a complete building and is based on roomware components. So the user is able to connect real world objects with virtual components. In the passage concept the user could put a physical object on a bridge. A bridge is a special device which is able to differentiate objects either by weight or by an electronic ID. After the physical object is identified the user sees a virtual bridge on his desktop and can exchange data with drag and drop (Figure 2.4). The data is not stored on the physical object and is copied in a database, accessible via network, instead. Actually, the physical object is

Passage uses real world objects to transport data.



**Figure 2.3:** The different kind of slots to use the mediaBlocks (left picture). Putting a mediaBlock into a whiteboard and printing the data for a handout (middle picture). (right picture) A mediaBlock in a computer transfer slot showing the transfer window to manage the data on the mediaBlock. Taken from Ullmer et al. [1998].

only the identifier to find those data in the database but the user gets the impression that the data is really stored on the object. If he loads data on an object and moves to another room to show these data to a colleague, the data shows up immediately after the object is identified by the bridge. This whole concept should make the whole data exchange as simple as carrying paper by providing the possibility to use every object for data transportation.



**Figure 2.4:** After the passenger has been detected by the bridge, the virtual bridge is showed and the user can add and remove data with drag and drop. Taken from Konomi et al. [1999].

In the same year Rekimoto and Saitoh [1999] presented the augmented surfaces, a computer augmented environment that allows collaborated work and data exchange for meeting rooms. It is based on a marker recognition system. With this approach they introduced a new interaction technique called "hyperdragging" and the possibility to attach digital data on physical objects to connect the physical and digital space. The idea is that meeting rooms are equipped with tablespots and wall sized displays which can be used as workspace extensions for portable computers or as shared workspace for collaborative tasks. For collaborative tasks each user brings his own portable computer into the meeting room where the camera-based marker recognition system is installed. By reading the visual markers on the computer, the system can distinguish the different devices and knows their current location on the table. When a user now wants to present or share his data he uses his normal input devices, as for example the mouse, and presses the cursor on the desired object and drags it towards the edge of the display. When the object reaches the boarder it will migrate from the mobile computer to the tabletop (Figure 2.5). Now the user can use the input device to place the data on the table wherever he desires. In the same way it is possible to put data onto a mobile computer or onto a wall size display. As in the passage concept it is possible to attach digital data to physical objects. An object only needs a visual marker attached and then it is possible to attach data on it by dragging the data on this object. When the object is removed from the recognition area the data will disappear and will be saved on a network server. The data will show up again when the object is put back in the recognition area either it is the same or a different recognition area in a another room.

Hyperdragging supports two exchange methods for collaborative work.

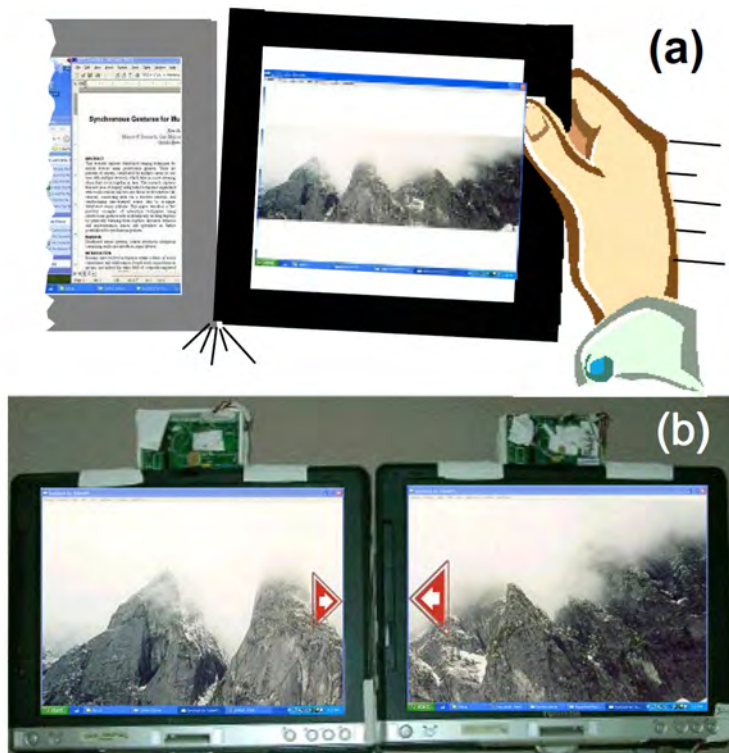
#### 2000: First commercial USB flash drives

An approach in a completely different direction was made by Hinckley [2003] with his synchronous gestures. This is a technique which allows two mobile devices to establish a radio connection to share data by bumping them together (Figure 2.6). Both devices are equipped with a two-axis linear accelerometer and a built-in wireless 802.11 network card. After the devices have been bumped together they



**Figure 2.5:** An example for hyperdragging: The user drags a picture to the edge of his display (first picture) onto the tabletop (second picture). From this position he drags it onto the wall sized display to present it (third picture). Taken from Rekimoto and Saitoh [1999].

establish a wireless connection. Hinckley describes different possibilities how to use this technique to exchange data between two mobile devices. One idea is that one user can “pour” data into the another user’s mobile device by angling the mobile device down while they bump the devices together. The software is then sending the clipboard data from the one device to the other. There is also a variation suggested where the bumping is used to exchange business cards between two devices.

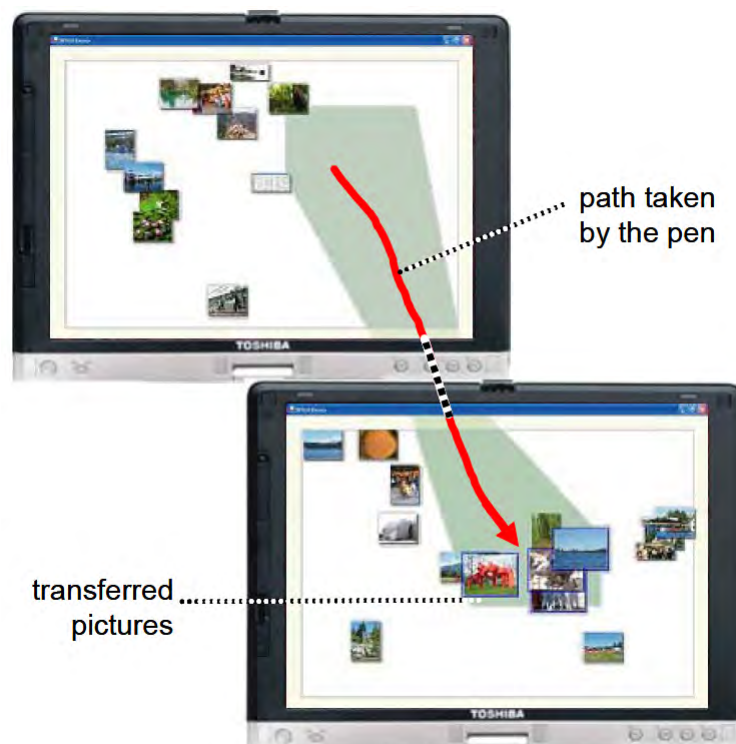


**Figure 2.6:** Connecting two computers by synchronous gestures. The devices are bumped against each other (picture a) and are used to display a picture expanded on both devices (picture b). Taken from Hinckley [2003].

An approach similar to Pick-and-Drop was made by Hinckley et al. [2004] as they introduced the stitching, a pen gesture for spontaneous data sharing. In their approach they built a photo sharing application which made it possible to exchange photos between two mobile pen input devices. To exchange a photo one user starts a pen mo-



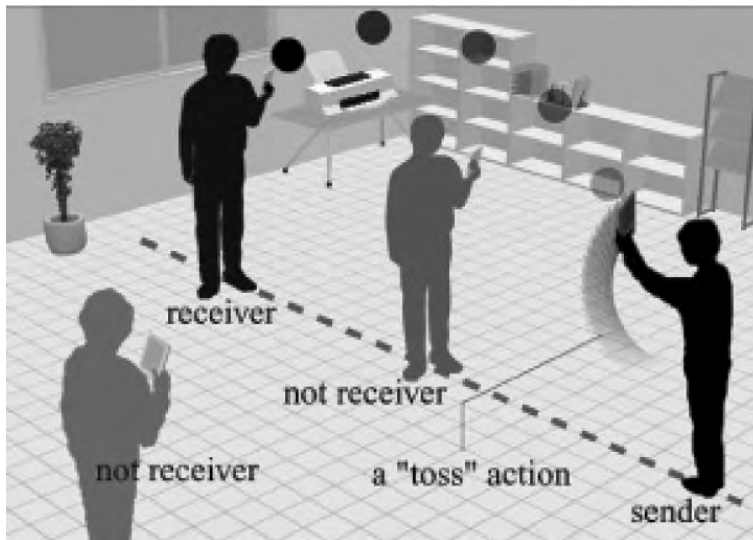
tion on his device until he reaches the edge and then continues it on the device of the other user (Figure 2.7). Though this technique looks very similar to Pick-and-Drop there are still some differences between them. The stitching is a spontaneous exchange technique where the pen has not got an ID and so it is not possible to store data on it permanently. With the stitching concept the user can choose in a menu whether he wants to copy, move or only present the picture on the other device.



**Figure 2.7:** Transferring a photo from one device on another by stitching. Taken from Hinckley et al. [2004].

Another gesture based data exchange method, Toss-It, was presented by Yatani et al. [2005]. It was designed to exchange data between PDAs. To exchange data between two users the one user has to fulfill the toss gesture. The distance a digital object can be “thrown” is regulated by the speed the user tossed the device. When the distance was correct the data get copied over wireless lan.





**Figure 2.8:** Scheme of the Toss-It data exchange. Taken from Yatani et al. [2005]

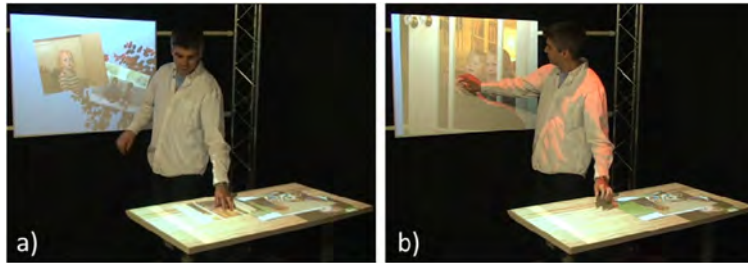
Zigelbaum et al. [2008] developed Slurp, a device to grasp digital objects. In their concept they treat digital information as a fluid and so the design of Slurp is quite similar to a pipette (Figure 2.9). The approach is based on the idea that in the future it will be possible to attach digital data to each real world object and as an aid to grab that digital information they suggest Slurp. But the usage of Slurp is not limited to that purpose and can also be used to transport data between two computers similar to a USB flash drive. The principal idea is that Slurp should be able to copy data when used on a touchscreen. The touchscreen is then able to identify the position. When the user squeezes the slurp a copy command is triggered by a IR signal. Slurp signals with an LED that it has data loaded. To paste the data the user has to squeeze again while Slurp is sending the paste signal via infrared light. Since Zigelbaum et al. did not have a touchscreen, they emulated the touches by a computer mouse. So the whole idea of using Slurp as USB drive replacement has been never completely tested.

With LightSpace Wilson and Benko [2010] presented another approach of an augmented collaborative environment. Instead of a camera-based maker system they decided to use a system of multiple depth cameras to al-

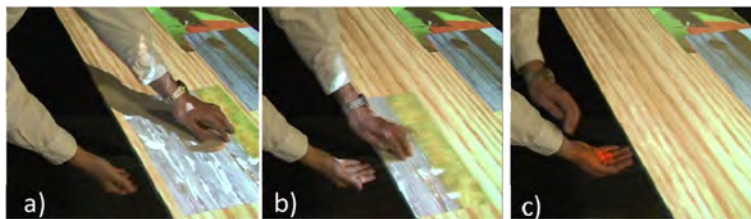


**Figure 2.9:** An example how Slurp could paste data onto a screen. Taken from Zigelbaum et al. [2008].

low the user to interact with tabletops and wall sized displays. This enables the possibility for direct object manipulation and transportation. So they introduced two interaction techniques to transport digital objects, the through-body transport and the “pick up” of objects. Further in LightSpace it is possible to transport data from one display surface to another by touching the digital object with the one hand and touching the desired new position with the other hand (Figure 2.10). The system recognizes that both hands belong to one person and then transfers the object from the one display to the other one. The other technique is that the user literally drags an object off an interaction surface. All digital objects in LightSpace have a physics-like behavior, so it is not necessary to track the hands of a user. The user can swipe a digital object from the table in his hand and carry it around and drop it on another surface. To avoid problems with big digital objects the user will only carry a small colored ball in his hand which symbolizes the digital object (Figure 2.11). After releasing it on a surface it transforms to the digital object again. So these techniques are more designed for collaborated work or spontaneous data exchange and it is not possible to transport data over long distances.



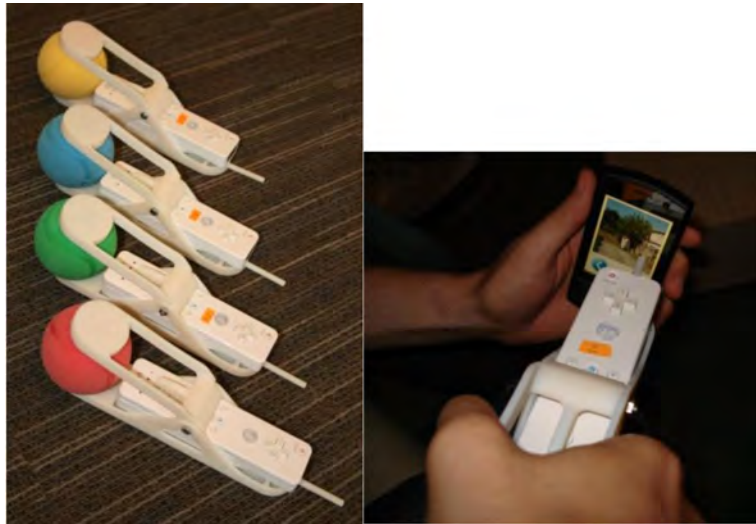
**Figure 2.10:** LightSpace's through-body transport: The user touches the desired object on the first surface (a) and then touches the desired destination on the second surface (b). The data gets transferred from the first surface "through the body" to the second surface. Taken from Wilson and Benko [2010].



**Figure 2.11:** Picking up a digital object in LightSpace by swiping it in the hand (a-b). When the object is on the hand it gets symbolized by a red ball to avoid problems with big object. The user can now carry the data to the other surface. Taken from Wilson and Benko [2010].

An interaction technique similar to Slurp was presented by Meerbeek et al. [2010] to share media within a group. In first place they wanted to find an interaction technique that allows a group of people to bring in their media devices, for example mobile phones, hard drives, laptops or digital cameras, and share them in the group as a kind of shared compilation. So they suggested Pipet, an interaction method for group collaborating and cross-device data exchange. The Pipet device is 3D printed and contains a Wii remote controller. They developed a special Windows Mobile application which made it possible to use the Pipet for browsing through a photo gallery and to suck up photos into the Pipet and shoot them onto a LCD TV. The communication between the smart phone, Pipet and the display is

managed with a computer. To make the usage easier Pipet provided a combination of visual, auditory and haptic feedbacks. When the Pipet is pressed on a mobile phone it starts to vibrate. When the Pipet is squeezed the vibration stops and an LED signals that the picture has been sucked in successfully. To help the user when aiming a colored cursor is displayed when Pipet is aiming on the LCD TV. When the user squeezes Pipet again the photo shoots on the TV and Pipet plays a sound as the LED is switched off.



**Figure 2.12:** Left: The different Pipet devices with their different colors. Right: A picture is selected with Pipet from a mobile phone. Taken from Meerbeek et al. [2010].

With SPARSH Mistry et al. [2011] presented a migration from Rekimoto's Pick-and-Drop on touch devices. The interaction is in general the same. If a user wants to copy an object he touches it one time and it is copied onto a server. When the user touches the next time on another device the data is pasted in the background on this device. Because the human finger could not be equipped with an ID the user has to authenticate himself with a gesture signature, a user-defined pattern which is drawn on the screen.

## 2.2 Evaluations of cross-device data exchange

While research for new interaction techniques has been done for years the evaluations about this topic are quite rare. In fact, there was only one evaluation regarding cross-device data exchange respectively multi-display reaching made in 2005 by Nacenta et al. [2005]. The main focus of this study is multiple display reaching, as it is used for collaborated working and exchanging data between displays. They decided to evaluate quantitative performance for all techniques which support multi display reaching. For this evaluation Nacenta et al. created a design framework which includes nine different attributes to characterize the techniques:

Multi display reaching approaches get evaluated.

- *topology of the underlying interaction space* — describes how the physical space and the virtual space are related to one another.
- *reaching range* — describes the the useful range of a techniques.
- *nature of the destination display* — describes if a technique cares about the exact position of the object on the destination display or not
- *feedback provided to the user* — describes that a technique gives feedback to allow the user to correct the task during he performs it
- *input device used* — describes the input device that is needed for the technique
- *display and input area requirements* — describes if the technique has any requirements in regard of display or input area
- *implicit privacy rules* — describes the privacy that is given by the technique
- *sidedness and symmetry* — describes if a technique requires a sender and a receiver (two-sided) or only needs a sender (one-sided) and if it is possible in both

directions (symmetric) or only in one direction (asymmetric)

After sorting the different techniques according their attributes Nacenta et al. decided to put the focus on six techniques:

- *Pick-and-Drop*
- *Corresponding-Gestures* — It is very similar to Pick-and-Drop. Instead of tabbing the object the user wants to copy he has to make a special predefined drawing gesture. To release the object on the desired destination he has to draw the gesture again.
- *Radar View* — In Radar View the user gets a small map from the destination display. Then he can place the objects he wants to exchange on the desired position of the other display.
- *Panthograph* — In this technique the user points with the pen on the object he wants to exchange and then makes a pen movement towards the desired destination. This technique needs knowledge about how the two displays are positioned to each other.
- *Slingshot* — Is similar to Pantograph but instead of making a pen movement towards the desired destination the user has to make a pen movement away from the desired destination like drawing a bow.
- *Press-and-Flick* — In this technique the user first chooses the distance he wants to move the object by pen pressure and afterwards he defines the direction by a single stroke towards the desired destination.

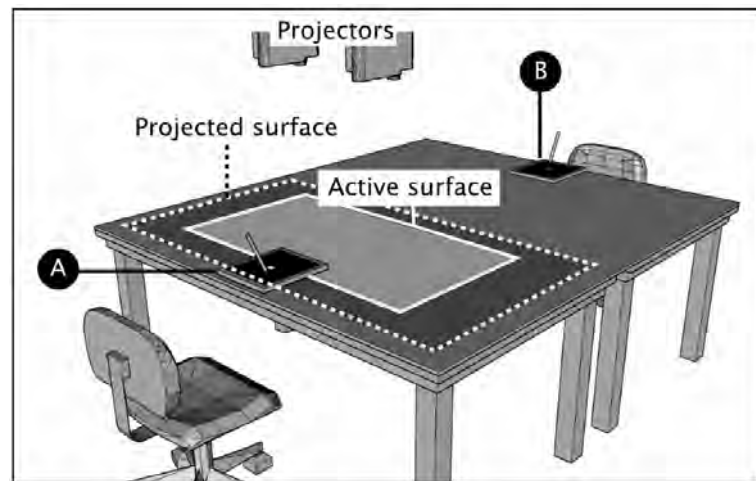
Another technique which is mentioned in this work but was not evaluated is the “wormhole”. A “wormhole” has an entrance and an exit which are set at the beginning. To exchange data the user has only to drop the files in the entrance of the “wormhole” and they will be copied to the exit of the “wormhole”.

Unfortunately Nacenta et al. did not published a complete list of all techniques including their attributes and so it is

difficult to judge the reasons for picking these six candidates. According to their opinions these candidates were the most relevant techniques for boardroom scenarios and due to practical limitations they were not able to choose more. Most of these techniques were developed for large displays or to navigate with multiple displays. This is reflected in the experiment setup (Figure 2.13). There were two experiments for this study. First, the “within hand’s reach” experiment where the user had to exchange icons between a tablet and a table in close position (A in Figure 2.13). The second experiment was the “beyond hand’s reach”. There the user had to sit at the opposite side on the table. So the distance between the tablet and the display surface was quite large (B in Figure 2.13). For each experiment they tested a different group and no participant was tested in both setups. In the “within hand’s reach” test they tested 10 persons with 72 training trails and 288 test trails. For the “beyond hand’s reach” test Nacenta et al. tested 8 persons with 48 training trails and 240 test trails. In the “within hand’s reach” Radar Views and Pick-and-Drop performed best. In the second test Pick-and-Drop was excluded reasoned by the fact that a user had to stand up to perform the task. So again Radar Views performed best in the second test.

Study consists of two experiments.

The suggested performance tests for these techniques comparing, time, error rate and efficiency seem to be convincing but are only applicable for multi-display reaching techniques.



**Figure 2.13:** Nacenta et al. 's experiment setup: In the first within hand's reach experiment the user has to exchange icons between tablet A and the active surface. In the second beyond hand's reach experiment the user has to exchange icons between tablet B and the active surface. Taken from Nacenta et al. [2005]



## Chapter 3

# Classification and redesign of proposed exchange techniques

As seen in the previous chapter there are different approaches and ideas regarding cross-device data exchange. Some authors see the cross-device data exchange between different devices as “well studied” in the work of Nacenta et al. [2005] but as we have seen in 2.2—“Evaluations of cross-device data exchange” this is not completely right. This study covers only a small part and techniques for permanent storage but long distance exchange, etc. are still undiscovered. For about 10 years USB flash drives have been available. Why are they so successful? Is it possible to improve the data exchange?

### 3.1 Classification by interaction of the common exchange techniques

Before we started with the evaluation we tried to classify the different techniques to see what they have in common, where there are parallels and what is maybe missing. At the start we took a closer look at the classifications introduced by Nacenta et al. [2005]. They defined a topology

Classifications from the earlier evaluation do not fit.

considering the virtual and physical space. So they arranged their reviewed candidates in four groups depending on the working space: *Virtual space, coupled virtual and physical space, physical space* and *discrete*. For multi-display reaching techniques this is actually a quite good topology but for data exchange techniques in general it seems not to work. For example a USB flash memory is a physical device but it is not coupled with the virtual space. According to the topology it has to be *discrete*. The mediaBlocks were sorted by Naventa et al. in the *coupled virtual and physical space* class. This is the same class that would be used for the Pick-and-Drop. So it seems with this topology that the mediaBlocks are more similar to Pick-and-Drop than to a USB flash memory. We decided to build our own two dimensional classification space. Generally for all techniques we distinguished between direct and indirect manipulation.

Definition:  
*direct manipulation*

**DIRECT MANIPULATION:**

All techniques where the user can directly manipulate a digital object with his fingers, hands or a pointing device like a pen are defined as direct manipulation techniques. The user gets the impression to manipulate the object directly like a real world object.

Definition:  
*indirect manipulation*

**INDIRECT MANIPULATION:**

All techniques where the user cannot directly manipulate a digital object and needs a tool, like a mouse or a keyboard, are defined as indirect manipulation techniques. The user has the impression to work in a virtual world which he cannot access directly.

This distinguisher builds the first dimension of our classification space. For the second dimension we distinguish between attributes of the object: *File system extension, GUI support, gesture* and *physical device*.

Definition:  
*File system extension (fs extension)*

**FILE SYSTEM EXTENSION (FS EXTENSION):**

A device, remote folder or method, that includes itself into the file system and is only accessible via the file system.

**GRAPHICAL USER INTERFACE SUPPORT  
(GUI SUPPORT):**

The technique has a special graphical user interface (GUI) that assists the user in the data exchange process. With this GUI the user can avoid to use the file system and the task of exchanging data gets simplified.

Definition:  
*Graphical user  
interface support  
(GUI support)*

**GESTURE:**

The technique uses a special gesture either to establish a connection between two devices or to exchange the data.

Definition:  
*Gesture*

**PHYSICAL DEVICE:**

This is an attribute for all techniques where the data is somehow connected with the physical device and the device is needed for the data exchange. A simple example for this is the USB flash memory.

Definition:  
*Physical device*

According to these attributes we classified all previously presented approaches in a diagram (Figure 3.1). As can be seen in this diagram there has not been a technique yet which tried to combine direct manipulation with GUI support. All approaches avoided to be a simple file system extension. As well can be seen that there is no approach trying to combine direct manipulation with a file system. Obviously most systems which have been developed for direct manipulation try to avoid classical file systems as for example modern tablet computers like Apple's iPad. Most techniques which need a physical device try to support the user with a graphical user interface. The hyperdragging is a special case because it offers a direct data exchange between two computers as well as using an object to transport data and exchange them. Also it is interesting that gesture based techniques avoid physical devices vice versa.

**LONG DISTANCE TRANSPORT:**

With long distance transport we define all kinds of data transportations which are not immediate, whether because of a long spatial distance or of a long time distance within the copy and past commands.

Definition:  
*Long distance  
transport*

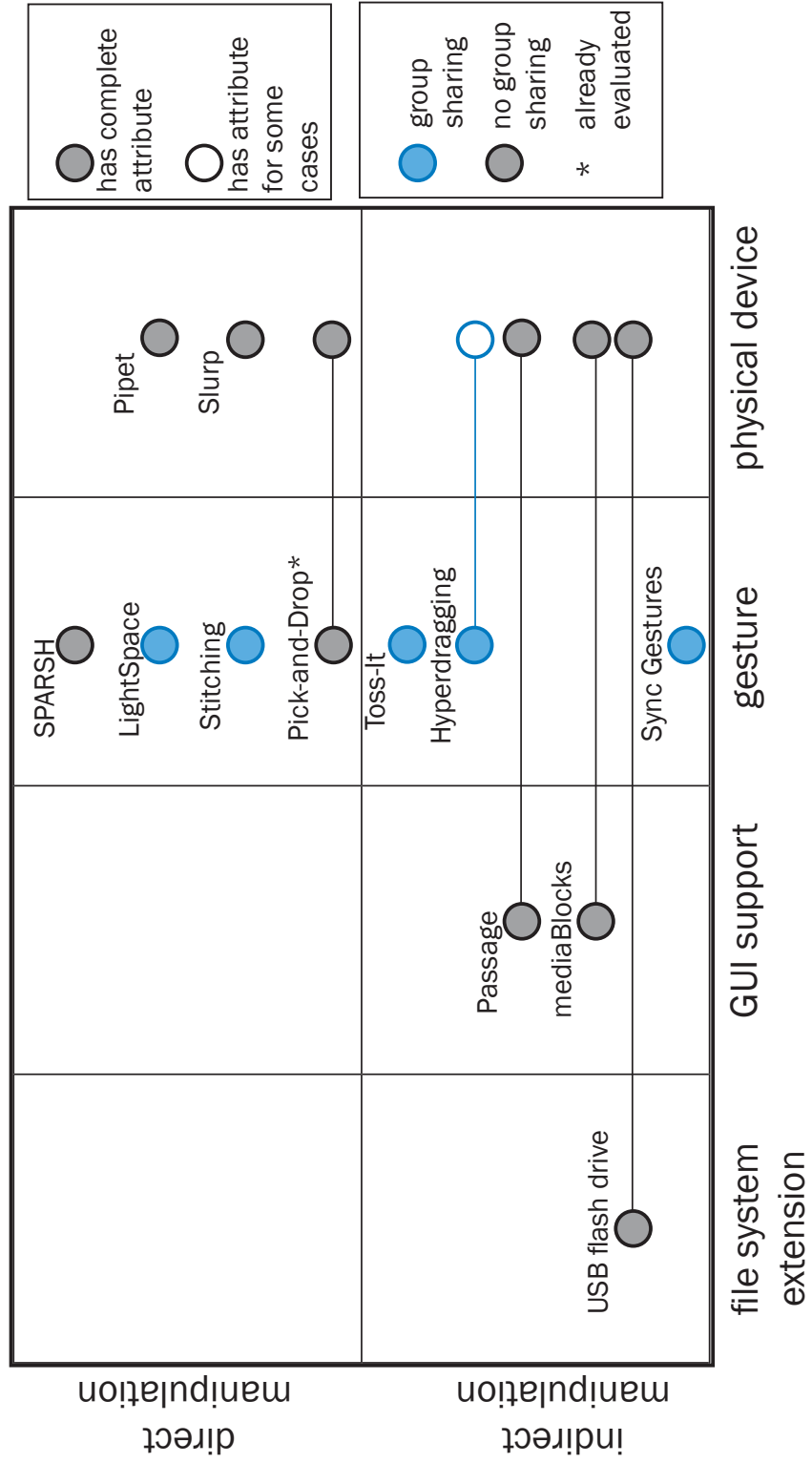


Figure 3.1: Classification space for cross-device data exchange techniques

Furthermore, we created a table 3.1 with an overview over the different techniques and their abilities. For obvious reasons most of the techniques based on gestures are not suitable for long distance transport and it is not possible to exchange private data because the data is visible for all people in the same room. Of course, this is an advantage for sharing data within a group which is needed for collaborated work. Approaches with a physical device seem to be better suited for a long distance transport because the physical object is a kind of representative for the digital data. This leads to the question: "Do users really favor a physical device?".

The aspect of sharing data within a group seems to be more difficult to narrow it down. For example, is a USB flash drive really suitable for sharing data within a group? One can argue that you can give it around within a group and everybody can copy the data onto his mobile computer. But comparing this with handing out a paper which was duplicated before a meeting, the exchange of data via USB flash drive seems to be very complicated and extensive. So we decided to define group sharing as followed:

**GROUP SHARING:**

A technique supports group sharing if it is possible to share data with more than two people, nearly as simple as handing out paper, so that each person gets his own copy.

Definition:

*Group sharing*

So just presenting data to a group by using a device to present the data on a big display or a projector is not group sharing, it is only presenting without providing a copy of the data for each person. In contrast to the long distance exchange, the gesture based techniques are mostly well designed for group sharing as they were developed for collaborating tasks. The Pipet device was developed for sharing data in a group but actually only provides the possibility to present data to a group on a screen. Though there were no hints in the original approach, we classified it as not group sharing capable. According to the original design Pick-and-Drop also is not not able to exchange data within a group. Although some small changes would be enough to make

Approaches for collaborative work support group sharing.

Pick-and-Drop suitable for group sharing, we classified it based on the original approach.

Another aspect of data sharing and transportation is the privacy aspect. According to Shen et al. [2003] data in collaborative environments can be classified as *public*, *personal* and *private*. They defined all data as *public* which is visible, accessible and editable by the members of a group that work collaboratively together. Further they declared *personal* data as data which is visible for the members of the group but is not accessible or editable. *Personal* data can be compared with papers a person takes to a meeting. All participants of the meeting can see that there are papers but the papers are only accessible by their owner. So all data which is hidden for the other members of the group is declared as *private*. *Private* data is normally stored on private devices like a laptop or a mobile phone. Therefore those devices are normally kept privately and are not used for data exchange. Since Shen et al. focused on collaborative environments only, we cannot take it over for all the different techniques. Hence we distinguish the devices only in the capability of private data exchange which we define as followed:

Definition:  
*private data*  
*exchange*

**PRIVATE DATA EXCHANGE:**

A technique which provides the possibility, so that a user can exchange private data between two devices, without a third person being able to see or access those data, then it is private data exchange.

Exchange methods which were designed for collaborative works have a lack of private data exchange. They are so designed that everybody around the table or in the same room can see the data that is exchanged. In contrast to the method that requires a physical device, they are well suited for private data exchange. It seems to be that controlling a physical device makes it easier to control the data exchange. This leads to the question: "Does the user feel it the same way? Does he have the feeling to be more in control of his data?" During our studies we have to investigate in this aspect.

Technique	Long distance transport	Group sharing	Private data exchange
Pick-and-Drop	yes	no	yes
MediaBlocks	yes	no	yes
Passage	yes	no	yes
Hyperdragging	yes	yes	no
Sync Gestures	no	yes limited	yes
Stitching	no	yes	yes
Toss-It	no	yes	yes
Slurp	yes	no	yes
Lightspace	no	yes	no
Pipet	no	no	yes
SPARSH	yes	no	yes

**Table 3.1:** Overview of the different classification attributes for the different HCI approaches

## 3.2 Pen related interaction techniques

Some of the already presented approaches were designed for pen input devices like the Pick-and-Drop or the Stitching. Other devices are only on the second view similar to a pen like the Slurp or the Pipet. In this section we want to discuss the advantages and disadvantages of the different techniques and propose some changes in regard to the evaluation.

The Pick-and-Drop is the earliest approach and was developed during a time in which pen input devices like personal organizers were seen as the future of mobile computing. Since Apple introduced the iPhone in 2007 the idea of personal organizing has changed and so pen input got quite unpopular and was replaced by touchscreens. With the introduction of touchscreens not only pen input got unpopular, also the behavior and expectation regarding the device changed. So the tap which was proposed by Rekimoto is used to start an application or to open a file. Hence using the tap for coping data would be quite confusing for experienced users. Another problem is that this technique only allows to transport one object at once. This is a typical scenario when copying data between currently running ap-

On touchscreens tabbing has a different meaning than in Pick-and-Drop.

plications as Stolee et al. [2009] explored about users copy & paste habits. Stolee et al. described this pattern as isolation pattern where only one object is moved from a source application to a destination application. The short distance cross-device scenarios are similar. We can easily imagine to copy a file from the personal device on a wall sized display to show something to a group or to hand over a document to a colleague. Although the long distance transport is possible with Pick-and-Drop, the scenario of transporting only one file seems to be a special case. For example, a student who works at a university computer and wants to take his file with him, will often have more than one document he wants to transport. Another problem is to transport data spontaneously when data has already been collected. Then the user has to decide which data he wants to transport. Even without any user study we can conclude that the user will not like this.

Pick-and-Drop is implemented as cut&paste.

Still there are more problematic aspects with the Pick-and-Drop approach. In the original approach this technique is implemented as a cut and paste mechanism. When lifting the pen tip the picked file disappears on the source display. When the pen tip touches the destination the file is copied to this device. Since Stolee et al. discovered that only about three percent of the clipboard usage are cut commands it seems to be that cut & paste is not the ideal method for exchanging data. Also the pen cannot be used for other tasks until the data exchange is finished. All these issues lead to the idea that Pick-and-Drop could be seen as kind of clipboard synchronization and its purpose is more the short distance transport. With the fact that it is proposed as a cut & paste mechanism we doubt that this reflects the daily work flow in offices, universities and schools.

Pick-and-Drop already was evaluated.

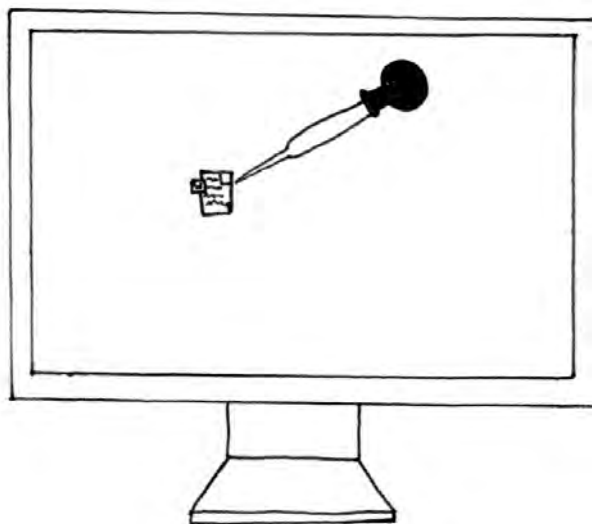
Rekimoto never evaluated the Pick-and-Drop but it was evaluated by Nacenta et al. in their study. The results from Nacenta et al. studies underlines that is more designed for a short distance transport and to bring a file from one device to another when they are co-located. In this task the Pick-and-Drop performed very well. When taking a closer look in which direction the Pick-and-Drop developed, we can see that Rekimoto and his team used it more and more as a collaborative tool for discussing and presenting on a



white board instead of exchanging files between different computers.

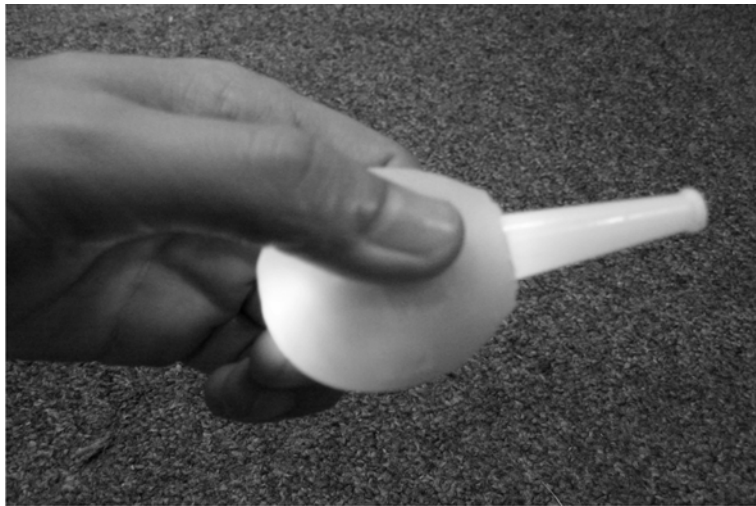
The problem with stitching is that it is only designed for mobile pen input devices. Since pen input devices are not so popular anymore and have been replaced by touch-screen, mobile devices with pen input are really seldom. Originally Hinckley et al. designed this gesture for physical proximity reasons. They wanted to introduce a technique which allowed users to fulfill collaborative tasks and keeping a social distance which feels comfortable. So maybe a user allows another unknown person to make a pen stripe on his device but will he feel comfortable to let the unknown person touch the device? Also Hinckely et al. developed more gestures than the pen stroke gesture which were normally not done by finger input like a lasso gesture, for example. In general we think this whole approach has its strengthen more in the spontaneous device connection than in data exchange techniques. Although it is the only approach that cares about physical proximity.

Stitching allows the user to keep a social distance.



**Figure 3.2:** Pipette concept for data exchange

When we started with this thesis we also thought about building a pipette device. During our literature research we found two approaches, Pipet and Slurp, which were inspired by the idea of pipette. Both of them had the idea of treating data as a liquid and so they decided to design the mechanism for “sucking” the data in similar to a pipette. Zigelbaum et al. decided to copy the rubber ball of a pipette and hide the electronics inside it whereas Meerbeek et al. decided for a foam ball as spring and a 3D printed mechanism.



**Figure 3.3:** Concept similar to a pipette

Slurp was never tested.

The Slurp concept was actually designed to grab digital information from physical objects and only later it was realized that it could also be used to transport data between different devices. Zigelbaum et al. claimed that a touchscreen display would be able to recognize the position of the Slurp device and so it could be used to transport data. In their own tests they did not have a touchscreen and emulated the touch by bringing the mouse cursor to the position the touch would occur. So in fact it was not really proved that this concept works and it was never evaluated.

For the Pipet a small evaluation was made where users compared it with a gyromouse. The focus of the evaluation was the group experience and not so much the data exchange. So this study cannot provide us any useful hints or data for our studies.

Since the idea of a pipette device was never evaluated regarding data exchange we decided to test this kind of concept. During our design phase we decided that the use of a stylus pen like in the Pick-and-Drop concept would be the best solution for precise navigation. Then we thought about the size of such a device and the position of the bulb. Of course a mechanism for collecting data does not need to create a vacuum and so there is no reason to put the bulb at the end of the device. Also other mechanisms like buttons or sliders could be used. Hence we decided to ask the user which kind of device he would prefer before comparing it with other devices.

### **3.3 USB flash memory enhancement**

For ten years the USB flash memory has been available as commercial product. It got faster and smaller but stayed nearly unchanged. Actually, there is no analysis about USB flash drives but the long period that they are on the market leads to the conclusion that they have been kind of successful. In this passage we will discuss the approaches that have a kind of similarity to the USB flash drive.

The passage concept by Konomi et al. is one of the oldest approaches which is similar to a USB flash memory. At the first glance a USB flash memory and the passage approach have not much in common, the first one is a special device which is limited by its capacity and the other one can use any kind of physical object to transport data. But when we take a closer look how a user has to store his data, we can see similarities. In the passage concept a passenger has to be placed at the bridge so that the computer can recognize it. Similar to this a USB flash drive has to be put in a USB port and there are more similarities. When plugging in the USB flash memory some operating systems open directly the root directory of the USB memory or offer to do it. In the passage device the virtual part of the bridge pops up at the display and shows the already loaded data. Since USB flash memory got cheaper and smaller many people transport a USB flash drive in their wallet or at their key. Also flash drives are available in form of a debit card or

MediaBlocks try to combine virtual and physical world with a transfer window.

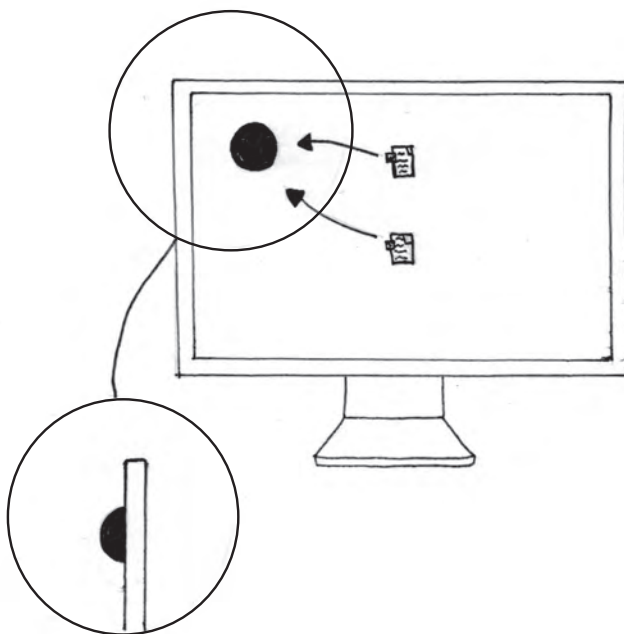
as keyring pendant. This is not completely the vision of Konomi et al. but it is very close to it.

The virtual bridge of the passage concept is also very similar to the transfer window presented in the mediaBlocks approach. The mediaBlocks were developed during a time in which floppy disks and CD-Roms were nearly the only commercial products for data transportation. Today we do not use mediaBlocks but USB flash drives and SD memory cards which seem to be more handy than carrying a wooden block. The big advantage of techniques like the SD card and the USB flash drive compared with Passage and the mediaBlocks is, that there is no real infrastructure needed. A USB slot or a card reader is enough because the data is stored on the medium. But the interaction methods proposed in the two concepts, in a modern form, could still be good additions to techniques like the SD card or the USB flash drive. The transfer window presented in the mediaBlock concept also tries to combine the real world with the virtual one by presenting the transfer window at the position where the mediaBlock has been plugged in. Such a behavior can provide the user a better overview and quicker access to manage the data more efficiently. Especially, for unexperienced users this could be a great benefit. It would also be possible that such a GUI provides the possibility to save small digital fragments like a URL directly on the USB flash drive. So we decided to include this kind of enhancement in our studies.

### **3.4 On-screen exchange methods**

Since computer displays got bigger over the years one of our ideas, when we started this work, was to introduce a technique that enables the user to put the transport medium directly on the display and fill it with data just by dragging it "on" the medium (Figure 3.4). Also for tabletop computers and interactive surfaces such a technique could be a benefit. We could not find any interaction concept regarding such a technique in literature although some concepts showed similarities. For example in Rekimoto's and Satioh's approach of hyperdragging they introduced

the possibility to attach digital data to physical objects for data exchange. Also hyperdragging is an indirect manipulation method because the user can only use his mouse and keyboard to navigate. So a touch sensitive surface is not necessary. Direct manipulation is also possible when using such a device on a tabletop or on interactive surfaces. When it is used with direct manipulation it is kind of similar to Wilson and Benko's LightSpace. Instead of swiping an object onto a hand, it is swiped on the device. Since we are limited in our time during this diploma thesis it is also a problem to rebuild the LightSpace concept because it uses 3D cameras and a room equipped with projectors to project the red ball on the hand. So in our opinion this is a good substitute which imitates the interaction quite well.



**Figure 3.4:** Concept of an on-screen exchange device

### 3.5 Techniques and devices excluded from the evaluation

Gesture based exchange methods are excluded from the study.

In this section we will shortly discuss which approaches we completely excluded from the evaluation and why we exclude them. One of the most obvious points to exclude techniques were the time constraints. We mainly focused on methods which support long distance data exchange although we made exception with LightSpace by introducing a slight modification. So we excluded Hinckely's synchronous gestures as well as stitching for the reason that they only support special mobile devices and they both do not support long distance transport. Also the "Pick-and-Drop" was excluded. The reasons for this decision we already explained in 3.2—"Pen related interaction techniques".

We also excluded Toss-It from this study although it is a very interesting approach. But this approach only works with mobile devices like PDAs or smartphone.

The SPRASH approach by Mistry et al. we excluded since we could not see any new interaction technique that is relevant for cross-device data exchange.

## Chapter 4

# Non-functional prototypes, contextual inquiry and survey

After examining all the HCI approaches that had been made for exchanging data, we had a couple of questions: “What does the user think about this?”; “Which design would the user prefer?”. For example the devices that are similar to a pipette, how should they be built so that a user can actually work with them? So we decided to build non-functional prototypes and make a contextual inquiry to see how we should build the techniques and to get a first impression how the users think about certain techniques. Though we did some research to see “which techniques are people using today? And why are they using them?”, we could not find any studies that could provide us any data regarding these points. Hence we decided to start our own survey to explore which techniques the users prefer today and why they do so.

In this chapter we will introduce the non-functional prototypes and their development. Then we will present the concept of the contextual inquiry and its results. After the contextual inquiry we will present the survey which was handed out during the inquiry and which was also an on-line survey to collect a bigger sample. Then we will present the results of the study.

## 4.1 Non-functional prototypes

Non-functional prototypes are developed for a first user feedback.

Before running a study where we really compare different techniques we want to make sure that the users get techniques they can really work with and so we eliminated possible sources of error. So we decided that the modifications and techniques should run through the DIA cycle or the design interaction process. Non-functional prototypes are a cheap and quick way for getting first user feedback on a new concept. Paper prototypes are a well known technique in user interface design which was discussed in detail by Snyder [2003]. So we orientated ourselves to paper prototypes to create our non-functional hard- and software prototypes.

In the Chapter 3.2—“Pen related interaction techniques” and following we already discussed several of the open questions regarding some of the exchange techniques. Here we will present the non-functional prototypes and the still open questions.

### 4.1.1 Scenarios

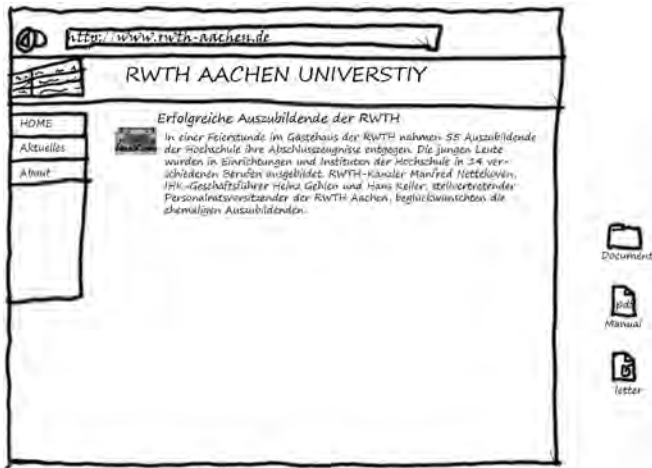
Two drawn scenarios were presented to the user.

In the inquiry we presented the user two typical scenarios which were hand drawn. We decided to use only digital drawings because for the interaction techniques it is important that they could be done on a real display to present a realistic setup. So we created two scenarios which should be normal situations the user often meets during his work with computers.

The first scenario should show a desktop with files stored on it and an open web browser (Figure 4.1). This scenario provides the user the possibility to try the interaction with files in icon size and also to interact with the browser to copy pictures or texts.

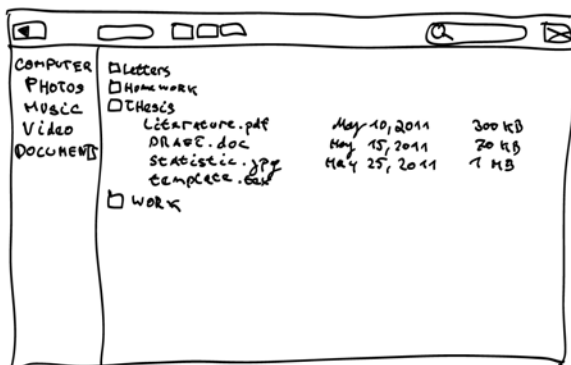
In the second scenario we presented the user a file manager which is typical of desktop computers (Figure 4.2). For data exchange techniques like the USB flash drive this is a typical scenario. Here we provided a list view, so that the user





**Figure 4.1:** Sketched scenario for the contextual inquiry. Showing an open web browser and files lying on the desktop.

is able to try the interaction with the prototype even for smaller objects and file lists. With these two scenarios we covered the daily challenges a user faces. Of course there are a lot of more scenarios possible but the interaction is in general the same.



**Figure 4.2:** Sketched scenario for the contextual inquiry. Showing an open file manager.

### 4.1.2 Pipette and pen techniques

There were several proposals for using a pen or pipette similar device to exchange data between computers. Unfortunately, the approaches do not contain any hints about the design process and do not have user studies either. So our original idea was to use a *Wacom*<sup>1</sup> stylus pen that we can modify in a way, that it is imitating the Slurp or Pipet approach. We think that a stylus pen with its higher resolution is a better choice than a touchscreen.

Best position for the pipette bulb was searched.

While thinking about the first designs we realized that facts like the device size and the position of the trigger mechanism have a significant influence over the evaluation. So we collected all possible trigger mechanism for such a device and built them as non-functional prototypes. Some devices already showed drawbacks as we constructed them. For example the Pipette, when adding the bulb to an average sized pen, it was difficult to use the device accurately while pressing the bulb. All concepts which could not be used with one hand were excluded since they change the interaction completely.

For the contextual inquiry we chose three devices. We took two different approaches of the pipette concept. The first one was similar to a pipette and the second one was more like a pen with the bulb in the first half of the device. In addition, we chose a concept similar to a classical non-bulb pipette in which the data got dragged into the device (Figure 4.3).

### 4.1.3 Graphical user interfaces for USB flash drive

In some approaches which used a physical device we found a special GUI to manage the data on the device. Especially the GUI introduced in the mediaBlocks which appears on the position where the devices are plugged in, seems to be an interesting enhancement to a USB flash drive. This GUI cannot only combine the physical and virtual world by giving the user the impression to see a virtual extension of the

---

<sup>1</sup><http://www.wacom.com>



**Figure 4.3:** Non-Functional prototypes of the pipette concept. On the left side: a small pipette with bulb at the end. In the middle: Pen with the bulb in the first half of the pen. On the right side: classical non-bulb pipette.

virtual device. It can also provide new characteristics like enable the possibility to save not only full files but also digital fragments like the clipboard. For example, a user can save only a marked passage of a text or a URL which then can be used directly on another computer without having to create a new file to buffer those digital fragments.

Another idea was the “wormhole” which was described by Nacenta et al. [2005] but was never evaluated. There are two possible scenarios in regard to such a “wormhole”. One is that it ends on the USB flash drive and enables the user to use the flash drive as kind of a heap where he just drops the files he wants to transport. The other scenario is that the other end is on a remote device on which the user wants to transport his data.

Two drawn GUIs were presented to the user.

For the inquiry we created drawn versions of this two GUIs. The first GUI was presented first as “files only” window, so that it was only possible to store full files in the window. Afterwards we presented the window as capable to store all kind of data as for example a URL. To show the connection between the USB flash drive and this GUI we installed a provisional USB slot at the position where the GUI would show up. When the user plugged in the USB device in this slot we popped up the GUI.

The “wormhole” GUI was also created in two versions. The first version was only a black hole in which the user could drop his files which would then be copied on the USB flash drive. The second version also showed which files or digital objects had already been loaded on the stick.

#### 4.1.4 Daily objects for data transport

Concept to transport data with real object was presented.

In two of the introduced approaches we found the idea of connecting digital data to daily objects for data transportation. Unfortunately, this concepts were never evaluated. So we were interested to see what the user thought about these ideas. Although this is not a new interaction technique itself, it is interesting to know if users want a special device for data transportation or if they prefer to transport data with their daily objects.

#### 4.1.5 On-screen exchange device

Concept of an on-screen device was presented to the user.

In section 3.4—“On-screen exchange methods” we presented the concept of an on-screen exchange device. Both the hyperdragging and the LightSpace were the only two interaction methods which provided a direct connection between the device or object that was used for transportation and the data. They have been developed for tabletops and augmented surfaces. With the on-screen exchange device we want to test if such a direct approach could also be extended for desktop computer. Since a display is normally not horizontal it is not possible to put a device on it directly. Although the navigation is indirect the connection between

the device and the data is direct. If the users liked such a concept it would be a great solution for the data exchange between tabletop computers and normal desktop computers.

In the contextual inquiry we presented the users three different versions of the on-screen device (??). The first version was only the device which could be mounted on the display. The second variant was the normal device with a GUI extension so that the user could see which data had already been loaded on the device. In the third variant we added a button on the device which allowed the user to realize the collected data.



Figure 4.4: Non-functional exchange dot prototypes.

## 4.2 Contextual inquiry

### 4.2.1 Concept of the contextual inquiry

For the contextual inquiry we followed the recommendations of Beyer and Holtzblatt [1998]. So we visited all participants either at their workplace or at home, equipped

Users were visited at work or at home.

only with the prototypes, a presentation laptop and an iPad for notation purposes. Before we started with the inquiry we asked the participants how they exchanged data between devices and their experiences with this technique. After this warm up phase we gave the user the first prototype and explained him the concept of the device. The user could then test the device in the two scenarios which we introduced in chapter 4.1.1. During the test he spoke out loudly his thoughts and feelings about the device. In the same manner we tested all devices. But we also tried to observe the body language and the way the user used the device to discover even more hidden effects.

Since we did not know which facts could influence the preferred exchange method and some of our prototypes needed a pen input, we asked a wide spread kind of people but made sure to have users who work regularly with a stylus pen.

In the sessions the users agreed that we were allowed to record them, we used the *TagPad*<sup>2</sup> Software provided by the University of San Diego. If people felt uncomfortable by being recorded, we noted everything in the classical way with paper and pen.

#### **4.2.2 Results and observations of the Contextual Inquiry**

In the contextual inquiry we had 14 people. We had two people who work daily with a stylus pen and three persons who work at least sometimes with a stylus pen. We avoided to have only people with computer science background in our study. So we had only two people with computer science background and two electrical engineers. All the other participants study or work in non-technical areas. The participants were between 22 and 42 years old.

---

<sup>2</sup><https://sites.google.com/site/ucsdtagpad/>

### The pipette concepts

The first observation we made was that some of the participants hesitated to use the device on the display. They explained that they were scared to damage the display and that they would never use such a device on their private display. We explained that all the devices were prepared in a way that they could not harm the display. The majority of participants did not have this concern and tested the devices without hesitating. Many participants asked themselves what would happen if the mechanism or bulb was pressed accidentally. The concerns were either that the data would get lost or that it would get injected at a wrong device nearby.

All participants had in common that they did not like the classical non-bulb pipette (Figure 4.3 right). One of the reasons for the rejection was the position in which the device had to be used. All participants preferred a normal pen position or at least the usage of the pen as pointing device. Also about half of the participants wanted to use the mechanism like a real pipette, so that the data was only hold as long as the mechanism was pushed. None of the participants wanted to use such a technique to transport data between computers.

The pipette device got a better feedback. Participants liked the concept of picking digital objects and files directly from the display. The size of the pipette device was described as well lying in the hand and the participants felt confident to have selected data precisely. But again people thought that such a device was only capable to carry one object per time. Some participants mentioned that they liked to order their data when transporting a bigger amount of files. So they missed it when using such a device. We already mentioned the aspect that people felt scared about data accidentally getting lost during the transport of the device. When the people used this device they had the greatest concerns about losing data. The people with a technical background were more scared about injecting the data on the wrong device while the non-technical people were more concerned that the data got lost. All participants felt confident in file copy but when it came to digital objects some participants

Participants were scared about losing data by accident.

struggled. These participants were unsure about how to select objects that were a lot bigger than normal files. For example in our web browser scenario they were unsure when pointing on the picture and pressing the bulb the picture or also the text around was copied. One participant suggested that he could control the area that got copied by the duration of time he pressed the bulb.

Participant suggest own interaction ideas.

The pen device with the bulb also got good feedback. Most participants immediately liked the device because they could hold it as a pen and felt able to select everything precisely. Especially people who had already used a stylus pen mentioned that such a method could be integrated in their normal work quite easily. Ten of the participants suggested another interaction technique for selecting text or multiple objects. They hold the bulb pressed while they selected all the desired passages or files. Most of them compared it with using a highlighter to mark the objects they wanted to copy. When using this device in highlighter mode people thought it could be capable to transport more than one file.

When the people could choose between the different devices the majority preferred the pen with the bulb to the pipette device because they saw advantages in navigation and found the position of the device in the hand the best. Two participants decided to use the pipette device instead because so they did not have concealments when they used the device.

Pipette was preferred for a nearby data exchange.

The general feedback to such an interaction technique was that the participants liked the interaction but would only use such a device when the other computer was nearby. Some participants would use the device for a long distance transport but with only four participants this was a minority. Especially, the two people who work daily with a stylus pen did not like the idea to use the pen as transportation device. Normally, the pen stays at their workplace at the computer. But the main problem for them was that if they forgot the pen but they would not only forget the data they could not work on this day, either.

During the inquiry four of the participants also created new ideas how the use of a pen could be possible. All of them



suggested to use the pen device with bulb only to collect and to place the digital objects or files. Three of them suggested to add a GUI to a USB flash drive like the one we presented to them and use the pen with bulb to add and remove data from the USB flash drive. One participant suggested to add another component to the devices. This device should be a kind of ink jar, so the user can put the data into this jar if he wants to transport them and then he takes only the jar with him. At the destination he can grab another pen and collect the files from the jar and place them on the destination display.

Some participants wanted pipette only for collecting data.

### USB flash drive with GUI support

The concept to add a GUI to a USB flash drive which appears at the same position the device was plugged in, got great feedback. People liked the metaphor that they can see the virtual part of the USB flash drive. Some participants hoped that ports would be all around the display which would make the data exchange more easily. Especially, when users work with an unknown device whose name they do not know, they would prefer such a technique because so the device is easy to find and easy to distinguish. In general participants thought this would increase their overview when they used a USB flash drive. Other participants mentioned that this would speed up their data exchange because they would need less clicks for the exchange. The access to get data from the flash drive into applications would be easier and faster.

Users liked the concept because it helps to distinguish devices.

Most users would use such a GUI but only when either the display had ports on all sides or the GUI had to deal with other applications that may block the location. Some users would only use such a GUI on large displays. Another aspect which was mentioned was that the GUI could get confused when there are a lot of files on the flash drive. In such a case users would prefer to open a classical window in a file manager to get a full overview.

The idea that such a GUI also can contain other digital objects like a text or a URL was rejected by all users. They all

preferred a strict file support and folders to sort the data if desired.

The concept of a “wormhole” got a very mixed feedback. A group of five participants would use such an interface for equipping the USB flash drive. They preferred the simple black hole with an option to open the file manager to see data on the flash drive. Those participants would open such a hole when they want to copy data onto the flash drive because they feel this would be a faster solution and make the way to copy the files more easily. After they had finished the task they would close the hole again.

Six of the participants would not use such an interface to manage data on a flash drive but to copy data onto their mobile device or another nearby computer as it was suggested by Nacenta et al. They liked the idea to put data in the one side of the “wormhole” and to see the data leaving the other end.

The concept of showing also the data being already on the stick was in general rejected. One of the main reasons was that the interface would be too big and the users wanted it to be small. Some of the users would prefer to see a short list of the last elements that were copied. Others only wanted a file manager window to see which data was already on the device.

Half of the participants would not use such an interface. The reasons for it were quite different. Three participants wanted to order their data in folders and wanted to have the full overview over the device. Two participants expected that the data would not be copied but moved instead and since they normally did not want to move the data but copy it, they did not want to use the interface. One participant felt unsure because he could not see the exit of the hole and so he would not use it. Another participant rejected all GUI extension because he thought the exchange with a normal file manager would be the fastest and most comfortable way to copy data.

### Daily objects for data transportation

The concept to connect real world objects with digital data was rejected by most participants. In general people knew that the data could not be directly on the object. Neither the idea that the object was only the metaphor for the transport nor an electrical solution really convinced the participants. Participants did not trust the data transport over the network when the object was the only key to lock the data access. Either the participants wanted to lock the data with a password or they rejected the idea to send data over the network in general. Some male participants also mentioned that the only objects they had always with them were a mobile phone, keys and their wallet and none of these objects they wanted to use to transport data.

Concept was rejected by most participants.

If the data could be really stored on the object, people complained that probably they would have to change the behavior in regard to the objects. The fact that there is data on the object forces them to handle that object with more care than usually. Some of the participants created out of this idea a new concept for wireless transportation (see Chapter 4.2.2—“New ideas by the participants”).

### On-screen exchange device

The concept of an on-screen device which can be filled with drag&drop and provides a possibility for a direct interaction polarized the participants opinion. Four participants really liked the idea because of the way they could fill the device with data. The fact that they did not have to search an empty USB slot to use the device was seen as a big advantage. One participant would use such a technique occasionally when he wanted to transport a few files quickly. The rest of the participants completely rejected this concept because they would lose a part of the display and it would distract them while working on the display. Again there was a group of people who were scared to destroy or scratch the display. Because of this fear they would not use such a device. The people who rejected this method,

Concept polarized the participants opinion.

Some users were afraid to scratch the display.

rejected all three versions because the main reason for their decline was that the device was on the screen.

The participants who liked the concept and wanted to use it did not like the idea of a button to release the data. About half of those people just wanted an option to see the data that were on the device in the file manager. The others preferred a graphical solution like our proposed ring to see which data were currently on the device.

All participants claimed that the actual size of the device was too big and that it was unhandy to transport.

### **New ideas by the participants**

During the inquiry six of the participants mentioned that they would like to have a kind of wireless flash drive. When the computer had recognized the device they wanted a window like we showed them which allowed them to manage the data on the device. Although this was not relevant for our evaluation we want to mention it. Maybe this knowledge will help somebody to invent a new device.

## **4.3 User survey**

### **4.3.1 Design of the survey and initial hypotheses**

In this section we will present the survey we made to figure out which techniques are mainly used today and what the reasons are for choosing these methods. When we started with the survey it was planned as a handout after the contextual inquiry. But since we got more and more questions about which techniques the users use today, we also decided to create an online version of this survey. Our main goal of the survey was to find out which technique is the most popular one and what are the reasons for this. Since we were not only interested in the way the user exchanges data between computers, we decided to investigate which techniques are used for smartphones and tablet computer.

Goal was to find out which exchange methods users use.

We tried to verify the following two hypotheses:

- H1 The preferred operating system does not effect the preferred exchange method
- H2 People with technical background (experts) prefer other data exchange methods than other people

In regard to designing, developing and evaluating exchange techniques it is important to understand these two aspects. Getting qualifier for the preferred operating system was quite easy, we only had to ask the user. Finding qualifiers to define a participant as an expert was more difficult. We decided to qualify experts regarding their profession and the time they spend working on a computer. If the participant was a student, we ask him for his field of study.

In our design we followed Mayer [2008] in his recommendations to start as early as possible with the main topic of the survey and asking personal question at the end of the survey. This order should make the participant get more quickly involved in the topic which increases the chances that he will finish the survey. Answering all the topic related questions should strengthen the bond of trust so that the participant is more willing to share the personal data.

Our survey consists of five parts:

1. Data exchange between computers
2. Data exchange between smartphone and computer
3. Data exchange between tablet and computer
4. Personal experience with the data exchange methods
5. Personal background information

The survey contained 20 questions. Since not all participants use a smartphone or a tablet computer some questions were excluded. So that the minimum were 12 questions for those participants. The complete survey can be found in the appendix A—“Summary Forms”. In each of

the data exchange sections we asked the participant if he used this device. In case he used this device we asked which operating system is on the device and how long he averagely used this device per day. Then he could choose his preferred exchange method from a list of today's common exchange techniques. We tried to keep this list simple so that even very unexperienced participants felt capable to choose their methods. From a technical point of view the list may seem a little imprecise but we expected that people with technical background should easily be able to find their preferred method.

The list of exchange methods for exchange between computers contained the following item:

- Do not share data
- USB flash drive or USB portable hard disk
- Other data medium like CD-Rom, SD card, floppy disk, etc.
- Shared folder
- Uploading data onto a server like FTP or web sharing services like *RWTH Gigamove*<sup>3</sup>
- Cloud service to synchronize the data like *Dropbox*<sup>4</sup>
- Email
- Social networks like Facebook

For exchanging data between computer and smartphone the participants could choose between these items:

- Do not share data
- Connect smartphone with a USB cable and exchange data as with a USB flash drive
- Connect smartphone with USB cable and use a software for synchronization

---

<sup>3</sup><http://gigamove.rz.rwth-aachen.de>

<sup>4</sup><https://www.dropbox.com>

- Email
- Cloud service like Dropbox
- Data medium like SD card
- Smartphone synchronizes itself

The possible items for the tablet computer were very similar to the smartphone:

- Do not share data
- Connect Tablet with a USB cable and exchange data as with a USB flash drive
- Connect Tablet with USB cable and use a software for synchronization
- Email
- Cloud service like Dropbox
- Data medium like SD card
- Tablet synchronizes itself

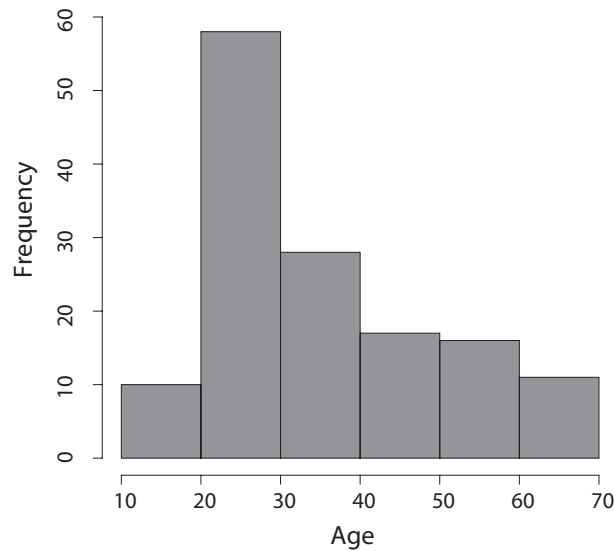
The items “cloud service” and “device is synchronizing itself” seem on the first glance redundant because obviously this self synchronization could also be seen as cloud service. But there were good reasons for this distinction. The first reason is that the users may not realize that this is already a cloud service. Also this kind of exchange method is very platform dependent as each platform has its own service.

We created the online version of our survey with *Google Docs*<sup>5</sup> and analyzed the data with *R*<sup>6</sup>.

---

<sup>5</sup><http://docs.google.com>

<sup>6</sup><http://www.r-project.org/>



**Figure 4.5:** Histogram of the survey participants' age.

### 4.3.2 Results of the survey

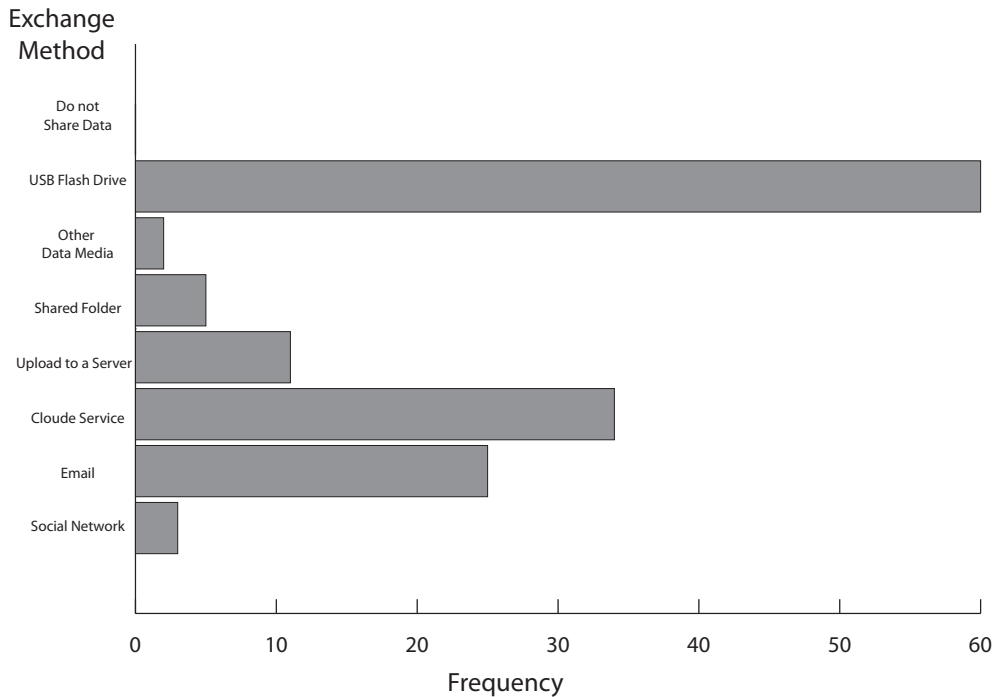
Survey had 140 valid responses.

In our survey we got 140 valid responses and had to exclude 5 answers because they were clearly filled in a wrong way. From those 140 participants 105 possessed a smartphone and 28 of them also own a tablet computer. The youngest participant in the survey was 15 years old while the oldest was 70 years old. In all relevant age groups we had at least 10 participants although the age group 20-30 is an over represented one (Figure 4.5).

#### General findings

The preferred exchange method for exchanging data between computers, as we expected, was the USB flash drive or USB hard drives. With 60 answers that means 42.86% it had a huge lead over cloud services with 34 answers that





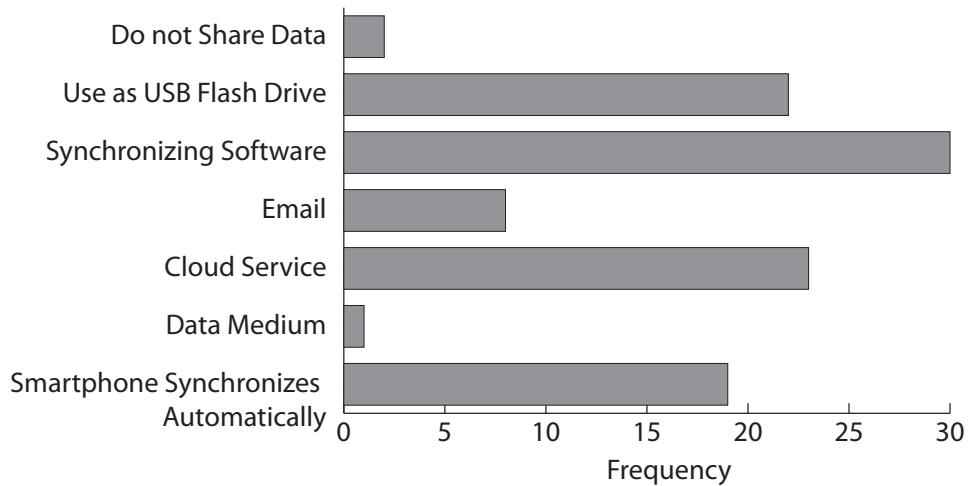
**Figure 4.6:** Preferred exchange method for data exchange between computers

means 24,29% (Figure 4.6). The third frequently chosen exchange method was e-mail with 25 answers that is about 17.86% fraction. The only other method that got more than 10 answers was the data upload onto a server with 11 answers. All the other exchange methods had less than 10 answers.

USB flash drive was the most preferred exchange method.

The preferred exchange method for exchanging data between smartphone and computer was using a cable with synchronization software with 30 answers which is about 28.57% (Figure 4.7). It is followed by the cloud service with 23 answers (21.9%) and “using a cable and use device as USB flash drive” with 22 answers (20.95%). Also the answer “smartphone is synchronizing itself” is with 22 answers (18.1%) close to most preferred techniques. It is recognizable that the distribution over the different methods is more even compared with the exchange methods between computers which were dominated by USB flash drives. The reason for this could be the higher dependence between mobile operating system and exchange method. In

Synchronization software was preferred for the exchange between computer and smartphone.

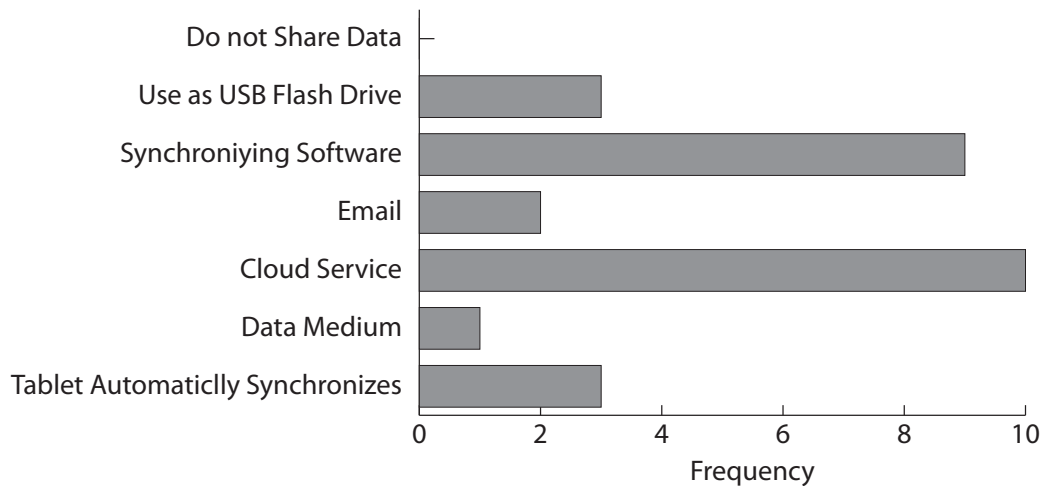


**Figure 4.7:** Preferred exchange method for data exchange between smartphone and computer

this aspect we will investigate later in this chapter in section 4.3.2—“Hypotheses and other findings”.

The preferred exchange method for exchanging data between tablet computer and computer was the cloud service with 10 of 28 answers (Figure 4.8). With 9 answers the second most exchange method was “using a USB cable with synchronization software”. The answers “use a USB cable and use device as USB flash drive” and “Tablet synchronizing itself” got each 3 answers. Although we had 28 participants who use a tablet computer most of them used a device with an iOS operating system. So we had 24 iOS devices and only 4 tablets with Android as operating system which made it hard to find any significant effects for the tablet computer.

Before we present the more specific findings and control our hypothesis we will first present the answers from the



**Figure 4.8:** Preferred exchange method for data exchange between tablet computer and computer

free text fields like why the participant prefers an exchange method and which aspects still annoy him.

### USB flash drive

When we started with this study, we already expected that the USB flash drive would be quite popular but we also wanted to understand why. So we collected the reasons in free text fields where we asked the participants to write about their personal experience with the exchange method whether they were good or bad.

On the one hand we found a lot of strict technical reasons why people liked USB flash drives. These characteristics were often mentioned:

- + platform independent

- + nearly all computers have a USB port
- + high data transfer rate
- + good for large amount of data
- + do not have to install any software
- + offline data exchange is possible / no Internet connection needed
- + it is cheap
- + method is allowed by company policy rules as others are forbidden
- + do not have to create an account

On the other hand there were human reasons like:

- + easy to use
- + technically inexperienced and glad this works for me
- + feeling of being able to control the access
- + like to have my data ordered in my way
- + fits in every pocket / have it always with me
- + do not want to put private/business/customer data into the Internet
- + do not know other exchange methods
- + company does not allow cloud services

Since the technical reasons kind of speak for themselves we want to dig a little deeper in human reasons. Technically inexperienced participants seem to favor the USB drive because they find it simple and easy to use. They have the feeling that this method does not need any technical understanding and that it will work reliably on all computers. That USB flash drives are platform independent was a reason which we could find often regardless of the technical background.

There is also another trend with people who do not want to put private or business data into the Internet especially not to an “unknown” third company. Also the participants believe that they are in full control of the USB flash drive access and so they feel more secure. Although the participants are aware of the fact that the flash drive could be stolen, they feel able to control this more than a possible hacker attack on an Internet account. So obviously the fact to have a physical device in hand gives the user the feeling of full control although a flash drive could get lost or could get stolen.

Many people do not want to put private data into the Internet.

Although the USB flash drive is quite popular there are still things that annoy people and situations in which they suffer from disadvantages. This is a list of disadvantages which were mentioned frequently:

- flash drive is too small / is full
- drive is not recognized
- forgetting the USB flash drive
- searching a free USB port
- not good when under time pressure
- only possible to save full files and not able to save digital objects
- laborious method if you only want to take a small file with you
- device defect

Some points of the list are not realistically changeable like the drive size, a device gets defect or that a device could be forgotten. That are disadvantages which are part of physical devices. Also that the drive was not recognized is a point which may be solved but will never be completely eliminated.

But there are also aspects where an improvement would be possible whether with new interaction methods or with slight modifications on the USB flash drive.

### **Data exchange with USB cable and the file system**

In the study a lot of people preferred to connect their mobile device only with a USB cable and exchange the data in manual way via file system. Most pro and contra points were already be mentioned in 4.3.2—“USB flash drive”. Some of them slightly changed as for example that forgetting the cable is annoying. The dissatisfaction with the synchronization software forced some people to exchange the data manually.

### **USB cable and synchronization software**

Although the variant of USB cable with synchronization software was one of the most chosen exchange techniques for mobile devices the list of positive arguments and experiences was quite short:

- + high security
- + company security does not allow cloud service
- + only option for my device
- + works well

The reasons “only option for my phone” we read surprisingly often. In fact, we know that there are more methods available for the phones. So it could be possible that people who chose this method did not really choose this method because they liked it. They did it more for the reason that they just did not know other methods.

Nevertheless we also wanted to find out what people disliked about this method:

- software deletes files
- not all data is supported

- problematic for exchanging data with other unknown computers

The negative aspects are in general all technical issues or application specific issues.

### Cloud services

Shortly, after we had observed which method for data exchange people at the Media Computing Group used, we noticed that a lot of them used Dropbox or similar services. So we were unsure if there was still any need for data exchange techniques since maybe cloud services are the future. With the survey we saw that cloud services were quite popular but there are still unsatisfying aspects. First we examined why people used cloud services:

- + group sharing possible
- + data is accessible from “everywhere” / possible access data spontaneously and unplanned
- + data exchange is automatic
- + provides an undelete function
- + do not need a cable / works wireless
- + very good for small files
- + works on all my devices

Some of the reasons address new functionalities like the undelete function or the possibility to share the access to files and so enable group sharing. Then there are as usual some technical reasons like that cloud services are good for small files. Without capacity limits and with a fast enough connection people can use it also for bigger files.

But there are also reasons in regard to the interaction technique as for example that the cloud service works for all

devices. Since the variety of computing devices got bigger over the last years, also the exchange methods have to support these devices. The real new aspect with cloud service seems to be the unplanned spontaneous access on the data. Actually, this is a unique feature which has not been mentioned in any other exchange method because most of them did not support it. So the other methods seem to have a lack of spontaneous data exchange.

Some mobile devices also offer the possibility of an automatic background synchronization. Although this is also a cloud service we want to separate it a little bit because it is strictly operating system dependent. What people like about background synchronization:

- + when once setup, best solution for calendar and contacts
- + simple

So this kind of synchronization is a special case which is mainly used for keeping the calendar and contacts up to date. This is in anyway a data exchange process which needs a kind of software support.

But we can also see that there are still aspects at cloud services that dissatisfy the users:

- needs an Internet connection / firewall
- expensive (in regard to mobile exchange)
- slow network / big files
- not secure enough for real private data
- needs to be setup first

Most of these aspects are technical or network specific problems. We are more interested in the last aspect because it was named by cloud service users. Although those people already use cloud services, they see a lack of security and



news contributions like “Dropbox accepted for four hours any passwords”<sup>7</sup> underline this issue.

## Email

Email is quite an old technique but still very popular. The survey shows that it is not only used for exchanging messages but also for exchanging data. The reasons people named why they use email:

- + very good for small files
- + quick (in regard of setup the file exchange)
- + no cable or plug-in position needed
- + allows exchange method from system administrators
- + good for working in a group

Again the wireless data exchange is a reason why people like a method. The point “good for working in a group” is an interesting point. Unfortunately, we could not ask the people why they prefer email for working in a group. Either they do not know other methods for this purpose or they still prefer email because it does not need any setup time.

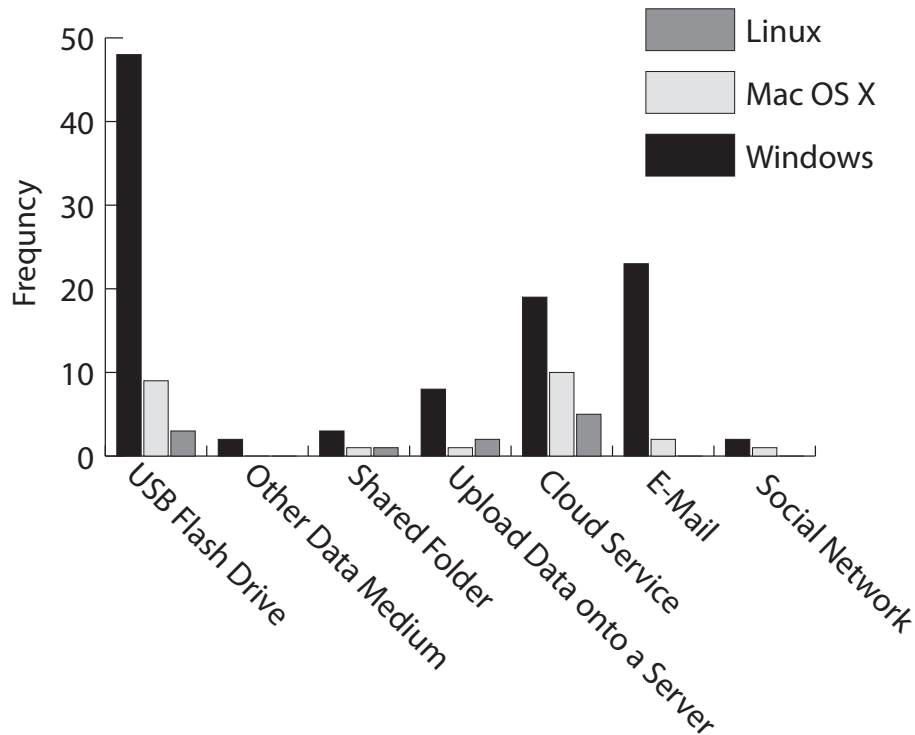
What is an interesting finding in regard to email is that it has the shortest list of disadvantages and all points in it are technical reasons:

- files too big
- inbox was full

It could be interesting to investigate deeper into the email data exchange to find out why people have not experienced more disadvantages and if this could help to increase data exchange.

---

<sup>7</sup><http://heise.de/-1264100>



**Figure 4.9:** Preferred data exchange method for exchange between computers distinguished by the preferred operating system.

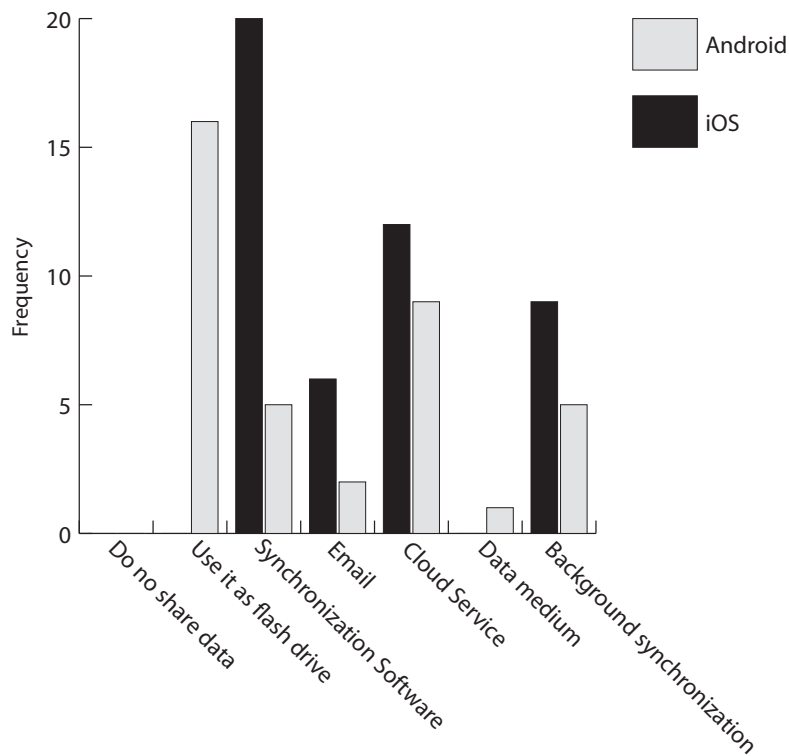
### Hypotheses and other findings

After we have discussed the general findings we will now discuss the hypotheses we made. We investigated into our first hypotheses:

H1 The preferred operating system does not effect the preferred exchange method

In the study we had 105 Windows users (75% of all participants), 24 Mac Os X Users (17.14% ) and 11 Linux users (7.85%). As can be seen in Figure 4.9 it seems that there could be a dependents between operating system and preferred exchange method.

*So we ran a Chi-square test with Yates' continuity correction which could not show a significant effect ( $p > 0.2$ ) on the pre-*



**Figure 4.10:** Preferred exchange method for the exchange between smartphone and computer for Android and iOS.

*ferred exchange method in regard to the operating system for computer data exchange.*

In mobile operating system 47 iOS users (44.47%), 38 Android users (36.19%), 7 Blackberry users (6.67%), 5 Windows mobile users (4.76%), 3 Symbian (2.86%) and 6 participants used other operating systems like Bada. First investigations showed that there seems to be an effect between preferred mobile operating system and preferred exchange method (Figure 4.10).

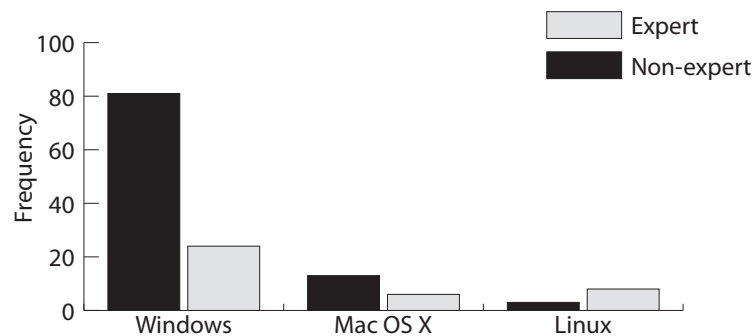
*Our Chi-square test with Yates' continuity correction revealed that the percentage of preferred exchange methods significantly differed by mobile operating system ( $\chi^2(1, N = 105) = 69.48, p < 0.001, \phi = 0.813$ ).*

So the effect size  $\phi = 0.813$  on the preferred exchange method in regard to the preferred operating system is large. This effect can be explained by the currently different

The smartphone operating system has influence on the preferred exchange method

philosophies of mobile operating systems. Since Apple offers its own free synchronization software which is needed to activate an iOS smartphone but Apple's cloud services, MobileMe, charges money many iOS users prefer synchronization software over cloud services. Android users favor the cloud service background synchronization more than iOS users because Google offers its cloud services for free. Also the smaller number of alternative exchange methods can be a possible reason.

Still we have not investigated in the effect that there are differences visible in Figure 4.9. When we analyzed it we found that the expert distribution was not even on all three operating systems (Figure 4.11).

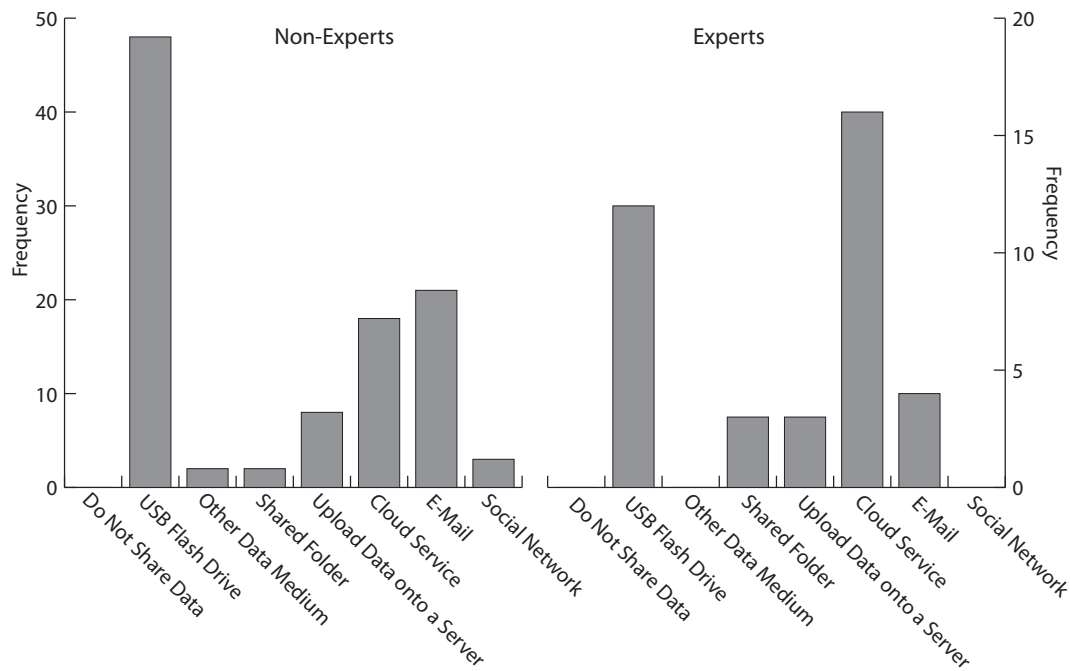


**Figure 4.11:** Distribution of experts over the different operating systems.

This discovery leads us to our second hypotheses:

H2 People with technical background (experts) prefer other data exchange methods than other people

The original idea was to classify experts by their profession and the time they use computer. Unfortunately, we falsely estimated the time that most people spend on a computer.



**Figure 4.12:** Preferred exchange method distinguished between non-experts and experts.

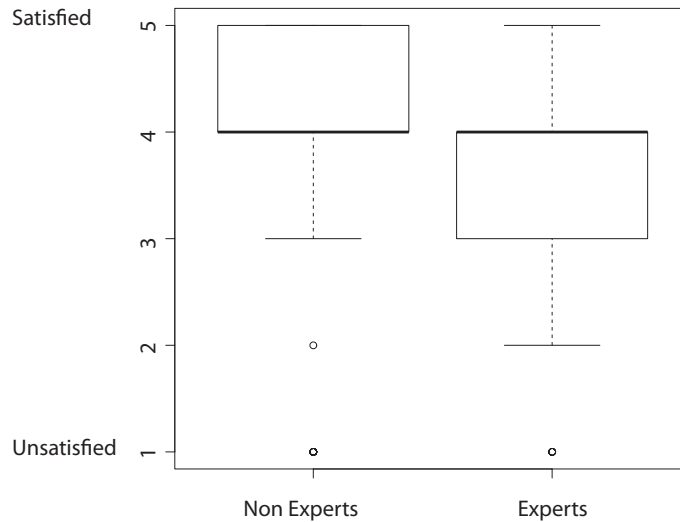
People tend to use the computer longer than we thought and so the only indicator which was left was the profession.

From Figure 4.12 can be seen that the frequencies differ for non-experts and experts.

*Our Chi-square test with Yates' continuity correction revealed that the percentage of preferred exchange methods significantly differed between experts and non-experts ( $\chi^2(1, N = 140) = 14.53, p = 0.024, \phi = 0.322$ ).*

Experts prefer other exchange methods.

The effect size is medium and the probability value  $p = 0.024$  is still a little bit high. This can possibly be explained by our expert classification. Some participants answered the question about their profession with things like "self-employed" or "salaried". From the answers about their experience with the exchange we could see that some of these persons had a lot of technical background. But we wanted to stick to a clear indicator and so we had to mark these per-



**Figure 4.13:** User satisfaction for data exchange between computers distinguished between experts and non-experts

sons as non-experts. So we believe that in the group of non-experts there still some experts are left who were wrongly classified.

Since experts and non-experts differ in their preferred exchange method and the experts are not equally distributed over the operating system we assumed that this effect was maybe visible in Figure 4.9.

We also discovered another effect in regard to the distinction between experts and non-experts. When we analyzed the user satisfaction, we recognized some differences between expert users and the rest of users (Figure 4.13). Although the median from both groups is the same, the differences in the quantiles and the whiskers are obvious.

*The medians of experts and non-experts were both 4.0. We ran a Mann-Whitney's U test to evaluate the difference in the responses of our 5-Likert scale question. We found a significant*

*effect of Group (The mean ranks of experts and non-experts were 57.99 and 72.58, respectively;  $U = 2261.5$ ,  $Z = -2.11$ ,  $p = 0.035$ ,  $r = 0.18$  ).*

Obviously, users with a technical background seem to be more dissatisfied with the data exchange between computers than the other users. We found the same effect also for mobile data exchange.

Experts are more dissatisfied with common exchange methods.

*The medians of experts and non-experts were 3.5 and 4.0, respectively. We ran a Mann-Whitney's U test to evaluate the difference in the responses of our 5-Likert scale question. We found a significant effect of Group (The mean ranks of experts and non-experts were 42.65 and 56.49, respectively;  $U = 1405.5$ ,  $Z = -2.25$ ,  $p = 0.024$ ,  $r = 0.21$  ).*

But there was still more to discover concerning user satisfaction. For the exchange between computers the satisfaction was quite high. When we compared the satisfaction with the other exchange methods we found that the median is the same. But the quantiles and the whiskers showed differences (Figure 4.14). So we looked if people who used the computer exchange as well as the exchange between computer and smartphone were really more dissatisfied with the smartphone exchange.

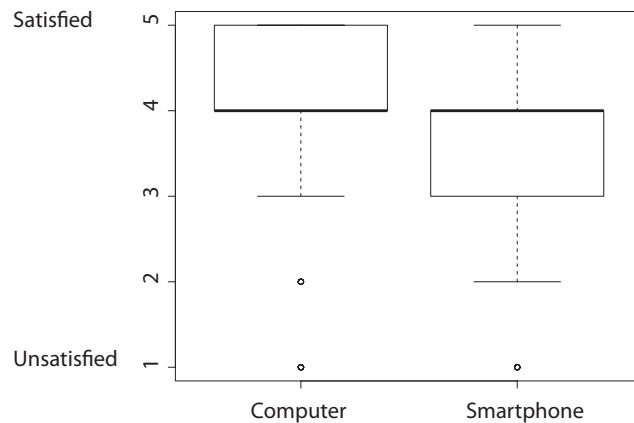
*The medians of computer exchange and mobile exchange were both 4.0. A Wilcoxon Signed-rank test shows that there is a significant effect of Group (  $W = 852$ ,  $Z = 3.65$ ,  $p < 0.001$ ,  $r = 0.36$ ).*

The estimate the satisfaction for the exchange between tablet computer and computer we did not have enough data to show any significant effect.

Users are less satisfied with the exchange between computer and smartphone.

## 4.4 Summary and conclusions

Before we come to our user study, we will sum up the most important findings from this chapter and what we conclude from them.



**Figure 4.14:** User satisfaction for data exchange between computers and for data exchange between smartphone and computer.

Users favored the natural position of a pen for the pipette

In the contextual inquiry the additional GUI for USB flash drives gets a great feedback and most of the participants would use such a GUI at least for some of their tasks. Especially the connection between the position of the USB flash drive and the GUI is favored from the users. The idea to put a device directly on the screen is not a concept for all users although a group of users really favor this idea. This concept gets good criticism, too. The position with the bulb or mechanism in the front of the pen is favored by most people because of the normal position in the hand. We learn that a special copy&paste device will be more realistic than an extension to the normal stylus pen. Especially, for a short term usage a pipette device is really popular.

The concept to use normal daily objects to transport data is rejected by the participants and also the “wormhole” is only liked by a small group.



The survey with 140 participants shows that users with a technical background prefer other exchange methods than average users. In general, the USB flash drive is the most preferred exchange technique. Although cloud services are also very popular they are especially preferred by experts. Users like the USB flash drive because it is a physical device which they can control better than data in the Internet. Also the facts that this method is very simple to use and that it is reliable are reasons why people like this method. About cloud services people like the aspect that they can use them in an unplanned and spontaneous way and that they work for all their devices. Also the additional functionalities like undelete, automatic synchronization or group sharing are reasons why people prefer cloud services as exchange method. For desktop computers the preferred operating system seems to have no effect on the preferred exchange method. But for mobile operating systems the effect on the preferred exchange method is large.

Users like physical device because they can control the access.

The satisfaction for the data exchange between computers is quite high but the satisfaction is smaller for the data exchange between computer and smartphone and probably also between computer and tablet computer. In general, experts seem to be more critical and they are less satisfied with current exchange techniques.

So for the design of exchange methods as well as for the evaluation it is important to know the influence of experts. Maybe experts like a method which will be rejected by non-experts and vice versa. There is also a group of users who do not like or are not allowed to put data into a cloud service. Those users are also interested to get better exchange methods.

Experts have a huge influence on the evaluation.

The high influence of mobile operating systems in regard to the exchange method can be explained by the lack of open standard for mobile devices and the different manufactures' philosophies. For this kind of data exchange the users still feel a lack of good alternatives and the satisfaction with current methods is smaller. For our next study we will focus on the devices that the users really want to use in the inquiry. Especially, we will focus on the pipette concept and the GUI for USB flash drives.



## Chapter 5

# User study

After we had presented different exchange methods to users in our contextual inquiry, we developed a setup in which the exchange methods could be compared with each other. Since we knew from the survey which were the most popular exchange methods and why people liked them we decided not only to compare the new approaches with each other but also to compare them with today's most popular exchange methods. So it is not only possible to see if the new approaches can really improve the cross-device data exchange but we can also compare them in regard to interaction time with today's common exchange techniques.

In this chapter we will present the design and results of the second user study we did.

### 5.1 Design of the user study

From the results of the contextual inquiry in Chapter 4.2.2—"Results and observations of the Contextual Inquiry" we re-engineered some of the concepts while other concepts which the users did not like at all got excluded. Since we decided not only to compare the methods with each other but also to include current exchange methods we decided to choose the USB flash drive and a cloud service. The USB flash drive was in general the most popular ex-

Techniques were re-engineered with the results from the inquiry.

change method in the survey and especially average computer users chose this exchange method. The cloud service was very popular on all three devices and especially experts seemed to prefer it over all other methods. So maybe experts are only early adopters and the future of cross device exchange will be cloud services. Hence we decided to choose those two data exchange techniques to be in the study.

### 5.1.1 Study setup

For the study we decided to let users exchange data between computers. Since the different data exchanges were quite different we needed an environment to make them comparable. Hence we decided to let users exchange files because this exchange was possible with all techniques.

In our setup we had two computers. One computer was a desktop computer with Mac OS X 10.6 as operating system and a Wacom Cintiq 21ux display which supported pens as input device. Unfortunately we were not able to get a second display which worked with the same pen as the Cintiq 21 ux. This had some influences on the pipette device (for details see Chapter 5.1.2—“Pipette concept”) but did not have an impact on the interaction method. The second device was an Axioton Modbook with a 13.3 inch display which also supported pen input.

Participants had to exchange files between computers.

The two computers were setup with a distance of two meters between them. In the study the participants copied three files from one computer to the other computer. We presented the different methods at random order and if the participant desired he could make one test run. Afterwards he had to copy three files from one folder of the first computer and copy them in a folder on the second computer. When there were no constrains from the exchange method itself, for example the pipette device could not be used with the keyboard, the participant was allowed to copy the data in his usual way. For example when the participants copied data to a USB flash drive, he could drag the data on the device, use the context menu or copy them with keyboard commands depending on their copy&paste habits.

The participant had to copy the three files five times with each exchange method and we measured the time for each run. The time a participant needed to change the computer and the time to plug in a device was not measured. From the measured times we took the three best trials and we calculated the average time a participant needed to copy&paste the data.

Time was measured for the interactions.

Since we know from the survey that experts have a significant influence concerning the preferred exchange method and our time was limited we decided to keep the number of experts small in this user study. Hence we avoided to ask too many experts from the Media Computing Group and focused more on the average computer user.

For the evaluation of the study we switched the statistic program from *R* to *IBM's SPSS*<sup>1</sup>. The reasons to switch the program was that working with *SPSS* seemed to be much faster and we spent less time in investigating in pointless hints and warning. Especially in combination with the book of Andy Field [2009], *SPSS* seemed to be the best choice.

### 5.1.2 Pipette concept

The pipette idea was quite popular during our contextual inquiry. Although many users would only use it to do a short distance data exchange there were some people who liked to use it as long distance transport medium. The main problem for long distance transport is the small capacity of the original approaches. For comparability reasons we had to enable the approach to be capable to transport more files than one file at once. Otherwise the participants had to walk several times between both computers to exchange the data and that would make it impossible to compare the time with the other techniques. So we added the possibility that the pipette device was capable to transport more than one file. Consequently the user could now collect several files one by one and press the bulb for each file. After he switched the computer he could release all collected

To make pipette comparable it got an extension.

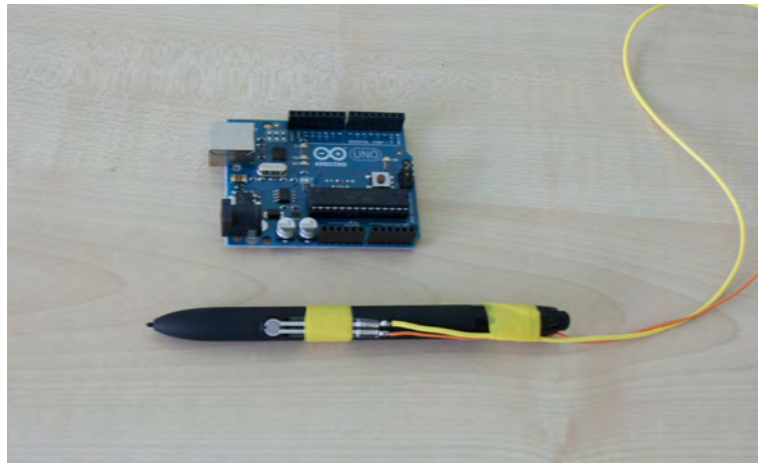
<sup>1</sup>[www.ibm.com/software/de/analytics/spss/](http://www.ibm.com/software/de/analytics/spss/)

data by pressing the bulb only once. Without this change the user had to switch the computer for each file and that would make it hard to compare it with the other exchange methods.

After the contextual inquiry we got the impression that the bulb mechanism in the front was the preferred design of the pipette concept. Since this is the position of the hand people normally have to write and sketch people felt confident to navigate precisely with this concept.

We built a first prototype with an FSR pressure sensor and an Arduino UNO board. With this prototype we wanted to test the idea of using the pressure and the duration a user presses the bulb to select the objects that should be copied (Figure 5.1). During our tests with the device we noticed that such a technique was good for big areas but really hard to control for small objects or if the objects were not symmetrically around the tip of the device. So we decided to use the sensor only as a better switch and give it the mode, pressed and not pressed.

First functional prototype did not work as desired.



**Figure 5.1:** First functional prototype of the pipette device build with a FSR sensor and an Arduino Uno.

The problem with our study setup was that we were not able to get to pen input devices that worked with the same pen. So we decided to reprogram the already existent buttons from the pens to simulate the bulb mechanism instead of building a second device. The position of those buttons

Problems with the study setup forced some changes.

was ideal and very similar to our original concept. In regard to the interaction this change did not have a big influence and had the advantage that the user had a wireless and light device.

As with the other pen or pipette approaches we copied the files over the network.

### 5.1.3 Exchange dot

The concept of the exchange dot we presented during the contextual inquiry was really favored by many participants although many users were scared of damaging or scratching the display. Also the size of the non-functional prototype was criticized. It was too big and too unhandy.

So our first idea was to use a tabletop computer. This would give the possibility to detect the device. Also the more robust surface of a tabletop computer would help that users were not scared to damage something. But including a tabletop computer into the setup would make a comparison of the interactions even more difficult since there were differences in mouse input and touch input [Sasangohar et al., 2009]. So we decided to set a fixed position for the exchange dot during the study and So detection was not needed.

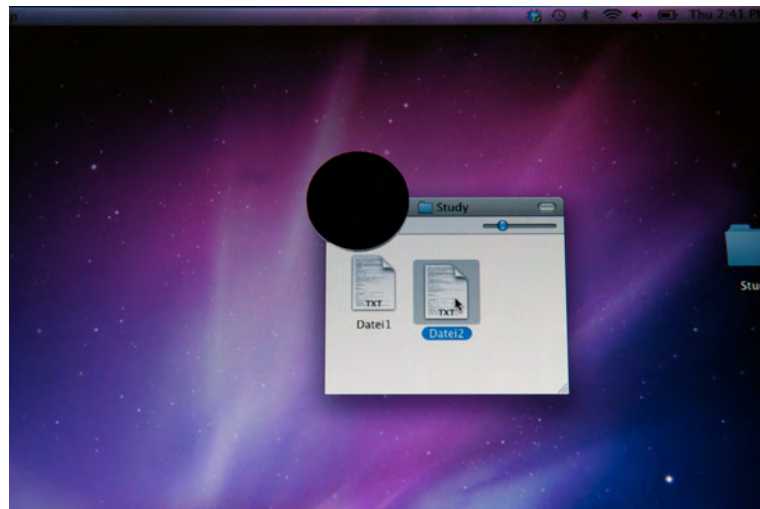
First ideas was to use a tabletop computer.

One big issue was the size of our non-functional prototype. So we created a new small version of the exchange dot which we cut out of black acrylic glass. Since we did not use any detection we set the position of the device fixed for this study and programmed a small application which detected when files were dropped in the region of the exchange dot. The files were then copied in the background onto a server while the user got the impression the data was really on the exchange dot.

Still there was the problem how to release the data from the exchange dot. Since our first approach of a GUI was rejected in the contextual inquiry and the solutions of Hyperdragging and LightSpace were not that simple to integrate in a normal operating system, we decided to present

Device recognition was setup as Wizard of Oz experiment.

the data in a customized file manger window. Although this solution was simple the interaction of this technique stayed untouched. Since we did not have detection we did this part as a Wizard of Oz experiment and started the customized file manger window manually (Figure 5.2).



**Figure 5.2:** Exchange dot with GUI support to paste data on a device.

#### 5.1.4 USB flash drive with graphical user interface

As the idea of connecting the virtual world and the real world with each other and showing a GUI at the position where the USB flash drive was plugged in was desired by a big group of participants we decided to include it into our user study. This experiment we set up as Wizard of Oz experiment and decided again for a customized file manger window (Figure 5.3). From the contextual inquiry we knew that the users favor a file manger like behavior for such a GUI it was obviously the best solution to provide a file manger window.

The Modbook already had a USB slot on one side of the display. So it could stay unchanged. The Wacom Cintiq display did not have a USB slot and so we had to mount a USB extension cable at one side. With the USB extension cable





**Figure 5.3:** USB flash drive with additional GUI to support the data exchange.

participants were able to plug in the USB flash drive while we started the customized file manger window to show up.

### 5.1.5 Common data exchange methods

As we have already mentioned we also included common data exchange methods into the study. We had two reasons for this decision. First we wanted to compare the time that people needed to exchange the data with common methods and with the new presented methods. The second reason were the results of our survey. From the results we saw that cloud services like Dropbox have got more popular and are already capable to exchange data with nearly all devices.

USB flash drive and  
Dropbox were  
included in the study.

We decided to use the USB flash drive since it was the most popular exchange method. To represent cloud services we decided to use Dropbox since we thought it was the most common one. We installed Dropbox in its default configuration without any customizations.

### 5.1.6 Study survey

Each participant also got a small survey where we asked some questions concerning computer usage and personal information. We asked the participant about his experience concerning Mac Os X and stylus pen input because this could have influence on the results.

Study survey with 5-Likert scale was provided.

The survey included a 5-Likert scale for each exchange method the participant used in the survey. A new interaction method could improve the productivity and speed but without a user who wanted to use it, it was useless. The list with all survey questions can be found in appendix A—“Summary Forms”.

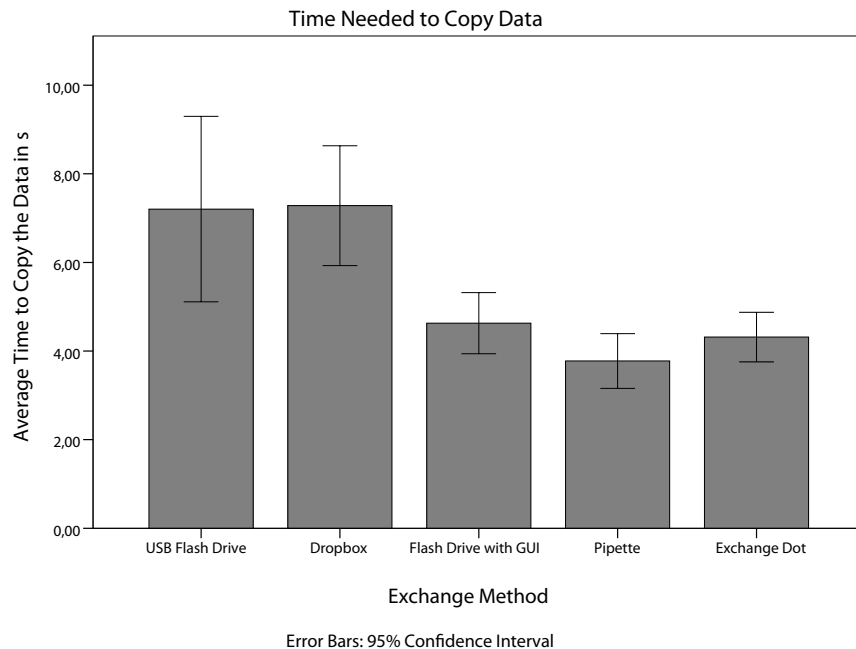
## 5.2 Results of the study

### 5.2.1 Study statistics

In the study we had 15 participants aged between 21 and 33. Six of the participants were female and nine were male. We had three Mac Os X users in the study and twelve Windows users. Three of the users had experience with stylus pen input.

Interactions with the new approaches were a lot faster.

We separately took the times the participants needed to copy the data on the one computer and to paste the data on the other computer. As we can see the in Figure 5.4 there is a difference in the average time the user needed to copy the three files. With the new concepts the participants seemed to copy the three files faster than with Dropbox or the USB flash drive. When we look at the average times the participants needed to paste the three file the results are quite similar (Figure 5.5). With most of the exchange methods the participants were faster when pasting the data. Only with Dropbox the participants needed more time to paste the file than to copy them. Compared with pipette the participants needed more than double of time. So it seems that the new methods improve the data exchange in regard to the speed. So we tested if these results were really significant:



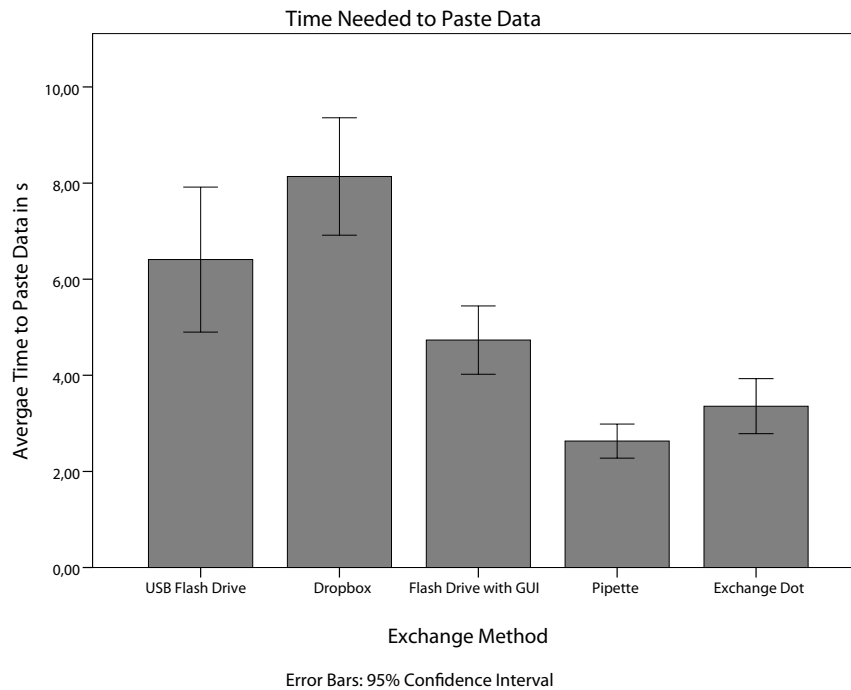
**Figure 5.4:** Average time a participant needed to copy the files per exchange method

*Mauchly's test indicated that the assumption of sphericity had been violated,  $\chi^2(9) = 62,89, p < 0.001$ , therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\varepsilon = 0.40$ ). The results show that the time to copy files was significantly affected by the exchange method,  $F(1.6, 22.29) = 14.64, p < 0.001, \omega^2 = 0.35$ .*

*Mauchly's test indicated that the assumption of sphericity had been violated,  $\chi^2(9) = 40,51, p < 0.001$ , therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\varepsilon = 0.41$ ). The results show that the time to paste files was significantly affected by the exchange method,  $F(1.65, 23.12) = 33.05, p < 0.001, \omega^2 = 0.61$ .*

So both tests show that there is a significant difference in regard to the exchange technique.

With the pipette device as can be seen in figures 5.4 and 5.5 the participants were able to copy and paste the three



**Figure 5.5:** Average time a participant needed to paste the files per exchange method

Pipette was the fastest method.

files the fastest. The difference of means in Table 5.1 shows that especially compared to today's exchange method it is significantly faster in copying the data. For pasting data the differences are even a little bit greater (Table 5.2). When we compare pipette with the other presented new interaction methods there are still differences but they are mostly not significant. Only in pasting the pipette device time needed to fulfill the task was significant faster compared with the USB flash drive with GUI.

The same effects show up for the other new presented exchange methods. Compared with today's exchange methods they are significantly faster in copying the data as well as in pasting the data (Tables 5.1 and 5.2). When we compare them with each other we can see tendencies but there are no significant differences with the exception from above.

With these significant results we expected to see people favoring the new exchange techniques because they are sig-

<b>USB Flash Drive</b>			
Method	Mean Diff.	Std. Error	p
Dropbox	-0.078	0.687	1.000
Flash Drive with GUI	2.576*	0.681	0.020
Pipette	3.429*	0.920	0.022
Exchange Dot	2.889	0.962	0.095

<b>Dropbox</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	0.078	0.687	1.000
Flash Drive with GUI	2.653*	0.476	0.001
Pipette	3.507*	0.561	<0.001
Exchange Dot	2.967*	0.510	<0.001

<b>Flash Drive with GUI</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	-2.576*	0.681	0.020
Dropbox	-2.653*	0.476	0.001
Pipette	0.853	0.382	0.424
Exchange Dot	0.313	0.376	1.000

<b>Pipette</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	-3.429*	0.920	0.022
Dropbox	-3.507*	0.561	<0.001
Flash Drive with GUI	-0.853	0.382	0.424
Exchange Dot	-0.540	0.169	0.065

<b>Exchange Dot</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	-2.889	0.962	0.095
Dropbox	-2.967*	0.510	<0.001
Flash Drive with GUI	-0.313	0.376	1.000
Pipette	0.540	0.169	0.065

\*. The mean difference is significant at the 0.05 level.

**Table 5.1:** The differences between group means for coping the three files

<b>USB Flash Drive</b>			
Method	Mean Diff.	Std. Error	p
Dropbox	-1.729*	0.316	0.001
Flash Drive with GUI	1.676	0.515	0.057
Pipette	3.778*	0.775	0.002
Exchange Dot	3.051*	0.774	0.015

<b>Dropbox</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	1.729*	0.316	0.001
Flash Drive with GUI	3.404*	0.453	<0.001
Pipette	5.507*	0.605	<0.001
Exchange Dot	4.780*	0.619	<0.001

<b>Flash Drive with GUI</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	-1.676	0.515	0.057
Dropbox	-3.404*	0.453	<0.001
Pipette	2.102*	0.444	0.003
Exchange Dot	1.376	0.534	0.219

<b>Pipette</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	-3.778*	0.775	0.002
Dropbox	-5.507*	0.605	<0.001
Flash Drive with GUI	-2.102*	0.444	0.003
Exchange Dot	-0.727	0.235	0.080

<b>Exchange Dot</b>			
Method	Mean Diff.	Std. Error	p
USB Flash Drive	-3.051*	0.774	0.015
Dropbox	-4.780*	0.619	<0.001
Flash Drive with GUI	-1.376	0.534	0.219
Pipette	0.727	0.235	0.080

\*. The mean difference is significant at the 0.05 level.

**Table 5.2:** The differences between group means for pasting the three files

nificantly faster. In figure 5.6 we plotted the results of the 5-Likert scale from the survey in a box plot diagram. As can be seen the medians really differ between the exchange methods. The median of the exchange dot is with a value of five the highest as the median of the USB flash drive is the lowest with three. But when we take a closer look at the box plot it is striking how large the lower and higher quantile is spread out for some exchange techniques. Especially for the pipette device and for the exchange dot the quantiles are wide spread.

New interaction techniques were higher rated in the 5-Likert scale.

So we tried to test the data for significant:

*We ran a Friedman's Test which showed that there are no significant preferred device ( $\chi^2(4) = 2.05, p > 0.05$ ).*

From the graph we already expected that we would not be able to show significant. It seemed that some of the participants preferred the new interaction methods to the common ones as other users stucked to the old methods. We will discuss other possible reasons for this in section 5.3—“Summary and conclusion”

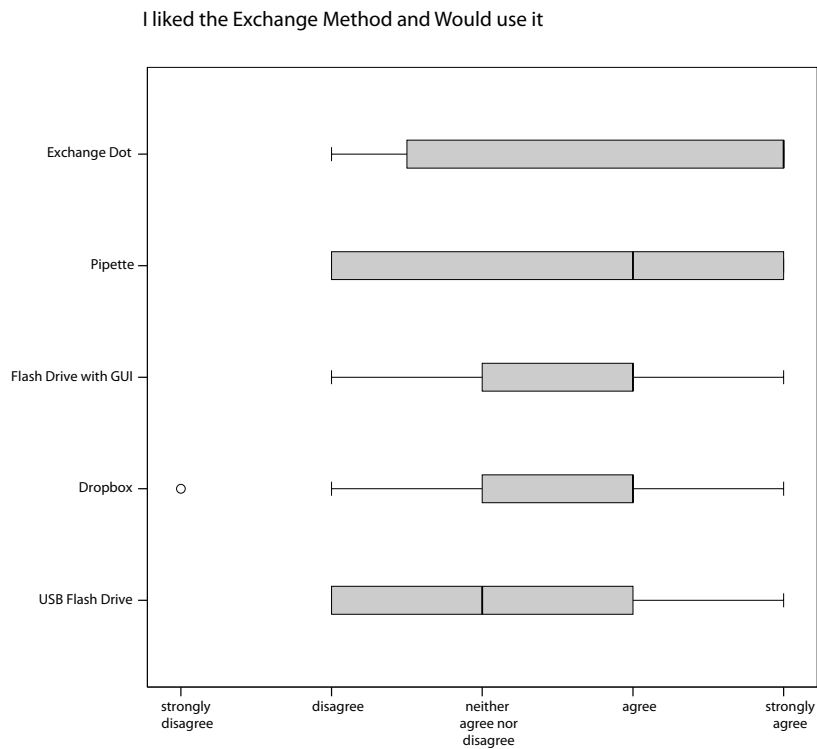
### 5.2.2 Observations during the study

In this section we will report about additional observations we made during the study which cannot be found in statistical data or can help to explain some of the data.

Because we did not make any restriction in regard to how participants should copy the files we could see a lot of different techniques to copy files. Three of the participants copied files onto the USB flash drive and into Dropbox by using the context menu. One participant switched between using the context menu and moving the files with drag&drop. Since the usage of the context menu is one of the slowest methods to copy files those participants were much slower compared with the others.

Some participants copied files with context menu.

The fastest participants during the study used the keyboard to support the selection process and then dragged the data into the desired location. Nobody used the keyboard short-



**Figure 5.6:** Results of the 5-Likert scale from the study survey.

cuts to copy the data. A possible explanation for this is the different keyboard layout for Mac Os X.

Since we used a server to transport the data for the pipette device and the network connection was so fast some users really believed that the data was actually on the device.

### 5.3 Summary and conclusion

As already described before you can see that the new interaction techniques are significant faster compared with the common methods USB flash drive and Dropbox. The new interaction techniques are faster in the copy action as well as in the paste action. Although the differences between the new techniques are not significant we see hints that the pipette concept is the fastest technique.



Although the participants need less time with the new interaction methods this effect is not reflected in their preferred exchange technique. One reason can be that people just stick to the exchange method they already know because they have proved its value over the years. Another explanation can be that they do not believe that such an interaction will really improve their daily work.

Some of the participants obviously favor cloud services. Most of them stick to this exchange method although the interaction is slower because of the features and services a cloud service offers. Especially the spontaneous and unplanned access to the data that is possible with a cloud service is not provided with the new exchange techniques.

Some participants stuck to the common exchange methods.



## Chapter 6

# Summary and future work

### 6.1 Summary and contributions

Since we started with this thesis we have found a lot of cross-device data exchange techniques which we presented in chapter 2—“Related work”. Due to the lack of a classification schema we presented them in a chronological order to show the development over the time. The only evaluation in regard to cross-device data exchange which were done by Nacenta et al. [2005] focused on multiple display reaching and provided a classification schema that was only for those techniques. So we created our own classification schema and classified the different approaches by their interaction in chapter 3.1—“Classification by interaction of the common exchange techniques”.

Only one other evaluation was made, yet.

After the classification we discussed about the different data exchange methods, their weaknesses and showed which techniques are outdated from today’s point of view. We chose a list of candidates which are, with small modifications, still up-to-date and that are comparable on an equal level. This list contain the pipette concept, the concept of transporting data with daily objects, a GUI to support the data exchange like presented in the passage concept or the

mediaBlocks and the exchange dot which was created from the hyperdragging concept.

Non-functional prototypes were built from all evaluation candidates.

From these candidates and the possible modifications we built non-functional prototypes which we presented the users in the contextual inquiry in chapter 4—“Non-functional prototypes, contextual inquiry and survey”. In the contextual inquiry we got a lot of feedback from the participants and could already figure out which new designs would not work and which concepts we could already exclude from the study. The concept to use a daily object to transport data was rejected by the majority of the participants for several good reasons. So this was the first candidate we excluded from our list. The study also supported us to find the preferred design for a pipette device. All the feedback we got we used to redesign the concepts.

Survey showed that USB flash drive is the most preferred exchange method.

We also researched in the aspect how the users exchange data today. To find out which are the most popular cross-device data exchange methods today and why the users prefer them we created a survey. This survey was filled out by 140 participants aged between 15 and 70 years. The results of the survey showed that for the data exchange between computers the USB flash drive is most preferred. But also the data exchange via email and cloud services are quite popular. In general the users feel a lack of cross-device data exchange techniques for their mobile devices. It seems that there is room for improvements and new concepts.

We found that there is a significant difference between experts and non experts in regard to the preferred exchange method as well as in regard to satisfaction. More experienced users are in general more dissatisfied with today's exchange techniques. Average users prefer the USB flash drive while more experienced users favor cloud services. These differences have to be considered in evaluations as well as for new cross-device data exchange methods. So when a new cross-device data exchange method gets developed people should think about who they want to address with this method.

We also found that desktop operating systems did not seem to have a significant effect on the preferred exchange

method. This is different to mobile operating systems where the influence is significant in regard to the preferred exchange method. Again this shows the lack of open, platform independent cross-device exchange techniques.

With the feedback and criticism we got in the contextual inquiry we redesigned and implemented our prototypes for the user study. After we saw the high popularity of the USB flash drive and cloud services we decided to include them in the study. Especially that the experts tend to use cloud services could be hint that cloud services are the future for cross-device data exchange. For the user study in chapter 5—“User study” we decided for any synthetic study in which we created conditions that make it possible to compare the different methods which each other. So in the study the participants had to copy three files from one computer onto another and they had five trials each. We measured their times to compare the different exchange methods.

Contextual inquiry helped to improve prototypes.

The result of this study is that the new cross-device data exchange methods are significantly faster in copying the data as well as in pasting the data. Especially the pipette concept is really fast and participants only needed half the time for the interaction as for the USB flash drive. Within the new exchange methods the differences are smaller and not really significant. In general the pipette concept is the fastest followed by the exchange dot.

HCI approaches were a lot faster than common exchange methods.

Although the users were able to fulfill the tasks faster with all three of the presented exchange methods they were not completely confidence with the methods. The 5-Likert scale from the study survey shows that many users favored the new approaches over today’s exchange methods but there is also a group that rejected the new methods and stucked to the common ones.

## **6.2 Future work**

### **6.2.1 Get more feedback from users**

Although we can find significant differences in regard to time between the different exchange methods the users' feedback does not show a clear favorite. In this aspect we have to investigate more either by a second larger user study or by a long-term user study. Either our study was too small to show significantly which cross-device data exchange method the users prefer or there is another effect.

We believe that a group of persons stick to the common exchange technique because it has already proved its value. So if users get more time to collect experience with the new data exchange methods and use them daily and not in a laboratory environment we will certainly get different results.

### **6.2.2 Comparison of the cross-device data exchange techniques on other devices**

Due to time constrains we were only able to focus on the data exchange between computers. But it would also be interesting how the cross-device data exchange methods perform on other devices like tabletop computer, smartphones and tablet computer. Since the survey shows that people see a lack of data exchange methods for mobile devices it will be interesting to see how the exchange methods would perform and if they are able to increase the users' satisfaction. The pipette concept will be a perfect candidate for data exchange between mobilephones, tablet computers and normal computers. The exchange dot can be a good candidate to evaluate the data exchange between computers and tabletop computers.

### **6.2.3 Evaluating other exchange methods**

Especially in regard to collaborative work there are many interesting approaches we had to exclude because of time

constraints. It will be interesting to revisit them and make another evaluation focusing on group sharing mainly. From the survey we can see that people today use email and Dropbox to share data in a group and to work collaboratively. So there is the need to have cross-device data exchange methods for collaborative work. There are already several approaches but another study focusing on this aspect will be useful.





## Appendix A

# Summary Forms

The following form were used for the contextual inquiry and the user study respectively. The question from the contextual inquiry survey were also used to create an online survey in Google Docs. In the survey we followed Mayer [2008] in his recommendation for questionnaires.

<p>1. What is your preferred OS?</p> <ul style="list-style-type: none"> <li><input type="radio"/> Windows</li> <li><input type="radio"/> Mac Os X</li> <li><input type="radio"/> Linux</li> <li><input type="radio"/> other _____</li> </ul>	<p>5. What OS is running on your Smartphone?</p> <ul style="list-style-type: none"> <li><input type="radio"/> Windows</li> <li><input type="radio"/> iOS</li> <li><input type="radio"/> Android</li> <li><input type="radio"/> Blackberry</li> <li><input type="radio"/> Symbian</li> <li><input type="radio"/> other _____</li> </ul>
<p>2. How long do you use your Computer every day?</p> <ul style="list-style-type: none"> <li><input type="radio"/> less than 1 hour</li> <li><input type="radio"/> 1-2 hours</li> <li><input type="radio"/> 3-6 hours</li> <li><input type="radio"/> more than 6 hours</li> </ul>	<p>6. How long do you use your Smartphone every day?</p> <ul style="list-style-type: none"> <li><input type="radio"/> less than 30 minutes</li> <li><input type="radio"/> 0.5-1 hour</li> <li><input type="radio"/> 1-2 hours</li> <li><input type="radio"/> more than 2 hours</li> </ul>
<p>3. How do you exchange data between two computers? (Please choose only your preferred method)</p> <ul style="list-style-type: none"> <li><input type="radio"/> I don't exchange data</li> <li><input type="radio"/> I use a USB flash drive or USB hard drive</li> <li><input type="radio"/> I use another data medium (for example floppy disk, CDs, etc.)</li> <li><input type="radio"/> I use a public accessible folder on my Computer (shared folder)</li> <li><input type="radio"/> I share data by uploading them onto a Server (for example RWTH Gigamove, Rapidshare.com, etc.)</li> <li><input type="radio"/> I use a software for synchronization (for example dropbox)</li> <li><input type="radio"/> I send the data via email</li> <li><input type="radio"/> I use a social network (for example Facebook, Twitter, Google+, etc)</li> </ul>	<p>7. How do you exchange data between your Smartphone and a computer? (Please choose only your preferred method)</p> <ul style="list-style-type: none"> <li><input type="radio"/> I don't exchange data</li> <li><input type="radio"/> I use a USB cable and use the phone like a USB flash drive</li> <li><input type="radio"/> I use a USB cable and use a software (for example iTunes, HTC Sync, etc.)</li> <li><input type="radio"/> I use a USB cable and the Smartphone exchange the data itself</li> <li><input type="radio"/> I send data via email</li> <li><input type="radio"/> I use a software for synchronization ( for example dropbox)</li> <li><input type="radio"/> I use a data medium (for example sd card)</li> <li><input type="radio"/> My Smartphone is somehow synchronizing itself in the background</li> </ul>
<p>4. Do you use a Smartphone?</p> <ul style="list-style-type: none"> <li><input type="radio"/> Yes</li> <li><input type="radio"/> No (Please continue with question 8 )</li> </ul>	<p>8. Do you use a tablet computer? (For example iPad, Playbook, etc.)</p> <ul style="list-style-type: none"> <li><input type="radio"/> Yes</li> <li><input type="radio"/> No (Please continue with question 12)</li> </ul>

Figure A.1: First two pages from the online survey which was also handed out during the contextual inquiry.

<p>9. What OS is running on the tablet computer?</p> <ul style="list-style-type: none"> <li><input type="radio"/> iOS</li> <li><input type="radio"/> Android</li> <li><input type="radio"/> Blackberry</li> <li><input type="radio"/> other _____</li> </ul>
<p>10. How long do you use the tablet every day?</p> <ul style="list-style-type: none"> <li><input type="radio"/> less than 30 minutes</li> <li><input type="radio"/> 0.5-1 hour</li> <li><input type="radio"/> 1-2 hours</li> <li><input type="radio"/> more than 2 hours</li> </ul>
<p>11. How do you exchange data between your tablet and a Computer? (Please choose only your preferred method)</p> <ul style="list-style-type: none"> <li><input type="radio"/> I don't exchange data</li> <li><input type="radio"/> I use a USB cable and use the phone like a USB flash drive</li> <li><input type="radio"/> I use a USB cable and use a software (for example iTunes, HTC Sync, etc.)</li> <li><input type="radio"/> I use a USB cable and the tablet exchange the data itself</li> <li><input type="radio"/> I send data via email</li> <li><input type="radio"/> I use a software for synchronization ( for example dropbox)</li> <li><input type="radio"/> I use a data medium (for example sd card)</li> <li><input type="radio"/> My tablet is somehow synchronizing itself in the background</li> </ul>

<p>12. In which situations your preferred exchange methods worked very well?</p>
<p>13. In which situation your preferred exchange methods worked badly?</p>
<p>14. Why do you prefer these exchange method over others?</p>

Figure A.2: Pages three and four from the online survey which was also handed out during the contextual inquiry.

15. How satisfied are you with the exchange methode?				
Exchange between	very dissatisfied	dissatisfied	Neither satisfied nor dissatisfied	very satisfied
two Computers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Smartphone and Computer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tablet and Computer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. Do you use a graphical tablet? (digital pen input)				
<input type="radio"/> No, I don't use one. <input type="radio"/> Yes but only rarely <input type="radio"/> Yes I use it regularly				
17. What is your gender?				
<input type="radio"/> female <input type="radio"/> male				
18. How old are you? _____				
19. What is your profession? _____				
20. If you are still studying; what are you studying? _____				

Figure A.3: Page five from the online survey which was also handed out during the contextual inquiry.

1. What is your gender? <input type="radio"/> female <input type="radio"/> male
2. How old are you?
3. What is your profession? / What do you study?
4. Which operating system are you using / do you prefer?
5. Do you have experience in using Mac OS X? <input type="radio"/> Yes, I used it often. <input type="radio"/> Yes, I have already used it a few times. <input type="radio"/> No, I have never used it before.
6. Do you have experience in using a stylus pen? <input type="radio"/> Yes <input type="radio"/> No
7. If you have experience, please classify <input type="radio"/> I work regularly with a stylus pen about _____ hours per week <input type="radio"/> I use it sometimes but not regularly <input type="radio"/> I have used it 1-2 times

8. How do you like the presented exchange methods?	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
I liked to use the USB flash drive and would use it to exchange data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I liked to use Dropbox and would use it to exchange data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I liked the USB flash drive with additional GUI and would use it to exchange	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I liked the Pipeite concept and would use it to exchange data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I liked the "Exchange Disc" and would use it to exchange data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure A.4: Study survey which was handed out after the study.



---

# Bibliography

Hugh Beyer and Karen Holtzblatt. *Contextual Design: Defining customer-centered systems*. Morgan Kaufmann Publishers, San Francisco, 1998. ISBN 1-55860-411-1.

David Dearman and Jeffery S. Pierce. It's on my other computer!: computing with multiple devices. In *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*, CHI '08, pages 767–776, New York, NY, USA, 2008. ACM. ISBN 978-1-60558-011-1. doi: <http://doi.acm.org/10.1145/1357054.1357177>. URL <http://doi.acm.org/10.1145/1357054.1357177>.

Alan Dix, Janet Finlay, Gregory D. Abowd, and Russel Beale. *Human-computer interaction*. Pearson Education Limited, Essex, 3. edition, 2004. ISBN 978-0-13-046109-4.

Andy Field. *Discovering Statistics using SPSS*. SAGE Publications Ltd, London, 3. edition, 2009. ISBN 978-1-84787-907-3.

Ken Hinckley. Synchronous gestures for multiple persons and computers. In *Proceedings of the 16th annual ACM symposium on User interface software and technology*, UIST '03, pages 149–158, New York, NY, USA, 2003. ACM. ISBN 1-58113-636-6. doi: <http://doi.acm.org/10.1145/964696.964713>. URL <http://doi.acm.org/10.1145/964696.964713>.

Ken Hinckley, Gonzalo Ramos, Francois Guimbretiere, Patrick Baudisch, and Marc Smith. Stitching: pen gestures that span multiple displays. In *Proceedings of the working conference on Advanced visual interfaces*, AVI '04, pages 23–31, New York, NY, USA, 2004. ACM. ISBN 1-58113-867-9. doi: <http://doi.acm.org/10.1145/1055558.1055573>.

1145/989863.989866. URL <http://doi.acm.org/10.1145/989863.989866>.

Shin'ichi Konomi, Christian Müller-Tomfelde, and Norbert A. Streitz. Passage: Physical transportation of digital information in cooperative buildings. In Norbert A. Streitz, Jane Siegel, Volker Hartkopf, and Shin'ichi Konomi, editors, *Cooperative Buildings. Integrating Information, Organizations, and Architecture*, volume 1670 of *Lecture Notes in Computer Science*, pages 45–54. Springer Berlin / Heidelberg, 1999. URL [http://dx.doi.org/10.1007/10705432\\_5](http://dx.doi.org/10.1007/10705432_5).

Horst Otto Mayer. *Interview und schriftliche Befragung: Entwicklung, Durchführung und Auswertung*. Oldenbourg Wissenschaftsverlag, München ; Wien : Oldenbourg, 2. edition, 2008. ISBN 978-3-486-58669-5.

Bernt Meerbeek, Peter Bingley, Wil Rijnen, and Elise van den Hoven. Pipet: a design concept supporting photo sharing. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, NordiCHI '10, pages 335–342, New York, NY, USA, 2010. ACM. ISBN 978-1-60558-934-3. doi: <http://doi.acm.org/10.1145/1868914.1868954>. URL <http://doi.acm.org/10.1145/1868914.1868954>.

Pranav Mistry, Suranga Nanayakkara, and Pattie Maes. Touch and copy, touch and paste. In *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems*, CHI EA '11, pages 1095–1098, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0268-5. doi: <http://doi.acm.org/10.1145/1979742.1979714>. URL <http://doi.acm.org/10.1145/1979742.1979714>.

Miguel A. Nacenta, Dzmitry Aliakseyeu, Sriram Subramanian, and Carl Gutwin. A comparison of techniques for multi-display reaching. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, CHI '05, pages 371–380, New York, NY, USA, 2005. ACM. ISBN 1-58113-998-5. doi: <http://doi.acm.org/10.1145/1054972.1055024>. URL <http://doi.acm.org/10.1145/1054972.1055024>.



- J. Rekimoto. Pick-and-drop: a direct manipulation technique for multiple computer environments. In *Proceedings of the 10th annual ACM symposium on User interface software and technology*, pages 31–39. ACM, 1997. ISBN 0897918819.
- 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*, pages 378–385. ACM, 1999. ISBN 0201485591.
- Farzan Sasangohar, I. Scott MacKenzie, and Stacey D. Scott. Evaluation of mouse and touch input for a tabletop display using fitts' reciprocal tapping task. In *Proceedings of the 53rd Annual Meeting of the Human Factors and Ergonomics Society*, pages 839–843, Santa Monica, 2009. CA: Human Factors and Ergonomics Society.
- Chia Shen, Katherine Everitt, and Kathleen Ryall. Ubitable: Impromptu face-to-face collaboration on horizontal interactive surfaces. In Anind Dey, Albrecht Schmidt, and Joseph McCarthy, editors, *UbiComp 2003: Ubiquitous Computing*, volume 2864 of *Lecture Notes in Computer Science*, pages 281–288. Springer Berlin / Heidelberg, 2003. URL [http://dx.doi.org/10.1007/978-3-540-39653-6\\_22](http://dx.doi.org/10.1007/978-3-540-39653-6_22).
- Carolyn Snyder. *Paper prototyping: the fast and easy way to design and refine user interfaces*. Morgan Kaufmann Publishers, San Francisco, 2003. ISBN 978-1-55860-870-2.
- Kathryn T. Stolee, Sebastian Elbaum, and Gregg Rothermel. Revealing the copy and paste habits of end users. *Visual Languages and Human-Centric Computing, IEEE Symposium on*, 0:59–66, 2009. doi: <http://doi.ieeecomputersociety.org/10.1109/VLHCC.2009.5295296>.
- Norbert A. Streitz, Jörg Geissler, Torsten Holmer, Shin'ichi Konomi, Christian Müller-Tomfelde, Wolfgang Reischl, Petra Rexroth, Peter Seitz, and Ralf Steinmetz. i-land: an interactive landscape for creativity and innovation. In *Proceedings of the SIGCHI conference on Human factors in computing systems: the CHI is the limit, CHI '99*, pages 120–127, New York, NY, USA, 1999. ACM. ISBN 0-201-48559-

1. doi: <http://doi.acm.org/10.1145/302979.303010>. URL <http://doi.acm.org/10.1145/302979.303010>.
- B. Ullmer, H. Ishii, and D. Glas. mediablocks: physical containers, transports, and controls for online media. In *Proceedings of the 25th annual conference on Computer graphics and interactive techniques*, pages 379–386. ACM, 1998. ISBN 0897919998.
- Andrew D. Wilson and Hrvoje Benko. Combining multiple depth cameras and projectors for interactions on, above and between surfaces. In *Proceedings of the 23rd annual ACM symposium on User interface software and technology, UIST '10*, pages 273–282, New York, NY, USA, 2010. ACM. ISBN 978-1-4503-0271-5. doi: <http://doi.acm.org/10.1145/1866029.1866073>. URL <http://doi.acm.org/10.1145/1866029.1866073>.
- Koji Yatani, Koiti Tamura, Keiichi Hiroki, Masanori Sugimoto, and Hashizu Hiromichi. Toss-it: intuitive information transfer techniques for mobile devices. In *CHI '05 extended abstracts on Human factors in computing systems, CHI EA '05*, pages 1881–1884, New York, NY, USA, 2005. ACM. ISBN 1-59593-002-7. doi: <http://doi.acm.org/10.1145/1056808.1057046>. URL <http://doi.acm.org/10.1145/1056808.1057046>.
- Jamie Zigelbaum, Adam Kumpf, Alejandro Vazquez, and Hiroshi Ishii. Slurp: tangibility spatiality and an eyedropper. In *CHI '08 extended abstracts on Human factors in computing systems, CHI EA '08*, pages 2565–2574, New York, NY, USA, 2008. ACM. ISBN 978-1-60558-012-8. doi: <http://doi.acm.org/10.1145/1358628.1358713>. URL <http://doi.acm.org/10.1145/1358628.1358713>.

---

# Index

- augmented surfaces ..... *see* hyperdragging
- contextual inquiry
  - concept ..... 41–42
  - daily objects ..... 47
  - exchange dot ..... *see* on-screen exchange device
  - GUI for USB flash drive ..... 45–46
  - new ideas ..... 48
  - on-screen exchange device ..... 47–48
  - passage ..... *see* daily objects
  - pipette ..... 43–45
  - wormhole ..... 46
- Corresponding-gestures ..... 18
- direct manipulation ..... 22
- evaluation
  - other ..... 17–19
- exchange dot ..... 32–33
- file system extension ..... 22
- fs extension ..... *see* file system extension
- future work ..... 90–91
- gesture ..... 23
- graphical user interface support ..... 23
- group sharing ..... 25
- GUI support ..... *see* graphical user interface support
- hyperdragging ..... 8–9, 32–33
- hypotheses ..... 49
- indirect manipulation ..... 22
- interaction design process ..... 2
- LightSpace ..... 13–14, 32–33
- long distance transport ..... 23
- mediaBlocks ..... 6–7, 32

- 
- non-functional prototypes
    - daily objects ..... 40
    - exchange dot ..... *see* on-screen exchange device
    - GUI for USB flash drive ..... 38–40
    - on-screen exchange device ..... 40–41
    - passage ..... *see* daily objects
    - pipette ..... 38
    - scenarios ..... 36–37
    - wormhole ..... 39–40
  - Panthograph ..... 18
  - passage ..... 7–8, 31–32
  - physical device ..... 23
  - Pick-and-Drop ..... 5–6, 27–29
  - Pipet ..... 14–16, 29–30
  - pipette concept ..... 27–31
  - Press-and-Flick ..... 18
  - private data exchange ..... 26
  - Radar View ..... 18
  - Slingshot ..... 18
  - Slurp ..... 12–13, 29–30
  - SPARSH ..... 16
  - stitching ..... 11–12
  - study
    - common exchange methods ..... 77
    - exchange dot ..... 75–76
    - pipette ..... 73
    - results ..... 78–84
    - setup ..... 72–73
  - survey
    - check of hypotheses ..... 62–66
    - design ..... 48–51
    - general results ..... 52–55
    - results ..... 67
  - synchronous gestures ..... 9–11
  - Toss-It ..... 12
  - wormhole ..... 18

