
Hybrid Groups of Printed and Digital Documents on Tabletops: A Study

Jürgen Steimle

Telecooperation Group
Technische Universität Darmstadt
D-64289 Darmstadt
steimle@tk.informatik.tu-
darmstadt.de

Mohammadreza Khalilbeigi

Telecooperation Group
Technische Universität Darmstadt
D-64289 Darmstadt
khalilbeigi@tk.informatik.tu-
darmstadt.de

Max Mühlhäuser

Telecooperation Group
Technische Universität Darmstadt
D-64289 Darmstadt
max@tk.informatik.tu-
darmstadt.de

Abstract

This paper presents an exploratory study investigating how physical and digital documents are used in combination on tabletops. Our results identify hybrid piles as the most common grouping concept and show that users willingly occlude digital documents with physical paper. These findings have considerable impact on the design of novel hybrid interaction techniques, which we sketch at the end of this paper.

Keywords

Interactive surface, paper, occlusion, study, tabletop.

ACM Classification Keywords

H.5.2 User Interfaces

General Terms

Human Factors

Introduction

The combined use of printed and digital media is inevitable in many knowledge work settings [7]. There is a growing trend towards interactive tabletop systems which address this issue by offering a tight paper-to-digital document integration, e.g. [10, 8]. These systems are composed of a tabletop on which both digital and paper documents can be manipulated. In order to provide smooth transitions between both realms, the

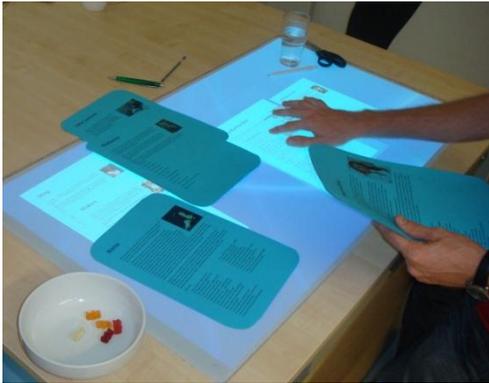


Figure 1. The setting of the study. The participants worked with printed and digital documents simultaneously on a tabletop display.

systems track the locations of paper documents and capture how users interact with them.

For example, this simultaneous use of paper and digital media on one integrated surface (which we call *hybrid use*) is helpful when integrating information from Web pages and printed documents. Another example is the planning of working activities by grouping and prioritizing action items, amongst others represented by (digital) e-mails as well as (physical) articles and books to read. The hybrid use poses new challenges for interaction design. For instance, it is unclear how users arrange and group documents and how they deal with the occlusion of screen contents caused by paper documents.

This paper contributes the results of an explorative user study. It analyzes fundamental challenges and problems of how printed and digital documents are used in combination, particularly, how they are grouped. Based on these results, we contribute design principles for hybrid tabletop systems.

The remainder of this paper is organized as follows. After describing the method of the study, we present and discuss our main results. Finally, we derive key implications for the design of hybrid tabletop interfaces.

Related Work

To our knowledge, it has not been systematically studied how users behave in a hybrid tabletop setting. Several previous studies have focused on comparing the different ways of interacting with only digital versus only physical media on tabletops: A comprehensive study by Terrenghi et al. [9] examined the affordances

of interacting with digital and physical media on tabletops. Their observations of a set of basic tasks with photos revealed profound differences in the way people interact in both realms. Piper et al. [6] compared the affordances of digital educational material with traditional paper handouts in collaborative study practices. Amongst others, they observed that participants were willing to use physical documents in addition to digital media on an interactive tabletop. In contrast to these studies, our focus is on studying the *combined* use of paper and digital media in order to inspire the design of hybrid tabletops.

With traditional paper, piling is a main form of organizing documents [5]. This has been imitated in digital grouping concepts, e.g. [5, 1, 2], but it is unclear which patterns emerge in the hybrid case and how these should be supported by the design.

Methodology of the Study

We recruited 10 volunteers (5 female, 5 male; 7 right-handers, 3 left-handers). All were experienced knowledge workers, from technical and non-technical backgrounds. They participated in individual user sessions of about 50 minutes. No compensation was provided.

The study used an interactive tabletop of 130x105 cm size with a display size of 100x60 cm. This is representative for the space available on a typical desk. The rear-projection had a full HD resolution of 1920x1080 pixels. The participants could interact with the digital documents using multi-touch gestures for moving, rotating, and zooming in and out of individual documents. Printed documents could be placed and manipulated on the display surface and also on the surrounding surface of the table. The setting is shown in Fig. 1.

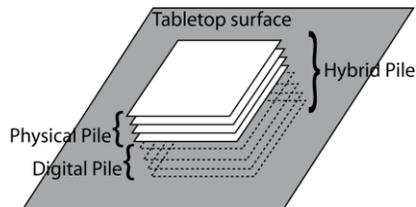


Figure 2. Conceptual sketch of a hybrid pile.

The participants were given a total of 12 single-page documents, each document containing textual biographical information on a popular musician. Six of the documents were printed on paper (A4 size), while the remaining six were displayed on the tabletop display. This set-up accounted for the typical knowledge work setting in which some information is available in printed form (e.g. printed papers) while other documents are available in digital form (e.g. web pages).

As our goal was to acquire a deeper understanding of how printed and digital documents are used in combination, we chose common knowledge work tasks which require a very tight integration of both types of documents. We opted for a *grouping task* (inspired by [9]), a *sorting task*, and a *searching task* with printed and digital documents. These tasks enabled us to study diverse activities related to groups, such as creating, moving and browsing them.

After five min. of training in how to interact with the tabletop, the participants first performed the *grouping task*. They had to arrange all documents depending on whether they like, don't like the artist or whether they are unsure. Then they had to browse the arrangement to present the result. This was followed by the *sorting task* in which participants had to sort all documents according to the number of albums of each artist, before browsing the result. The final *searching task* consisted in finding all albums which appeared in a specific year. In all tasks, physical documents and digital documents were initially presented as two separate adjacent piles. The study used a think-aloud protocol. Moreover, semi-structured interviews were conducted after each task. All sessions were recorded on video.

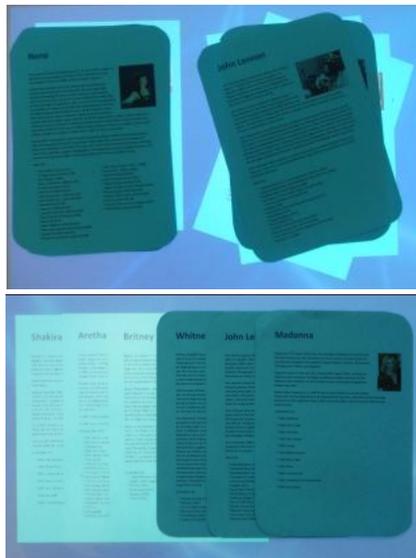


Figure 3. Examples of hybrid piles on the tabletop. A neat pile (upper left), a rather messy pile (upper right), and a spread-out representation (below), which affords getting an overview and comparing pages.

Results and Discussion

We base our results on a descriptive video analysis. Where appropriate, we also refer to statements made in the interviews. This section describes our findings on how users group documents in the hybrid settings and on the effects of physical occlusion created by paper on the display.

Hybrid Piles

The grouping task allowed us to analyze the representational forms chosen by the participants for groups of both printed and digital documents. Depending on the mental concepts of the users and on the affordances of the hybrid tabletop, various forms of representations can be imagined. For instance, users could arrange a hybrid result as two separate adjacent groups, each containing only physical or only digital documents. Or users could create an arrangement that tightly integrates both types of media.

An essential finding is that all participants grouped physical and digital documents in one combined representation, a layered arrangement which we call hybrid pile. This is an arrangement of (partially or entirely) overlapping digital and physical documents (see Fig. 2 and 3). Figure 4 shows the result of the grouping task created by a participant.

These results indicate 1) users have the mental concept of a hybrid group and 2) they can efficiently represent this concept on tabletops using hybrid piles.

All participants easily and intuitively created hybrid piles by placing first digital and then physical documents into the three groups. To browse hybrid piles, all participants sequentially picked up the topmost docu-

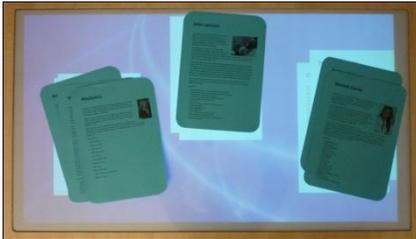


Figure 4. Grouping created by a participant, containing three different hybrid piles. This arrangement is representative for the results of all participants.



Figure 5. Representation of one single hybrid group in a *sorted* arrangement.

ment of the pile or dragged it away, starting with the physical documents before going on to the digital ones.

In the second task, the participants had to create a group of *sorted* physical and digital documents. In contrast to the aforementioned case (of unordered groups), sorted groups could not be represented with a hybrid pile, as the sorting would require to also placing digital documents on top of physical ones. In consequence the participants created complex structures, consisting of several adjacent hybrid piles (Fig. 5). These structures turned out not to be clear nor to provide enough flexibility for rearrangements. We conclude that in contrast to the case of unordered groups there exists no intuitive representation on tabletops.

Occlusion: Creating Hybrid Piles

We analyzed how users cope with occlusion generated by physical artifacts.

The above finding of hybrid piles falsifies the common assumption that occlusion of digital screen contents by physical artifacts is problematic and should be avoided in any case. We found that the participants did not partition the available space into separate zones of physical or digital documents. Instead, by creating hybrid piles, they willingly occluded digital documents. This enabled participants to express the tight relation between physical and digital documents. Due to the high degree of spatial proximity of overlapping printed and digital documents, the *Gestalt* [4] of a hybrid pile highly suggests that the elements of the group belong to one mental concept.

To our surprise, the results show that *physical* occlusions of screen contents are generally less problematic

than occlusions created by *digital* contents. This originates from the fact that paper is tangible and can easily be picked up to look underneath. This temporary removal action is more intuitive and faster than moving digital contents.

Occlusion: Getting an Overview

We now discuss how users deal with occlusions created by overlapping documents when they desire getting an overview on the documents contained in a pile and browsing piles.

In pure physical piles, occlusion turned out not to be problematic. This is due to the fact that piles of paper can be easily transformed from a “pile state” (containing occluded documents) (Fig. 3 above) to a juxtaposition of pages or a partially overlapping arrangement (Fig. 3 below). These create less or no occlusion and thereby afford getting an overview on the documents, reading and comparing them. With paper only, we frequently observed participants performing these transitions with one quick and intuitive bimanual movement. In contrast, in the digital and in the hybrid case, the participants did not make these transitions, as each digital document would have to be moved individually.

This missing possibility of interacting with hybrid piles had the consequence that participants were missing the awareness if there were digital documents hidden under physical ones. In the interviews, five participants reported this to be highly problematic. In order to provide better awareness on the presence of digital elements, three participants slightly displaced the physical pile after creating a hybrid pile so that the digital portion became visible.

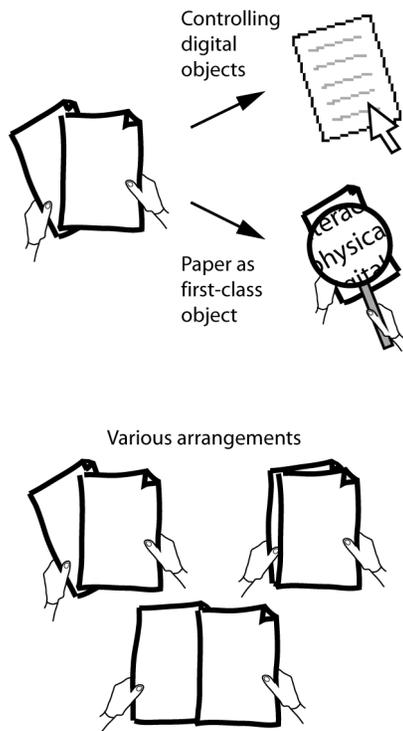


Figure 6. Paper sheets as tangible controls have a dual function (above) and provide more degrees of freedom than single controls (below).

Occlusion: Moving Documents

Moving documents is a core interaction for managing the working space. A particularly important question is how users deal with occlusions created by the hybrid setting: Using touch interaction (dragging), a digital document cannot be moved over positions which are occluded by paper documents.

The most frequent approach to overcome this limitation consisted in moving the digital document around the physical one (11 instances). If this move-around approach was tedious or impossible, the user picked up the physical document or moved it away with the non-dominant hand while or before moving the digital one with the dominant hand (3 instances). Overall, this situation was not deemed problematic, because both approaches are quick and easy to perform.

Design Implications

The results of the study have shown that hybrid piles are an intuitive and adequate representation for (unordered) groups of paper and digital documents on tabletops. Physical occlusion turned out to be much less problematic than one could intuitively assume. Nevertheless, current tabletops lack the intuitiveness, directness and flexibility that we have in interacting with groups of paper documents. This is a key factor for coping with occlusions. We now sketch central aspects of an interaction concept for hybrid piles.

Physical Pile as Tangible Control with a Dual Function

Our concept uses the physical pile as a tangible control for the entire hybrid pile, enhancing hybrid piles with the ease of interacting with paper. This implies a novel view on the concept of tangible controls.

- In contrast to classical tangible controls, a paper document has a dual function: It acts both as a *tangible control* for the digital documents and as a *first class object*, since it consists of documents which have a value on their own (Fig. 6 above).
- The physical control does not consist of one single object, but of several sheets of paper contained in a physical pile. The manifold arrangements possible with several tangible objects offer more degrees of freedom for controlling the digital part than one single object (Fig. 6 below).

Using paper piles as tangible controls causes new possibilities and challenges for the hybrid interaction design. While it provides more flexibility, the dual function of the physical objects makes it difficult to determine

- if the user interacts with them in order to manipulate the digital part (tangible control) or
- if she is interested in the physical documents *per se* and does not want to alter the digital part (first class objects)

To solve this problem, we suggest leveraging the metaphor of magnetism. As a default, the digital portion of a hybrid pile remains attached to the physical documents. If the user wants to interact only with the physical or with the digital part (e.g. for looking under the physical part or for moving only the digital part), she disassociates both parts by holding the digital part with one finger while moving the physical part away or picking it up. Then the magnetism has no influence and one can interact with both parts separately. Both parts can be easily reconnected by placing them near each other, resulting in a magnetic “snap-in”.

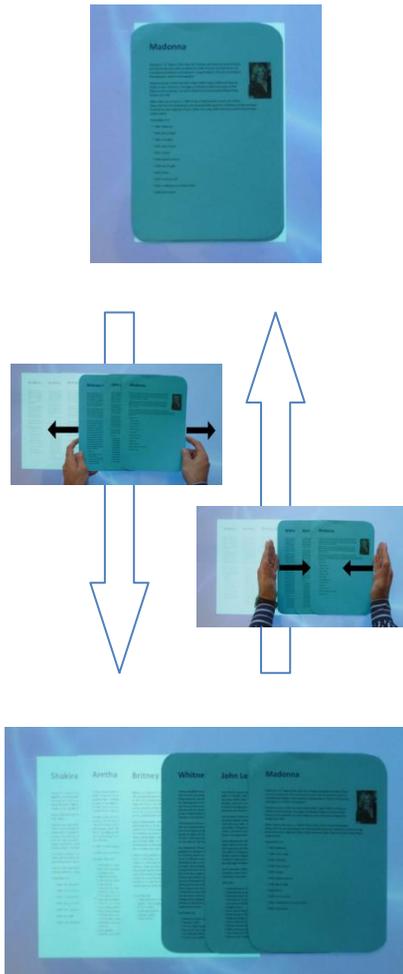


Figure 7. The pile of paper documents can be used as a tangible control for the entire pile in order to easily perform transitions between different representations.

Fluid Transitions Between Group Representations

We have discussed how users leverage fluid transitions between different physical arrangements of groups of paper documents to cope with occlusion created by overlapping documents.

Our design leverages the many degrees of freedom of the tangible control to offer these fluid transitions also for hybrid groups. In order to arrange all documents of a hybrid group in a particular representation, the user has to arrange only the physical part in this manner. The digital documents of the group are automatically relocated and rotated to form the same representation. Hence, these hybrid transitions are as easy to perform as with pure paper. Figure 7 depicts a design sketch that indicates the transitions from a tidy pile to a spread-out representation and back.

Summary and Future Work

We have presented the results of the first exploratory study which examines how users interact simultaneously with printed and digital documents on tabletops as well as what are the effects of physical occlusion.

Hybrid piles turned out to be an adequate and intuitive structure for unordered hybrid groups of documents. Most important, the results show that physical occlusion is not problematic in most cases. Yet, occlusion is troublesome if it is not possible to simply transform between different pile representations.

Based on the findings, we have designed an interaction concept for hybrid groups of documents on tabletops. Paper has a dual function: it is a first-class object but also used as a tangible control for the hybrid group. This provides for flexible and highly intuitive transitions

between different representations of the hybrid pile. We are currently implementing these design solutions and plan to evaluate them with knowledge workers.

Finally, the study has shown that sorted groups cannot be efficiently expressed on current tabletops. For our future work, we plan to design interaction concepts for sorted hybrid groups.

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