Interaction Support for Hybrid Groups of Paper and Digital Documents on Tabletops

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ABSTRACT
Based on the results of a user study, this paper presents a set of hybrid interaction techniques for groups of paper and digital documents on interactive surfaces. By leveraging a novel concept of tangible controls, these techniques allow highly flexible, fluid and lightweight interactions.

Author Keywords
Interactive surface, grouping, paper, digital media, tabletop.

ACM Classification Keywords
H5.2. User Interfaces.

INTRODUCTION
Printed and digital media are very often used in combination to efficiently support knowledge work. There is a growing trend towards interactive tabletop systems which address this issue by offering a tight paper-to-digital document integration [e.g. 1, 2]. While these works introduce a range of sophisticated interaction techniques, e.g. for cross-media hyperlinks or cross-media copy/paste, they do not investigate nor offer support for the more basic issues of working with documents like grouping and arranging digital and physical documents. Yet, these are highly important activities for organizing documents and performing real-world workplace tasks.

In an initial user study, we found that knowledge workers intuitively create and use hybrid piles of paper and digital documents on interactive tabletops. Based on these findings, this paper contributes several hybrid interaction techniques for interacting with groups of documents. These techniques leverage a novel concept of tangible controls that has considerable impact not only on document work but on all types of tangible user interfaces.

INFORMING THE HYBRID INTERACTION DESIGN
In order to examine how printed and digital documents are used in combination on tabletops, and particularly how they are grouped, we conducted a comprehensive user study with 10 participants (submitted to CHI2010). Based on video recordings, we analyzed how the participants grouped, sorted and searched both physical and digital documents (with different contents) in a combined manner. This section very briefly summarizes three main findings of the study, which are the basis for our design.

First, we found that the main representational form for organizing documents was the *hybrid pile*. This is a layered arrangement of (partially or entirely) overlapping digital and physical documents. All participants intuitively arranged documents in hybrid piles. It became obvious that there is a need for an explicit support of hybrid piles: The user should be able to easily combine several documents in order to interact with them as with one single entity, e.g. for moving. However, we observed that users need more awareness of the digital documents of a hybrid pile, as these might be entirely occluded by the physical ones.

Second, we observed two main representational forms of groups: 1) a "tidy" pile of documents, which affords interaction with the group as whole, e.g. moving, and 2) a juxtaposition or partially overlapping arrangement, which affords getting an overview on the documents, reading and comparing them. Groups of paper documents allow fluid transitions between both these representations. We frequently observed participants performing these transitions with one quick and intuitive movement. In contrast, in the digital and in the hybrid case, these transitions are much harder to perform, as each digital document has to be individually moved. In these cases, no transitions were made by the participants.

Finally, one of the fundamental activities to optimally manage the working space is moving. Physical piles were relocated very frequently by moving them on the tabletop or by picking them up and placing them at other positions. In contrast, digital and hybrid groups were never moved because suitable functionality was missing.

HYBRID INTERACTION TECHNIQUES
Based on the design insights from the user study, we present a set of interaction techniques for hybrid piles.

Novel concept of tangible controls

It seems highly promising to leverage tangible interaction for hybrid piles. The physical part thereby acts as a tangible control for the entire pile. This implies a fundamentally novel view on the concept of tangible controls. In contrast to classical tangible controls, the physical part 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 *per se*. Second, the physical control does not consist of one single object, but of several ones. The manifold arrangements possible with several tangible objects offer more degrees of freedom for controlling the digital part than one single object.

This novel concept 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).

Awareness and fluid transitions between representations

Our design leverages the many degrees of freedom of the tangible control to offer fluid transitions between hybrid group representations. 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 1 shows examples of arrangements of digital documents which are triggered by the arrangement of paper documents. (a) depicts a "tidy" pile, while (b)-(d) represent different overlapping styles (e.g. top-down overlapping to get an overview of the titles). Finally, (e) shows the juxtaposition of all documents to get a complete overview.

These transitions can be used for getting an overview on all documents of a hybrid pile. Moreover, they allow quickly switching between different forms of interaction (e.g. moving a group vs. comparing the documents). To further enhance the awareness of digital documents, a shadow is displayed in the tidy pile mode (Fig. 1 a), as an intuitive means for indicating the presence of digital documents.

Moving hybrid groups

Moving highlights the conceptual challenge of the novel concept of tangible controls. If the user moves the physical part of the a hybrid pile, it is unclear whether she wants to move the entire pile, using paper as a tangible control, or if she wants to remove the physical part in order to access the underlying digital part.

To cope with this issue, our design solution leverages the metaphor of magnetism. As a default, the digital documents
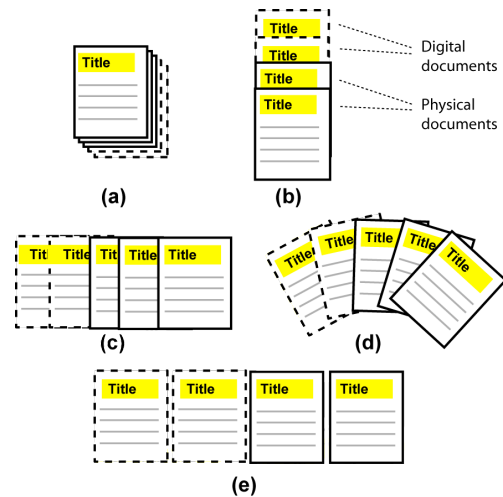
Figure 1. Exemplary arrangements of a hybrid pile. (The physical form is automatically reflected by the dig. part)

of a hybrid pile are attached to the paper documents that belong to the same pile. So, the physical part acts as a handle for the whole pile, e.g. for moving as well as picking and dropping. If the user wants to interact only with the physical part and does not want the digital part to be controlled, 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 move and arrange both parts. Both parts can be reconnected by placing them on each other, resulting in a magnetic "snap-in".

EARLY USER FEEDBACK AND FUTURE WORK

In order to get early feedback, we made semi-structured experiments with knowledge workers and discussed mock-ups of our design. The initial user feedback was very promising. All experts appreciated the hybrid group support. Three of them preferred to have more explicit gestures for creating hybrid piles in addition to the magnetic snap-in. The users particularly valued the fluid transitions between different representations and reported that this is more flexible and makes it easier to get an overview on all documents than browsing them one by one.

We are currently implementing the interaction techniques as part of a prototype tabletop system. Moreover, we plan to perform more profound user testing to further confirm the usefulness of the novel hybrid interaction techniques.

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