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Paper-Centric Interaction Concepts for Collaborative Learning

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Abstract

Field studies show that in many learning settings paper has intrinsic advantages over electronic documents. In this paper we present concepts for the collaborative annotation and structuring of paper documents and digital documents in both distributed and co-located settings. The CoScribe prototype supports the annotation of printed lecture slides and collaborative sharing of annotations. Digital Paper Bookmarks and tag buttons are means for the efficient semantic structuring, indexing and tagging of paper documents. We then detail on results of an ethnographic study on learning group meetings. These demonstrate that printed and digital documents form one document space and that personal interactions go in hand with manipulating documents. Based on these findings we present the design of a prototype which supports efficient annotation and structuring in co-located learning group meetings.

1 Introduction

Despite the advancements in computing, traditional paper keeps being widely used in learning and knowledge work. Although the end of paper use has been predicted, the paperless office is far from being reality and the use of paper is even augmenting, which is due to the inherent advantages of paper over digital documents (Sellen & Harper 2003). Paper provides for easy reading and intuitive annotation and it allows for two-handed interaction and navigation. Moreover, multiple paper sheets can be laid out in physical space. This enables comparing document pages as well as flexible arrangements depending on the work context.

We conducted several studies on the use of paper in learning settings. A quantitative study with 408 university students found that paper is by far the preferred medium for taking notes in lectures (Steimle et al. 2007). An ethnographic study, detailed in this paper, found that in learning group meetings, different paper media have a crucial role. Based on these results, we developed several interaction concepts which combine paper with computing to support collaborative learning processes. Our approach focuses on taking on established paper-based interaction techniques and on augmenting these by computing.

The main contributions of this paper are paper-based interaction concepts for both distributed and co-located collaborative learning settings. The paper is organized as follows. After shortly reviewing related work, we present our approach for the paper-based annotation of lecture slides. We then discuss how paper can efficiently support the indexing, tagging and structuring of printed and digital documents. Finally we describe our ongoing research on the paper-based support in co-located learning group meetings.

2 Related Work

Paper-based Annotation and Notetaking. Several systems use real paper as an input medium for annotating electronic documents. PADD (Guimbretière 2003) and PaperPoint (Signer & Norrie 2007) enable users to annotate electronic documents by using their printouts as a proxy. ButterflyNet (Yeh et al. 2006) is an electronically augmented paper notebook. All these systems are limited to one specific document type, whereas the support a broader range of documents is crucial in learning group meetings.

Document Structuring and Linking. The PaperPDA (Heiner et al. 1999) is an early system combining a conventional paper notebook and organizer with electronic capabilities. It enables users to create links between paper pages with adhesive stickers. PapierCraft (Liao et al. 2005) presents a set of gesture commands, like copy/paste and linking, for manipulating paper documents. These commands focus only on paper and require an additional device for mode switching, e.g. a foot pedal or a second Anoto pen. The Interactive Multimedia Textbook (Lai et al. 2007) enables students to individually augment a paper textbook with hyperlinks to Web pages, but not vice versa. A number of systems (e.g. The Sandbox for Analysis (Wright et al. 2006), EverNote, Mindjet MindManager) enable users to link and organize electronic, but not paper documents when collecting or abstracting information.

3 Collaborative Annotation

Many electronic systems for student notetaking and sharing have been proposed. However, as we found out in a field study, most students prefer traditional pen and paper for taking notes. We therefore developed CoScribe, an annotation system which enables students to collaboratively annotate lecture slides. The design was guided by the goal to allow a smooth transition from traditional pen and paper annotations to an augmented annotation practice.

Annotation and Notetaking. CoScribe comprises a mobile part for in-classroom annotation. A student only requires paper printouts of the lecture slides and a personal electronic pen, which can be used to write normally on paper (Fig. 1). The equipment is thus highly mobile, lightweight and comparable to that used traditionally for notetaking in lectures. CoScribe is implemented in Java and currently supports PowerPoint lecture slides. For the electronic synchronization of the handwritings on paper, our system relies on the Anoto technology and Logitech io2 electronic pens. During writing, the electronic pen identifies both the page and its position on this page by detecting a specific, nearly invisible dot pattern with a built-in camera. An ordinary laser printer can print out documents including this pattern.

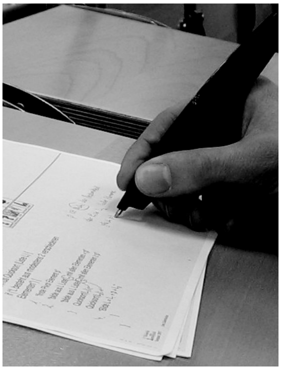

Figure 1: Annotating printed lecture slides

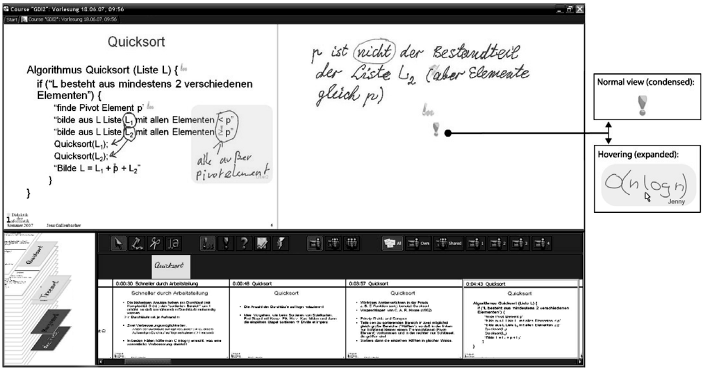

Figure 2: The CoScribe software viewer

The printouts were designed to constrain the personal annotation style as little as possible. Handwritten annotations can be made anywhere on the printouts. In addition to the printed lecture slides, the pages can contain free areas. A CoScribe print toolkit can be used to create printouts with various layouts, providing for an adaptation to the course and the users. Additional empty paper sheets can be written on and are associated with the corresponding slide by drawing a link gesture. Moreover, users can classify individual annotations with semantic types (i.e. important, question, to do, error in the script) by performing a pen tip on a corresponding button of a paper toolbar, which is printed on each page.

Collaborative Visualization. Once the pen is docked to a user's PC, all annotations are automatically transferred to the backend system, which stores them in a database on a central server. Alternatively pen data can also be streamed in real-time via Bluetooth to a nearby computer. Own annotations and shared ones of other learners can then be accessed in the CoScribe software viewer (Fig. 2), which displays them on the corresponding slides and supports remote collaboration with other learners.

A challenge with shared handwritten annotations is their clearly arranged visualization, particularly for a large number of users. We developed a novel visualization for shared handwritten annotations. This displays both one's own and shared annotations in an integrated manner. It supports overview and access to shared annotations without the need of explicitly switching between different user views. Accounting for the restricted space within the document, one's own annotations are visualized as they are written on paper, whereas shared comments of other users are displayed in a condensed form. Instead of the annotation itself, a small icon is visualized at the position of the annotation (Fig. 2, upper right). This icon corresponds to the type of the annotation and varies in size according to the size of the annotation. When hovering the mouse over the icon, the annotation is expanded and displayed at the correct position in its original size (Fig. 2, lower right). Shared annotations considered especially relevant can be permanently expanded. An additional preview function provides for an overview on all shared annotations on a page by expanding all of them in a scaled-down manner.

Evaluation. In order to assess the appropriateness of the system for in-classroom annotation and collaborative visualization, we conducted a user study with overall 38 students (Steimle et al. 2008). Our findings show that participants considered the system to be easy to use (M=4.4 on a 5-point Likert-scale, SD=.8, N=37). Participants valued the possibility to classify annotations with semantics directly on paper. A substantial percentage of 18.7 % of all 1983 annotations made on the lectures we observed was tagged with a semantic type. This leads us to the conclusion that minimal constraints can be imposed to the highly unconstrained and highly personal annotation process if they offer a significant benefit. This seems to be true even in difficult conditions for annotating, e.g. when time is scarce. When seeking a quick overview of all comments, the novel collaborative visualization of shared annotations was clearly preferred to a single-user view, where one must manually switch between different views for each user (M=4.3, SD=.9 vs. M=2.1, SD=0.9, N=9).

4 Paper-based Document Indexing and Tagging

Besides easy annotation, the paper medium offers inherent advantages for indexing and tagging documents. Paper bookmarks allow efficiently marking specific passages on paper and quickly accessing them later on. Digital Paper Bookmarks combine these advantages with electronic support.

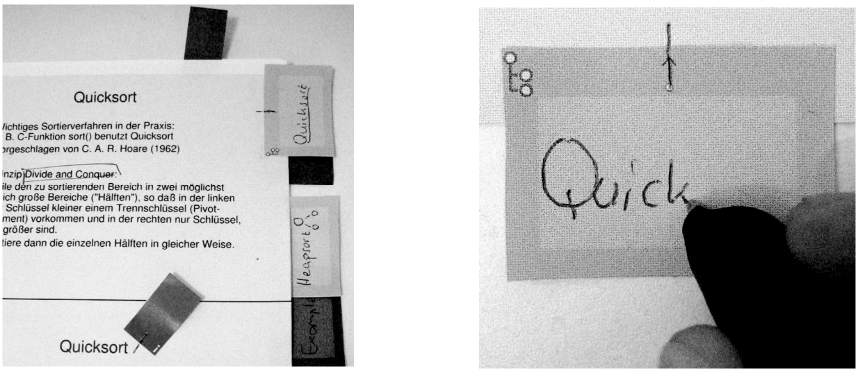

Figure 3: Digital Paper Bookmarks

Digital Paper Bookmarks are adhesive stickers of different colors, which can be attached to physical pages of printed documents at arbitrary positions (Fig. 3 left). As they are covered with the Anoto pattern, they can be labeled with a title using an electronic pen. Once synchronized with the electronic system, they also serve as electronic bookmarks. Creating digital paper bookmarks includes three intuitive steps: First a bookmark is attached to an arbitrary position at any page of the printed document. Then it is associated with the page by drawing a short line connecting the bookmark with the page. Finally users can write a title on it (Fig. 3 right). It can be modified by sticking it to another position and performing the association gesture again. Deletion includes removing and writing a cross out gesture.

In addition to tagging with a freely chosen label, different colors of bookmarks enable users to tag passages with one of several pre-defined semantic types. Our current prototype includes four types for structuring and marking up learning documents: section heading, key passage, important and unclear.

In the digital world, Digital Paper Bookmarks can be used in manifold ways like electronic bookmarks. The CoScribe viewer displays them along with the document in a 3D representation of the paper stack (Fig. 2 lower left) or directly attached to the document pages.

In a pilot study, we asked nine randomly selected students attending an introductory computer science lecture to structure printed slides of one lecture with digital paper bookmarks. Our observations and semi-structured interviews with the participants indicate that digital paper bookmarks are very intuitive to create and modify (M=4.7 on a 5-point Likert-scale, SD=.5). They judged digital paper bookmarks as very helpful for finding specific pages (M=4.4, SD=.5) as well as for orientation in the paper document (M=4.7, SD=.5). Several participants particularly valued the possibility to fade away from the given structure and instead to create an own structure of the document.

5 Multimodal Support for Co-located Collaboration

In this section we present first results of our ongoing research on the support for co-located collaboration in learning group meetings. As in the lecture notetaking setting, notetaking and structuring are crucial processes. However, the multitude of documents used in learning group meetings and the physical interactions between people implicate new challenges for the paper-centric support. In the following we will first discuss results from an ethnographic study and then present the design of our prototype.

5.1 Ethnographic Study

We conducted an initial ethnographic study to inform our system design. The goal was to find out which document types are frequently used and to explore the ways participants interact with documents and with each other. The theoretical basis for our observations was the concept of Information Ecologies (Nardi & O’Day 1999) and the Distributed Cognition framework (Hollan et al. 2000). Roughly speaking, these state that in a given work context, physical and digital artifacts, people and practices form a unity and therefore must be considered together. We made hidden observations of a dozen of groups working in publicly accessible group learning spaces at our university. Moreover, we conducted overt more in-depth observations with five groups, which lasted between 45 and 90 minutes each and which were followed by group interviews. Our main findings were as follows:

Different paper and digital documents form one document space. The meetings comprised a multitude of different document types. All groups used paper notebooks or empty sheets of paper and several other paper documents (printed scripts, books, file cards or other documents). About half of the groups also used electronic documents displayed on one up to three laptops. Laptops were mostly used for accessing lecture slides. Less frequently, users looked up information on web pages (above all Wikipedia) or programmed code snippets in Eclipse. Most groups covered the available table surface to a high degree with documents. Figure 4 depicts a typical learning group meeting.

Although, at first sight, this multitude of documents may appear disparate and unclear, it forms one document space, in which the different documents are tightly interwoven, each having a particular function. Most tasks we observed include working with several documents at a time or shortly consecutively. The task of understanding a particular problem can for example include reading a slide of the course script on the screen of a laptop, making a sketch on a scratch paper at the same time and then formulating a summary on a new sheet of a paper notebook. Three functions of documents became particularly evident:

1. *Reference*: Documents provide input about the contents to discuss. Reference documents include course scripts, books and web pages.

2. *Externalization*: Documents are used to illustrate own thoughts and to document results of the learning process. This includes scribbling on scratch paper to foster shared understanding (temporary externalization) and condensing the contents in summaries written on empty sheets of papers or file cards (permanent externalization).

3. *Process structuring*: All but one group used documents as structuring scaffolds for their meeting. They followed the structure of the course script or of a list of exam questions provided by the instructor and discussed the topics in this sequential order.

Interacting with people goes in hand with interacting with documents. When discussing in a meeting, most participants constantly interacted with documents (see Fig. 4). The most frequent activity was pointing to one's own documents or to documents of other group members (in the latter case mostly to documents of the person directly addressed when speaking). Another frequent activity consisted in moving documents on the table to allow shared working on a personal document or to retrieve a document to individually work on it. The joint or alternate writing in documents often occurred as well.

Importance of the spatial arrangements. We observed that the spatial arrangements of documents relates to ownership and to their current functions and importance. Documents that several people work with typically have another position than non-collaborative documents. The former ones usually are positioned between two persons or in the middle region of the table, at least during active collaboration. Different document functions became particularly clear with one group, which heavily relied on scratch paper. This was situated in front of one group member and collaboratively used. Each time, the current topic was understood, another group member wrote a synopsis and the used sheets of scratch paper were moved towards the border of the table. This way, they did not take up valuable space but still could be grasped quickly. Similarly, documents that are less frequently used were positioned at the outer zones of the table and moved to the center when needed. This demonstrates that group members implicitly partition the space available on the table surface into zones of different priority (cf. the distinction of hot, warm and cold zones of Sellen & Harper 2003).

Figure 4: A typical learning group meeting

5.2 System Design

Current electronic systems do only support partial aspects of this complex ecology of documents and interpersonal interactions in group meetings. Our research takes an integrated view on the various aspects of this meeting ecology. Again, our approach relies on supporting two central pillars for document work: annotation and structuring. We will discuss each of them in the following.

5.2.1 Annotation in the Document Ecology

In the lecture notetaking setting discussed above, only a very restricted number of media are used (typically lecture scripts and empty sheets of paper). In contrast, learning group meetings are characterized by a multitude of documents. We therefore augment CoScribe to support other media types than lecture slides and empty sheets of paper. These additional types are PDF documents, Web pages and books. Books, which are not covered with Anoto pattern, can be registered using their barcodes and can then be linked to other documents. As described above, all notes and annotations, links and bookmarks are automatically captured, stored in a central database and, if shared, available to all group members.

Besides annotating on paper, users can annotate electronic documents on a computer screen. This screen is located on the meeting table and acts as a shared display for all group members. To support integrated workflows which span paper and digital documents, we constructed a prototype of an interactive pen display that enables user input with Anoto pens. This is a backlit display covered with a specific film the Anoto pattern is printed on. The system is thus multimodal and provides for a seamless transition between paper and computer screens with only one single input device.

5.2.2 Creating Structure

Above we presented Digital Paper Bookmarks and semantic tag buttons, which are paper-based mechanisms for creating structure *within individual* documents. In learning group meetings, structuring the entire *document space* is crucial, i.e. relations between several documents and their relations to the meeting: As described above, group meetings are characterized by a large number of documents and document snippets, which are strongly interrelated with each other. Frequently, a single document (e.g. a sketch or a mindmap) only gets meaning in conjunction with other documents it refers to (e.g. a passage in the lecture script). The capturing of these metadata provides for an integrated way of browsing the document space.

Relations between documents. Users can choose amongst two interaction techniques for explicitly creating relations between entire documents and/or document passages. The first technique, link gestures, is motivated by electronic hyperlinks. This gesture connects two passages either by a line drawn from passage A to passage B or by performing two consecutive pen tips on both passages within a short period of time. A link gesture is not only possible between two paper sheets but also between paper and electronic documents, which are displayed on our display prototype. The second technique is inspired by traditional paper-based practice. Putting several printed documents into a physical folder automatically associates them with the folder and with each other. This is possible as document positions are tracked with a camera that detects small visual barcodes printed on folders and paper sheets.

Relations between documents and the meeting. Relating documents to the meeting situation can create a process-based overview. Important aspects of meetings are the temporal process flow, personal actions (like annotating, linking) and the discussion itself. The system therefore associates timestamps and user IDs to all handwriting events and records the speech of the meeting.

Structured meeting overview and browsing. The metadata on the structure of both contents and processes is used to index the meeting documents. Several meeting visualizations and a search function shall facilitate later access, for example when reviewing a meeting or when seeking more information on a particular document passage. We implemented a first visualization of document relations and user actions (Fig. 5). Moreover, we envisage a time-centric view. This depicts the document activities along a timeline of the meeting and provides structured access to the speech recording.

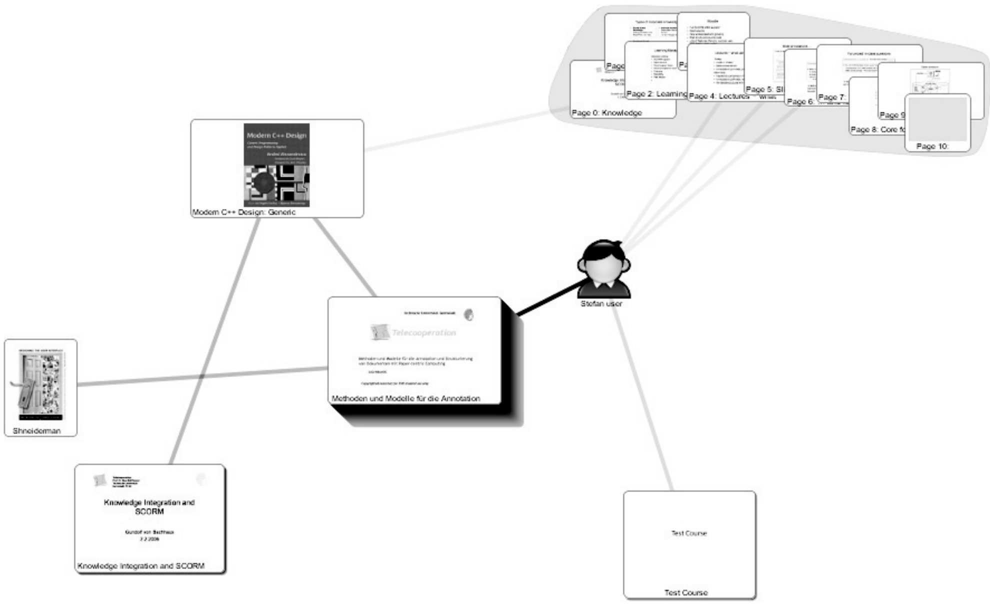

Figure 5: Visualization of document relations and user actions. Folders and documents can be unfolded to show individual pages (upper right)

We plan to conduct subsequent user studies to investigate the use of our prototype, which is currently under development. Moreover, we plan to examine if implicit document links can be automatically generated from user interactions. Promising features are the temporal co-occurrence of writing events in two documents and spatial arrangements where documents are positioned near each other.

6 Conclusion

We presented several concepts which combine the affordances of traditional paper-based learning with electronic support. They provide for intuitive annotation and structuring both in distributed and co-located collaborative settings. While in the lecture notetaking scenario, the electronic support focuses on sharing paper annotations and bookmarks over the distance, in the learning group meeting scenario, we provide an integrated support for both physical and digital documents, as these are part of one information ecology. Although we designed our concepts for the learning domain and evaluated them in this setting, they are rather generic, and we envisage them to be helpful in more general settings of knowledge work as well.

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