

# CoScribe: Using Paper for Collaborative Annotations in Lectures

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## Abstract

*In a study of notetaking in university courses, we found that the large majority of students prefer the paper medium to the computer for taking notes and making annotations. Based on this finding, we developed CoScribe, a system which supports students in making collaborative handwritten annotations on printed lecture slides. It includes mechanisms for the paper-based sharing and semantic tagging of annotations and slides. Moreover, we present a novel visualization of shared handwritten annotations providing an integrated access to annotations from all learners. A user study indicates that the system efficiently supports student annotation and can be easily integrated into current annotation practice.*

## 1. Introduction

University lectures are often considered as suboptimal learning settings, as the communication is centered to the instructor and learners easily become rather passive listeners. Collaborative notetaking and annotation processes are important elements to overcome these problems and foster active learning [14]: Taking personal notes stimulates students to actively follow the lecture, to consciously select important content and to rephrase it in their own words. Moreover, notes have a reminding effect during review after class [7]. The sharing of notes with other learners may support students to complete their notes, to critically examine their own understanding and to co-construct a shared understanding with other learners.

Many electronic systems for student notetaking and sharing have been proposed (e.g. [3, 6]). However, as we found out in a field study, most students do not use electronic tools for notetaking and annotation but prefer traditional pen and paper [17]. Compared to Tablet PCs, working with paper implicates a lower cognitive load [13]. This is due to the paper-inherent affordances like it being intuitively writable, highly mobile, cheap, offering two-handed navigation, haptic feedback and the possibility to be laid out in physical space for com-

paring and organizing pages and documents [15]. Combining the advantages of paper with the benefits of digital documents (like electronic search and collaboration) thus presents novel opportunities for improving classroom annotation, review and collaboration.

In this paper, we present CoScribe, an annotation system which enables students to collaboratively annotate lecture slides. During class, students can use an electronic Anoto [1] pen to make handwritten annotations on printed slides and empty pages as with a traditional pen. When reviewing the contents after class, a software viewer provides for access to both their own annotations and shared ones of other learners.

The contribution of this paper is two-fold: 1) We discuss the design of paper-based user interfaces for the annotation of course material and present two mechanisms for the semantic tagging, indexing and structuring of paper content. 2) We present a novel visualization of shared handwritten annotations for the efficient overview and access to annotations of other users. Both contributions have been validated in a user study conducted with students in several lectures.

## 2. Related Work

Much research has been conducted on systems enabling learners to annotate course material on *pen-sensitive displays* imitating the use of pen and paper. NotePals [3] automatically associates notes taken on a PDA during a lecture with the appropriate slides. Own and shared notes can be retrieved later on. Livenotes [6] uses Tablet PCs and focuses on the synchronous sharing of classroom annotations on lecture slides, which form a shared workspace. Dynamite [18] combines handwritten meeting notes, made on a pen display, with audio recordings. Its so-called properties, semantic types for classifying individual handwritten annotations, inspired our tagging function.

Several systems use *real paper* as an input medium for annotating electronic documents. PADD [4] and PaperPoint [16] enable users to annotate electronic documents by using their printouts as a proxy. PaperCP [10] (an extension to the Tablet PC-based



Figure 1. Annotating lecture slides with CoScribe.

Classroom Presenter) integrates paper input with synchronous collaboration: During class, students can submit annotations they made on printed slides to the teacher or the group. But each slide is printed on an own paper sheet resulting in extensive printouts. Air-TransNote [12] offers functionality similar to PaperCP, but only supports taking notes on an empty page (no annotation). The Interactive Multimedia Textbook [8] enables students to individually augment a paper textbook with hyperlinks to Web pages, but not with annotations. While borrowing the idea of paper input, we focus on asynchronous collaboration, the visualization of shared handwritings and paper-based tagging.

The PaperPDA [5], combining a conventional paper notebook and organizer with electronic capabilities, includes interaction techniques for manipulating and tagging content on paper. It introduces the general idea of paper buttons and enables users to create links between paper pages with adhesive stickers. PapierCraft [9] presents a set of gesture commands, like copy/paste and linking, for manipulating paper documents. PaperCP [10] expands on that and discusses other techniques for tagging paper content. These have in common that they require an additional device, like a foot pedal or a second Anoto pen. The techniques proposed in this paper do not require this.

### 3. Field Studies on Student Notetaking

Before designing the system, we conducted two field studies to examine notetaking and annotation processes in university courses, since notetaking in general and the use of annotation software in learning are not well studied [2]. The first study [17] was a quantitative questionnaire-based investigation with 408 students in several computer science and pedagogy lectures. The large majority (81.7 %) of the students taking notes used only paper although more than three quarters of them own a laptop. Important factors for the choice of paper mentioned are the flexibility of

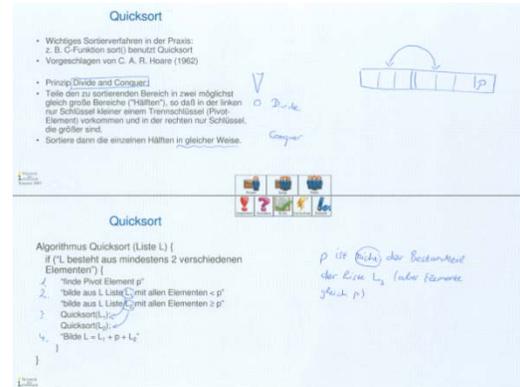


Figure 2. One out of several paper layouts.

handwritten notes and the easy transport. The study further showed that an annotation system should offer both the possibility to annotate printed handouts (e.g. slides of the lecture) and to take longer notes in free areas or on empty sheets of paper.

In a second study, we analyzed annotations created by 24 postgraduate students during nine sessions of a university course. The participants formed three groups: One group made handwritten annotations with pen and paper, another group with a Tablet PC and a third group typed annotations on a laptop. A main finding was that the use of a keyboard to type annotations seems to constrain the annotation process. Participants of the notebook group in average made considerably less annotations per participant and session ( $M=7.0$ ,  $SD = 4.6$ ) than those of the paper group ( $M=21.6$ ,  $SD = 11.8$ ). We infer that the user interface of an electronic annotation system should impose as little constraints as possible. Another outcome relevant to our system design was that many learners used semantic classification schemes to mark document passages or own annotations for later retrieval. These schemes comprise specific symbols, such as question marks, exclamation marks or asterisks. An important proportion of 11.0 % of the total of 1081 handwritten annotations acted as semantic markers containing nothing but one of these symbols.

### 4. CoScribe System Design

In this section, we will discuss the system design of CoScribe. It enables students to 1) create handwritten annotations on lecture slides, 2) to *semantically classify, structure and tag* annotations and document pages on paper for later retrieval and 3) to *collaborate* with other learners by sharing annotations. Our design was guided by the goal to allow a smooth transition from traditional pen and paper annotations to an augmented annotation practice. Moreover, the system should be easily deployable in real university settings.

The system comprises a *mobile part*, which can be used for in-classroom annotation and only requires paper printouts of the lecture slides and an 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, so that the technology remains in the background as much as possible. After class, students can use a PC to synchronize their annotations with the *backend system*, which stores them in a database on a central server. Own annotations and shared ones of other learners can then be accessed in the *CoScribe software viewer* (Fig. 3), which displays them on the corresponding slides and supports remote collaboration with other learners. CoScribe is implemented in Java and supports PowerPoint lecture slides.

#### 4.1 Mobile Paper-based User Interface

**Digital Paper Technology.** For the electronic synchronization of the user actions on paper, our system relies on the Anoto technology [1] and Logitech io2 electronic pens [11]. 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 be used to print out documents including this pattern. The pen stores its movements as vector graphics, which are synchronized with the backend system once it is docked. In contrast to other solutions for capturing handwriting on paper, no sensing device other than the electronic pen is needed. This provides for real mobile use and a natural writing and switching between multiple paper sheets like with a traditional pen and paper.

**Annotation and Notetaking.** The printouts were designed to constrain the personal annotation style as

little as possible. Handwritten annotations can be made anywhere on printouts. In addition to the *printed lecture slides*, the pages contain *free areas* (see Fig. 2 for one example printout). Our observations have shown that free areas seemed necessary to most students, because firstly the slides often do not contain enough empty space for extensive annotations and secondly it is considered important to take notes independently of the instructor's structuring. Once the pen is docked, all annotations are automatically transferred and displayed in the CoScribe viewer (Fig. 3).

*Various printout layouts* of slides and free areas are possible, providing for an adaptation to the course and the users. One physical paper sheet can contain up to four slides with or without free areas. In addition users can dynamically add empty notetaking areas when more space is needed: *Additional empty paper sheets* can be written on and associated with the corresponding slide by drawing a link gesture. This is a line connecting a slide printout with an empty paper sheet and has been earlier suggested in [9].

**Paper-based Tagging.** Tagging learning content with semantic markers is closely related to annotating: It can support individual structuring of the learning contents (e.g. marking the beginning of new sections) and classifying passages (e.g. as important or unclear). Our field study has shown that these tagging processes occur frequently. Moreover, in a collaborative system, tagging can be used to define if an annotation should be visible to other users or not. We therefore developed two paper-based tagging mechanisms to be easily integrated into current annotation practice.

*Tag Button on Paper.* The first mechanism was inspired by interacting with buttons in computer interfaces. For this purpose, a toolbar containing several but-

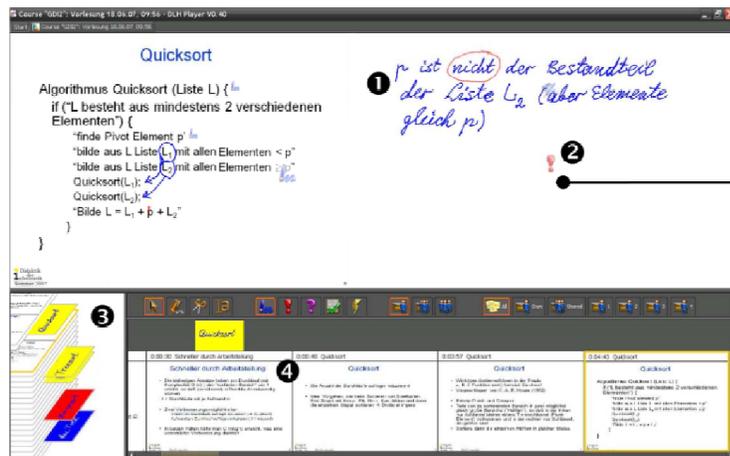


Figure 3. The CoScribe software viewer for own (1) and shared annotations (2), bookmarks (3) and navigation (4). Shared annotations expand when hovering over (right).

#### Shared Annotations

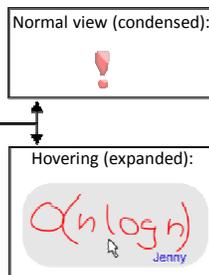


Figure 4. Digital Paper Bookmarks.



**Figure 5.** A button toolbar is printed on each page.

tons is printed in the center region of each paper sheet (see Fig. 5 and 2). Annotations can be tagged with one of four currently supported semantic types, derived from the needs identified in our field study (important, question, to do and correction). Moreover, users can define the visibility of the annotation (private only, visible to the members of the user’s learning group or visible to all students attending the lecture). Tags can be associated to individual annotations by tipping with the pen on the corresponding tag button(s) before or after writing the annotation. Tagging is optional, allowing the user to maintain its personal annotation style. This “tag button on paper” approach allows a fast classification of fine-grained objects with a set of pre-defined classes. In the CoScribe viewer the tags are visualized with specific symbols and colors (Fig. 3 (1), (2) and right). However, on paper, no graphical feedback on the tagging can be provided.

*Tagging with Digital Paper Bookmarks.* Adhesive bookmarking stickers are a well established practice for structuring documents, marking specific passages and accessing them later on. We augmented these by printing the Anoto pattern on adhesive stickers of different colors (Fig. 4). Stickers can be attached to physical pages of the printed document at arbitrary positions. A simple link gesture with the electronic pen then informs the system about the position (1). Handwritten labels are electronically captured as well, providing for free tagging with user-defined tags (2). Once the pen data is synchronized, the bookmarks are visualized in the viewer (Fig. 3 (3)). Digital paper bookmarks include the intuitiveness of paper-based indexing. They provide a graphical feedback on paper but are of a less fine granularity than button tags.

## 4.2 Visualization of Shared Annotations

A challenge with shared handwritten annotations is their clearly arranged visualization, particularly for a large number of users. We explore two approaches:

*Single-User View.* By separating the annotations of different users into different views, each of these views in itself becomes easier to read. CoScribe provides an single-user view for each member of the user’s learning

group. This view can be accessed by selecting a button in the toolbar associated with a specific user view. Yet, this implies the need to manually switch between views, which becomes particularly cumbersome in larger communities. Therefore, we developed a novel visualization of collaborative handwritten annotations.

*Integrated Multi-User View.* This visualization displays both one’s own and shared annotations in an integrated manner supporting overview and access to shared annotations without the need of explicitly switching. 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. 3, 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. 3, 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.

## 5. Evaluation

In order to assess the appropriateness of the system for in-classroom annotation and collaborative visualization, we conducted a two-part user study with overall 38 students. First the in-classroom setting was evaluated with 29 randomly selected computer science students who used the paper interface of the system during one of their normal lectures (each lasting about 90 min.). Second the review setting after class was evaluated in formal experimental sessions with nine participants (each lasting about one hour), where we observed them performing specific tasks with paper and the CoScribe viewer. In both parts, feedback was gathered with Likert-scale questionnaires and semi-structured interviews. To avoid positive bias, none of the students was personally known to us nor did they attend one of our courses. Fig. 6 resumes main results.

Our findings show that the integration of paper with computing is judged helpful for lecture annotations. Participants valued the possibility to classify annotations with semantics directly on paper. A substantial percentage of 18.7 % of all 1983 annotations was tagged with a semantic type. The two most frequently chosen types were ‘important’ (12.5 %) and ‘question’ (3.2 %). Although tagging with visibilities was performed only for a small percentage of annotations

