
Integrative Workplace: Studying the Effect of Digital Desks on Users' Working Practices

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Abstract

Digitally augmented workspaces have been extensively researched in the last two decades. However, studies that examine how digital desks might change knowledge work practices and its outcomes compared to tools used at nowadays desks do not exist. This paper reports our work on the design and implementation of *Integrative Workplace*, a digital desk to support legal work. The prototype allows the user to search and excerpt content from digital and printed documents. In contrast to related works, the system enables parallel interaction with multiple paper documents spread on an entire desk. We identified five key requirements to develop the system and tested it in a pre-study. The study revealed a system usability between *OK* and *GOOD* having an average SUS score of 66.94. In future work, we want to conduct a comparative study to research the effect of digital desks on users' working practices in the domain of legal work.

Author Keywords

Digital desk; interactive workplace; comparative study

ACM Classification Keywords

H.5.2. User Interfaces: Evaluation/methodology, Prototyping.

Introduction

In 1991, Pierre Wellner presented his seminal work on the DigitalDesk that interweaves a physical desk with digital functions [15]. The focus of his work is to make the manipulation of electronic documents similar to the manipulation of paper documents. His envisioned system allows the user to choose freely between electronic and paper-based information “without being constrained to the limitations of either” [11]. This idea inspired researchers to advance the integration of digital functions into physical paper. Nowadays research prototypes enable excerpting of content from paper documents [3,9,10], full-text search in paper documents [10], and the linking between content in paper documents and content in digital documents [9,14]. It is foreseeable that digital desks will enter the offices as consumer electronics. For example, in 2014 Fujitsu plans to launch a product that enables touch-based interaction with books and paper documents¹. Although such user interface technology will enter the consumer market soon, we do not yet understand how such digital desks might change knowledge work practices or effect outcomes of knowledge work. For this reason, the focus of this work is to study the effect of a digital desk on users’ knowledge work practices in the particular case of legal work.

In the following, we present the overall research goal, the current system design of Integrative Workplace, and its technical implementation. Then, we report results from a pre-study that inform the next iteration of our prototype. We conclude with a summary and future work.

¹ <http://www.fujitsu.com/global/news/pr/archives/month/2013/20130403-01.html> (last accessed: January 6, 2014)



Figure 1: Workplace of two law students solving a legal record.

Research Goal

The research goal of this work is to understand the effect of digital desks on work practices and the outcome of knowledge work. For this purpose, we want to compare legal work with nowadays tools and legal work at digital desks. Conceivable consequences, for example, are that digital desks may cause users to gather excerpts of inferior quality because the act of excerpting text does not require much time nor great physical or cognitive effort. Or perhaps, users have less internalized knowledge because digital desks suppress handwriting and the physical act of writing better preserves information in human memory. Another thinkable consequence might be that the possibility to save excerpts from digital and printed sources in one place increases the clarity over collected information. This may cause users to be able to apply more information when creating something new. These and other consequences of digital desks on working practices will explicitly be researched in a future comparative study. As a result, we want to name chances and risks of digital desks as they are entering offices and on this base inform their future design.

Use Case

To conduct the comparative study, a real-world task in the domain of knowledge work is needed. We chose the use case of law students building a solution sketch for a legal record (Figure 1). A solution sketch describes the strategy to *solve a legal case*. Law students create this document based on a literature review before they start writing a legal opinion. The particular use case facilitates the comparison of students’ working practices and, at the end, allows a quality review of their outcomes by a lecturer. The next section presents the use-case-specific design of Integrative Workplace.



Figure 2: The desk and the projector (1920 x 1200 pixels) of Integrative Workplace.

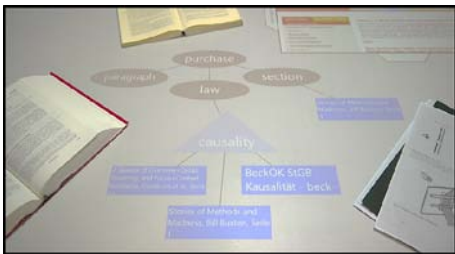


Figure 3: A mind map with excerpts from digital and analog sources.

Design

The system design is based on a requirements analysis to ensure that Integrative Workplace matches working practices of law students. Therefore, we interviewed 14 law students (10 female, 4 male) who wrote a seminar paper in the summer term break of 2012. First, they had to explain their procedure of designing a solution sketch. Afterwards an unstructured interview was held to further investigate their method and to recognize issues of the current tools they use. From these interviews, we derived five key requirements, which we directly implemented in the design of Integrative Workplace. The key requirements are described in the following.

Parallel Reading

Law students spot sources in parallel to compare different opinions about a legal problem. The digital desk should allow situating digital and analog documents side by side in order to compare contents. Integrative Workplace implements this requirement with a widespread tabletop, which is digitally augmented by a wide-screen projector mounted above the desk. This enables the use of multiple digital and analog documents in parallel (Figure 2).

Excerption

Law students continuously excerpt text from literature in order to have relevant information at a glance. The digital desk should allow students to easily excerpt text from digital and analog media. In Integrative Workplace this is realized using the same input device and the same interaction for physical and digital documents. For both, users mark the text of interest using digital pen. Afterwards they excerpt the text by

dragging it with the pen on the tabletop (Figure 4 and Figure 5).

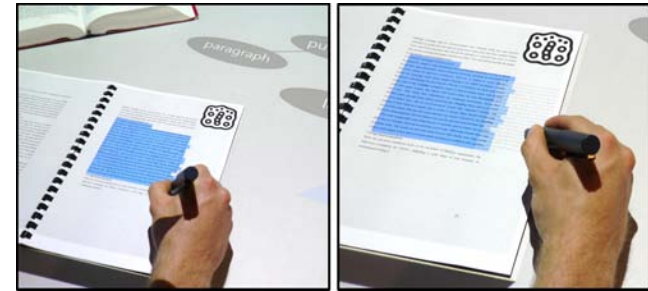


Figure 4: Marking and dragging text from a book.

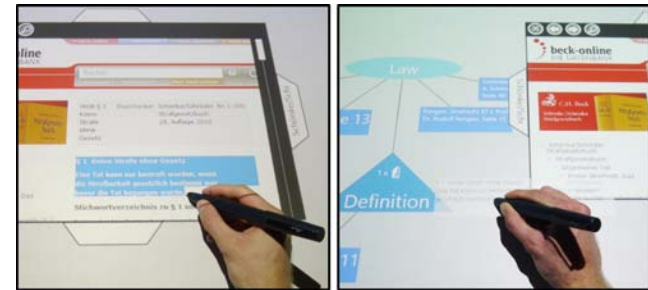


Figure 5: Marking and dragging text from a web page.

Knowledge Archiving

Participants wanted a place where they could save all passages of interest, no matter if they originate from printed books or web pages. The digital desk should allow to store all information in one place. In Integrative Workplace, this place is the tabletop where all excerpts are saved as graphical items, which can be semantically related using a mind map (Figure 3). We chose mind mapping as visual representation, because it offers structural freedom and leaves it to the users to decide how they arrange items (linear, arboreal, etc.).



Figure 6: Full-text search in a book.

Full-text search

Law students mentioned that they often use the index of a book as a starting point for their literature review, taking a catchword of the legal record to find relevant information. The digital desk should simplify this procedure by offering a full-text search in physical books. The full-text search of Integrative Workplace highlights all occurrences of the searched word on the opened page. A visualization on the right of the physical book shows matches for every page of the book (Figure 6).

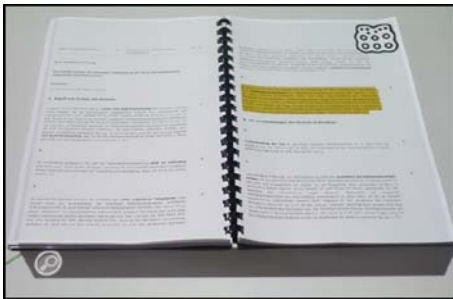
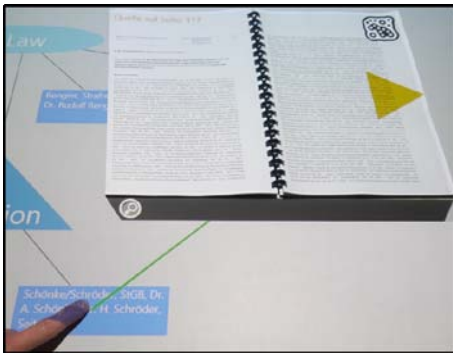


Figure 7: Backtracking from mind map item to its source (top). Highlighting of excerpted passage on a page (bottom).

Backtracking of references

Participants quoted that they often search for the same texts to reread or check for further citations. The digital desk should facilitate these excerpted work retrievals. In Integrative Workplace, users can link a mind map item (visualization of an excerpt) with its source. The excerpt's page number is projected on the book and an arrow indicates the direction in which the student needs to flip pages (Figure 7, top). On the corresponding page, the excerpted text is highlighted (Figure 7, bottom). If a source is not located on the desk a visual wildcard is displayed.

The possibility to layout documents in space is a substantial need of knowledge work according to research [7,13], as well as our requirement analysis (see Parallel Reading). Therefore, it is important to mention that all presented features work with multiple paper documents spread on an entire desk. The requirement analysis also revealed that the working practices of law students match different theoretical frameworks about the methods of knowledge workers [6,12]. This is interesting regarding a possible generalization of results from the comparative study.

Implementation

We realized the prototype using various frameworks and toolkits. A fiducial marker identifies every page of a book. Based on the markers, the reactIVision² framework identifies the documents on the desk and their physical location. To interact with the digital contents on the desk, Integrative Workplace uses pen and touch interaction. Touch interaction is realized using the capacitive Displax Skin Multitouch³ foil. The Anoto⁴ technology enables both interaction with physical documents to extract or to mark content on paper (like in [3]) and interaction on the desk. The latter is realized using the InputFramework⁵.

Pre-Study

Before conducting the comparative study to research the effects of digital desks on knowledge work practices, Integrative Workplace was tested in a pre-study to identify usability issues and to check if the obtained key requirements match juristic working practices. Therefore participants used Integrative Workplace to solve a real-world legal record by building a solution sketch. After completing the task, they had to answer the System Usability Scale (SUS) [2] and an additional questionnaire to receive feedback concerning the support of juristic working practices and the interaction design. This questionnaire used a five point Likert scale ranging from 1 for "I agree" to 5 for "I disagree". Last, participants were interviewed to go deep on the questionnaire answers and to get ideas for

² <http://reactivision.sourceforge.net/>

³ <http://www.displax.com/>

⁴ <http://www.anoto.com/>

⁵ InputFramework from Media Interaction Lab of FH Hagenberg

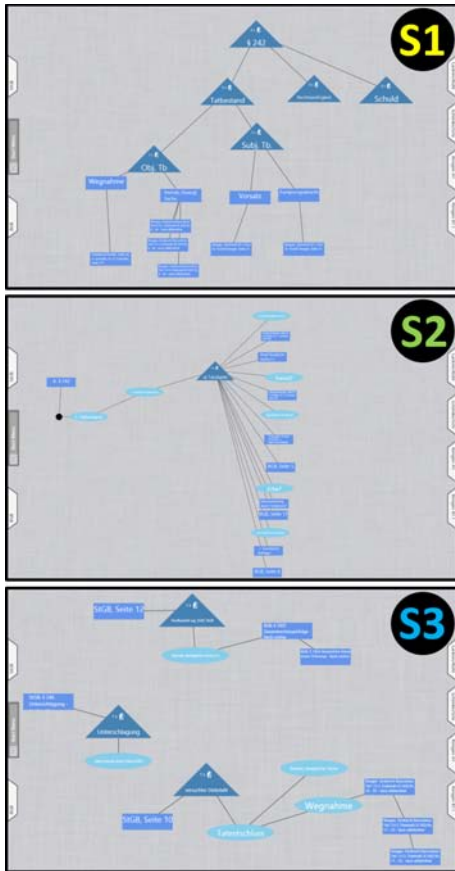


Figure 8: Three examples of solution sketches implemented with Integrative Workplace. S1 is showing a proper mind map picturing the solution sketch. In S2 the law student build the solution sketch in a linear way. In S3, no distinct structure is recognizable.

improvements. Nine law students (3 female, 6 male) were recruited as participants. A screening ensured that participants had sufficient skills to solve a legal record (e.g., it required them to have at least written two seminar papers that include solving a legal record).

Results of the Pre-Study

The participants rated the system with a *SUS Score* of 66.94 ($SD=13.22$). This classifies the system's adjective rating between *OK* and *GOOD* and the system's acceptability as *marginally acceptable* (according to [1]). This demonstrates that the system can be considered usable in the context of solving legal records, though the *SUS Score*, and therefore usability, must be improved. This result is supported by the additional questionnaire where, in one question, participants rated Integrative Workplace with an average Likert value of 1.78 as useful to solve legal records. In the interview, participants most frequently mentioned "saving all excerpts at one place, no matter if excerpted from digital or analog sources" as advantage of Integrative Workplace. Moreover, the students stated that the reference backtracking and the digital full-text search in printed documents are very useful for juristic work.

A current limitation of Integrative Workplace is the mind map visualization, which is not the appropriate tool to implement a solution sketch. In the interview, five participants clearly indicated that a mind map does not support building a solution sketch. One participant said: "In law, there is a distinct evaluation order of legal issues. It is not possible to reflect this order with a mind map." In connection with the statement, it stands out that 46.15% of the created mind map items were deleted later. This might be an indicator that

participants are uncertain about their solution sketches when creating them with a mind map. This uncertainty can be seen further in the solution sketches the participants implemented using Integrative Workplace. The solution sketches from 6 out of 9 participants did not have a mind map structure (Figure 8). When asked for ideas to better describe a solution sketch, four participants suggested visualization, which pictures a linear solution sketch scheme.

Interestingly, the user study discovered that using pen and finger for mode-switching between moving and tracing tasks is not as clear cut as one might think. Although this behavior is adapted from reality, seven out of nine participants had problems to distinguish interaction between finger and pen. For instance, in the interview one participant stated: "I didn't know when I had to use the pen and when the finger." Another student claimed that he needed some time to get used to the system: "sometimes you need to use the finger, sometimes the pen."

Future Work

In future work, we will design and conduct a comparative study to research the effect of digital desks on knowledge work practices in the context of legal work. Therefore we compare the method and the quality of outcomes of two conditions. In the first condition, students solve a legal record using their usual tools. In the second condition, students solve the same record with Integrative Workplace. If this study reveals promising results, the examination of another discipline is conceivable. To ensure the system's usability for the final study, the usability issues obtained in the pre-study will be fixed. Consequently, the major component of a future study will be the

design and implementation of a visualization that depicts the linear way a legal case is solved. In addition, as there are different opinions in literature about using pen and touch for mode-switching between different kinds of tasks (e.g., [4,5]), we want to conduct a study that qualitatively and quantitatively compares different mode switching techniques in pen and touch user interfaces (similar to [8]).

Conclusion

We presented Integrative Workplace, a digital desk for knowledge work. The system supports law students building a solution sketch for a legal record. We conducted a requirements analysis to understand the working practices of law students and to gather key requirements for a digital desk. The Integrative Workplace was designed and implemented according to the key requirements. It allows the user to search and select content of digital and printed documents on a word-level and, in contrast to related works, the system enables this interaction with multiple documents in parallel. The results of a pre-study evidence that Integrative Workplace facilitates juristic working practices. Next steps are explained in future work.

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