

DocuDesk: An Interactive Surface for Creating and Rehydrating Many-to-Many Linkages among Paper and Digital Documents

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Abstract

Knowledge workers often undertake tasks that involve a variety of information artifacts, including both paper and digital documents. In this paper, we first summarize findings from a study that illustrate some of the challenges of managing tasks that include both paper and digital content. We then introduce DocuDesk, a prototype interactive desk that demonstrates interaction techniques for establishing many-to-many linkages among paper and digital documents which can be used to quickly “rehydrate” task state.

1. Introduction

While digital technology has transformed work practices, the paperless office has yet to materialize. Applications such as word processing, email, and spreadsheets support revision, replication, search, and remote collaboration. Nevertheless, research has shown that people continue to rely on paper for many tasks, due to its flexibility and mobility [7].

Researchers have begun to support users’ preferences for paper by developing systems to simplify the process of transitioning between a paper and digital version of a document. Most research in this vein has focused on supporting a one-to-one relationship between the same document across both mediums. For example, the PADD system transfers marks made with an Anoto digital pen on a printed document onto the digital version of that same document [2]. The Designers’ Outpost captures images of sticky notes on a digital whiteboard and displays those images as proxies when the physical sticky notes are removed [4]. Video-Based Document Tracking uses a camera to create a representation of physical documents atop a user’s desk, recording images as items are added to a pile so that the depth of a particular item is known and can be queried [3]. PaperSpace detects finger position over specially marked paper to allow fluid switching between digital

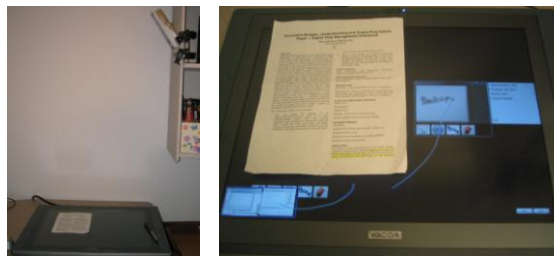


Figure 1. The DocuDesk. Left: A Wacom Cintiq 21UX is augmented with IR lighting and an overhead camera to enable paper tracking and identification. **Right:** Lines drawn with a stylus link a paper document, a “pinned” sticky note, and an application running on the user’s main display (linked via its representation in a world-in-miniature view).

and paper documents [8]. ButterflyNet uses Anoto pen technology to allow biologists’ paper notes to be integrated with time-stamped digital photos [10].

However, people often use a variety of both paper and digital resources, with relationships not addressed by these prior systems, in order to accomplish a single task. For example, someone might refer to a notebook while preparing a slide presentation, or use a printed specification document in conjunction with related source code and bug databases. Surface computing researchers have shown that interactive horizontal displays hold potential for enhancing office workers’ experiences by creating “interactive desk” systems such as the DigitalDesk [9] or EnhancedDesk [5]. Bondarenko and Janssen [1], as well as our own study, have noted the need to combine documents from different sources. We introduce DocuDesk, a system that uses interactive desk technology in order to address the challenges of creating and utilizing relationships amongst paper and digital documents.

2. Motivation

To better understand when and how people use paper and digital documents together, we interviewed

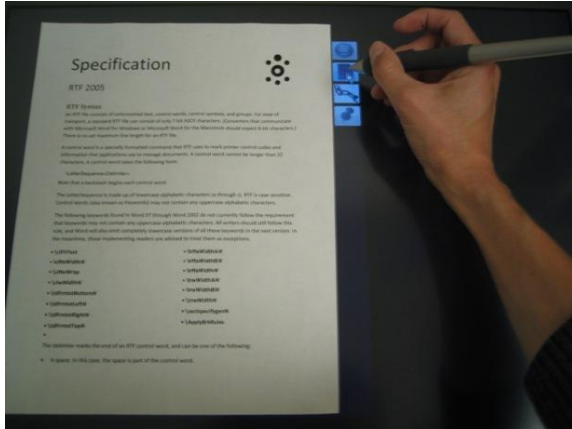


Figure 2. A shadow menu augments a paper document when it is placed upon the DocuDesk.

fifteen knowledge workers with jobs such as administrative assistant, software engineer, and research scientist. The fifteen interviewees (seven female) included twelve employees at a large technology company and three at a local university. Even though all of our participants were experienced computer users, they all used paper every day.

Our interviews revealed many tasks that involved a mixture of paper and digital documents beyond the one-to-one relationships between physical and digital counterparts. Here are a few motivating examples:

Gathering information from various sources (*i.e.*, to prepare a report or presentation) was mentioned by seven of our participants. One researcher described the process of writing a research paper: “I’ll have a spread out set of [printed] background material. I’ll usually have two or three [paper] versions of the [research] paper on my desk with lots of critiques. I usually work on the computer and laptop so I can have the [electronic research] paper and some code or a diagram or data I’ve collected.”

A software engineer discussed using a paper copy of a specification document when she tested software. She noted, “I keep it by the computer so I can run test cases off of the spec. I use the tables in it to make sure everything is behaving correctly. I usually check it off on the [paper] spec.” She would also use the specification with paper copies of a test plan, and electronic code and the application she was testing.

A common pattern was the use of scrap notes and paper documents to support digital tasks. Administrators used information on post-it notes to reduce look up time and developers and researchers used scrap notes for conceptual work. Many participants also used paper for planning. The paper was often a focus point during the task. The DocuDesk



Figure 3. Detailed view of a shadow menu, offering options to email a paper document’s digital counterpart, view its digital counterpart, capture an image, create or retrieve linked documents, or pin the digital counterpart onto the DocuDesk.

system photographs these paper scraps and allows them to be connected with more structured content.

A key challenge described by our interviewees was *task rehydration*, or re-establishing the state of open windows and documents when resuming a task. Having multiple paper and electronic documents makes task resumption more challenging. Re-finding digital documents can be a challenging aspect of task rehydration, as one participant noted in a description of how he “loses” digital content: “... by losing, [I mean not] remembering where I stored it.” Paper is also frequently lost, especially small notes in notebooks and information written on scraps. The DocuDesk system is designed to address these challenges by enabling the placement of a paper document on the desk to initiate task rehydration, and by capturing digital copies of users’ paper documents as they sit upon the desk.

3. The DocuDesk System

The DocuDesk augments a user’s existing PC setup by including a Wacom Cintiq 21UX display, laying flat atop the user’s desk, bathed in IR light from above and filmed by an overhead video camera with an IR filter (Figure 1, left). The Cintiq is a commercially-available, 1600 x 1200 pixel LCD display, measuring 21.3” diagonally, that can be operated with a stylus, and can run in a multi-monitor configuration with a user’s existing PC setup.

Paper placed atop the DocuDesk is observed by the system’s camera. Using standard vision algorithms, the system recognizes objects matching several standard paper sizes (*e.g.*, 8 ½ x 11”, sticky-notes, and notebook pages). When an object on the DocuDesk is recognized as paper, the system checks for the presence of a 2D barcode to determine whether the paper document has a digital counterpart; if the document does not have a barcode, then the overhead camera records an image of the document.

The interactive desk surface enables a juxtaposition of physical paper and digital input and output. A *shadow menu* is displayed next to a document when it is placed on the surface and augments the paper document by offering a set of interactions to simplify common tasks (see Figure 2). Figure 3 shows the

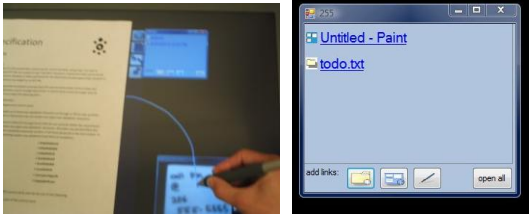


Figure 4. Left: Using the stylus, a user draws a line to establish a link between a paper document and a digital one, to indicate that they are used together for a single task. **Right:** A list of the items linked to the current document. Linked items can be opened individually by clicking their name in the list, or the “open all” button can be used to quickly rehydrate an entire task. Links can be added via a filename browser, a world-in-miniature view, or line-drawing.

shadow menu’s options. The “email” option opens a new email message containing the paper’s digital counterpart as an attachment. The “digital document” option opens up the paper’s digital counterpart and displays it adjacent to the paper document in order to facilitate side-by-side comparison (*i.e.*, to check for changes between versions and to switch mediums). The “camera” option signals the system’s overhead camera to automatically capture, crop, and store a new image of the paper document (*i.e.*, to capture any new annotations that have been added to the paper since it was initially laid atop the desk or to duplicate scrap notes). The “pin” option opens the paper’s digital counterpart and locates it at the same spot as the paper itself, thus enabling the user to remove the paper from the desk but providing a proxy for reference.

The aforementioned shadow menu options show how an interactive desk’s ability to co-locate imagery and interaction with paper can facilitate the types of one-to-one paper/digital correspondences of the type proposed by systems such as PADD [2]. In addition, the shadow menu’s “link” functionality supports many-to-many mappings among paper and digital documents, which goes beyond prior paper-support systems to enable support for complex task scenarios such as those described in our interviews.

Selecting the “link” option from the shadow menu opens the link creation and rehydration interface for the active paper document (Figure 4, right). Links can be created connecting a paper document to any number of other digital and/or paper documents, in order to indicate that these items are all used together as part of a task. Establishing such links can facilitate resuming a suspended task – placing a paper on top of the DocuDesk and using the “open all” option from the link interface repopulates the display with the set of related documents, instantly rehydrating the user’s task

state. Inked lines appear between the selected document and related documents in order to assist users in finding them. If a linked-to item was a paper document which has since been removed from the DocuDesk, its digital counterpart (electronic document or photograph) will appear instead during task rehydration. Linked documents can also be opened individually by selecting their names from the list shown in the link creation and rehydration UI.

Links can be established using any of three methods. The first method is to open a traditional file browser and allow the user to navigate their computer’s directory hierarchy in order to select the file they would like to link to the current paper document. The second method of linking is to use the DocuDesk’s stylus to draw visible lines connecting the current paper document to other paper or digital documents that are on the DocuDesk (Figure 4, left). The third method of linking displays a world-in-miniature view of the windows from the user’s traditional vertical monitors on their DocuDesk, thus enabling the user to draw inked lines connecting the current paper document to representations of windows that are not on the DocuDesk itself (Figure 1, right). The world-in-miniature can also be shown as a list of all currently-open application windows, in order to enable establishing a linkage to a window that is open but not visible (*i.e.*, is occluded by other windows). These three methods allow linking of documents regardless of medium (paper or electronic), location (desk or computer) or input type (stylus or mouse).

3.1 Sample Use Scenario

Here, we describe an example use scenario, illustrating how the DocuDesk can assist with managing multi-document, paper + digital tasks, such as those described during our formative study.

Andrea is a geology professor who is writing a journal article on the topic of climate change. On her computer, she has several documents open: a web browser showing a *New York Times* article about polar bear extinction, a PDF file of an article from an online journal about the melting of polar ice, and a word-processing document where she is composing the draft of her journal article.

Andrea has just returned to her office after a trip to the library, and has a photocopy of a related journal article that she found there. She also has an outline of her article’s conclusion that she wrote in her notebook during her trip to the library. Andrea places the journal article and her notebook on her DocuDesk. The DocuDesk recognizes both items as untagged paper, and automatically stores digital images of each, as well as displaying shadow menus adjacent to both items.

Andrea uses her stylus to select the “email” action from the outline’s shadow menu; she sends DocuDesk’s digital image of her outline to a colleague and asks for his feedback on her plan for the concluding arguments. Knowing she’ll want to quickly return to the draft when her colleague responds, she selects the “link” option from the journal article’s shadow menu. Using her stylus, she draws a link connecting the journal article to the outline. She uses the world-in-miniature view to add the *New York Times* webpage, the PDF e-journal article, and her word-processing article draft to the list of linkages.

A few days later, Andrea receives a reply from her colleague, commenting on her proposed conclusion to the article. This reply prompts Andrea to resume editing her draft; however, in the intervening few days, the state of her desktop has changed. Andrea takes the journal article she had photocopied at the library and places it back onto her DocuDesk. She chooses the “link” option from the shadow menu and selects “open all” – the web page, PDF file, and word-processing document reappear on her screen, as well as a photo of the notebook page. Reminded of the state of her task by the associated context, Andrea quickly resumes editing her journal article.

4. Discussion

The ability of horizontal surfaces to support natural interactions with tangible objects is one of the defining features of interactive tables and desks. The DocuDesk illustrates how the co-location of paper with an interactive surface can facilitate managing rich tasks that involve a combination of paper and digital documents. The DocuDesk goes beyond prior paper-support systems by facilitating the creation of many-to-many relationships among paper and digital documents; the desk can then be used as a quick mechanism for task rehydration.

Currently, the DocuDesk provides three mechanisms for manually establishing links between documents. A rich area for further work is in exploring mechanisms for automatically inferring and suggesting links to the user. One automatic approach to infer task-based groupings of digital documents is to use temporal patterns of use, like SWISH [6]. In addition to extending this type of approach to incorporate paper documents, the physical nature of the DocuDesk would also provide opportunities for inferring task-based links based upon the physical arrangement of items on the desk itself, *i.e.* by piling.

In addition, we envision that future iterations of the DocuDesk will automatically establish 2D barcode tag mappings as documents are printed, rather than

requiring manual creation of the association between a barcode and a digital document.

5. Conclusion

Even as office technology becomes more advanced, research suggests that the “paperless office” is unlikely to become a reality soon [7]. The DocuDesk is an interactive surface designed to assist office workers in managing tasks that span the paper and digital worlds.

In this paper, we summarized findings from an interview study that illustrated the types of complex paper + digital tasks undertaken by a variety of knowledge workers, motivating the design of DocuDesk. We then described the DocuDesk prototype, which uses shadow menus to make paper documents placed atop the desk interactive. In addition to facilitating a variety of interactions between a paper document and its digital counterpart, the DocuDesk provides several interactions for establishing many-to-many links amongst paper and digital content. These links can then be used to quickly rehydrate task state when an associated document is placed atop the desk.

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