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### ► To cite this version:

Thomas Pietrzak, Sylvain Malacria, Éric Lecolinet. S-Notebook: Augmenting Mobile Devices with Interactive Paper for Data Management. Proceedings of the Conference on Advanced Visual Interfaces (AVI 2012), May 2012, Capri, Italy. pp.733-736, 10.1145/2254556.2254696 . hal-00757125

**HAL Id: hal-00757125**

**<https://inria.hal.science/hal-00757125v1>**

Submitted on 28 Nov 2012

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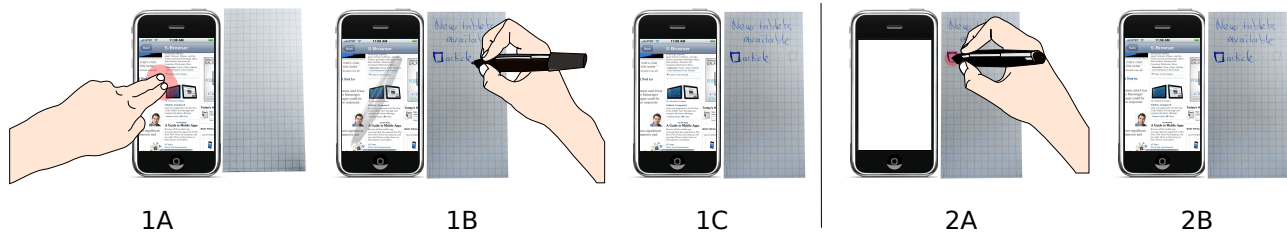
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# S-Notebook: Augmenting Mobile Devices with Interactive Paper for Data Management

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**Figure 1: S-Notebook makes it easy to annotate digital documents by using augmented paper to expand the interaction space: (1A) The user taps on a given location on a document with two fingers to create an anchor; (1B) The user writes notes or draw sketches on augmented paper; (1C) The notes are automatically linked to the anchor, taking into account the spatial or temporal location of this anchor in the document and the zoom level of the view; (2) The user just needs to tap on a note with his pen to make appear the corresponding document as it was displayed when the note was taken.**

## ABSTRACT

This paper presents S-Notebook, a tool that makes it possible to “extend” mobile devices with augmented paper. Paper is used to overcome the physical limitations of mobile devices by offering additional space to annotate digital files and to easily create relationships between them. S-Notebook allows users to link paper annotations or drawings to anchors in digital files without having to learn pre-defined pen gestures. The system stores meta data such as spatial or temporal location of anchors in the document as well as the zoom level of the view. Tapping on notes with the digital pen make appear the corresponding documents as displayed when the notes were taken. A given piece of augmented paper can contain notes associated to several documents, possibly at several locations. The annotation space can thus serve as a simple way to relate various pieces of one or several digital documents between them. When the user shares his notes, the piece of paper becomes a tangible token that virtually contains digital information.

## Categories and Subject Descriptors

H.5.2 [User Interfaces - Interaction styles]

## 1. INTRODUCTION

While smartphones and tablets make it simple and convenient for users to store and access digital documents and various types of media, annotating and sharing digital content remains uneasy on such devices. Most of these devices lack a hard keyboard, a compromise that maximizes the screen size but makes it harder to en-

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AVI '12, May 21-25, 2012, Capri Island, Italy

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ter text. Moreover, typing notes on a keyboard is far from offering the flexibility of handwriting and free-drawing. Free-drawing allows users to write notes wherever needed, to cross out, encircle or link parts using arrows and other marks, and to sketch for externalizing or memorizing ideas [17]. However, efficient free-drawing requires using a stylus, an accessory that is now seldom used, probably because touch is now the primary way of interacting with mobile devices. Users are now used to interact directly with their fingers despite a lower precision than when using a stylus. Moreover, precision remains limited even with styluses because the resolution of capacitive touch screens is far inferior to those of graphics tablets and other pen-based technologies. Finally and most importantly, sufficient space is missing for writing handwritten annotations conveniently in addition to the displayed data. This is especially true for smartphones because their screen real estate is limited. For that matter, it is interesting to notice that people often use pen and paper in conjunction with their mobile device in various kind of situations (e.g. online courses, meetings, proofreading, etc.)

In this paper we propose to use augmented paper to “extend” the screen of the mobile device. S-Notebook, the system we present, offers more space and capabilities to the user, by combining the advantages of digital devices with the simplicity, precision and flexibility of paper note-taking. Using S-Notebook, users can bind a handwritten note on augmented paper with a user-defined anchor located at an arbitrary location within a digital file. It makes easier structuring and organizing digital resources by regrouping the corresponding notes in the annotation paper space. Our system does not rely on any paper gestural command system, hence avoiding visual pollution, and one can use his own note taking vocabulary to semantically organize his notes. We evaluated the usability of S-Notebook in an augmented active reading task.

## 2. RELATED WORK

The arrival of technologies like Anoto digital pens [3] is the root of a profuse research on paper interaction. While some systems intend to augment digital documents with paper, other systems use paper to bookmark digital information. In addition we also present, we present research on note-taking tools and active reading systems with a mobile device.

### 2.1 Paper-augmented systems

Paper offers many advantages that electronic devices do not provide yet, and this probably one of the reasons why, despite decades of fruitful research on new computational devices, paper has not disappeared and is still widely used in various contexts [14]. Not only paper is cheap, lightweight and flexible, but it is also easy to fold, cut, past, merge and share. Taking handwritten notes is easy and the user is not restricted to specific characters as he would be with a keyboard. Paper is also convenient for quickly drawing sketches [5]. However paper has drawbacks of its own: dynamic medias (audio, video...) are inherently hardly printable, and digital versions of a document lie in different worlds, with no direct connections between them. It is therefore difficult to map annotations on the paper with digital content.

Various systems have used physical paper to enhance the interaction with digital documents, generally by using printouts as proxies with digital pen technology. Some of them help users to annotate a text document while proofreading it, and merge physical annotations with the digital version of the document [6]. Paperproof [18] interprets specific annotations for seamlessly editing a digital text document according to gestural annotations made on its paper proxy. PapierCraft [9] extends this concept and maps pen gesture commands made on a printout with digital manipulations such as copying/pasting a block of text. Finally, Plink [15] relies on paper notes to physically manage digital documents on physical paper. Plink links a region on paper with any webpage, folder or document in the local file system, or a pdf file, but creates visual pollution on paper because of gestural commands. Moreover, it can not create a link to a specific part of a document.

Augmented note-taking systems enrich a physical notebook with information captured in the real-world. For example Memento [19] uses gestural commands to explicitly augment handwritten notes with digital medias. On the contrary, U-Note [12] relies on temporal association for implicitly linking notes of students' notebooks with various events that occurred during a class. ButterflyNet [20] combines both explicit and implicit augmentation to help field-biologists to insert photos or real-world samples in their notes. It also associates information such as their GPS coordinates or the photos they took on field. While these systems use the paper notebook as a central media for organizing digital data, they focus on specific types of data for a particular use case. Besides, they merge paper notes and digital content afterwards, while our system needs to attach annotations as soon as they are written.

### 2.2 Combining mobile devices with paper

[11] studied the combination of mobile devices and physical paper in the A-book, a PDA used as an "interaction lens", to digitally augment handwritten notes and interact with them. The A-Book focuses on a laboratory environment, and situations when the pieces of information are written or printed on paper. The PocketPad [2] combines a PocketPC with a digital pen to manage data in mobile contexts. This system digitalizes handwritten notes and transfers them to the Pocket PC for a later access of this digital copy.

### 2.3 Mobile devices for active reading

Active Reading [1] refers to a situation where the user does not only read a document, but also connects sections, highlights specific parts, etc. With XLibris [13], users can structure their documents with a Tablet PC by marking sections through underlining, circling, or adding annotations in the margin. Codex [7] is a dual screen tablet that makes it possible to annotate a wide range of digital documents. Among other things, Codex highlights the benefits of dividing tasks into two screens: one for reading the document and another one for taking notes. These systems rely on touchscreen annotations, which cannot provide the same benefits nor the same flexibility as paper regarding folding, cutting, pasting, the fact that no power is needed, etc.

## 3. SYSTEM DESCRIPTION

S-Notebook allows the user to link a browsing space with an note-taking space (Figure 2). The former is a browser application, called "S-Browser", that runs on a mobile device while the latter consists of Anoto paper. Both spaces can be manipulated independently so that the user can browse the document and annotate it in parallel. The "S-Browser" can handle various kinds of documents and files, such as Web pages and video files. It provides the capability to create user-defined anchors at arbitrary locations in the browsed file, creating a link between strokes on paper and meta-data of the file. The way these anchors are specified by the user will be detailed in section 4.



Figure 2: The annotation space can have various forms such as spare sheets (left) or a dedicated notebook (right).

### 3.1 Interaction space extension

As said before, S-Notebook associate a *navigation* space (the smartphone) with an *annotation* space (one or several sheet(s) of Anoto paper), hence increasing the interaction space. The user can take handwritten notes or draw sketches on the paper without hiding the digital files on the mobile device. The navigation and the annotation spaces can be manipulated independently so that the user can browse the document and annotate it in parallel. This also makes it possible to create notes groups, as explained below, where each note is associated with a different part of the document (or with a different document). The annotation space can be any piece of Anoto paper such as a spare sheet of paper (Figure 2, left) or a dedicated notebook (Figure 2, right).

### 3.2 Paper bookmarks

S-Notebook provides the capability to bind a handwritten note with a user-defined *anchor* located at an arbitrary location in the browsed file. The anchor is either spatial (for a static document such as a PDF file or a Web page) or temporal (for a multimedia document such as a video or an audio file). We refer as *active notes* handwritten notes or drawings that are associated to an anchor in a file. Conversely, handwritten notes made without previously defining an anchor are called *passive notes*. As expected and contrary to active

notes, passive notes do not open an associated document on the mobile device when pointed with a digital pen. Active notes rely on a fine-grained relationship between each note on the paper and the state of the document when the note was taken. For instance, this makes it possible to index key moments in a video file or various text passages, images, videos, etc. in a HTML file. The document will be displayed appropriately, restoring the scrolling and zooming levels when the note was made.

## 4. INTERACTION WITH S-NOTEBOOK

For each feature of S-Notebook, we present how the system works and our design choices in more details.

### 4.1 Adding notes

Technically the system can link any active note to any information on the mobile device. We decided to link active notes with the content displayed on the screen of the mobile device when they are written. The scope of information associated with the notes is an interesting problem. We believe that notes are more interesting when they are relative to a specific location in the file rather than to the entire file that is currently displayed. Thus, as explained above, we decided to link active notes to *anchors* in the digital file.

**Implicit VS explicit links.** We chose the interaction for anchor creation with care since it is a key point of our system. The user can write whatever he wants on paper and some notes may have no direct relationship with the data currently displayed on the mobile device (e.g. notes taken during a phone call that interrupted the user activity). For this reason we decided that the user must create the links explicitly. This led us to differentiate between *passive* notes and *active* notes. Passive notes are created by default when the user writes something, they just exist in the paper space and are not linked to anything. In contrast, active notes are linked to a digital content on the mobile device.

**Explicit self-delimited gestures.** The interaction required to create anchors strongly depends on the context of use of the system. Several systems use recognition of self-delimited handwritten gestures to create anchors [8, 18]. This solution is well adapted for these systems since paper and computers are not supposed to be used altogether. Thus they rely on an interaction that only uses the pen and the paper. However this solution has important drawbacks. First, it requires a recognition system. Then, users must generally learn predefined symbols and cannot not use their own symbols and preferred note-taking style. Finally, these self-delimited gestures tend to increase visual pollution. This is why we adopted a solution that let users able to organize their active notes using their own symbols and avoids visual pollution.

**Mode switching.** We use an explicit annotation mode for creating links without having to perform self-delimited gestures. All the strokes written during this mode are associated with the digital content displayed on the mobile device when the mode started. Various mode switchers for handwritten notes have been proposed in the literature, such as gestures [16], a physical button [10] or printed buttons [4]. While these solutions are interesting, they introduce limitations to the system.

Since our system combines a mobile device with paper, we decided to use the mobile touchscreen for mode switching. After informal pilot studies, tapping the screen with two fingers, without moving them, appeared to be a good choice for creating anchors. With this solution, users are not required to learn somewhat complex gestures

that may be wrongly recognized. Moreover, it does not interfere with regular multi-touch gestures such as pinch-and-expand or two-fingers swipes for scrolling. Finally, as the user's main focus of interest is the file displayed on the device, it seems more natural to interact with the device first.

**Our design choice.** Tapping with two fingers on the touchscreen of the device enters the active note mode: whatever the user writes on the paper is then linked with the anchor, corresponding to a specific location within the displayed document (Figure 1, 1A). A pen is displayed in transparency on the browser so that the user knows he is in the "active note" mode (Figure 1, 1B). The data associated with the anchor differs according to the type of the file. The scrolling and zooming levels are stored for "static" files such as a Web pages. A timestamp is stored for "dynamic" files such as a video or audio files. Handwritten notes can comprise text and/or drawings: both are just seen as a series of strokes. Each anchor has an ID that identifies the corresponding document, the location in the document view and the time when the selection occurred (this being especially useful for audio and video files). The "active note" mode is automatically exited if the user does not write any stroke for 3 seconds (Figure 1, 1C). No explicit action is required in order to avoid undesirable linkings. If the user had to exit the active note mode explicitly, there would be a post-completion problem when he forgets doing this action. Whatever he writes on the paper would be automatically linked to the last anchor, even if written at a much later time in a completely different context.

### 4.2 Accessing notes

At any time, the user can open the anchor associated to an active note by tapping it with his ANOTO pen (Figure 1, 2A). Then the mobile device opens the digital content associated to the anchor, with the same view as when the note was created (Figure 1, 2B). The user can browse the webpage, watch the video or listen to the audio content that was saved with the anchor. This technique implies few visual pollution. We observed that most of the users draw buttons, and they click on them even if they can click on the whole surface covered by the active note.

### 4.3 Sharing notes

The user can share active notes by giving physical paper (either whole pages or teared up pieces) to another person. This person can then access the associated digital data in the same way as described in the previous section. The piece of paper hence becomes a tangible token that "virtually contains" digital data. Trust relies on physicality: giving a physical object provides the right to access its digital counterpart.

### 4.4 Modifying and deleting notes

We carefully considered pros and cons about integrating a deletion feature. On the pro side users may want single use links, so the ability to erase them afterwards while keeping the notes. Another reason is a security issue with the sharing feature: users may want to share only some of the links written on the sheet of paper. The cons are mostly related to user interaction. We do not want to introduce new gestures: it would be against the intuitive design we want to preserve, and it would add visual pollution if the user has to cross out the note he wants to delete. Moreover there may be involuntary deletions, which we want to avoid at all cost. To avoid that we would need to introduce a visual confirmation dialog on the mobile device. We believe this solution is not natural. Hence we decided not to add a specific deletion feature to our current system. We preferred to get advantage of interaction we already de-

signed to enable modifications and deletions. One solution to share only one of the note is to tear the piece of paper to only give the part containing the link to be shared. If the user really wants to delete a link while keeping the paper note, he can overwrite the current link by creating a dummy link to an empty page, and encircling or just write in the corners of the area to erase. The links underneath will not be accessible anymore since the user can only access the top-most link.

## 5. IMPLEMENTATION

The system comprises two pieces of software that communicate through a TCP/IP connection in a client-server model. The first program, the *S-Browser*, is a client software, which serves to browse digital files on the mobile device. The *S-Browser* has been developed in Objective C with the iOS SDK. The second program, the *S-Linker*, is a server which links the anchors in the digital files with the handwritten (active) notes on the paper. It stores all the links in a database, as well as the pictures taken with the *S-Browser*. The *S-Linker* has been developed in JAVA, using the Paper Toolkit [21].

During the note creation process, *S-Browser* sends the two finger tap event to *S-Linker*. Then *S-Linker* stores the bounding box of the strokes coming from the ANOTO pen stream until the *S-Browser* sends a stop event. In the final implementation, *S-Browser* will receive the pen strokes, then compute and send the bounding box as well as the anchor to the *S-Linker*. A similar process occurs when accessing a note. When the user taps his ANOTO pen on his paper notes, *S-Linker* retrieves the coordinates and the corresponding note in his database. If there is at least one match, it sends the corresponding anchor to the mobile device. Then the mobile device opens the digital data. In the final implementation, *S-Browser* will receive the pen event, and transmit the coordinates to *S-Linker*. Only the top-most link is retrieved. This makes it possible to modify or remove an anchor.

## 6. CONCLUSION

We presented *S-Notebook*, a hybrid system that takes both benefits of mobile devices for their ability to browse a great variety of digital data, and paper for its facility for note taking. *S-Notebook* uses the mobile device as a navigation space and the paper as an annotation space. This separation prevents from overloading the visual space on the mobile device, which size is strongly constrained. *S-Notebook* makes it possible to create fine-grained links between handwritten notes and various kinds of data (including video and audio files) considering the the spatial or temporal location. These notes allows to retrieve the corresponding file at a later time and to display it as it was when the note was taken. We let the user free to use his own note-taking style to make the interaction more natural and to avoid recognition problems.

Handwriting makes it possible to annotate quickly and easily with a high level of expressivity (e.g. by drawing symbols, arrows, sketches...). Moreover, it allows users to create associations between notes easily just by writing notes close one to another, by drawing marks between them, etc. *S-Notebook* hence provides two types of associations: the links between the handwritten notes and the digital data, and the visual associations between the notes. This makes it possible to link digital elements together in a simple and flexible way, just by writing notes. Additionally, the tangibility of paper allows other interesting interactions such as cutting, pasting, exchanging pieces of papers with handwritten notes and the digital data if they are liked to.

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