PaperProof: A Paper-Digital Proof-Editing System

Nadir Weibel
Institute for Information Systems
ETH Zurich
CH-8092 Zurich, Switzerland
weibel@inf.ethz.ch

Adriana Ispas
Institute for Information Systems
ETH Zurich
CH-8092 Zurich, Switzerland
ispas@inf.ethz.ch

Beat Signer
Institute for Information Systems
ETH Zurich
CH-8092 Zurich, Switzerland
signer@inf.ethz.ch

Moira C. Norrie
Institute for Information Systems
ETH Zurich
CH-8092 Zurich, Switzerland
norrie@inf.ethz.ch

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Abstract
We present PaperProof, a paper-digital proof-editing application that allows users to edit digital documents by means of gesture-based mark-up of their printed versions. This enables users to switch seamlessly back and forth between paper and digital instances of a document throughout the document lifecycle, working with whichever medium is preferred for a given task. Importantly, by maintaining a logical mapping between the printed and digital instances, editing operations on paper can later be integrated into the digital document even if other users have edited the digital version in parallel. The system is based on Anoto digital pen and paper technology and is implemented using the iPaper framework for interactive paper.

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H5.m Information interfaces and presentation, H4.m Information systems applications

General Terms
Human Factors

Keywords
Proof-Editing, Digital Pen and Paper, Interactive Paper, Document Life-cycle, Gesture-based Interface

Introduction

Producing a new publication, whether it is a book, a brochure, an article or any other type of document, implies managing the document over several iterations. Multiple authors may participate in the composition of the final artefact and additional reviewers may be involved in refining its content. Studies have shown that while the initial authoring and editing of documents is performed digitally, authors, reviewers and copy-editors still tend to read and correct documents on paper [1]. Users tend therefore to choose the preferred medium during the document lifecycle (Figure 1) according to a particular task and setting. For example, users will often read and correct on paper while away from the office. The drawback is that corrections made on paper have to be later carried out manually on the digital source document.

It has been shown in earlier projects how digital pen and paper technologies developed by Anoto [2] can be used to bridge the paper-digital divide. This technology is able to

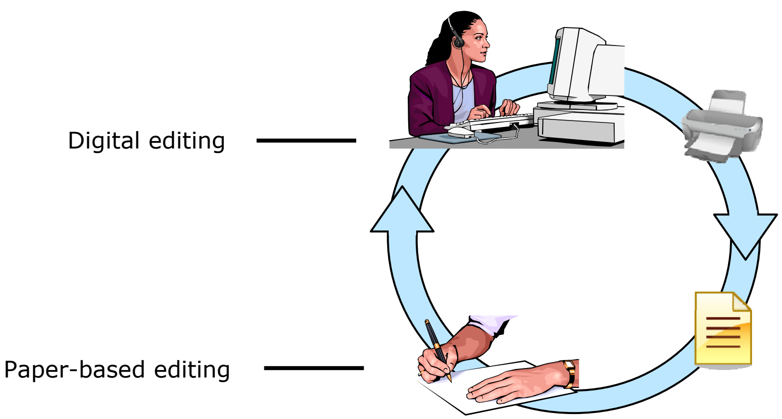

Figure 1: Document lifecycle

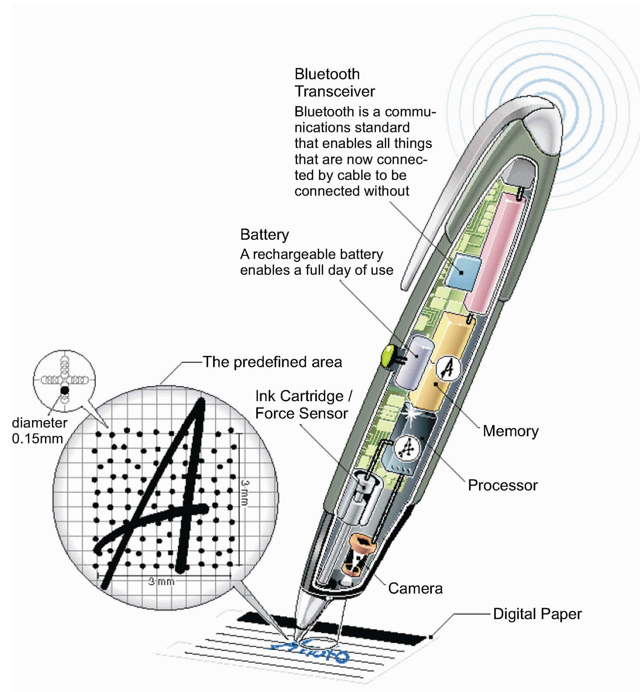

Figure 2: Anoto Technology

track and store the position of a pen on paper through a combination of a special dot pattern printed on paper that encodes position information and a camera inside the pen as illustrated in Figure 2. For example, ProofRite [3] is an Anoto-based paper-digital word processor which allows annotations on printed instances of a document to be integrated into the digital source document automatically as a superimposed ink layer. This means that pen strokes are not interpreted, but simply captured and reproduced in the digital source document by anchoring them at the relative positions identified by the pen mark on paper. In the case of subsequent digital alterations of the document, the position of an annotation is updated without taking into account structural elements, such as paragraphs, sentences, words or characters. This means that, if a paragraph with an annotation is split into two paragraphs, then the attachment of an annotation to the original paragraph may no longer be positioned correctly. A further problem is that the system cannot cope with other users editing the digital document in parallel to the paper-based editing as the one-to-one correspondence between the paper and digital versions will be lost and annotations possibly attached in the wrong place.

PaperProof

As part of our research on interactive paper based on the iPaper framework [4], we have created PaperProof [5], a paper-based proof-editing application that maps pen-based interactions with Anoto-enabled paper documents to corresponding operations within the digital counterparts.

In contrast to previous prototypes, our system actually interprets the pen strokes made by the users on paper and can automatically execute the intended editing operations in the digital source document. This can be done either in real-time to support users reviewing documents at their workplace or at a later time if the user is currently on the move and does not have access to a digital version of the document. We are able to achieve this by maintaining a mapping between the printed and digital document instances that allows gestures such as a stroke through a word to be mapped back to the corresponding structural word element within the document. Further this allows us to maintain this logical mapping even if the digital instance of the document has been edited in parallel.

PaperProof offers a gesture-based interface, an approach supported by early user studies such as [6]. Hand-drawn gestures and textual input are used to trigger editing operations on the corresponding digital instance of the document. Currently, PaperProof is integrated with the open source word processing tool OpenOffice [7].

While there are standards available for copy-editing such as the BS 5261 proof-reading mark revision [8] or the ISO standard 5776 [9], we were interested in supporting all stages of the document lifecycle and not just the final stage of professional copy-editing. After analysing the proof-editing habits within our research group and exploiting the gestures currently supported by the Microsoft Application Gestures [10], we chose to use a set of gestures that are closer to the common forms of informal mark-up used by document authors and reviewers.

PaperProof offers a set of five proof-editing operations: insert, delete, replace, move and annotate. The editing commands are triggered by an ordered sequence of one or more pen-based gestures optionally followed by the user's textual input. In order to guarantee the best accuracy in the interpretation of the gesture-based commands, we use the iGesture framework [11] to recognise the specific gestures and the MyScript Intelligent Character Recognition (ICR) software from VisionObjects [12] to translate the textual information into digital string representations. Both technologies demonstrated very high accuracy and are therefore suitable for our application. To ensure correct gesture interpretation and inform the user about the recognised commands, an optional acoustic and/or visual message is provided. Once an operation has been identified, it is stored in a special buffer until the paper-digital

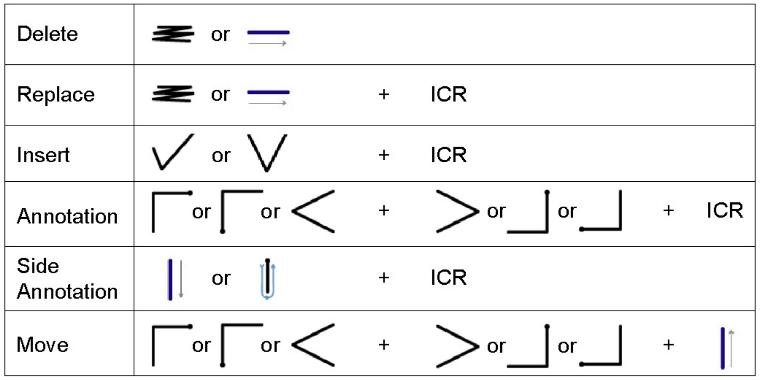

Figure 3: PaperProof gesture-based commands

synchronisation is performed. In the case of an erroneous interpretation, the user may iteratively remove the stored operations by touching a special *undo* button. Figure 3 summarises the supported operations and the corresponding gestures.

We describe the different operations supported by our system below. Note that it is possible to apply all of these operations at different granularity levels such as section, paragraph, word etc. One author might want to delete a whole paragraph, while another author just wants to correct a typo at the character level. An annotation might be made for an entire section or just for a particular word. The different granularity levels are automatically recognised by PaperProof.

DELETE
To issue a delete command the user simply needs to sketch a horizontal line gesture striking through the content to be removed. The corresponding digital entities are also eliminated.

REPLACE
The replacement of information is performed by first marking the content to be removed with a horizontal line gesture. Next the user writes the substitute text on paper. The ICR result is used as a replacement for the original information within the digital source document.

INSERT
To insert content, first a user has to specify the position by drawing an inverted caret gesture. Next, they write down the new information which is recognised by the ICR software and inserted into the digital document.

ANNOTATION
To annotate structural elements such as paragraphs or sentences, the user first has to enclose them between the opening and closing horizontal angular bracket gestures. Next, the annotation is written on paper. Finally, the ICR recognised textual information is added to the original document.

SIDE ANNOTATION
PaperProof also supports side annotations. In this case, the target of the annotation is indicated by a vertical line gesture. As for the previous operation, the annotation is handwritten next to the annotated content and in the end inserted into the digital artefact.

MOVE
To move specific pieces of information to different positions, another composite gesture is used. First, the target entity is marked by sketching an enclosing pair of opening and closing angular bracket gestures. Then, the user points to the new location of the designated content with an upwards vertical line gesture.

While this is the set of gestures and operations currently implemented, we believe that a system's set of gesture commands should be adapted to the particular context domain and user interests and expertise. Moreover, the system should support the definition of new gestures and the assignment of operations to these gestures. Choosing the appropriate set of gestures for a particular application is a known issue [13] and we plan to further investigate this matter in the case of our system applying, for example, a dynamic assignment of gestures as done in [14].

Our goal is to enable an integrated digital and paper-based document lifecycle allowing users to seamlessly move back and forth between digital and physical document instances. No additional effort should therefore be required to perform an interactive paper version of the digital document that can be used for paper-based editing. To support the transparent transition from digital to paper documents we have developed the integrated iDoc Virtual Printer [15] that can be selected from the set of available printers and performs the required document analysis and Anoto pattern allocation during the printing process. Thus the user perceives it as a single printing step. The document analysis performed during the printing operation enables a mixed physical-logical document model to be constructed that will allow areas on a printed page to be mapped to structural elements of a document such as characters, words, sentences, paragraphs etc. [16]. Once the document has been printed the user can immediately begin to perform the corrections using a Magicomm digital pen [17] used in streaming mode.

When the reviewing process is finished, the user can touch a synchronisation button which is printed on the document and the sequence of buffered operations are then executed by mapping them to operations of the word processing system on the corresponding digital document. The system is started automatically and a log of all operations executed is displayed so that the user may easily check each operation and undo it if desired. This was implemented by extending the change tracking functionality offered by the OpenOffice Writer tool.

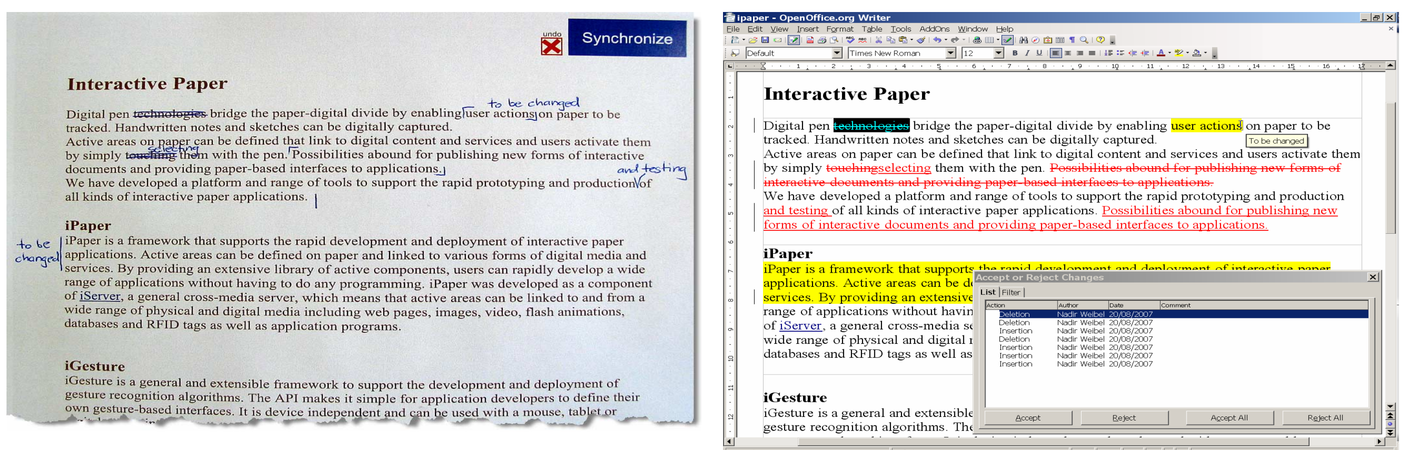

Figure 4: PaperProof

Figure 4 shows the physical and digital representations of a text document processed by our system. On the left-hand side the marks are done on paper with a digital pen and on the right-hand side they are transferred into the OpenOffice Writer application.

Conclusions

We have presented PaperProof, an interactive paper application which illustrates how handwritten gesture-based commands may be used to support a document's seamless transition between physical and digital representations. Initial experiments with users have shown that the gesture-based commands can be learned quickly and users find the interface easy and natural to use. Detailed studies evaluating our prototype and comparing it with standard proof-editing tools are planned for the near future and during these studies we would also like to investigate the use of other gestures. Generally, we believe that it should be possible to adapt the set of gesture commands to a particular context such as the task and user expertise. Moreover, the system should support the definition of new gestures along with a definition of their mapping to operations in the word processing system. Choosing the appropriate set of gestures is a known issue and the integration of a general gesture recognition platform such as iGesture that supports extensibility and experimentation with different gestures sets and recognition algorithms is a vital component.

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