Requirements for Intelligent Pen-based Annotation Systems – An Exemplary Study with Semantic eInk

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Abstract. In this paper we describe aspects to be considered for designing an intelligent pen-based annotation system. The ideal aim of such a system is to automatically recognize unconstrained free-form annotations and save the interesting information in the personalized digital memory on the computer. A first prototype which recognizes handwritten annotations and interprets their semantic meanings is described in this paper. It serves as a basis for a usability study to assess the requirements before such a system may be used in practice. The results of this study might be interesting for developing an advanced pen-based annotation system in the future.

1. Introduction

Making notes, putting down someone's thoughts, or adding annotations to an existing document are typical tasks performed in our everyday life. In many cases the devices of choice are ordinary pen and paper (Sellen & al., 2001). Using paper is motivated by several issues. First, the person is not bound to a specific device or to a specific medium. Second, paper is portable, allowing for making notes anytime and anywhere. Furthermore, among other issues, writing on paper is most natural to many persons, making the pen their preferred writing instrument for tasks such as brainstorming, collaborative work or reviewing documents. Using pen on paper also supports creativity, because it is easy to use, natural, flexible, and informal (Misue & al., 2005).

A problem of using an ordinary pen on paper, however, arises when someone wants to bring his or her paper-based annotations into the digital world. It takes time to transfer the handwritten information into the machine, since the notes have to be found again, read and finally typed into the machine. An ideal intelligent pen-based annotation system would automatically perform all these tasks and make the handwritten notes available for tasks commonly performed by knowledge workers, e.g., searching, reusing, sharing, and augmenting information.

A prototype which implements the first steps to an intelligent annotation system is the Semantic eInk system. It automatically processes handwritten annotations on printed documents and interprets the semantic information of these annotations. This information is expressed through formal semantics using the individual's vocabulary, and is integrated into the personal knowledge base, the Semantic Desktop. The integration makes this knowledge searchable, reusable, sharable, and gives a context for its interpretation. Thus it supports personal knowledge work on paper. The current version of Semantic eInk works on two different pen-input devices and defines a specific formal way of expressing the annotations.

To assess the requirements and the practicability of the Semantic eInk system, we have made a usability study where we asked people to make their annotations using our system. Afterwards, we interviewed them to find out what the most important points are in consideration of an intelligent pen-based annotation system. Subsequently, we asked about 200 persons to express their annotations in a less restricted situation to find out how they would use an ideal system if it existed.

The rest of this paper is organized as follows. Section 2 gives a short overview over existing pen-based systems. Next, Section 3 introduces the Semantic eInk Systems. Subsequently, the setting of the usability study is described in Section 4. Finally, Section 5 presents the results and draws some conclusions.

2. Pen-based Note-Taking and Annotation Systems

Using a pen on paper makes it easier and faster for the users to attach their thoughts to the document. Unfortunately, the interpretation of the notes is often more complex compared to the situation where digital comments are made. To overcome this drawback, several document analysis approaches have been proposed which automatically process human made notes and transform them into digital format.

For processing the handwritten notes, commercial systems such as those from Vision Objects[1] and Microsoft (Pittman & al., 2007)[2] are available. These systems try to characterize the handwritten strokes written on any digital pen-input device, segment handwritten text from drawings transform the text into a machine

[1] http://www.visionobjects.com/
[2] http://www.microsoft.com/windowsxp/tabletpc/default.mspx

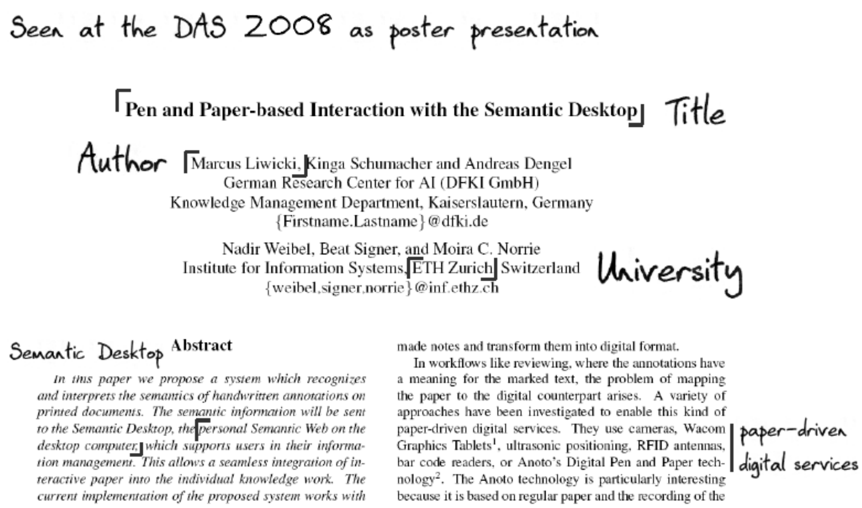
readable format (ASCII). One can also view the images of the real stroke information and search for specific text in the handwritten notes.

Beside these note-taking and recognition devices, there exist tools for electronic pen interfaces which support the user during the creation of the annotations. Tivoli, for example, supports informal workgroup meetings on a whiteboard (Gross & al., 1996). Pegasus (Igrashi & al., 1997) and Teddy (Igrashi & al., 1999) support users during sketching of geometric objects by beautifying them. Kazuo & al. (2005) propose a handwriting input tool to support creative activity by allowing the user to arrange previously drawn strokes with simple gestures. However, these systems do not target to recognize the meaning of the handwritten strokes. AC-SPARC (Gennaria & al. 2005) and Feng & al. (2008) also try to recognize the sketches, but these systems do not support unconstrained sketches and handwritten text.

While the systems described above are helpful for transferring simple notes and complex drawings to the computer, they do not support the more complex task of annotating documents, where the annotations have a meaning for the marked text. For an intelligent handling of annotations, the problem of mapping the paper to the digital counterpart arises. A variety of approaches have been investigated to enable this kind of paper-driven digital services. They use cameras, Wacom Graphics Tablets[3], ultrasonic positioning, RFID antennas, bar code readers, or Anoto's Digital Pen and Paper technology[4]. The choice of the device is very important, because one has to consider the precision of the mapping as well as the handling of the paper device, which should be very natural to the user, like writing with a real pen on real paper.

3. First Prototype – Semantic eInk

The Semantic eInk system is a first approach to design a pen-based annotation system which supports the user during all steps of the annotation workflow. Semantic eInk allows a seamless integration of interactive paper technology into personal knowledge work. To be more specific, the workflow of printing a document, annotating it while reading, and integrating the new information into the personal knowledge base are supported by an automated interpretation of user annotations. Since the first prototype has been introduced in (Liwicki & al., 2008), Semantic eInk has been extended to support annotations for any kind of document. Furthermore it now works with two different electronic pen-input devices, namely the iLiad digital eBook reader[5] and the Anoto dot-pattern (See Section 4). Since the main focus of this paper is the usability study and the requirements analysis only the most important information for this aspect will be included in this paper. For further details on Semantic eInk refer to (Liwicki & al., 2008).



Pen and Paper-based Interaction with the Semantic Desktop

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Abstract

In this paper we propose a system which recognizes and interprets the semantics of handwritten annotations on printed documents. The semantic information will be sent to the Semantic Desktop, the personal Semantic Web on the desktop computer, which supports users in their information management. This allows a seamless integration of interactive paper into the individual knowledge work. The current implementation of the proposed system works with made notes and transform them into digital format.

In workflows like reviewing, where the annotations have a meaning for the marked text, the problem of mapping the paper to the digital counterpart arises. A variety of approaches have been investigated to enable this kind of paper-driven digital services. They use cameras, Wacom Graphics Tablets[1], ultrasonic positioning, RFID antennas, bar code readers, or Anoto's Digital Pen and Paper technology[2]. The Anoto technology is particularly interesting because it is based on regular paper and the recording of the

Figure 1: Example annotations made with the Semantic eInk system

The current version of Semantic eInk still restricts the user to make the annotations in a predefined format. It is allows to make the following annotations (see Figure 1):

1. The user can put a comment at any place in the document (The topmost handwritten text in Fig. 2). This text is recognized by the handwriting recognition engine and stored as a comment in the knowledge base.

[3] http://www.wacom.com
[4] http://www.anoto.com
[5] http://www.irextechnologies.com/

Figure 2: Annotation with the Anoto Pen[6]

Figure 3: Annotation with the iLiad

2. The user can mark a text passage with right angle strokes ("┌" "┐") and write a comment or a word representing an ontological concept in the knowledge base ("Title" in Fig. 2). For processing the annotation, the handwriting is first recognized. Then several steps are applied to interpret the semantic meaning of the annotation (Liwicki & al., 2008).
3. The user can create a side mark ("|") and write a comment, which is similarly processed as in Case 2.

Semantic eInk supports two different digital pen-input devices. First, the Anoto system allows to annotate the documents using real ink on real paper, which makes the annotation process quite natural (For an example image of the Anoto Pen see Figure 2). Second, the iLiad system is based on electronic ink, a special display device which does not need backlight and consumes less power than conventional displays, making it useful for longer operation times. The high resolution of eInk displays make them appear like looking on a paper behind a small glass panel (see Figure 3).

Note that the iLiad is the only eInk device which supports general (digital) ink-based annotations. Recently, Golovchinsky (2008) compared several such devices and emphasized that the annotation capabilities of the iLiad are the most advanced. Other systems simply support the use of keys to mark of text passages. Furthermore, the iLiad allows to read and annotate any pdf-document, while other eInk devices only support proprietary formats.

4. Usability Study

In order to assess the usability of the current Semantic eInk system, we performed an initial usability study. We asked four volunteers to make annotations on given documents using the Anoto pen and paper technology. Although the allowed kinds of annotations were defined to be quite usual, the test users felt too restricted. They would like to use other gestures for marking the text (e.g., encirclements) and also to draw a connection line between the annotated text and the annotation. The restriction would have a negative influence on the creativity aspect mentioned earlier.

Therefore we have made another usability study with more than 100 persons where we assumed an ideal annotation processing system. The users were allowed to use any of the following metaphors for marking the text: marking the beginning and ending of the phrase with right-angle strokes or straight lines, underlining the desired text, encircling the words, drawing a line next to the text, or drawing a connection line between the annotation and the text. We also did not restrict the users to use a specific temporal order of the actions. While most test persons used the Anoto technology, some others used the iLiad.

An independent person observed the annotating situation to see what problems arise during annotating. After the writing process we made an informal interview where the people were asked to express their thoughts about the system, the useful benefits, as well as possible drawbacks. Finally, the digital ink information is used to analyze the annotation habits of the different users.

[6] image provided by www.anoto.com

Table 1: Pros and cons for the pen-input devices iLiad and Anoto (Issues concerning the writing process itself are highlighted)

	iLiad	Anoto
Pros	• Could give direct response • Carbon-free document processing • Thousands of documents may be stored on the device • Lightweight device	• **Natural writing with ink on real paper** • Writing on unlimited paper size • Physical documents may be separated
Cons	• **Plastic pen too small for a good handling** • **Writing on acrylic is not natural** • Size of the screen is too small • **Delay (>100ms) between writing and seeing the ink**	• **Pen is too thick, heavy, and bulky** • **Vibration of the pen is confusing** • Black printer-ink confuses dot-pattern (no black should be used for the print)

5. Results and Conclusions

Many interesting observations have been made during the experiments and useful comments were provided by the test persons. The results concern the pen-input device and the abilities of the system.

The pros and cons of the pen-input devices are listed in Table 1. The highlighted points are those which influence the writing process itself. As it is more natural to write with the Anoto pen, people would prefer this device. However, the Anoto pen is quite heavy and bulky because of all the technical components inside the pen. If the pen has problems with recording the positions, it vibrates, which irritated the writers. The disadvantages of the iLiad systems are more substantial. Most users needed some time to adapt to the delay by the digital ink. We observed that in most cases there was no straight base line for the handwritten text. Furthermore, some letters contained too many arcs (writing an “m” instead of an “n”). It is desirable to have direct digital ink on the paper.

By allowing the participants to make any kind of the above mentioned annotations, they did not feel restricted anymore. None of the 100 users said that he or she would like to use more possibilities. An interesting research issue for the next version of Semantic eInk would be to recognize the annotations under these less constrained conditions (Such a system was only assumed to exist for the experiments).

Concerning the usability of intelligent pen-input annotation systems, some suggestions and wishes for future systems have been made. People do not want to be restricted to use only one single pen. In usual annotation tasks they take different colors for different semantic meanings. Furthermore, a highlighter would be a nice extension of the provided tools.

An interesting outcome of the study is that the users did not always make the annotations directly after marking the text. The initial thought of the Semantic eInk prototype was to take advantage of the online information, by restricting the user to first mark the text and subsequently write the annotation. However, users tend to change the order of annotating and marking the text. Some users even first marked several text passages and then annotated them in another order. Others wrote one annotation and then connected it to several text passages. This behavior is due to the fact that users only think about what they see (in two dimensions), and not about the sequential information which might be useful for the processing system. An intelligent pen-based annotation system should consider this observation and not restrict the user to a specific writing order.

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This work has been financially supported by the “Stiftung Rheinland-Pfalz für Innovation“. We would like to thank Beat Signer and Nadir Weibel for providing us with the iPaper framework.

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