Towards Understanding Erasing-based Interactions: Adding Erasing Capabilities to Anoto Pens

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ABSTRACT
Anoto pens are a powerful technology for capturing contents written on paper. However, current pens do not support erasing contents. We show how to easily construct refills for Anoto pens that allow users to erase handwritten traces. Moreover, we discuss how to design software solutions that incorporate paper-based erasing as a first-order command.

Author Keywords Anoto, pen, deleting, digital paper, erasing, rubber.

ACM Classification Keywords H.5.2 User Interfaces.

General Terms Design, Human Factors.

INTRODUCTION

The Anoto [1] technology has considerably bridged the gap between computing and pen and paper, which still prevails in many contexts of use. Electronic Anoto pens are capable of capturing handwriting on plain paper and make this data available to computer systems. Anoto pens are used in many research prototypes and commercial applications, mainly for the purposes of form filling (e.g. Anoto Forms Processing) as well as for notetaking and annotation (e.g. [2],[3],[4],[5]). Notetaking solutions allow users to write and draw with an electronic pen on a paper notebook or on printed documents. The system then automatically creates a digital version of the document, which can be used for archival purposes, for full-text search within contents or for sharing contents with co-workers, to state only some examples.

Yet the use of Anoto pens entails a problem: while pens can be used for writing and drawing strokes, the reverse action is not possible, as they cannot be used for physically erasing strokes. Some systems allow the user to make a specific pen gesture for indicating that strokes should be deleted, e.g. a cross-out gesture preformed on the content to delete. This however decouples the physical representation from the digital representation. While the content is deleted from the digital representation, it is still visible in the physical one. This is particularly problematic if some contents are to be replaced by others, since it is not possible to write (or draw) over "erased" contents which are still visible. In contrast, digital graphics tablets allow for erasing contents with a specific erasing pen or with the backside of the pen.

The aim of this paper is to encourage the field to take physical deletion into account and to gain a deeper understanding of erasing-based interactions. We contribute to this by showing how to modify Anoto pens such that they can be used for physically (and electronically) erasing handwritten contents on paper. The prototype can be easily constructed and requires only cheap standard materials. We further discuss how software solutions should be designed for taking into account paper-based erasing as a first-level command.

ANOTO TECHNOLOGY

The Anoto technology depends on two components: A specific dot pattern which is printed on the sheets of paper encodes the unique position. The Anoto pen behaves like a traditional ballpoint pen and leaves visible ink traces on paper. During writing, it (see Fig. 7) uses a built-in camera to read the pattern and decodes its position. Moreover a sensor recognizes the force with which the pen tip is pressed onto paper while writing. This data is either streamed in real-time to a nearby computer or temporarily stored on the pen.

The ink reservoir and ballpoint unit can be easily replaced with a refill by just pulling the old one out and plugging the new one in. Current refills for Anoto pens come with standard ballpoint ink in blue color, which cannot be erased. Even if one found a material which is capable of erasing ballpoint ink, the erasing activity would not be electronically tracked.

BRIEF SURVEY OF CONVENTIONAL ERASING PENS

As a reference for our solution, we investigated on traditional solutions for erasing handwritten content.

One solution for removing ink of a fountain pen is to use an ink eraser. These have traditionally two tips. One for erasing the ink, the other one is for rewriting on the erased area. Whiteout overcomes the limitation of having to use a specific pen for rewriting. It can erase any content on a sheet of paper. Rewriting is possible with a large range of pens. However, whiteout needs time to dry, is permanently visible and moreover erases all contents, not only handwritten traces.

Another well known technology for erasing is using a rubber in combination with a pencil. The graphite ink of the

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pencil gets gradually deleted by rubbing over it with a piece of specific synthetic gummy or caoutchouc. The combination of pencil and rubber has the advantage that content can be modified in a large variety of ways. For example, the transparency of the content can be adjusted with a fine granularity. Moreover, the graphite can also be smeared with a finger on the paper, which is specifically interesting for artists. However, a pencil is not adequate for writing something durable (e.g. signing a contract or making notes during a lecture).

A more recent technology uses a specific ink which becomes transparent when heated. When the user rubs with an erasing unit over the ink, this generates heat and makes the ink disappear. If temperature is very low (e.g. in the freezer), the ink becomes visible again. The Pilot Frixion Ball uses this technology. It is available in different versions with 10 different ink colors.

Ink erasers and whiteout are not appropriate for use with the Anoto pen. In contrast, traditional pencil and rubber as well as the Frixion pen are promising technologies.

ADDING ERASING CAPABILITITES TO ANOTO PENS

In this section we formulate some general requirements for building a custom refill for an Anoto pen. Then, we show how to construct two different types of erasing pens. The first is a pencil and a rubber, the second one is based on the Frixion technology. For each type of erasing pen, we constructed a writing and an erasing refill. In the case of the pencil and the rubber, we built a refill with a pencil as tip and a refill with an eraser as tip. In the other case, we built a refill which allows to write with the specific ink used in Frixion pens and a refill with a rubber ball as tip which is used for erasing.

All refills are working with all common types of Anoto pens. We successfully tested them with Logitech io2, Nokia SU-1B and Anoto ADP 301 pens. For ease of construction, we decided to separate the erasing and writing capabilities and created a second pen specifically for erasing (as done by rubber pens or ink erasers). Future Anoto pens could include an eraser on the upper end (like pens of Tablet PCs). Nevertheless, separating erasing and writing into two pens reflects also common work practice of creative workers (e.g. industrial or graphic designers).

The shape of the pen and its technology form several general requirements for an eraser pen: 1) The ink and the eraser must preserve the Anoto pattern. 2) The refill must correctly activate the pressure sensor, while writing with the pen. Therefore, the refill must fit in the casing. 3) The tip of the pen must be small enough to ensure that the pattern remains visible to the camera.

Preparation

Before detailing of how we constructed both types of erasing pens, we list the tools and materials that we used: superglue, nipper pliers, a pair of scissors, a drill machine and a 2mm drill, a Frixion pen, a rubber, a 1.5cm long and 2mm wide graphite refill for drop action pencils, a medical syringe, a 12cm long and 2mm wide plastic pipe and two Anoto ballpoint refills.

Generally, each refill consists of a reservoir for the ink and a tip. We constructed two refills with a plastic pipe as reservoir, each with a length of 6 cm. Since the tip of the Frixion pen and the one based on graphite do not fit in the plastic pipe, we widened the opening of both plastic pipes with the 2mm drill for a length of 4mm each.

Pencil & Rubber

In order to connect the graphite lead to the widened plastic pipe, we added a drop of superglue on the lead and inserted it into the pipe. If the refill is inserted into the pen, it might not stick inside, since the pipe and the tip are too small in diameter. As workaround, we added a 5mm wide and 20 mm long adhesive tape around the upper part of the pipe. Figure 1 shows the completed refill that can be plugged into the pen.

Figure 1. Graphite refill.

Figure 2. Rubber refill.

In order to build the eraser, we took a standard Anoto ballpoint refill as reservoir and plugged a piece of rubber (6mm long and 3mm in diameter) on its tip. Therefore, we drilled a 4mm deep and 2mm wide hole into the rubber. Figure 2 shows the result.

Depending on the frequency of use, graphite and rubber might have to be replaced in regular intervals. If the rubber is worn down, it can be easily replaced on the refill. Our current construction of the graphite refill, however, does not allow to replace only the graphite lead, as the lead is glued to the refill. One has to use a new refill, but this is cheap and easy to construct.

Frixion & Rubber ball

We now describe how to built the refills for using the Frixion approach. The components for the writing refill consist of a widened plastic pipe as reservoir and the tip of the original Frixion Pen. The tip can be pulled out of the Frixion pen's reservoir by using nipper pliers. Then, we added a drop of superglue on the rear part of the tip and plugged it into the pipe. The result is shown in Figure 3.

Figure 3. Frixion writing refill.

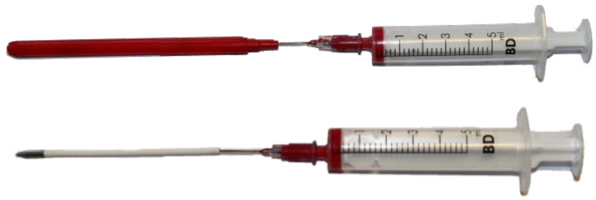

Figure 4. Filling the ink reservoir.

In order to transfer the ink from the Frixion pen into the refill, we used a medical syringe. First, we filled up the syringe with ink of the Frixion pen (see Fig. 4 upper part). Thereafter, we inserted the ink into the refill (lower part). It takes approximately five to ten minutes until the ink reaches the tip. Then the refill is ready to be plugged into the Anoto pen.

We also experimented with the M70 Lamy IT refill. This is a refill with a plastic tip and a stable reservoir of metal, which has the correct length and diameter to fit in the Anoto pen and to carry the tip of the Frixion pen. However, we found that it is highly difficult to create a stable connection between the tip and the reservoir. Both are made of metal, a material that is hard to glue together with standard materials.

In order to create the rubber, we used the standard Anoto refill as reservoir and constructed a tip using part of the Frixion pen's rubber ball. First, we pulled the rubber ball out of the casing of the Frixion pen. Next, we cut the eraser with a pair of scissors into two pieces (see Figure 5). Then we plugged the smaller part onto the tip of the Anoto refill. In order to avoid that the Anoto refill leaves ink traces, we added a drop of superglue on the tip of the refill. Figure 6 shows the completed Frixion eraser refill which can be used with a digital pen.

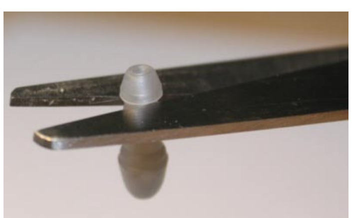

Figure 5. Frixion rubber ball.

Figure 6. Frixion eraser refill.

ERASING-BASED INTERACTIONS

In this section, we discuss how software solutions should be designed for taking into account paper-based erasing as a first-level command.

Facsimile of handwritten content. Many applications of paper-based computing show a facsimile of the handwritten content. Erasing-based interactions can be used to keep the digital facsimile in-sync with handwritten content on paper, even if content is erased.

Deletion on computers typically is an atomic action, the file being either deleted from its original location or left as it is. In contrast, erasing handwritten content is situated on a continuum. When rubbing once, content is deleted only to a certain extent. Only when rubbing over the same point several times, the content gets totally deleted. This allows different graduations of erasing.

From a physical perspective, the amount of deletion depends on the material of the sheet, the type of the pen and the type of the eraser. For example, it makes a difference whether to erase a stroke of a pencil with a high or low degree of hardness and whether it is written on a coarse or glossy page. These different graduations of deletion as well as the characteristics of the materials should be taken into account by applications. This allows to maintain the visual appearance of (partially and fully) erased ink traces on paper in-sync with the digital facsimile.

We developed a prototype application for notetaking and sketching. Users can take handwritten notes or make graphical sketches on paper and erase them on paper. Pen data is streamed to a computer via a Bluetooth connection. A digital facsimile is automatically made available in a software viewer. The application tracks not only the position information of writing and erasing traces, but also the pressure on the pen tip. If a trace is written with higher pressure, the user has to perform more pressure with the erasing pen or has to rub more often to erase it than if the trace is written with lower pressure. This creates a very authentic visual appearance of the facsimile and allows the user to maintain the expressiveness of traditional erasing techniques. Figure 7 shows an example of physical erasing and how the traces are visualized in the software viewer.

In order to keep the appearance of physically deleted content in-sync with its digital counterpart, a calibration step is necessary. The calibration depends on of the type of refill (e.g. graphite or ink), the surface of the paper and the material of the rubber. Currently, we manually calibrate the software, but we plan to implement a module for semi-automatic calibration in the near future.

Semantic interpretation. Besides ensuring a faithful facsimile, erasing-based interactions can also be leveraged for semantic interpretation by computers. This allows to attribute a semantic meaning to the grade of a note, which is situated on a continuum between fully visible and fully deleted. This opens up a design space for a novel class of very intuitive interactions. For example, slightly decreasing the note's visibility by rubbing over it could mean to lower its priority. In contrast, thickening up the traces of a stoke by writing or drawing them again could increase the priority.

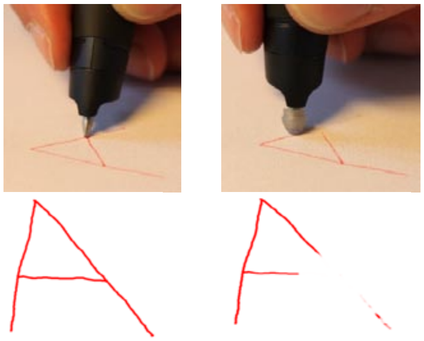

Figure 7. The user writes a letter (above left) and then gradually erases it (right). The visualization is shown below.

QUALITY TESTS AND EARLY USER FEEDBACK

In order to evaluate the quality of the solution presented, we performed several mechanical tests with common Anoto pens (Nokia SU-1B, Logitech io2, and Anoto ADP 301). We evaluated the following criteria: robustness of position tracking, robustness of pressure sensing, influence of strong mechanical forces, effects on the pattern, as well as wearout of the refills. Our reference was an Anoto pen with a standard Anoto refill.

The results show that the novel refills do not disturb the field-of-view of the camera, such that the pattern remains decodable. The applications receives correct data from the pen even if the pen is inclined up to 45 degrees from the vertical position. This is the same maximum angle as with a standard refill. Generally, the radius of the tip should be smaller than 3mm in order to not disturb not camera.

The next test verified if the pressure sensor in the pen works correctly. To simulate heavy use, we tapped with each refill successively 50 times in about 15-20 seconds. Even in this case, the pen correctly recognized all pen down and pen up events.

Then we tested use with strong mechanical forces, both in the horizontal and in the vertical dimensions. With each refill, we pressed the pen strongly onto the paper sheet and rubbed with very quick back-and-forth movements. The rubber refill, Frixion writing refill and Frixion erasing refill worked properly without any problems. The pencil graphite refill, however, could not resist to strong forces because then the graphite lead broke. In cases of normal use, without purposely applying strong forces, also this latter refill proved to be sufficiently stable. Moreover, we continuously shaked the Frixxion refill for three minutes and put it upside down for two hours. The ink remained inside the refill.

We also tested if the Anoto pattern remains intact after a large number of writing and erasing cycles. For both types of writing/erasing refills, we repeatedly wrote and completely erased contents at the same position. Even after 30 cycles, the pattern was decodable at the erasing position.

The graphite lead refill and the rubber refill get worn out by use and reduced in height. We measured the minimal and maximum length of the refill that still ensures that the pen works correctly. The minimum length is 6.2 cm and the maximum length is 7.2 cm. This tolerance of 1.0 cm is large enough for the reduction in height generated by longer use.

In order to verify, that the refills bear up the usage habits of actual users, we gathered early feedback from two members of our lab. Each of them used our prototype for 20 minutes, while being free to draw and erase whatever he wanted. He could see the digital facsimile at the same time. We encouraged the participants to use the pen naturally. After ten minutes we exchanged the erasing and writing refills.

Both participants were enthusiastic about the possibility to delete handwritten content. One participant even stated, that "this pencil feels more natural than the Anoto ballpoint pen itself". While both reported that the mapping of the pressure force of the pen to the digital version creates a natural facsimile with the graphite lead and rubber refills, they also stated that this mapping has to be improved when using the Frixion refill. Moreover, both stated that the Frixion eraser needs more pressure force than the rubber to erase contents. One participant repeatedly wrote and erased content with the Frixion refills. He was surprised, that even after the paper felt coarse, the pattern could still be read by the pen.

SUMMARY AND CONCLUSIONS

As a first step towards research on pen-and-paper interactions that involve erasing, we demonstrated how to construct two different types of erasing pens that work very reliably with standard Anoto pens. Furthermore, we gave an example of how erasing-based interactions can be used to create faithful and naturally looking digital facsimiles of handwritten content. Moreover, we gave an outlook on how erasing-based interactions can be semantically interpreted. In future research, we plan to investigate the design space of erasing-based interactions more deeply.

REFERENCES

[1] Anoto. Digital pen and paper technology. Anoto AB. http://www.anoto.com.

[2] F. Guimbretière, "Paper augmented digital documents," Proc. UIST 03, 2003.

[3] R. Yeh, C. Liao, S. Klemmer, F. Guimbretière, B. Lee, B. Kakaradov, J. Stamberger, and A. Paepcke, "ButterflyNet: a mobile capture and access system for field biology research," Proc. CHI 06, 2006.

[4] B. Signer and M.C. Norrie, "PaperPoint: a paper-based presentation and interactive paper prototyping tool," Proc TEI 07, 2007.

[5] J. Steimle, O. Brdiczka, and M. Mühlhäuser, "CoScribe: Integrating Paper and Digital Documents for Collaborative Knowledge Work," IEEE Trans. on Learning Technologies, 2(3), 2009.