IllumiPaper: Printed Displays for Novel Digital Pen-and-Paper User Interfaces

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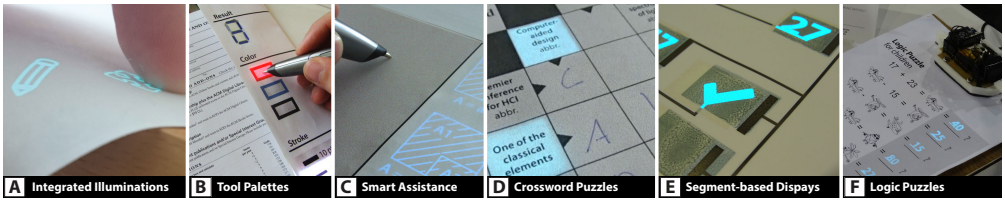

Figure 1: IllumiPaper integrates visual feedback for digital pens on standard paper by using novel thin-film technologies. We demonstrate a research platform with completely printed, paper-integrated illuminations.

Abstract

In this paper, we demonstrate IllumiPaper: A system that combines new forms of paper-integrated feedback with digital pen-and-paper solutions to address the lack of dynamic visual feedback in digital pen applications. We aim to visually support typical paper-related tasks by providing active visual feedback that is directly integrated into standard paper and thereby eliminate the problem of visual inconsistencies between physically written content and associated digital information. In contrast to our prior work, we present an extended version of our augmented paper sheets that are entirely printed with emerging conductive and electroluminescent thin-film technologies. These advanced fabrication methods enable paper illuminations with a high degree of quality and integration. As a major contribution, we want to demonstrate the feasibility of IllumiPapers systematic feedback repertoire for real-world applications and share hands-on experiences with the IllumiPaper research platform consisting of a paper-controller, digital pen and printed illuminated, digitally controlled papers with the German HCI community.

1 Introduction

Although many people have forecasted the end of physical paper and predicted the paperless office, the widespread dissemination and ubiquitous availability of paper and writing highlight its importance until today's information age. The success of paper is based on its sensory and haptic qualities, which allow and afford actions of grasping, folding or writing (cf. Sellen and Harper, 2003). Pen and paper interfaces are an essential part and powerful tool of our everyday

Veröffentlicht durch die Gesellschaft für Informatik e. V. 2017 in
M. Burghardt, R. Wimmer, C. Wolff, C. Womser-Hacker (Hrsg.):
Mensch und Computer 2017 – Workshopband, 10.–13. September 2017, Regensburg.
 https://doi.org/10.18420/muc2017-demo-0289

life and are often used, for instance, to highlight words in active reading tasks, mark graphics, add drawings or annotate documents and thereby provide unique advantages over digital media. However, in spite of these benefits, the increasing requirements of the digital integration of pen-and-paper interfaces into our daily life and workflows require new, innovative approaches. While maintaining the unique properties of paper, effective software tools and computing assistance should be combined with real paper for added digital value.

2 Digital Pen-and-Paper User Interfaces

Camera- (e.g., Anoto™ technology) or sensor-based digital pens laid the basis for recognizing handwritten text on paper, but the provision of visual feedback, e.g., to communicate pen or system states, remains challenging. To address this problem, a lot of research have been done in providing visual feedback for digital pens (e.g., Signer, 2006). However, until now visual feedback – while sometimes displayed on the pen (e.g., LiveScribe Echo® SmartPen) or projected onto paper (e.g., DitigalDesk: Wellner, 1993 or PenLight: Song et al., 2009) – is not *directly* integrated into the paper, which would allow providing feedback close to the ink and directly related to the content itself. This would eliminate visual inconsistencies between physically written content and digitally associated, but otherwise imperceptible information.

In order to address the lack of dynamic visual feedback, we see high potential in emerging printed electronics and displays as an important enabling technology towards seamlessly integrated digital paper enhancements that could also support advanced digital functionalities (cf. Figure 1, B+C). Printed technologies provide ultra-thin, flexible and versatile input and output capabilities on standard paper, thereby preserve almost all unique paper properties and can even be produced in low-cost printing processes in large-scale. In our work, we aim to enable paper augmentation without additional projector setups or display devices, which often seem to be at odds with the flexibility and portability of paper and most of its natural advantages.

3 IllumiPaper Approach

The IllumiPaper concept (Klamka and Dachselt, 2017) addresses the lack of visual feedback of digital pen and paper solutions by contributing the idea of paper-integrated active feedback with novel thin-film technologies. In this prior work, we introduced design dimensions for segment-based displays (*Design of Visual Feedback*), provide a rich generic feedback repertoire (*Fundamental Feedback Components*) and contribute a technical prototype (*IllumiPaper Research Platform*) to visually support several digital pen-and-paper applications.

First versions of the illuminated paper sheets used paper-attached electroluminescent (EL) panels that are cut and foil-masked. In this demo paper, we follow the future work of the IllumiPaper system by printing the paper sheets with advanced fabrication methods to increase the degree of quality and integration. By completely printing the IllumiPapers with conductive tracks, illuminating substrates and inkjet content layers, scalability is facilitated and even potential mass-production can be achieved.

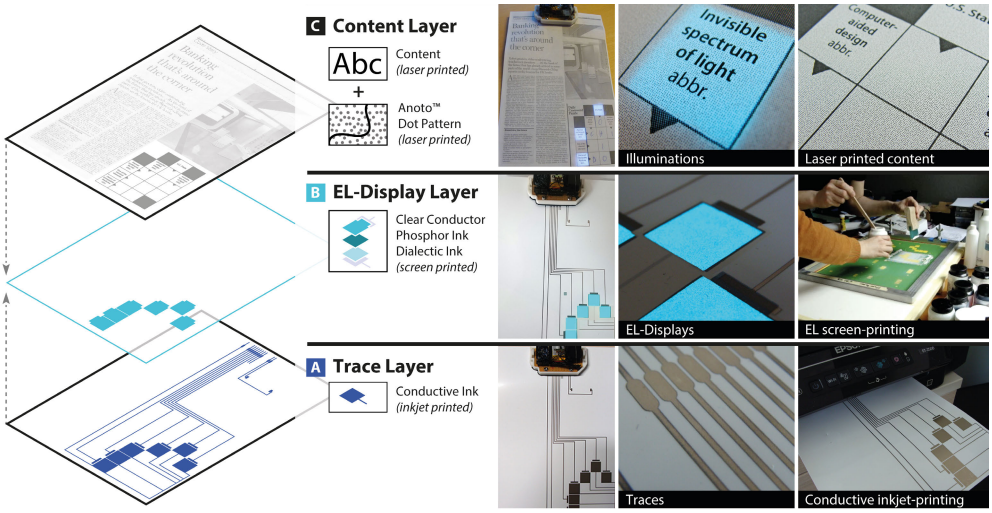

Figure 2: ***Fabrication process:*** *Our completely printed IllumiPaper sheets consist of three layers: A conductive printed trace layer* ***(A)****, a screen-printed EL-display layer* ***(B)*** *and a digital pen-enabled content layer* ***(C)****.*

4 Fabrication of Printed Interactive Illuminated Paper

To fabricate completely printed and paper illuminations, we used technologies that are easy-to-use, ultra-thin, flexible and robust. Therefore, we screen-print electroluminescence (EL) displays and realize all traces and electrodes with conductive inkjet-printing. For this design, we require three functional layers (see Figure 2, A-C) that we will briefly describe in this section:

Trace Layer (A). The IllumiPaper Research Platform provides a smart clip controller that can be seamlessly attached to digitally-enabled paper to control the paper-integrated displays (see Figure 1, F). We realize the paper traces and the back-electrodes for the paper-integrated EL-displays with a conductive inkjet-printing process (cf. Kawahara et al., 2013). Therefore, we used silver nanoparticle ink from Mitsubishi Imaging[1] with an Epson ET-2500 inkjet printer.

EL-Display Layer (B). To realize paper-integrated illuminations, we focus on printed EL displays that we printed on the back of standard paper. Therefore, we screen print electroluminescence displays (cf. Olberding et al., 2014) by adding a dialectic, a high bright phosphor and a clear conductor layer[2] on top of our previous conductive inkjet-printed electrode layer. The displays shine through the paper and are powered by the smart clip (see Figure 1 and Figure 2).

Content Layer (C). As a third layer we used 120g paper onto which we printed the application content and an Anoto™-Pattern[3] to enable digital pen interaction. We glue this layer onto the previously printed trace and display paper with adhesive spray and thereby protect the paper-integrated illuminations from both sides. For thinner paper sheets, we have also successfully printed all traces and displays (in a reverse printing order) on one single paper sheet.

[1] **Mitsubishi Imaging**. Silver Nanoparticle Ink (NBSIJ-MU01). http://www.mitsubishiimaging.com/
[2] All materials for electroluminescent panels are available at Gwent Electronic Materials Ltd. http://www.gwent.org/
[3] **Anoto**. Digital Writing Solutions. http://anoto.com/

5 Applications and Demonstration

Our demo shows the IllumiPaper system by means of two interactive real-world examples, demonstrates its technical realization and provides hands-on experience. We present a crossword and logic puzzle as examples of our printed IllumiPaper sheets (see Figure 1, D+F) that immediately highlight correct answers. Technically, we stream the digital pen position via WiFi to an Android application that handles all logics (e.g., handwriting recognition, validity checks) and sends respective display commands to the paper-attached clip[4].

6 Conclusion and Future Work

We presented an improved version of the IllumiPaper research platform using emerging printed, segment-based display technologies to enhance common interaction tasks in pen-and-paper user interfaces. As main part of our demo paper, we presented completely printed IllumiPaper sheets which use conductive inkjet and electroluminescence screen printing methods to produce seamlessly paper-integrated illuminations for digital pen and paper solutions.

For future work, we would like to improve our existing paper sheets by investigating further thin-film technologies (such as Rohinni's[5] printed *Micro LEDs*) and miniaturizing the Smart-Clip. In addition, we would like to extend our set of applications, compare it to current on-pen feedback solutions and investigate them in a field study. Finally, an IllumiPaper Toolkit could be a promising future work to give users the opportunity to produce their own applications.

References

Kawahara, Y., Hodges, S., Cook, B. S., Zhang, C., & Abowd, G. D. (2013). Instant inkjet circuits: Lab-based inkjet printing to support rapid prototyping of ubicomp devices. In *Proc. of UbiComp '13* (pp. 363–372). Zurich, Switzerland: ACM.

Klamka, K. & Dachselt, R. (2017). Illumipaper: Illuminated Interactive Paper. In *Proc. of CHI '17*. Denver, Colorado, USA: ACM.

Olberding, S., Wessely, M., & Steimle, J. (2014). Printscreen: Fabricating highly customizable thin-film touch-displays. In *Proc. of UIST '14*. Honolulu, Hawaii, USA: ACM.

Sellen, A. J. & Harper, R. H. (2003). *The myth of the paperless office*. Cambridge, MA, USA: MIT Press.

Signer, B. (2006). *Fundamental concepts for interactive paper and cross-media information spaces* (Doctoral dissertation, ETH Zürich).

Song, H., Grossman, T., Fitzmaurice, G., Guimbretiere, F., Khan, A., Attar, R., & Kurtenbach, G. (2009). Penlight: Combining a mobile projector and a digital pen for dynamic visual overlay. In *Proc. of CHI '09*. Boston, MA, USA: ACM.

Wellner, P. (1993). Interacting with paper on the digitaldesk. *Commun. ACM*, *36*(7).

[4] **IllumiPaper Research Website.** For further details see: https://imld.de/illumipaper/

[5] **Rohinni.** LightPaper. http://www.rohinni.com