IllumiPaper
Illuminated Interactive Paper

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Paper

- Natural paper properties
  - wide spread
  - cheap
  - flexible
  - sensory and haptic qualities
Digital Pen-and-Paper

- promising potential to become a part of our daily work
- potential to bridge the gap between handwritten and virtual information
Lack of visual feedback

- no advanced digital functionalities
- risk of triggering incorrect actions (e.g., tap twice)
Motivation and problem

Digital Pen Solutions: Promising Potential

But: Lack of Visual Feedback

Enabling technology

Emerging Novel Printed Electronics
IllumiPaper integrates visual feedback for digital pens on standard paper by using novel thin-film technologies.
Some of you may have already visited our demo booth…

Demo Hours

Today, 11:00 AM - 1:00 PM
A lot of research has been done in providing visual feedback for digital pens.
Utilizing the pen

**Pen-top Feedback**

- Liao et al., 2006. Pen-top Feedback

**Integrated Pen Display**

- Livescribe, 2010. Echo Smartpen

**Pen Feedback**

- Livescribe, 2013. Smartpen 3

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**Approach**

**Extend**

**Pen for visual feedback**

- **+** no additional hardware
- **−** limited visual capabilities
Using additional displays

Beside

Tsandilas, 2012. Interpreting Strokes on Paper with a Mobile

Above

Mackay et al., 2002. The Missing Link

Underneath

Everitt et al., 2008. DocuDesk

Associated

Decurtins et al., 2003. Digital annotation of printed documents

Approach

Extend

Use existing displays

+ rich visual capabilities

− requires additional hardware

− interrupt workflow, media break
Projecting digital overlays

**Projected** fixed to ground
- Wellner, 1993. DigitalDesk
- Mackay et al., 1995. Ariel

**Projected** fixed to object
- Song et al., 2009. PenLight
- Song et al., 2010. MouseLight

**Approach**
Combine

**Projected overlays**

- rich visual capabilities
- preserve natural paper properties and workflow
- requires additional and complex hardware setups
Visual Feedback Classification

<table>
<thead>
<tr>
<th>approach</th>
<th>mobile</th>
<th>stationary</th>
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<tbody>
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<td>extend</td>
<td>associated second display</td>
<td>underneath</td>
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<td></td>
<td>pen</td>
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<table>
<thead>
<tr>
<th>combine</th>
<th>integrated</th>
<th>attached</th>
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<tbody>
<tr>
<td></td>
<td>our work</td>
<td>fixed to object</td>
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<tr>
<td></td>
<td></td>
<td>fixed to ground or wall</td>
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A: extend
B: combine
And how can we achieve that?

Design Goal: Integration
- sensory properties have to be preserved
- augmentation should be lightweight and subsidiary

Idea: enhance paper with novel printed technologies
Next generation displays are ...
- ultra-thin
- bendable
- interactive
- high-resolution

but they lack ...
- sensory and haptic qualities
- simplicity, familiarity
- cost-effectiveness
Printed displays

- preserve natural paper properties and workflows
- require only simple hardware extensions
- potential mass production
- limited visual capabilities
Concept: Design of Visual Feedback

Where? – Feedback Position

How? – Visual Types

When? – Feedback Time
At which place is feedback required and possible?

- **in-place**: point of interaction
- **close-by**: region of interaction
- **page-related**: associated generic
- **book-related**: contextual beyond page
How?

What forms are possible?

single-segment
- region
- icons, symbols

multi-segment
- digits
- characters
- iconographic

matrix
- semiotic system
- graphical
When?

At what time can feedback be provided?
Feedback Components

Controls and Widgets

Validity Feedback

Layout Feedback

Motion Sequences

Smart Request Feedback
Feedback Components

Controls and Widgets

- **feedback for controls & widgets** reduces risk of triggering incorrect actions (e.g., tap twice)
- provides simple but useful feedback for states and selections
- can be applied to many existing digital pen notebook applications
**Feedback Components**

**Controls and Widgets**

**Validity Feedback**

- **validity feedback** enables immediate simple validity feedback concerning a specific task
- **examples**
  - completion of an application form
  - correctness of a grid word puzzle
  - multiple-choice question

**Layout Feedback**

**Motion Sequences**

**Smart Request Feedback**
Feedback Components

Controls and Widgets

Validity Feedback

Layout Feedback

- **layout feedback** supports the user by providing
  - on-demand rulers
  - different grid systems
  - predefined design templates

- can be enabled at any time

- examples are math, writing or orthogonal sketching
Microcontroller switching logics for displays and pen actions

Traces highly conductive, seamless integration

Paper Displays thin, flexible, printable colorful, illuminating
**Paper Displays**
thin, flexible, printable colorful, illuminating

**Traces**
highly conductive, seamless integration

**Microcontroller**
switching logics for displays and pen actions

**IllumiPaper Research Platform**

Off-the-shelf EL foil with printed stencil foils
Paper Displays
thin, flexible, printable
colorful, illuminating

Traces
highly conductive,
seamless integration

Microcontroller
switching logics for
displays and pen actions

EL Screen Printing
Paper Displays
thin, flexible, printable
colorful, illuminating

Traces
highly conductive,
seamless integration

Microcontroller
switching logics for
displays and pen actions
IllumiPaper Research Platform

Paper Displays
thin, flexible, printable
colorful, illuminating

Traces
highly conductive,
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Microcontroller
switching logics for
displays and pen actions

Conductive Inkjet Printing
Paper Displays
thin, flexible, printable
colorful, illuminating

Traces
highly conductive, seamless integration

Microcontroller
switching logics for
displays and pen actions
Paper Displays
thin, flexible, printable
colorful, illuminating

Traces
highly conductive, seamless integration

Microcontroller
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Further Fabrication Details

Project Website: http://imld.de/illumipaper/
- six semi-structured expert interviews
- five functional example applications
- each hands-on session 60 minutes
- video recordings and protocol

Experts

- Psychology Experts
  - 2
  - cognitive aspects

- Educational Experts
  - 2
  - learning & assistance aspects

- HCI Experts
  - 2
  - interaction aspects
“The system feels very natural since the feedback is immediately shown at the place of interaction without any media breaks or attention switches.”

Postdoctoral Psychology Researcher

“The system could enable adjustable, personalized feedback options that can either be defined by the student or the teacher.”

Postdoctoral Educational Researcher

“In addition, I see high potential to enhance the system with touch interactions on the paper itself.”

Many years Research Associate HCI
Conclusion

- IllumiPaper provides a basis for research towards paper-integrated illuminations:
  - design space for segment-based visual feedback
  - a rich set of generic feedback components
  - fully functional prototype
- potential to enhance digital pens and bridge the gap between physical and virtual layers
- first evaluations indicate promising potential, especially for educational applications

Future Work

- study comparing pen feedback
- miniaturize and further improve our prototype
- extend our set of applications
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Come and visit us!
Today, **11:00 AM - 1:00 PM**

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Project Website
http://imld.de/illumipaper/

Thank you.
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References (2/5)


References (3/5)


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MouseLight: Bimanual Interactions on Digital Paper Using a Pen and a Spatially-aware Mobile Projector. 


Circuit Stickers: Peel-and-stick Construction of Interactive Electronic Prototypes. 

PrintScreen: Fabricating Highly Customizable Thin-film Touch-displays. 
http://www.printoo.pt/.