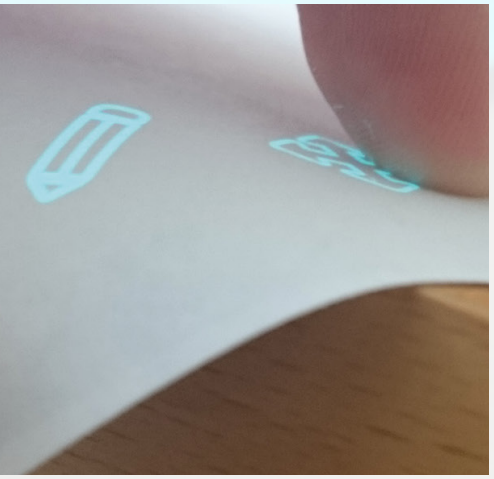
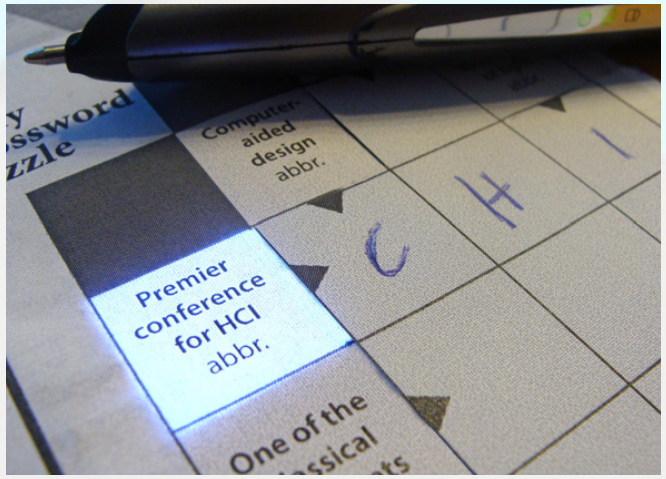
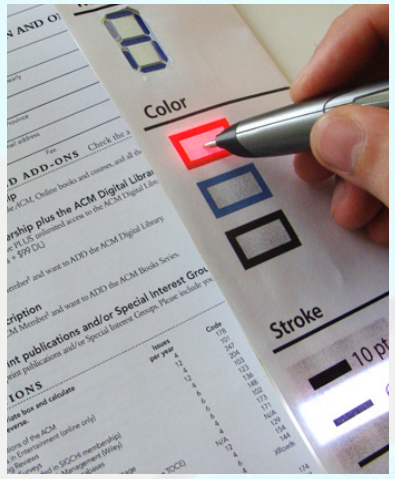
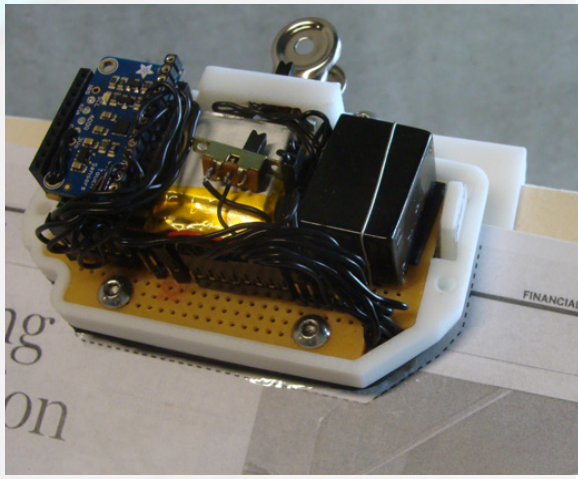
IllumiPaper

Illuminated Interactive Paper



Konstantin Klamka, Raimund Dachselt

ACM CHI 2017
11.05.2017, Denver, CO, USA

TECHNISCHE UNIVERSITÄT DRESDEN
INTERACTIVE MEDIA LAB DRESDEN

Paper

- **Natural paper properties**
  - wide spread
  - cheap
  - flexible
  - sensory and haptic qualities

Livescribe Echo Pen

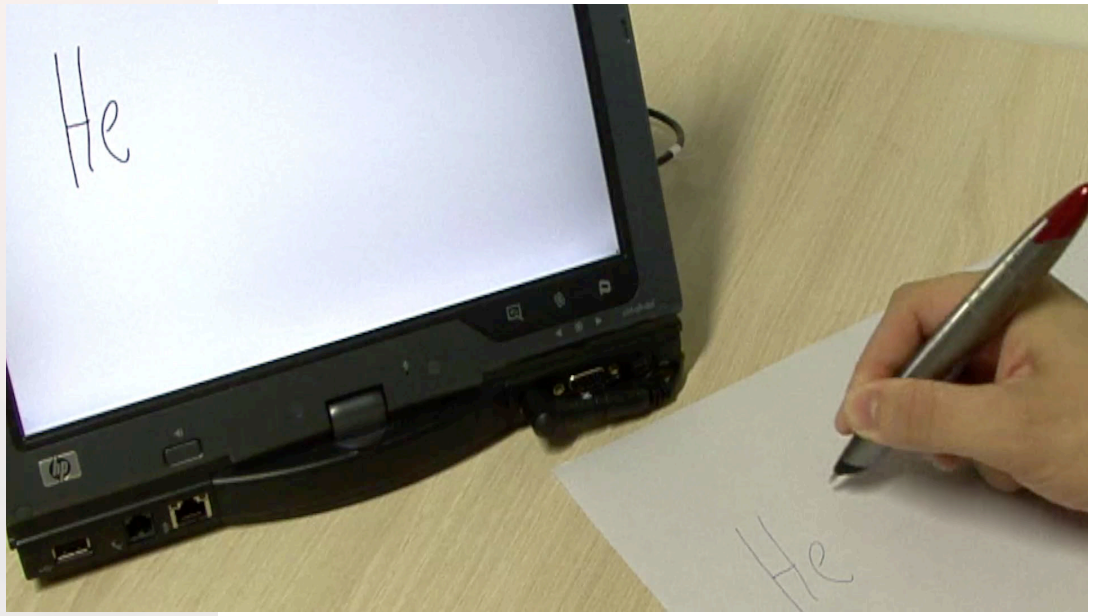
Digital Pen-and-Paper

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

Equil SmartPen 2

Wacom Inkling Digital Sketch Pen

Lack of visual feedback



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

IllumiPaper in a nutshell

Motivation and problem

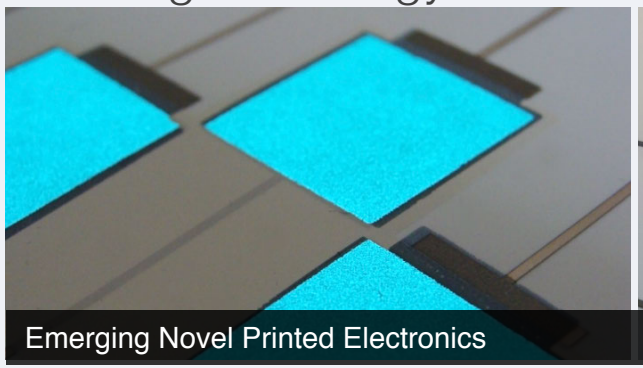
Digital Pen Solutions: Promising Potential

&

But: Lack of Visual Feedback

+

Enabling technology

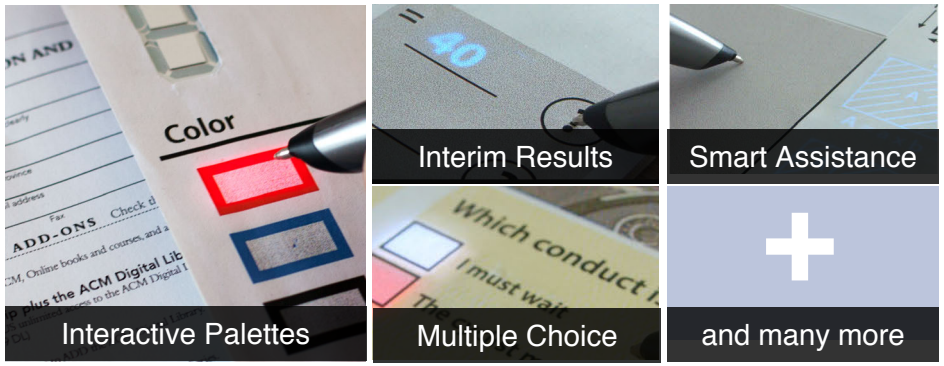


Emerging Novel Printed Electronics

IllumiPaper in a nutshell

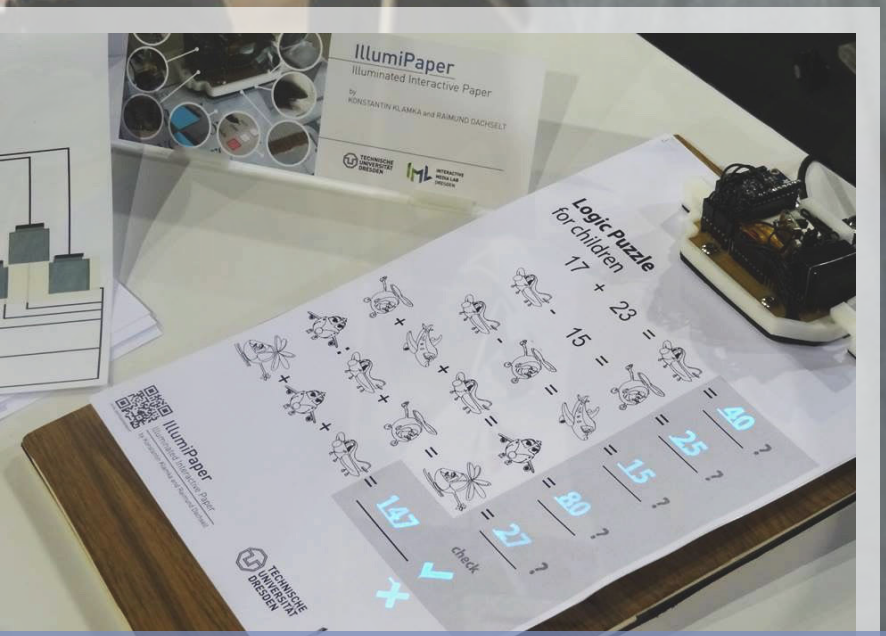
Our approach: IllumiPaper

=



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

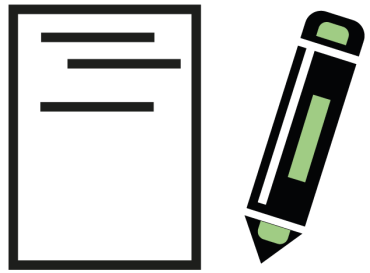
Livescribe, 2010. **Echo Smartpen**

Pen Feedback

Livescribe, 2013. **Smartpen 3**

Approach

Extend



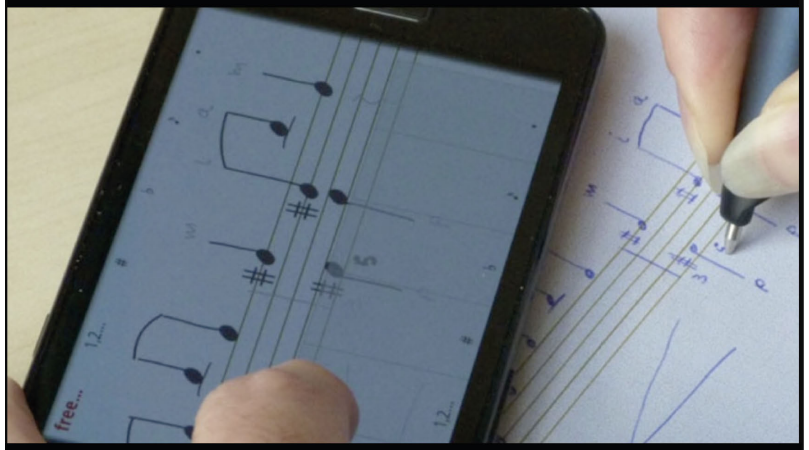
Pen for visual feedback

⊕ no additional hardware

⊖ limited visual capabilities

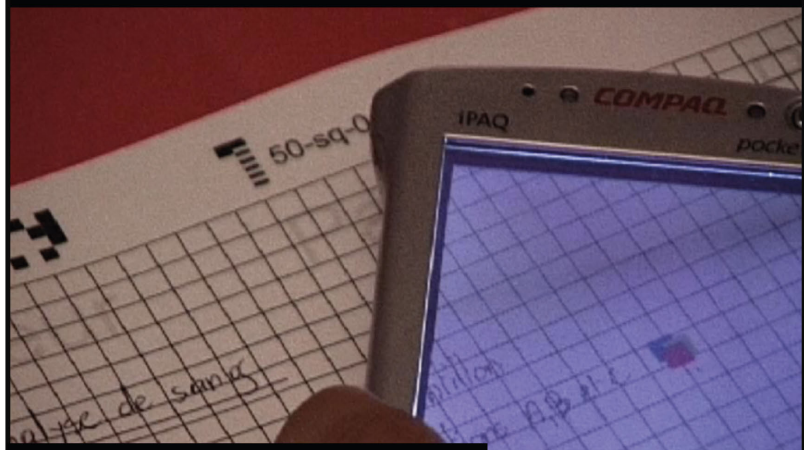
Using additional displays

Beside



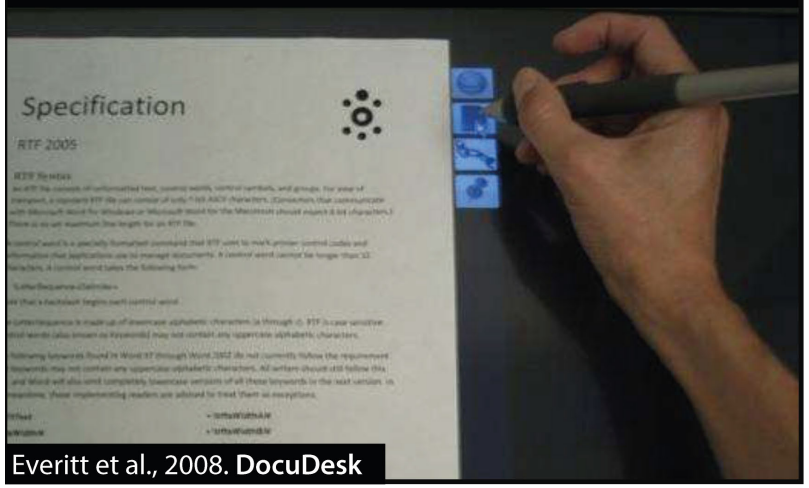
Tsandilas, 2012. **Interpreting Strokes on Paper with a Mobile**

Above



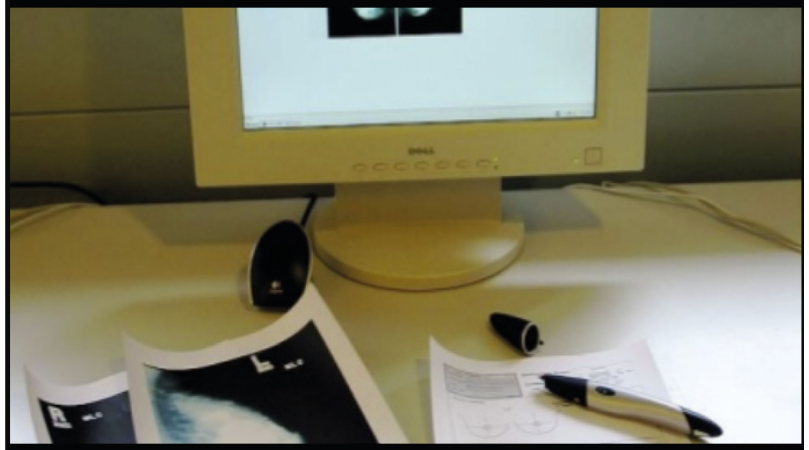
Mackay et al., 2002. **The Missing Link**

Underneath



Everitt et al., 2008. **DocuDesk**

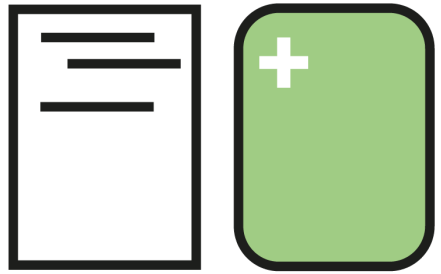
Associated



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

Approach

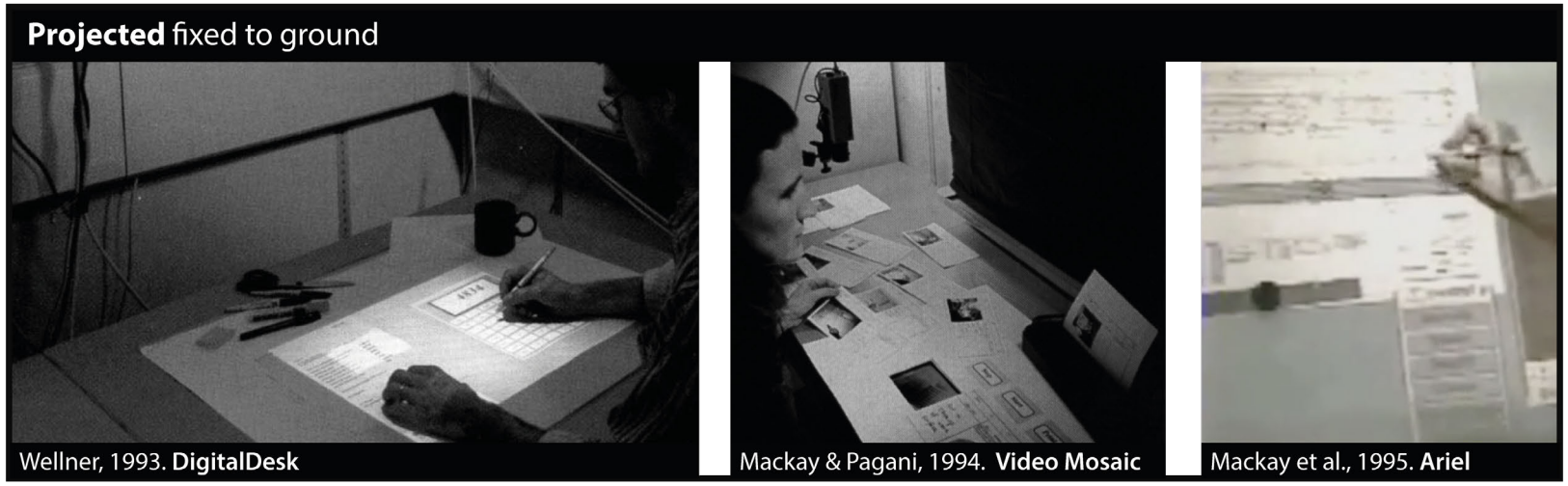
Extend

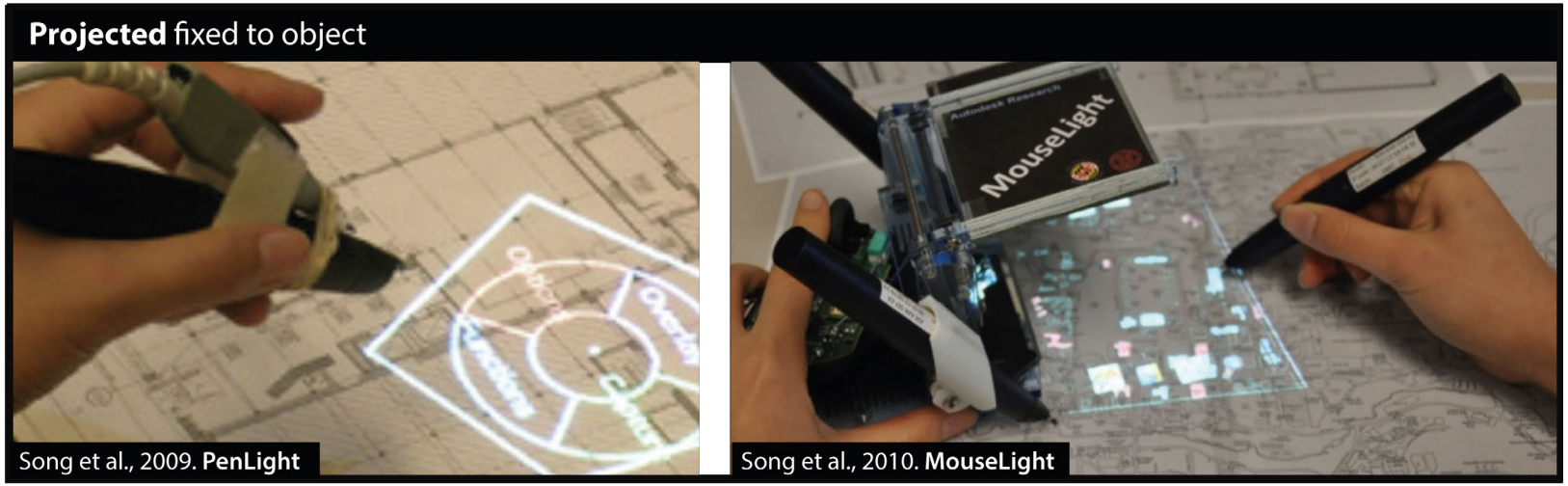


Use existing displays

- ⊕ rich visual capabilities
- ⊖ requires additional hardware
- ⊖ interrupt workflow, media break

Projecting digital overlays





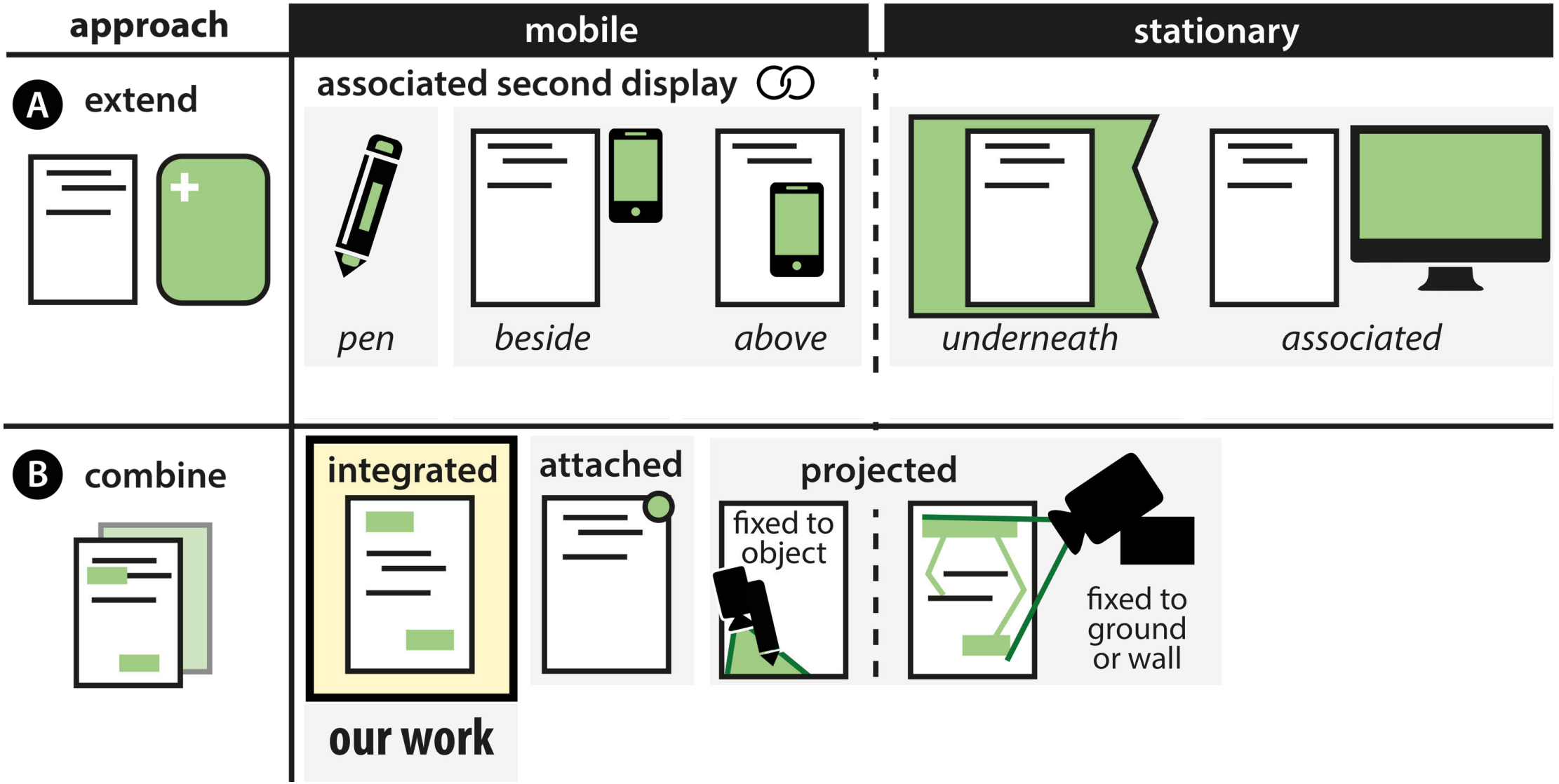
Approach

Combine

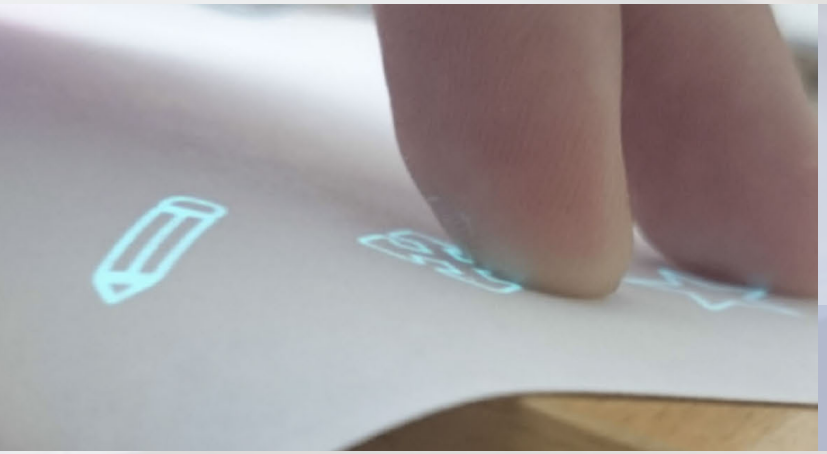
Projected overlays

- ⊕ rich visual capabilities
- ⊕ preserve natural paper properties and workflow
- ⊖ requires additional and complex hardware setups

Visual Feedback Classification



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

Flexible OLED & E-Ink Displays?

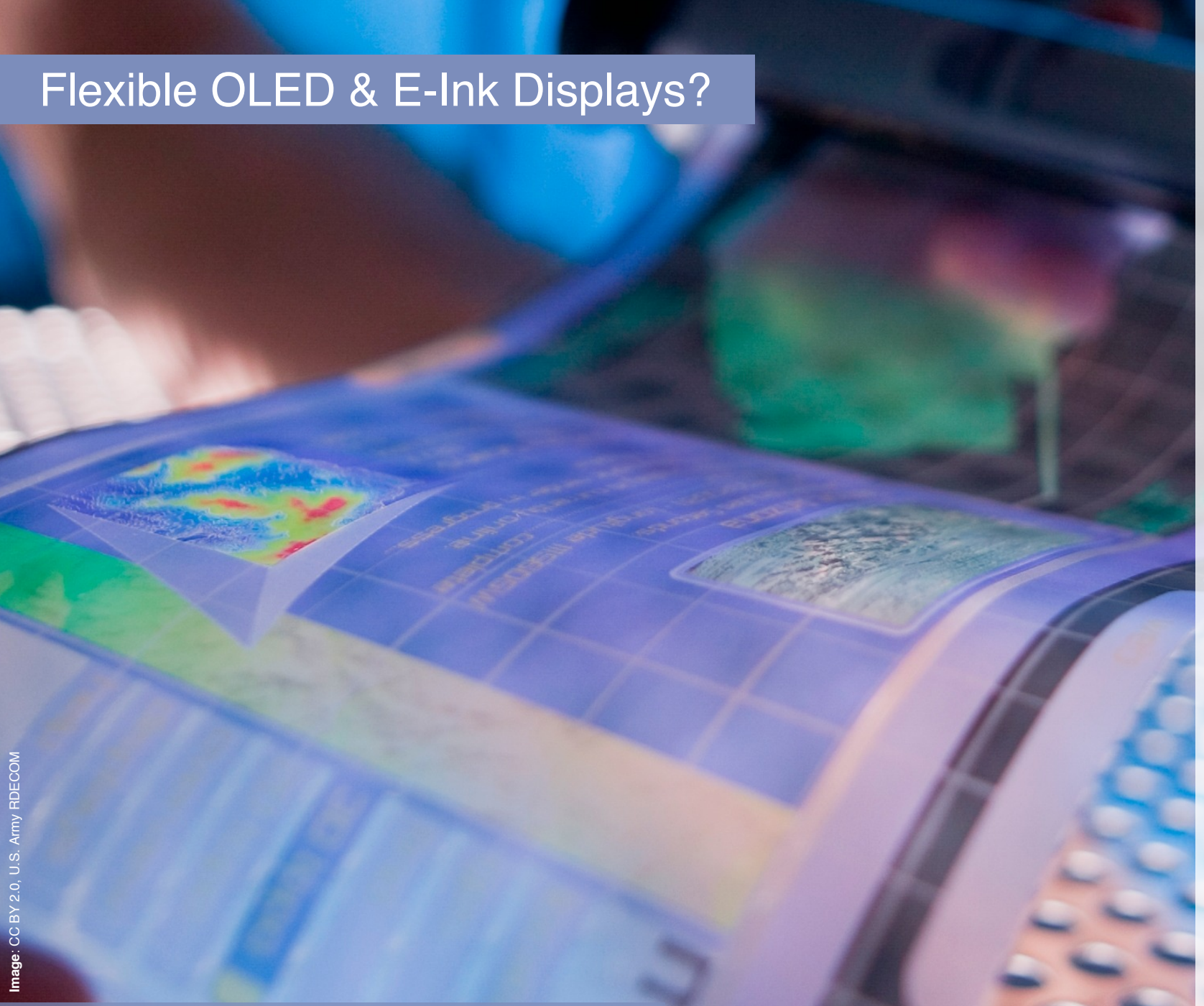


Image: CC BY 2.0, U.S. Army RDECOM

⊕ **Next generation displays are …**

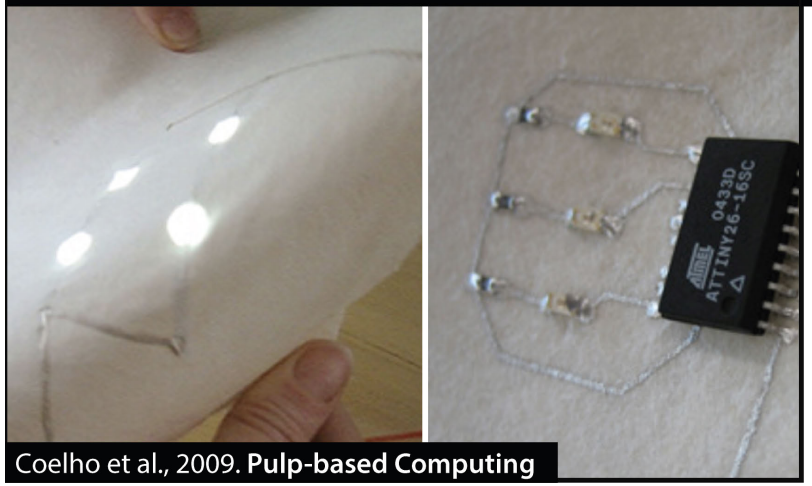
- ultra-thin
- bendable
- interactive
- high-resolution

⊖ **but they lack …**

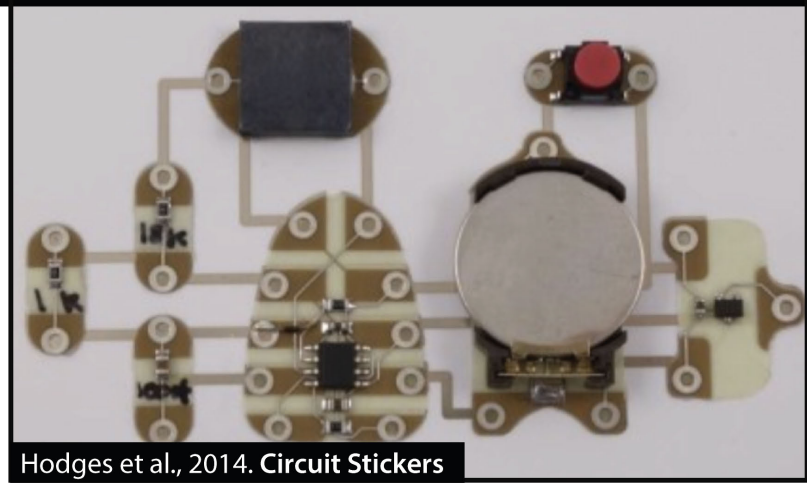
- sensory and haptic qualities
- simplicity, familiarity
- cost-effectiveness

Novel Electronics

Attached ▼SMD LEDs

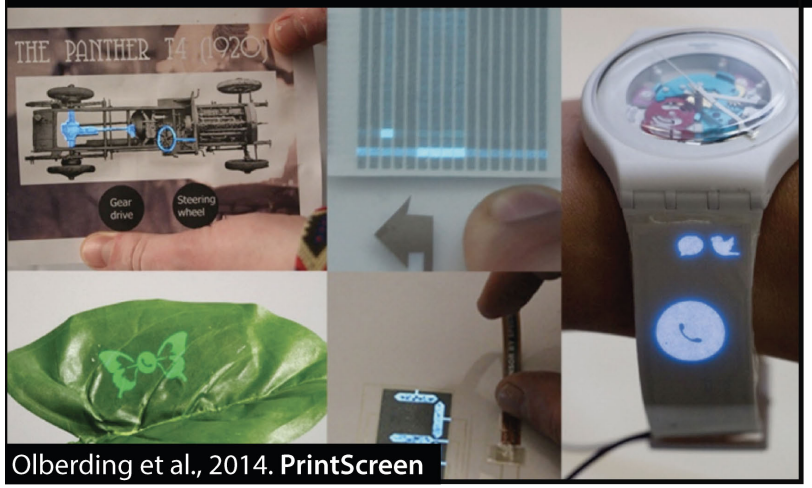


Coelho et al., 2009. **Pulp-based Computing**



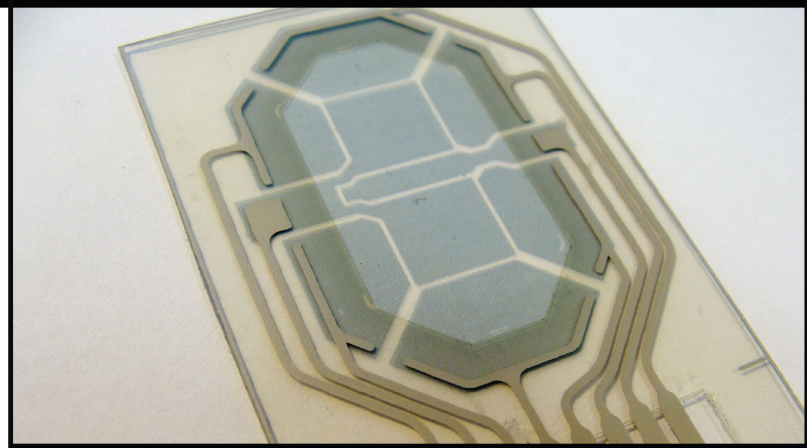
Hodges et al., 2014. **Circuit Stickers**

Printed ▼Electroluminescence



Olberding et al., 2014. **PrintScreen**

▼Electrochromic



Ynvisible, 2015. **Electrochromic 7-segment Display**

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

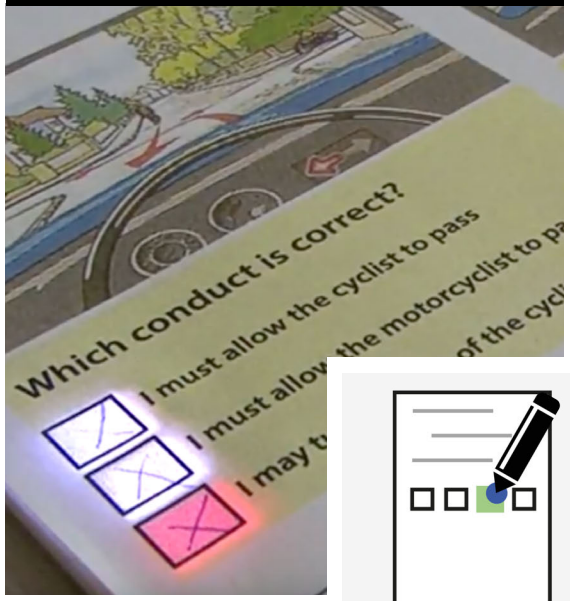
How? – Visual Types

When? – Feedback Time

Where?

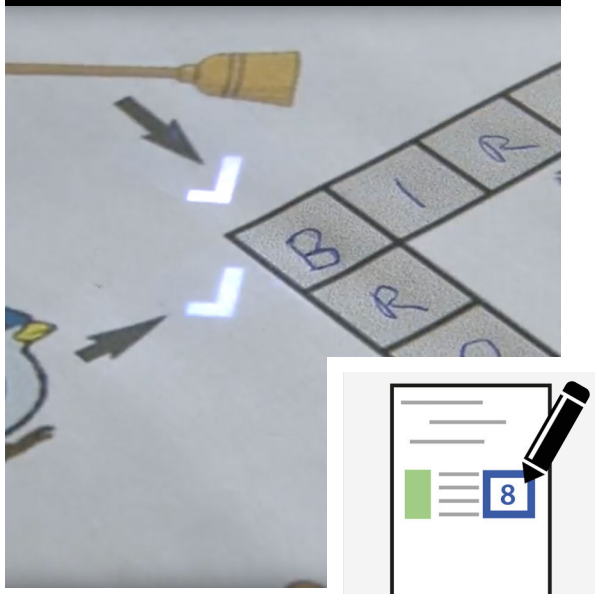
At which place is feedback required and possible?

in-place



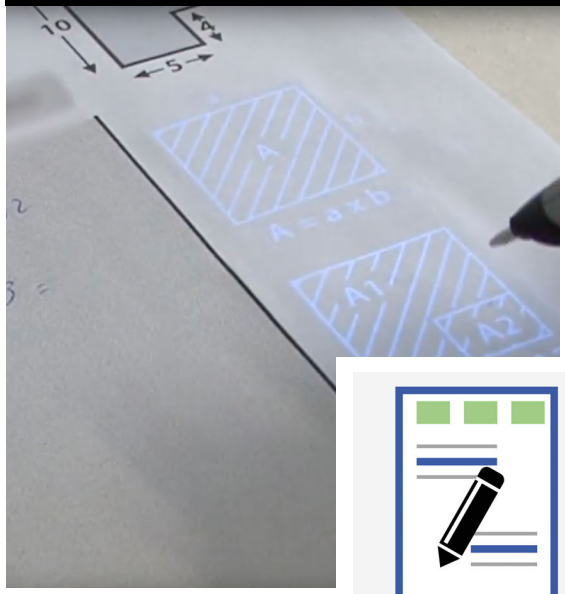
***point** of interaction*

close-by



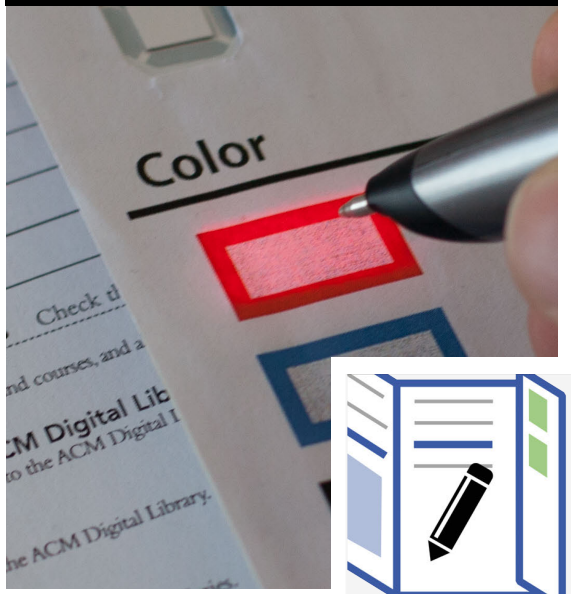
***region** of interaction*

page-related



***associated** generic*

book-related



***contextual** beyond page*

How?

What forms are possible?

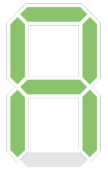
single-segment

region

icons, symbols

multi-segment

digits

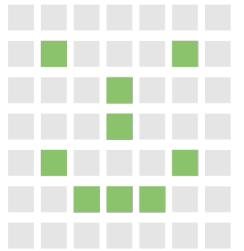


characters

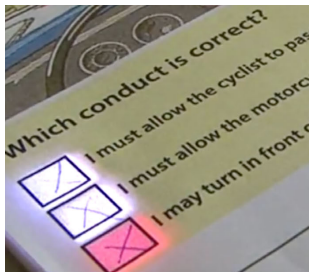
iconographic

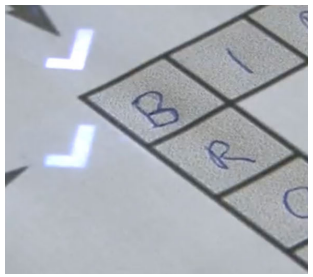
◄ *semiotic system* ►

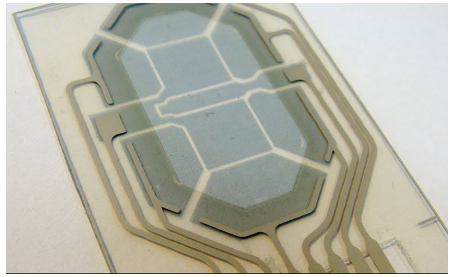
matrix

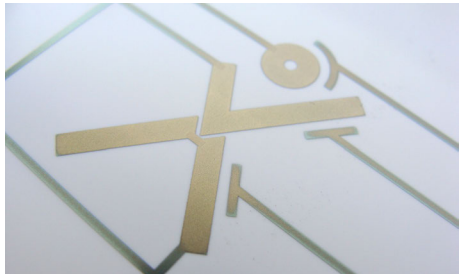


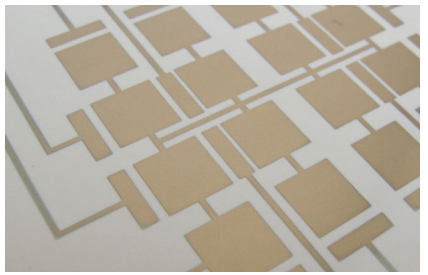
graphical







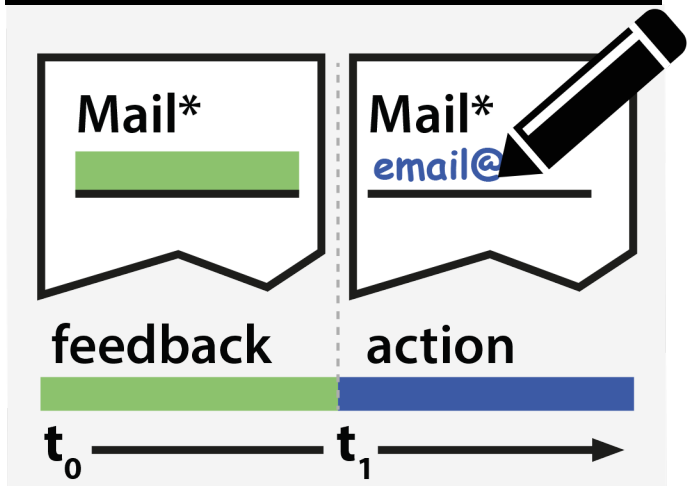




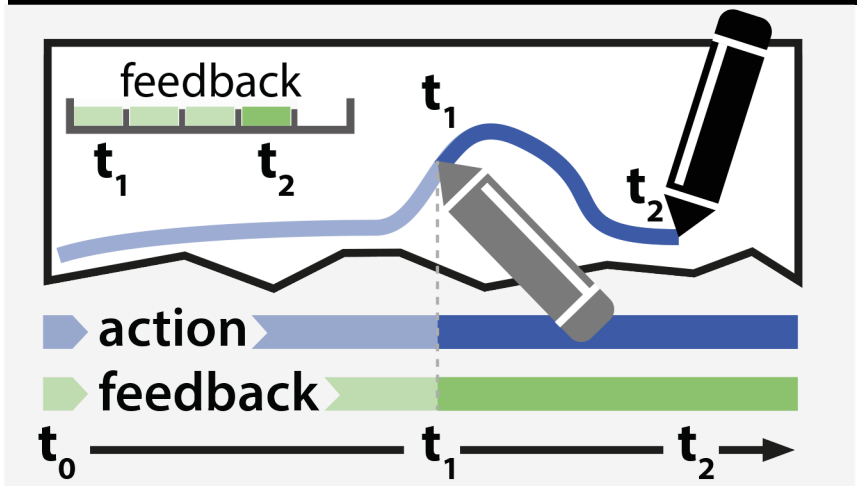
When?

At what time can feedback be provided?

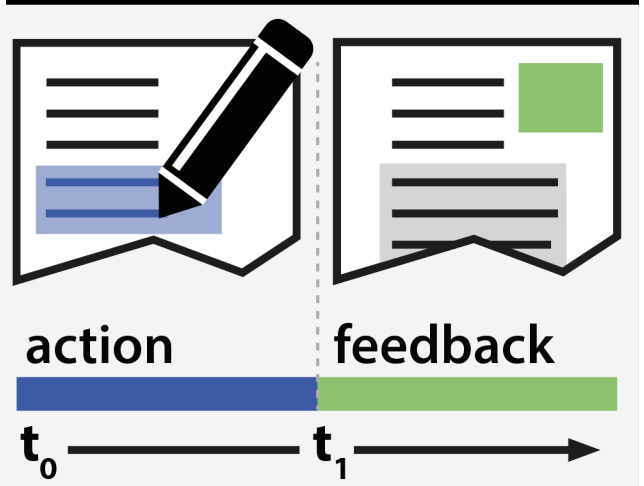
feedforward



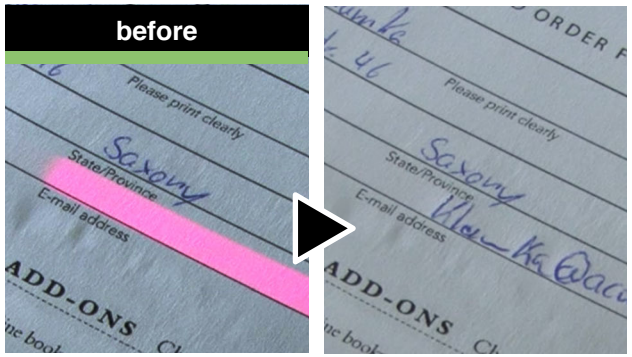
continuous feedback



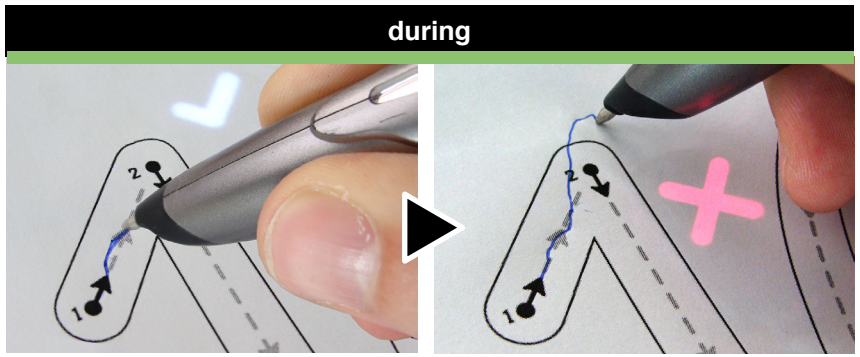
post-feedback



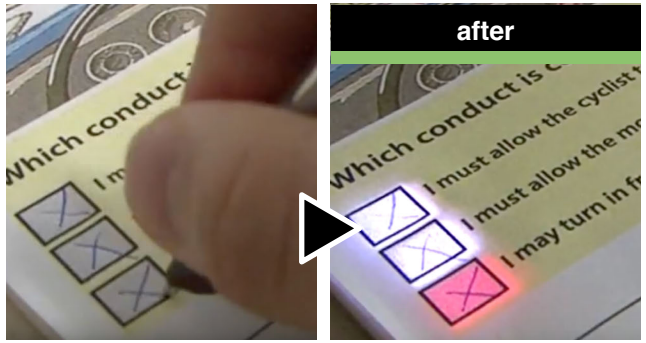
before



during



after



Feedback Components

- Controls and Widgets
- Validity Feedback
- Layout Feedback
- Motion Sequences
- Smart Request Feedback

Feedback Components

Controls and Widgets

Validity Feedback

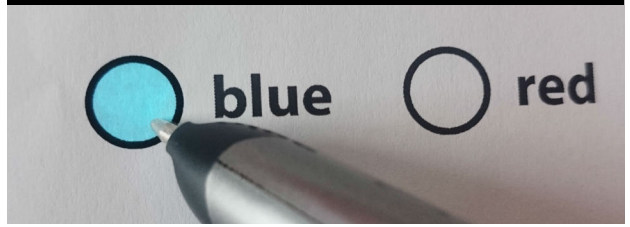
Layout Feedback

Motion Sequences

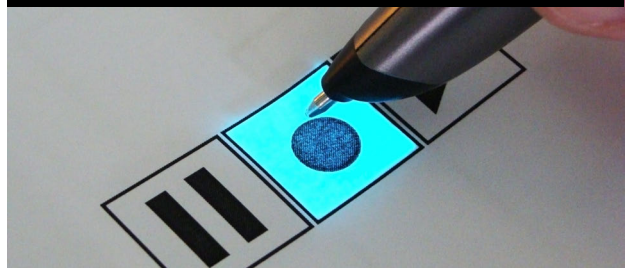
Smart Request Feedback

- **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

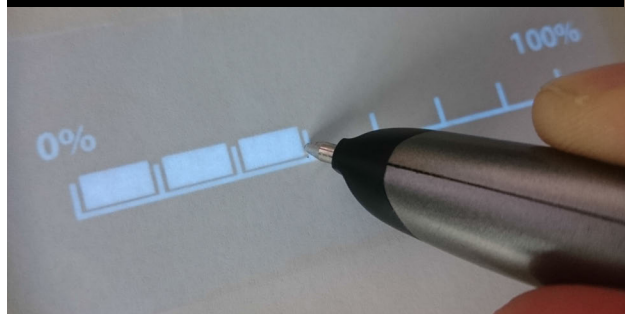
Options



Buttons



Slider



Feedback Components

Controls and Widgets

Validity Feedback

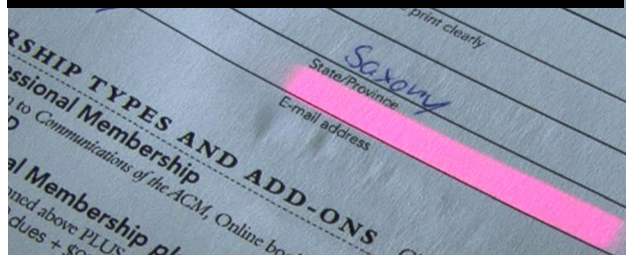
Layout Feedback

Motion Sequences

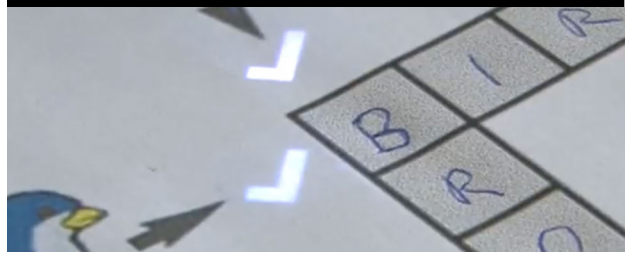
Smart Request Feedback

- **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

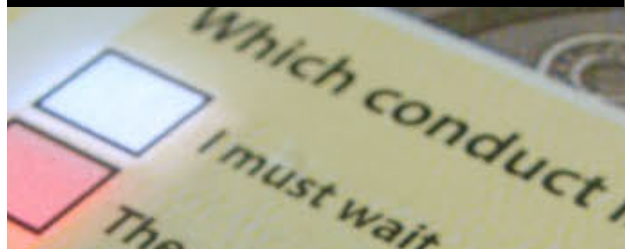
Form fields



Interpretable tasks



Assignment tasks



Feedback Components

Controls and Widgets

Validity Feedback

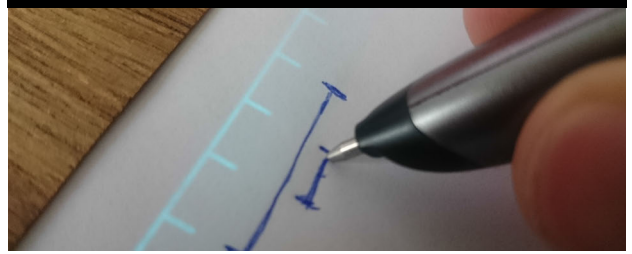
Layout Feedback

Motion Sequences

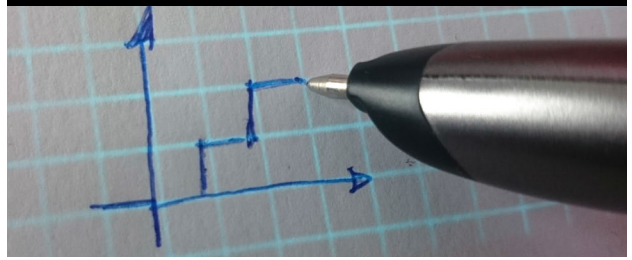
Smart Request Feedback

- **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

Ruler

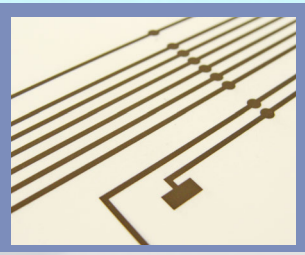


Grids



IllumiPaper Research Platform

Paper Displays
thin, flexible, printable
colorful, illuminating

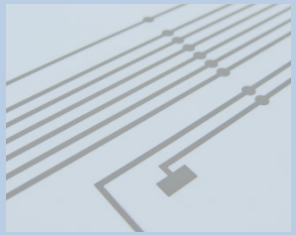


Traces
highly conductive,
seamless integration

Microcontroller
switching logics for
displays and pen actions

IllumiPaper Research Platform

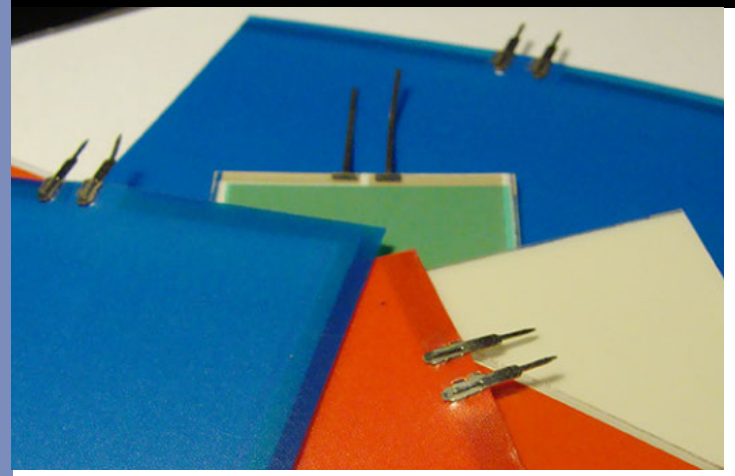
Paper Displays
thin, flexible, printable
colorful, illuminating

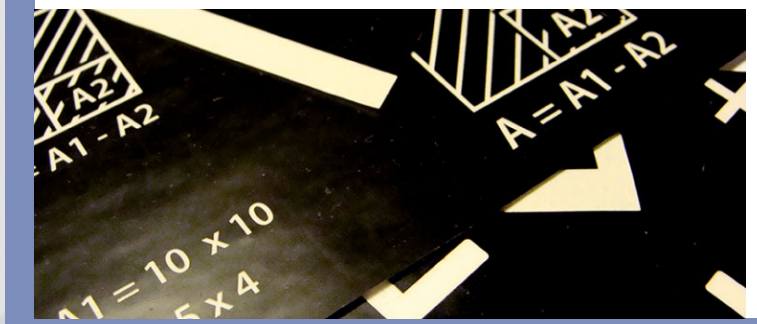


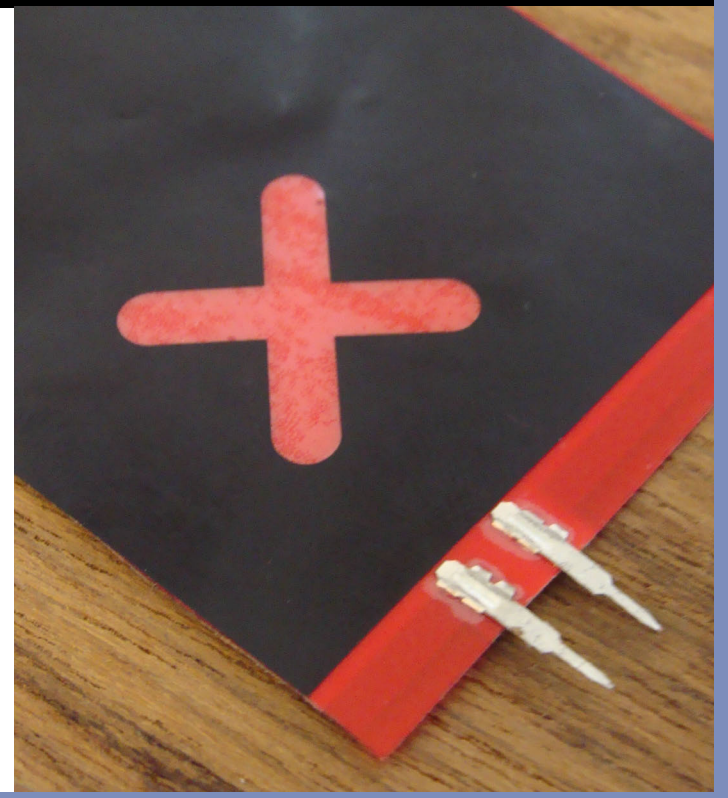
Traces
highly conductive,
seamless integration

Microcontroller
switching logics for
displays and pen actions

Off-the-shelf EL foil with printed stencil foils

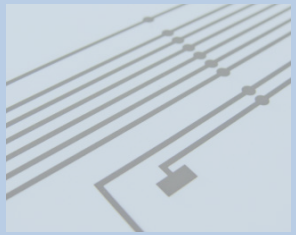






IllumiPaper Research Platform

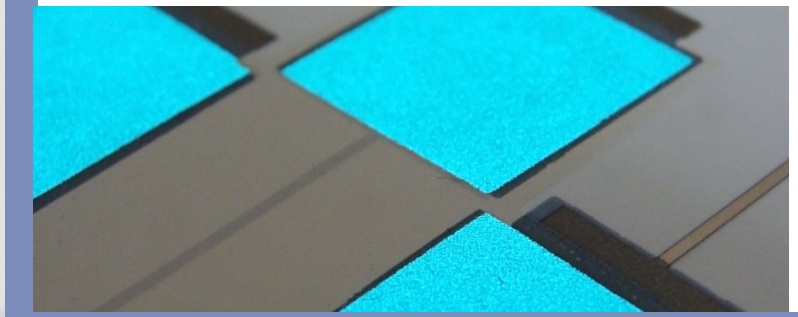
Paper Displays
thin, flexible, printable
colorful, illuminating



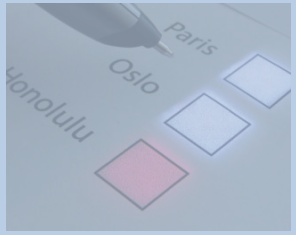
Traces
highly conductive,
seamless integration

Microcontroller
switching logics for
displays and pen actions

EL Screen Printing



IllumiPaper Research Platform



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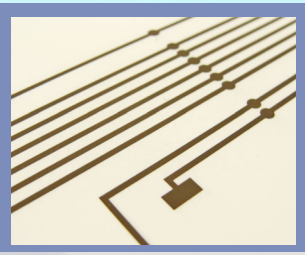
thin, flexible, printable
colorful, illuminating



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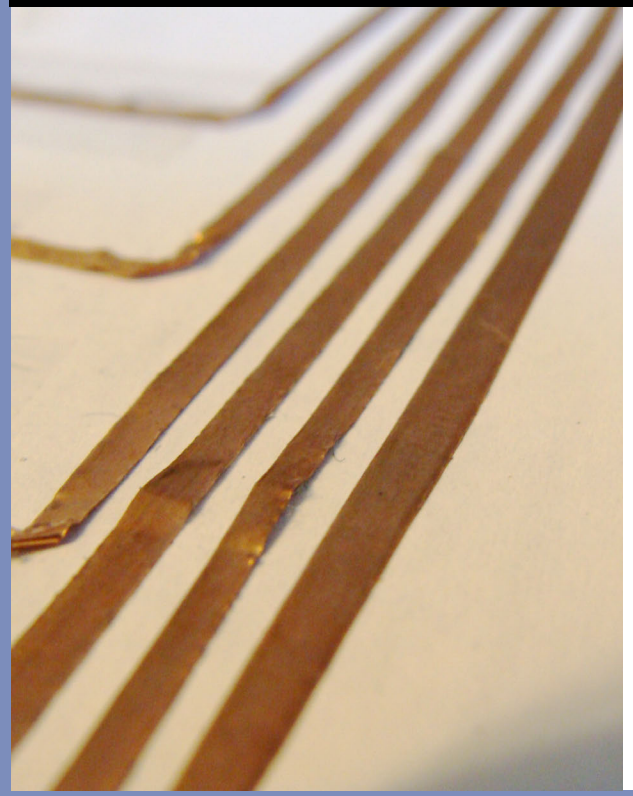
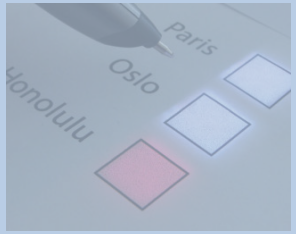
Copper Tape



IllumiPaper Research Platform



Paper Displays
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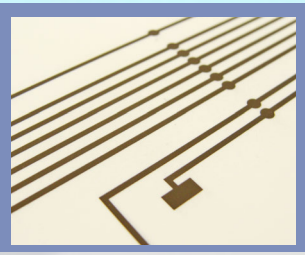

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Microcontroller
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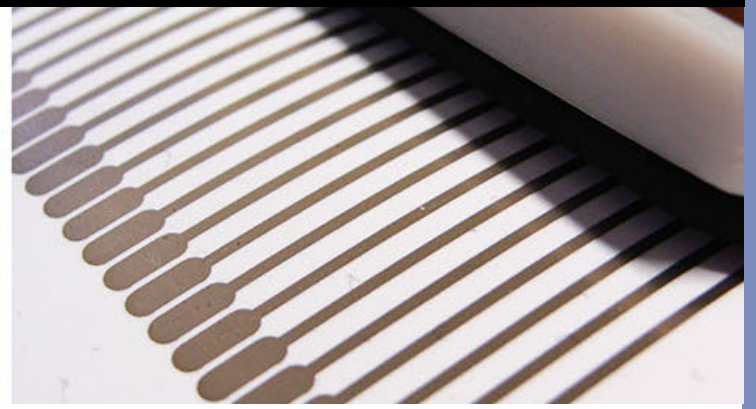
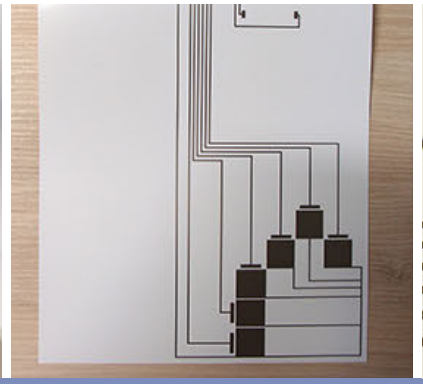
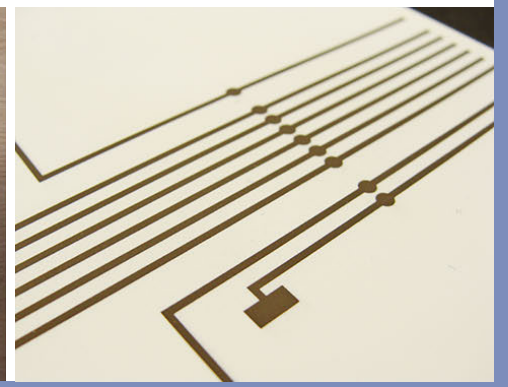
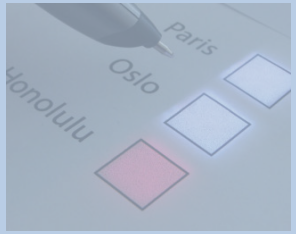
Conductive Inkjet Printing







IllumiPaper Research Platform



Paper Displays
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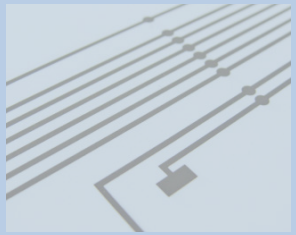
colorful, illuminating



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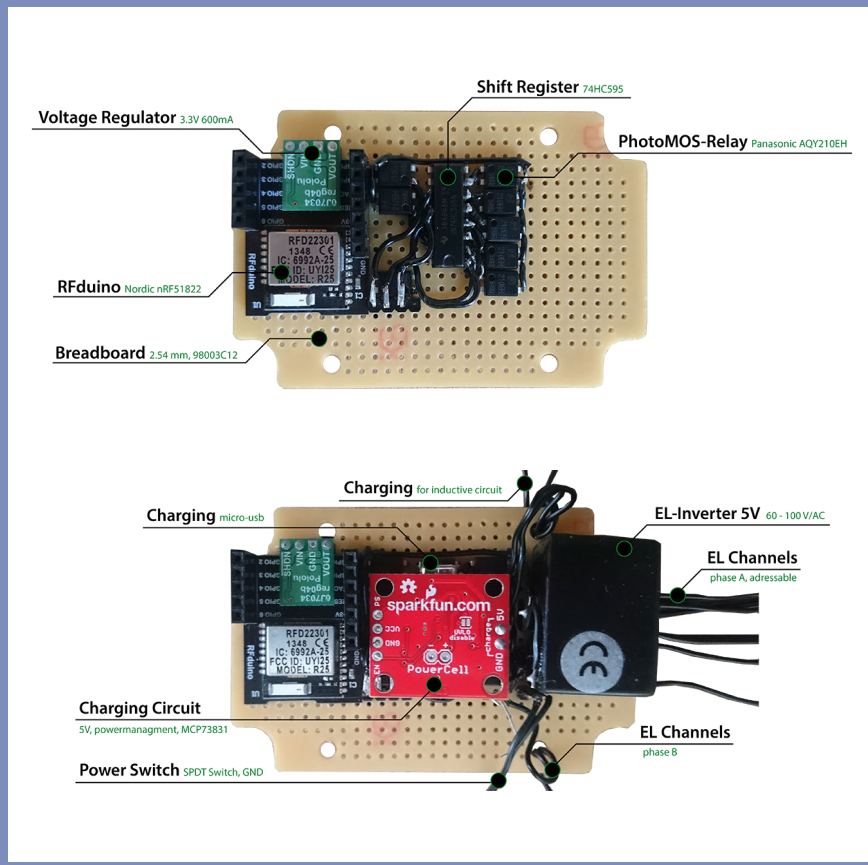
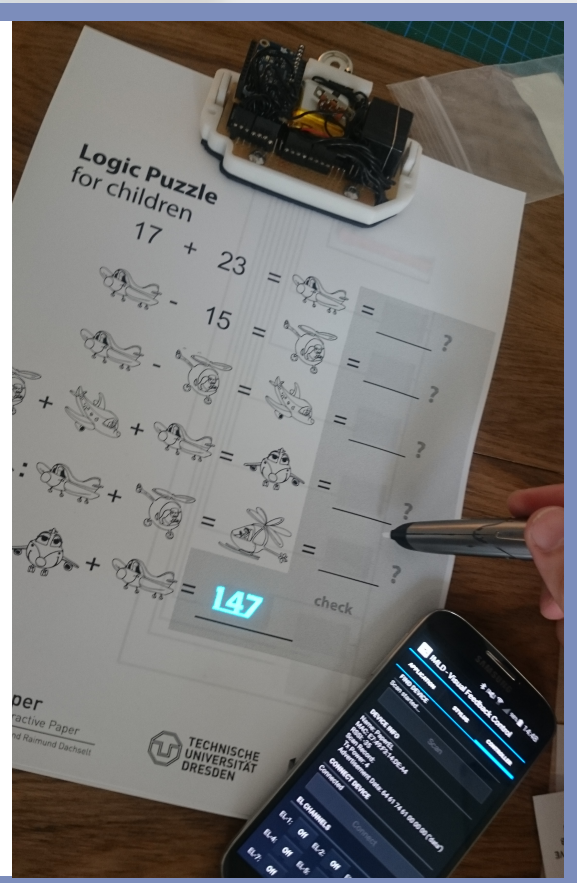
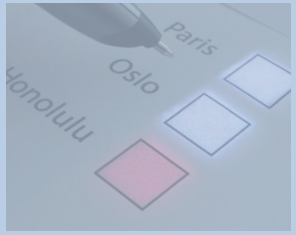




IllumiPaper Research Platform



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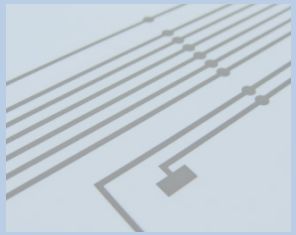

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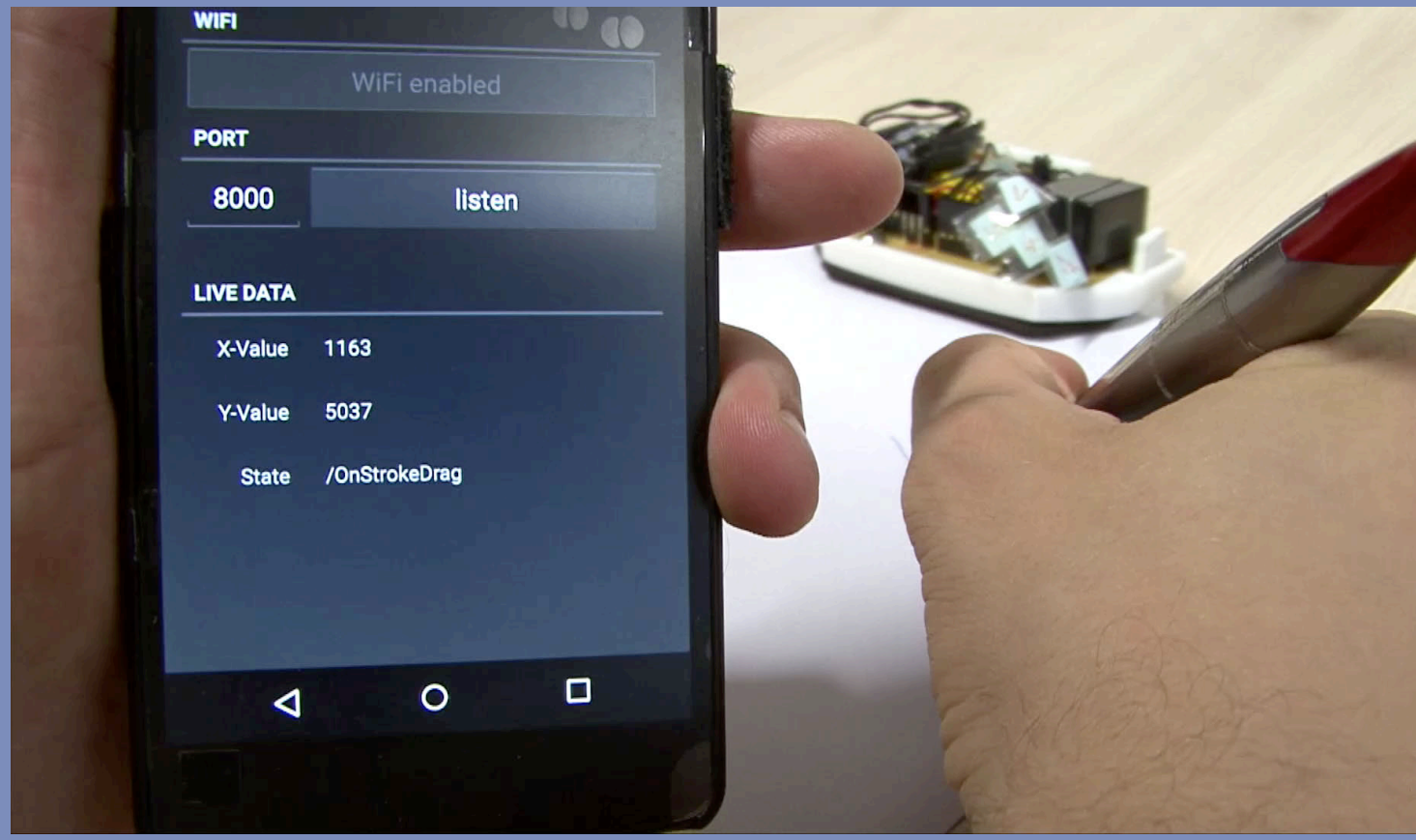
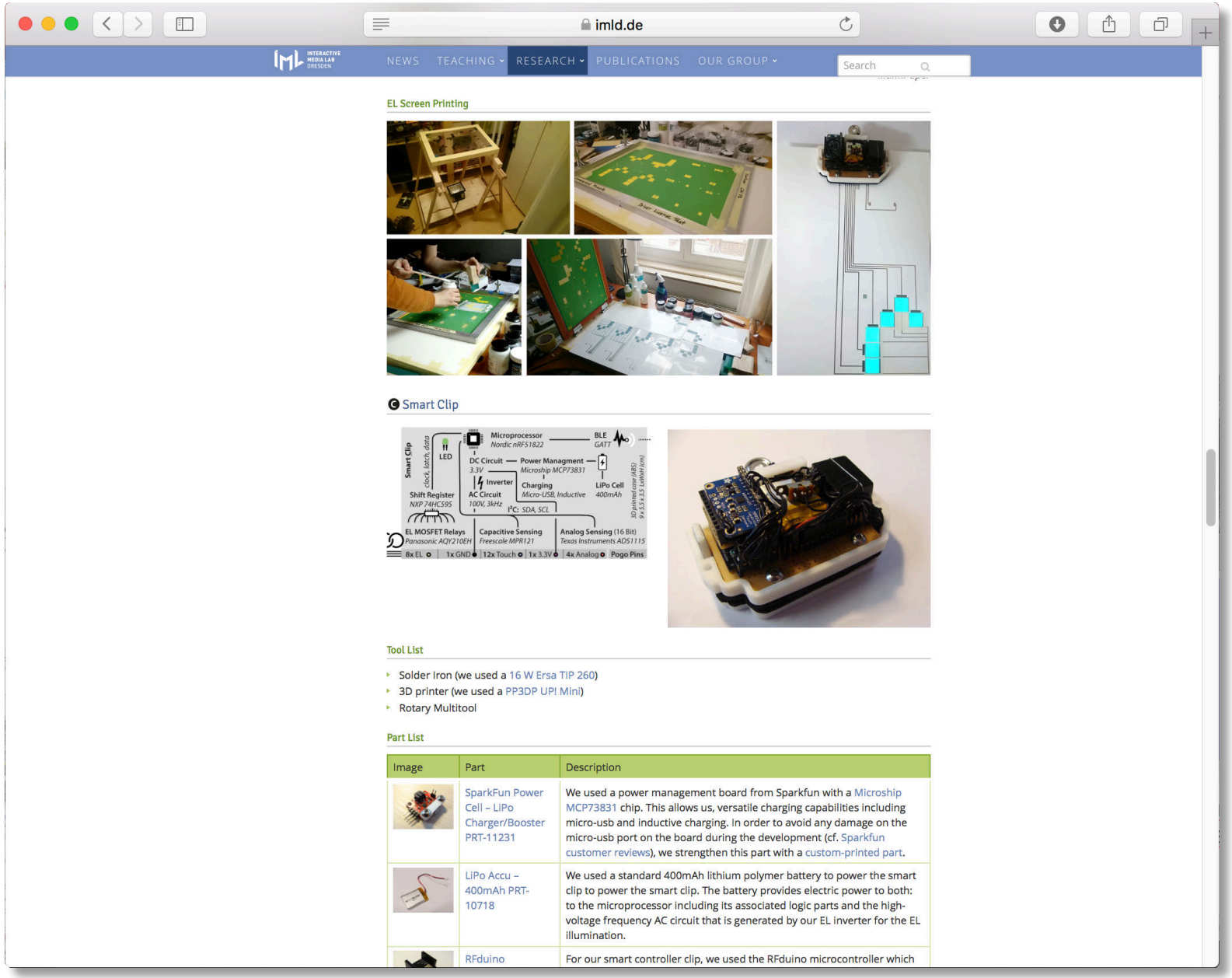
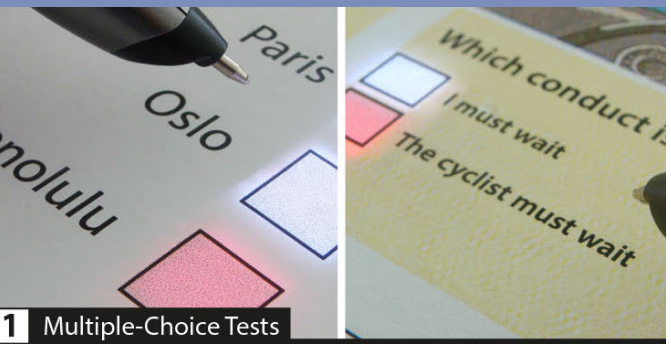


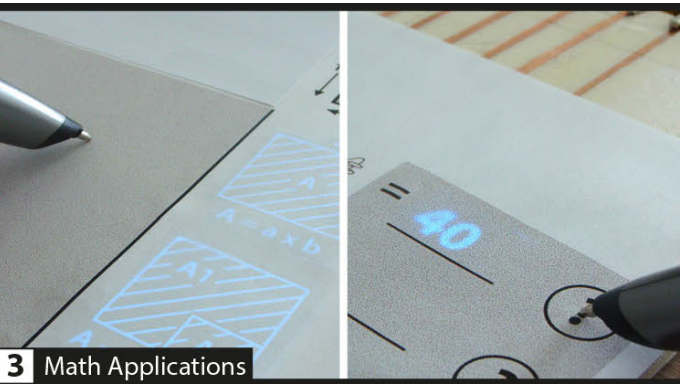
Further Fabrication Details

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



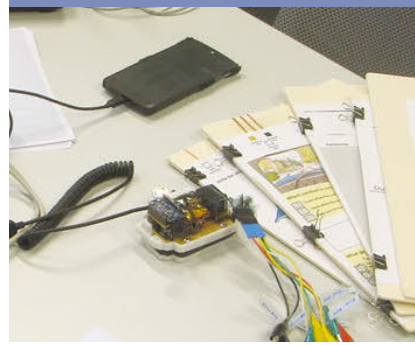
Applications





- six semi-structured expert interviews
- five functional example applications
- each hands-on session 60 minutes
- video recordings and protocol

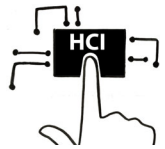
Interviews



Experts

2 **Psychology Experts**
cognitive aspects

2 **Educational Experts**
learning & assistance aspects



2 **HCI Experts**
interaction aspects

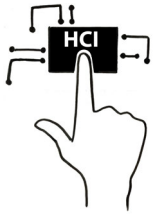
Interviews

*"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*

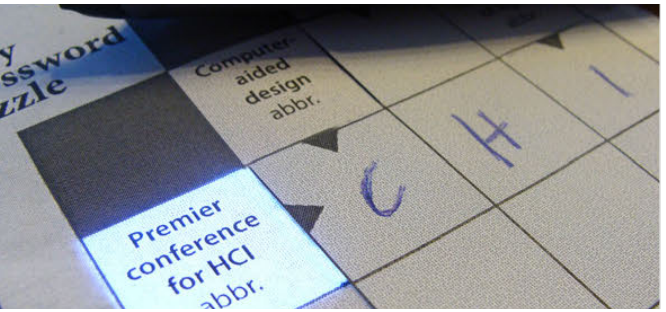


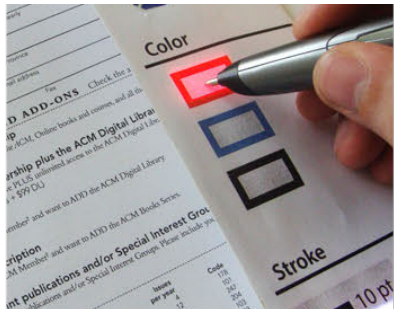
*"In addition, I see high potential to enhance the system with **touch interactions** on the paper itself."*

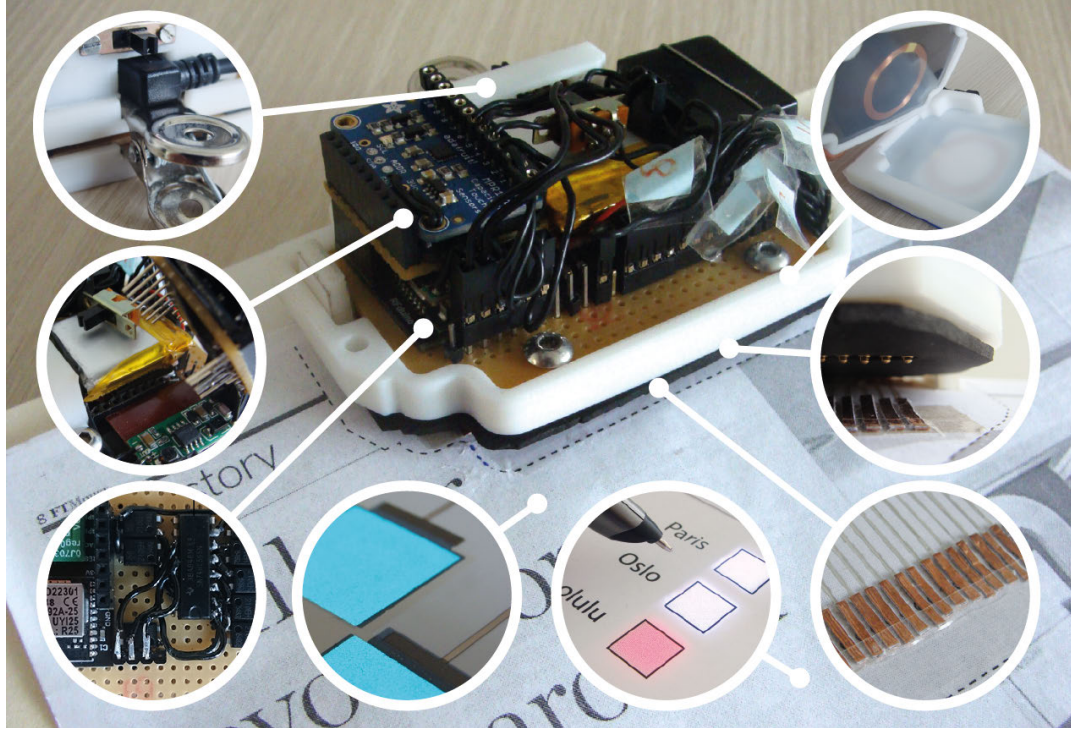
*Many years Research Associate **HCI***

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





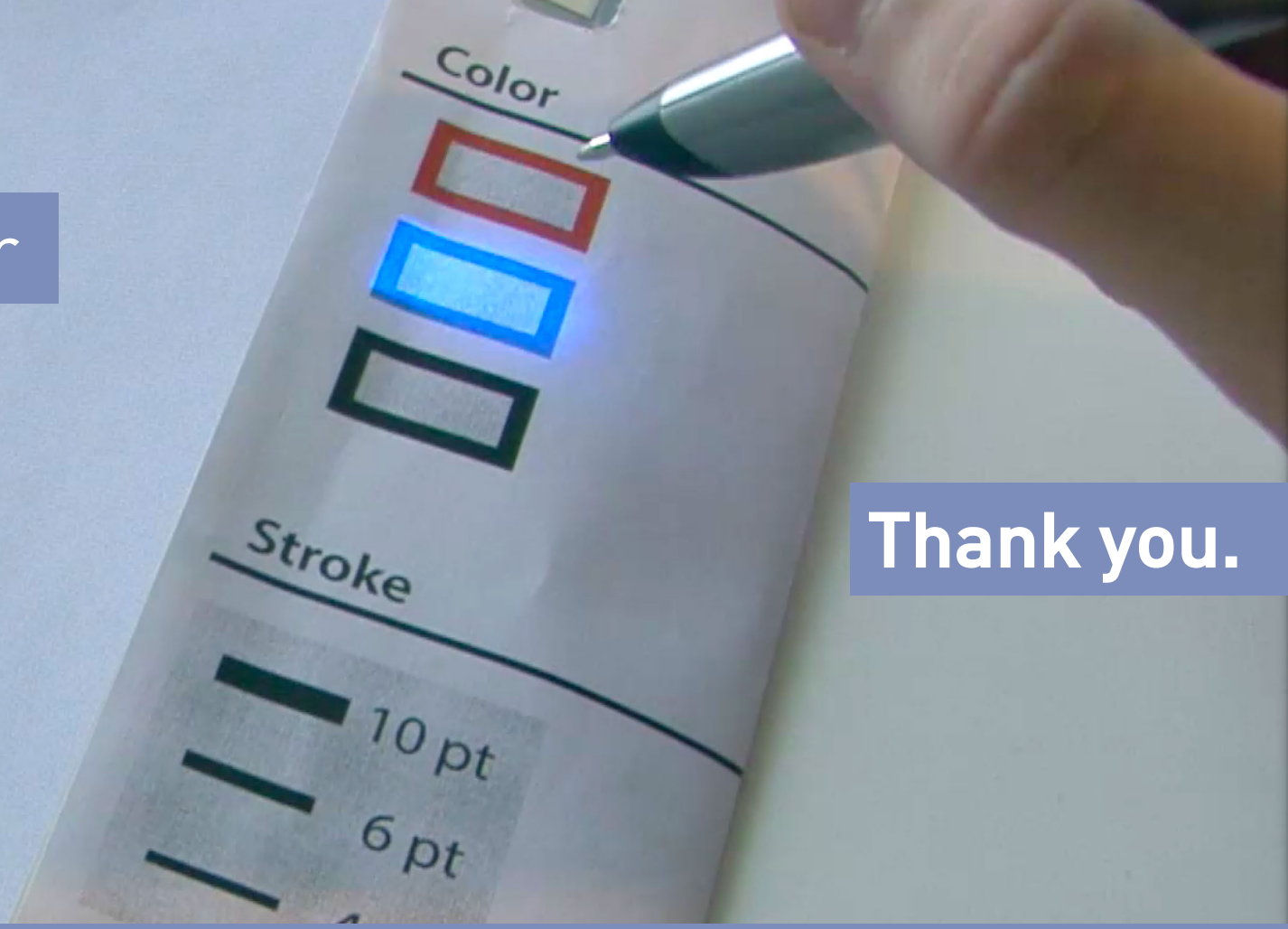


Future Work

- study comparing pen feedback
- miniaturize and further improve our prototype
- extend our set of applications

IllumiPaper

Illuminated Interactive Paper



Thank you.

Come and visit us!

Today, **11:00 AM - 1:00 PM**

Konstantin Klamka, Raimund Dachselt

TECHNISCHE UNIVERSITÄT DRESDEN

INTERACTIVE MEDIA LAB DRESDEN

Contact
klamka@acm.org

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

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