



Shape-Changing Interface: Paper-Like

TOBIAS BRÜHWILER | UBIQUITOUS COMPUTING SEMINAR 2015

Vision

- ▶ Paperless Office
- ▶ Summon display at will
- ▶ Changed in size and shape



Content

- ▶ Interaction Language
- ▶ Technical Explanation
- ▶ Prototypes:
 - ▶ Foldable Interactive Displays
 - ▶ Paperphone
 - ▶ Flexpad
 - ▶ Other Devices
- ▶ Industrial Designs
- ▶ Summary

Interaction Language: Properties

- ▶ Orthogonality
- ▶ Consistency
- ▶ Polymorphism
- ▶ Directionality

[5] Byron Lahey et al. "PaperPhone: Understanding the Use of Bend Gestures in Mobile Devices with Flexible Electronic Paper Displays", 2011

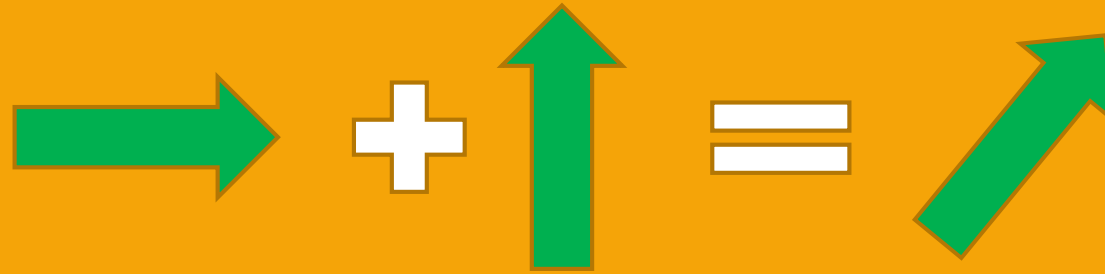
Orthogonality

- Independent from another bend gesture
- Combination result in a predictable outcome

Consistency

Polymorphism

Directionality



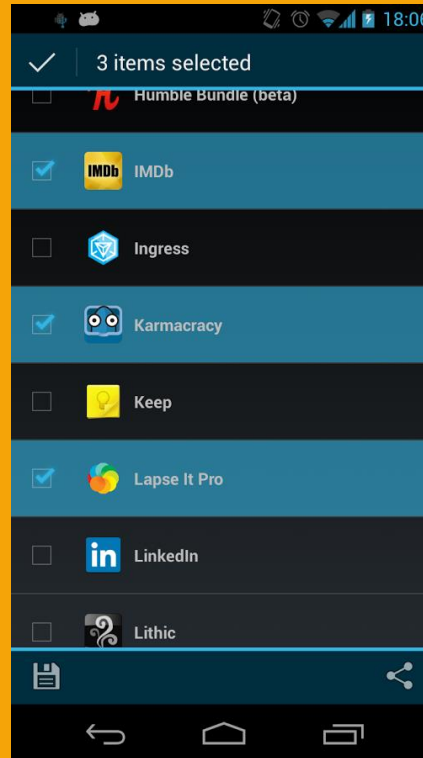
Orthogonality

Consistency

Polymorphism

Directionality

➤ Same gestures trigger same actions in different applications



Orthogonality

Consistency

Polymorphism

Directionality

- Same gesture triggers different actions which are semantically related



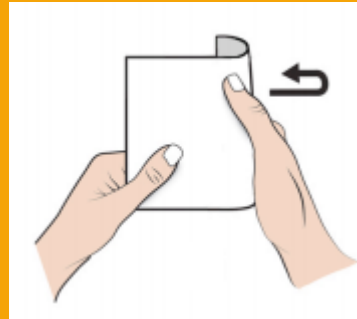
Orthogonality

Consistency

Polymorphism

Directionality

➤ Spatial relationship defined by the application



Technical Explanation

Sensor-Based

- Plastic Sheet
- Bend Sensors

Simulation

- Overhead Projector
- Infrared Camera
- Passive Sheet
- Augmentation with IR reflective points

Flexible Displays

- Flexible display
- Bend sensors
- Cable to Controller



Prototypes

Foldable Interactive Displays

PaperPhone

Flexpad

[5] Byron Lahey et al. "PaperPhone: Understanding the Use of Bend Gestures in Mobile Devices with Flexible Electronic Paper Displays". 2011

[6] Johnny C. Lee, Scott E. Hudson, and Edward Tse. "Foldable Interactive Displays". 2008

[10] Jurgen Steimle, Andreas Jordt, and Pattie Maes. "Flexpad: Highly Flexible Bending Interactions for Projected Handheld Displays". 2013

Foldable
Interactive Displays

PaperPhone

Flexpad

Foldable Interactive Displays

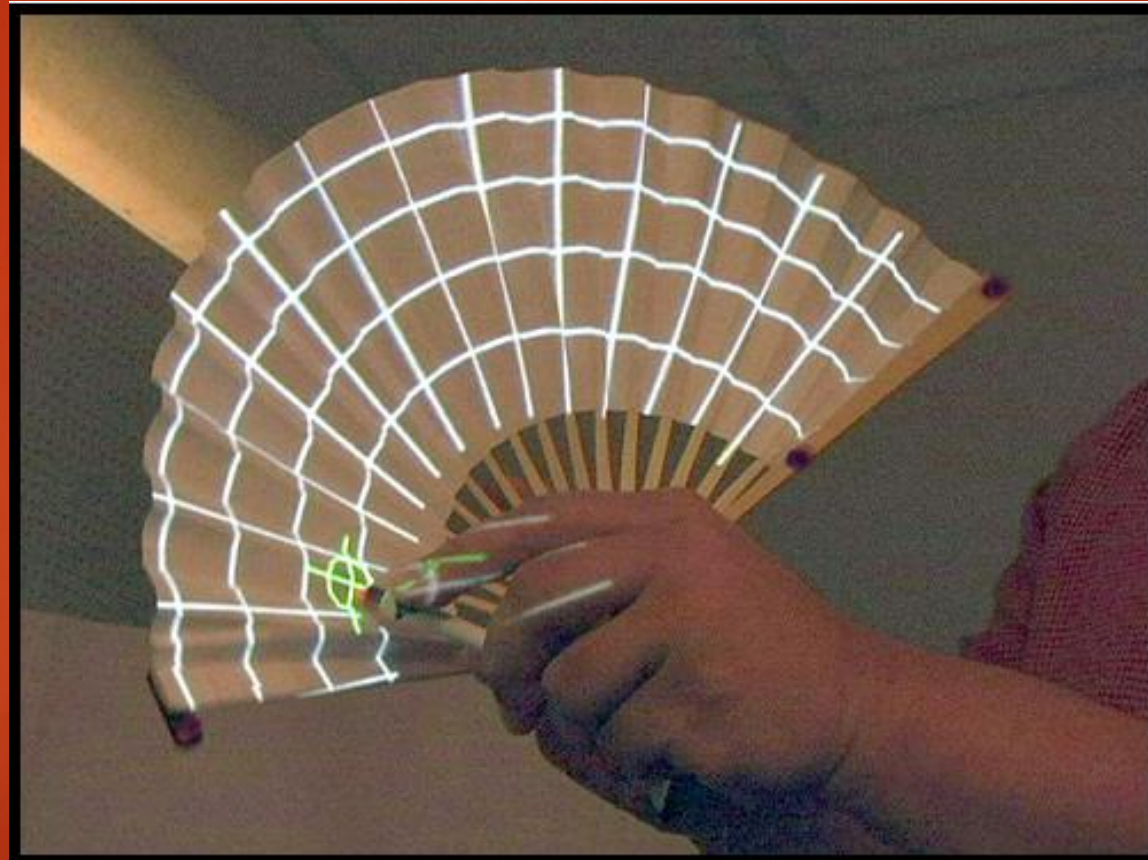


Foldable
Interactive Displays

PaperPhone

Flexpad

Foldable Interactive Displays



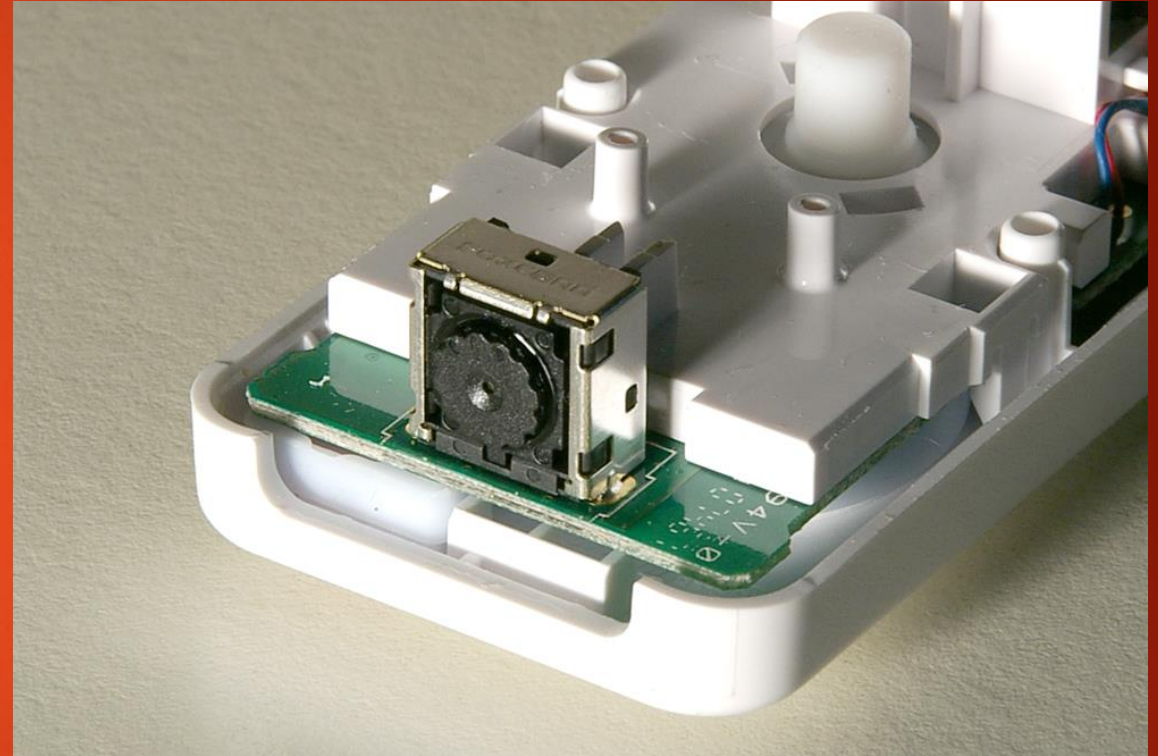
Foldable
Interactive Displays

PaperPhone

Flexpad

System

- ▶ Overhead projector
- ▶ PixArt Camera (Nintendo Wii Remote)
- ▶ Passive Sheet
- ▶ Up to 4 Infrared LEDs embedded
- ▶ No depth information

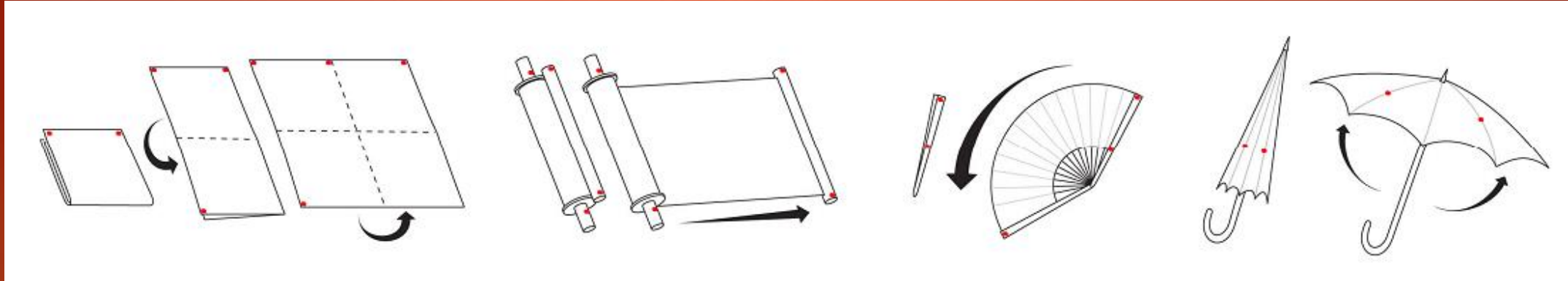


Foldable
Interactive Displays

PaperPhone

Flexpad

Display types



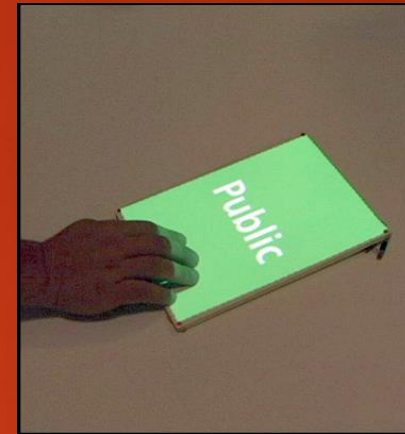
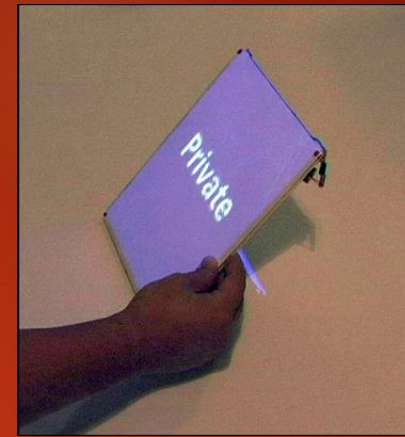
Foldable
Interactive Displays

PaperPhone

Flexpad

Usability

- ▶ Tilting triggers different actions:
 - ▶ Tilting toward myself -> Private state
 - ▶ Placing it flat -> Public state
 - ▶ Tilting it away -> Excluded state
- ▶ Possible addition of a stylus to generate input



Foldable
Interactive Displays

PaperPhone

Flexpad

Pro/Cons

- + Large display surface
- + Interaction with display
- + Low cost

- Occlusion
- Only 4 IR LEDs

Foldable
Interactive Displays

PaperPhone

Flexpad

PaperPhone

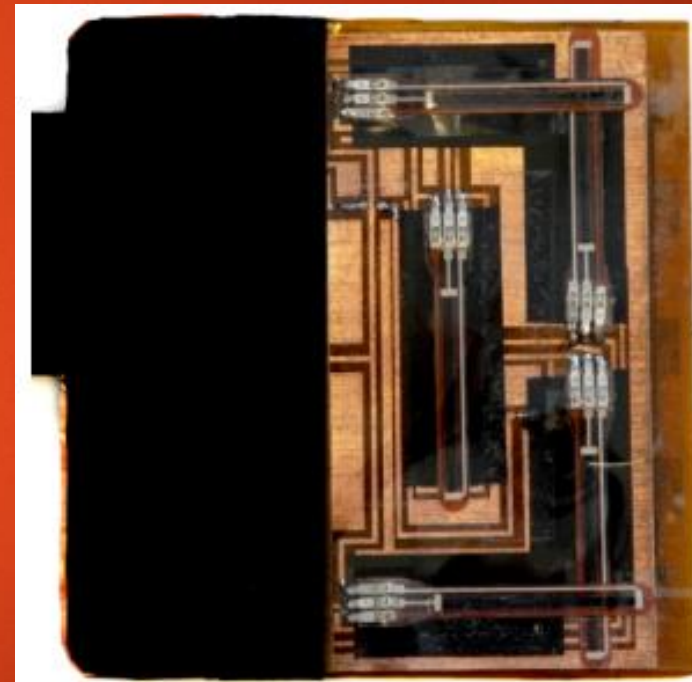


Foldable
Interactive Displays

PaperPhone

Flexpad

PaperPhone



Foldable
Interactive Displays

PaperPhone

Flexpad

System

- ▶ 3.7 Zoll Electrophoretic display
- ▶ 5 bidirectional bend sensors
- ▶ External processing power
- ▶ Plastic board on left side

Foldable
Interactive Displays

PaperPhone

Flexpad

System

Training Session of
Gestures



Connecting
Gestures to Actions



Evaluation

Foldable
Interactive Displays

PaperPhone

Flexpad

Algorithm

- ▶ K-nearest algorithm with $k=1$
- ▶ Flat shape is neutral state
- ▶ Multiple samples taken after algorithm to reduce false-positives

Foldable
Interactive Displays

PaperPhone

Flexpad

Study

- ▶ 10 participants
- ▶ 3 sessions
- ▶ Results:
 - ▶ Different assignments for bend gestures to actions
 - ▶ Bend gestures mostly simple and less physical demanding
 - ▶ Desire for fully flexible display expressed

Foldable
Interactive Displays

PaperPhone

Flexpad

FlexPad

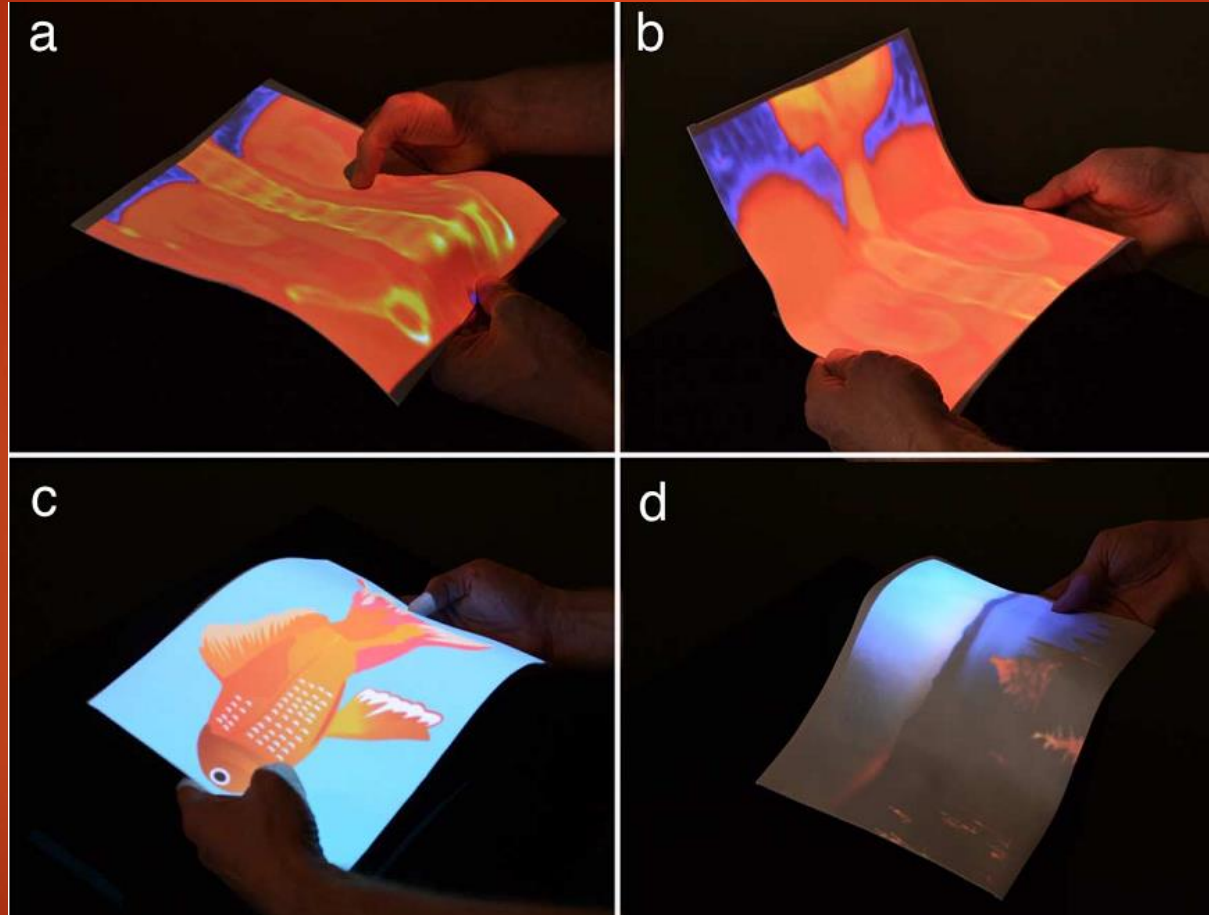


Foldable
Interactive Displays

PaperPhone

Flexpad

FlexPad



Foldable
Interactive Displays

PaperPhone

Flexpad

System

- ▶ Kinect camera
- ▶ Full HD projector
- ▶ Passive sheet
 - ▶ Flexible
 - ▶ Shape-retaining



Foldable
Interactive Displays

PaperPhone

Flexpad

Algorithm

- ▶ Distinguish between hand and paper



- ▶ Map to model: 25x25 vertex plane by minimizing the error
- ▶ Map model to gesture
- ▶ Slow movement: more accuracy
- ▶ Fast movement: less accuracy

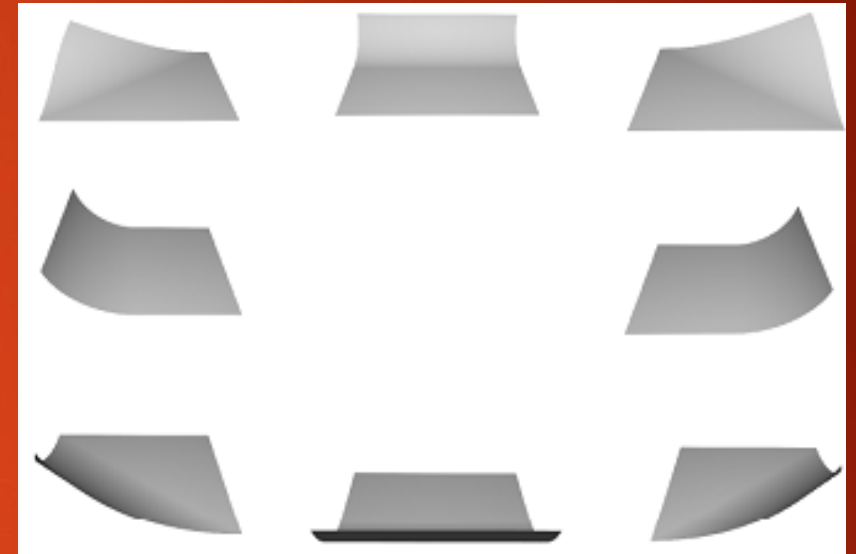
Foldable
Interactive Displays

PaperPhone

Flexpad

Algorithm

- ▶ Predefined Models
- ▶ Error: Mismatch between model and image
- ▶ Angle is variable

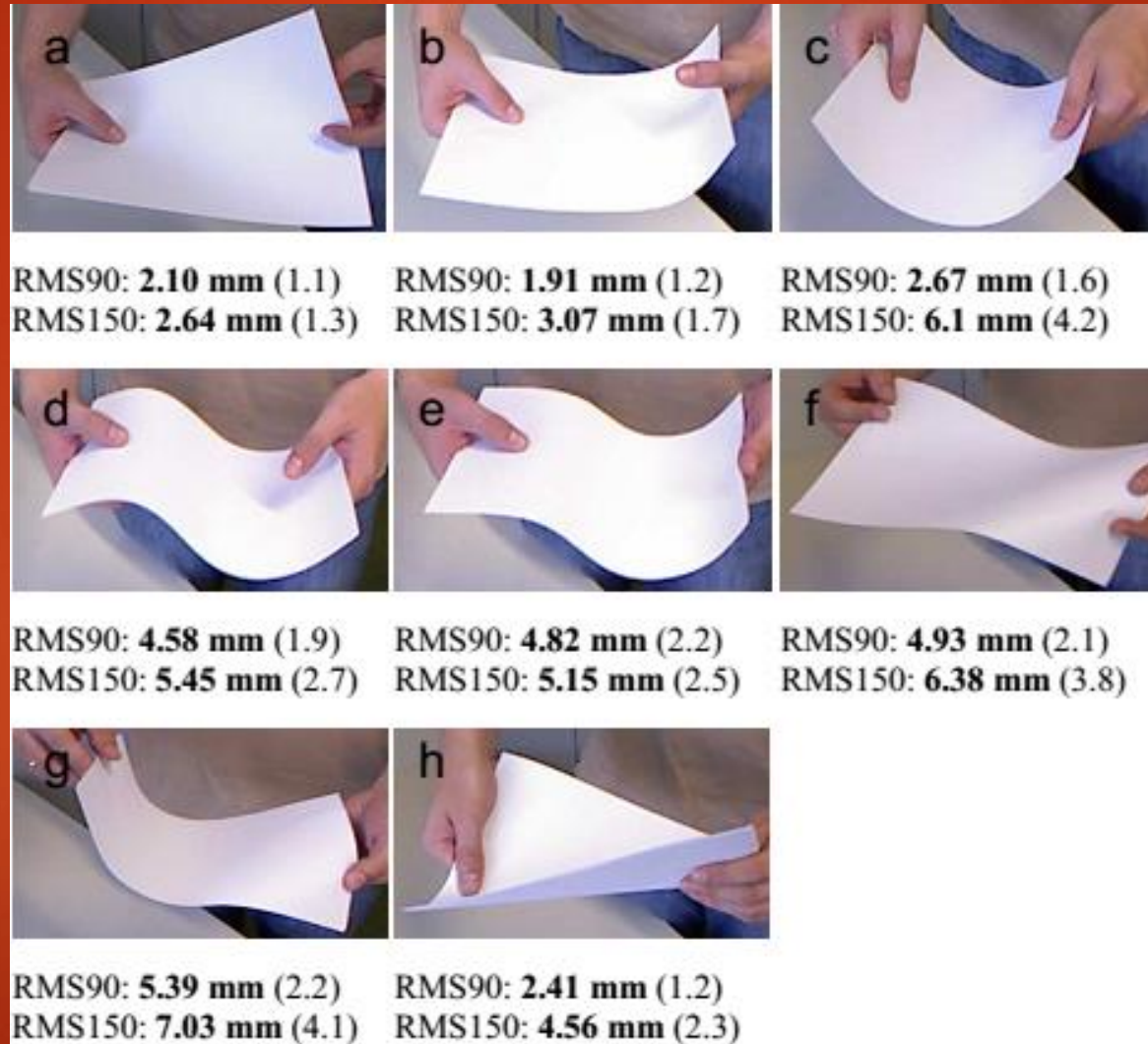


Foldable
Interactive Displays

PaperPhone

Flexpad

Study

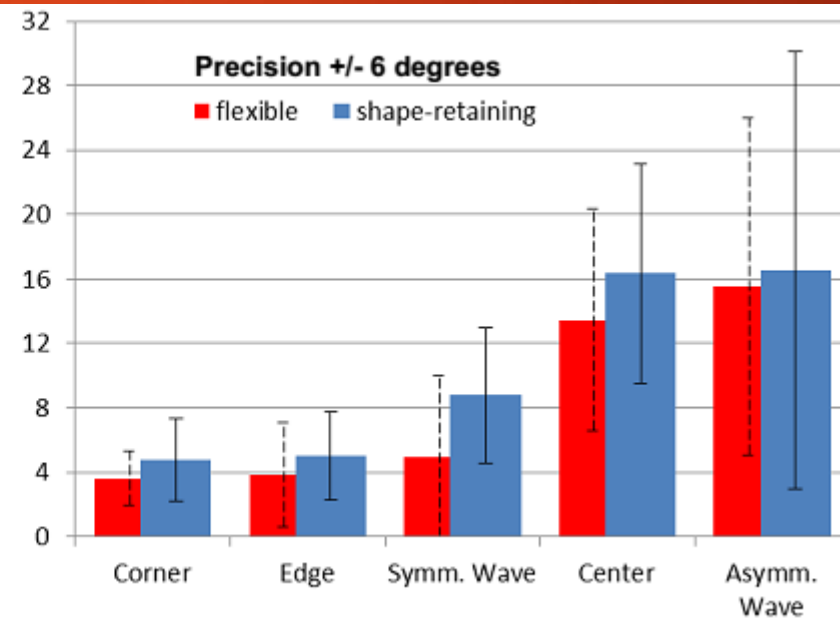
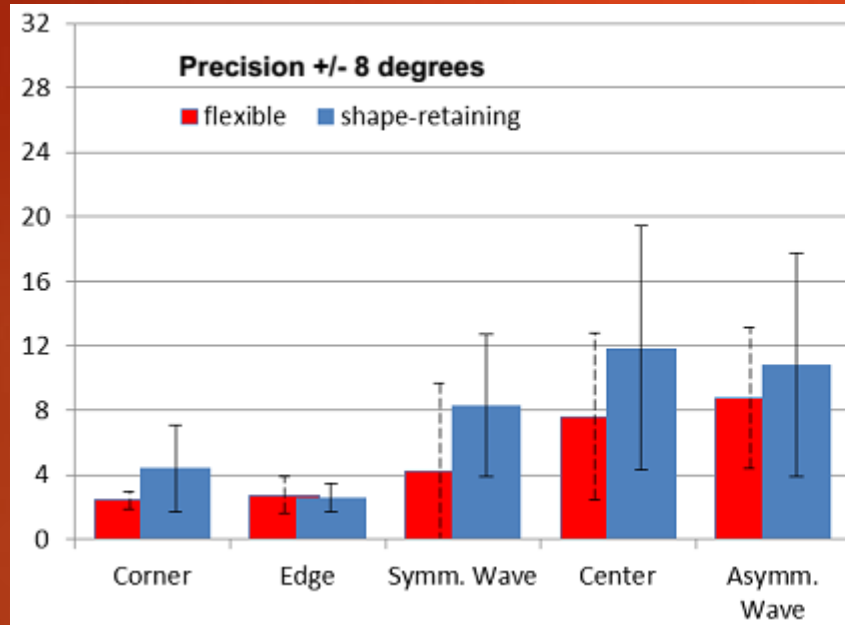


Foldable
Interactive Displays

PaperPhone

Flexpad

Study



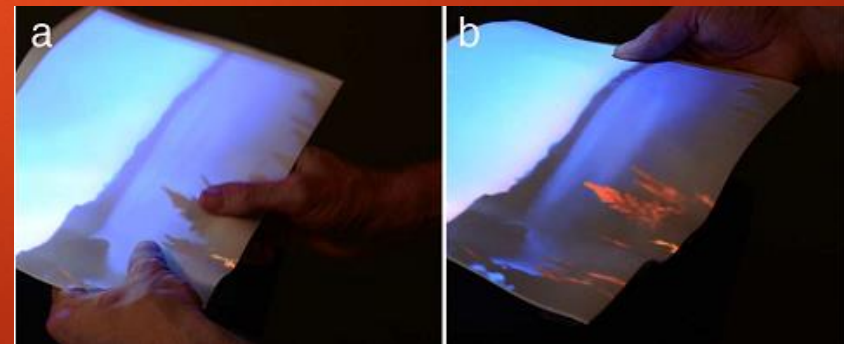
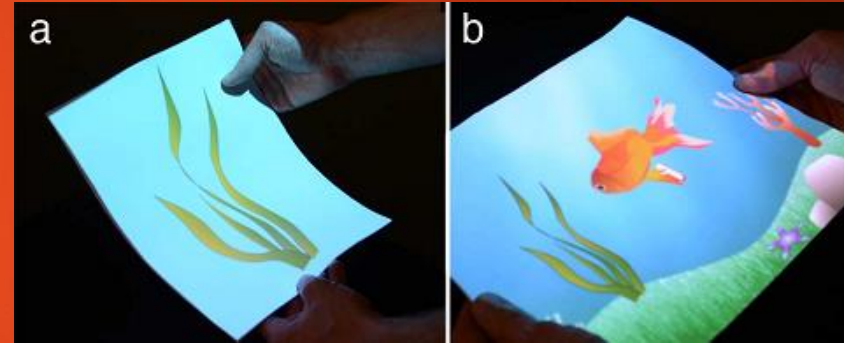
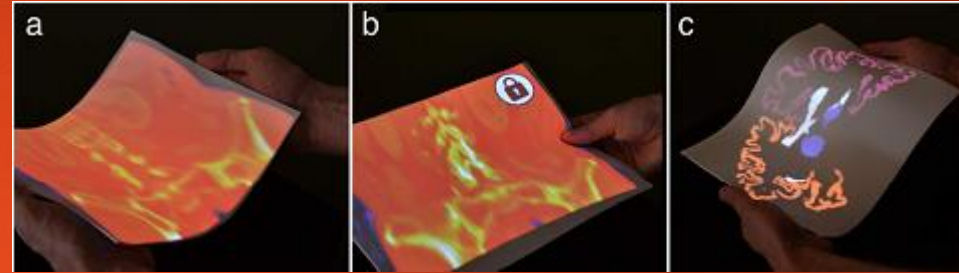
Foldable
Interactive Displays

PaperPhone

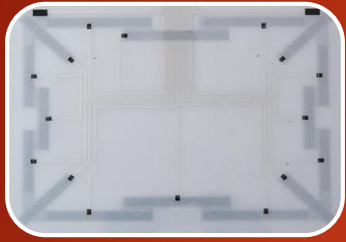
Flexpad

Applications

- ▶ Volumetric Datasets
- ▶ Animating virtual Paper Characters
- ▶ Slicing through Time in Videos



Other Devices



FlexSense



Gummi



MorePhone



PaperFold



PaperTab



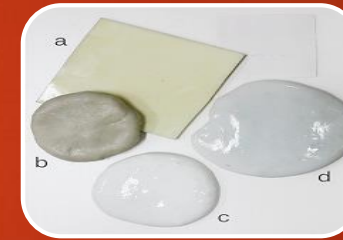
FoldMe



PaperWindows



Bookisheet



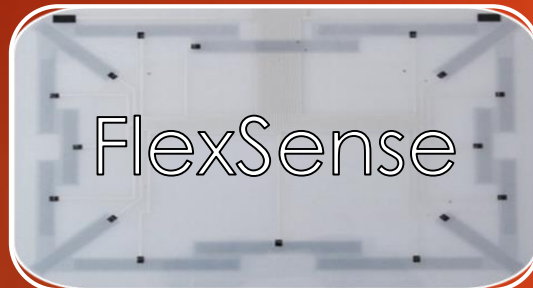
DeformMe

Other Devices: Sensor-Based



- Deformable object
- Infrared marker
- Camera

[7] Parinya Punpongsanon, Daisuke Iwai, and Kosuke Sato. 2013



- Piezoelectric Sensors
- Plastic Sheet

[8] Christian Rendl et al. 2014



- Simulate a book
- Speaker

[12] Jun-ichiro Watanabe, Arito Mochizuki, and Youichi Horry. 2008

Other Devices: Simulation



- Optitrack motion capturing system
- Hinges

[4] Mohammadreza Khalilbeigi et al. 2012



- Multiple Pages
- Paperless Office
- Stacking/Rubbing/Staple

[3] David Holman et al. 2005

Other Devices: Flexible Displays



- First flexible Display
- Trackpad
- Bend Sensors

[9] Carsten Schwesig, Ivan Poupyrev, and Eijiro Mori. 2004



- Shape-changing
- Bend Sensors

[1] Antonio Gomes, Andrea Nesbitt, and Roel Vertegaal. 2013



- 3 flexible displays
- Magnetic hinges

[2] Antonio Gomes and Roel Vertegaal. 2015



- Flexible display
- Bend sensors
- Touching for transfer data

[11] Aneesh P. Tarun et al. 2013

Industrial Prototypes

- ▶ Nokia
 - ▶ Morph
 - ▶ Kinetic
- ▶ Sony
- ▶ Samsung
 - ▶ Galaxy Round
 - ▶ Galaxy Note Edge

Nokia Morph & Kinetic



Concept Design



Real Flexible Display

Sony



Prototype

Samsung



Galaxy Round



Galaxy Note Edge

Flexible Displays: Benefits

- ▶ Unbreakable/robust x
- ▶ Large in Size, but still storable ✓
- ▶ Lightweight ✓
- ▶ Wearable x
- ▶ Low Power ✓
- ▶ Intuitive handling ✓
- ▶ While wearing gloves ✓
- ▶ Without visual feedback ✓
- ▶ Interaction without occluding x

Summary

- Still no fully flexible displays
- Bending possible, but not flexing

- + A lot of research is done
- + Interaction seems to be promising
- + Lots of applications

Thank you for listening!

References

- [1] Antonio Gomes, Andrea Nesbitt, and Roel Vertegaal. “MorePhone: A Study of Actuated Shape Deformations for Flexible Thin-film Smartphone Notifications”.
- [2] Antonio Gomes and Roel Vertegaal. “PaperFold: Evaluating Shape Changes for Viewport Transformations in Foldable Thin-Film Display Devices”.
- [3] David Holman et al. “Paper Windows: Interaction Techniques for Digital Paper”.
- [4] Mohammadreza Khalilbeigi et al. “FoldMe: Interacting with Double-sided Foldable Displays”.
- [5] Byron Lahey et al. “PaperPhone: Understanding the Use of Bend Gestures in Mobile Devices with Flexible Electronic Paper Displays”.
- [6] Johnny C. Lee, Scott E. Hudson, and Edward Tse. “Foldable Interactive Displays”.
- [7] Parinya Punpongsanon, Daisuke Iwai, and Kosuke Sato. “DeformMe: Projection based Visualization of Deformable Surfaces Using Invisible Textures”.
- [8] Christian Rendl et al. “FlexSense: A Transparent Selfsensing Deformable Surface”.

References

[9] Carsten Schwesig, Ivan Poupyrev, and Eijiro Mori. “Gummi: A Bendable Computer”.

[10] Jurgen Steimle, Andreas Jordt, and Pattie Maes. “Flexpad: Highly Flexible Bending Interactions for Projected Handheld Displays”.

[11] Aneesh P. Tarun et al. “PaperTab: An Electronic Paper Computer with Multiple Large Flexible Electrophoretic Displays”.

[12] Jun-ichiro Watanabe, Arito Mochizuki, and Youichi Horry. “Bookisheet: Bendable Device for Browsing Content Using the Metaphor of Leafing Through the Pages”.