ACM ITS 2012
INTERACTIVE TABLETOPS & SURFACES

Beyond Flat Displays

Towards Shaped and Deformable Interactive Surfaces

Tutorial at ACM ITS 2012

Jürgen Steimle, Daniel Leithinger, Pol Pla
MIT Media Lab

Hrvoje Benko
Microsoft Research

SHAPED DISPLAYS

Pol Pla and Hrvoje Benko

Novel Form Factors

or the world is not flat

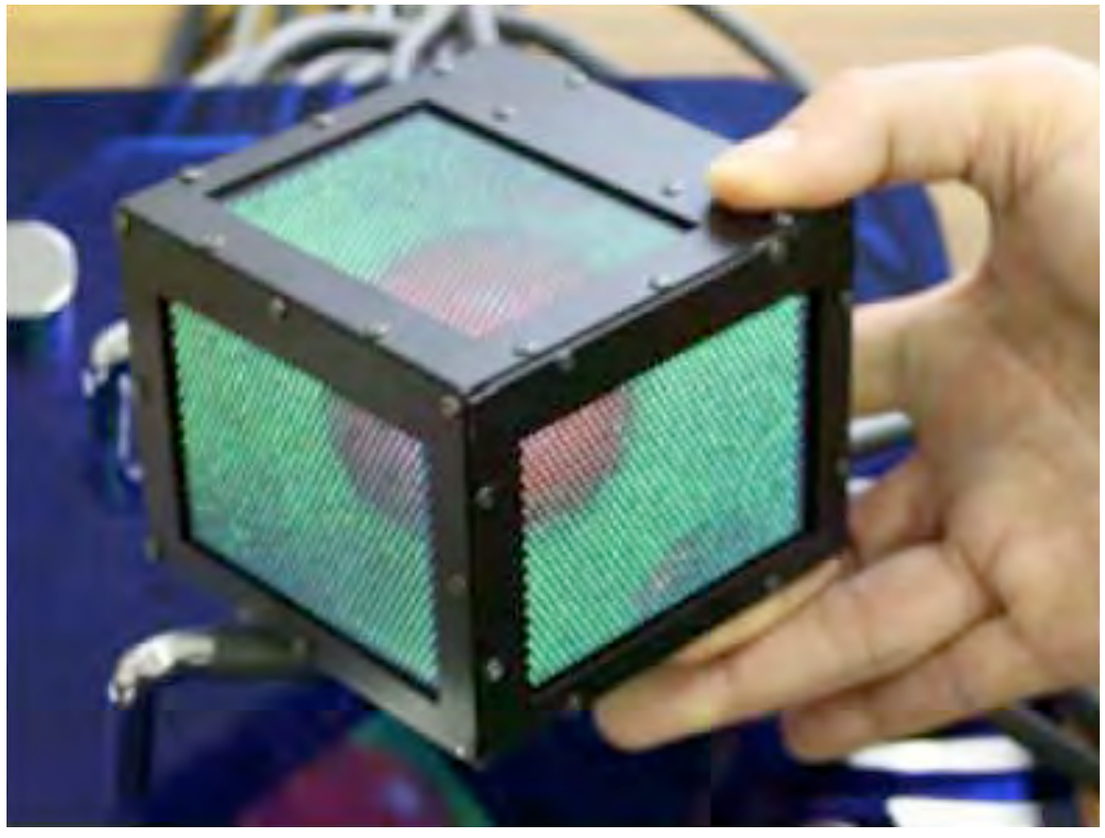
BendDesk
Malte Weiss, Simon Voelker, and Jan Borchers

Samsung SDI Bracelet

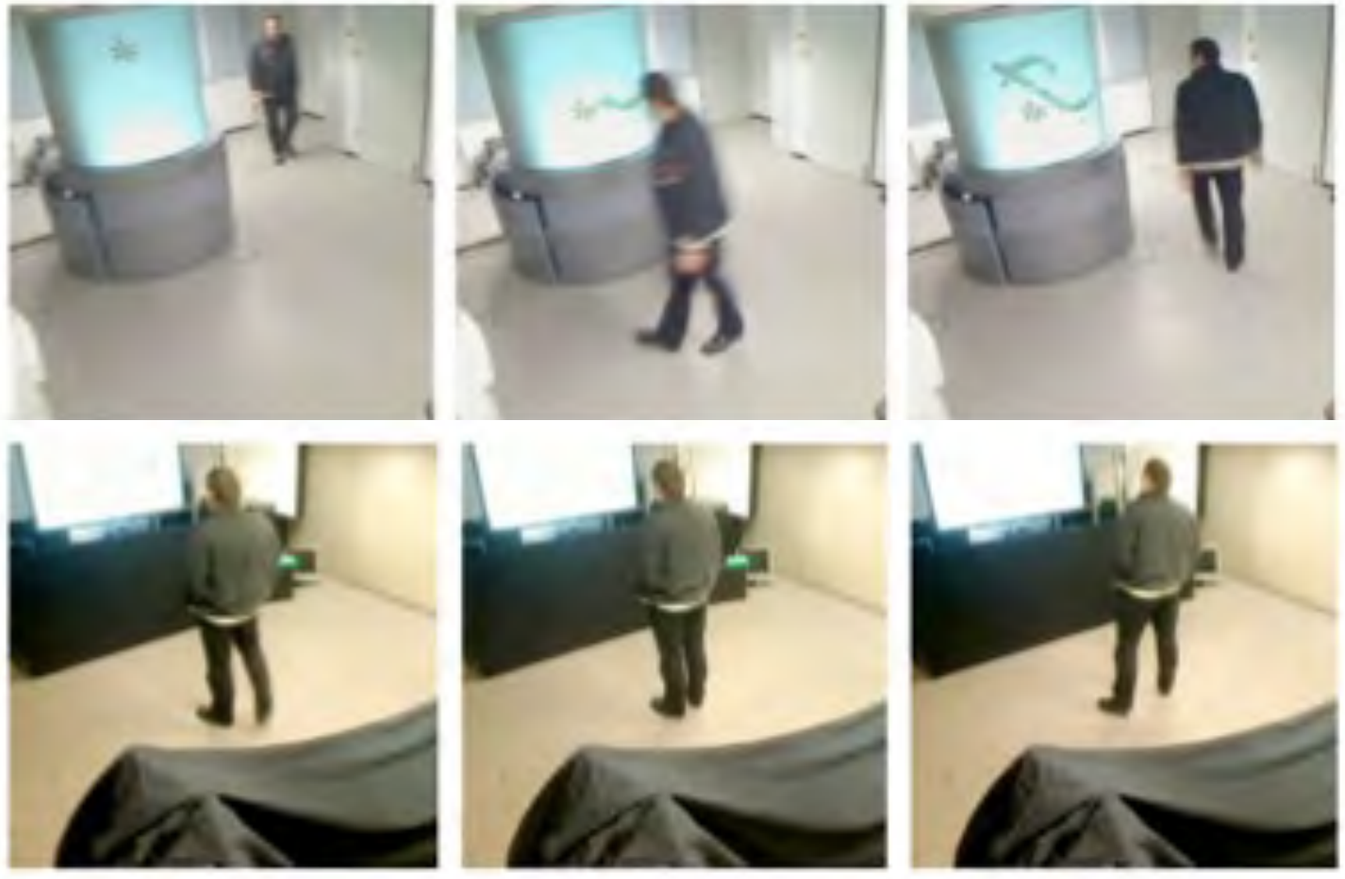
Facet: A Multi-Segment Wrist Worn System
Kent Lyons, David. H. Nguyen, Daniel Ashbrook, Sean White

Microsoft Sphere
Hrvoje Benko, Andy Wilson, Ravin Balakrishnan, Billy Chen

pCubee
I Stavness, B Lam, S Fels

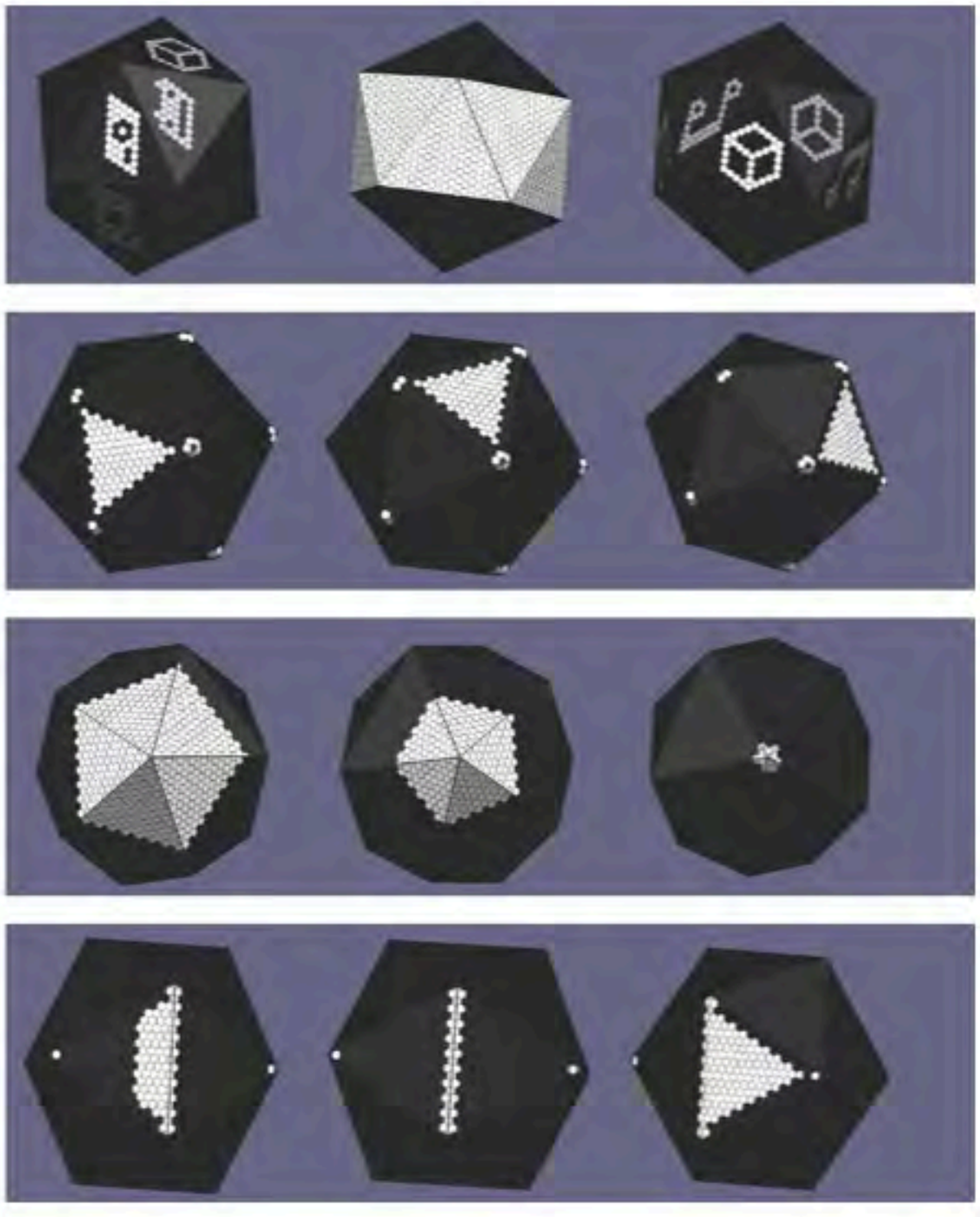


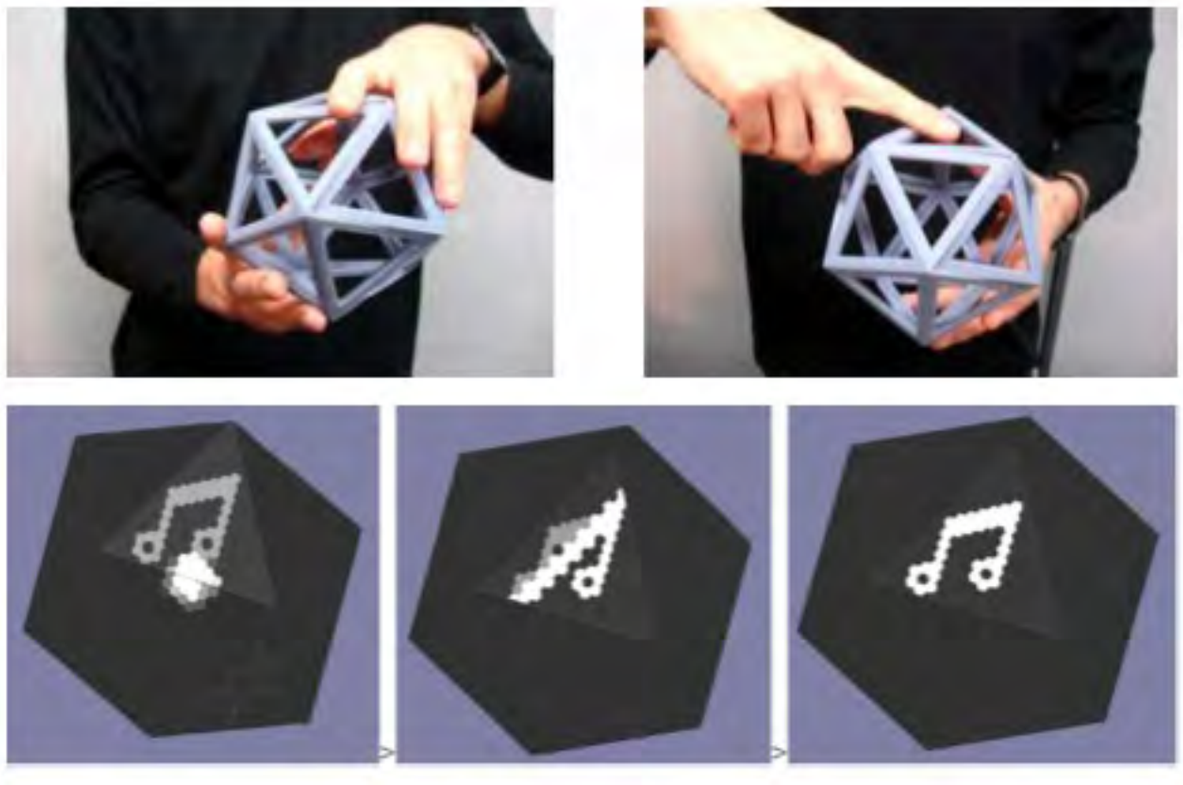
GCubik
R Lopez-Gulliver, S Yoshida, S Yano, N Inoue



Audience Behavior around Large Interactive Cylindrical Screens

Gilbert Beyer, Florian Alt, Jörg Müller, Albrecht Schmidt, Karsten Isakovic, Stefan Klose, Manuel Schiewe, Ivo Haulsen





D20

Ivan Poupyrev, Henry Newton-Dunn, Olivier Bau

Display Blocks
Pol Pla and Pattie Maes

“Beyond Flat Displays” @ Microsoft Research

Hrvoje Benko

Microsoft Research – Nov. 11, 2012

Two research directions

New display forms

Interactivity everywhere

In common: projector + (depth) camera

New Display Forms

Sphere

Benko, Wilson, Balakrishnan, UIST 2008.

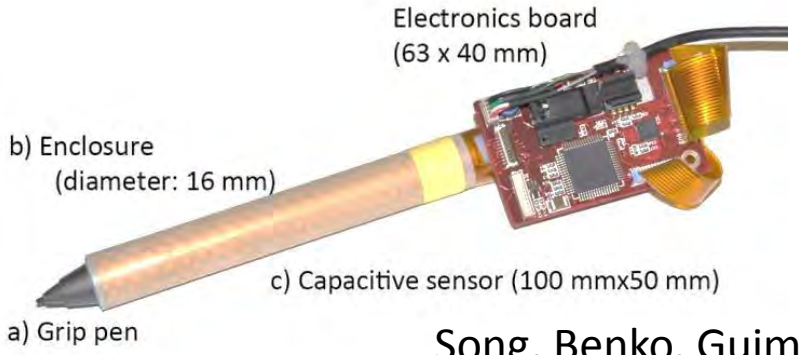
Pinch-the-Sky Dome

Benko & Wilson, ITS 2010.

Mouse 2.0

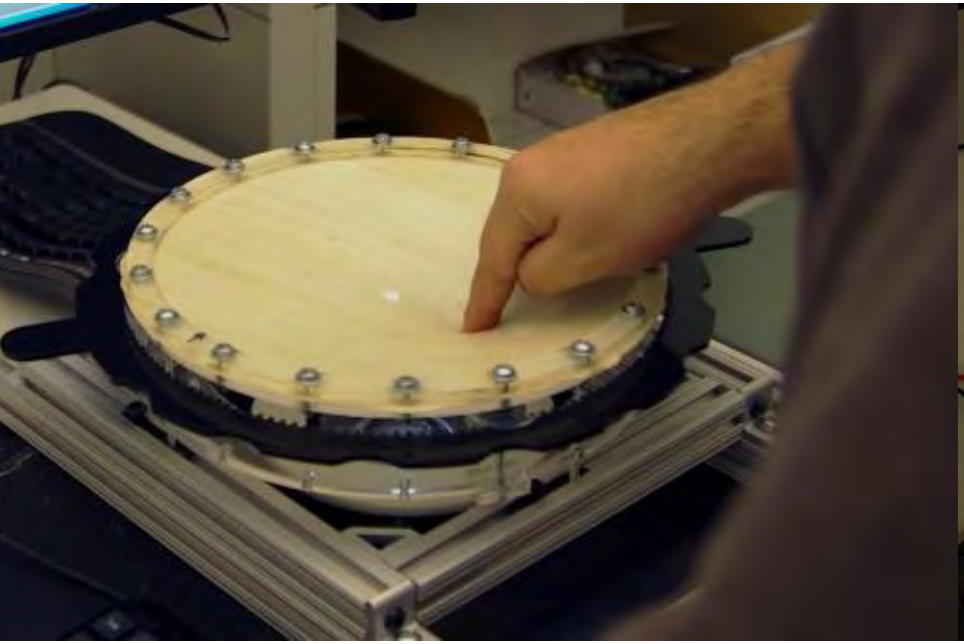
Villar, Izadi, Rosenfeld, Benko, Helmes, Westhues, Hodges, Ofek, Butler, Cao & Chen, UIST 2009

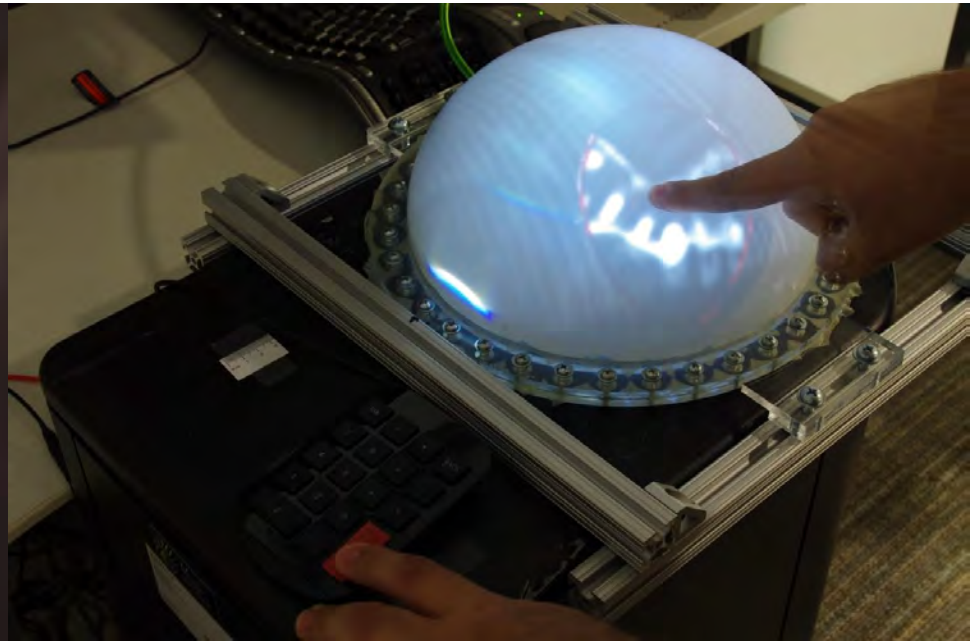
MultiTouch Pen



Song, Benko, Guimretiere, Izadi, Cao & Hinckley, CHI 2011.

Deformable Curved Displays





Bacim, Sinclair & Benko, ITS 2012

What are curved surfaces good for?

It depends…

If data matches shape

- Great

If viewing 2D data

- Probably worse

If viewing a 3D scene

- No different than flat displays

If exploiting some unique capability

- Potentially much better!

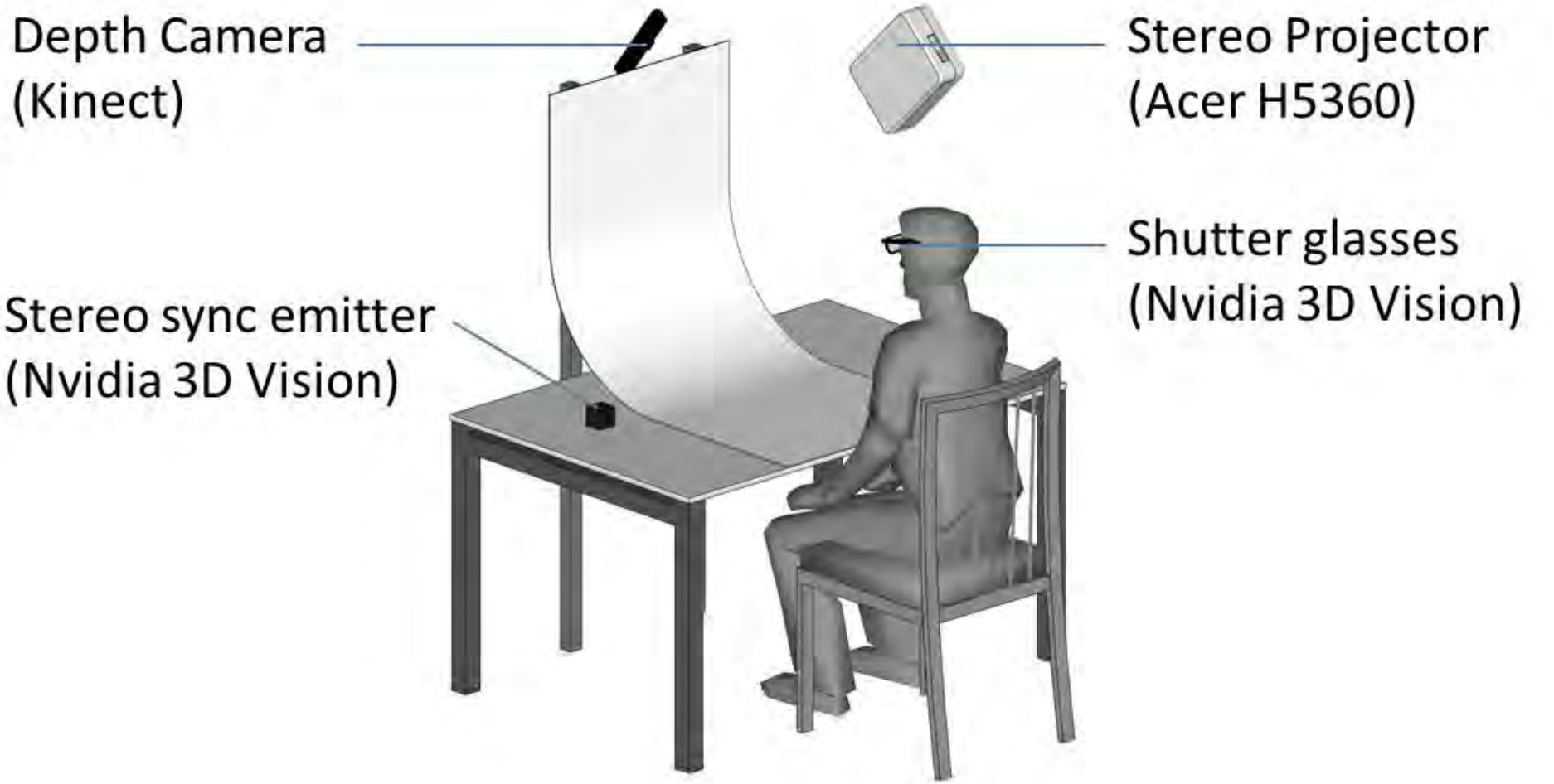
Sphere Unique Characteristics

- Non-visible hemisphere
- Visibility changes with position
  - “Pseudo-private” and “public” areas
- No master user position / orientation
- Borderless, but finite display
- Few natural landmarks: poles
- Smooth transitions in depth and orientations
  - Near – far
  - Horizontal – vertical

MirageTable

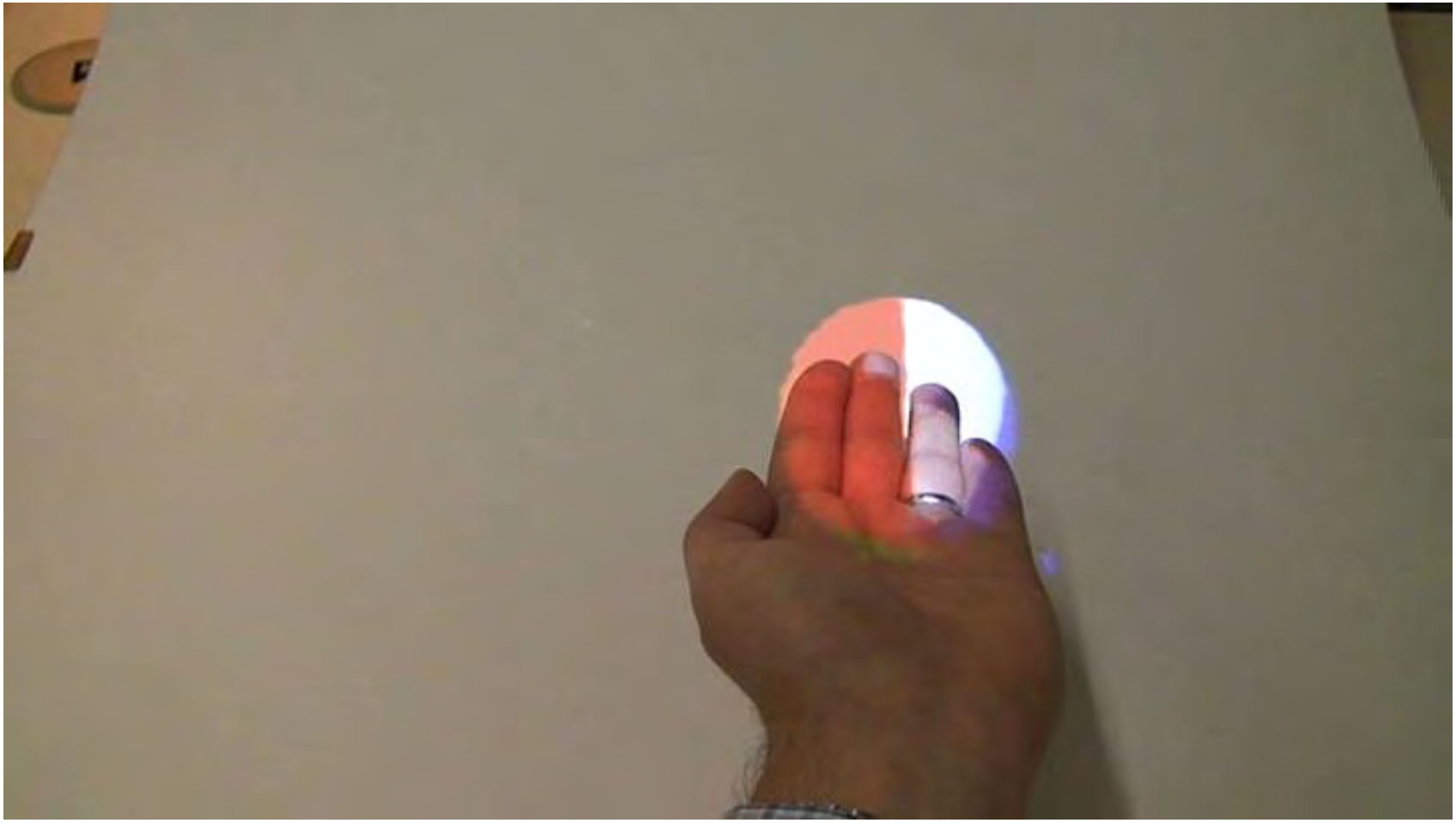
Benko, Jota, Wilson, CHI 2012

MirageTable



Benko, Costa, and Wilson, CHI 2011

3D in your hand



Benko, Jota, Wilson, CHI 2012

Interactivity everywhere

What if you could use any available surface (including your body) as an *interactive* surface?

Rather than *reach* for a device…

simply *touch* where you want to see information…

and *interact* with it.

LightSpace

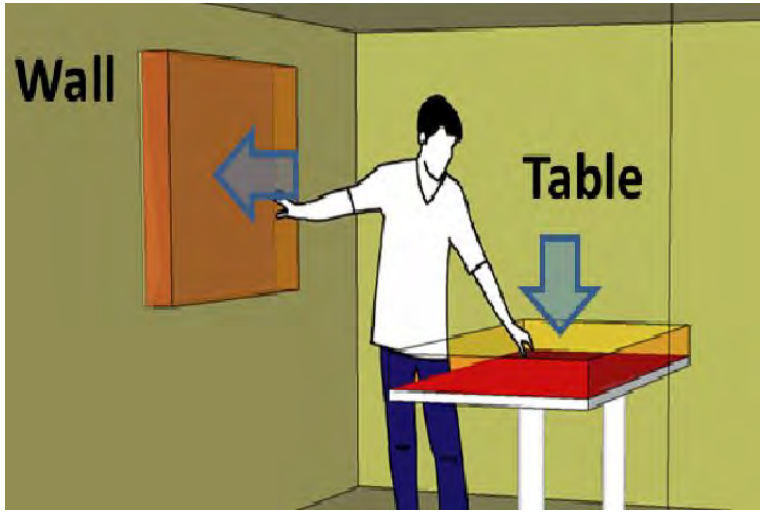
Combining Multiple Depth Cameras and Projectors for Interactions On, Above, and Between Surfaces

Wilson & Benko, ACM UIST, 2010

How to get the surface?

Analytic Approach

- Problems:
  - Slight variation in surface flatness
  - Slight uncorrected lens distortion effect in depth image
  - Noise in depth image



How to get the surface?

Empirical Approach

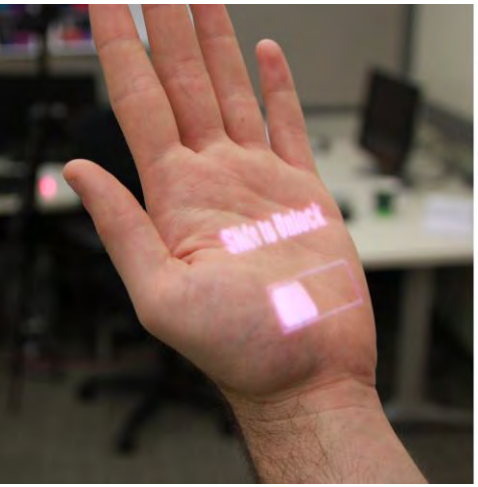
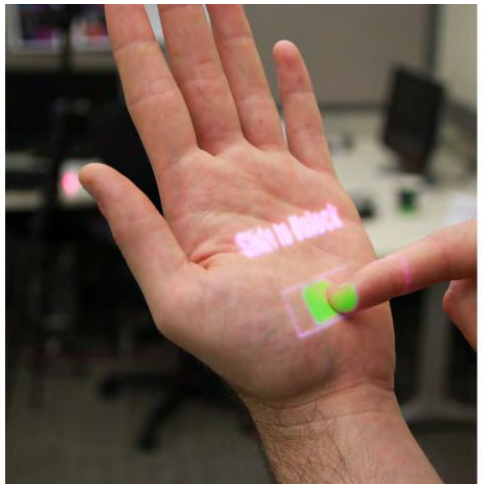
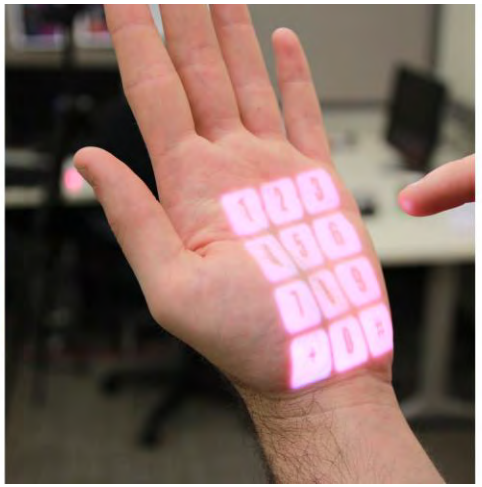
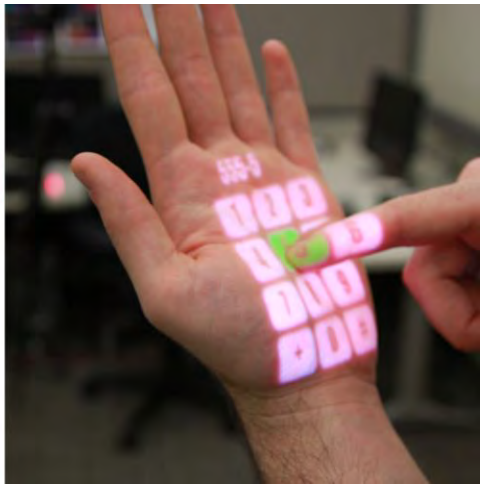
- Take per-pixel statistics of the empty surface

KinectTouch

Wilson, ACM ITS 2010

But this works for static surfaces only!

What about dynamic surfaces?

~~How to get the surface?~~

~~What is a surface?~~

Can we track the finger?

- Hard in general
- Simple from a body-centric perspective

OmniTouch

Wearable Multitouch Interaction Everywhere

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Andrew Wilson
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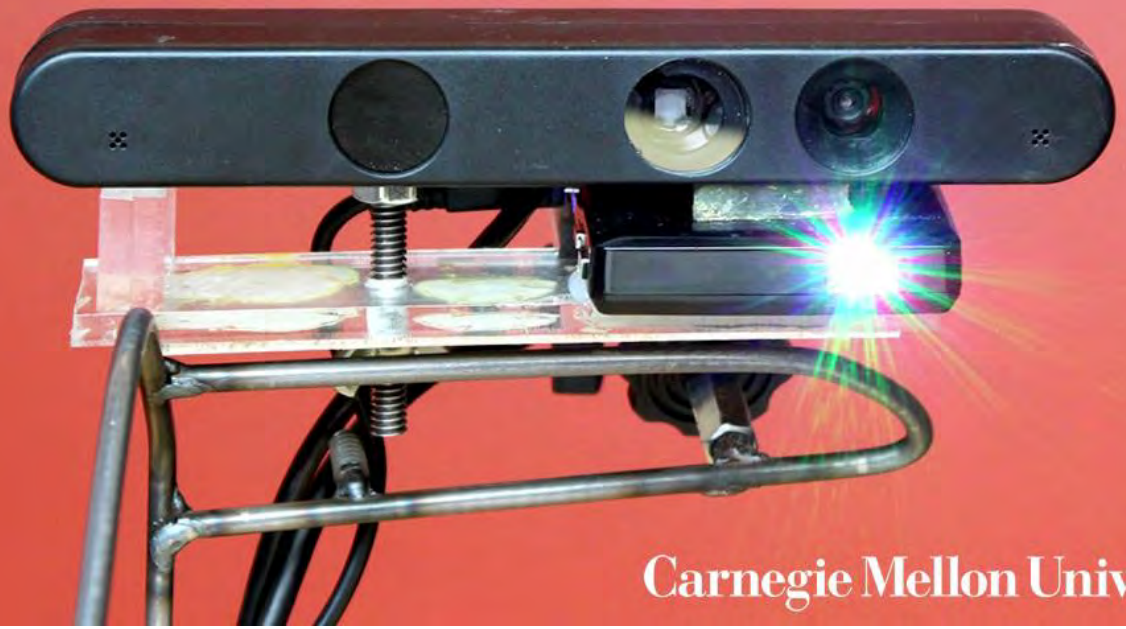
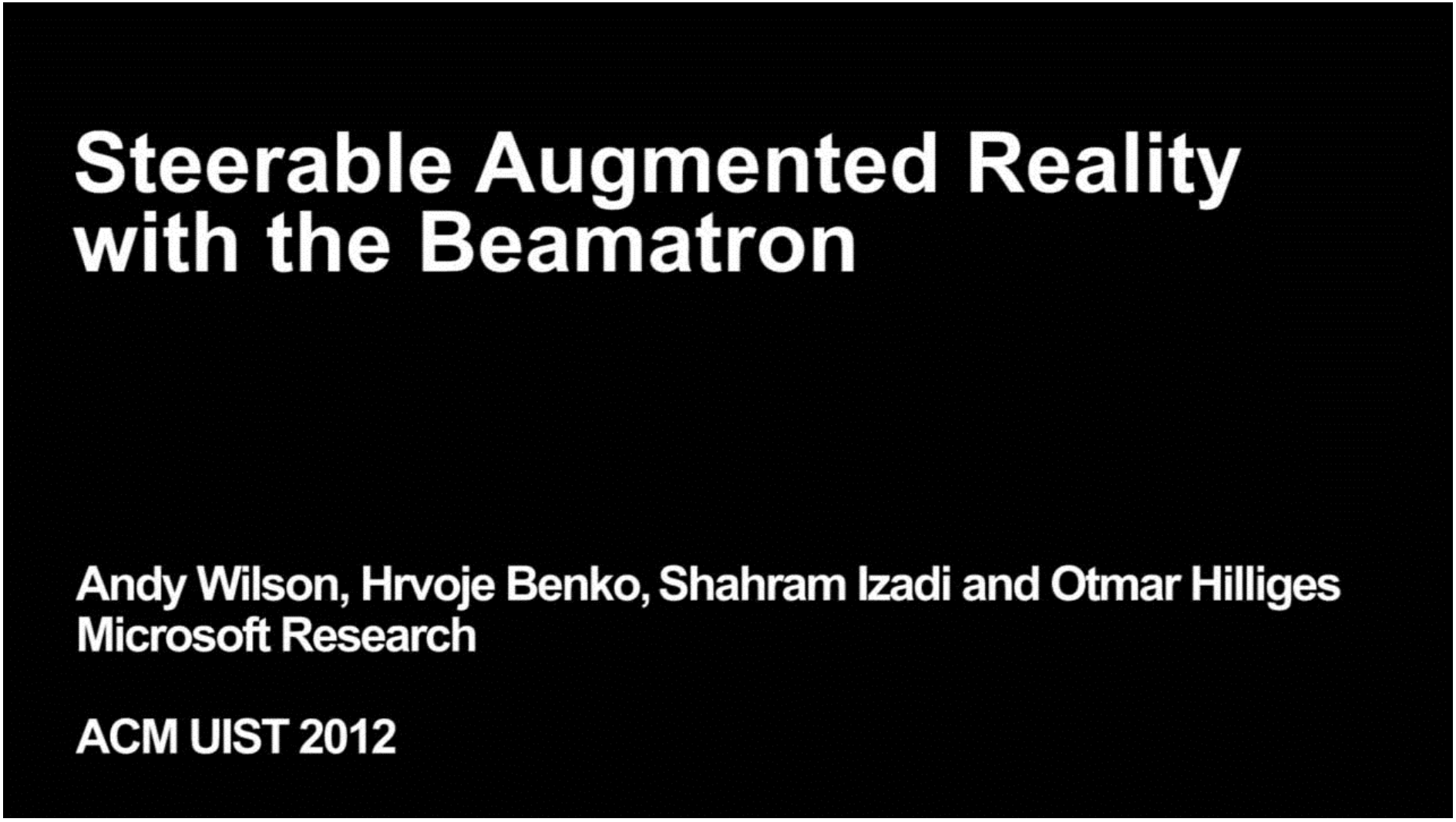


Microsoft

Carnegie Mellon University

Harrison, Benko, and Wilson, ACM UIST 2011

Beamatron


Steerable Augmented Reality
with the Beamatron
Andy Wilson, Hrvoje Benko, Shahram Izadi and Otmar Hilliges
Microsoft Research
ACM UIST 2012

FLEXIBLE DISPLAYS

Jürgen Steimle

Technology Trends

Flexible e-paper and OLED displays are the most promising technologies for general-purpose displays.

Projection is likely to play an important role for providing in-situ information by visually augmenting physical objects.

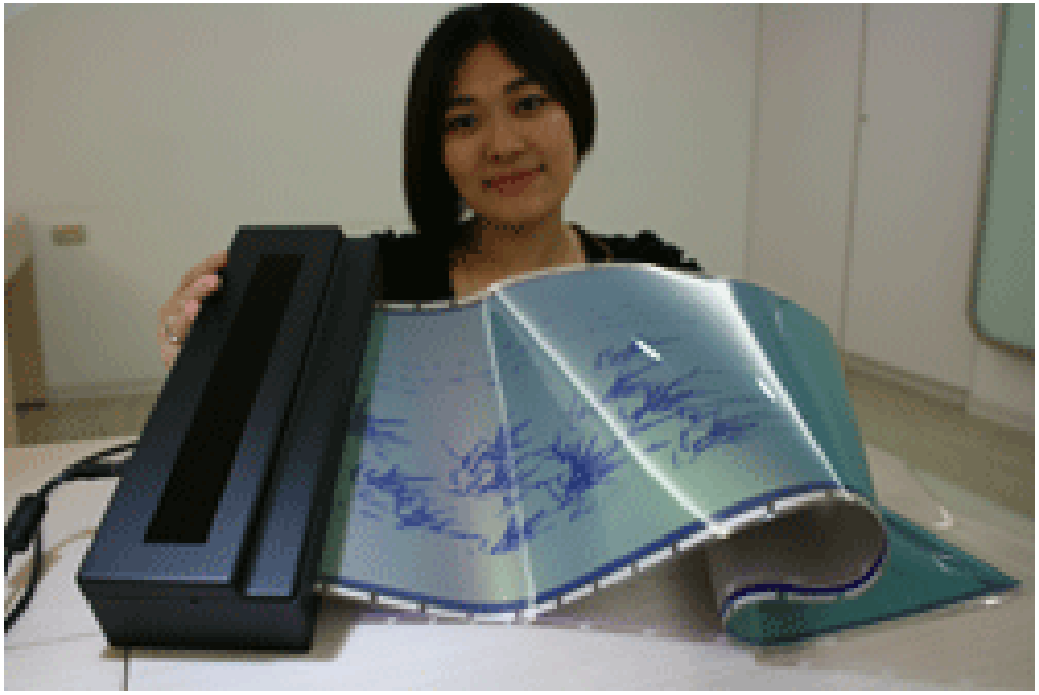
There are some other technologies that have potential to support more specific use cases.

Flexible ePaper

Sony, 2011

Flexible ePaper

LG, 2010



ITRI, 2011

Flexible OLED

Samsung, 2011

Flexible OLED

Samsung, 2009

Sony, 2010

LEDs in Textiles

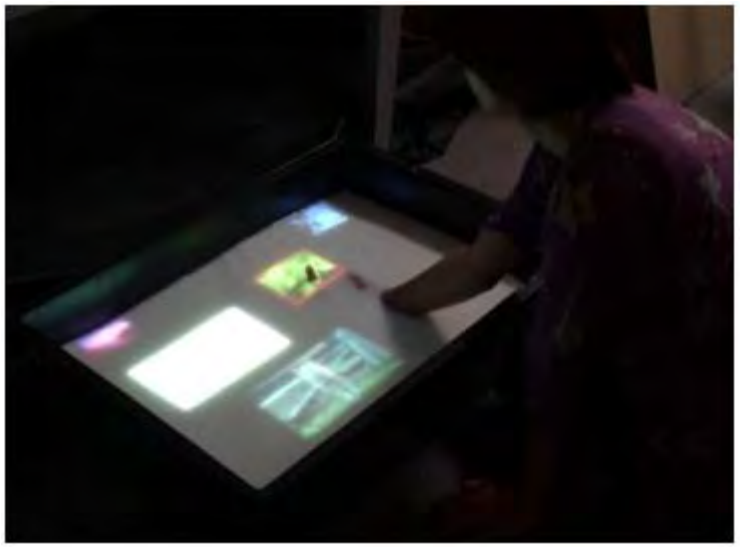
Philips Lumalive, 2006

Thermochromic Ink

Saakes et al.: Shader Printer, 2012

Projection

Cassinelli et al.:
SkinGames, 2012



Takahashi et al.:
Fluid Surface, 2012

Mistry et al.:
Sixth Sense, 2009

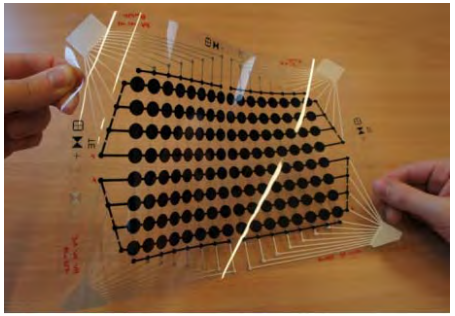
Flexible Sensing

Deformation

Surface Input

External

Internal



E.g.

Omnitouch (UIST'11)

Jamming User Interfaces (UIST'12)

E.g. printed:

Ink-jet Printed Ubiquitous Sensing (UbiComp'11)

PyzoFlex (UIST'12)

optical:

Twend (CHI'08)

FlexAura (UIST'12)

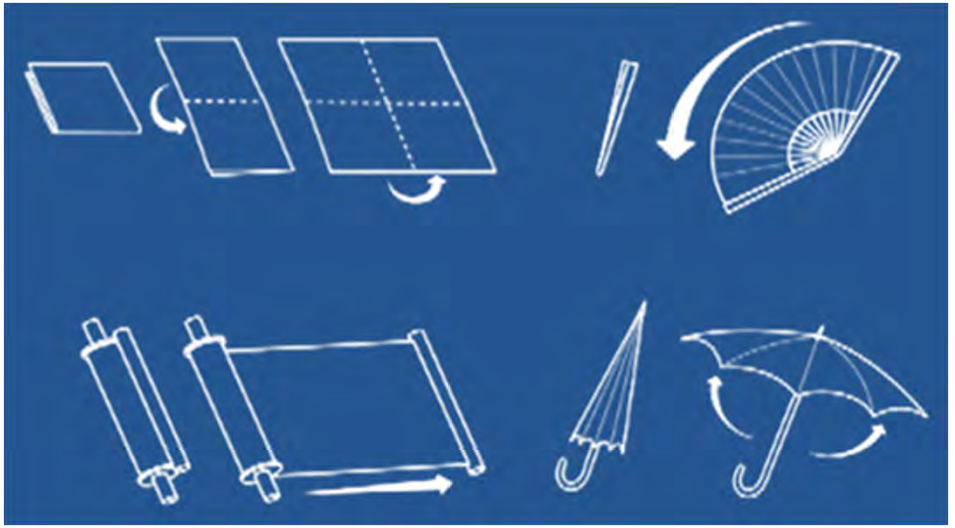
Stretchable sensor (UIST'12)

INTERACTION

Flexible displays allow for

- Incorporating displays into objects previously not compatible with displays (e.g. textiles)
- Highly portable devices
- Malleable devices that adapt their shape to the current functionality
- Paper-like/paper-inspired interfaces that draw upon the affordances of paper
- More expressive, more varied ways of interaction and presentation of information
- + … ?

Portability and Ergonomic Use



Lee et al.: Foldable Interactive Displays, UIST'08

Nokia Morph Concept

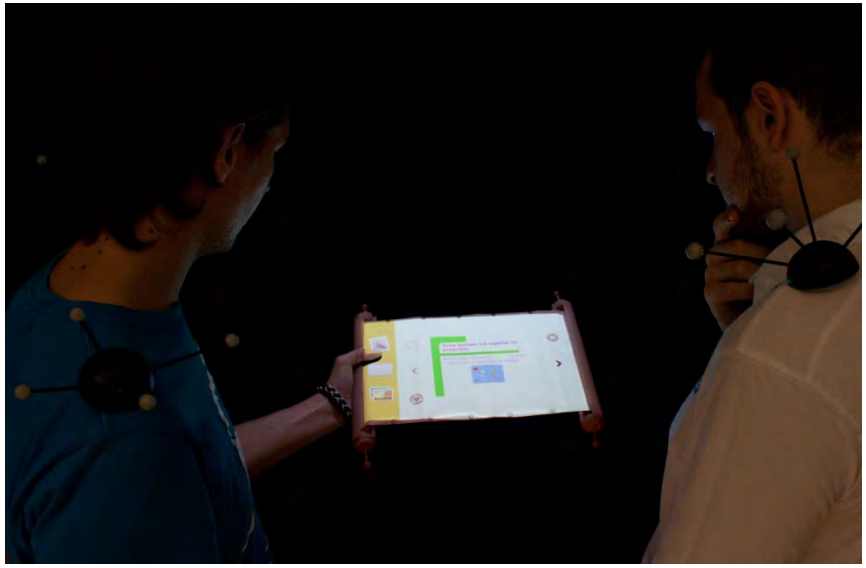
Reconfigurable Devices: Folding

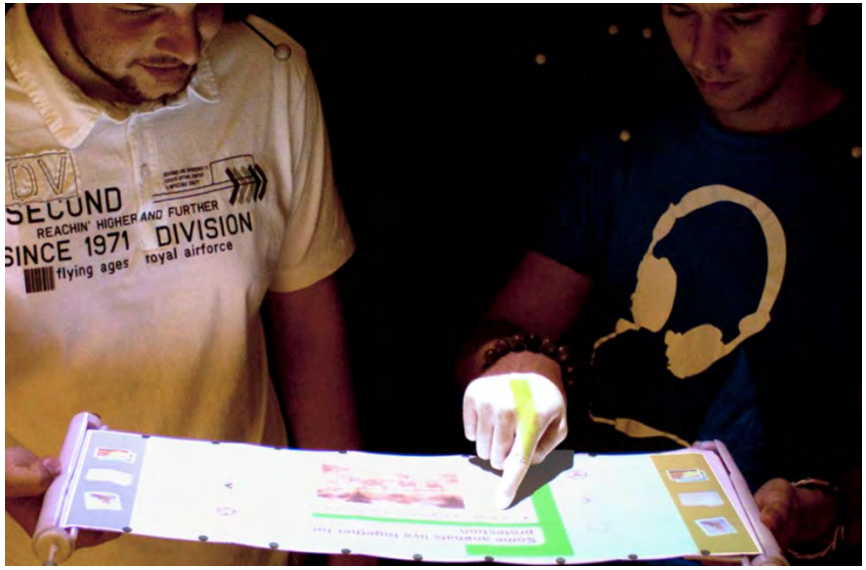
OLPC xo-2, 2008

Reconfigurable Devices: Rolling out

Khalilbeigi et al.: Xpaaand, CHI'11

Reconfigurable Devices: Rolling out





Steimle and Olberding: Handheld Tabletop, CHI'12

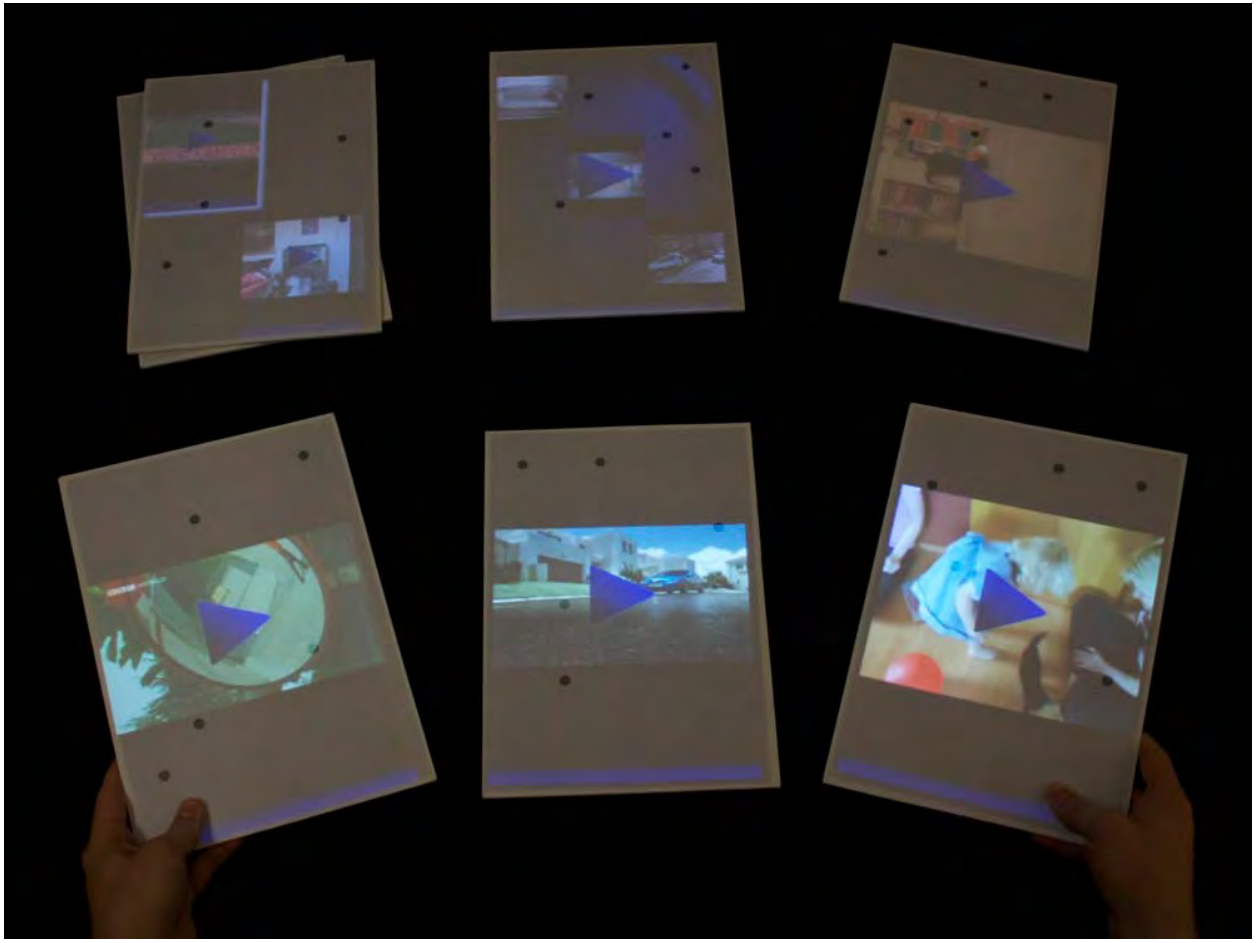
Paper-like Interactions

Holman et al.: PaperWindows, CHI'05

Paper-like Interactions: Stacking

Girouard et al.: DisplayStacks, CHI'12

Paper-like Interactions: Arranging



Lissermann et al: PaperVideo, ACM Multimedia, 2012

Paper-like Interactions: Folding

Khalilbeigi et al.: FoldMe, TEI'12

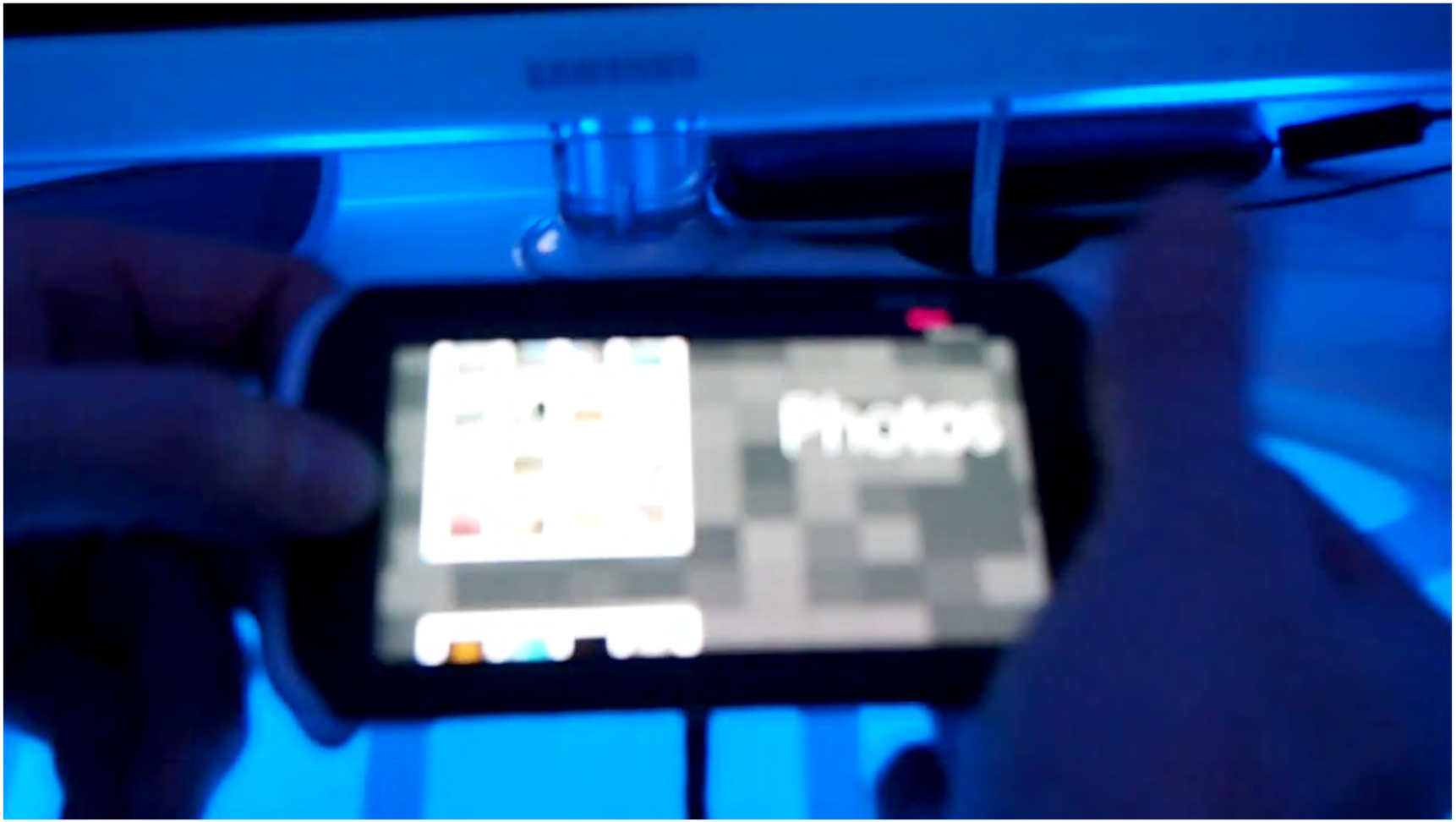
Navigation by Bending

Schwesig et al.: Gummi, CHI'04

Navigation by Bending

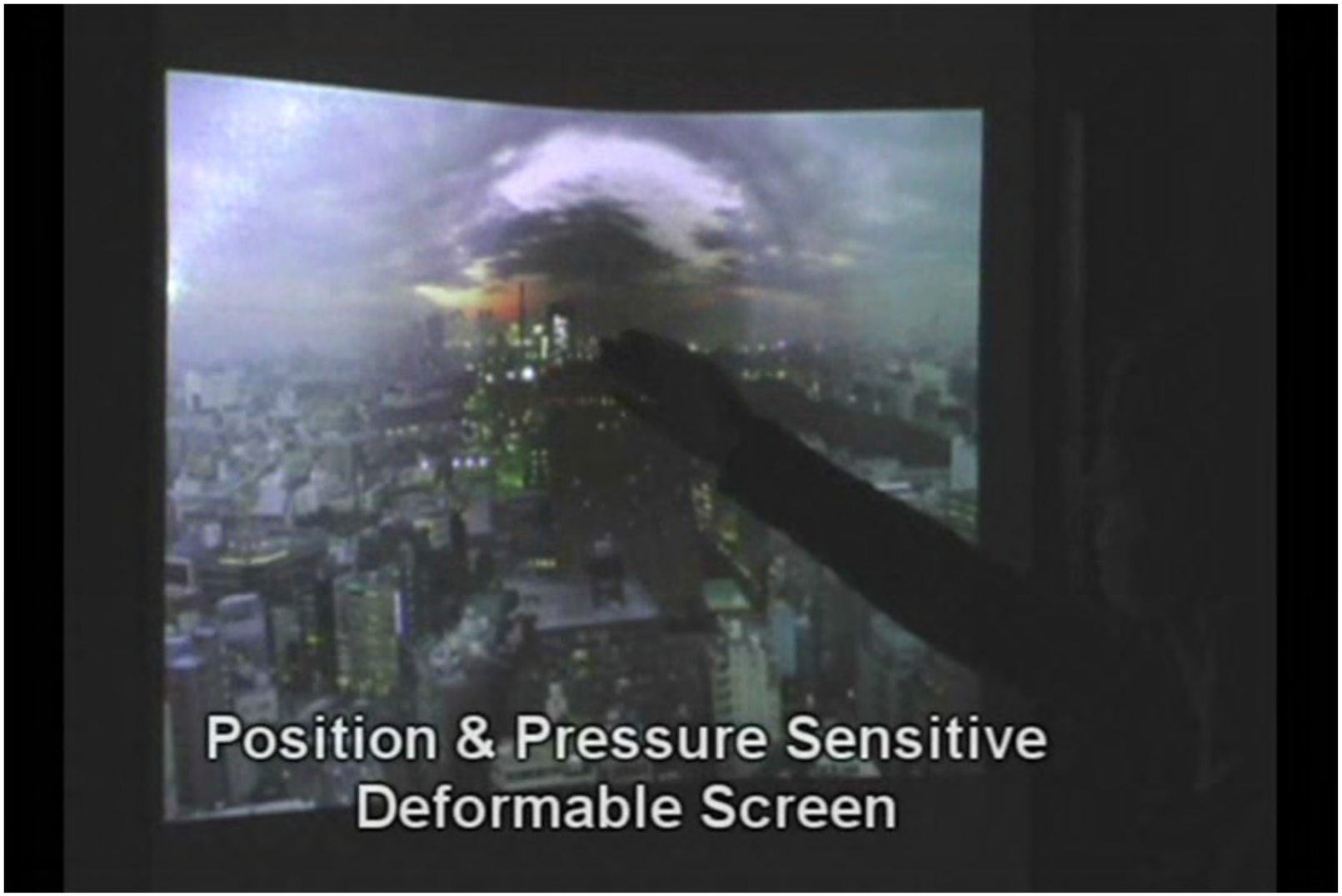
Lahey et al.: PaperPhone, CHI'11

Navigation by Bending



Nokia Kinetic, 2011

Navigation by Bending



Cassinelli and Ishikawa: Khronos Projector, 2005

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Nan-Wei Gong, Steve Hodges, and Joseph A. Paradiso. 2011. Leveraging conductive inkjet technology to build a scalable and versatile surface for ubiquitous sensing. In *Proceedings of the 13th international conference on Ubiquitous computing* (UbiComp '11).\

Christian Rendl, Patrick Greindl, Michael Haller, Martin Zirkl, Barbara Stadlober, and Paul Hartmann. 2012. PyzoFlex: printed piezoelectric pressure sensing foil. In *Proceedings of the 25th annual ACM symposium on User interface software and technology* (UIST '12).

Gero Herkenrath, Thorsten Karrer, and Jan Borchers. 2008. Twend: twisting and bending as new interaction gesture in mobile devices. In *CHI '08 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '08).

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Munehiko Sato, Ivan Poupyrev, and Chris Harrison. 2012. Touché: enhancing touch interaction on humans, screens, liquids, and everyday objects. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12).

Johnny C. Lee, Scott E. Hudson, and Edward Tse. 2008. Foldable interactive displays. In*Proceedings of the 21st annual ACM symposium on User interface software and technology*(UIST '08).

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David Holman, Roel Vertegaal, Mark Altosaar, Nikolaus Troje, and Derek Johns. 2005. Paper windows: interaction techniques for digital paper. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '05).

Audrey Girouard, Aneesh Tarun, and Roel Vertegaal. 2012. DisplayStacks: interaction techniques for stacks of flexible thin-film displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12).

Roman Lissermann, Simon Olberding, Benjamin Petry, Max Mühlhäuser, Jürgen Steimle. 2012. PaperVideo: Interacting with Videos On Multiple Paper-like Displays. Proceedings of ACM Multimedia (MM'12)

Mohammadreza Khalilbeigi, Roman Lissermann, Wolfgang Kleine, and Jürgen Steimle. 2012. FoldMe: interacting with double-sided foldable displays. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction* (TEI '12)

Carsten Schwesig, Ivan Poupyrev, and Eijiro Mori. 2004. Gummi: a bendable computer. In*Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '04).

Byron Lahey, Audrey Girouard, Winslow Burleson, and Roel Vertegaal. 2011. PaperPhone: understanding the use of bend gestures in mobile devices with flexible electronic paper displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*(CHI '11).

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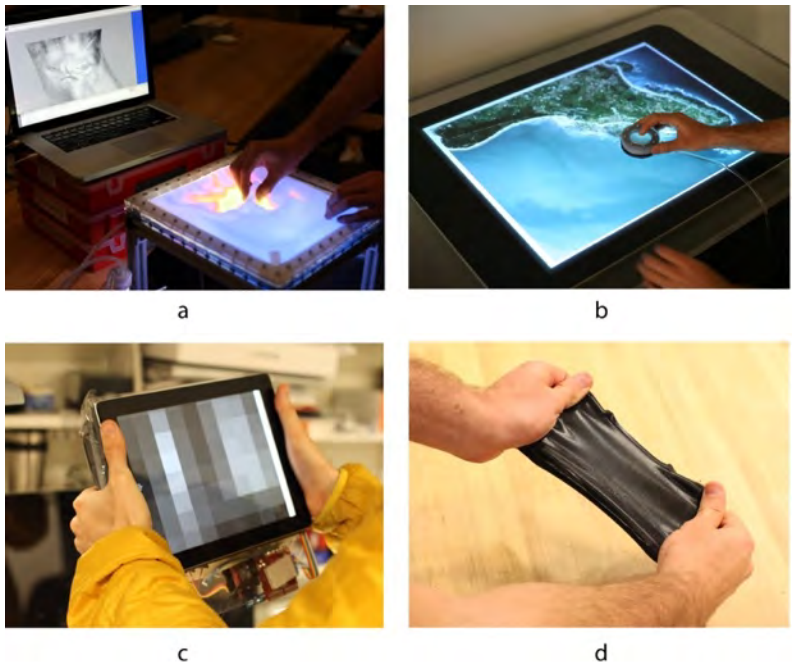
ACTUATED DISPLAYS

Daniel Leithinger

Daniel Leithinger
Tangible Media Group (MIT Media Lab)

Shape Output

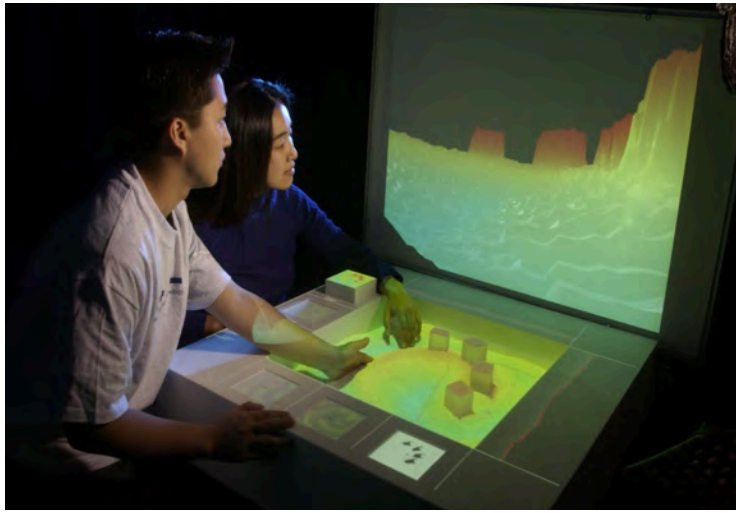
Material Properties



Bend, stretch, fold, shape, ...

Nokia Morph

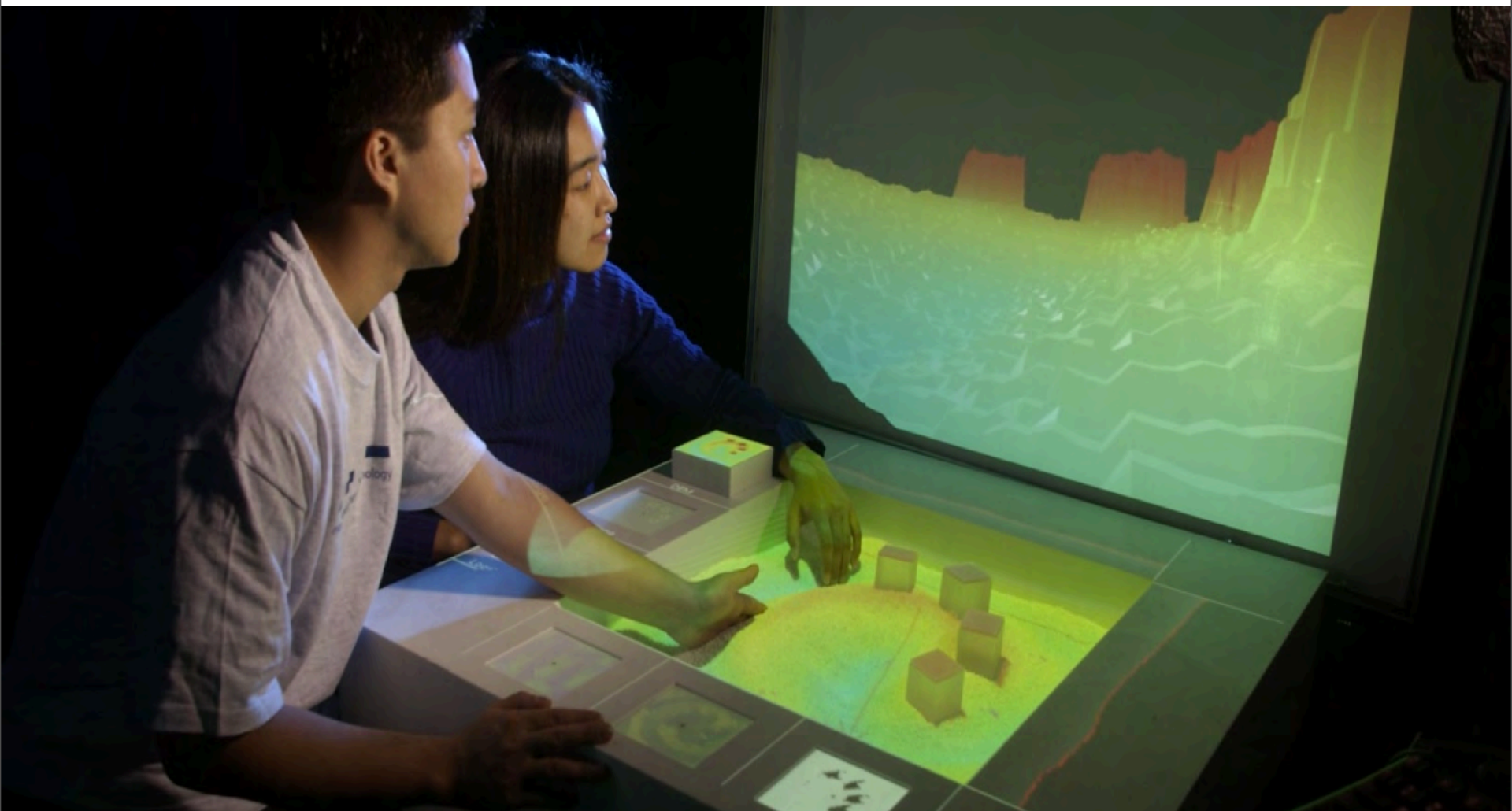
Surface 2



Illuminating Clay [Piper et al. 2002]
SandScape [Wang et al. 2003]

Illuminating Clay, SandScape

Ben Piper, Carlo Ratti, Yao Wang, Assaf Biderman, Bo Zhu, Saro Getzoyan, Hiroshi Ishii



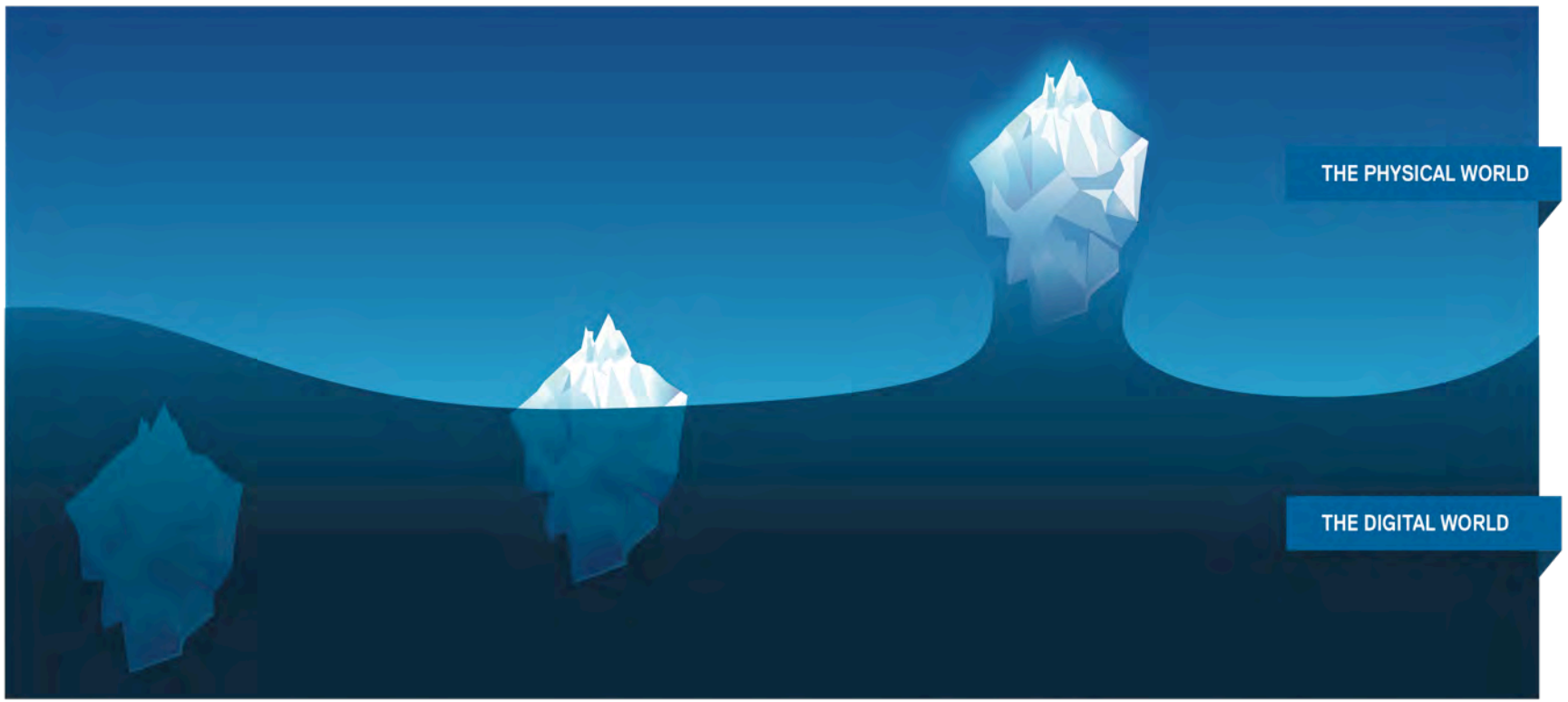
Piper et al. Illuminating clay: a 3-D tangible interface for landscape analysis. CHI ’02

Tangible Media Group Vision:

GUI PAINTED BITS

TUI TANGIBLE BITS

RADICAL ATOMS

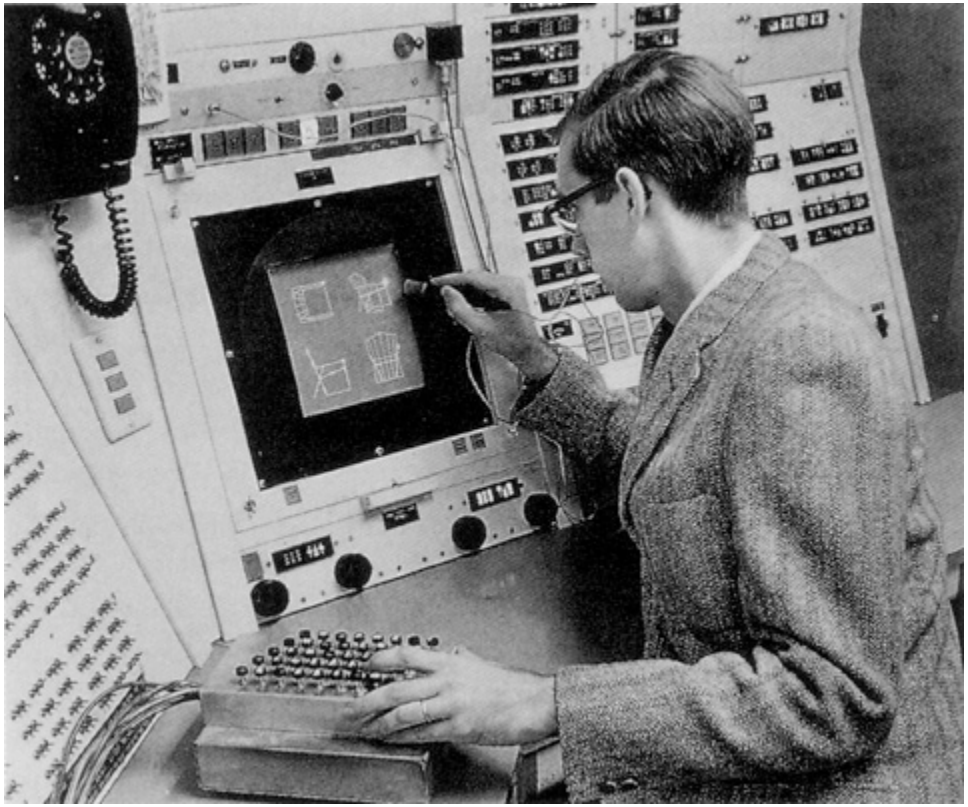


A **graphical user interface** only lets us see information and interact with it indirectly, as if we were looking through the surface of the water to interact with the forms below.

A **tangible user interface** is more like an iceberg: there is a portion of the digital that emerges beyond the surface of the water - into the physical realm - so that we may interact directly with it.

Radical Atoms describes our vision for the future of interaction, in which all digital information has physical manifestation so that we can interact directly with it - as if the iceberg had risen from the depths to reveal its sunken mass.

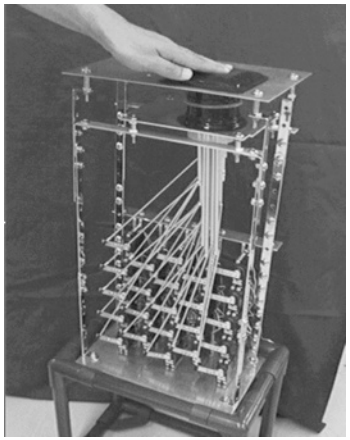
The Ultimate Display



The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.

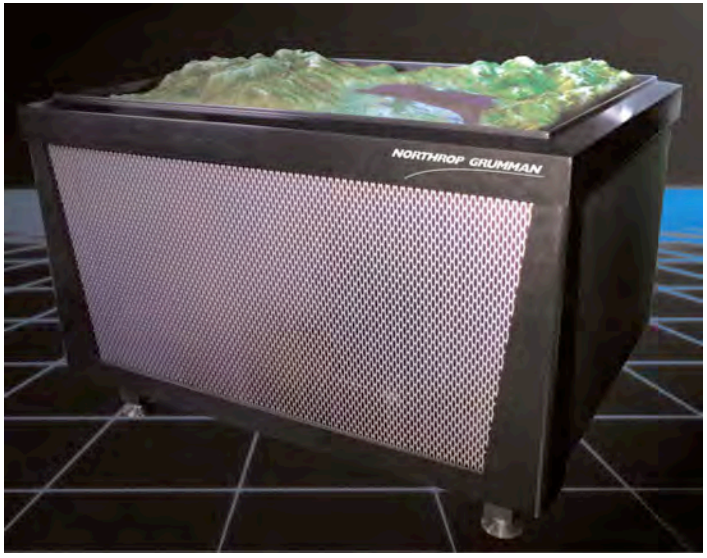
Ivan Sutherland (1965)

Shape Output: Related Work

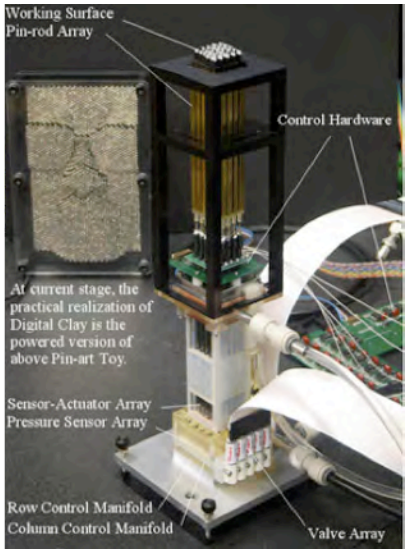


Iwata et al. 2001. Project FEELEX: adding haptic surface to graphics. SIGGRAPH '01.

Poupyrev et al. Lumen



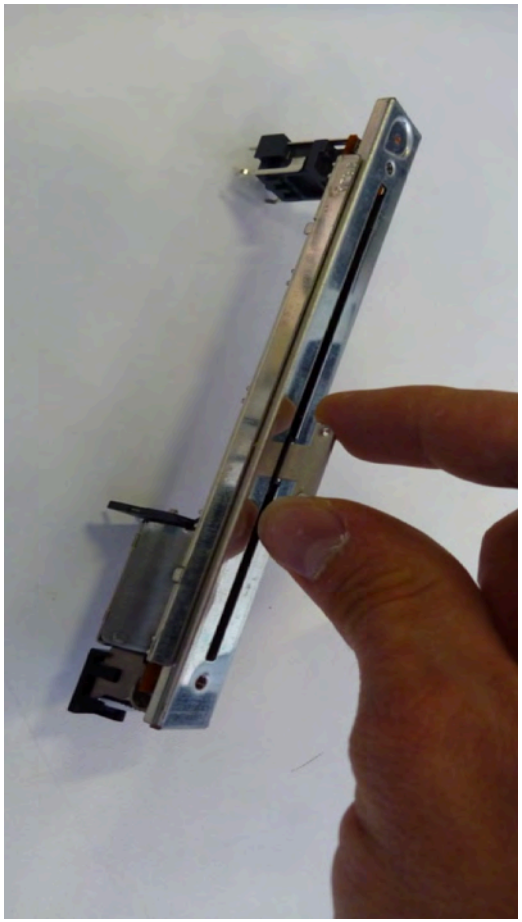
Xenotran XenoVision Mark III

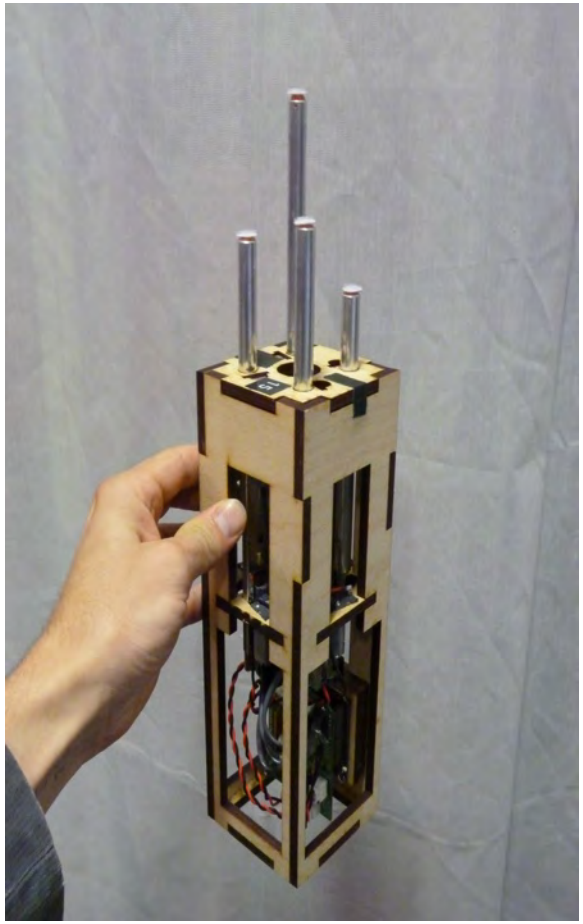


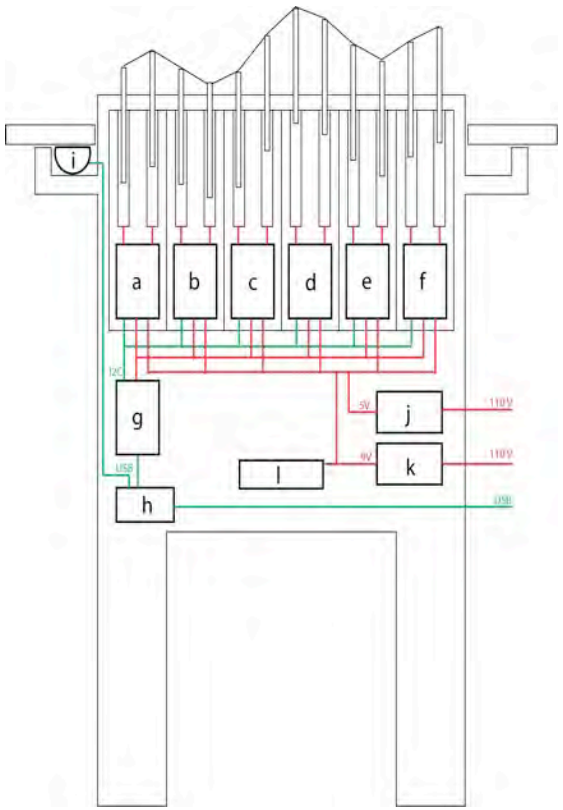
Zhu et. al. 2003. Digital Clay

Relief

Daniel Leithinger, Hiroshi Ishii

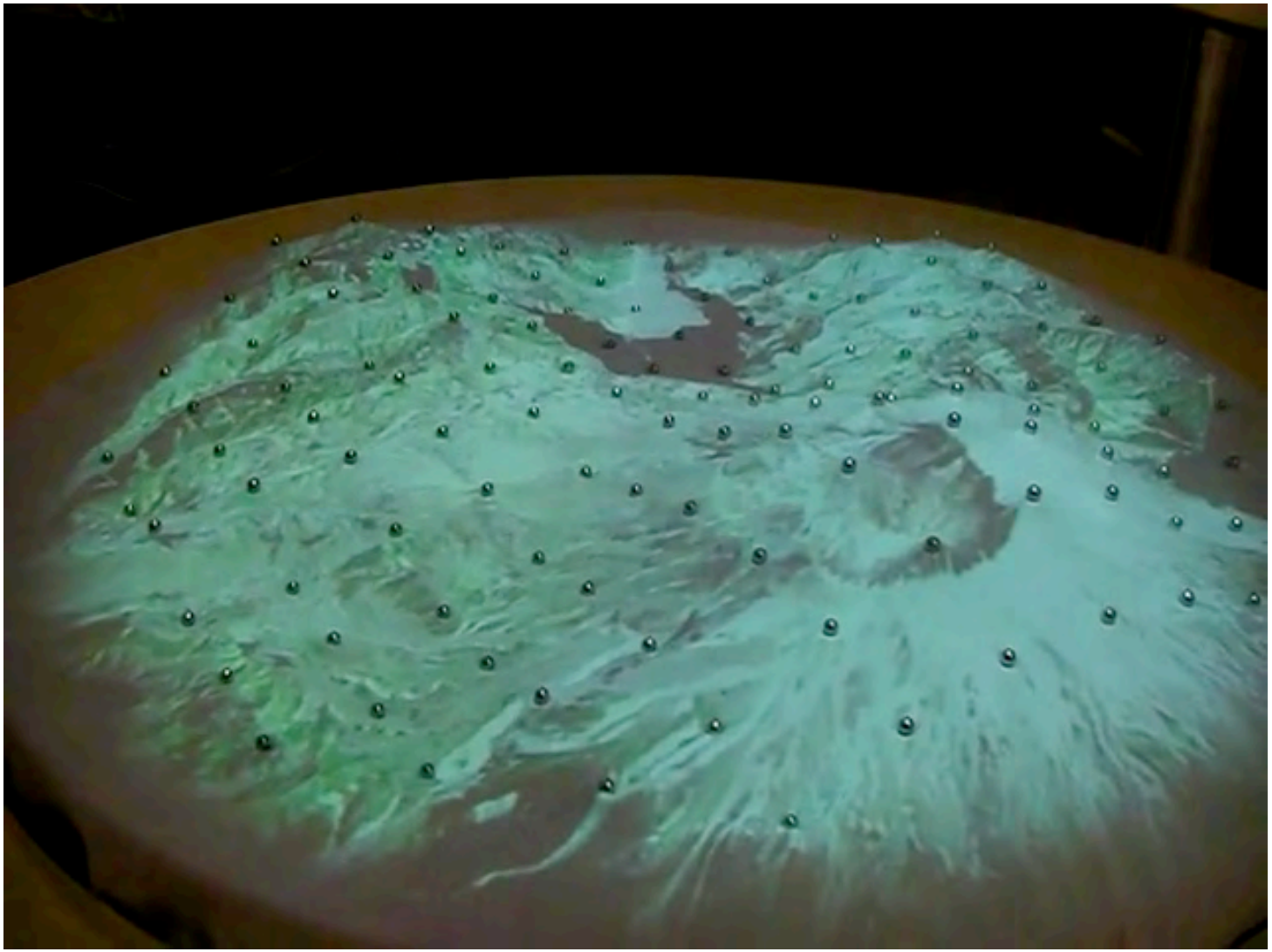






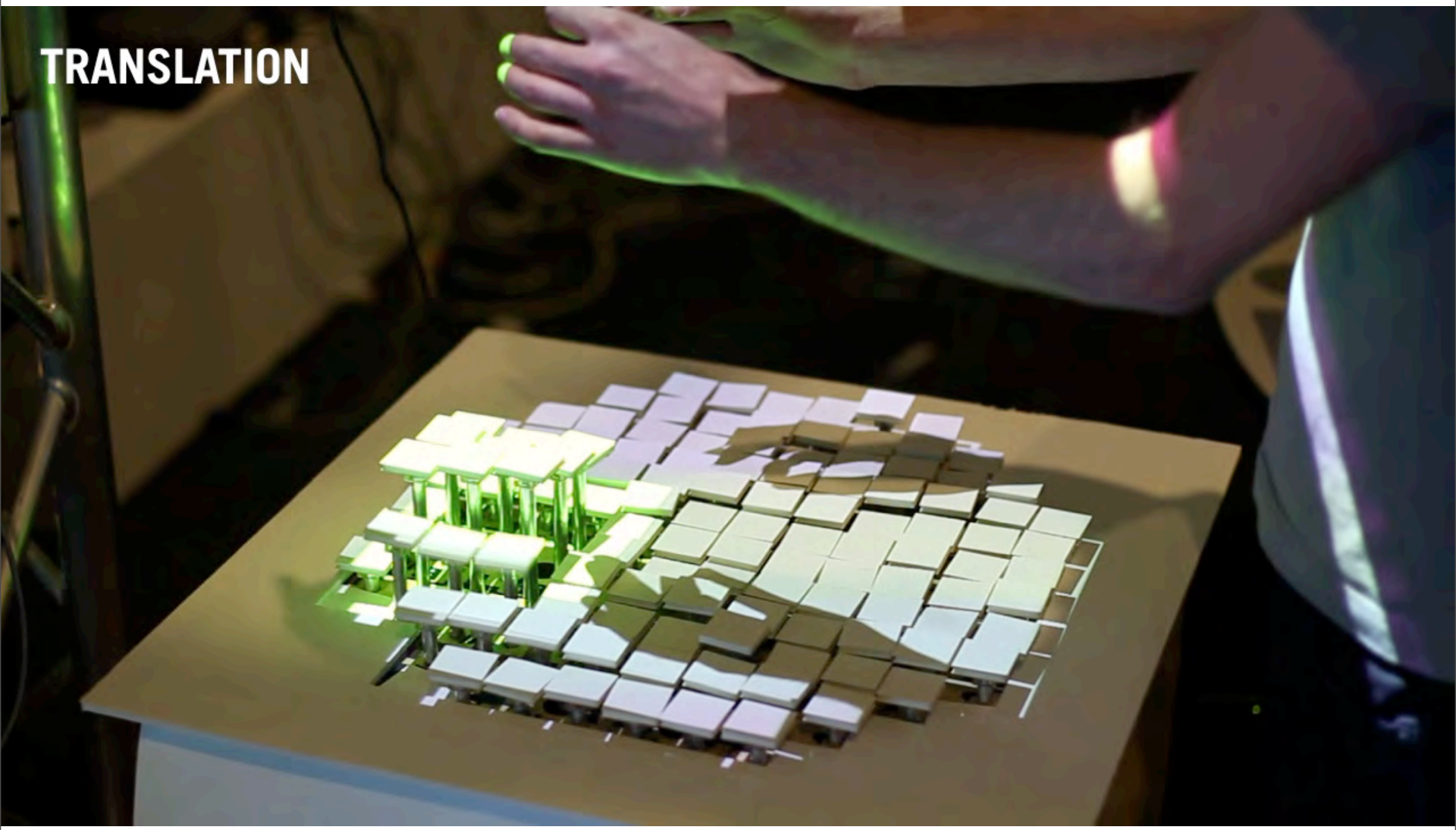
Relief

Daniel Leithinger, Hiroshi Ishii



Recompose

Matt Blackshaw, David Lakatos, Tony DeVincenzi, Daniel Leithinger, Hiroshi Ishii



Material Properties

- Optical Properties
  - Color, Opacity, Reflectivity, Luminosity
- Surface Properties
  - Texture
- Thermal Properties:
  - Temperature, specific heat, Thermal Conductivity
- Electro/Magnetic Properties:
  - Conductivity, Dielectric Properties, Diamagnetism
- Mechanical Properties:
  - Plasticity, Elasticity, Ductility, Hardness, Density, Coefficient of Friction, **Stiffness**

Jamming User Interfaces

Sean Follmer, Daniel Leithinger, Alex Olwal, Nadia Cheng, Hiroshi Ishii

a

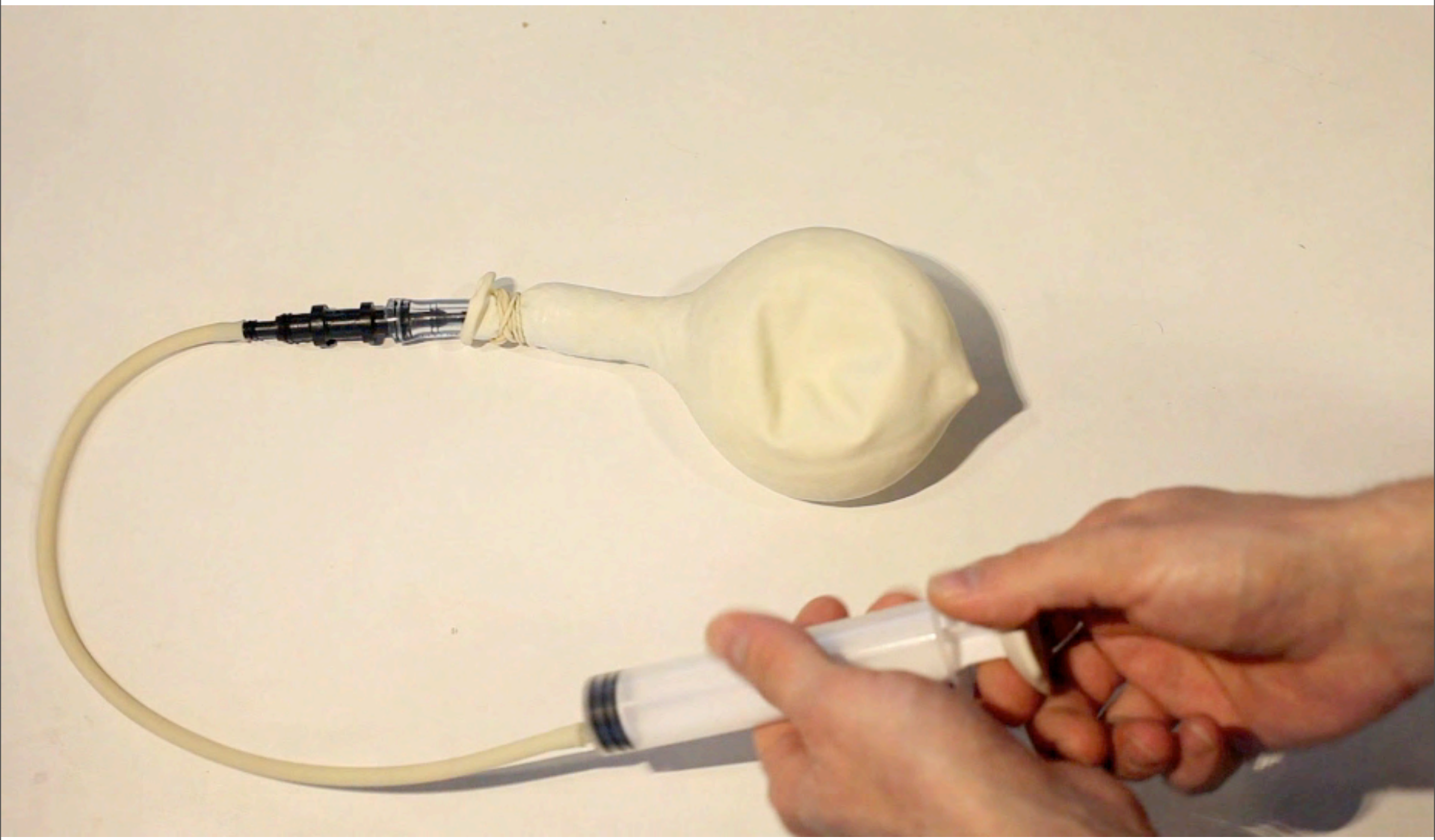
b

c

d

Jamming User Interfaces

Sean Follmer, Daniel Leithinger, Alex Olwal, Nadia Cheng, Hiroshi Ishii



Programmable Affordances

Sean Follmer, Daniel Leithinger, Alex Olwal, Nadia Cheng, Hiroshi Ishii

Haptic Feedback

Sean Follmer, Daniel Leithinger, Alex Olwal, Nadia Cheng, Hiroshi Ishii

Shape Change

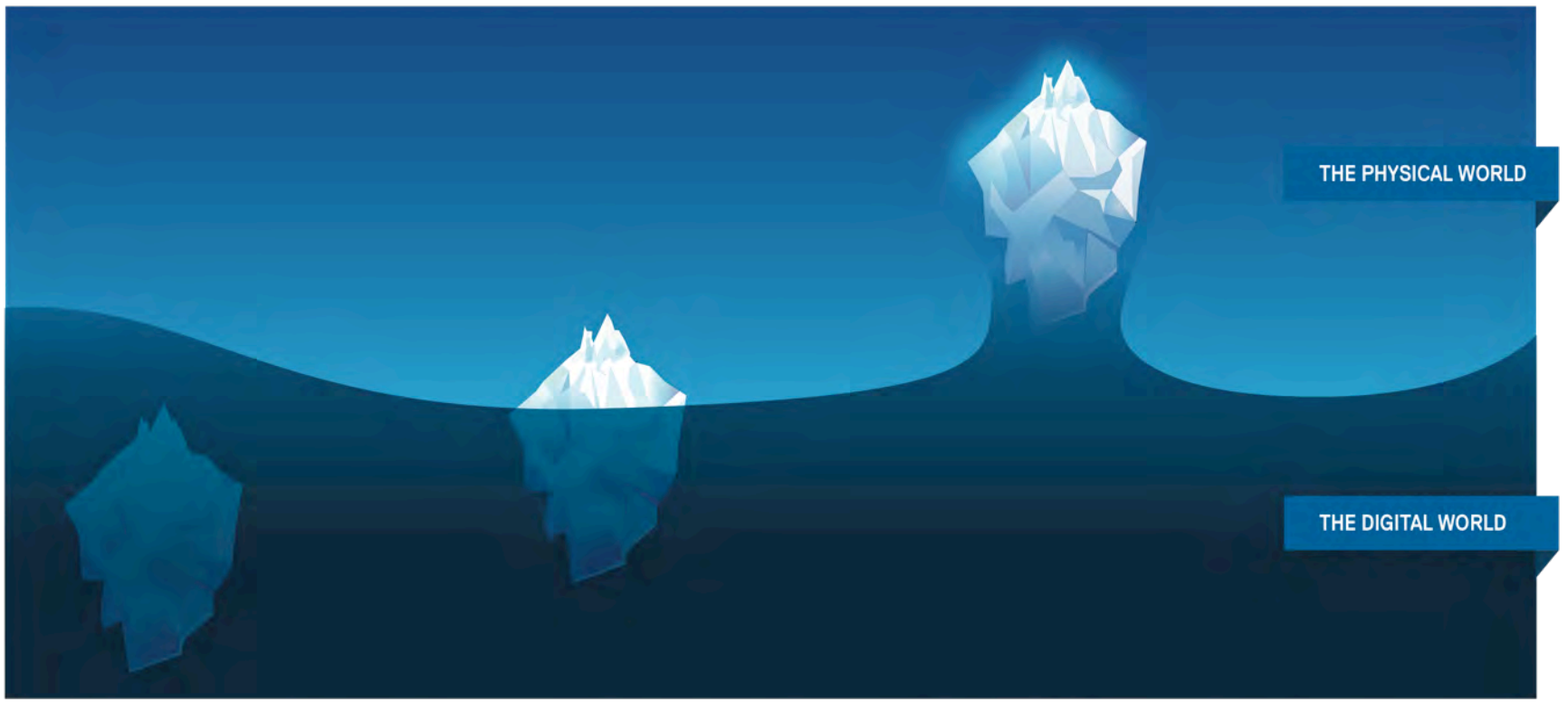
Sean Follmer, Daniel Leithinger, Alex Olwal, Nadia Cheng, Hiroshi Ishii

Radical Atoms

GUI PAINTED BITS

TUI TANGIBLE BITS

RADICAL ATOMS



A **graphical user interface** only lets us see information and interact with it indirectly, as if we were looking through the surface of the water to interact with the forms below.

A **tangible user interface** is more like an iceberg: there is a portion of the digital that emerges beyond the surface of the water - into the physical realm - so that we may interact directly with it.

Radical Atoms describes our vision for the future of interaction, in which all digital information has physical manifestation so that we can interact directly with it - as if the iceberg had risen from the depths to reveal its sunken mass.

Wagner: Der Ring des Nibelungen

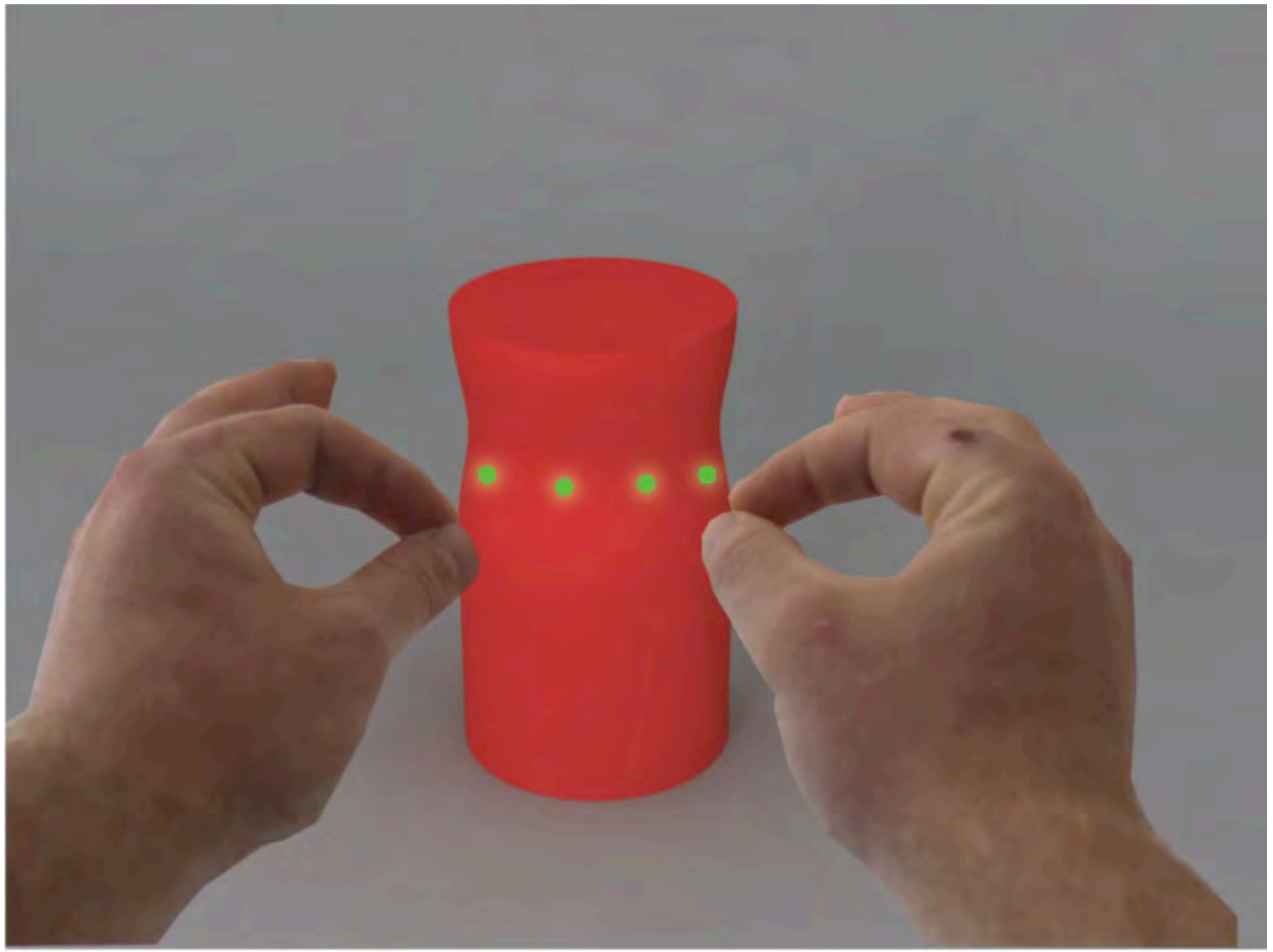
Wagner's Dream, The Metropolitan Opera

Wagner: Der Ring des Nibelungen

Wagner's Dream, The Metropolitan Opera

Amphorm

David Lakatos, Hiroshi Ishii

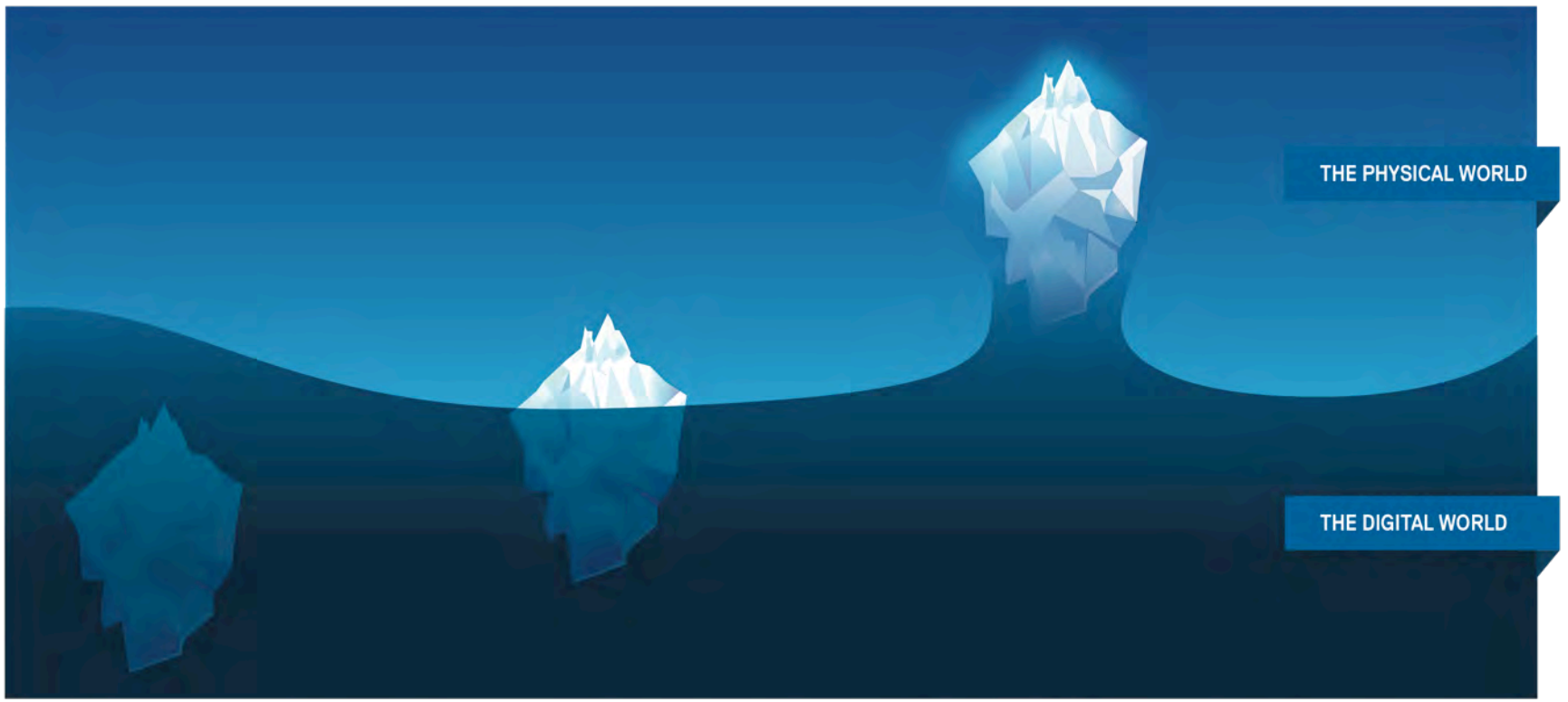


Thank you!

GUI PAINTED BITS

TUI TANGIBLE BITS

RADICAL ATOMS



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