mixed reality
&
(tactile and) tangible interaction

Jeanne Vezien
&
Anastasia Bezerianos

tangible interfaces and a bit of augmented reality

Anastasia Bezerianos

touch vs. tangibles

HANDS FEEL THINGS

HANDS MANIPULATE THINGS

http://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/

touch vs. tangibles

Power grip, fingers vs palm

Precision grip, fingers vs thumb

Hook grip, between phalanges

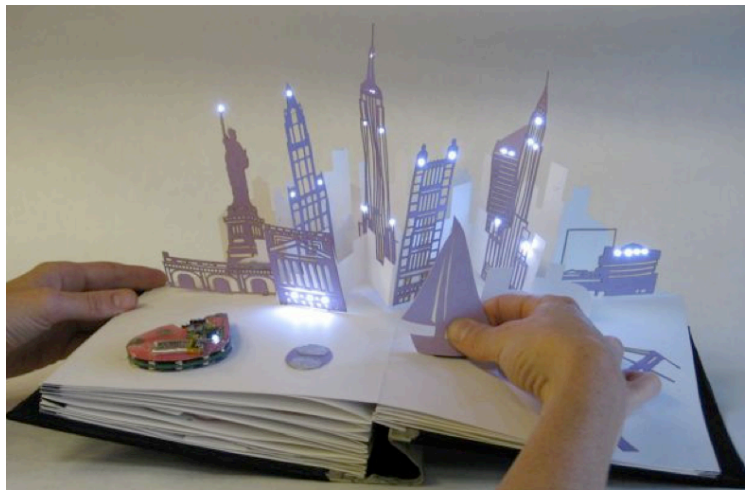
Scissor grip, between fingers

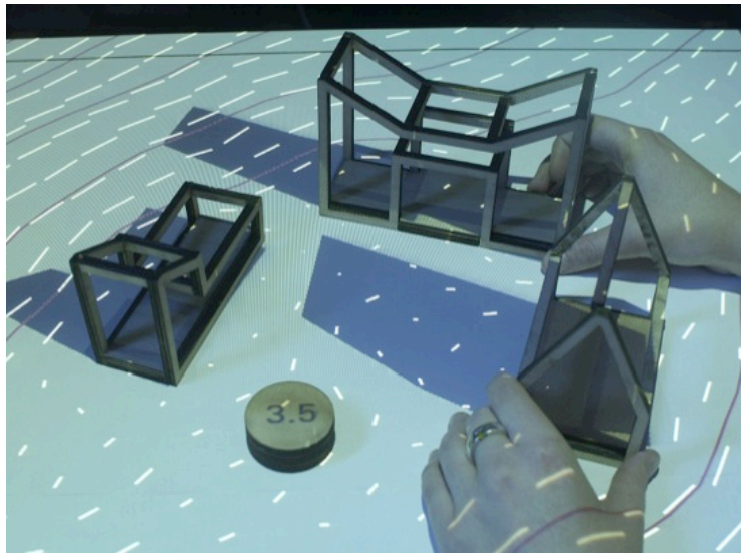
http://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/

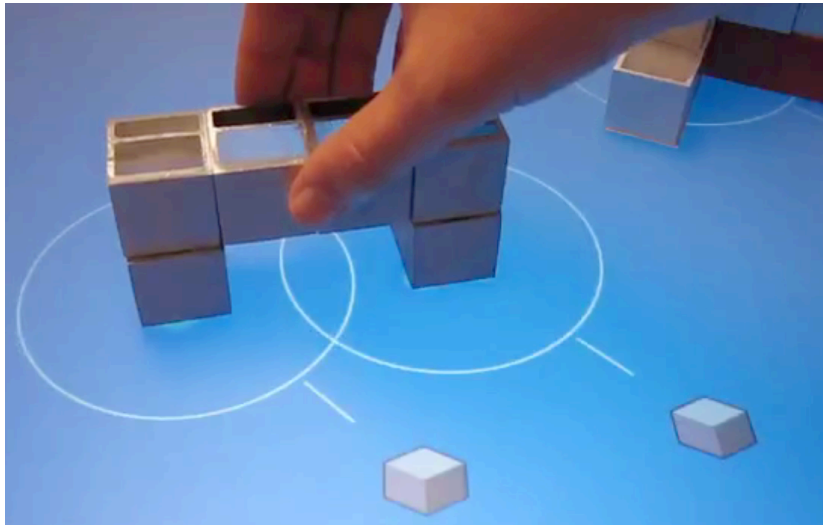
touch vs. tangibles

http://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/

tangible interfaces







(Other reading) « Tangible user interfaces: Past, present, and future directions » by C O. Shaer, E. Hornecker http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.187.3793

principles

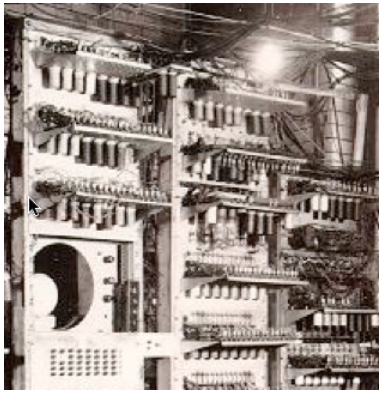
virtual world beyond the desktop

computing integrated in everyday life experience and physical world

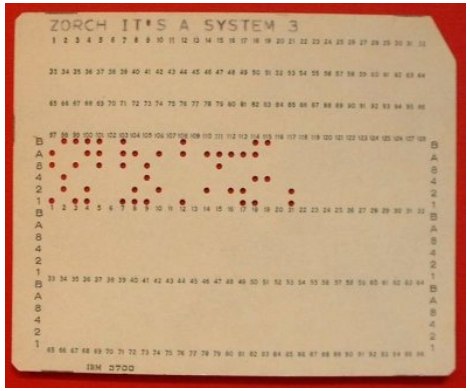
approach:

- distribute computing across many devices (objects)
- augment the physical world with digital interfaces

history of interfaces

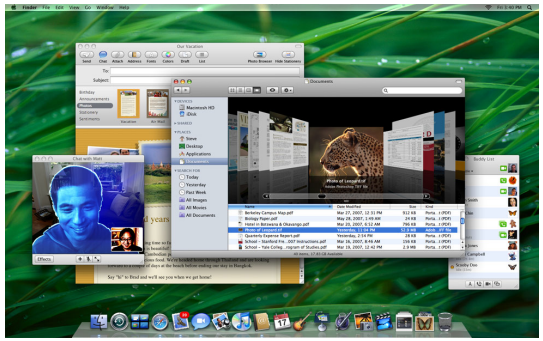


electrical

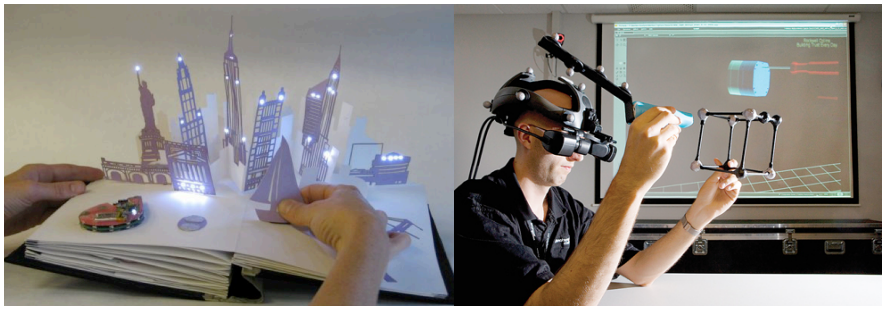


symbolic
« punch cards »

textual



graphical



embodied

[ToCHI special Issue, 2011, ed. Dourish]

Interaction moves from being directly focused on the physical machine to incorporating more and more of the **user's world** and the **social setting in which the user is embedded**. The scope of human-computer interaction is expanding to include larger-scale, longer-term phenomena of computer use.

[Dourish, 2004]

activity theory

our actions take place in a social context composed by individuals and artifacts

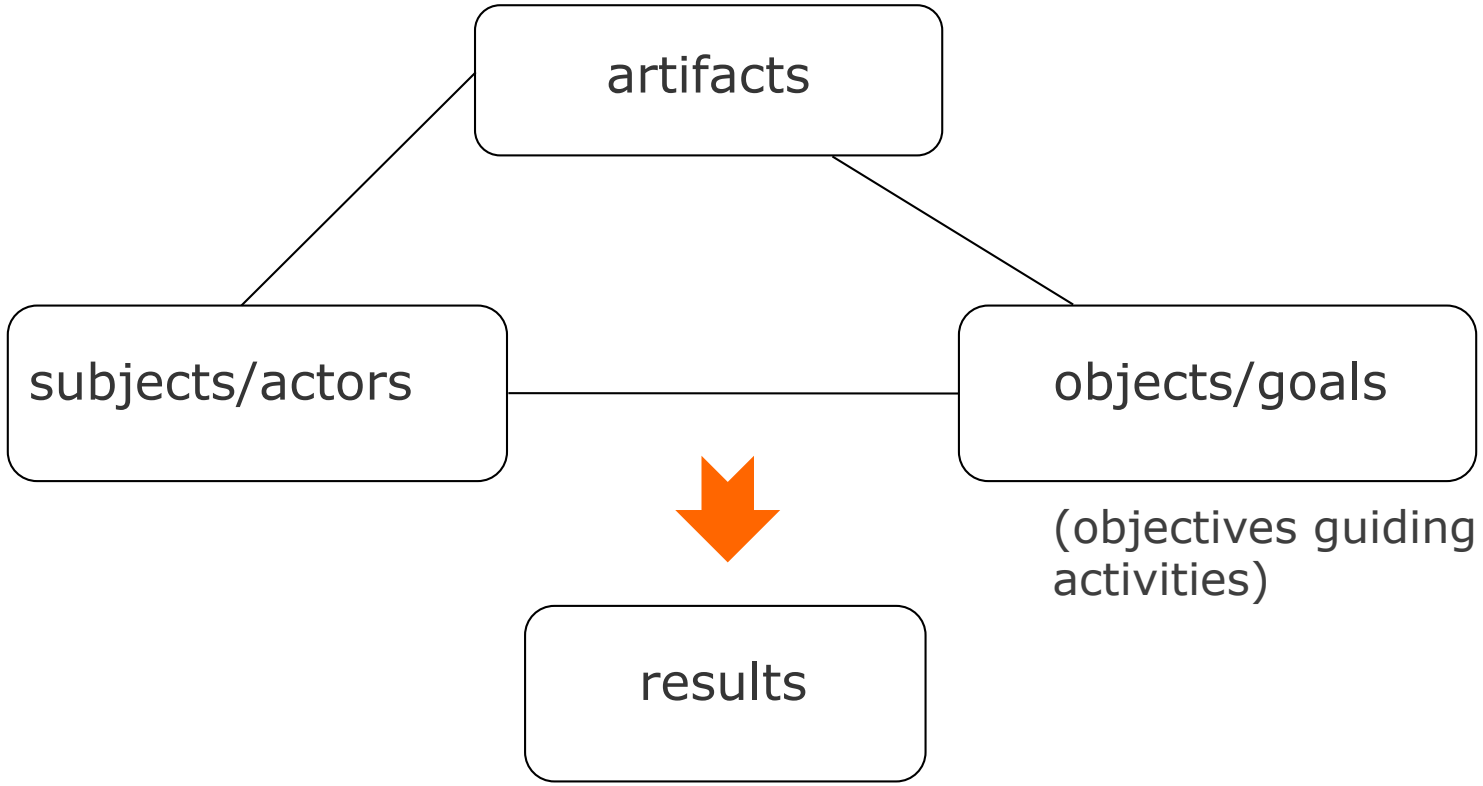
just the cognitive processes are not enough to describe our actions/interactions

need to consider interaction in context.

activity theory

activity

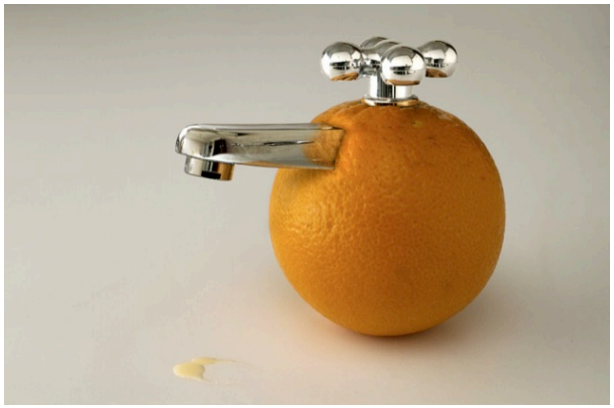
plans, methods, utilities
(scissors, computer)



[Leontiev, 78]

TUIs supporting activities

- Physical environment part of the activity support
- No single locus of interaction
- No enforced sequentiality and modal interaction
- Use of affordances to show possible actions of artifacts

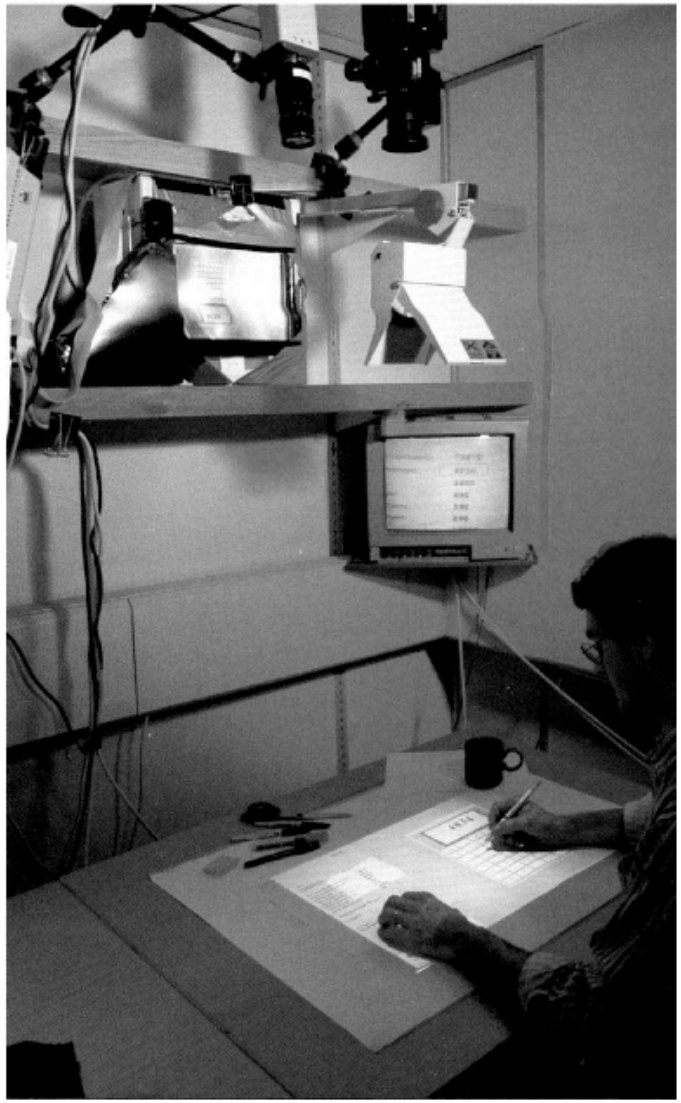


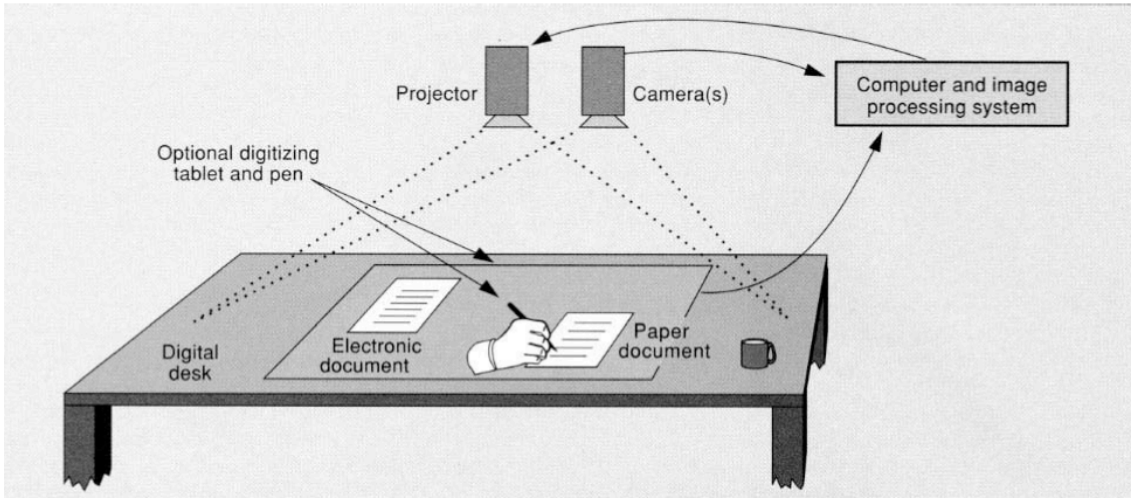
by Giuseppe Colarusso

by Nostalgia Electrics

TUI pioneers

DigitalDesk [Wellner, 1991-93]





http://youtu.be/S8lCetZ_57g

DigitalDesk [Wellner, 1991-93]

images projected on table and paper

pen and finger interaction

identification of documents placed on table

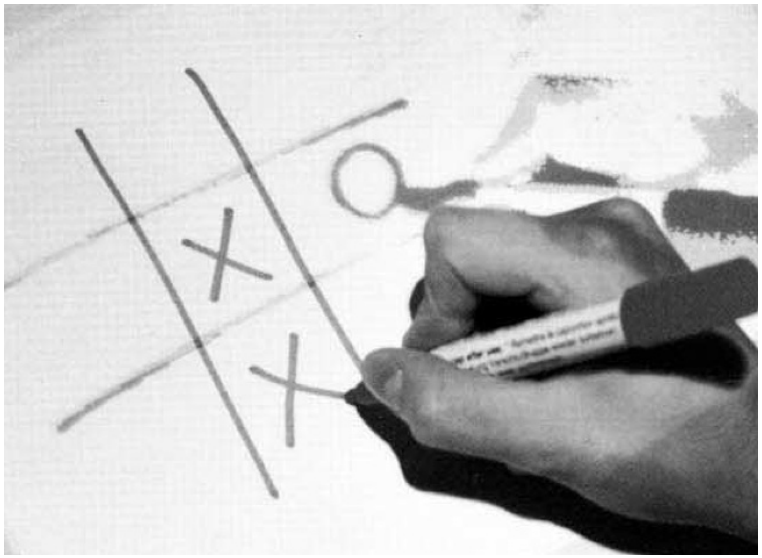
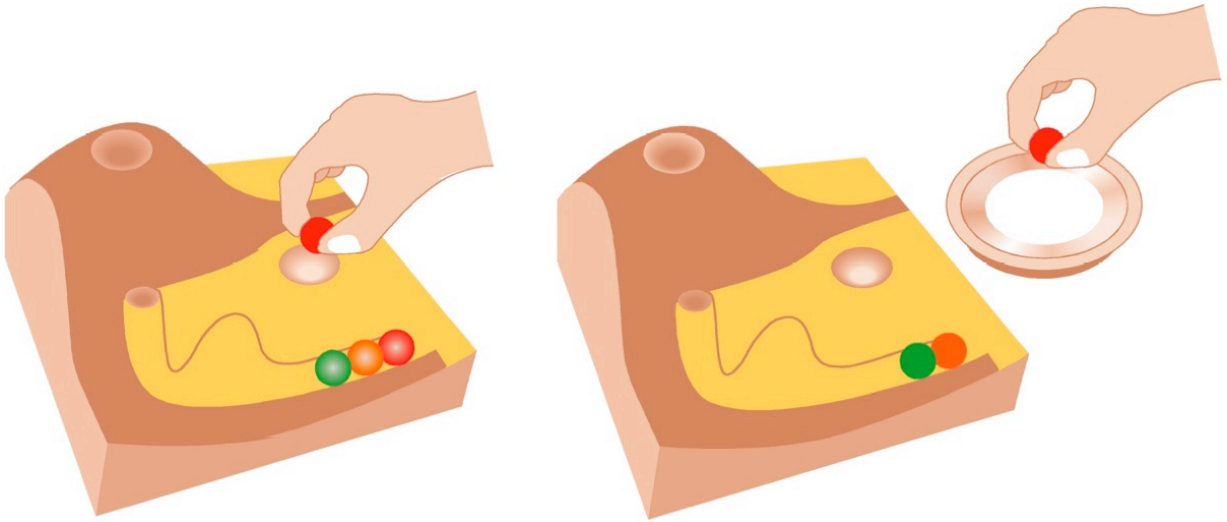


image of the hand of a 2nd remote user projected on the paper

DoubleDigitalDesk

marble answering machine
[Bishop, 1992]

answering machine: each marble a message

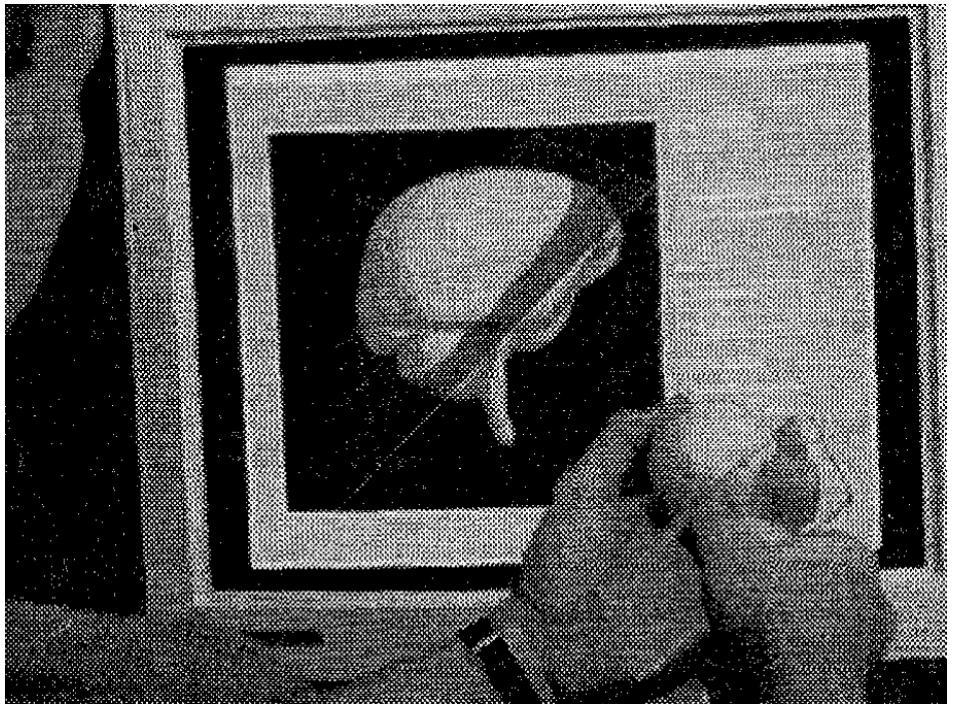


place marble in slot to hear

place marble in bowl to store

Props [Hinckley, 1994]

3D interaction through manipulation of physical objects (« props »)

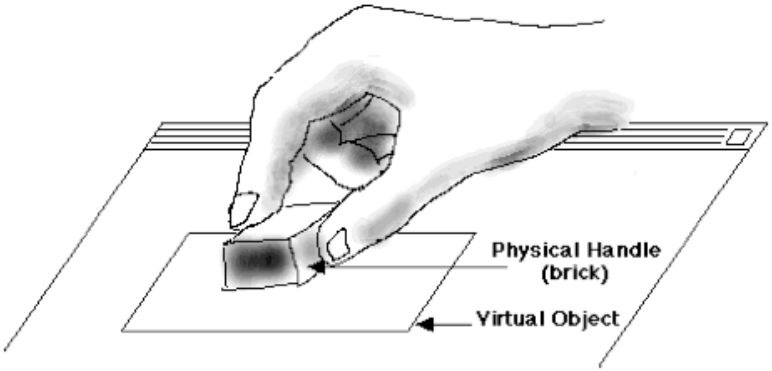


Props [Hinckley, 1994]

advantages

- *Familiarity:* with manipulation of physical objects
- *Direct actions:* correspondence between action and tasks
- *Clear use:* the form of the object reveals its function
- *Tangible:* user aware of the physical existence of « props »
- *Absence of modes*: each « prop» has a specific function
- *Physical feedback:* visual, tactile, kinesthetic
- *Bi-manual interaction*
- *Physical constrains:* adapted to tasks
- *Creativity:* use of physical objects in unpredicted ways

Bricks [Fitzmaurice et al., 1995]



Graspable UIs

physical objects: control virtual objects

direct mapping between the properties of physical objects and those of virtual objects

physical constraints guide interaction

http://www.autodeskresearch.com/publications/bricks

Bricks [Fitzmaurice et al., 1995]

traditional GUIs

- output space-multiplexed
  (icons & widgets occupy specific space)

- but input time-multiplexed
  (most actions controlled by the same input device, the mouse)

➡ sequential interactions, one action at a time

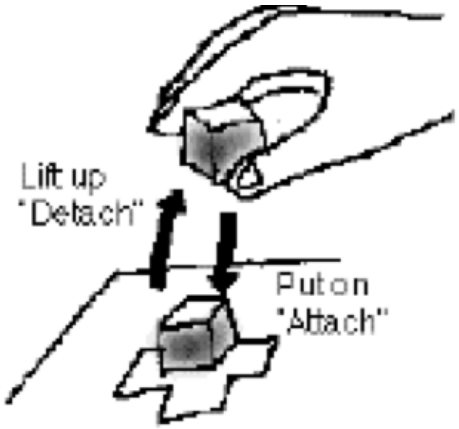
Bricks [Fitzmaurice et al., 1995]

space multiplexing rather than time in traditional UI

- each function is associated with a different controller that occupies a specific space

Bricks [Fitzmaurice et al., 1995]

interactions with one brick (proxy)

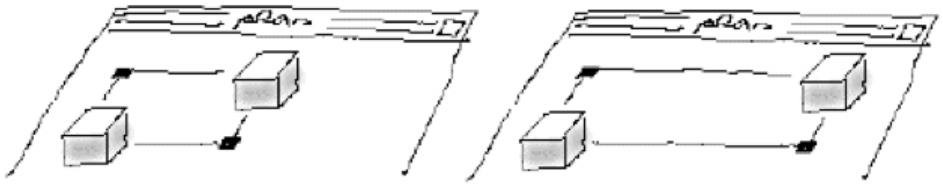


attach (detach) brick to virtual object

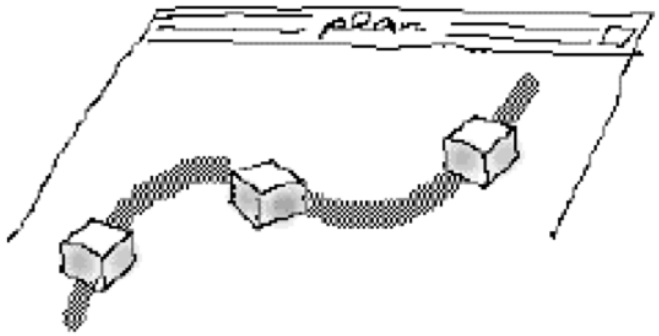
move and rotate the virtual object

Bricks [Fitzmaurice et al., 1995]

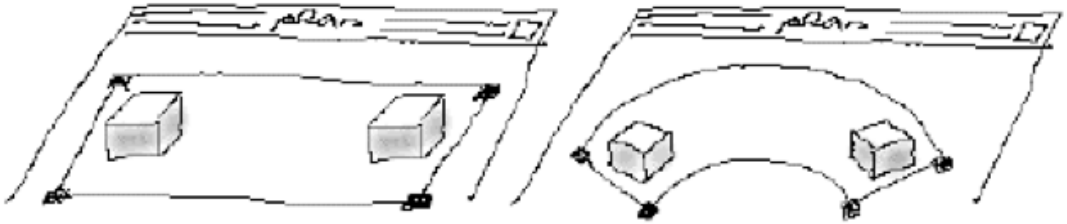
interactions with multiple bricks (controller)



change the size of an object



create a curve



deform

Bricks [Fitzmaurice et al., 1995]

more interactions with bricks (action palette)

use brick to select a property (e.g., color) to apply to objects

Bricks [Fitzmaurice et al., 1995]

questions :

- how to manipulate multiple objects in space?
- are the movement vocabularies identifiable?
- how to coordinate the two hands?

exploratory studies: observe how multiple participants execute physical object manipulation tasks

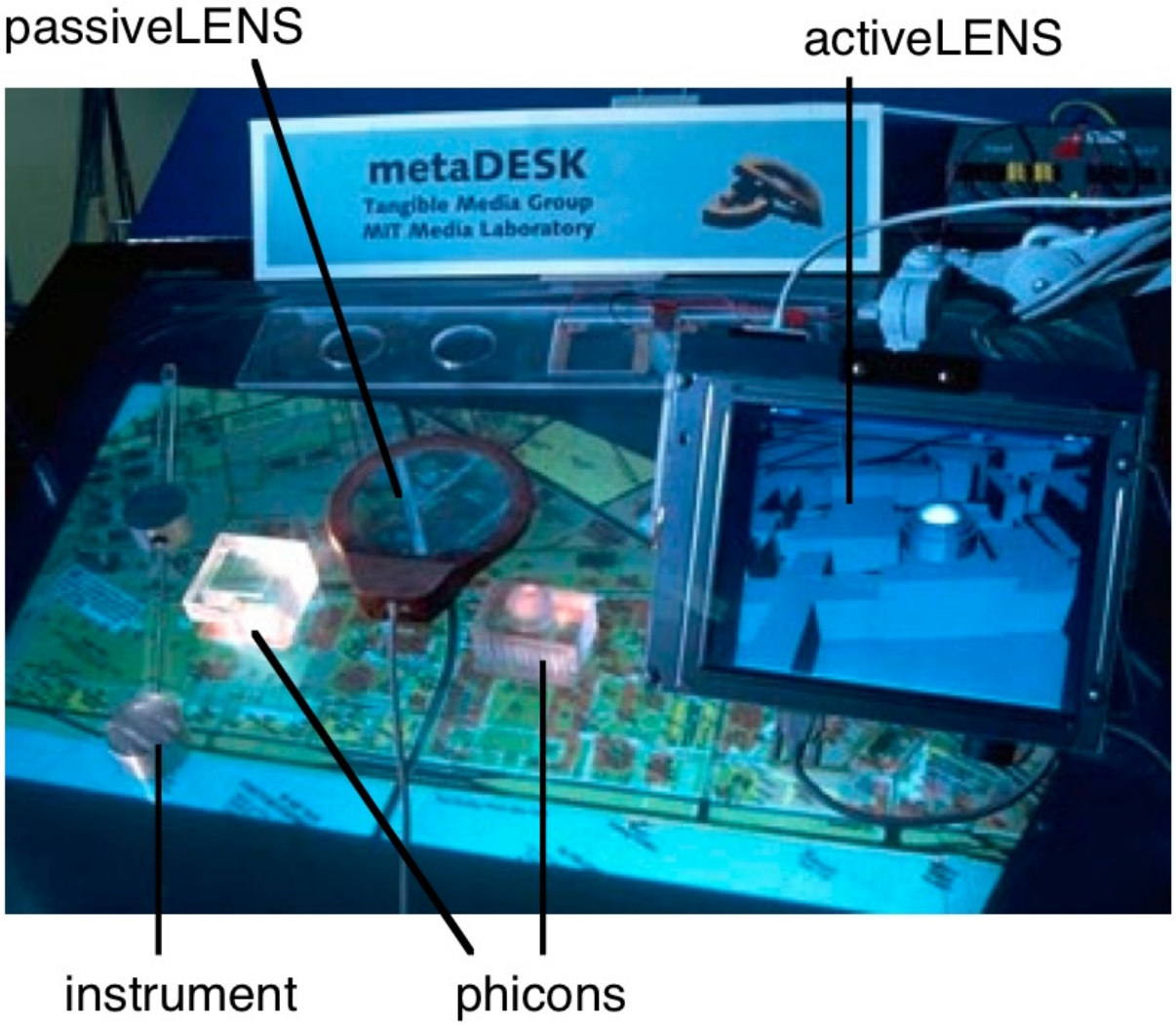


Bricks [Fitzmaurice et al., 1995]

some observations

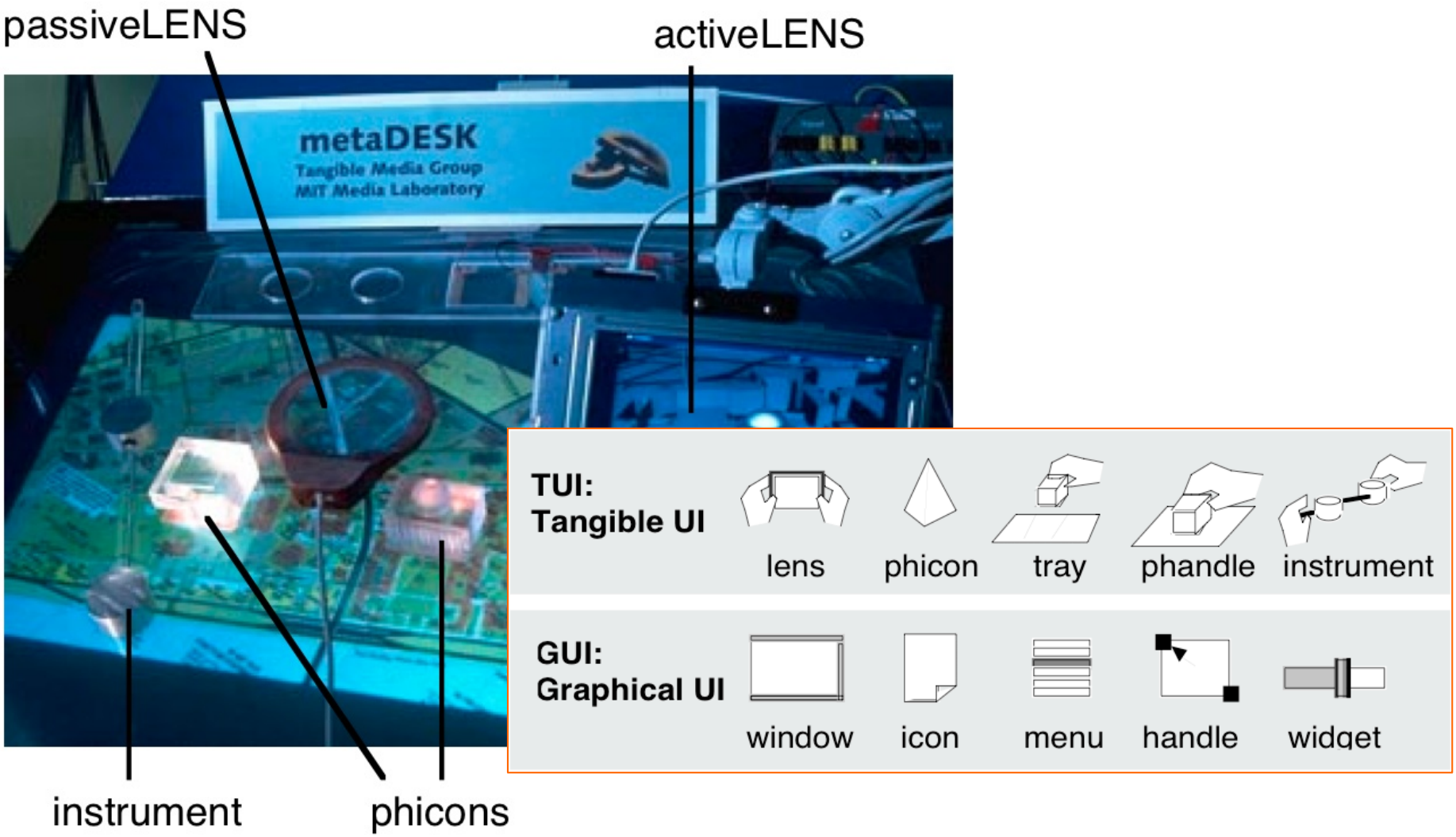
- Parallelism, use of two hands concurrently
- One hand translates and aligns objects, the other collects new objects
- Frequent hand crossing
- Use of left hand as a « clipboard » (temporary buffer)
- Eyes-free parallel task execution thanks to tactile feedback
- Memorization of geometric properties of bricks
- Placing objects in piles to save space
- Use of all 10 fingers to deform and position a flexible curve
- Use of palm to preserve the shape of part of the curve

metaDESK [Ullmer & Ishii, 1997]



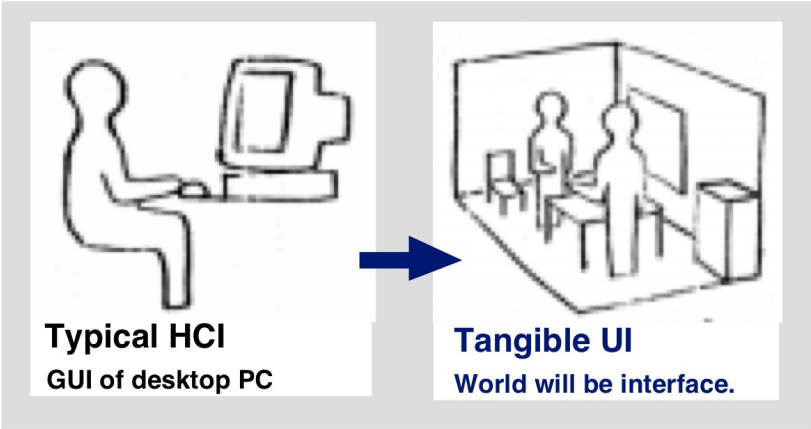
http://vimeo.com/44545109

metaDESK [Ullmer & Ishii, 1997]



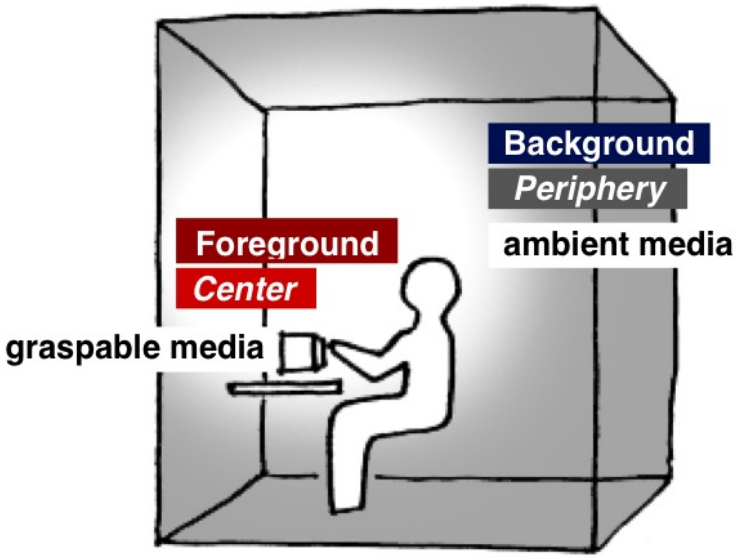
tangible bits [Ishii & Ullmer, 1997]

introduced the concept of « tangible interface »



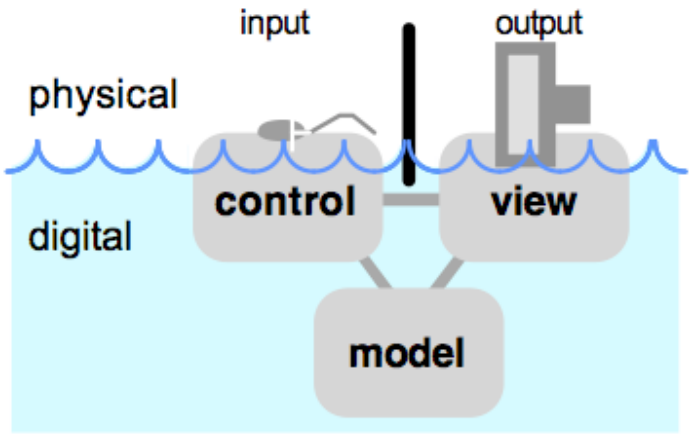
« Human interfaces that employ physical objects, surfaces, and spaces as tangible embodiments of digital information and processes. These interfaces explore interactions in both the foreground and in the background.
Foreground interfaces use graspable objects and augmented surfaces, exploiting the human senses of touch and kinesthesia. Background interfaces use ambient light, sound, airflow, and water movement as indicators of activity at the periphery of awareness. »

From the MIT tangible media mission



center and periphery of attention in the physical environment

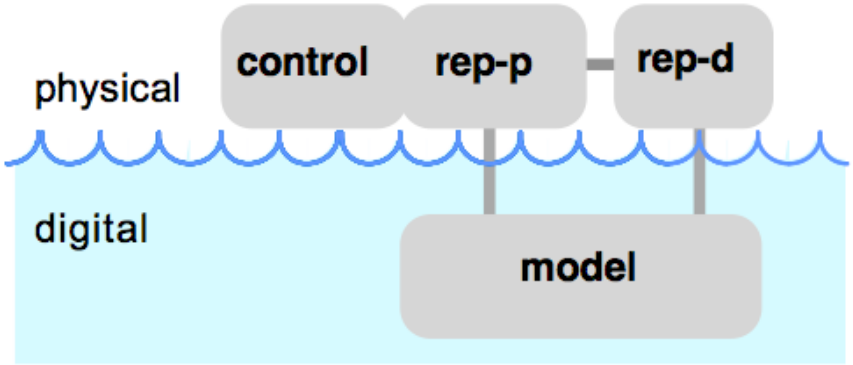
tangible interaction model



MVC model of graphical interfaces

physical representations manipulated by hand

non-physical representations (projection, audio)

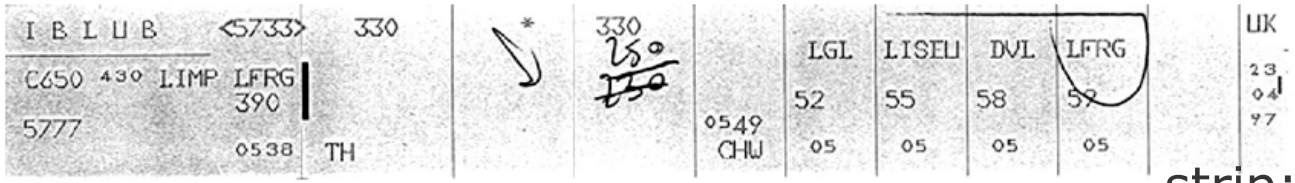


tangible interface model MCRit

[Ullmer & Ishii, 2001]

flight strips [Mackay, 1997-98]

studies on the use of paper strips for air traffic control

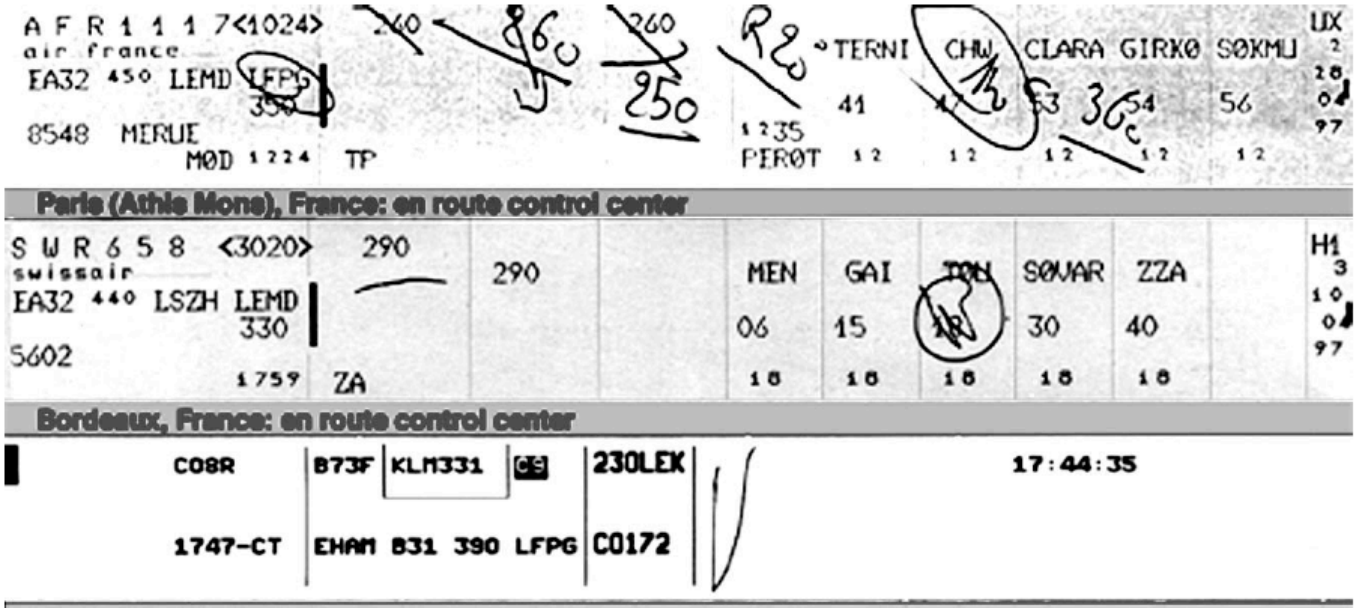


strip: paper band representing flights

use of strips by controlers

flight strips [Mackay, 1997-98]

observations of strip use



each strip contains information on a plane and its flight plan: id, plane type, scheduled route, etc.

controllers annotate strips with the instructions given to planes

flight strips [Mackay, 1997-98]

observations of strip use

communication between controlers

co-annotation

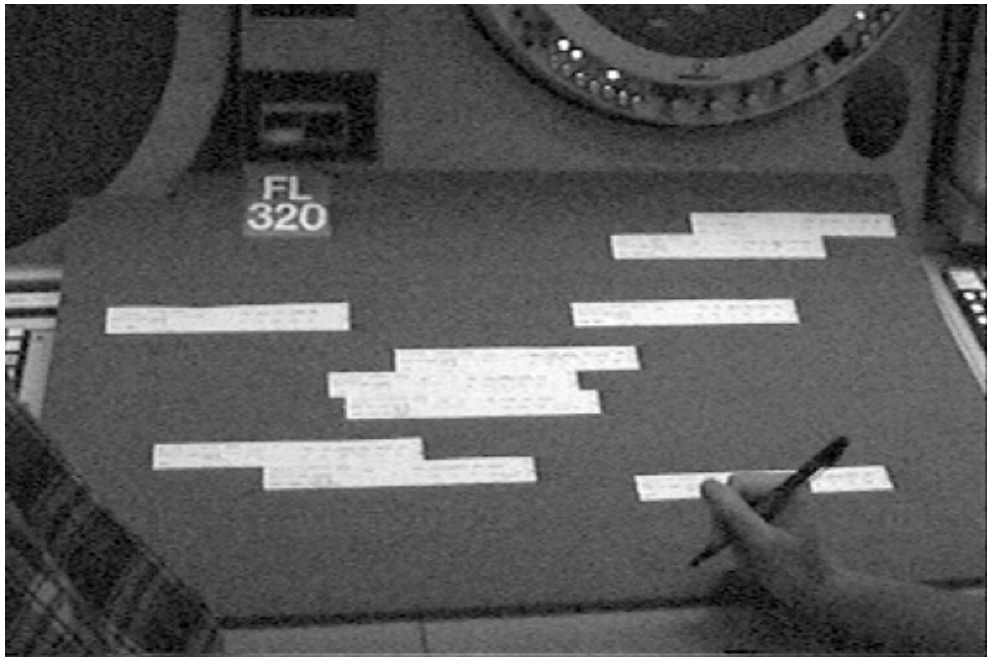
placement of a strip in the space of another controller for immediate processing

flight strips [Mackay, 1997-98]

observations of strip use

spatialisation

left/right alignement to mark strips



space positioning depending on geographic plane positioning

flight strips [Mackay, 1997-98]

conclusions on paper strip use

- Tangible system: safe and stable
- Based on decades of experience
- Difficult to replace by a software system (high risk, new protocols needed)

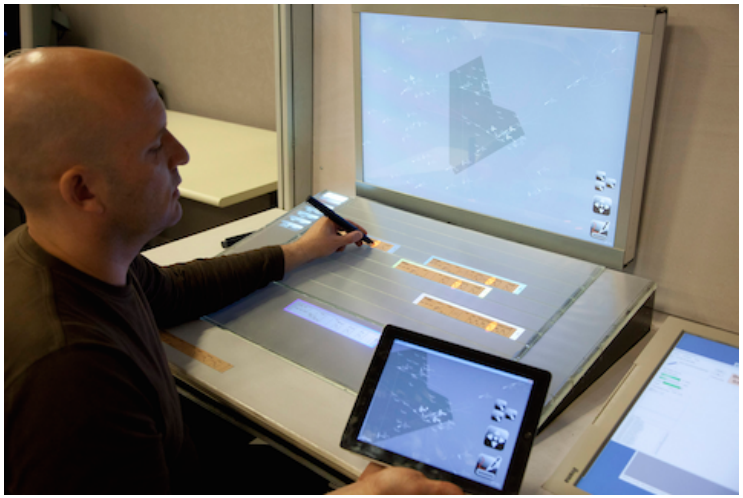
recommendation

- augment strips rather than replace them

… later Strip'Tic [Hurter12, Letordal13]

StripTic prototype

- Participatory design process
- Combination of paper and virtual strips
- Gestural interactions



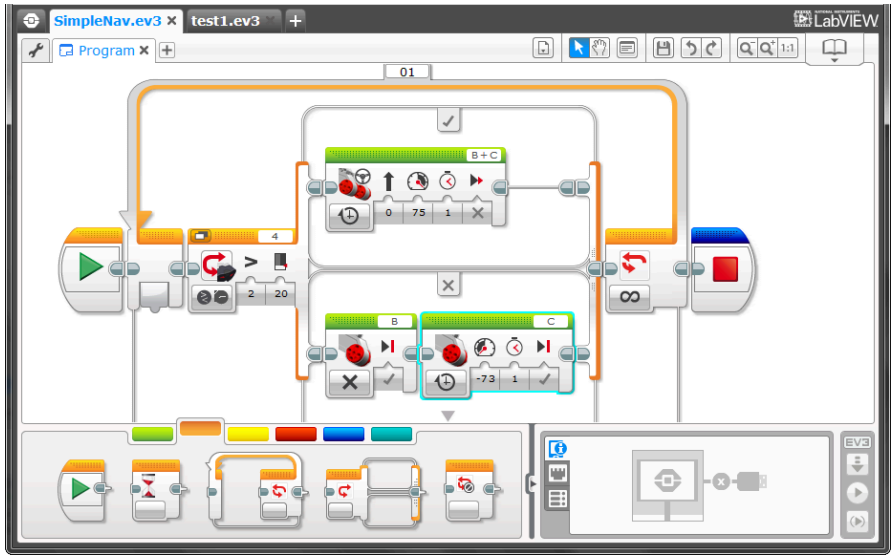
http://www.youtube.com/watch?v=HJEMBhVTzso

applications
(metaphors, feedback, detection)

applications:
1. TUI’s to learn

digital manipulatives

construction and programming kits



e.g. LEGO Mindstorms

building blocks

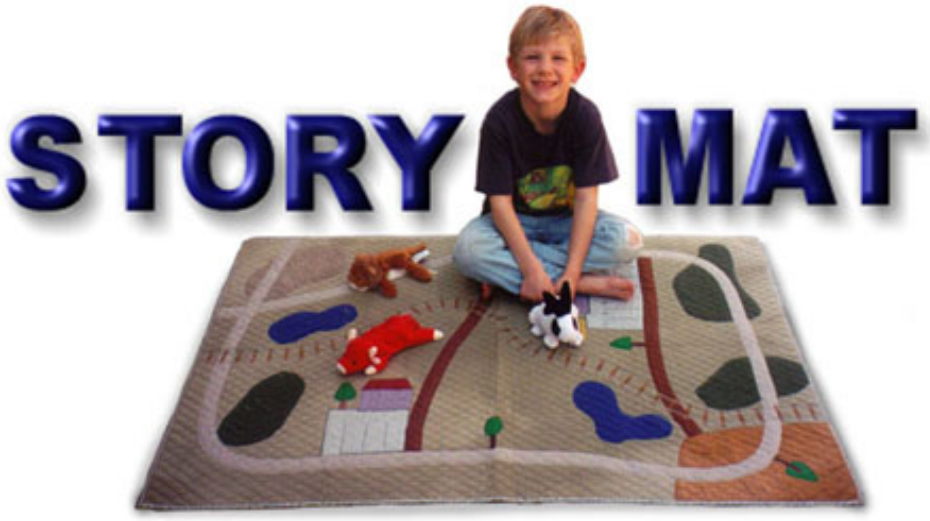
touch, relative position, gestures in space

e.g. Shifteo Cubes

http://youtu.be/fEqq8JykQoQ

computationally enhanced

record, replay explore



e.g. StoryMat

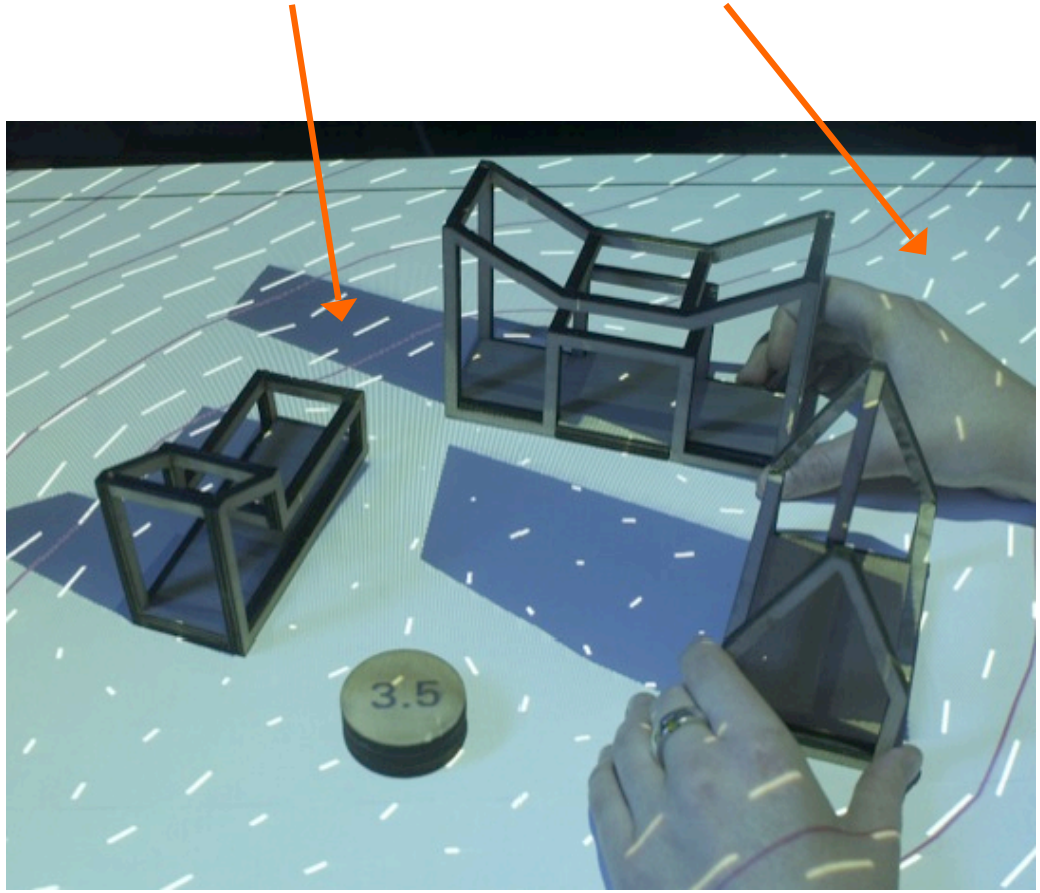
Topobo

… And many more (have a look at the TUI survey paper)

applications:
2. TUI’s to problem-solve & plan

architecture, urban planning

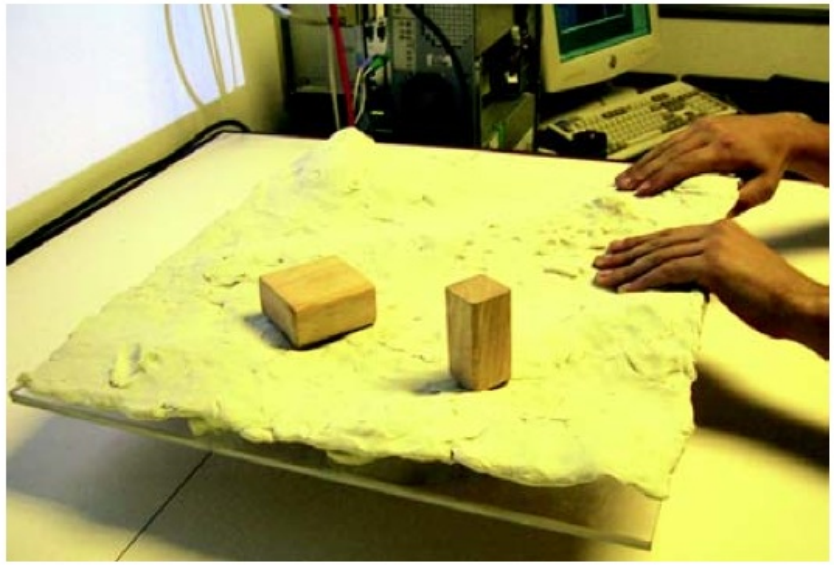
modelling /visualization of shadows and winds

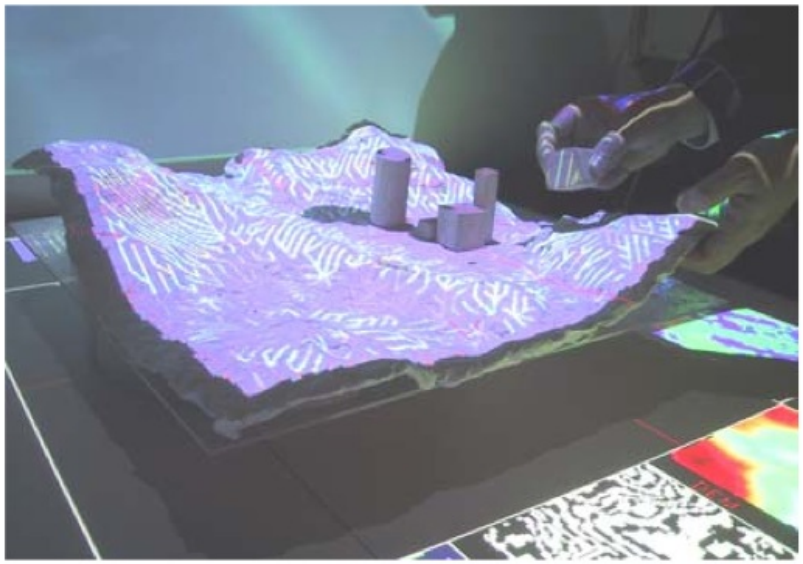


Urp [Underkoffler & Ishii, 1999]

http://vimeo.com/48600713

illuminating clay [Piper and Ishii, 2002]



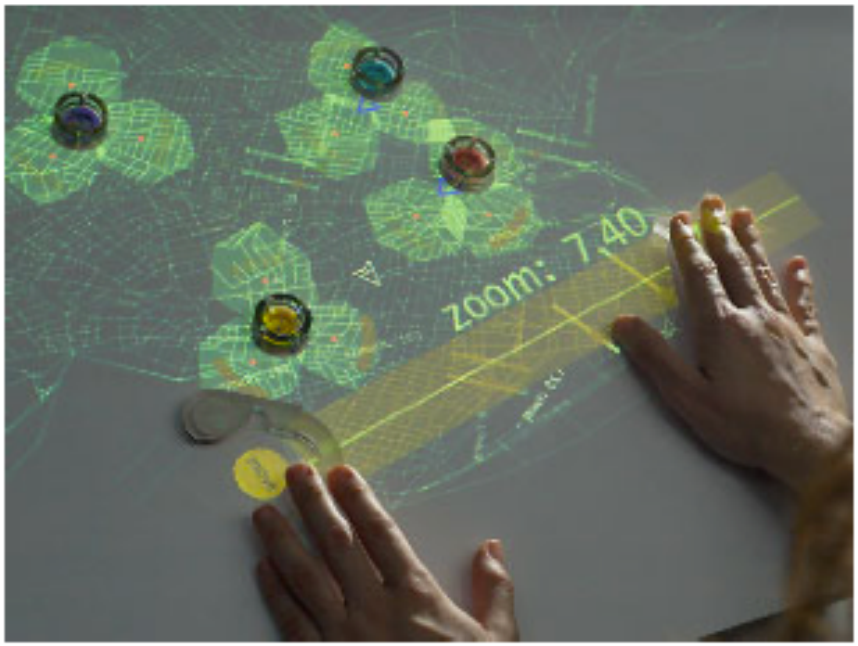


3D clay models scanned, and augmented with pictures/videos projected on their surface (e.g. simulation of water flow)

http://youtu.be/csMXwWR5q2g

Pico [Patten and Ishii, 2007]

table can track and move small objects on it



Used for solving spatial layout problems (e.g. cell phone tower placement). Users can constraint the tower's movement during optimization.

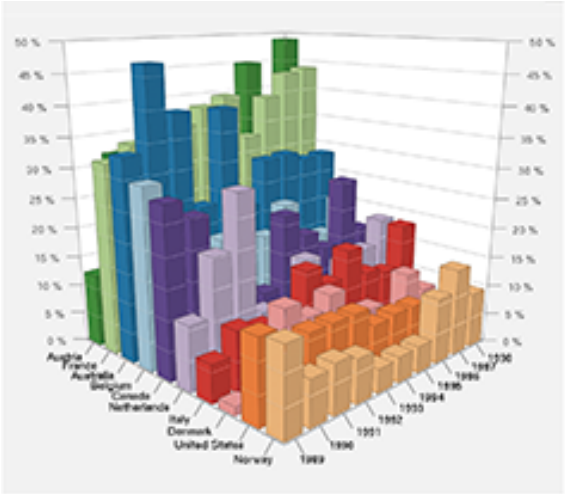
http://vimeo.com/44539342

Others

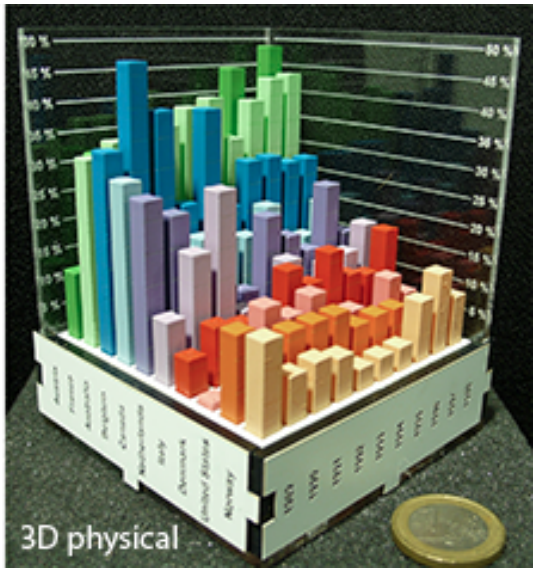
- Illuminating light [Underkoffler & Ishii, 1998] for optics
- Graphmaster [Schweikardt et al., 2009] for graph theory
- [Zuckerman et al. 2005] for constructive assembly
- Tinkersheets [Zufferey et al., 2009] for warehouses
- [Edge and Blackwell, 2009] for office work
- Senseboard [Jacob et al.,2002] for organization
- ColorTable [Maquil et al.,2004] for urban planning

Visualizations [Jansen et al, 2012]

tangible data visualizations



3D on-screen

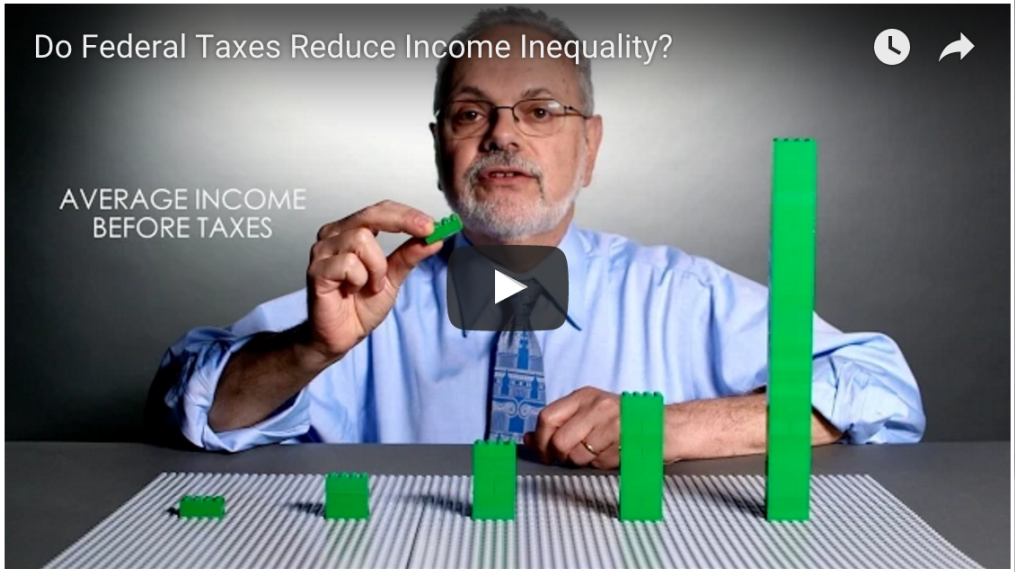


Initial studies showed that real physical visualizations performed overall better than virtual 3D visualizations (stereoscopic or not). But for a specific visualization and task

Dynamic data visualizations

tangible data visualizations that can be updated

…. manually , e.g.



David Wessel on tax distribution using LEGO

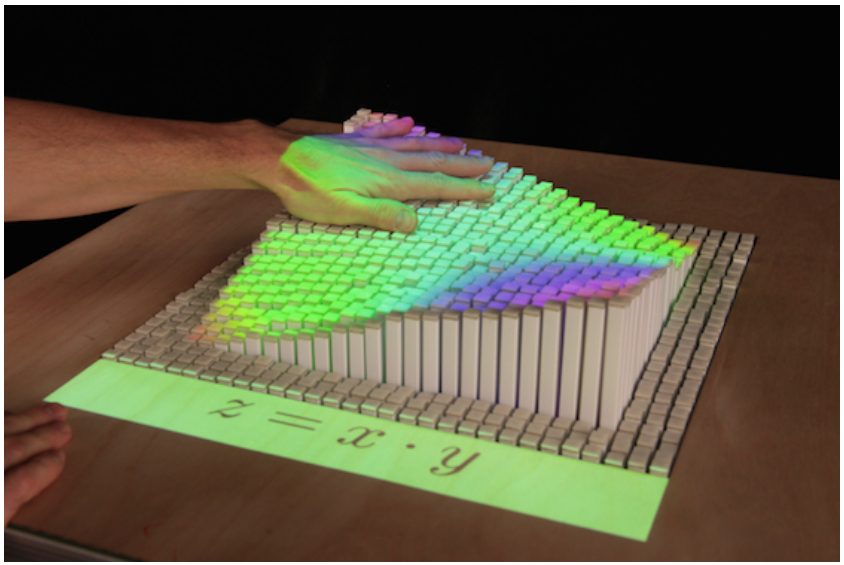
Participatory vis of sleeping hours by Jennifer Payne (inspired by visual sedimentation of Samuel Huron)

Dynamic data visualizations

tangible data visualizations that can be updated

…. or automatically, e.g.

Hive Big Data Think Tank



inForm from MIT media lab

Other dynamic visualizations

general physical vis dynamically updated,
or ambient displays (another topic …)

Poly by Digit showing
online poll data

Tempescope by Ken Kawamoto

physical visualizations

a comprehensive list collected at:

http://dataphys.org/list/

applications:
3. TUI’s to entertain

I/O Brush [Ryokai et al., 2004]

brush for “picking” up textures and applying them to images

music bottles [Ishii et al., 2001]

each bottle controls a voice or an instrument

http://youtu.be/U4IYyNL4ld8

Reactable [Jorda et al., 2005]

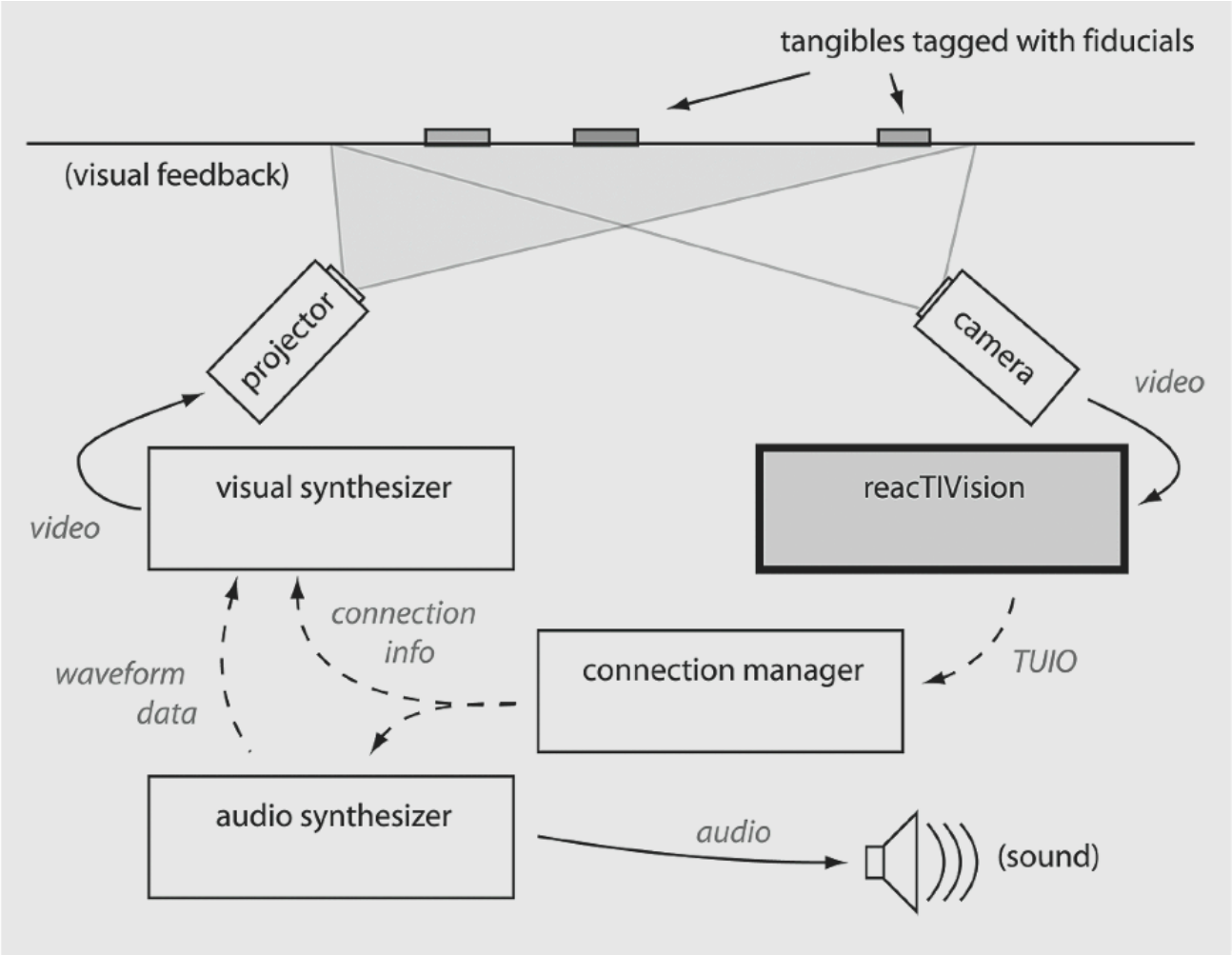
electronic music instrument

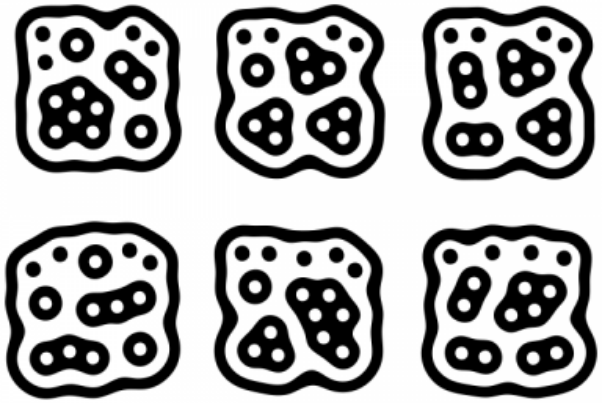
Tangible controls

Rich visualisation of links between controls

http://www.youtube.com/watch?v=x8WuWagPTwk

Reactable [Jorda et al., 2005]





Markers attached to controls

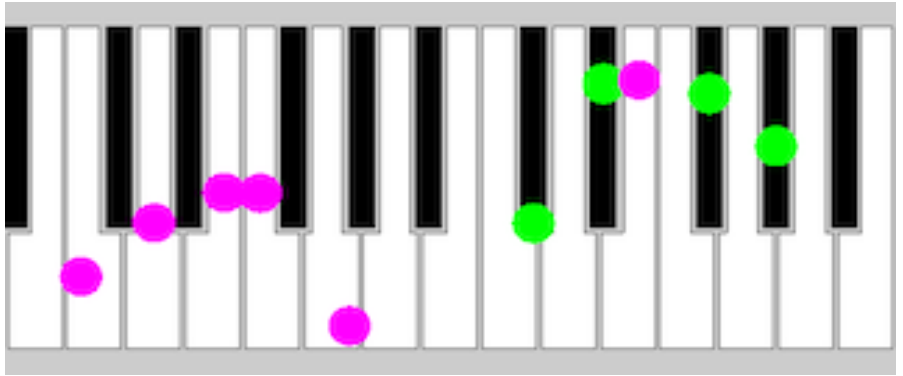
… And many more, e.g. have a look at the mit tangible media site

The space ... [McPherson et al., 2013]

Adding multi-touch support to pianos.

Use touch to control note properties

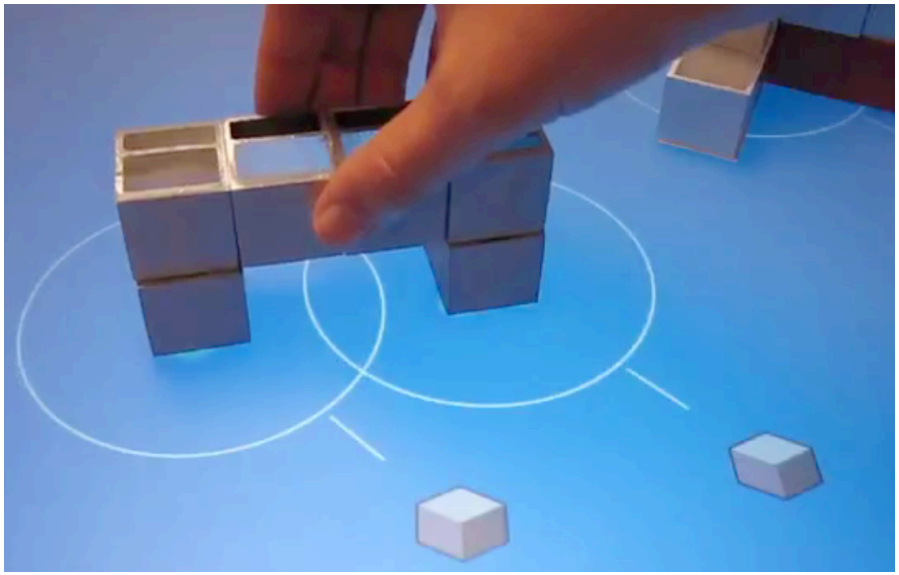
Study of experts to determine appropriate interactions



http://www.youtube.com/watch?v=BmRYuDOzTqU

applications:
4. TUI’s as widgets

Lumino and CapStones
[Baudisch et al., 2010 and Chan et al.,2012]



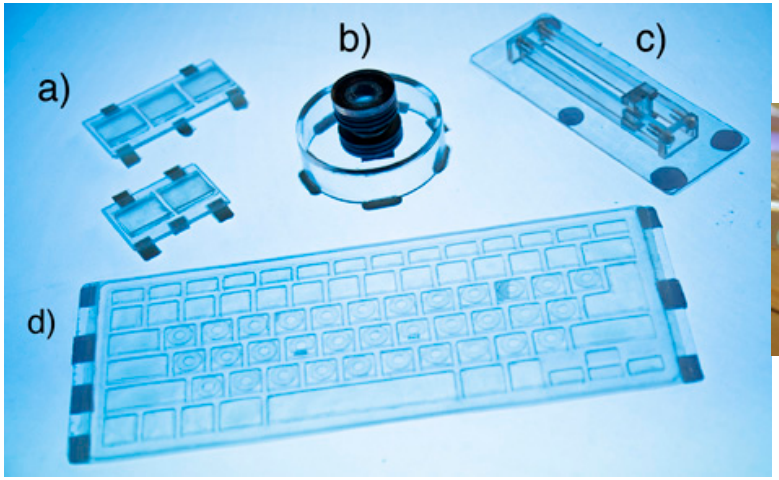
Manipulation and detection of overlapping cubes

Identify “blocks” or other components (e.g.. widgets) and their structure

http://www.patrickbaudisch.com/publications/2010-Baudisch-CHI10-Lumino.mp4
http://www.youtube.com/watch?v=ePGWKBqcug0

SlapWidgets [Weiss et al., 2009]

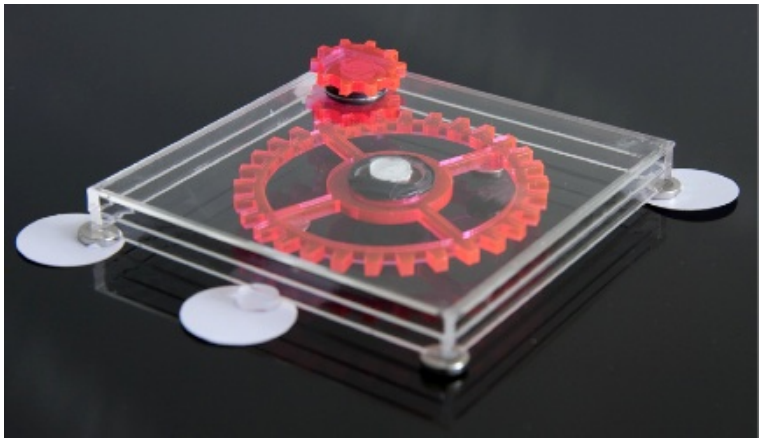
Transparent tangible controls with interactive mechanical parts, that can be customized based on content projected from below

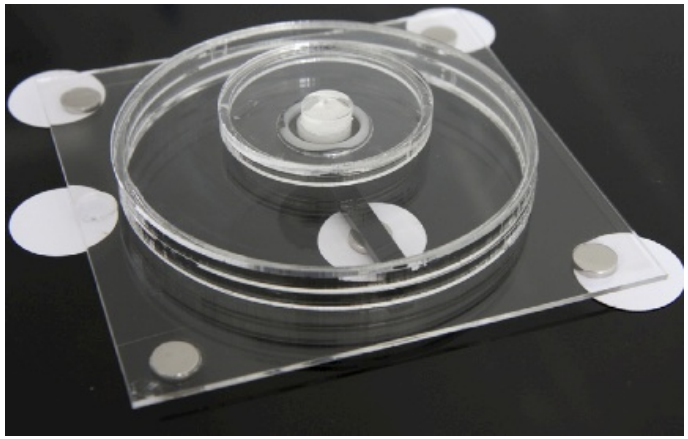


http://hci.rwth-aachen.de/slap

Madgets [Weiss et al., 2010]

Tangible controls with interactive mechanical parts that are actuated

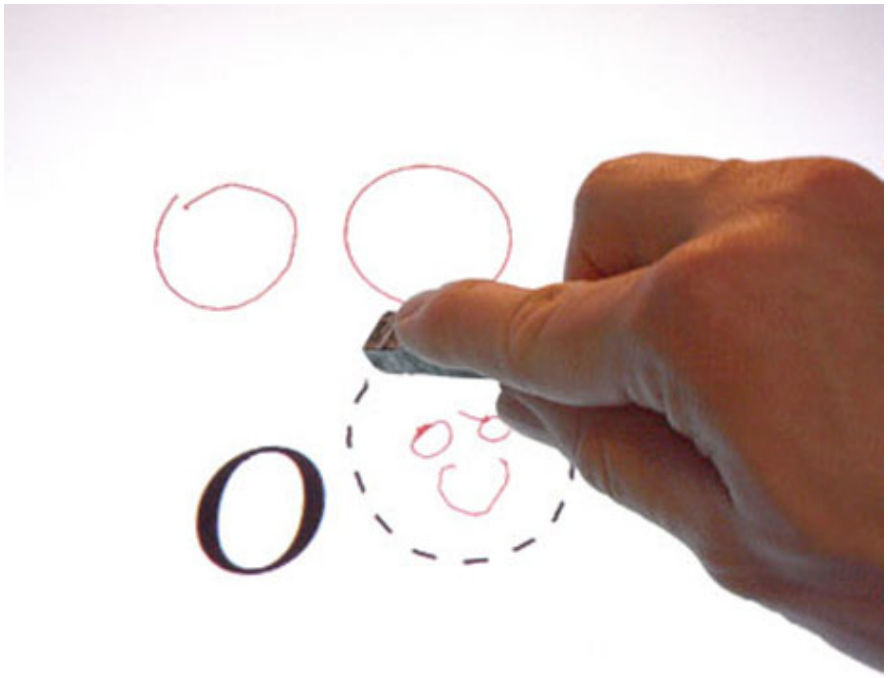




http://youtu.be/DVlHrySzcJI

Conté [Vogel et Casiez, 2011]

A crayon that changes behavior depending on user's hold.



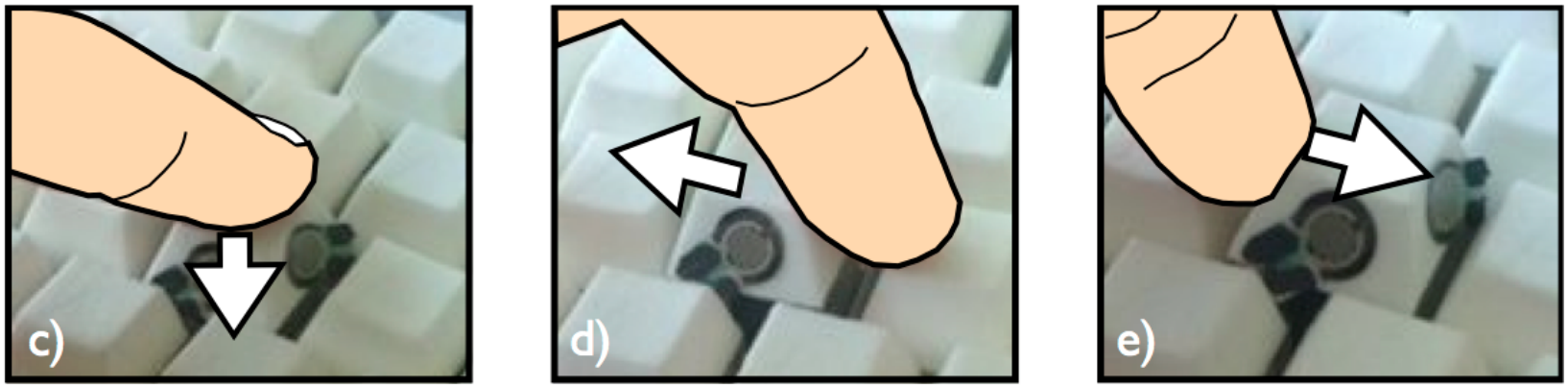
http://www.nonsequitoria.com/v.php?s=research&f=conte

Tangible Remote Controllers
[Jansen et al., 2012]

Tangible controls (mainly sliders) on touchpad for controlling large display applications

Augmented keyboards - Metamorphe [Bailly et al., 2013]

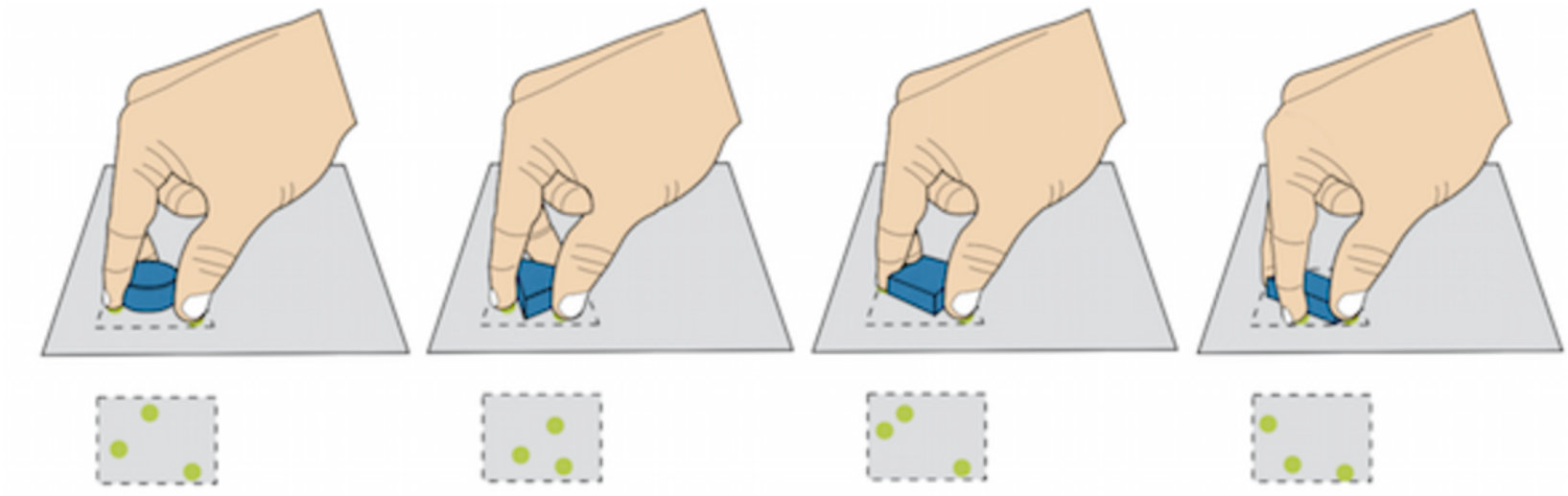
Keyboard keys can change height and act as joysticks



Metamorphe [Bailly et al., 2013]

not so augmented guides

Touch tokens: passive objects, whose shape guides finger placement, helps the detection and identification of gestures+ postures



[Morales et al., 2016]

applications:
5. TUI’s as general displays

Physical displays

Actuated/kinetic physical displays, e.g.

Lumen [Poupyrev et al., 2007]
http://youtu.be/RwrNAtVmztw

inForm [Follmer et al., 2013]
http://youtu.be/ouP9xNujkNo

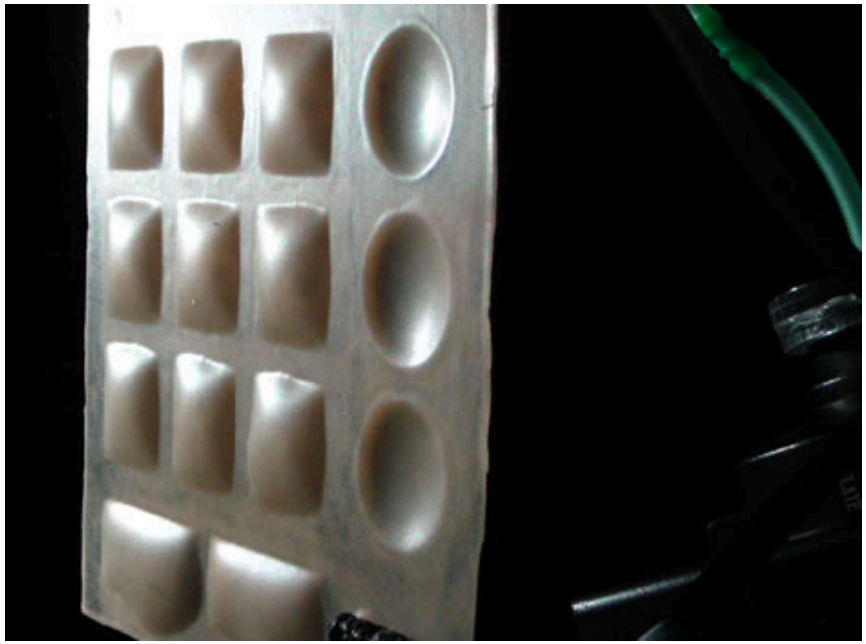
Physical displays

Swarm displays, e.g.

[Le Goc et al., 2016]
http://www.aviz.fr/swarmui

Physical displays

Flexible/deformable physical displays, e.g.



[Harrison & Hudson, 2009]
http://youtu.be/Smai_Z_galE

Morphees [Roudeaut et al. 2013]
http://youtu.be/oaZHj9SEzLQ

applications:
6. TUI’s as social proxies

(ambient and communication devices ...
different topic ...)

TUI pros

- Tangible representation
- Direct manipulation
- Space multi-plexing
- Affordances and constraints
- Collaboration
- Situatedness
- Tangible thinking
- Gestures

TUI cons

- Scalability
- Loss of tangibles
- Versatility and malleability
- Affordances and constraints
- User fatigue
- Degradation

prototyping

some technologies

- AR markers and Computer vision (e.g. Urp)
- RFID tags (e.g. Senseboard)
- Microcontrollers [sensors & actuators] (e.g. Arduinos)
- …

Differ w.r.t.

- Properties sensed
- Cost
- Performance
- Aesthetics
- Robustness
- Setup cost
- Scalability
- Portability

TUI design

Challenges

- no interface styles and abstractions
- apps with no parallel interactions
- finding metaphors and mappings

General approaches:

- Sketching (although limiting)
- Physical prototypes (3D or physical sketches)
- Storyboards and Kinetic Sketchup [Parkes & Ishii]
- Functional prototypes
  - electronics and actuation tools: Phidgets, Arduino, iStuff, …
  - AR + RFID toolkits: Exemplar, Papier-Mâché … (more on fabrication)

… what about evaluation?

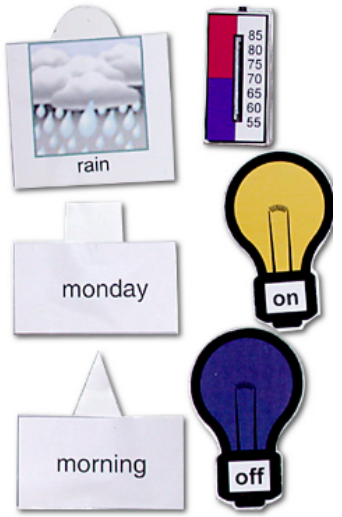
vision and RFID tracking

AR + RFID tools and toolkits:

Vuforia / ARToolKit
vision marker tracking + virtual imagery

Papier-Mâché [Klemmer, 2004]
high level API abstractions
passive AR ➔ RFID prototypes

… and many more



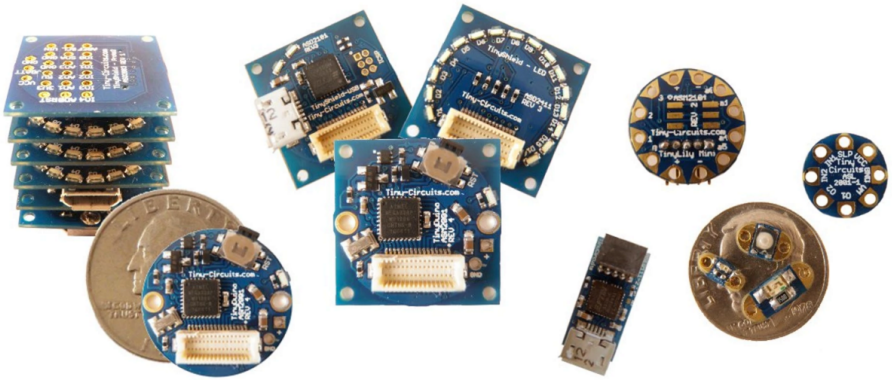
Sketch-a-TUI [Wiethoff et al., 2012]

Build low fidelity physical prototype

Draw on it using conductive ink

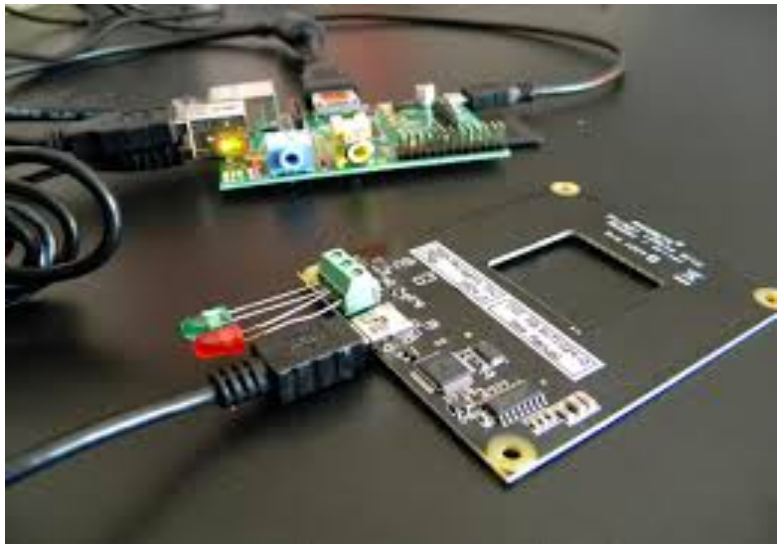
Recognize ink pattern on touch devices

electronics & actuation



Arduino
www.arduino.cc

Phigets [Greenberg & Fitchett, 2001]
www.phidgets.com



Midas [Savage et al., 2012]

http://youtu.be/WHcQgtjD_zY

related internship topics (1)

AnimHands: Creating Opportunistic Interfaces with Hand Gestures in Augmented Reality

(Left) A soda can turned into a music player [ZSF20]. (Right) A mug turned into a slider to control ambient light intensity [FXJ23]

Most Augmented Reality systems (e.g., Meta Quest 3 or Apple Vision Pro) can reliably track users' gaze and hand movements. They can also scan the environment to detect uncluttered, flat surfaces like walls and tables. However, they still struggle with the real-time tracking of physical objects or surfaces that are cluttered. This is a limitation that prevents the development of opportunistic interfaces where users could turn any object around them into a user interface. The HCI literature envisions such opportunistic interfaces [HEF08], with, for example, a soda can turned into a music player or a mug turned into a slider to control ambient light (see Figure above).

https://ilda.saclay.inria.fr/jobs.html

related internship topics (2)

Augmented Reality for Situated Outdoor Visualization

Context

Augmented Reality (AR) superimposes information in the user's field of view and is particularly relevant to outdoor contexts of use, where users can access digital data and seamlessly relate those data to their physical surroundings. This can be useful for leisure activities (outdoor games, tourism), but in a variety of work contexts as well such as urban planning, construction work, and a variety of scientific activities. To take one particular example, geologists often need to access data about the location they are currently visiting: terrain models, soil sample data analyses, documents about the area, including maps.

Figure 1: Artist's rendering of a geologist working in the field and interacting with data in AR.

and many more topics !!!!

https://ilda.saclay.inria.fr/jobs.html

thinking exercise

Remember SandCanvas [Kazi et al. 2010]?
How/why would you create a TUI for it?

getting there

DIRTY tangible interfaces [Savary et al., 2012]

http://vimeo.com/62069049