

mixed reality
&
(tactile and) tangible interaction

J. Vezien
&
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tangible interfaces and a bit of augmented reality

Anastasia Bezerianos

some slides adapted by T.Tsandilas

touch vs. tangibles

HANDS
FEEL THINGS



HANDS
MANIPULATE
THINGS



touch vs. tangibles



Power grip, fingers vs palm



Precision grip, fingers vs thumb



Hook grip, between phalanges



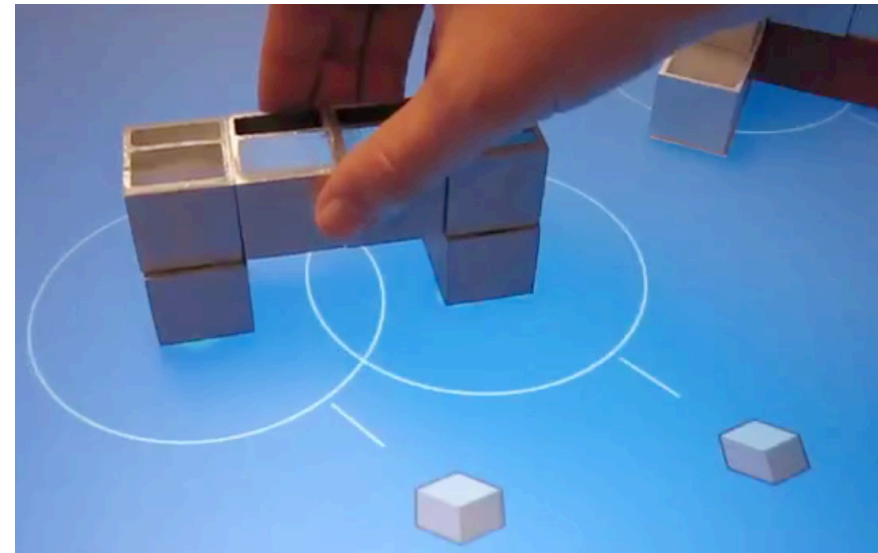
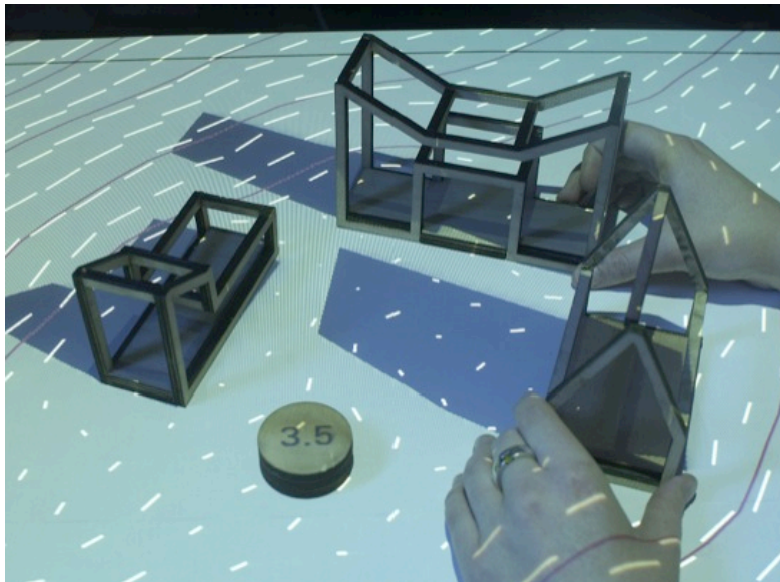
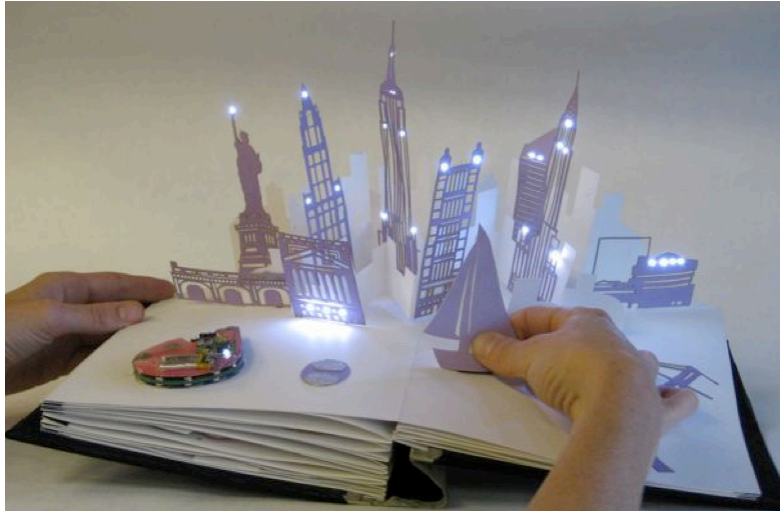
Scissor grip, between fingers

touch vs. tangibles



<http://worrydream.com/>

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

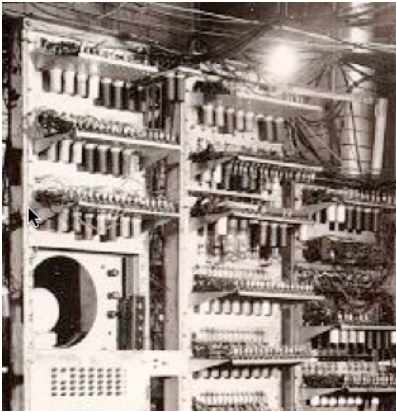
virtual world beyond the desktop

computing integrated in **everyday life** experience
and **physical world**

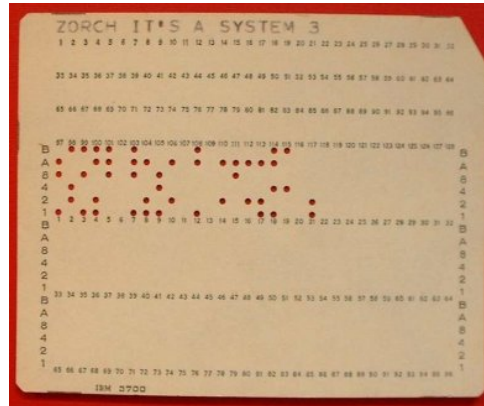
approach:

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

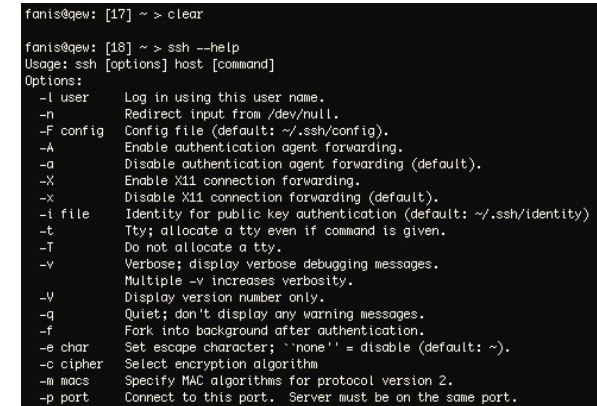
history of interfaces



electrical



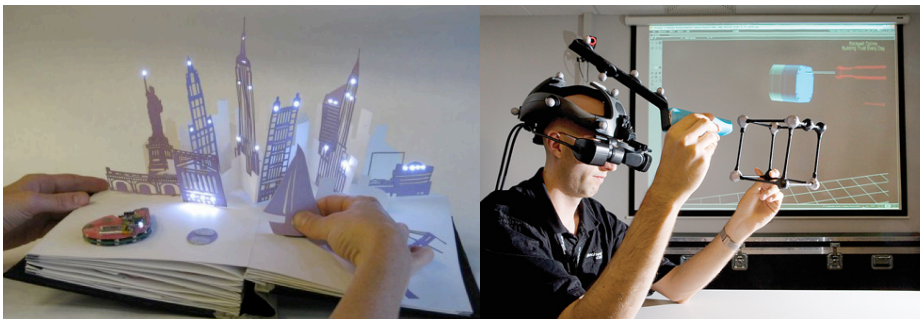
symbolic
« punch cards »



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

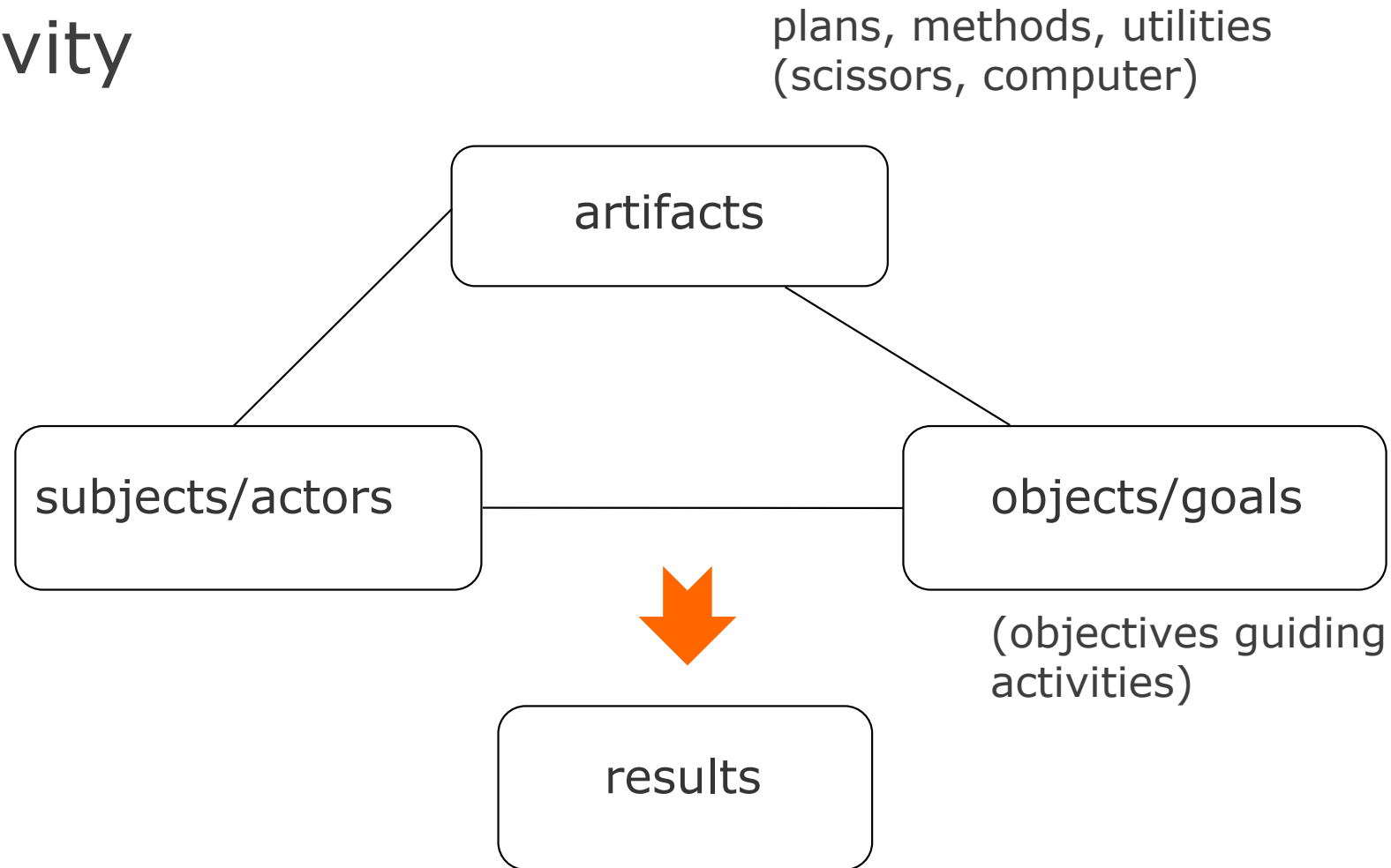
our actions take place in a **social context** composed by **individuals** and **artifacts**

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

 need to consider interaction in context.

activity theory

activity



[Leontiev, 78]

activities and HCI design

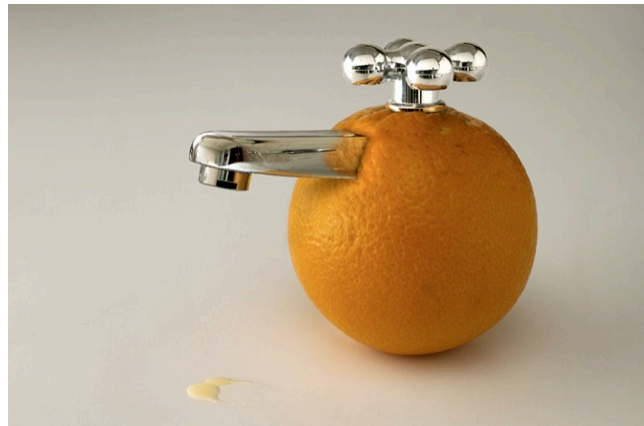
design for human activities
... not just widgets and tools

"Designing interaction not interfaces"

[Beaudouin-Lafon, 2004]

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



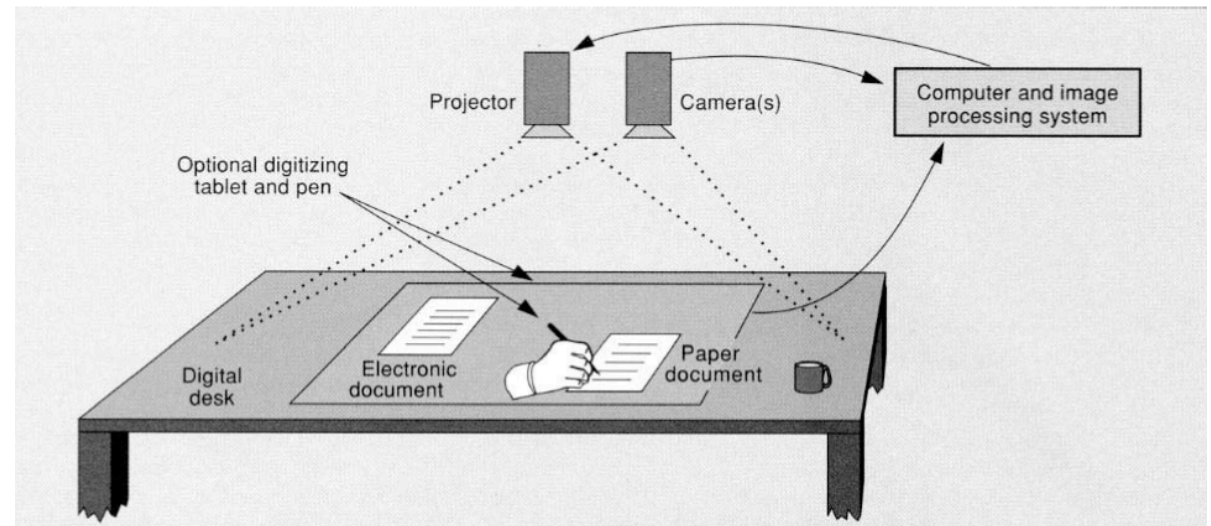
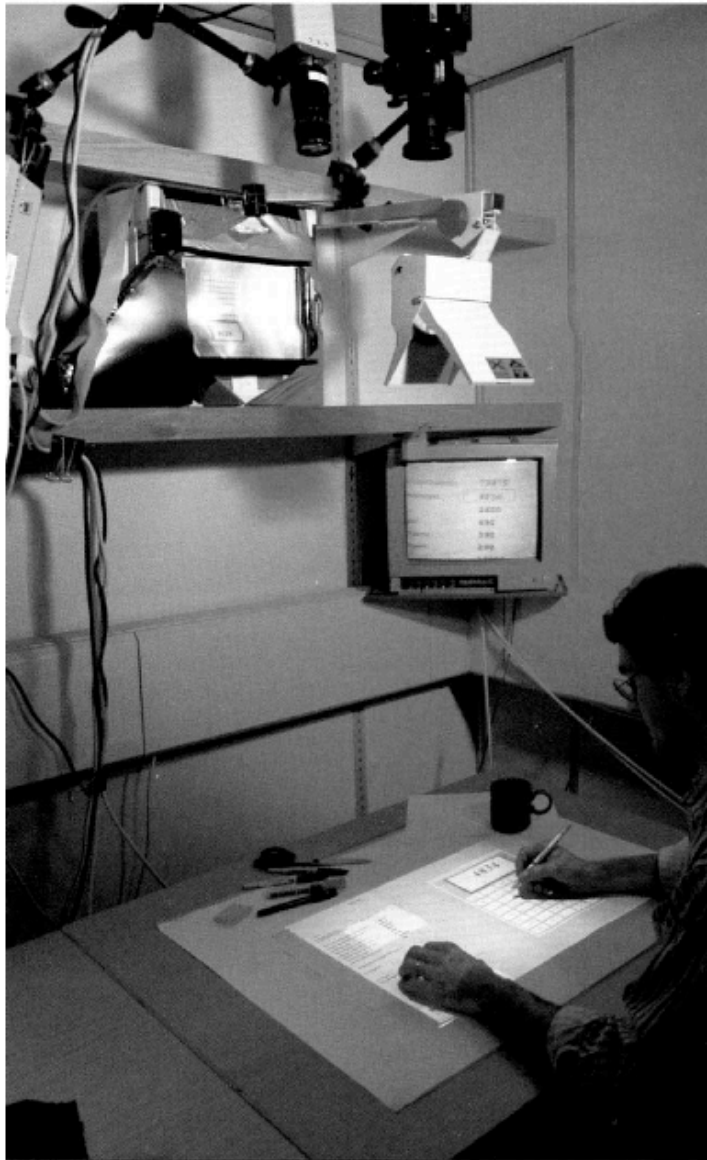
by Giuseppe Colarusso



by Nostalgia Electrics

TUI pioneers

DigitalDesk [Wellner, 1991-93]



http://youtu.be/S8lCetZ_57g

DigitalDesk [Wellner, 1991]

here?

images projected on table and paper

pen and finger interaction

identification of documents placed on table

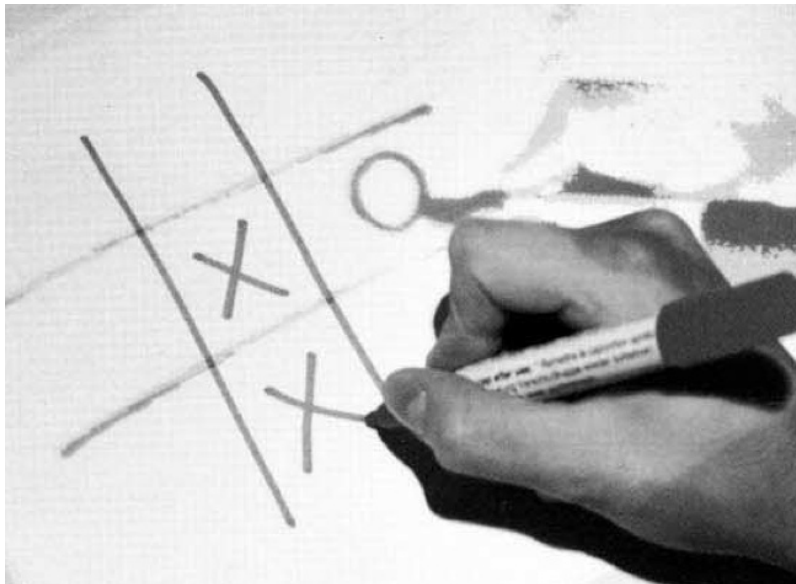


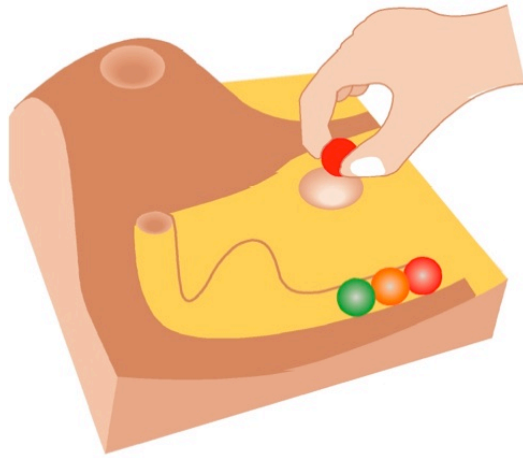
image of the hand of a 2nd
remote user projected on the paper

DoubleDigitalDesk

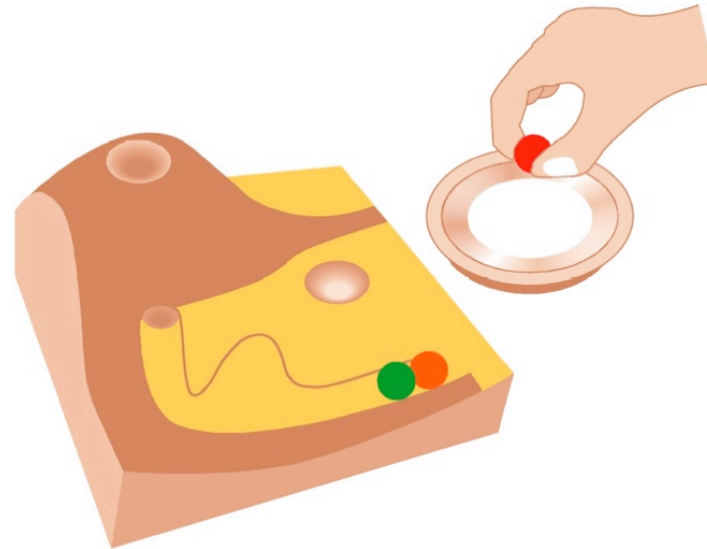
marble answering machine

[Bishop, 1992]

answering machine: each marble a message



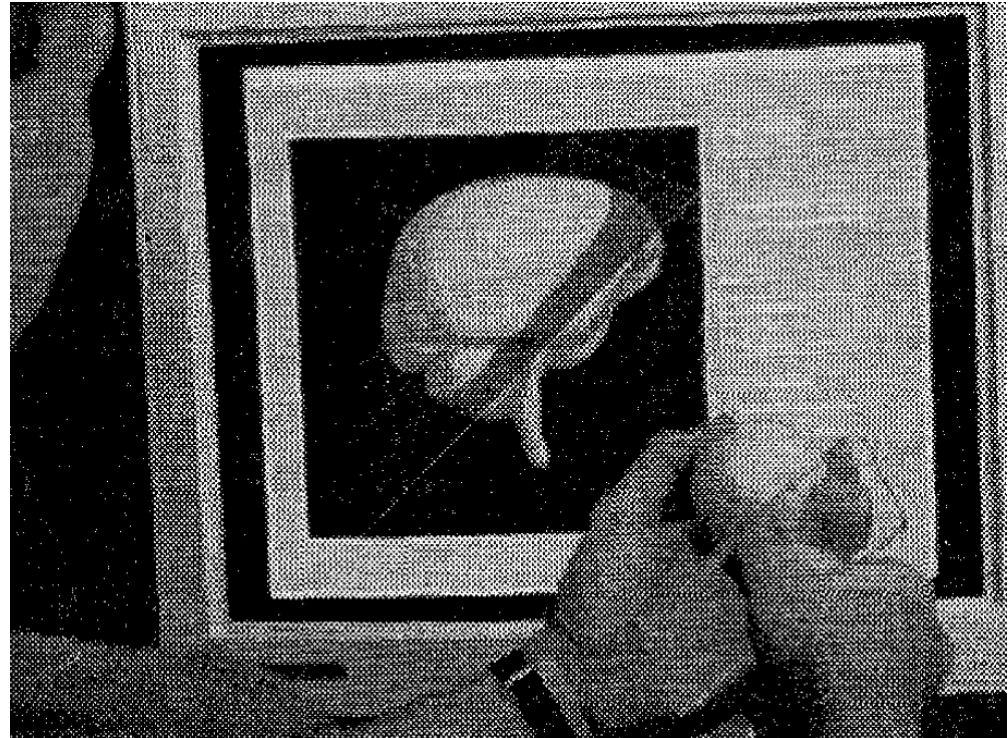
place marble in slot to hear



place marble in bowl to store

Props [Hinckley, 1994]

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

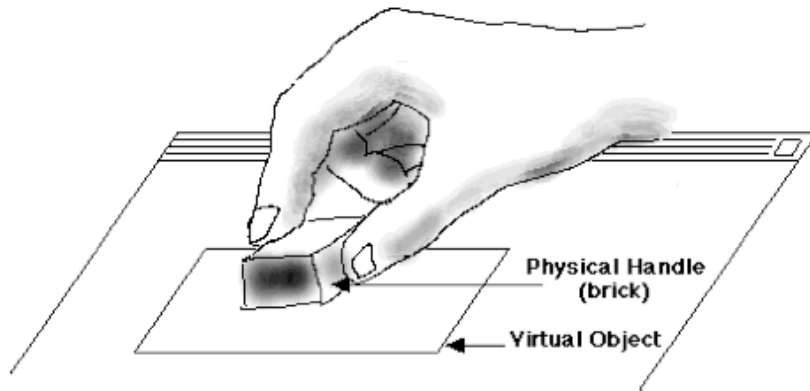


Props [Hinckley, 1994]

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

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]

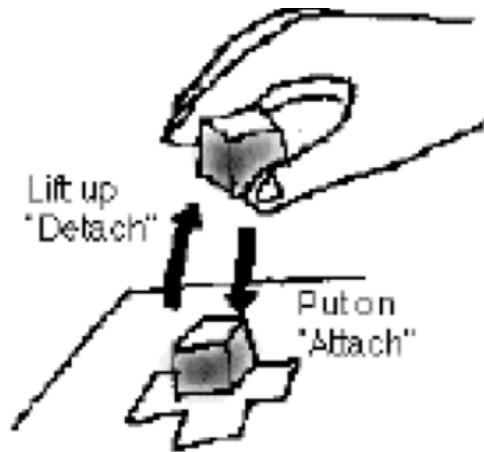
space multiplexing rather than time in traditional UI

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

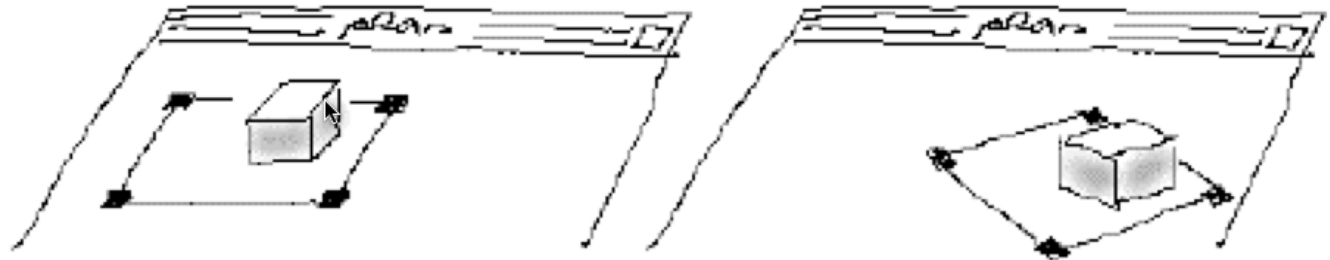


Bricks [Fitzmaurice et al., 1995]

interactions with one brick (proxy)



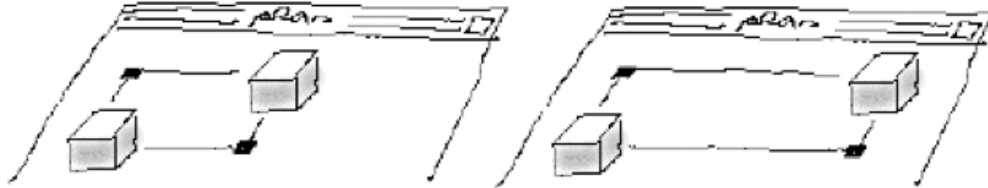
attach (detach) brick to
virtual object



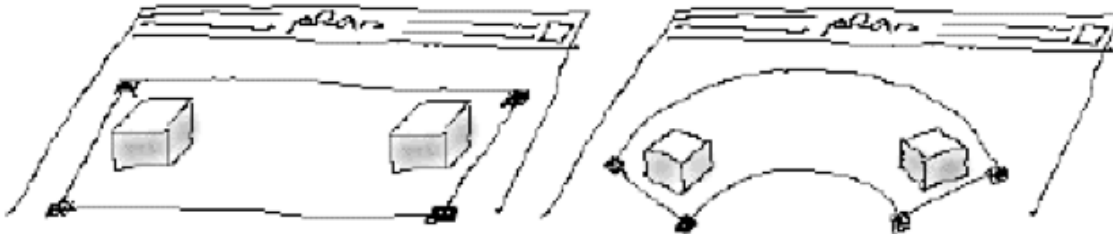
move and rotate the virtual object

Bricks [Fitzmaurice et al., 1995]

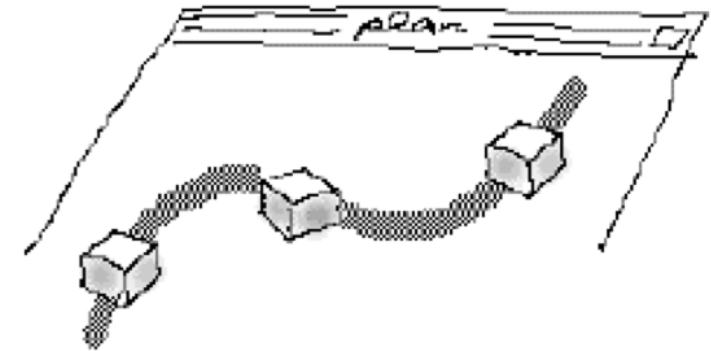
interactions with multiple bricks (controller)



change the size of an object



deform



create a curve

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

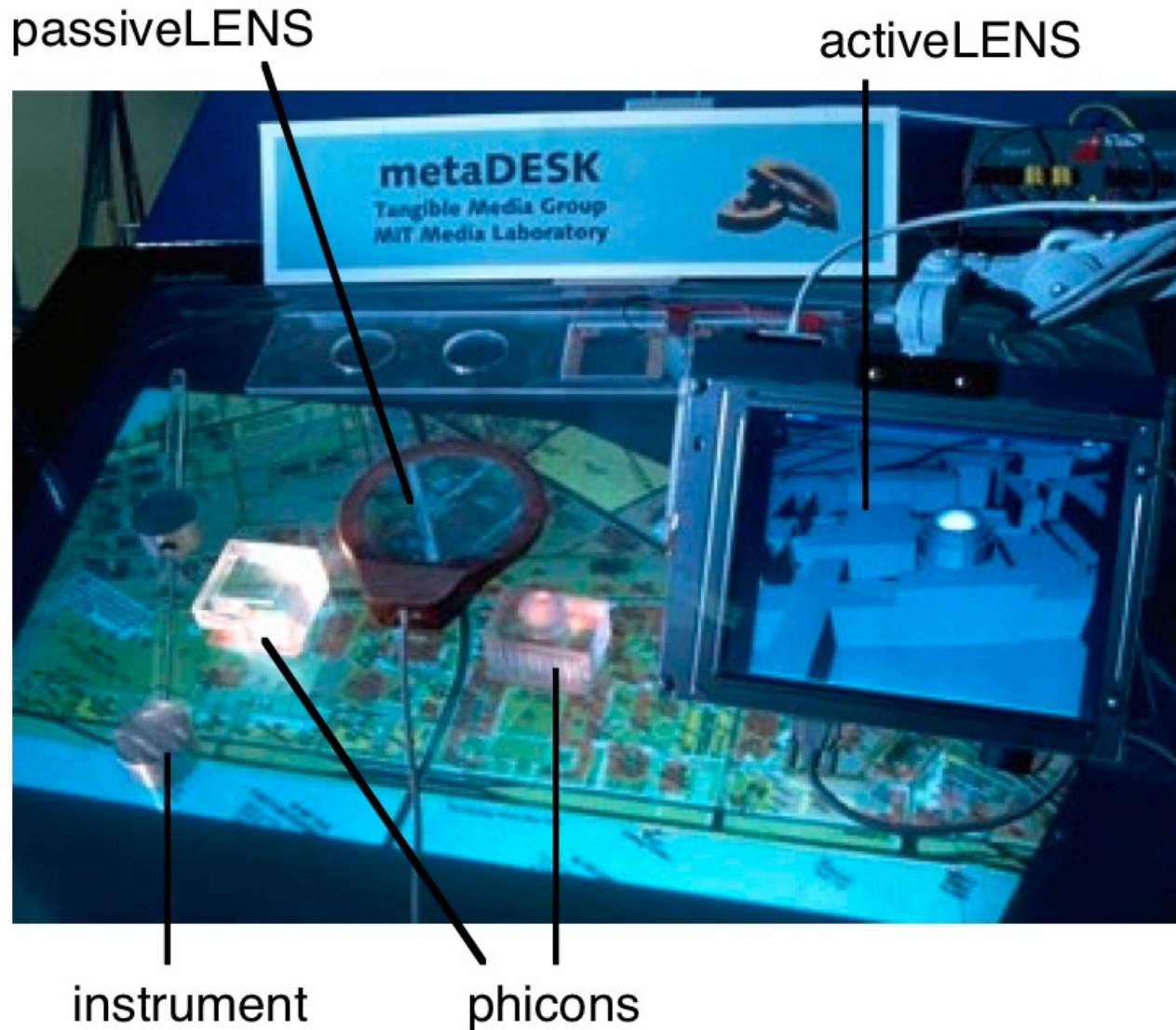


Bricks [Fitzmaurice et al., 1995]

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]

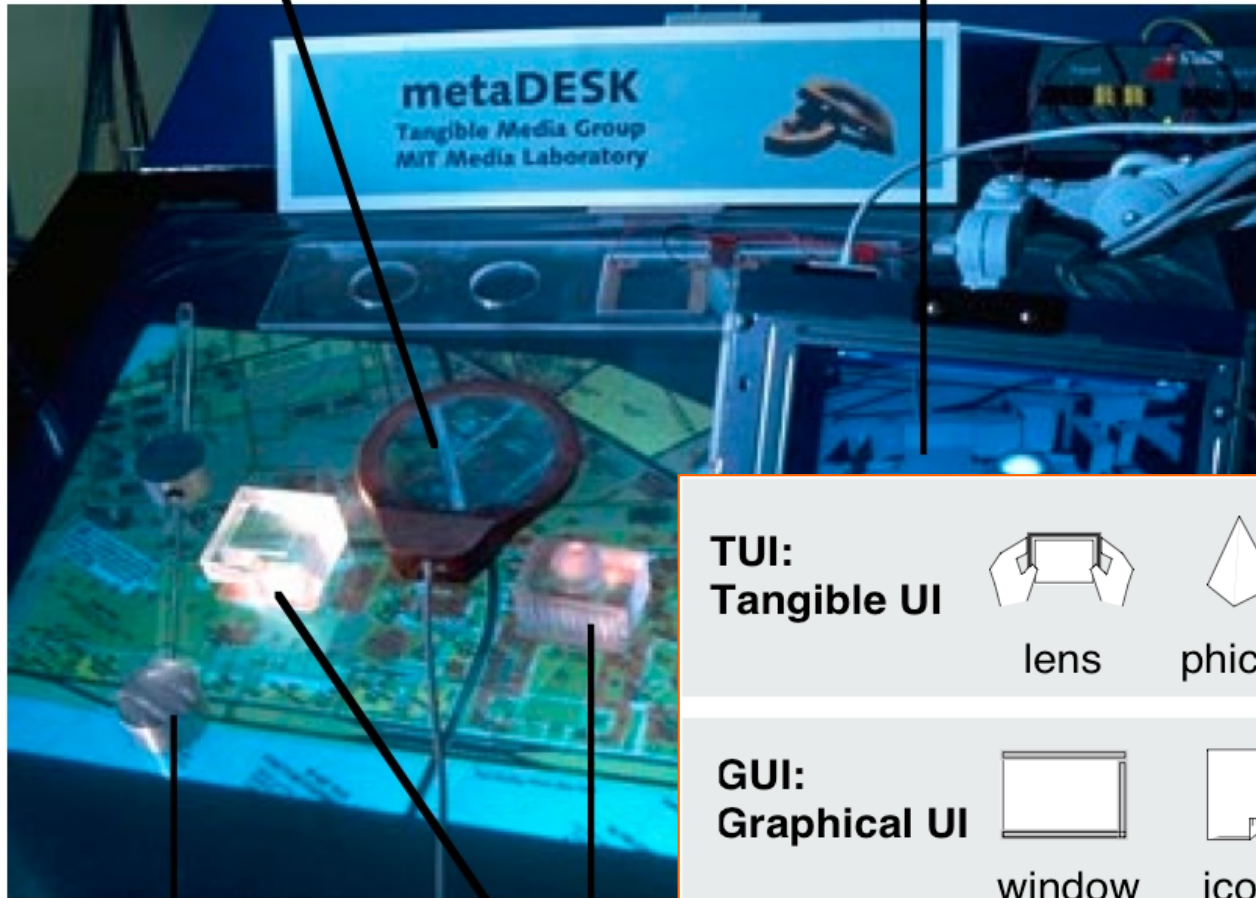


<http://vimeo.com/44545109>

metaDESK [Ullmer & Ishii, 1997]

passiveLENS

activeLENS



instrument

phicons

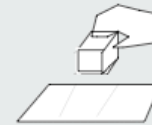
TUI:
Tangible UI



lens



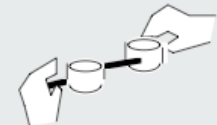
phicon



tray



phandle



instrument

GUI:
Graphical UI



window



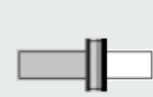
icon



menu



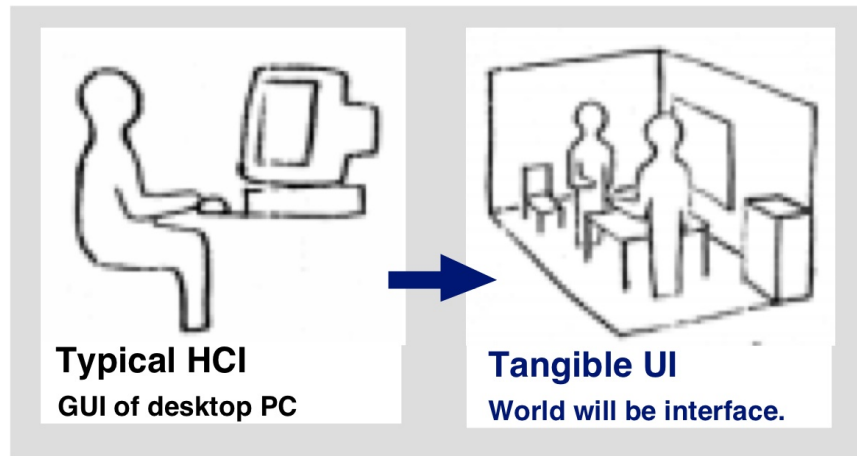
handle



widget

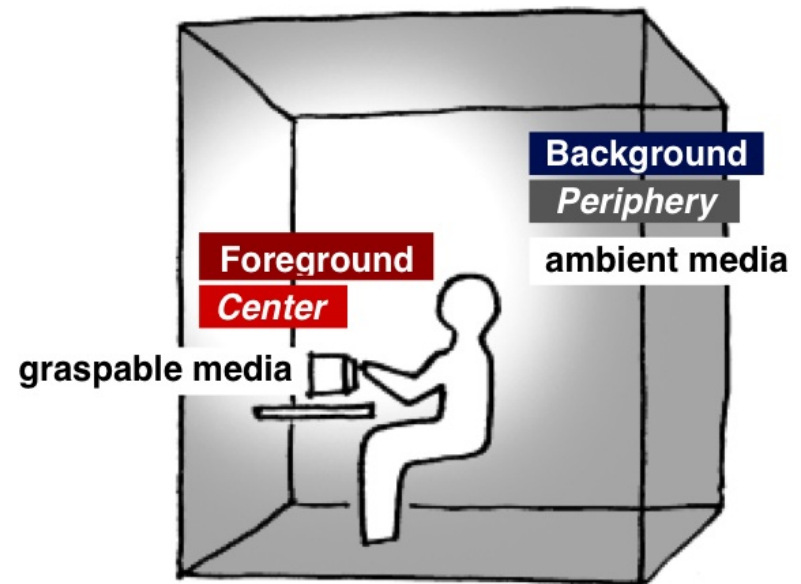
tangible bits [Ishii & Ullmer, 1997]

introduced the concept of « tangible interface »



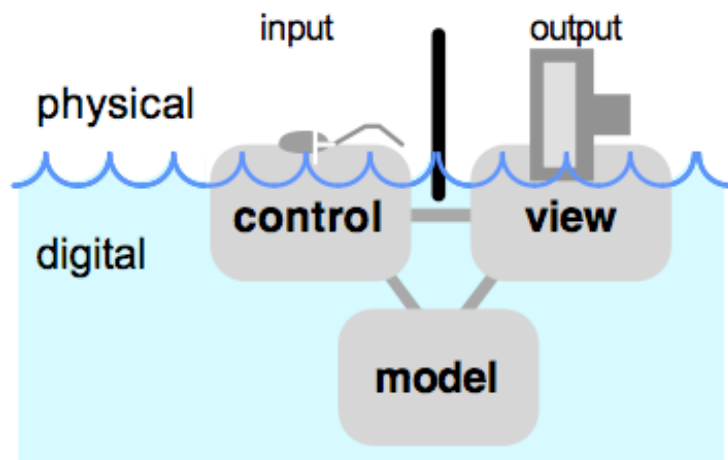
« Human interfaces that employ physical objects, surfaces, and spaces as tangible embodiments of digital information and processes. These interfaces explore interactions in both the foreground and in the background.

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. »



center and periphery of attention in the physical environment

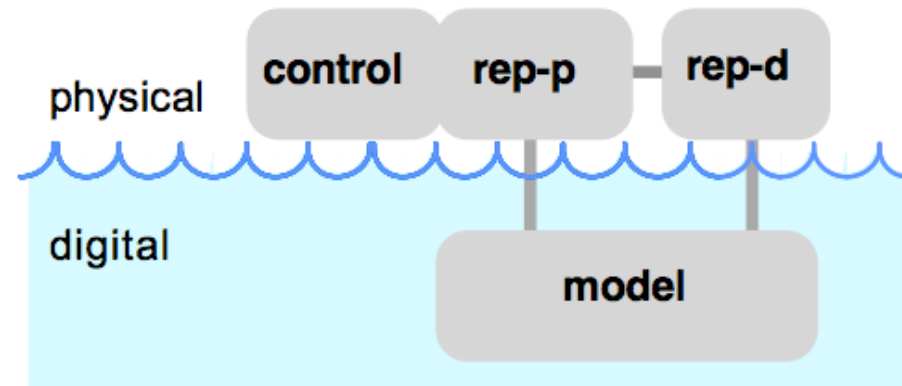
tangible interaction model



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

IBLUB	<5733>	330								UK
C650	430	LIMP	LFRG							23
5777		390								04
	0538	TH								97
					LGL	LISEU	DVL	LFRG		
					52	55	58	59		
					05	05	05	05		
					0549					
					CHW					

strip: paper band
representing flights

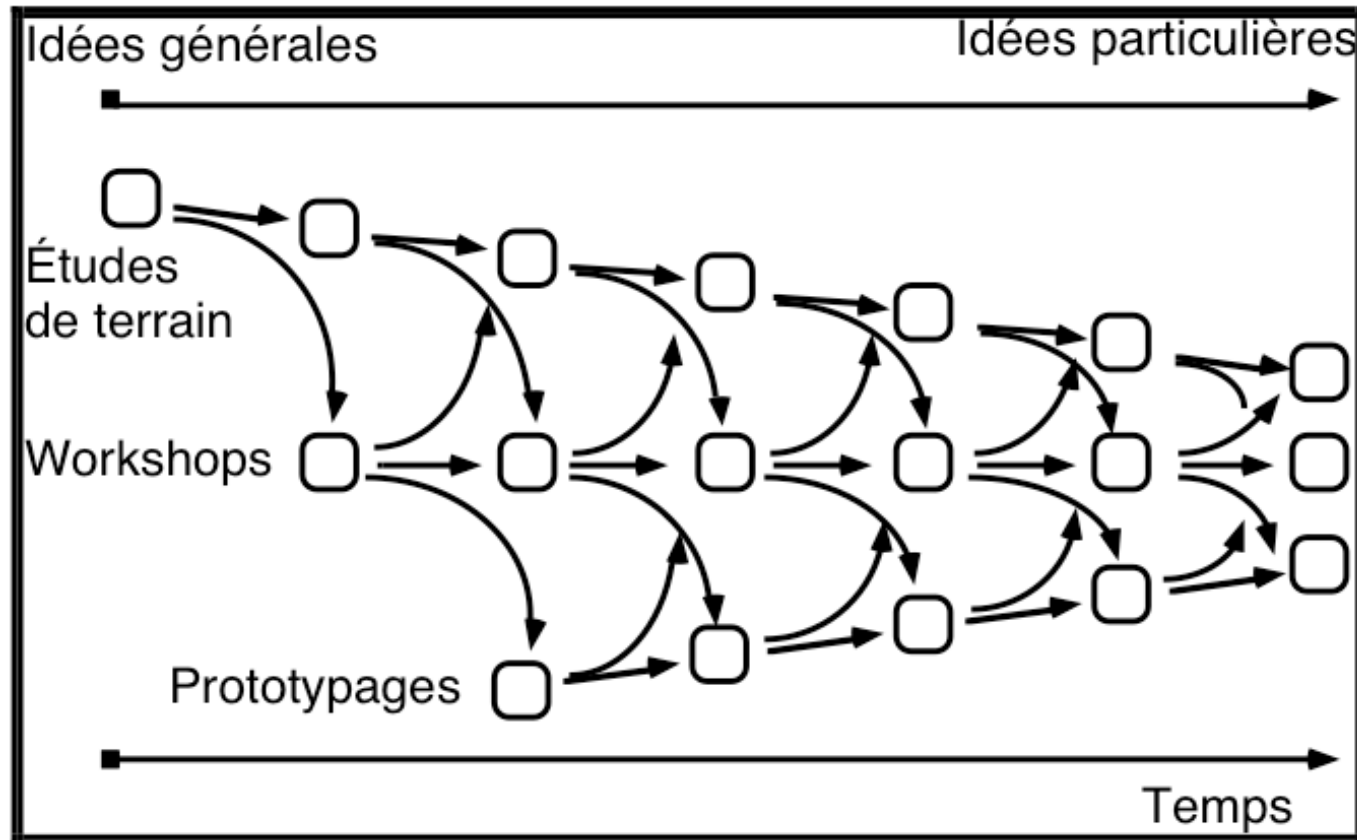


use of strips by controllers

flight strips [Mackay, 1997-98]

approach:

ethnographic studies to observe strip use
+ participative design session to create new interfaces



flight strips [Mackay, 1997-98]

observations of strip use

AFR 1 1 1 7<1024> air france EA32 450 LEMD LFPG 8548 MERUE MOD 1224 TP										260 860 250	260 250	PEROT 12	TERNI 41	CHW 12	CLARA GIRKØ 12	SØKMU 12	UX 2 28 04 97	
Paris (Athle Mons), France: en route control center																		
SWR 658 <3020> swissair EA32 440 LSZH LEMD 5602 1759 ZA										290 290		MEN 06 18	GAI 15 18	TON 18	SØVAR 30 18	ZZA 40 18	H1 3 10 04 97	
Bordeaux, France: en route control center																		
C08R										B73F	KLM331	CS	230LEX	17:44:35				
1747-CT										EHAM	B31 390	LFPG	C0172					

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 controllers



co-annotation



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

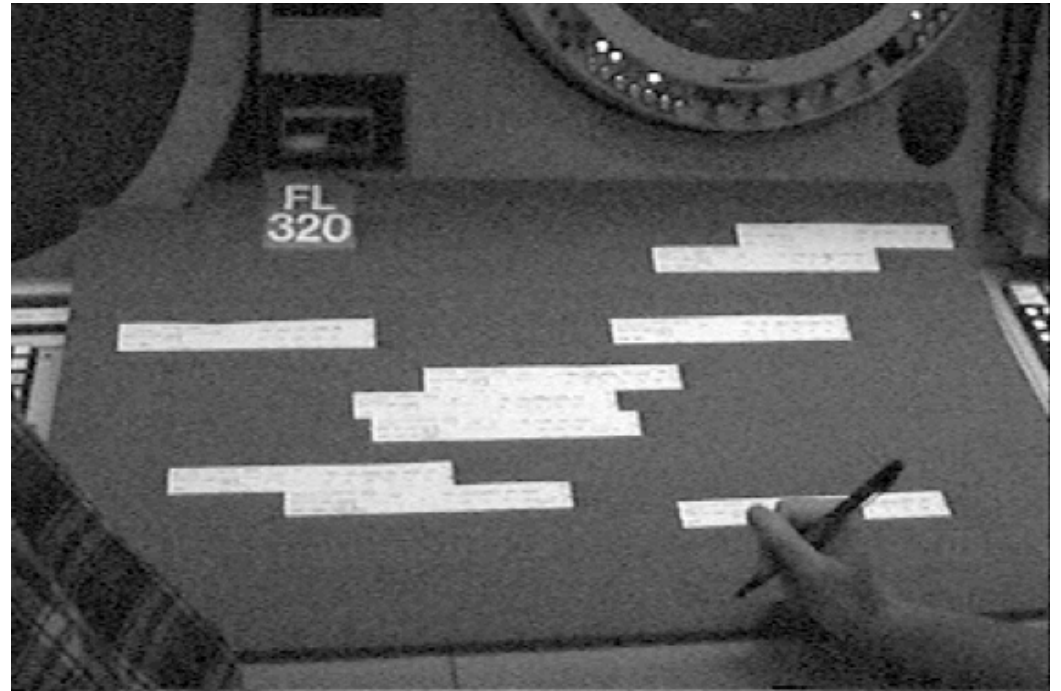
flight strips [Mackay, 1997-98]

observations of strip use

spatialisation



left/right alignment 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)

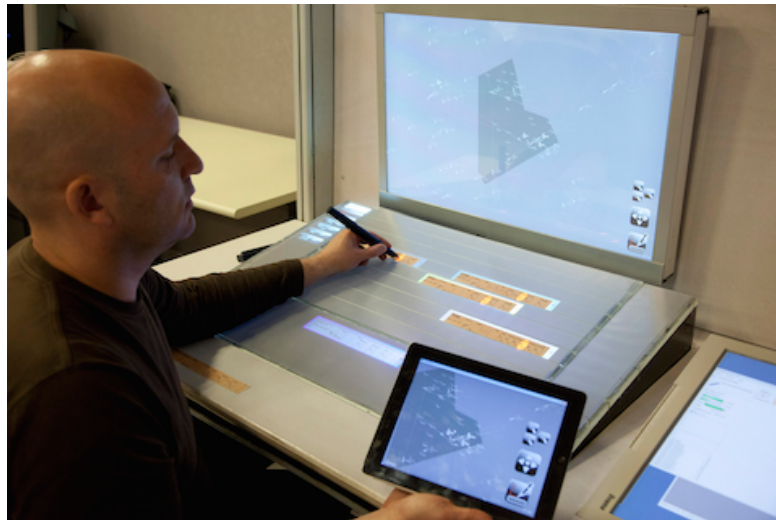
recommendation

- augment strips rather than replace them

... later Strip'Tic [Hurter12, Letordal13]

StripTic prototype

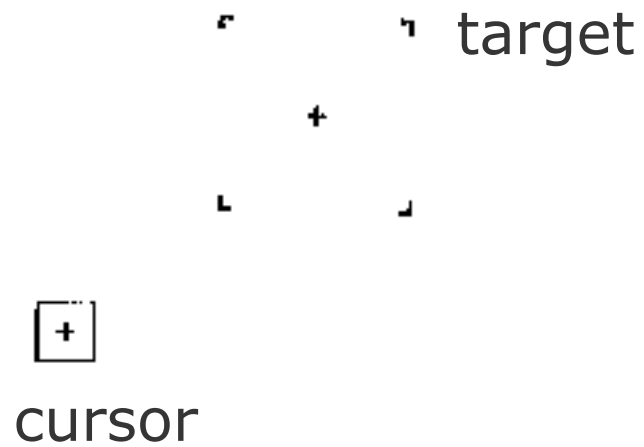
- Participatory design process
- Combination of paper and virtual strips
- Gestural interactions



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

bi-manual interaction and motor control

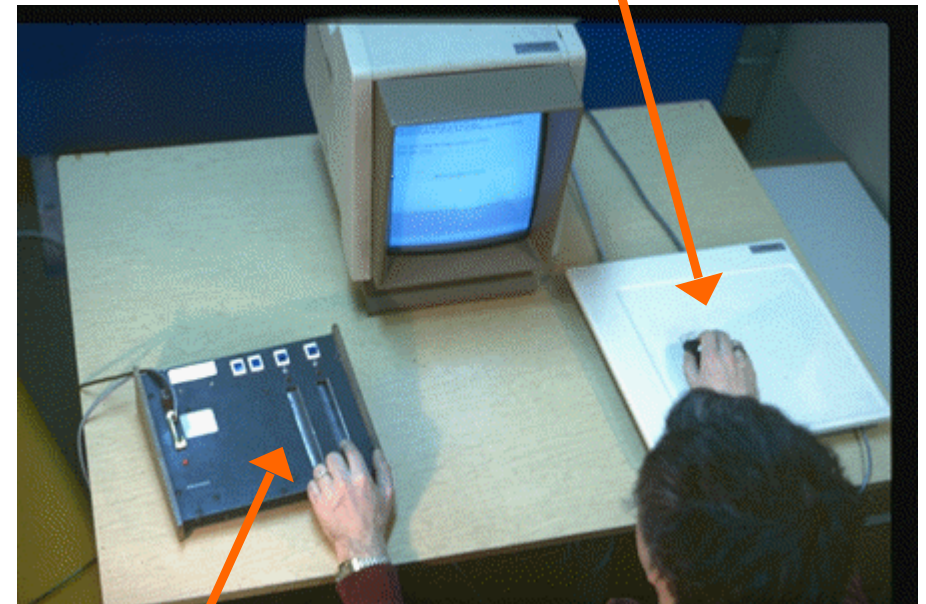
first studies in HCI [Buxton & Myers, 1986]



The cursor needs to be positioned and applied on the target

Result: parallel movements for 40.9% of time

position control:
puck on tablet



size control: slider

first studies in HCI [Buxton & Myers, 1986]

a 2nd study showed bi-manual interaction as faster than single hand interaction for a navigation and selection task.

kinematic chain model [Guiard, 1987]

The kinematic chain is a sequence of abstract joints

- e.g. shoulder -> elbow -> wrist -> finger

For some sequence links (e.g. elbow -> wrist) the movement of the 2nd element (wrist) is defined by the movement of the 1st element (elbow)

kinematic chain model [Guiard, 1987]

The kinematic chain is a sequence of abstract joints

- e.g. shoulder -> elbow -> wrist -> finger

For some sequence links (e.g. elbow -> wrist) the movement of the 2nd element (wrist) is defined by the movement of the 1st element (elbow)

➔ Hypothesis: bi-manual movement works like a kinematic chain (dependant frames of reference)

non-dominant hand -> dominant hand

kinematic chain model [Guiard, 1987]

Principles :

1. Dominant hand moves inside the reference frame defined by the non-dominant hand.
2. Asymmetry in operations: the movements of the dominant hand are more precise.
3. The non-dominant hand precedes the dominant one.
(e.g. the left hand positions a piece of paper and then the right hand starts writing)

Verification of the model

Manipulation of physical objects [Hinckley, 1997]

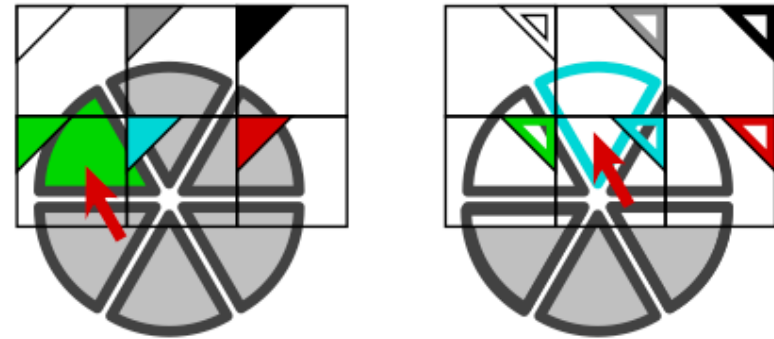
- Asymmetry between the two hands for difficult tasks
- ... but the asymmetry disappears when the tasks become sufficiently easy

Several research projects have investigated other aspects of the model

- Visual feedback and separation of the input space [Balakrishanan & Hinckley, 1999]
- Symmetrical tasks [Balakrishanan & Hinckley, 2000]

toolglasses [Bier, 1993]

Palettes of filters superimposed over objects of interest



Bi-manual interaction

- Left hand positions the filters (toolglasses)
- Right hand selects the filter over an object

<http://www.youtube.com/watch?v=BwIAcczLUUA>

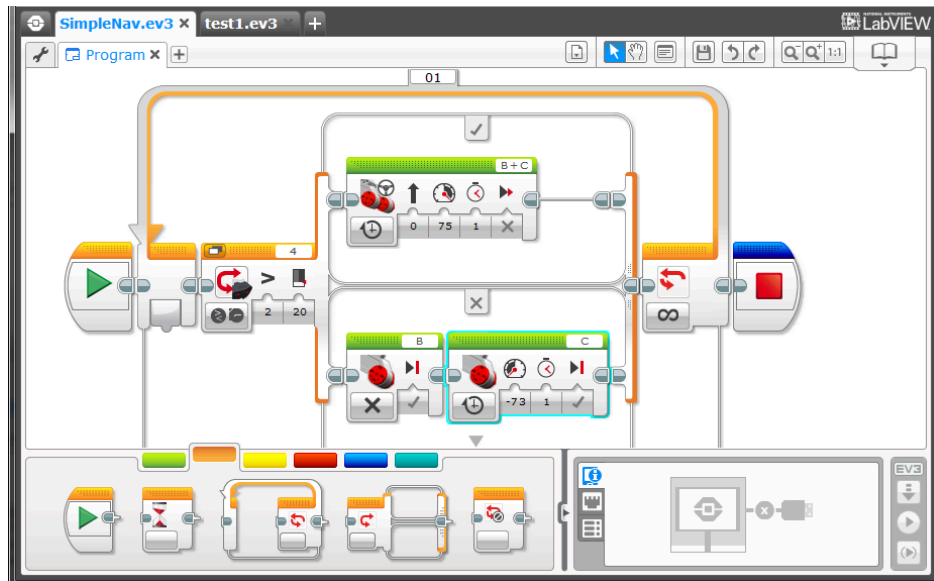
**applications
(metaphors, feedback, detection)**

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

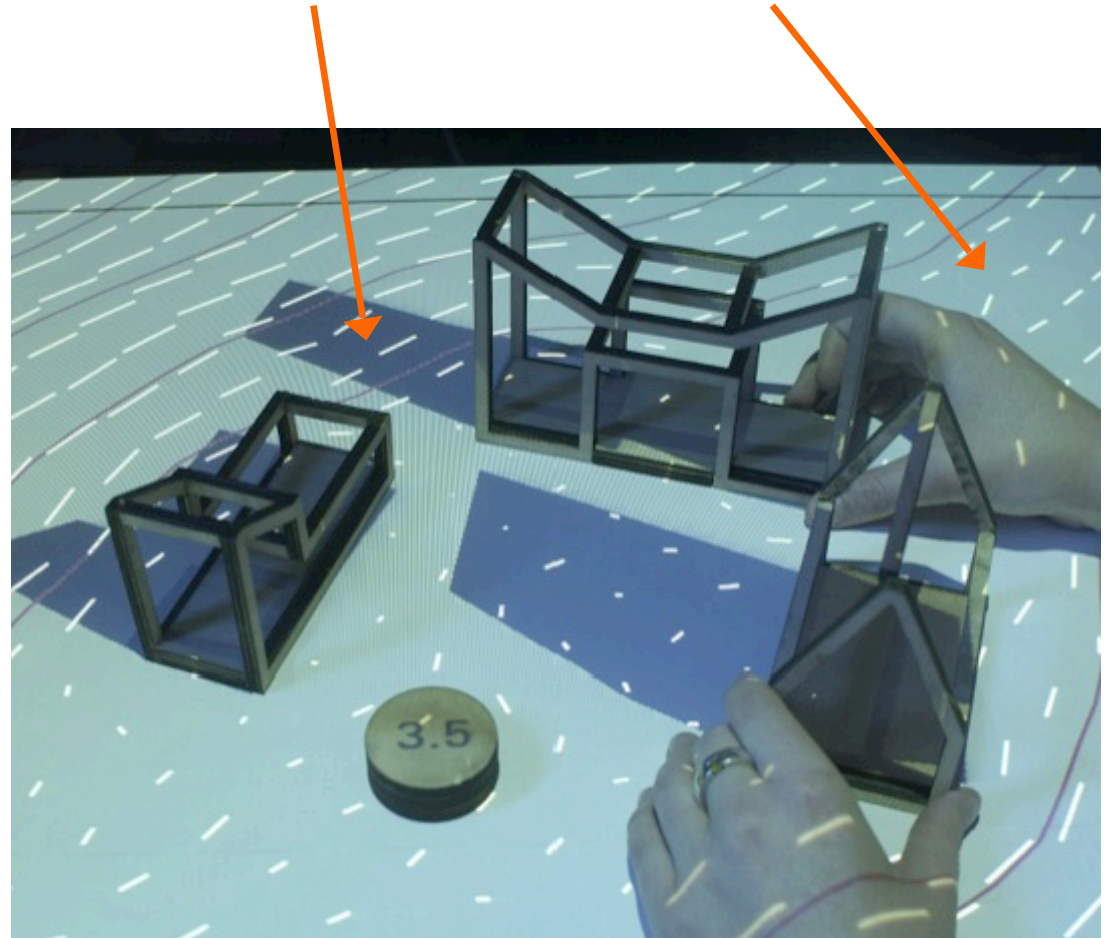
... And many more (have a look at the TUI survey paper)

applications:

2. TUI's to problem-solve & plan

architecture, urban planning

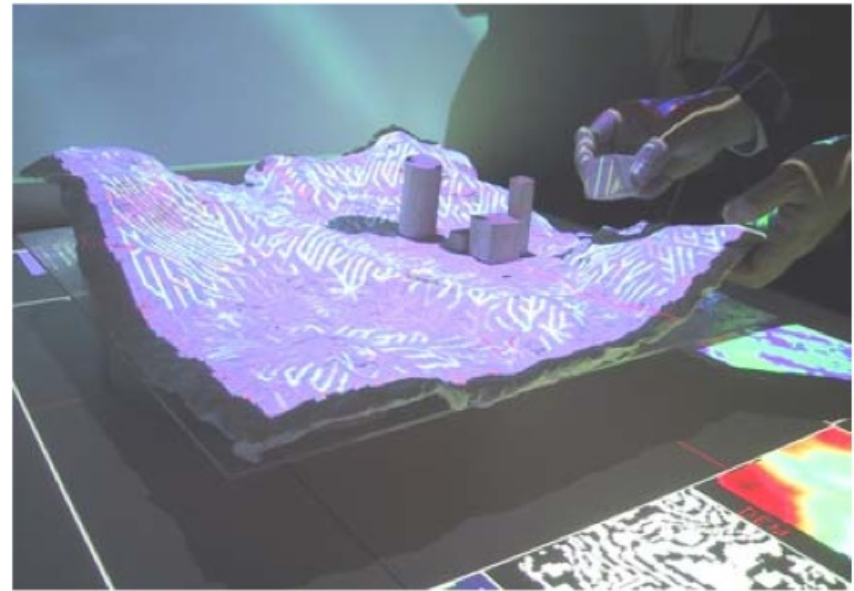
modeling /visualization of shadows and winds



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.

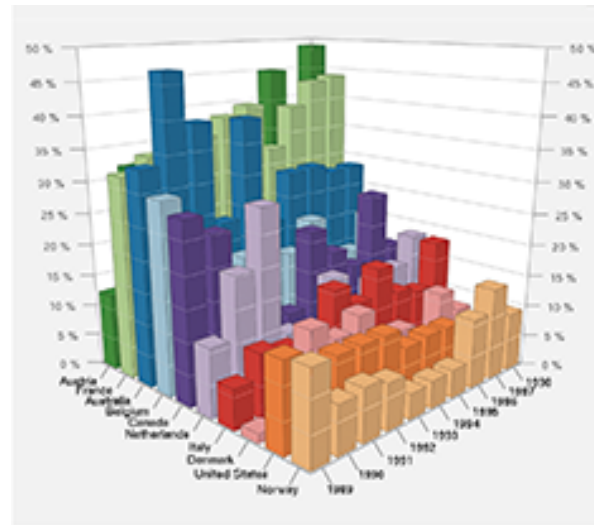
<http://vimeo.com/44539342>

Others

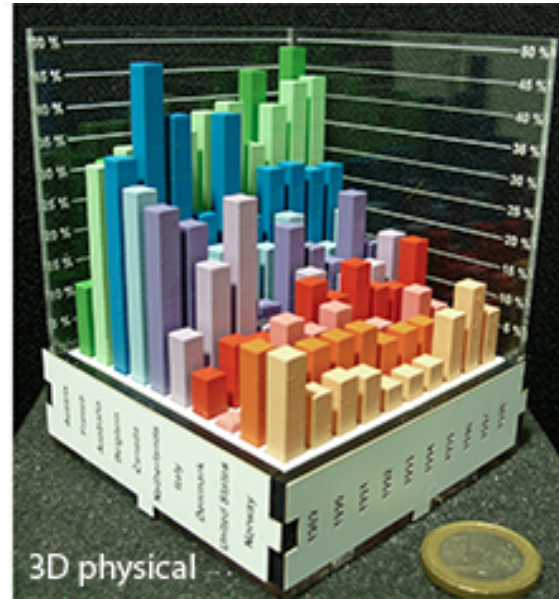
- Illuminating light [Underkoffler & Ishii, 1998] for optics
- Graphmaster [Schweikardt et al., 2009] for graph theory
- [Zuckerman et al. 2005] for constructive assembly
- Tinkersheets [Zufferey et al., 2009] for warehouses
- [Edge and Blackwell, 2009] for office work
- Senseboard [Jacob et al., 2002]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

Visualizations [Jansen et al, 2012]

tangible data visualizations



3D on-screen



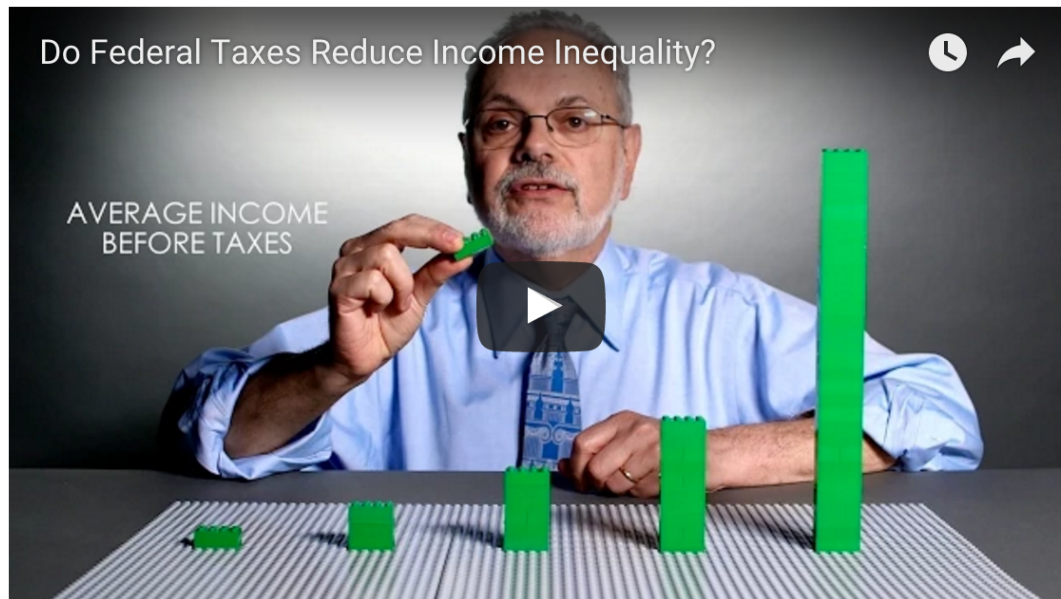
3D physical

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)

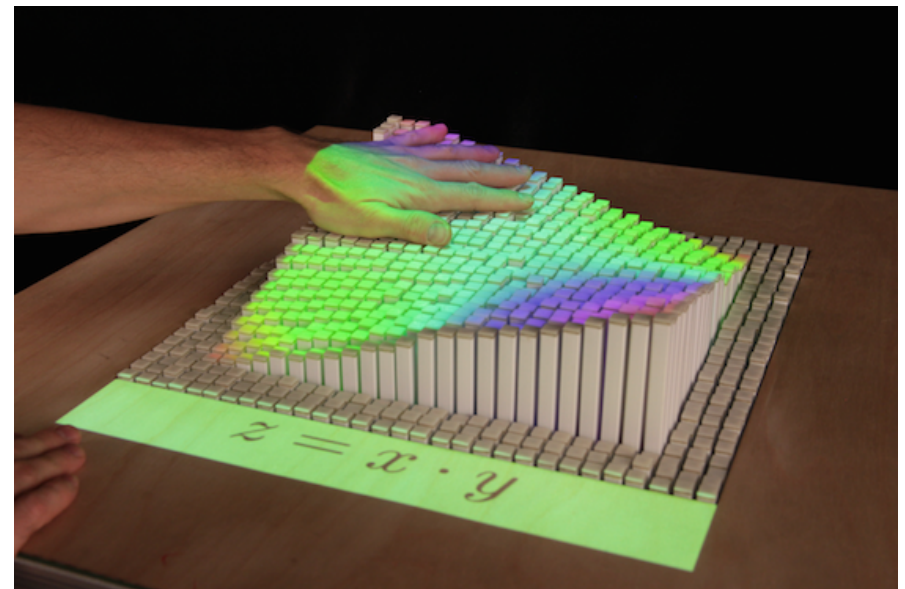
Dynamic data visualizations

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/U4IYyNL4Id8>

Reactable [Jorda et al., 2005]

electronic music instrument

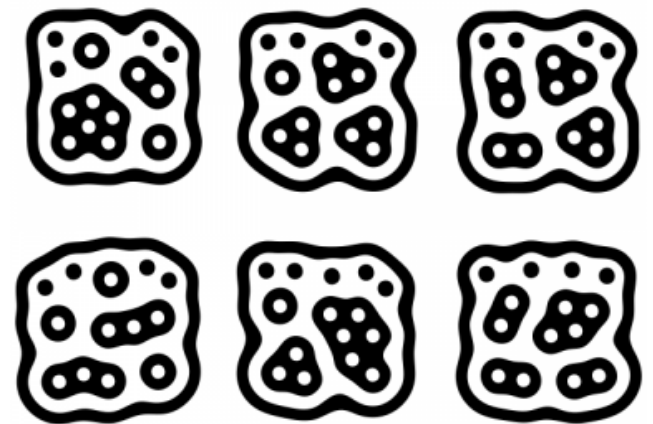
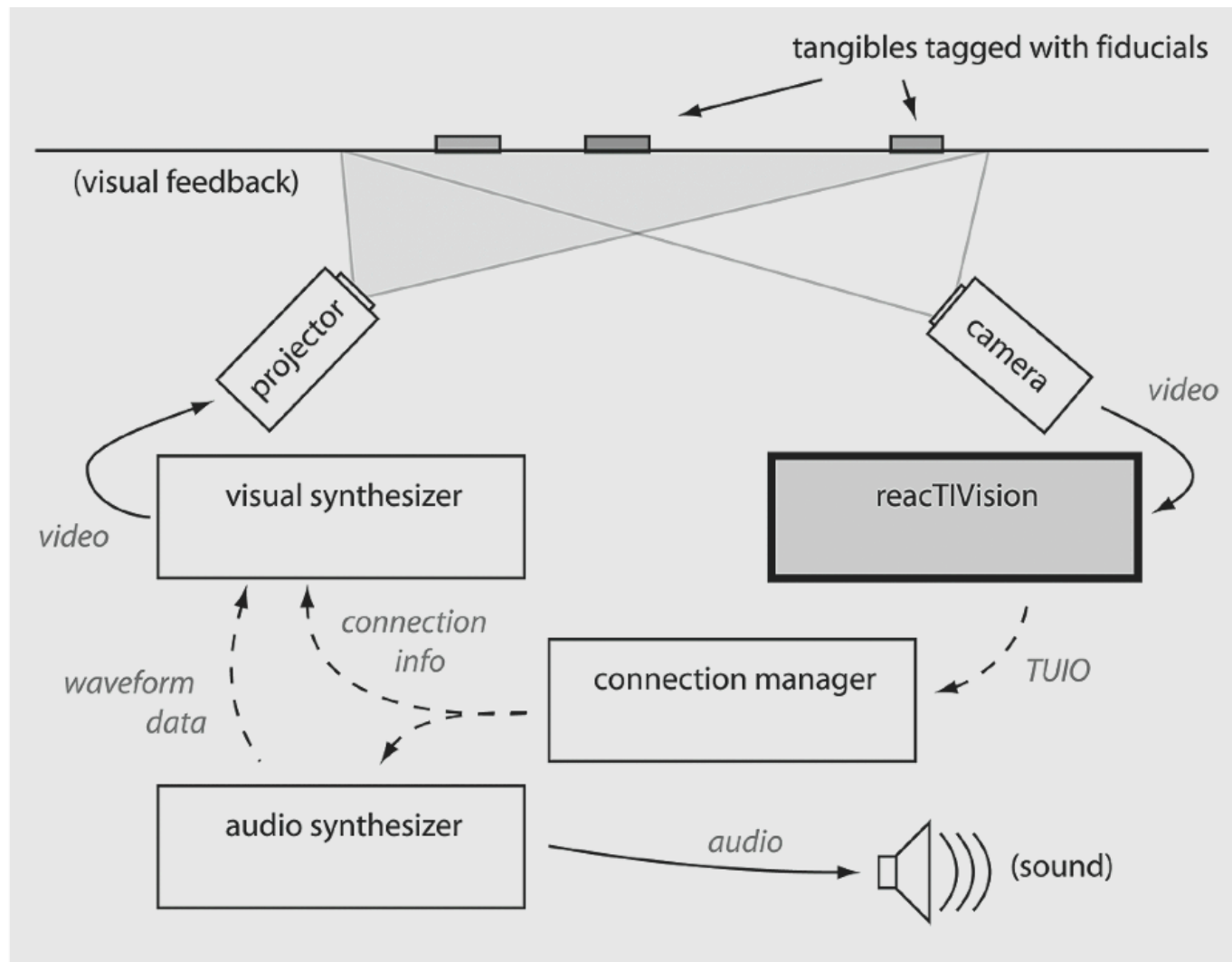
Tangible controls

Rich visualisation of links
between controls



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

Reactable [Jorda et al., 2005]



Markers attached to controls

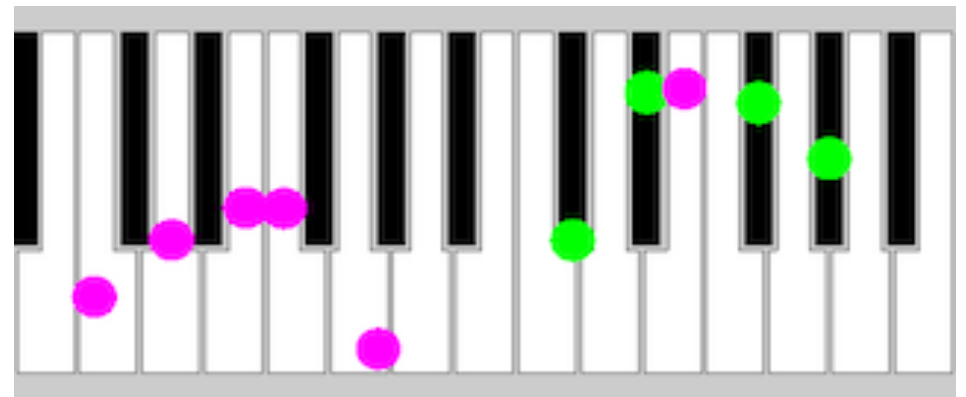
... And many more, e.g. have a look at the mit tangible media site

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



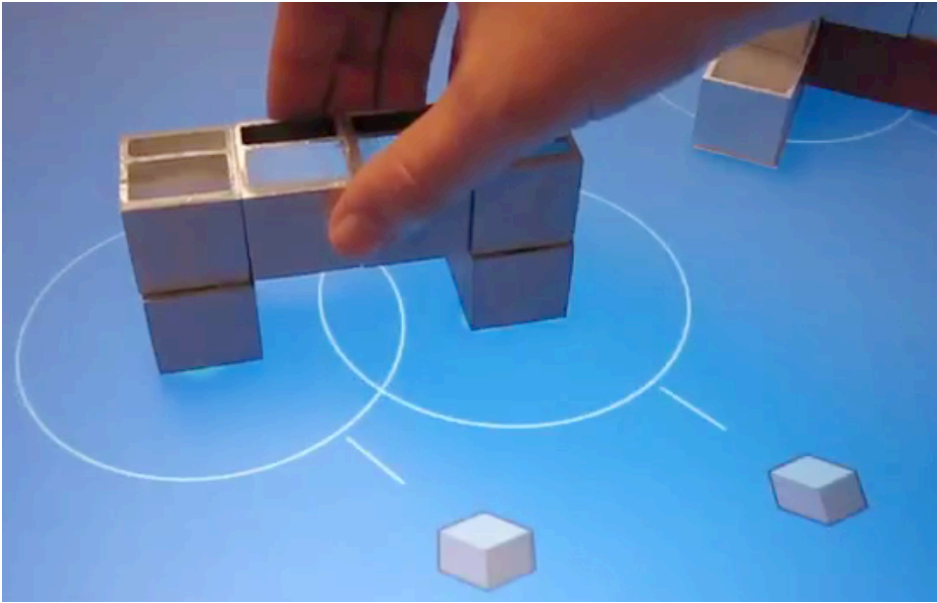
<http://www.youtube.com/watch?v=BmRYuDQzTqU>

applications:

4. TUI's as widgets

Lumino and CapStones

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



Manipulation and detection of overlapping cubes

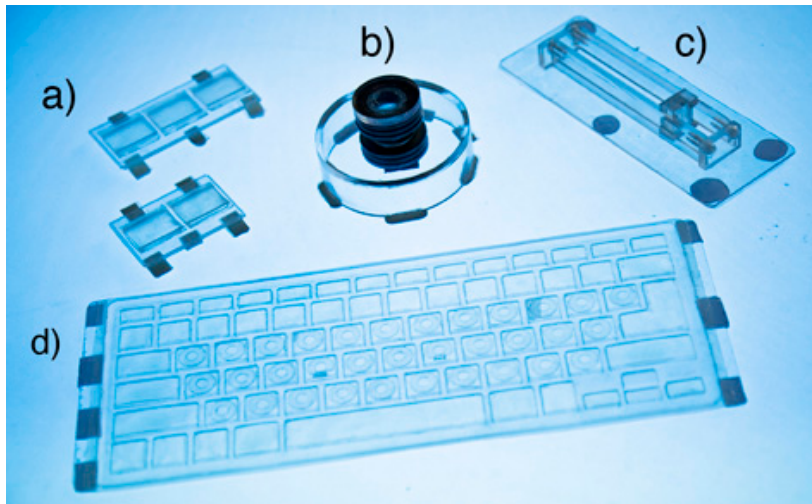
Identify “blocks” or other components (e.g.. widgets) and their structure



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

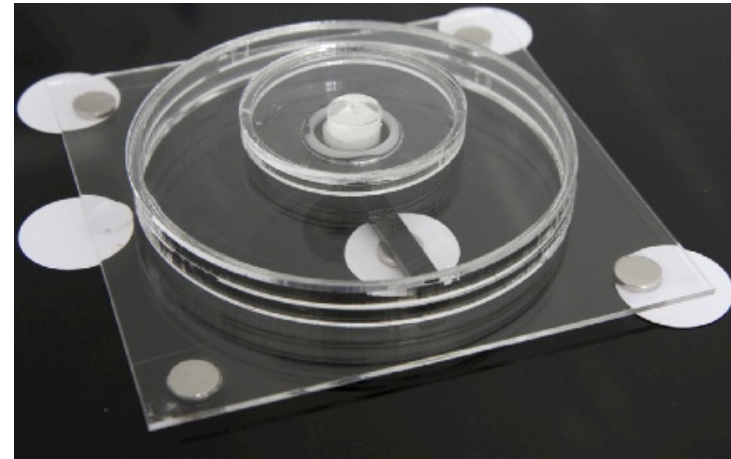
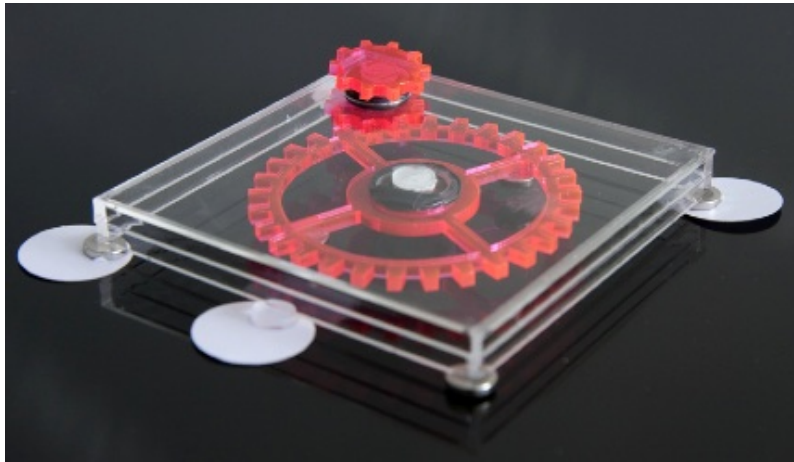
SlapWidgets [Weiss et al., 2009]

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



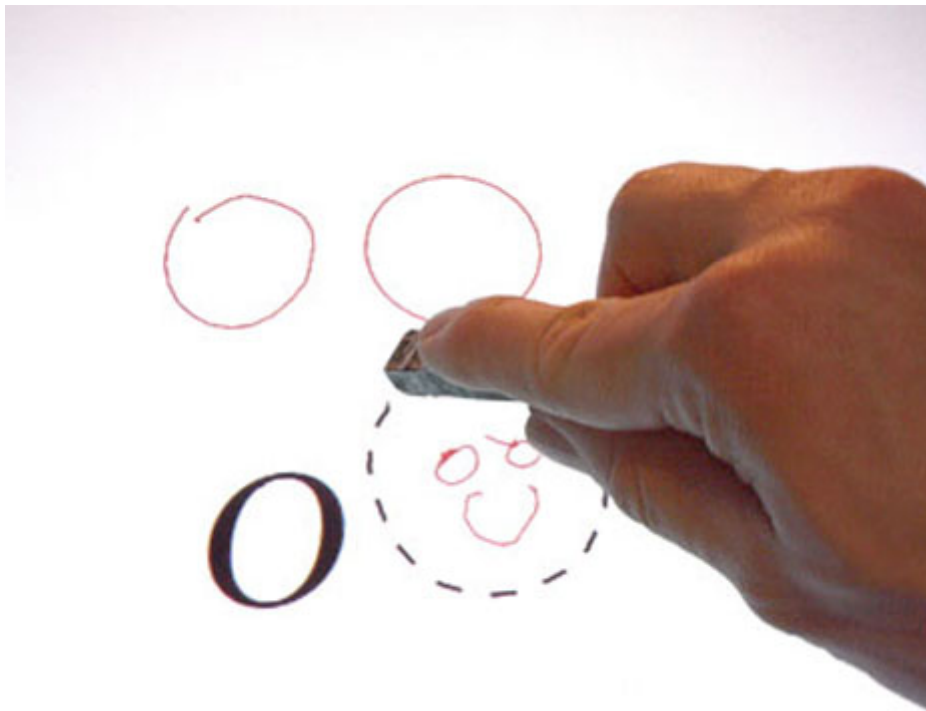
Madgets [Weiss et al., 2010]

Tangible controls with interactive mechanical parts that are actuated



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]

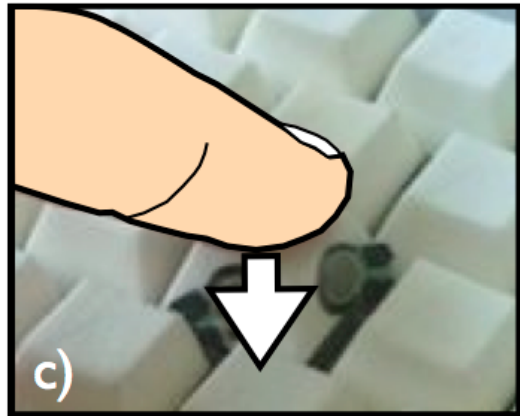
Tangible controls (mainly sliders) on touchpad for controlling large display applications



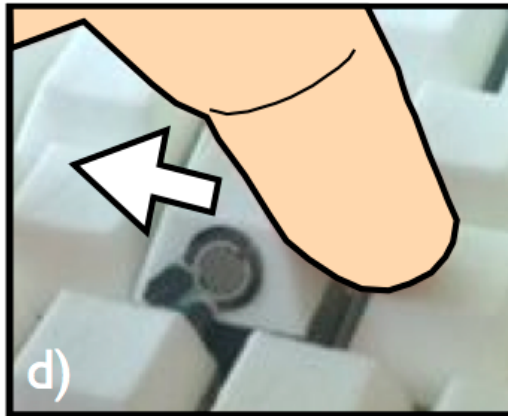
Augmented keyboards

- **Metamorphe** [Bailly et al., 2013]

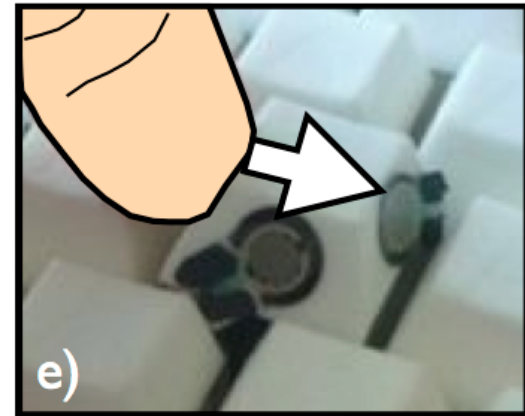
Keyboard keys can change height and act as joysticks



Top Push on 'F'
("Find")



Push to Left on 'F'
("Find Previous")

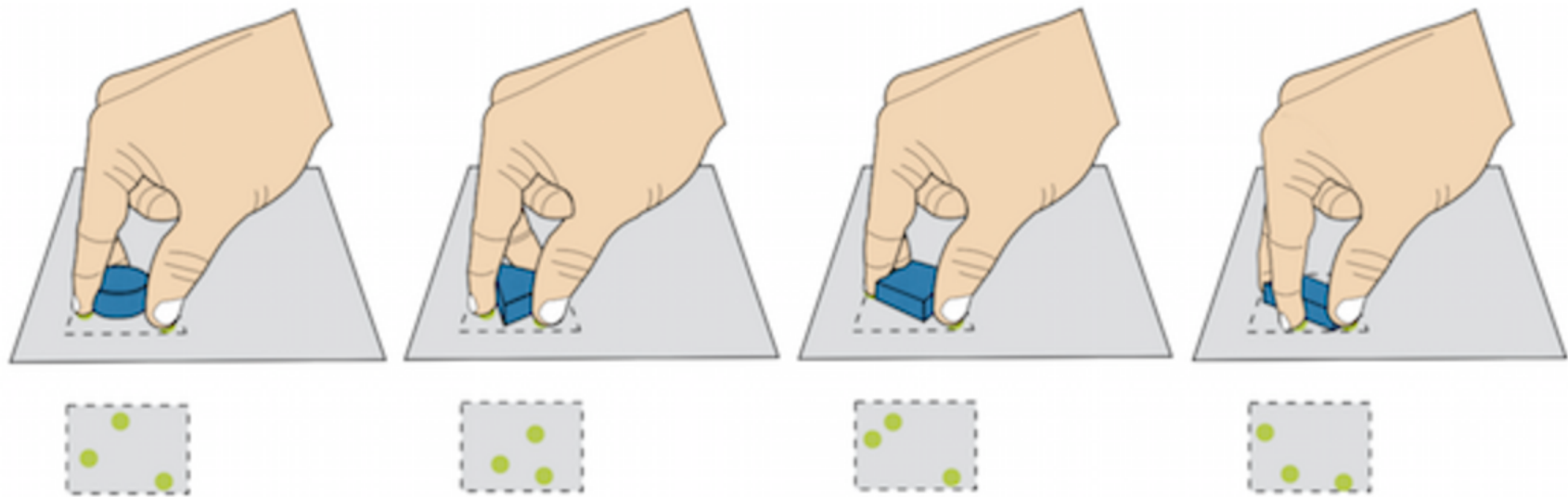


Push to Right on 'F'
("Find Next")

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.

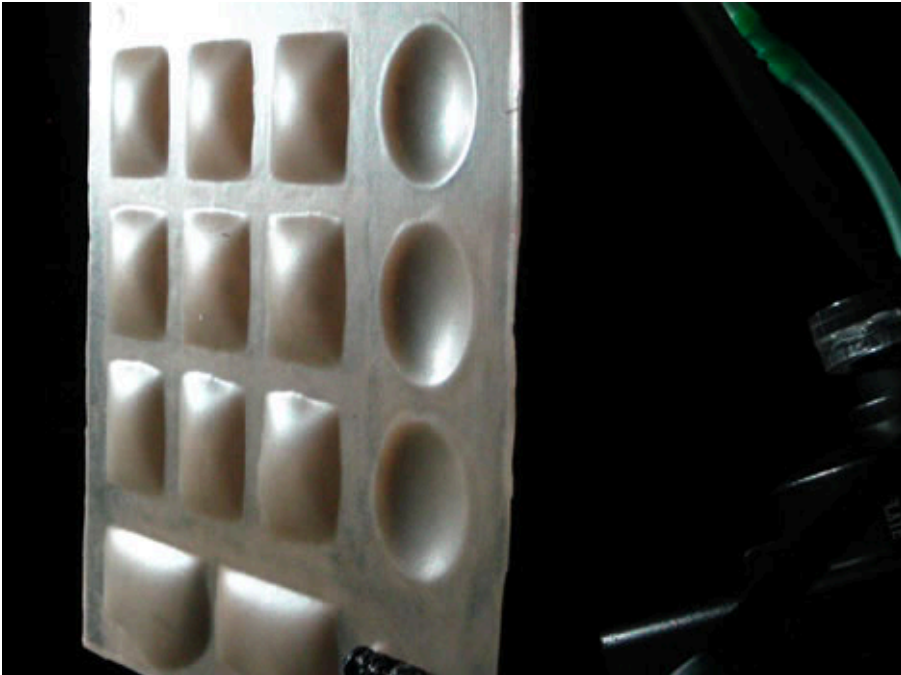


[Le Goc et al., 2016]

<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 s ... es

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

Topic 3: ambient displays

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

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?

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

Build low fidelity physical prototype
Draw on it using conductive ink
Recognize ink pattern on touch devices



vimeo.com/38793875

vision and RFID tracking

AR + RFID tools and toolkits:

Vuforia / ARToolKit

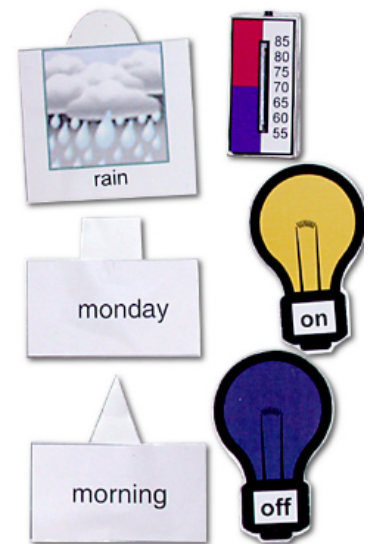
vision marker tracking + virtual imagery

Papier-Mâché [Klemmer, 2004]

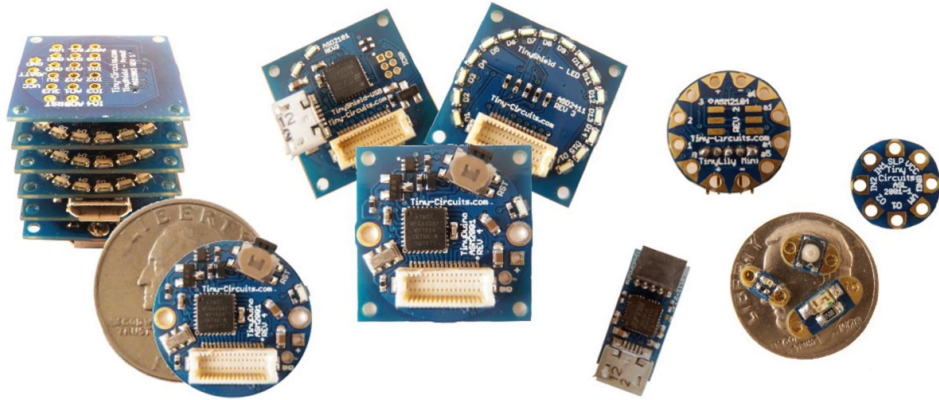
high level API abstractions

passive AR → RFID prototypes

... and many more



electronics & actuation



Arduino
www.arduino.cc/

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

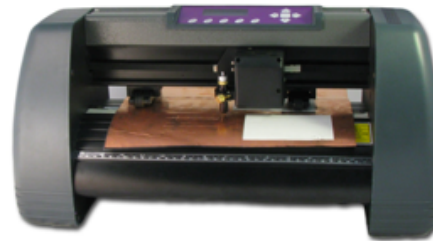


Midas [Savage et al., 2012]

Design
Touch Areas



Fabricate



Assemble



Run

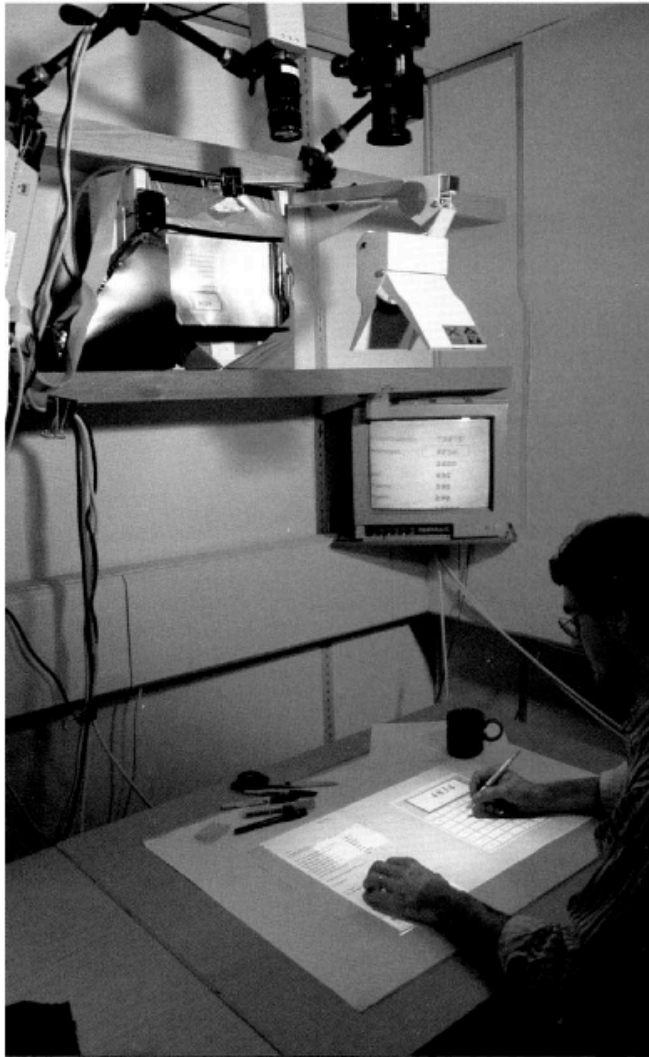
Define Events



http://youtu.be/WHcQgtjD_zY

augmented & interactive paper

first attempts and studies

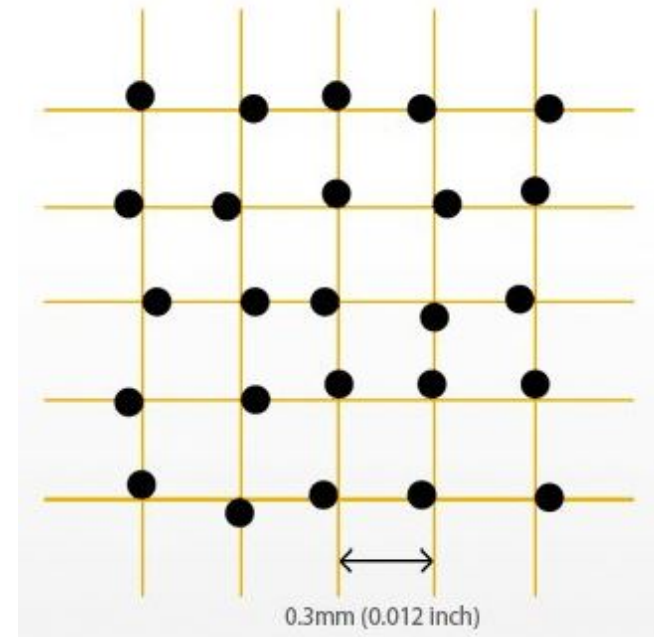
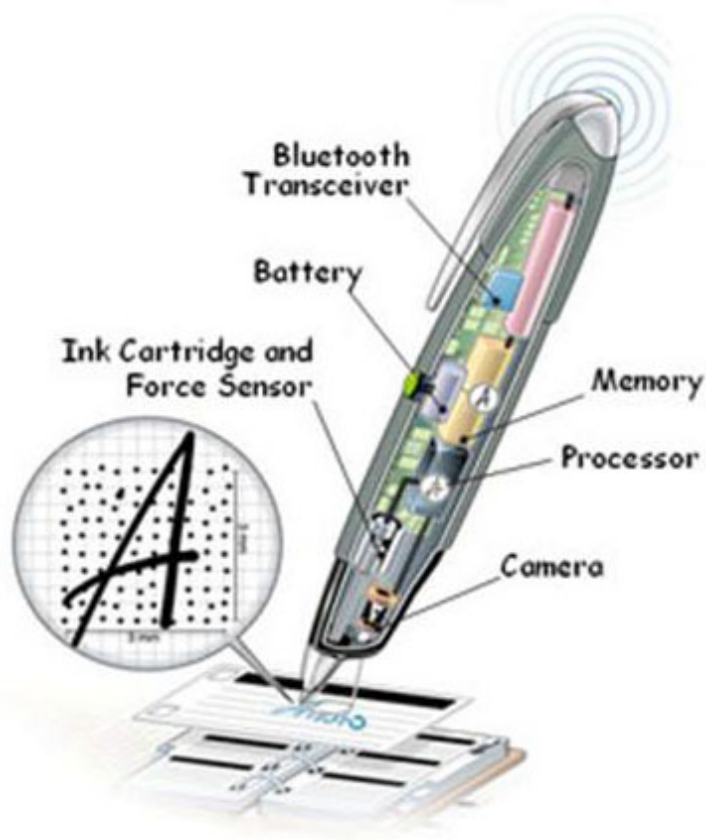


DigitalDesk [Wellner, 1993]



Video Mosaic [Mackay & Pagani, 1994]

Anoto technology (www.anoto.com)



Detection of pen position on paper – digitization of handwriting

will paper disappear?



The Myth of the Paperless Office [Sellen & Harper, 2001]

paper

Properties and qualities?

Uses?

paper

Properties: cheap, thin, flexible, tangible, mobile

Actions : write, design, annotate, print, grasp, pile, archive

example 1 : lab notebooks

Studies of use of paper by biologists
[Mackay et al., 2002]

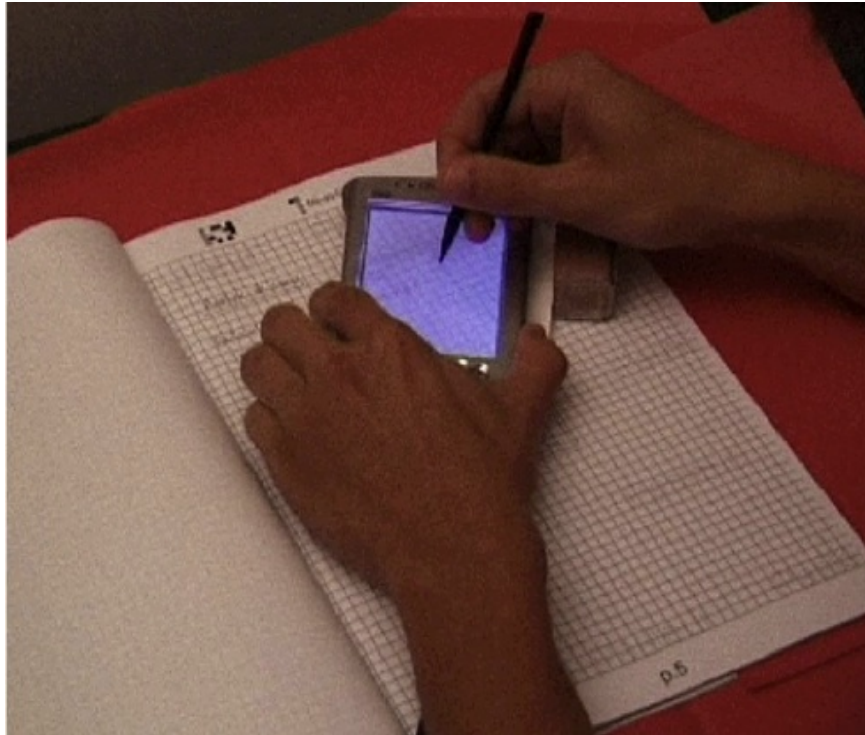
The lab notebook contains detailed information on experiments done by researchers: methods, protocols, data, hypothesis, results.

Can it be replaced by a digital system?



example 1 : lab notebooks

Studies of use of paper by biologists
[Mackay et al., 2002]



aBook : augmenting paper with a digital layer (tangible « toolglass »)

example 2 : musical composition

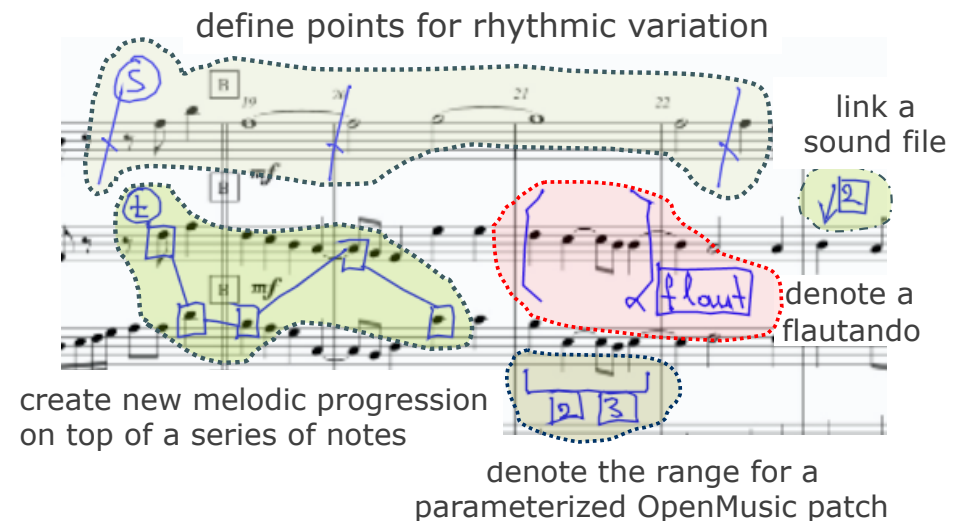
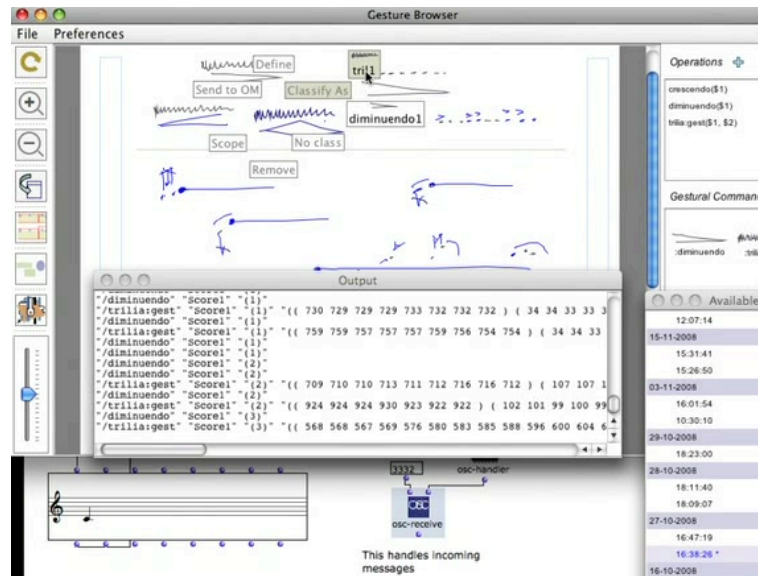
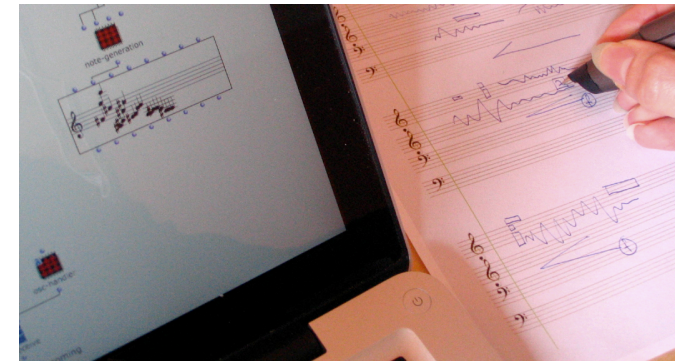


Musical score by K. Penderecki: paper supports personalized and expressive writing, not yet possible in digital tools.

example 2 : musical composition

Study of the use of paper and computers by contemporary composers [Tsandilas et al., 2009]

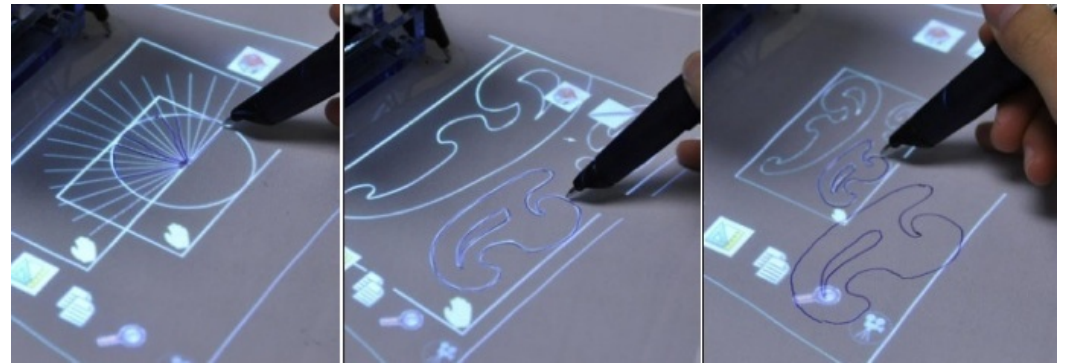
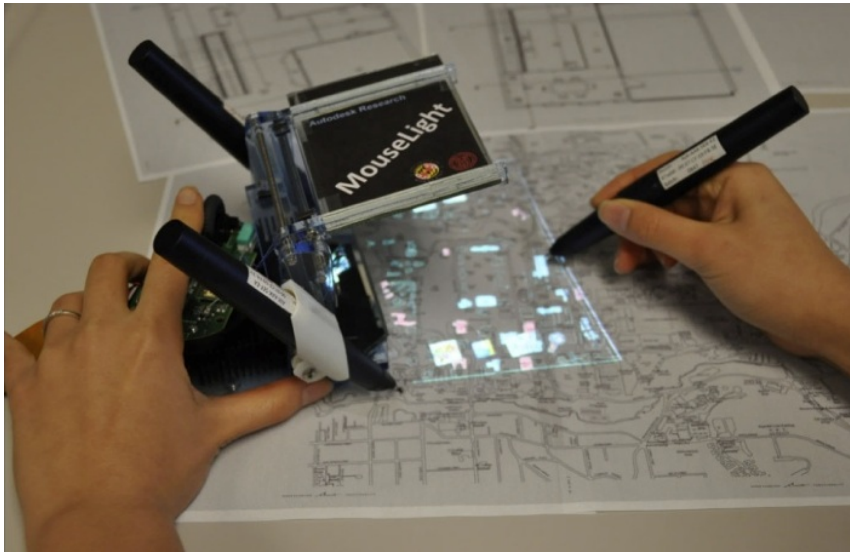
Musink [Tsantilas et al. 2009]:
Combination of gestural language
on paper with virtual musical objects



<http://vimeo.com/9535278>

example 3 : architectural design

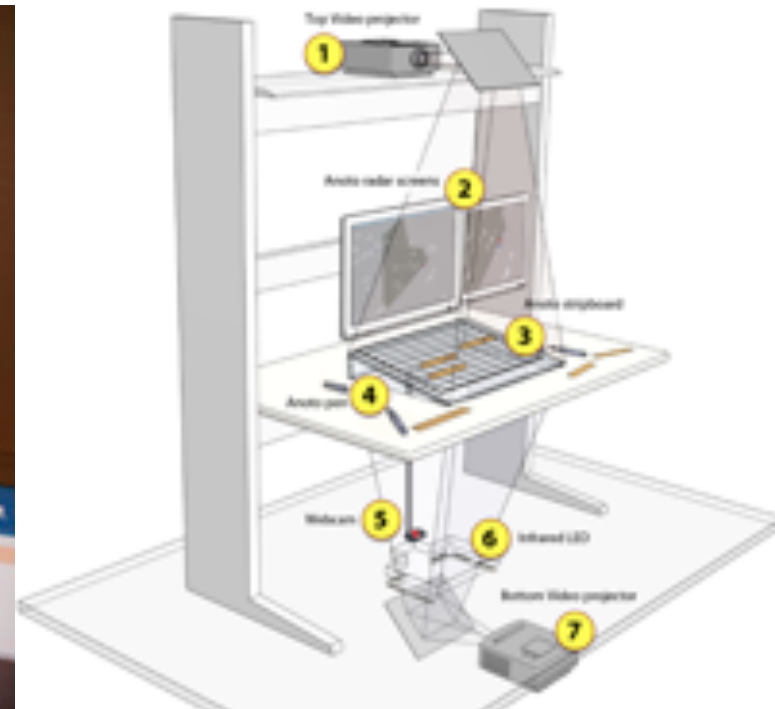
MouseLight [Song et al., 2010]. Projection of different layers of information on paper. Bi-manual interaction.



<http://youtu.be/KGHZ8FaWJRc>

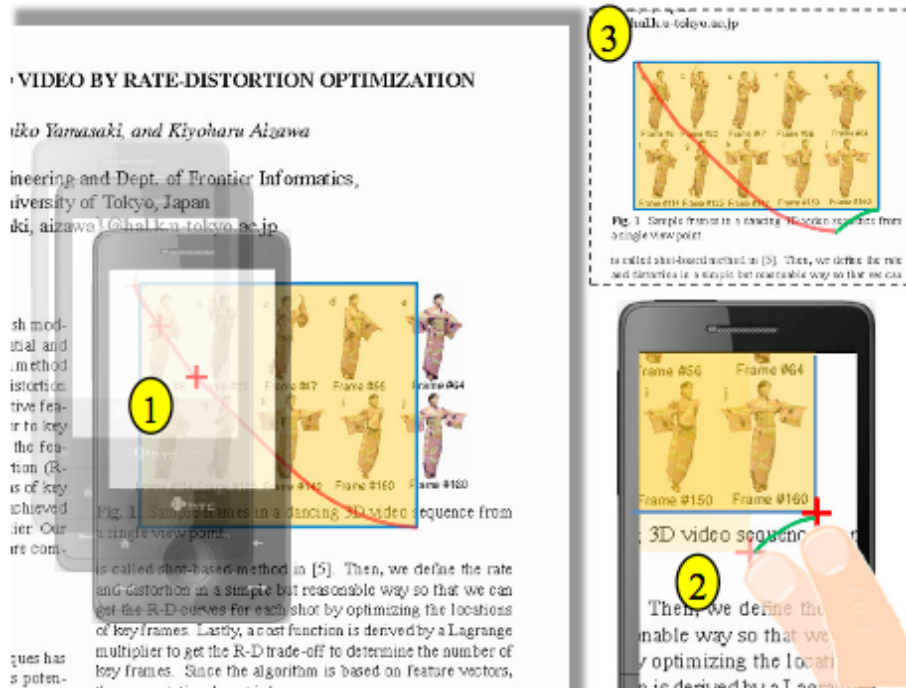
example 4 : air traffic control

Strip'Tic [Song et al., 2010]. Projection of different layers of information on paper. Bi-manual interaction.

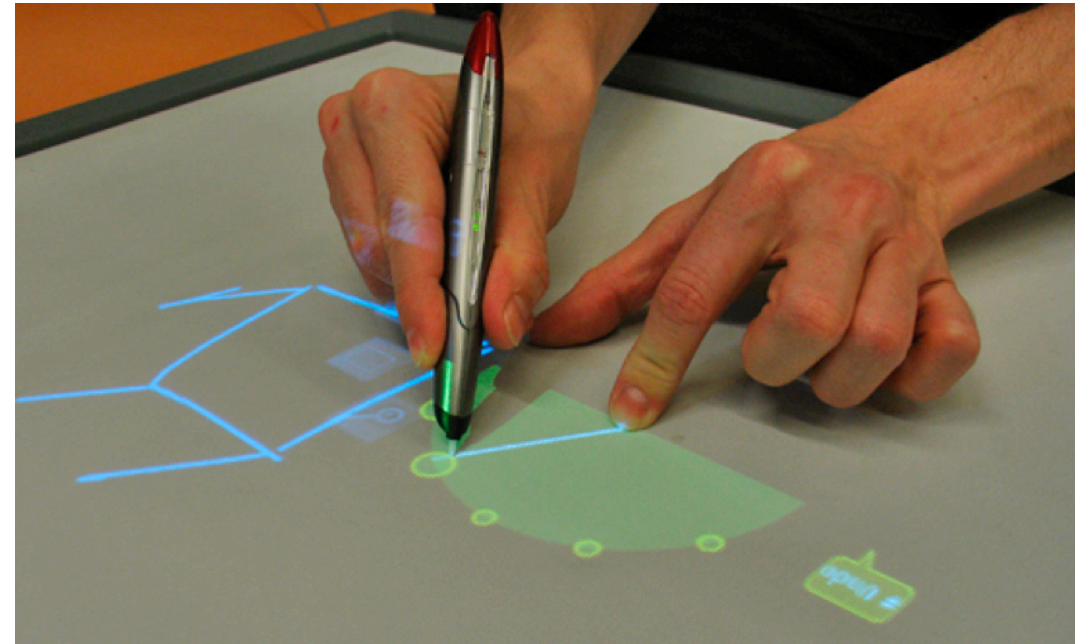


<http://youtu.be/G9bXJUup3BU>

other work



PACER [Liao et al., 2010]



Pen + Multi-touch [Brandl et al., 2008]

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>