Tangible User Interfaces
Advanced HCI
IAT351

Week 12 Lecture 1

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Lyn Bartram

lyn@sfu.ca

Administrivia

FINAL PROJECTS ARE DUE DECEMBER 13 at 5 PM

- ~4000 words
- As many images as you want
- At least 10-15 research papers

Final project: grading (100)

Writing, grammar and paper structure	20%
Appropriate number of **cited** sources (in other words, you have done research at a reasonable depth)	30%
Coverage of the topic and discussion; THIS IS AN HCI paper, so make sure your approach is related to interaction/UIs	50%

From GUI To TUI

GUI (Graphical User Interface)

TUI (Tangible User Interface)

Recap: Graphical User Interface

- WIMP
  - Principle input devices: Keyboard, Mouse
  - Principle output devices: screens, windows
- Complete separation between input and output
- Advocates of TUIs propose
  - Cognitive mismatch
  - Semantic mismatch

GUI (Graphical User Interface)

- Desktop metaphor
- Digital spaces are manipulated with simple **input** devices (e.g., keyboard and mouse)
- Input devices are used to **control** and **manipulate** visual representations displayed on **output** devices such as monitors, whiteboards or head-mounted displays.

Motivation for TUIs

- Desktops and laptops suck in our entire attention
- As a result we live in two worlds: the real physical world and the virtual cyber world
- Constantly “wired” in order to be in both worlds
- Loss of rich interactions found in everyday things (particularly haptic)

GUI: mismatches (Gazzardo)

- Example: I have to move the mouse in 2D on a metaphorically *horizontal* surface ("the desktop"), yet the output appears on a *vertical* 2D plane (the screen)
- MISMATCH 1:
- The **mapping** between the **manipulation** of the physical input device (e.g. the point and click of the mouse) and the resulting digital representation on the output device (the screen) is relatively **indirect** and **loosely coupled**

GUI: mismatches (cont.)

Example 2: A mouse is shaped as a mouse (animal), but the is no analogy between the animal shape and the effects of mouse actions on the screen

↓

MISMATCH 2:

The **digital affordances**of using an input/control device are (metaphorically) unrelated with the **physical** characteristics of the device

Enter Tangible User Interfaces

Broadly, TUIs are founded on [Hornecker]

- tangibility and materiality of the interface
- physical embodiment of data
- whole-body interaction
- the embedding of the interface and the users' interaction in real spaces and contexts.

UI design

- embodied interaction (embodied cognition)
- tangible manipulation of objects as control
- *physical representation of data*
- Interaction with the 3D world

Tangible Interaction

Tangible Manipulation	Spatial Interaction	Embodied Facilitation	Expressive Representation
Haptic Direct Manipulation	Inhabited Space	Embodied Constraints	Representational Significance
	Configurable Materials		
Lightweight Interaction	Non-fragmented Visibility	Multiple Access Points	Externalization
	Full Body Interaction		
Isomorph Effects	Performative Action	Tailored Representations	Perceived Coupling

TUI

- Designing a TUI system involves designing **PHYSICAL** and **DIGITAL** OBJECTS
- Physical objects are **enriched** with digital capabilities:
  - Computational functions
  - Function to control/interact/communicate with other devices

- The digital effects of interacting with physical objects are **consistent with** the physical characteristics of the interaction and the device

Tangible Bits

From painted bits to tangible bits

- give physical form to digital information
- physical objects, surfaces, and spaces become tangible embodiments of digital information.

Hiroshi Ishii
MIT

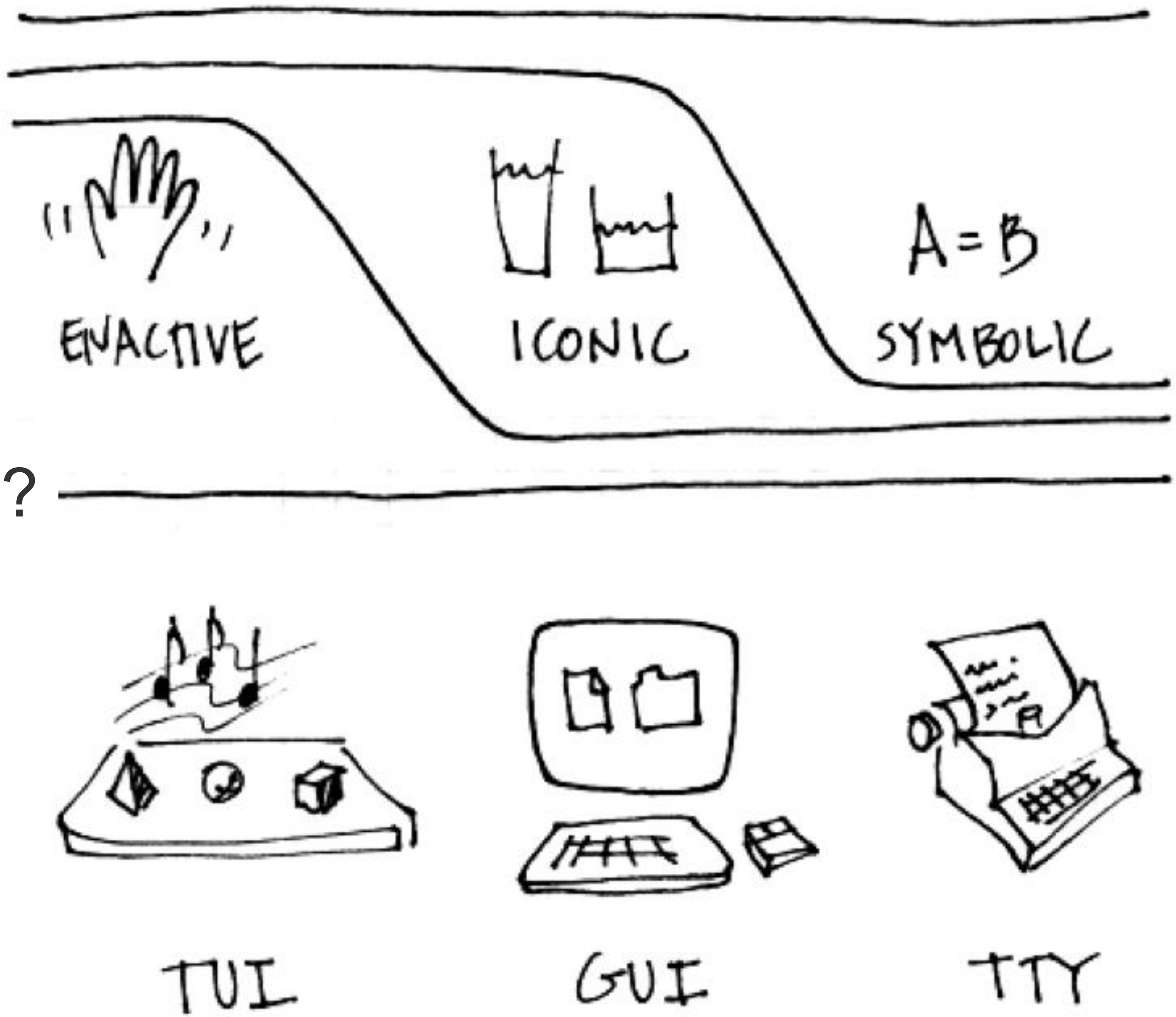
Seamlessly couple bits, atoms and pixels

- Input: grasp and manipulate
- Output: change digital and physical properties of pbject

Tangible Bits (Ishii)

GUI		TUI
Visual	→	Tactile
General Purpose	→	Special Purpose
Remote Control	→	Direct and Collaborative

Now??



Then

From B. Verplank: Interaction Design Sketchbook

The GUI model of the typical user

from Igoe & Sullivan: Physical Computing

Are these tangible user interfaces?

Touchscreens ?
no physical representation

Haptic devices ?
Remote control with haptic feedback

Gloves?

Object still virtually manipulated

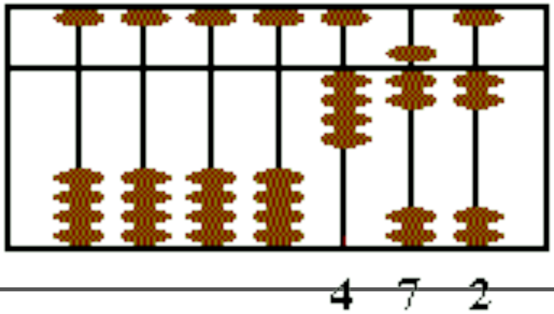
My first experience (shudder)

- Interactive Barney ActiMates™

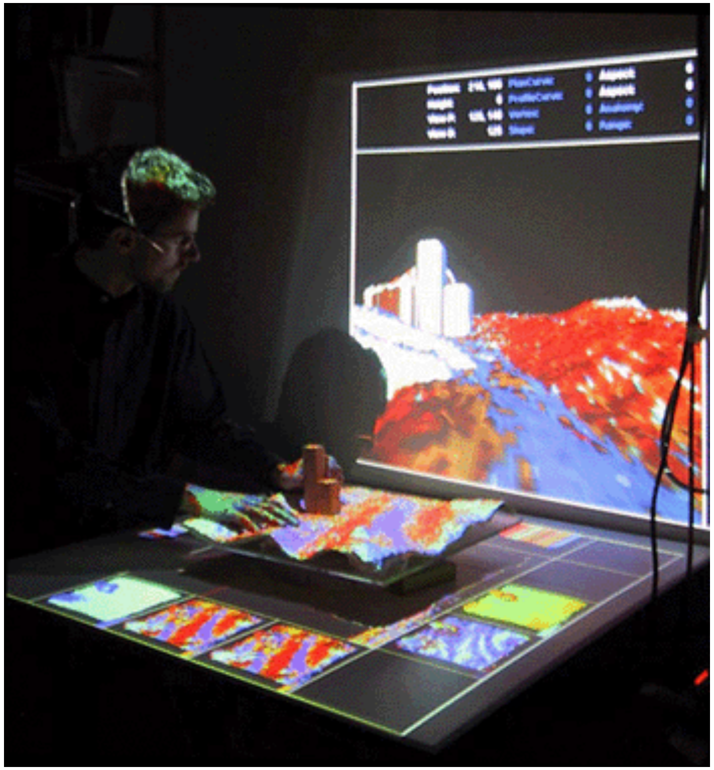
TUI motivation : abacus (Hiroshi ishii, MIT)

The oldest tangible computing system (much before IS)

- beads, rods, and frame provide (physical) representations of numerical values that can be manipulated to control the representations themselves (no distinction between control device and output device)



Examples



Illuminating Clay
MIT Media Lab

Landscape analysis

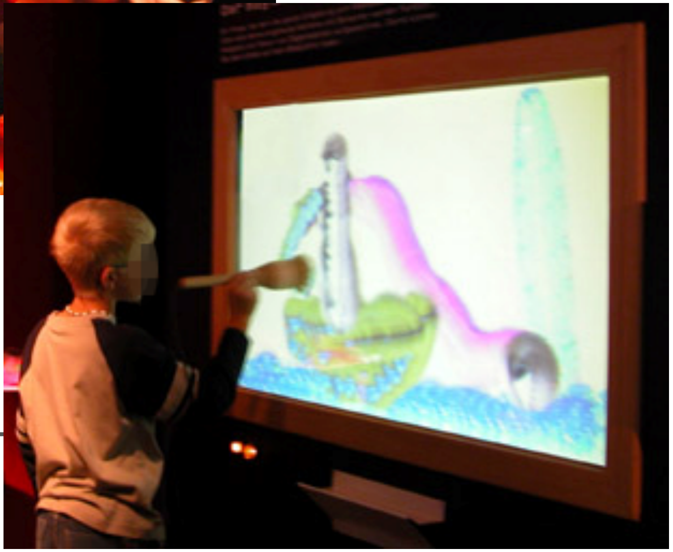
First Microsoft Surface™

TUI example

I/O Brush- MIT Media Lab

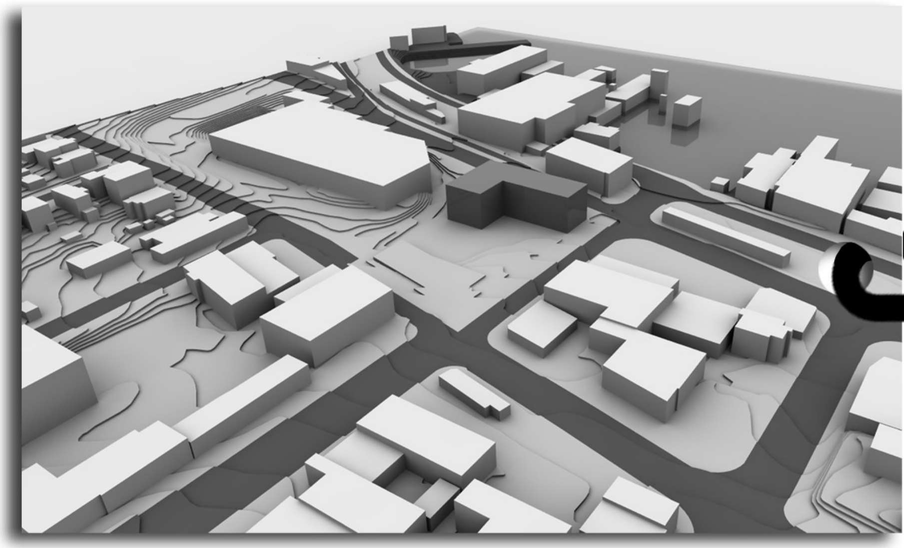
Input: coloured balls

Input and Control Device:
Brush



(http://web.media.mit.edu/~kimiko/iobrush/)

Enhancing existing tools (LMT architects,2012)



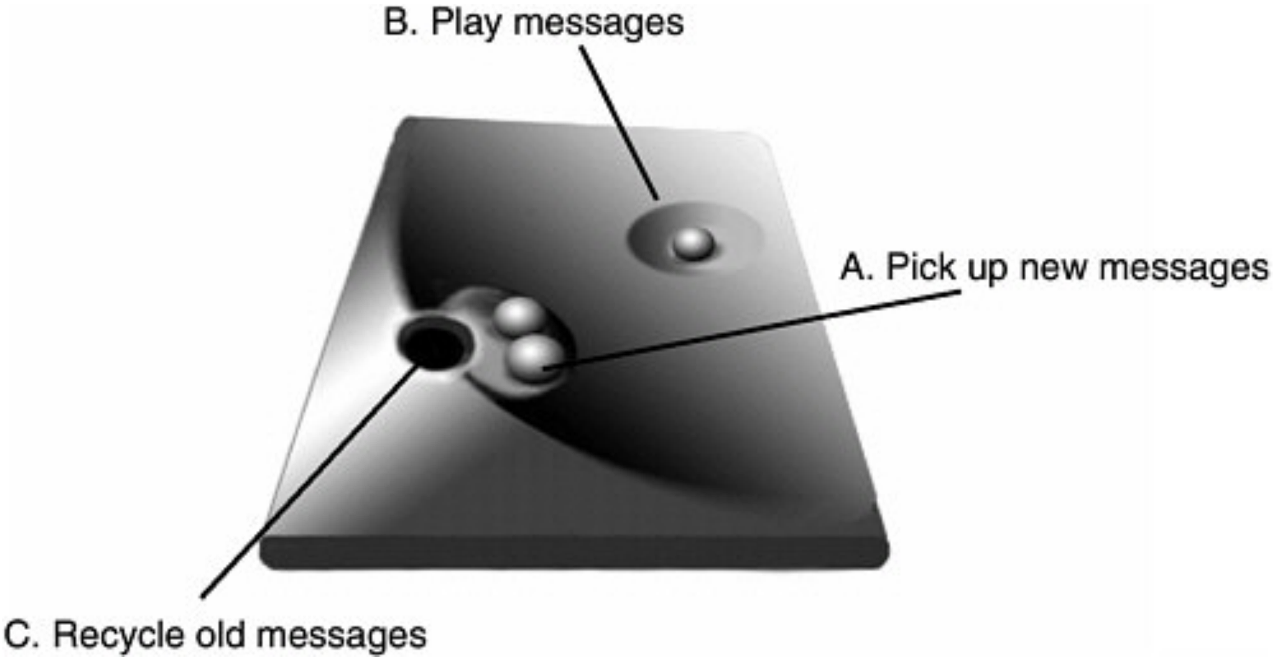
Some early examples

Topographic Torch, 2003

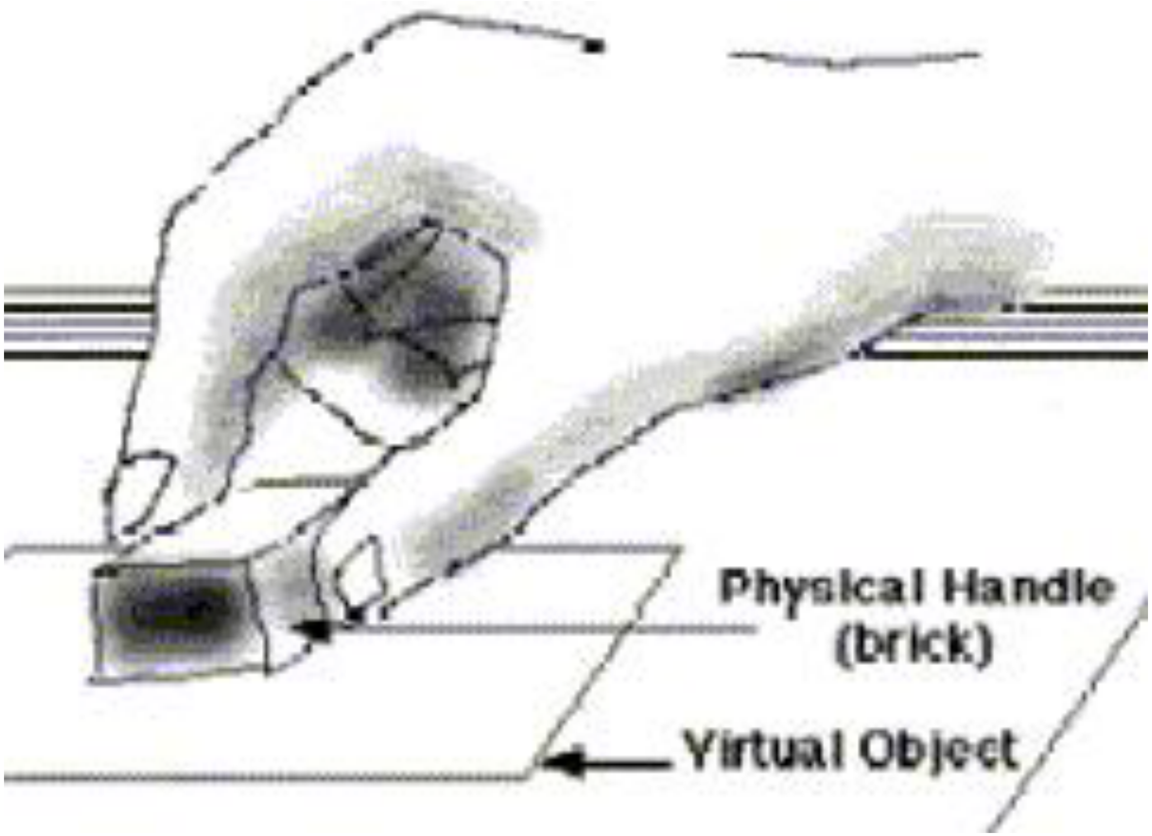
Pebble Box, 2004

It started with …

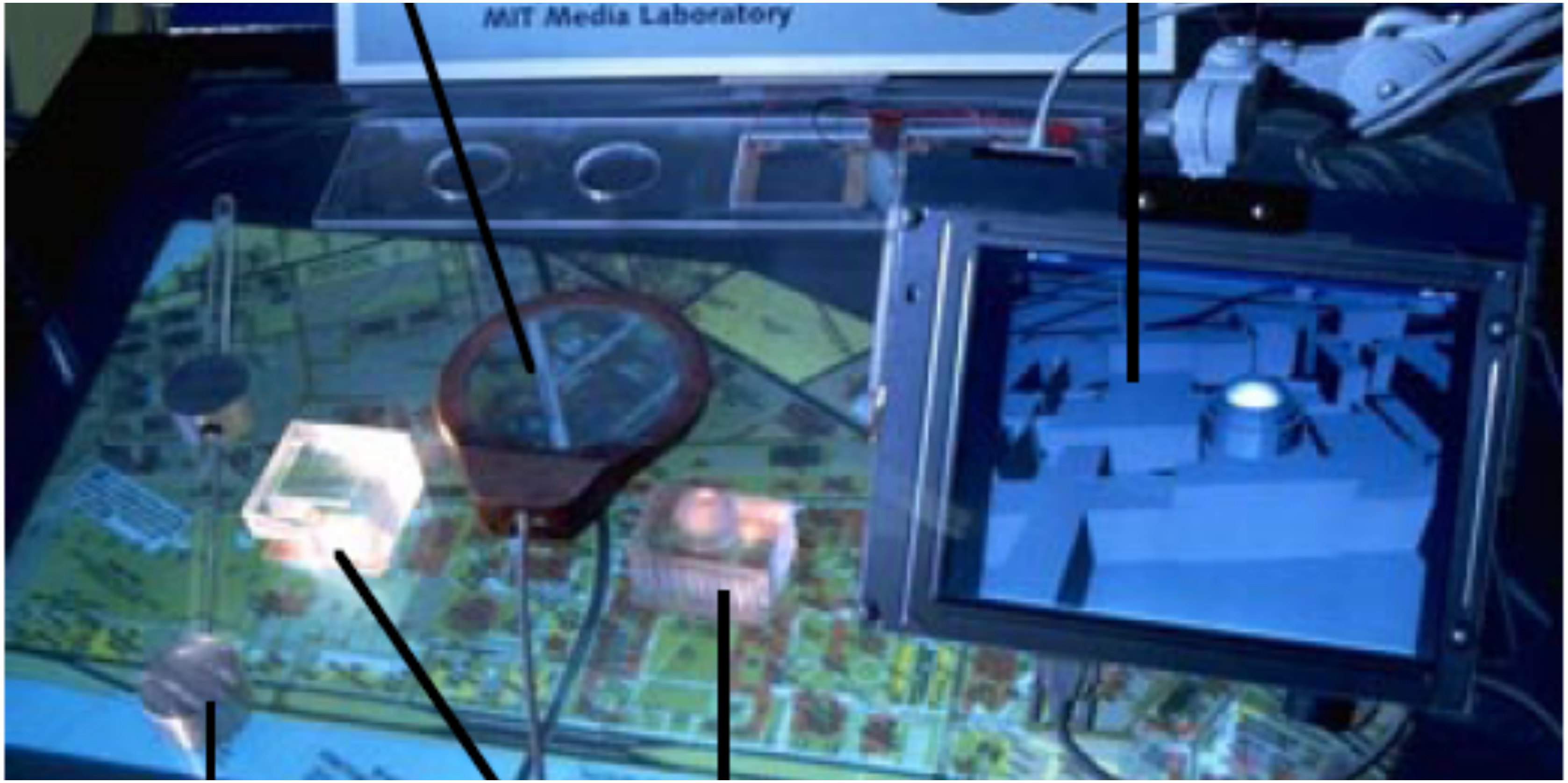
- The marble answering machine (Bishop, 1992)



Graspable Objects (Fitzmaurice, Ishii & Buxton: Bricks ,1994)



MetaDesk (MIT Media Lab, 1997)



Moving on

Media Blocks (Ishii and Ullmer)

The mediaBlocks project is a tangible user interface based upon small, electronically tagged wooden blocks. The blocks serve as physical icons ("phicons") for the containment, transport, and manipulation of online media

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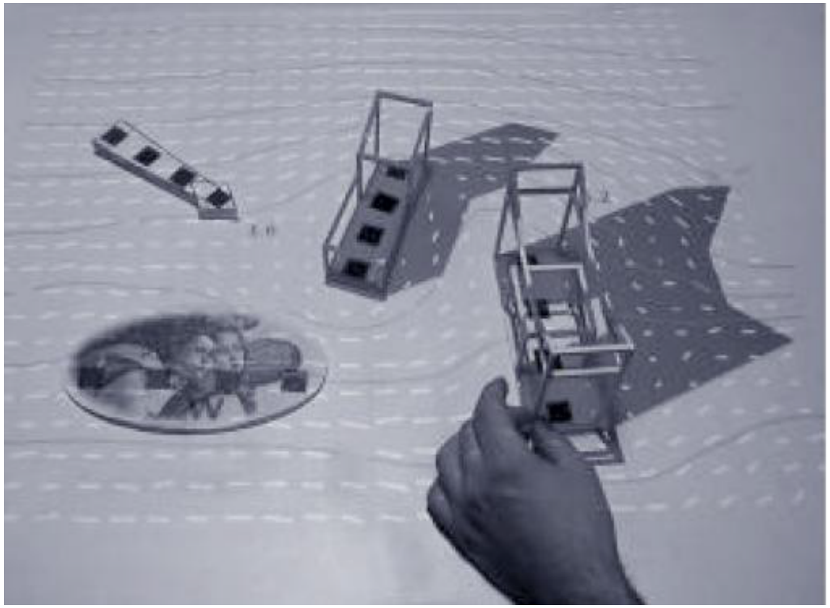
Moving on

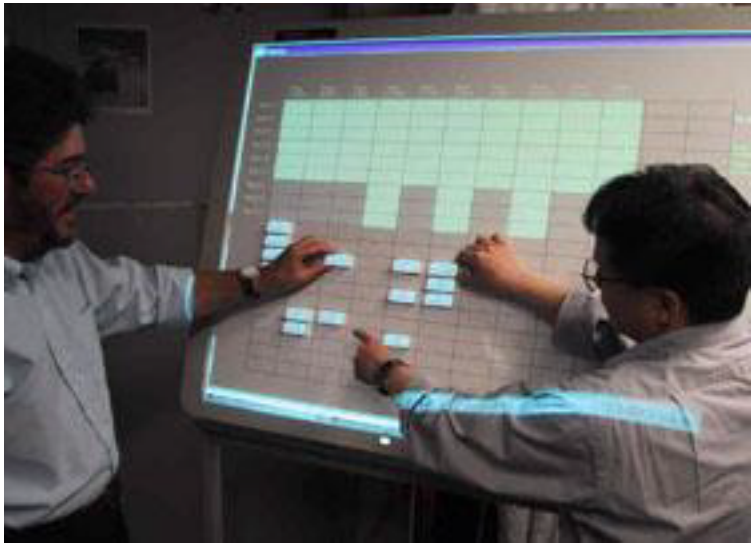
Urban Planning Workbench (Ishii)

"Urp" is an urban planning workbench in which simple architectural models cast accurate shadows, pedestrian-level wind patterns can be observed and tested for different arrangements of buildings, interstructure distances are automatically calculated and displayed around the models, reflections off the surfaces of glass buildings onto surrounding terrain made visible, etc.,



Collaborative Surfaces: SenseBoard (Ishii & Jacob)

Allows the user to arrange small magnetic pucks on a grid, where each puck represents a piece of information to be organized, such as a message, file, bookmark, citation, presentation slide, movie scene, or newspaper story. As the user manipulates the physical puck, the corresponding digital information is projected onto the board. Special pucks may be placed on the board to execute commands or request additional information

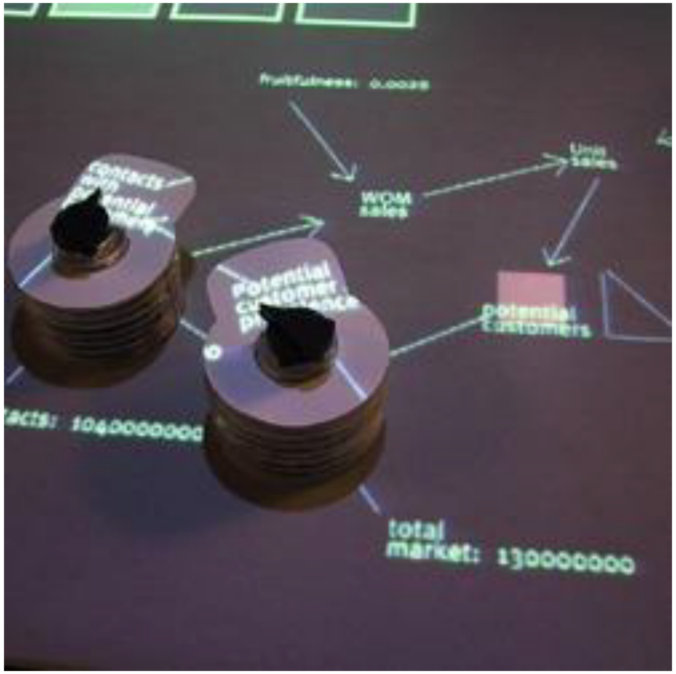


Tangible games: Playkka (Finnish Institute of Technology ??, 2009)

Interactive tables: SenseTable (Patten)

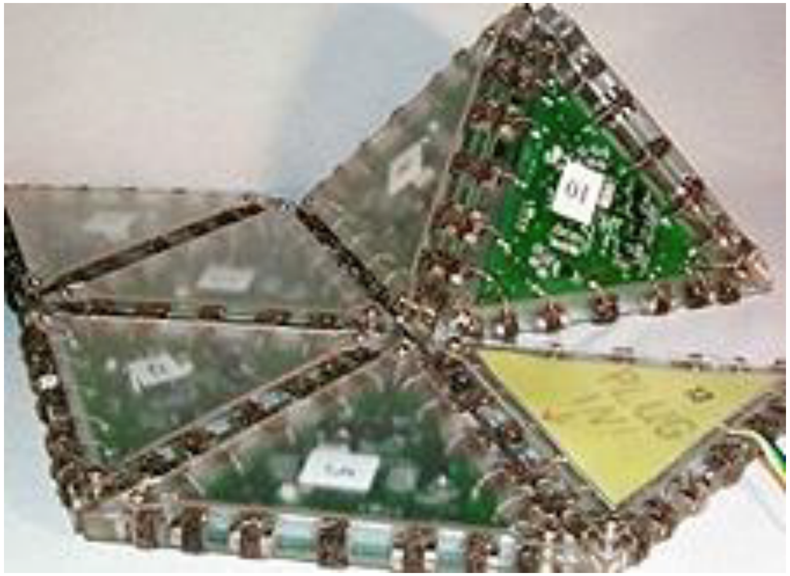
Sensetable is a system that wirelessly tracks the positions of multiple objects on a flat display surface quickly and accurately. The tracked objects have a digital state, which can be controlled by physically modifying them using dials or tokens.

Prototype application in business supply chain visualization using system dynamics simulation



Abstraction Spaces: Triangles (Gorbet & Ishii)

The triangles connect together both physically and digitally with magnetic, conducting connectors. When the pieces contact one another, specific connections can trigger specific digital events. Users can create both two and three dimensional patterns whose exact configuration is known to the computer.



Interactive storytelling, education, UI design

Aesthetic Engagement : Music Bottles(Ishii & Mazalek)

a specially designed table and various sets of three corked bottles that "contain" the sounds of three instruments or tracks of various musical genres. Custom-designed electromagnetic tags embedded in the bottles enable each one to be wirelessly identified. The opening and closing of a bottle is also detected. When a bottle is placed onto the stage area of the table and the cork is removed, the corresponding instrument becomes audible.

And now for something different (Pangaro & Ishii)

The **Actuated Workbench** is a device that uses magnetic forces to move objects on a table in two dimensions. It is intended for use with existing tabletop tangible interfaces, providing an additional feedback loop for computer output,

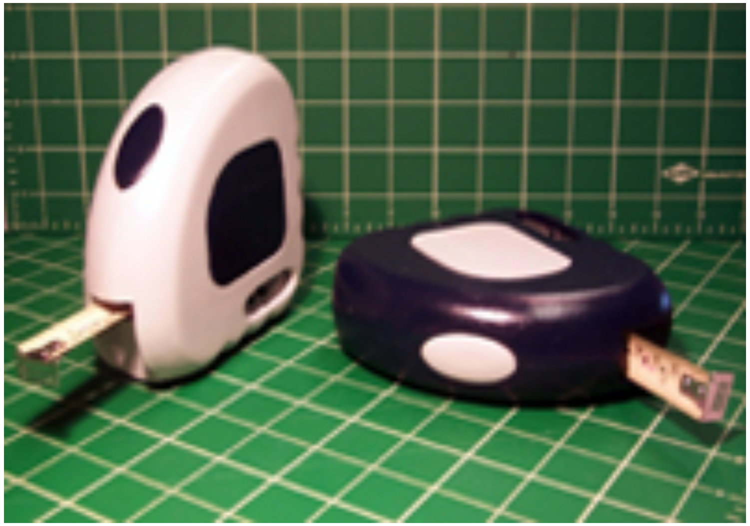
And now for something different (Pangaro & Ishii)

The **Actuated Workbench** is a device that uses magnetic forces to move objects on a table in two dimensions. It is intended for use with existing tabletop tangible interfaces, providing an additional feedback loop for computer output, and helping to **resolve inconsistencies that otherwise arise from the computer's inability to move objects on the Table.**

HandScape

- A vectorizing digital tape measure for digitizing field measurements, and visualizing the volume of the resulting vectors with computer graphics.

- Using embedded orientation-sensing hardware, it captures relevant vectors on each linear measurements and transmits this data wirelessly to a remote computer in real-time.

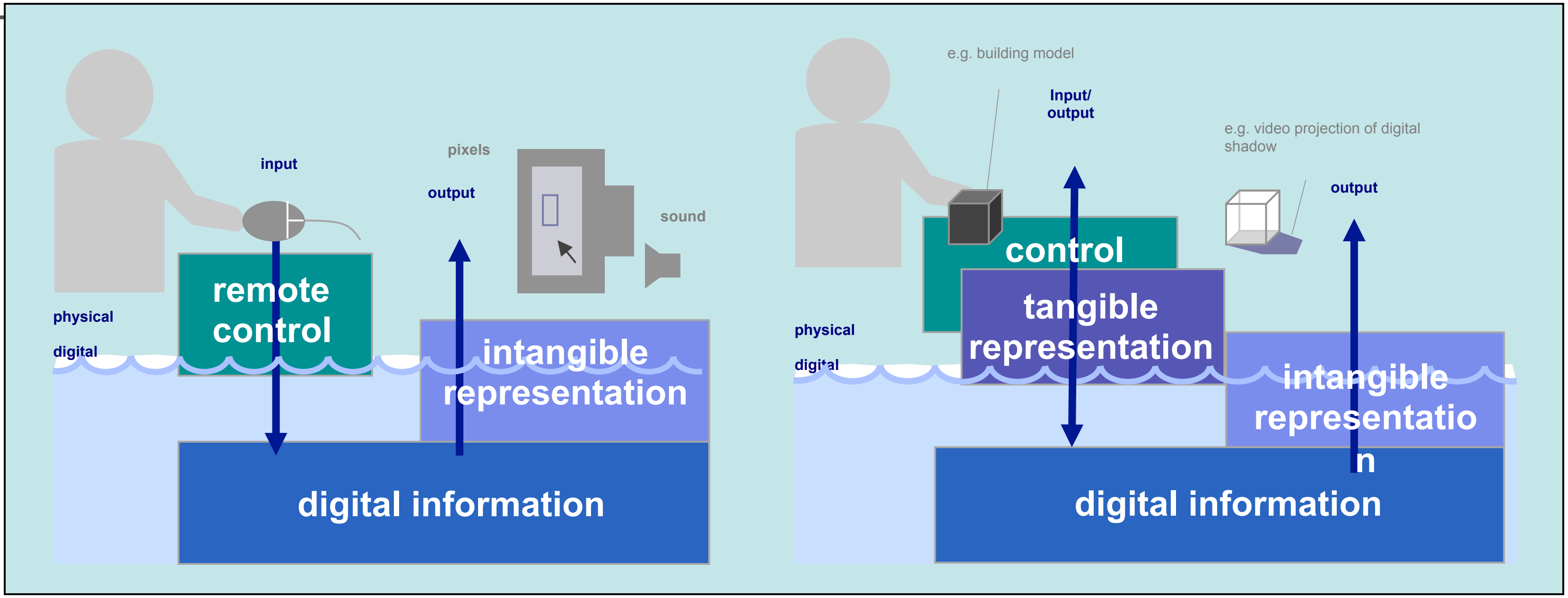


Extracted from Tangible Media Group web site

Recap: Features of Tangible Computing

- Physical mappings
  - physical objects rather than abstract entities
  - *specificity* and *specialisation*
- Exploiting physical affordances
  - suggesting and guiding action
- Distributed interaction
  - interaction across a range of objects
  - interaction spread throughout a space
  - moving beyond enforced sequentiality

Models of GUI and TUI



GUI

TUI

Computational coupling of tangible representations to underlying digital information and computation

TUI Contributions

- Double Interactions Loop – immediate tactile feedback
- Persistency of tangibles
- Coincidence of Input and Output Spaces
- Special Purpose vs. General Purpose
- Space-Multiplexed Input

TUI - Functionality

- Physical input for arranging electronic content
- Physical input for invoking action
- Electronic capture of physical structures
- Coordinating physical input and graphical output
- *Coordinating input and physical output ?????*
- An add, update, remove event structure

How you make them: Hardware

- Encompasses touch, gestures, haptics, ……

- Sensors
- Actuators
- RFID tags
- Vision/camera

- Object properties itself (a deformable surface? Block?)

How you make them: software

- Phidgets (2001…)
  - Complete, balanced, varied assortment of physical objects easy to program with
- Calder (2004)
  - Small size allows for more fluid prototyping at the PHYSICAL level
- Papier-Mâché (2004)
  - Unified event model allows easier development and retargetting at the SOFTWARE level

- Not much software support for deforming object

TUI design considerations

TUIs:

- a close correspondence in behavioural meaning between input and output
- the effects of interaction are related to the perceived properties of the control device
  - eg the effects of using a stylus to draw a line directly on a tablet or touchscreen are related to the (apparent) physical nature of the stylus, e.g. its size
- The physics of the interaction define the “gesture space”

TUI Design Considerations

- Emphasis on **touch** and **physicality** in both **input and output**.
- Control device closely coupled to the physical **representation** of actual objects represented by the digital ones
    - E.g., buildings in an urban planning application are manipulated using tangible bricks in a children's block building task
- Two levels of **direct manipulation**:
    - Manipulation of the control device
    - Manipulation (via the control device) of the digital objects

So what are the issues with TUIs?

- ??? Discussion ??

Designing out of the box (Greenberg)

- The problem:
  - programming / designing with physical devices is hard
    - circuit design (electrical engineering)
    - microprocessor interface to digital/analog devices
    - ‘wire’ interface (serial, USB, wireless, IR…)
    - wire protocol
    - connection/disconnection/intermittent connectivity
    - software to use devices
    - maintenance and extensibility
  - simple things take a long time to do
  - most people don’t bother

So what are the issues with TUIs? (Blackwell 2003)

- It is likely that manipulation of physical objects will further enhance mnemonic effects by multiple encoding
- • But 3D arrangements of tangible items reduces retrieval performance with respect to 2D arrangements (Cockburn & McKenzie 2002)
- Reaching to grasp a close physical object can be faster than moving a mouse pointer
- But moving to grasp a physical object that is out of reach is slower than scrolling a GUI window
- We have relatively few conventional physical symbols, other than literal scale representations

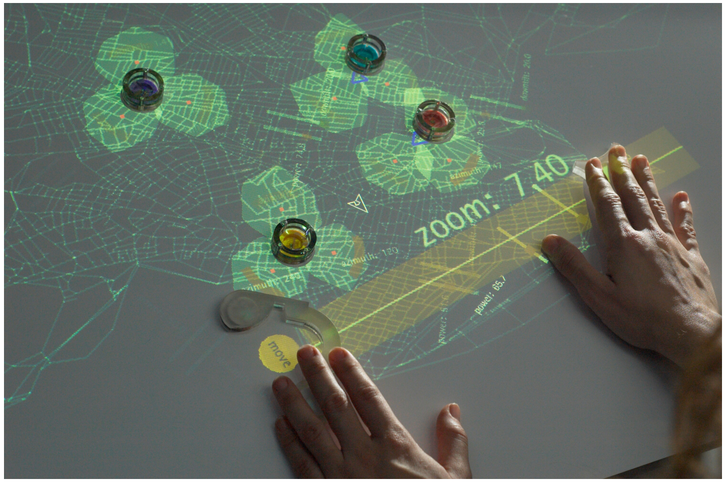
So what re the issues with TUIs?

- Most early TUIs were ASYMMETRIC
- Physical input, virtual output
- Exceptions: Barney, AnnotatedWorkbench

- Limited physical response

Actuation

- Current research direction is in actuation
- Make the output reflect the input with objects



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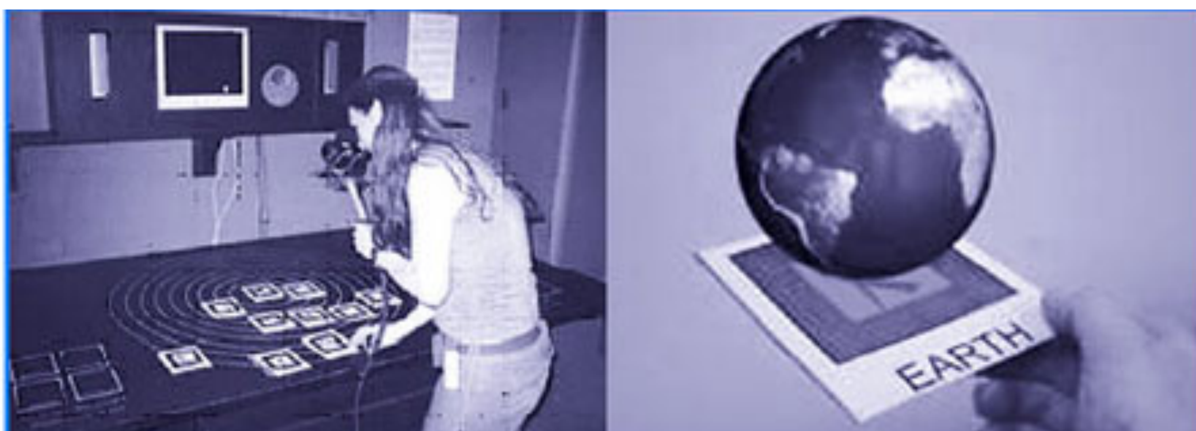
So what are the issues with TUIs?

- Metaphor and embodiment
- Is a marble a reasonable metaphor for a voice message?
- Is a bottle a reasonable metaphor for an instrument?
- Is a block a reasonable metaphor for a building?

TUI example

MAGICPLANET: to help kids understand planetary motion

- The **physical** table showing orbital paths around the sun is augmented with **overlaid 3D animations**.
- The children have to place **cards** depicting each of the planets in its correct position. As they do, they can see overlaid on the cards a 3D animation of the planet spinning on its own axis and orbiting around the sun



TUI: Classification dimensions

Tangible technologies may differ for several **interdependent** aspects:

- **metaphor**
- **behavioral mapping**
- **embodiment**

TUI classification dimensions: **metaphor**

Two aspects:

1) The degree of **analogy** between the physical (visual, tactile, auditory) **appearance** of the control device and its corresponding appearance in the real world

Two extremes

- Control device resembles its digital counterpart (e.g. physical models of the building are used to move buildings around a digital map on the display)
- Abstract symbolic objects (with limited or no analogy at all)

2) The extent to which the user's **action** with the control device are analogous to real world effects of similar actions

Digitally augmented books_1

Interactive storybooks for Children:

"Listen reader" (MIT MEDIA Lab 2001)

The book has RFID tags embedded within it which sense which page is open, and additional sensors (capacitive field sensors) which measure an individual's position in relation to the book and adjust the sound accordingly

Soundtrack (music/voice) triggered by moving one's hands over the book.

http://xenia.media.mit.edu/~mbb/listen.html

Digitally augmented books_2

Interactive storybooks for Children:

LeapPad® (LeapFrog Enteprises Inc., USA)

http://www.leapfrog.com/

- Industrial Development of Listen Reader

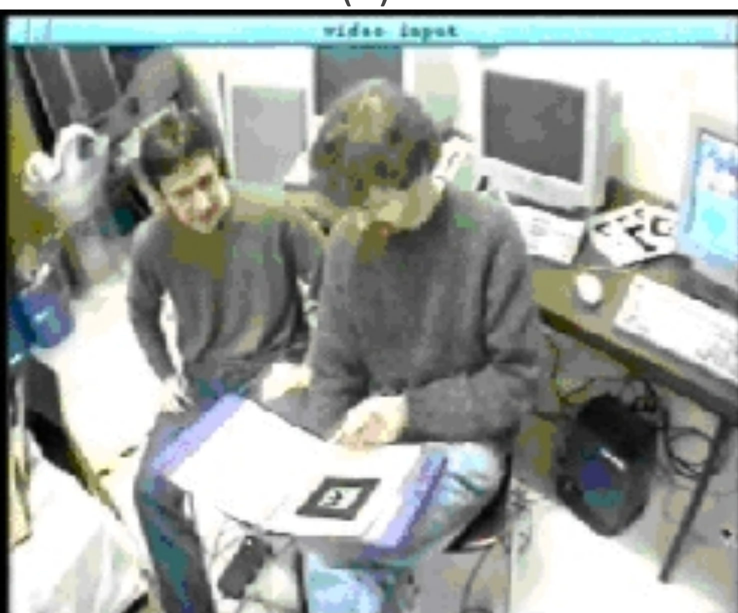
- A digitally augmented book with a pen that **enables words and letters to be read out when a child touches the surface of each page**. The book can also be placed in writing mode and children can write at their own pace.

Digitally augmented books_3:

Immersive virtual reality: Magic Book (*www.hitl.washington.edu/magicbook/*)

- A MagicBook looks like a normal storybook with colorful pages and simple text.
- ~~When readers turn the pages, the pictures pop off the page and come to life as three-~~dimensional animated virtual scenes, which they see images overlaid onto the page of the book (fig 1)
- When they wear a lightweight head mounted display (HMD), by touching a switch on the HMD, readers can fly into the virtual scene and freely explore the immersive 3D virtual reality environment (fig 2 and 3)

(1)



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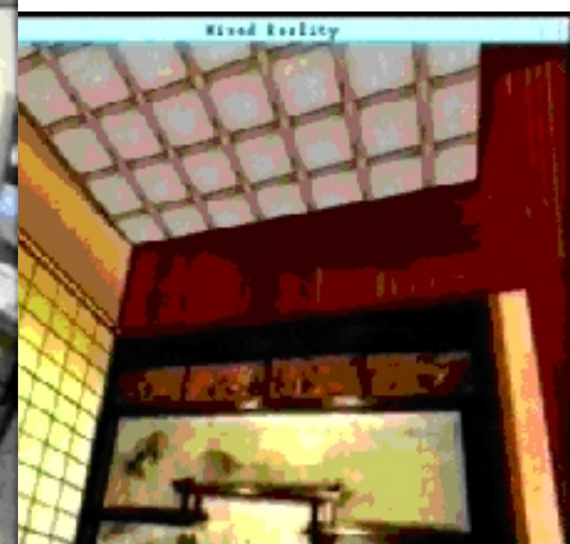


Tangible storytelling

KidStory project (*www.sics.se/kidstory*)

Using tangibles to allow kids create and explore interactive stories.

Children's physical **drawings** on paper are RFID tagged, digitally reproduced, and inserted in the interactive stories they are building. Kids can use their paper drawing, via a RFID reader, to physically navigate between episodes in their virtual story displayed on a large screen, using the KidPad storytelling software. http://www.kidpad.org/

(Kids can also use tagged toys, representing story character, for the same purpose)

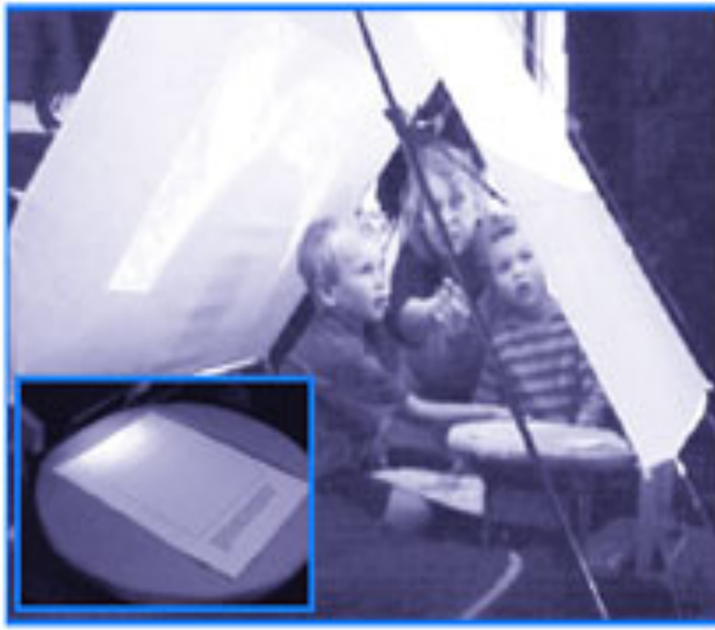
Digitally augmented paper and ambient intelligence

SHAPE project http://www.shape-dc.org/index.html; http://www.shape-dc.org/highlights/story.html

- a mixed reality experience to aid children (and adults) to discover, reason and reflect about historical places and events
- A (digitally augmented) paper-based 'history hunt' around Nottingham Castle + a mixed reality experience in a Story tent

During history hunt, kids search for clues about historical events which took place in the castle and make drawings or rubbings on paper at a variety of locations. The paper is electronically tagged and used to interact with a virtual reality projection on a display called the Storytent inside the castle museum.

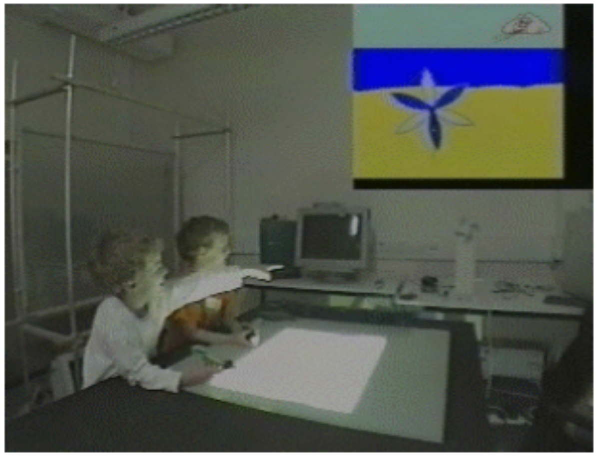
Inside the Storytent, a Radio Frequency ID (RFID) tag reader is positioned embedded in a turntable. When placed on the turntable, each paper clue reveals an historic 3D environment of the castle from the location at which the clue was found, thus explicitly linking their physical exploration of the castle (using the paper clues) with a virtual reality simulation of the castle as it was in medieval times.



Child and adult in the Storytent with close-up of turntable (inset).

PHICONS:
PHIsical objects as digital **iCONS**

- physical objects other than paper (such as toys, blocks etc.) used to trigger digital effects



Examples: CROMARIUM

A mixed reality activity space that uses tangibles to help children aged 5-7 years experiment and learn about colour mixing, using a variety of physical and digital tools.
It allows children to combine colours using physical blocks, with different colours on each face.
By placing two blocks together children could elicit the combined colour and digital animations on an adjacent screen

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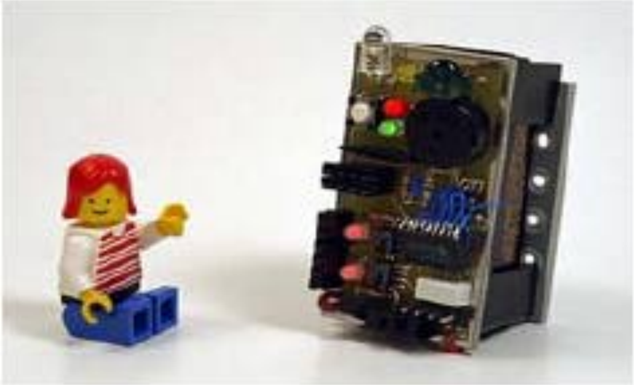
DIGITAL MANIPULATIVES

- ~~physical devices which have **computational properties** embedded~~ in them
- In some case, **computationally enhanced versions of <u>toys</u>** enabling dynamics and systems to be explored

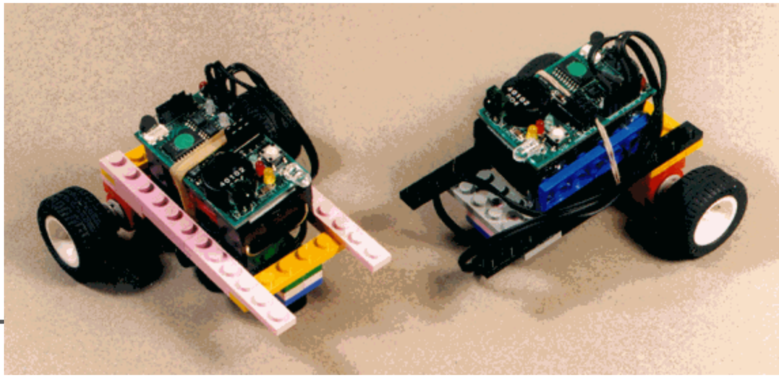
DIGITAL MANIPULATIVES: EXAMPLE_1

LEGO Mindstorm

Born at MIT (1993) http://mindstorms.lego.com/



- robotics construction kit by which children can create Logo (*) programs to control LEGO assemblies.
- The kit consists of motors and sensors and children use Logo programs to control the items they build, and Programmable Bricks (P-Bricks) that contain output ports for controlling motors and lights, and input ports for receiving information from sensors (e.g light, touch, temperature).
- Programs are written in Logo and downloaded to the P-Brick or to the robots, which then contains the program and are autonomous.



(*) LOGO: a simple programming language for kids that gives them commands and control structures for operating a turtle, representing the on-the-screen cursor or a physical object, e.g., a robot

(A Funny example of LEGO Mindstorm use)

- One girl built a bird feeder with a sensor attached so that when the bird landed to feed, the sensor triggered a photo of the bird to be taken.
- The girl could then see all the birds that had visited the feeder while she was away.

DIGITAL MANIPULATIVES: EXAMPLE_2

BitBalls (MIT Media Lab)

- A transparent rubbery ball that can be thrown up into the air and can store acceleration data which can then be viewed graphically on a screen
- used in scientific investigations with children in learning kinematics.