Painted Bits (GUI)

General input devices as remote-controllers of intangible representation (pixels on a screen)
Tangible Bits (TUI)

Tangible representation as interactive control mechanism to manipulate the information represented in both tangible and intangible forms

Double Interaction
Double Interaction Loops: Physical and Digital

Physical Interaction + Digital Interaction

Double Interaction Loops: Physical and Digital

digital feedback loop

Physical Interaction + Digital Interaction
Evolution of Workbench
for Collaborative Design and Tangible Thinking

1996-7 metaDESK
1997 I/O Bulb
1998-9 Urp
1997-8 Illuminating Light
1999 PingPongPlus
2000-02 Luminous Table
2001-02 Senseboard
2000-02 Sensetable
2001-02 Illuminating Clay
2002 Actuated Workbench
2002 SandScape
2002-03 PingPongPlus
I/O Bulb and Luminous Room
Underkoffler and Ishii, 1997 - 1999

- I/O Bulb
  - High resolution output, two-way information

- Luminous Room
  - Multiple I/O bulbs illuminating architectural space

- Give life to architectural surfaces and physical objects.
- Enable direct manipulation of digital world by grasping and manipulating objects with digital shadows.
Urp:
Urban Planning Workbench (an I/O Bulb AP)
Underkoffler and Ishii, 1997 - 1999

digital shadows

light reflections

wind
Luminous Room with multiple I/O Bulbs
Underkoffler and Ishii, 1997 - 1999

Integration of Tangible and Intangible Representations

Principle of Tangible Interface Design

Urp 99
Luminous Table
in Urban Design Studio at MIT

Urban Planning Workbench used in the spring 2000 / 2001 MIT courses
Sensetable
James Patten & Hiroshi Ishii

• TUI platform to track multiple objects and their states on a table with video projection

• Applications
  – Music “Audiopad” in collaboration with Ben Recht
  – System Dynamics simulation for Supply Chain Analysis
  – Chemistry

Business
System Dynamics Simulation for Supply Chain Analysis
Patten, Hines, Malone, Murphy-Hoye & Ishii 00-03

Collaboration with Intel and MIT Sloan School
IP Network Design Workbench
NTT Comware + TMG

• Event-Driven Simulation + NTT Comware’s network design consulting expertise
• TUI supports cooperative direct manipulation of IP Network simulator.

IP Network Design Workbench: NTT Comware + TMG (senseetable)

• Based on Event-Driven Simulation Engine and NTT Comware’s NW consulting expertise
• This workbench helps designers to evaluate the effects of changing topology, bandwidth, server location in real time, to optimize the network performance.
• TUI supports cooperative direct manipulation of IP Network simulator.
**IP Network Design Workbench**
**NTT Comware + TMG**

- Event-Driven Simulation
- TUI supports cooperative direct manipulation of simulator to evaluate the effects of changing topology, bandwidth, server location in real time, to optimize the network performance.

Thanks to Mr. Kase, Mr. Hirano, Mr. Narita, Ms. Kobayashi, Mr. Tanaka, and many other NTT Comware people.

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**BusinessWeek Nov. 3, 2003**

Want to upgrade your company's computer network—or redesign it from scratch? This "gadgetable" has a built-in antenna that reads what's happening to objects on the table representing network routers, storage systems, mail servers, and the like. The data are transmitted to a computer that instantly remodels the network and projects the new design. Additional information about the cost and capacity of the upgraded network is displayed on screens.
Audiopad
James Patten and Ben Recht (Physics & Media)

• A new way to perform electronic music.
• Designed to combine the expressive power of traditional musical instruments with the modularity of a computer
• Based on the Sensetable project.
Audiopad
James Patten and Ben Recht* (*Physics & Media Group)

• A new way to perform electronic music.
• Designed to combine the expressive power of traditional musical instruments with the modularity of a computer
• Based on the Sensetable project.

Sensetable: TUI Platform + Applications

- TMG
- TMG + Intel + Sloan
- NTT Comware + TMG

Applications
- Urp [fluid dynamics]
- Audiopad
- CircuiTUI
- Supply Chain Visualization [System Dynamics]
- IP Network Designer [Event Driven Sim]
- Business Process Analyzer [Event Driven Sim]

Hardware platform
- Sensetable: TUI platform to track multiple objects and their states on a table with video projection
- NTT Comware Sensetable Product 2003
- Patten Studio
Actuation

Actuated Workbench
Dan Maynes-Aminzade, Gian Pangaro & Hiroshi Ishii 02

Function
Magnetic forces to move objects on a table in two dimensions.

Application
Augment existing “Sensetable” providing an additional physical dynamic display capability.
Actuated Workbench
Dan Maynes-Aminzade and Gian Pangaro & Hiroshi Ishii 02-03

Application 1
• Clearing up inconsistencies that arise from the computer’s inability to move the objects on the table

• Synchronization of distributed “Sensetables” in realtime remote collaboration
Tangible Thinking

Mechanical Representation of Knowledge: Orrery
Mechanical constraints, coupled with computer-controlled actuation, provide a novel and effective way to interact with computers.
Mechanical constraints

Guiding the motion of physical objects to guide the computational process

Mechanical constraints

• legible
• flexible
• ad hoc
Illuminating Clay
Ben Piper, Carlo Ratti & Hiroshi Ishii

- 3-D Tangible Interface for Landscape Analysis

  1. Physical Manipulation
  2. 3-D Capture
  3. Computational Analysis
  4. 3-D Projection

- Physical Clay as 3-D Physical Input & Visual Display for intuitive manipulation and understanding of spatial relationships
- 3D Laser Scanner + Video Projector
Users can alter the form of the landscape model by manipulating sand while seeing the resultant effects of computational analysis projected on the surface of sand in real-time.
System

A ceiling mounted IR camera captures the radiance of the light passing through the sand model to determine the geometry of the surface. The resulting landscape analysis is projected back on to the surface.
Physical Design Media

- Clay
- Cardboard
- Wooden Blocks
- Found Objects

Physical Outcomes
Stata Center 2002

Frank O. Gehry, Architect

Lack of Continuity Between Physical and Digital Representation in Design

<table>
<thead>
<tr>
<th>Physical</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of manipulation</td>
<td>Greater precision</td>
</tr>
<tr>
<td>Clearer communication</td>
<td>Easy distribution</td>
</tr>
<tr>
<td>Aids spatial understanding</td>
<td>Quantitative analysis</td>
</tr>
</tbody>
</table>

How can we merge these media?
Tangible Design Media for Seamless Form Giving & Computational Reflection

Physical

Upper Stream

Rough and rapid form giving with hand for ideation

Digital

Lower Stream

Precise and quantitative computational reflection

simultaneous form giving + computational reflection

Representation of Idea Matters …

... because the mental operations are made possible by the representation.
... GUI/CAD is not for ideation.

e.g.
- Mathematical representation
- Drawings
- Physical models
- Computational models
Media for Design Thinking

• **Visual Thinking**
  – sketch

• **Tangible Thinking**
  – tactile manipulation of physical representations coupled with digital computation
  – design + analysis

Evolution of Workbench for Collaborative Design and Tangible Thinking

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PingPongPlus
Ishii, Lee, Wisneski, Orbanes 1999

- Digital augmentation of ping pong play with "reactive table."
- Ball tracking using microphone array underneath table.
- From competition to collaboration
PingPongPlus
Ishii, Lee, Wisneski, Orbanes 1999

- Digital augmentation of ping pong play with "reactive table."
- Ball tracking using microphone array underneath table.
- “From competition to collaboration”

- ICC, Tokyo 2000
- Centre Pompidou, Paris 2003
- Victoria and Albert Museum, London 2005

PingPongPlus at Centre Pompidou, Paris 2003

- Digital augmentation of ping pong play with "reactive table."
- Ball tracking using microphone array underneath table.
- “From competition to collaboration”
Invisible
extension of body - good fit

• customize
• personalize
• adapt
• co-evolve

Visible
center of focus - goal of task

• Critical representation of task
• Ball has to be always visible in the foreground with a table as reference
• You need an interface (paddle) to control the ball