Tangible User Interfaces

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TOC

Origins

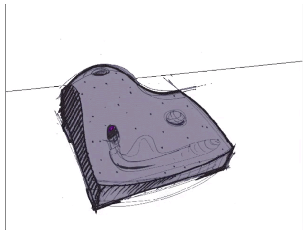
- 1993 - CACM “Back to the Real World”
- WIMP estranges humans from their “natural environment”
- Virtual world vs enriching real world
- Richness of physical interaction
- Embedding computing

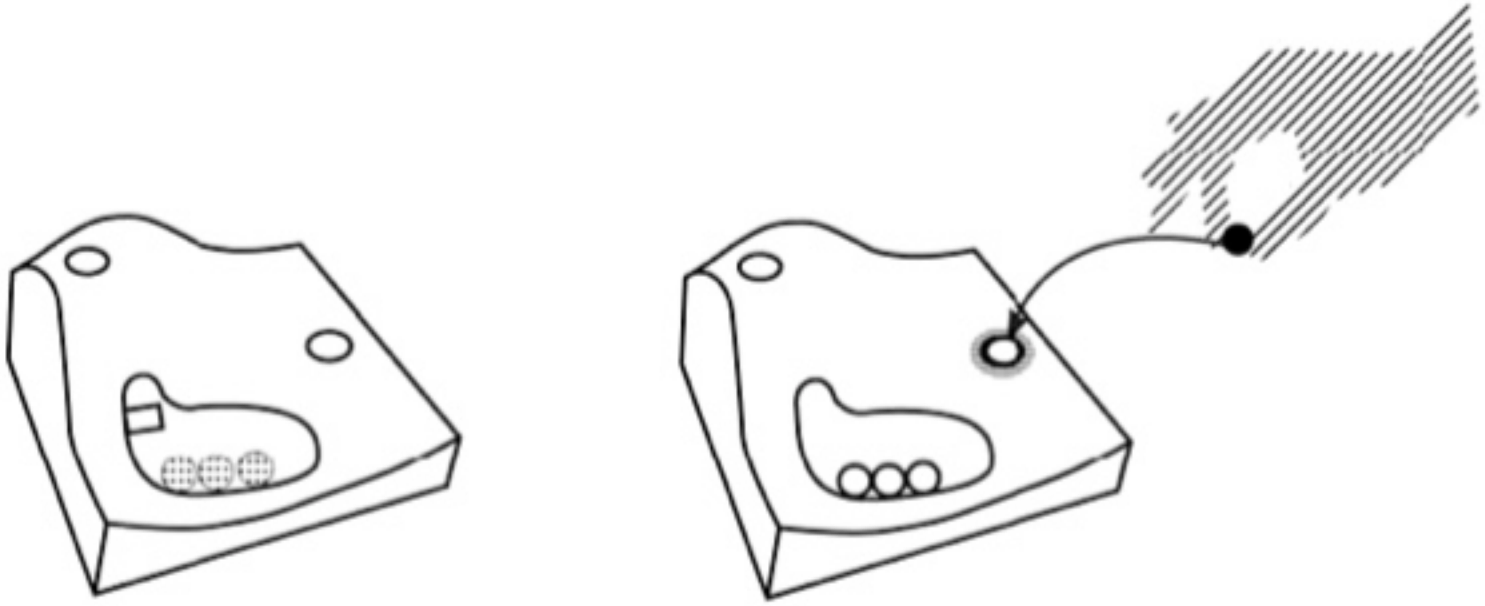
“We live in a complex world, filled with myriad objects, tools, toys, and people. Our lives are spent in diverse interaction with this environment. Yet, for the most part, our computing takes place sitting in front of, and staring at, a single glowing screen attached to an array of buttons and a mouse.”

– P. Wellner, W. Mackay, and R. Gold, “Computer-augmented environments. Back to the real world,” Communications of the ACM, vol. 36, no. 7, pp. 24–26, 1993.

Marble answering machine

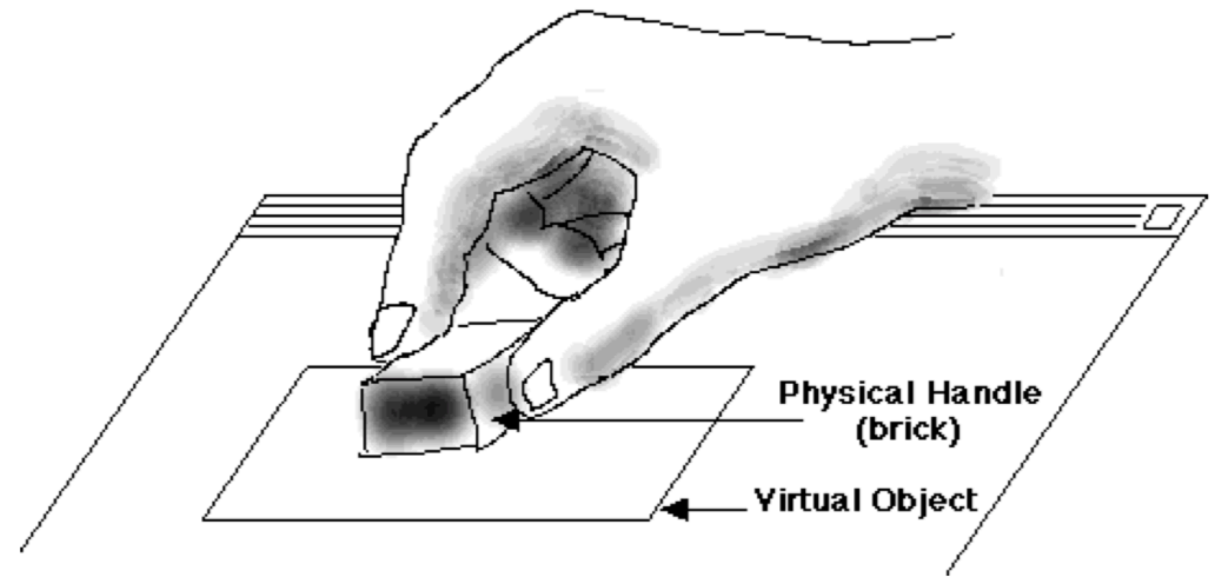
- Bishop, 1992

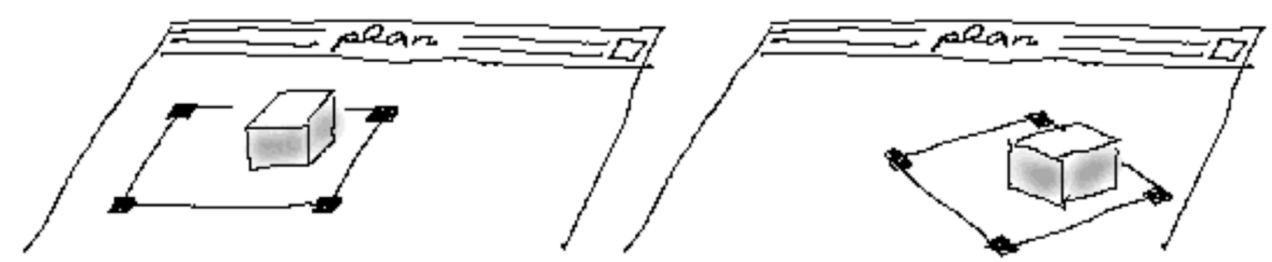




Graspable Interfaces

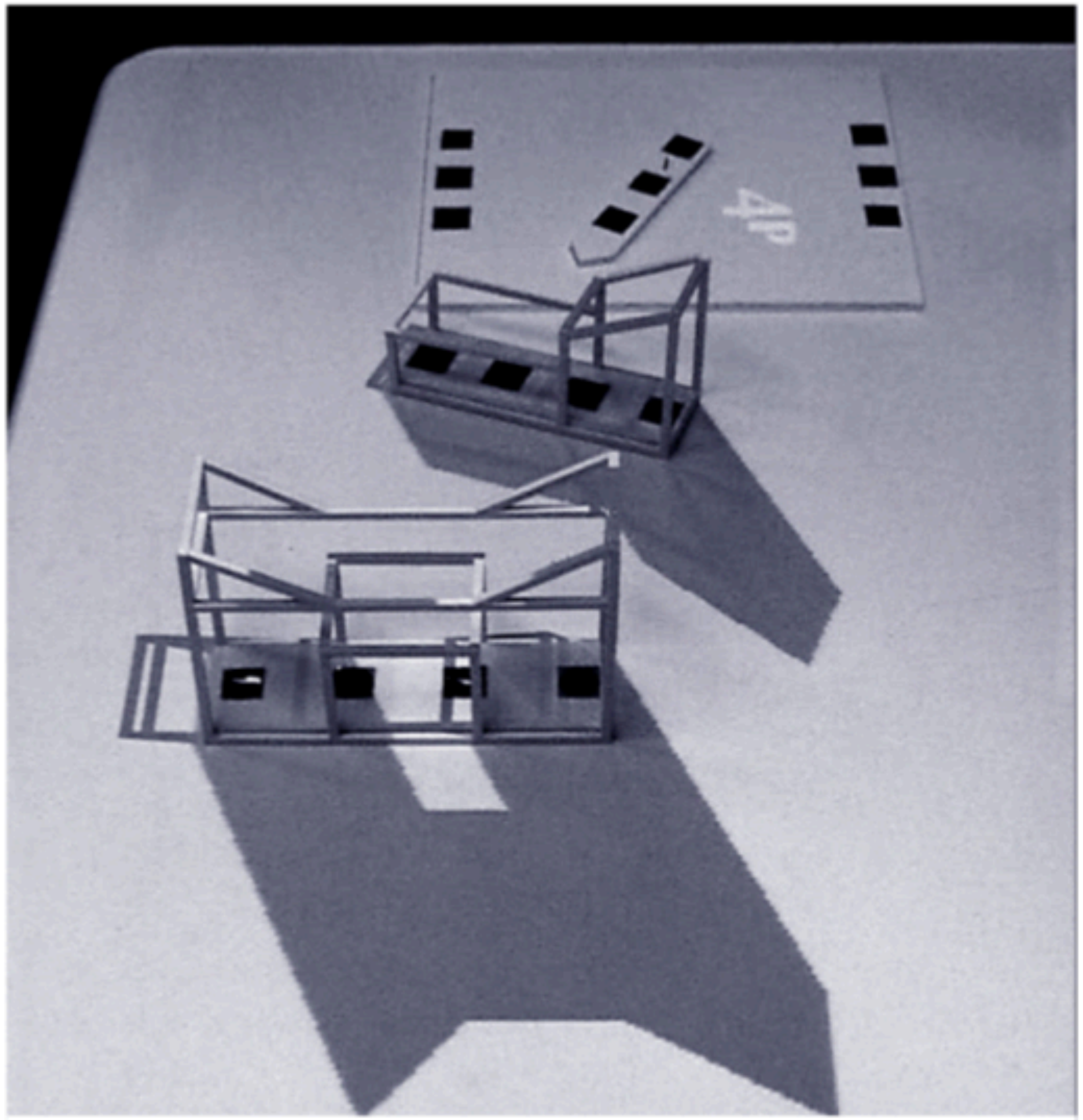
- Fritzmaurice et al, 1995: **Graspable interfaces**
  - Graspable handles used to manipulate digital objects





Tangible Bits

- Ishii, 1997
  - Connect object and surfaces with digital data
  - Painted bits (GUI) vs Tangible bits
  - Manipulate and represent data



Urp and shadow simulation. Physical building models casting digital shadows, and a clock tool to control time of day (position of the sun).

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Tangible bits

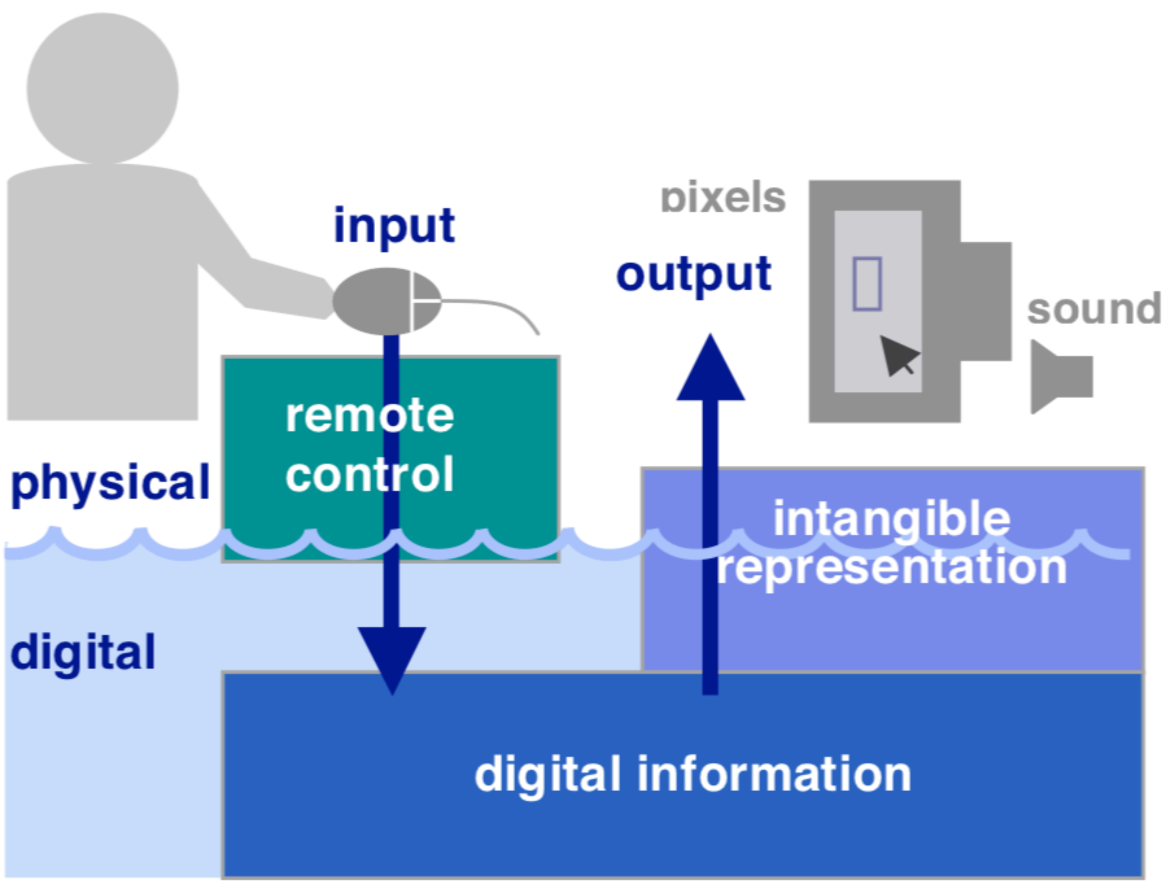


Figure 3. Graphical User Interface. GUI represents information with intangible pixels on a bit-mapped display and sound. General-purpose input devices allow users to control those representations.

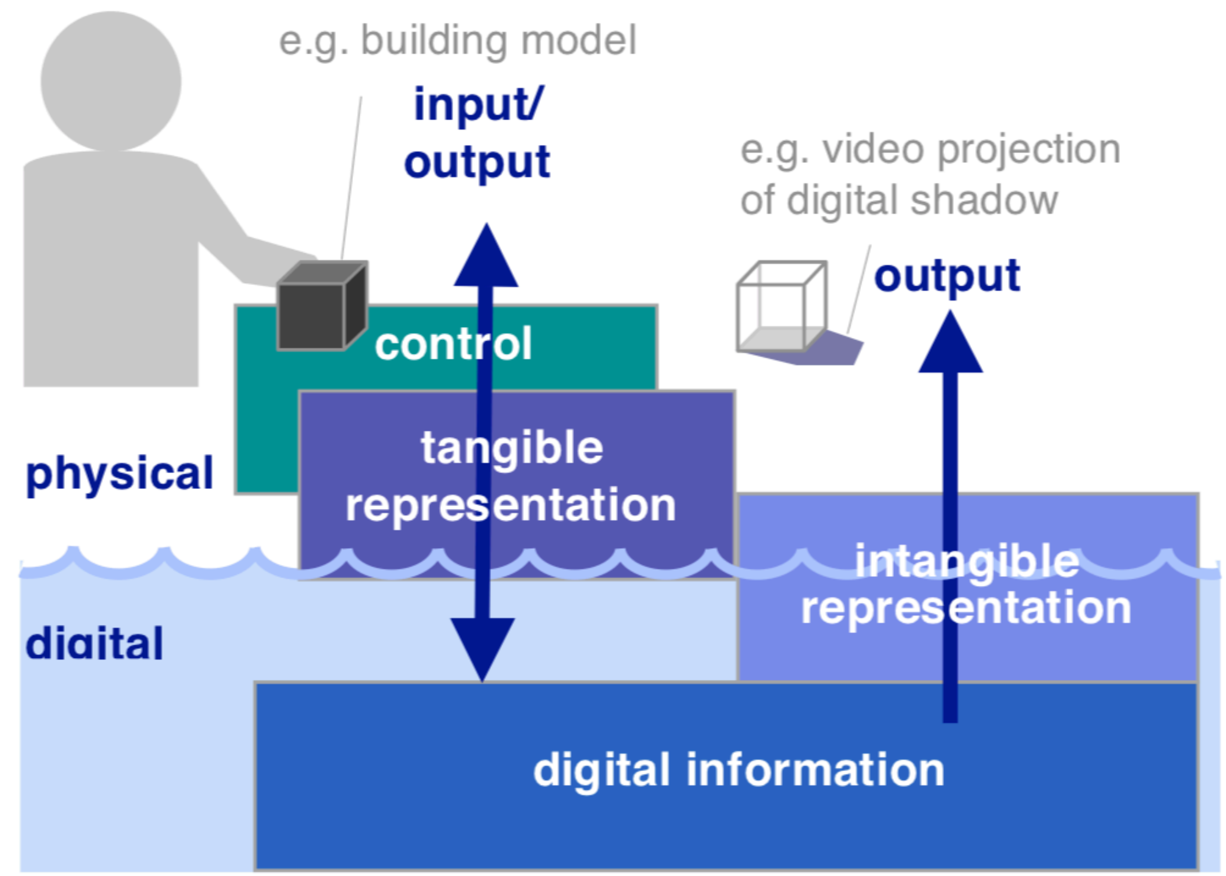
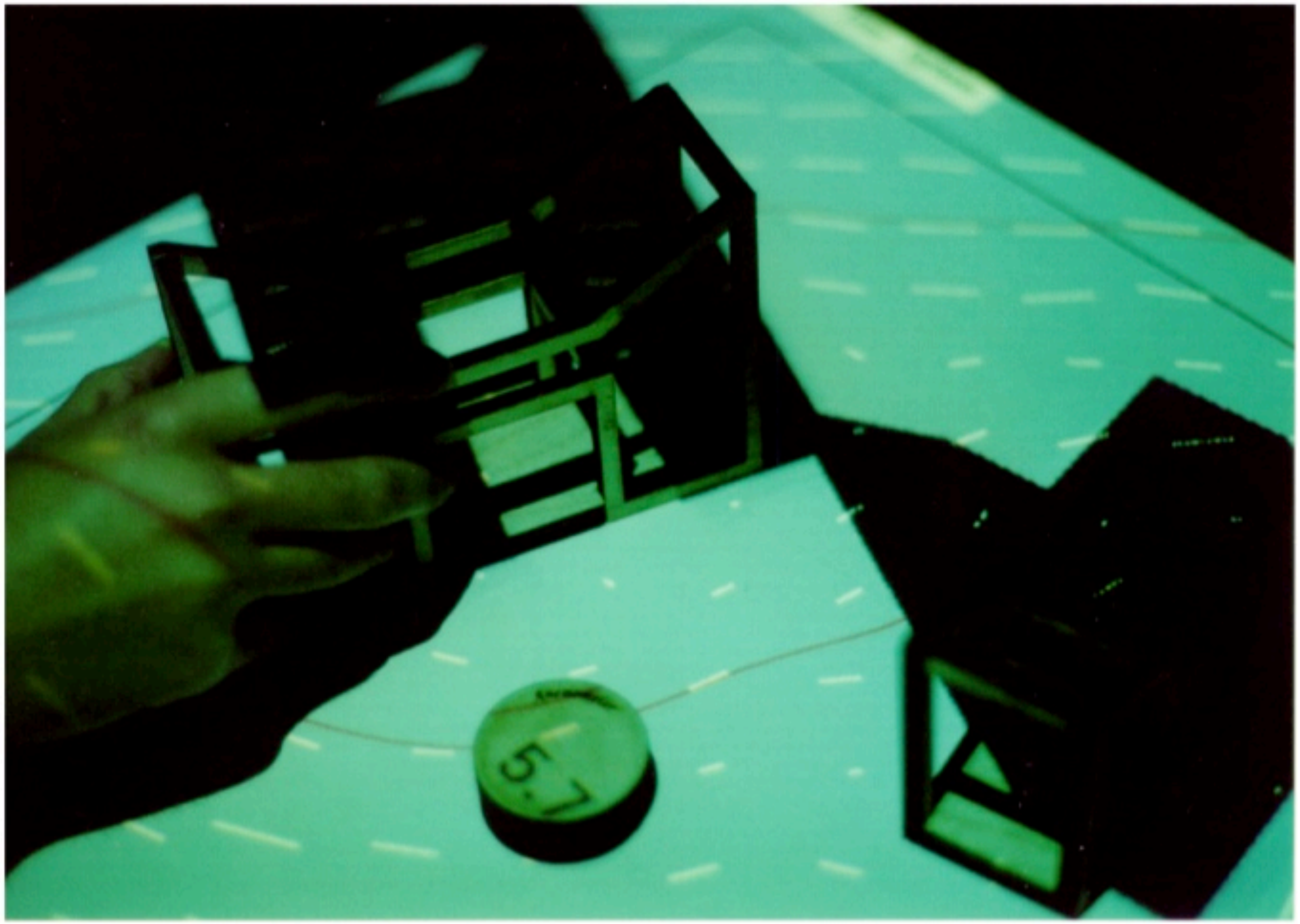
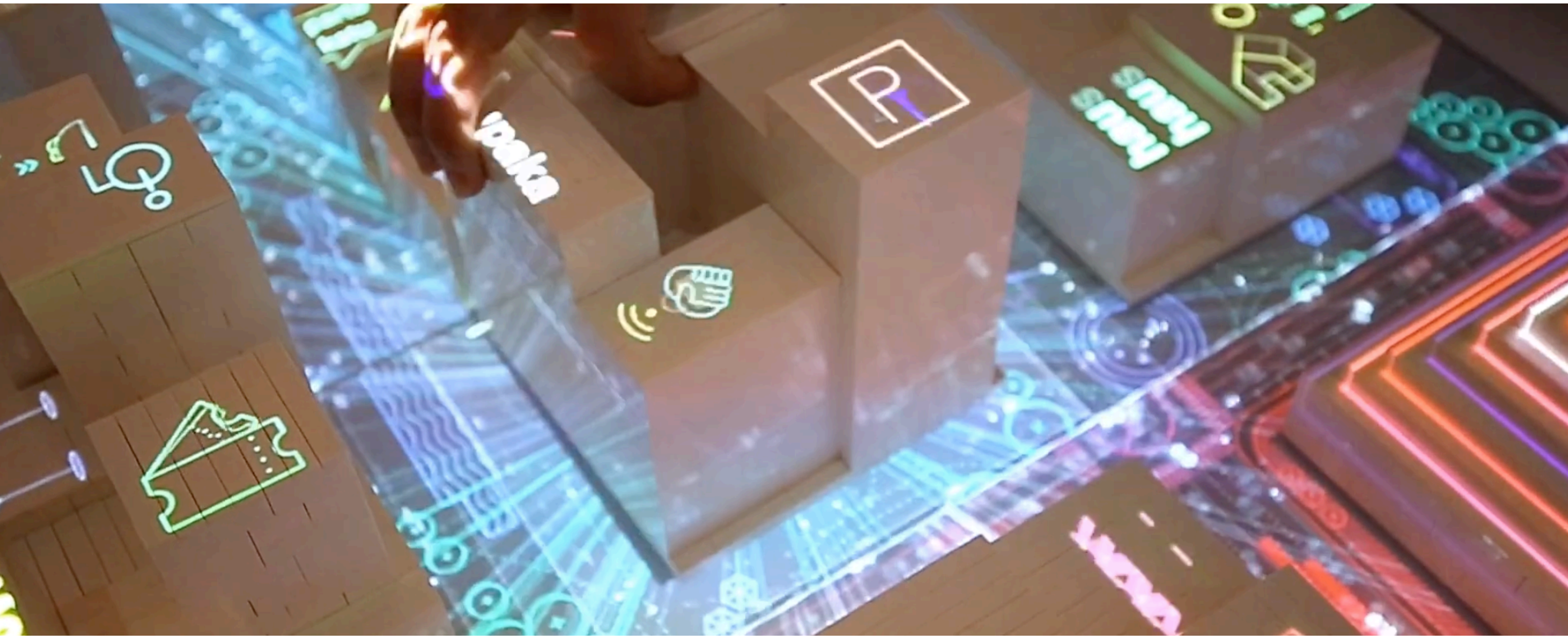


Figure 4. Tangible User Interface. By giving tangible (physical) representation to the digital information, TUI makes information directly graspable and manipulable with haptic feedback. Intangible representation (e.g. video projection) may complement tangible representation by synchronizing with it.

Tangible bits

- wind

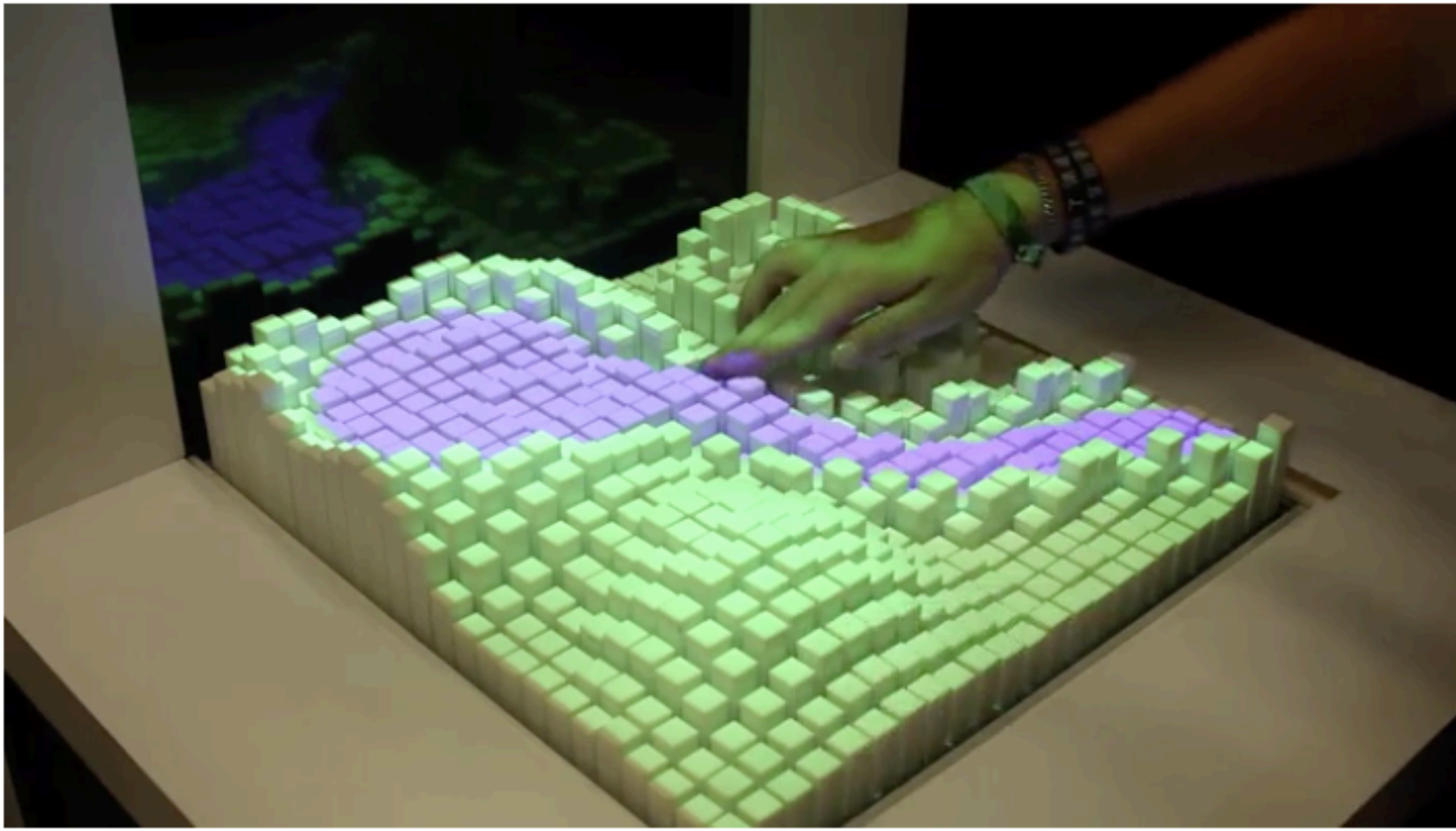




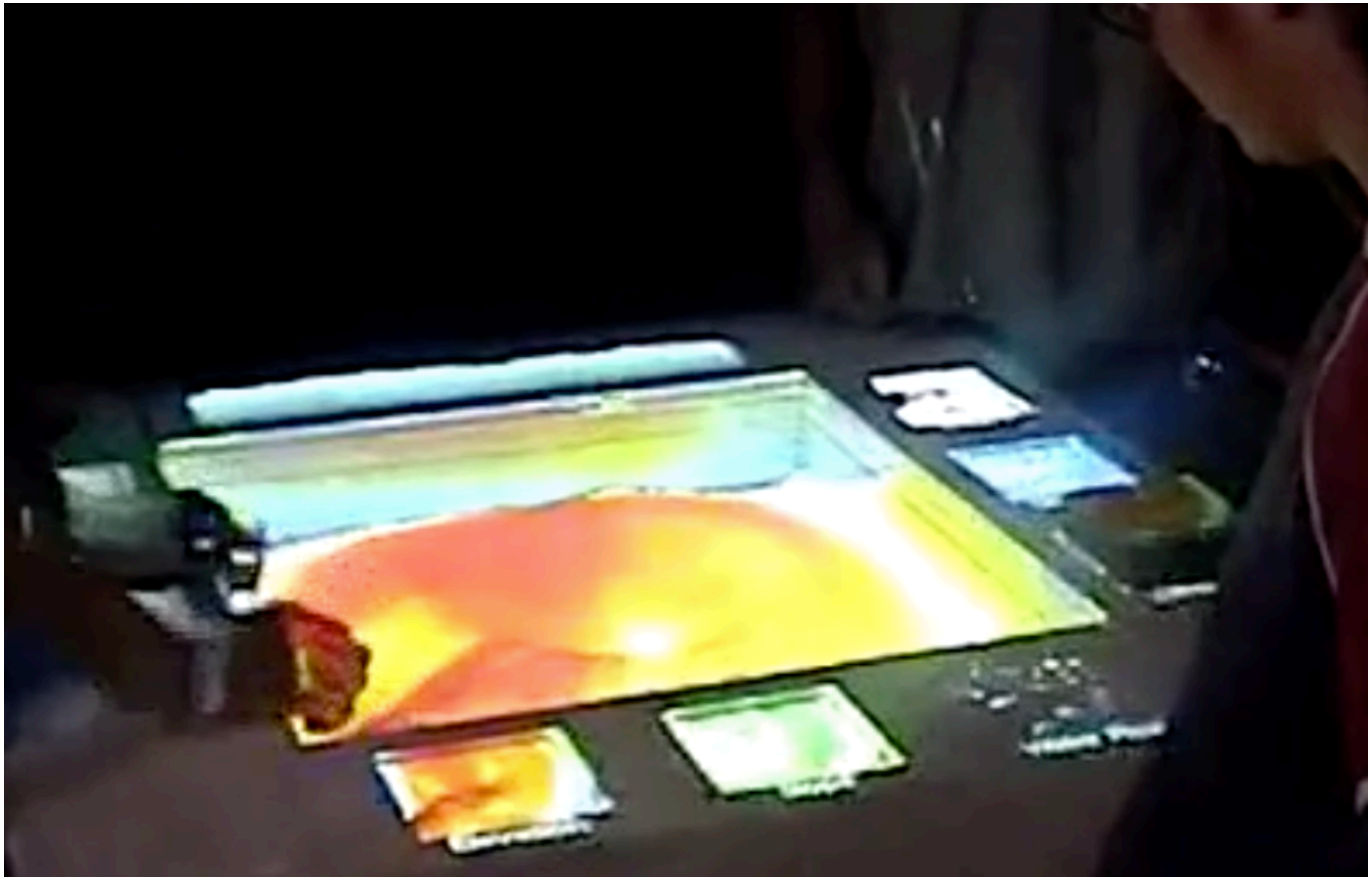
CityScope

Mit Media Lab

Shape-Shifting Digital Clay — MIT



Sandscape



TUIs: systems that give physical form to digital information, employing physical artifacts both as representations and controls for computational media

–Ullmer and Ishii

Affordance

- properties of an object that invite and allow specific actions — Norman, D.
- e.g. a handle affords holding and turning, a button affords pressing
- real affordances vs. perceived affordances (eg. button in a GUI)

Overlap with other areas

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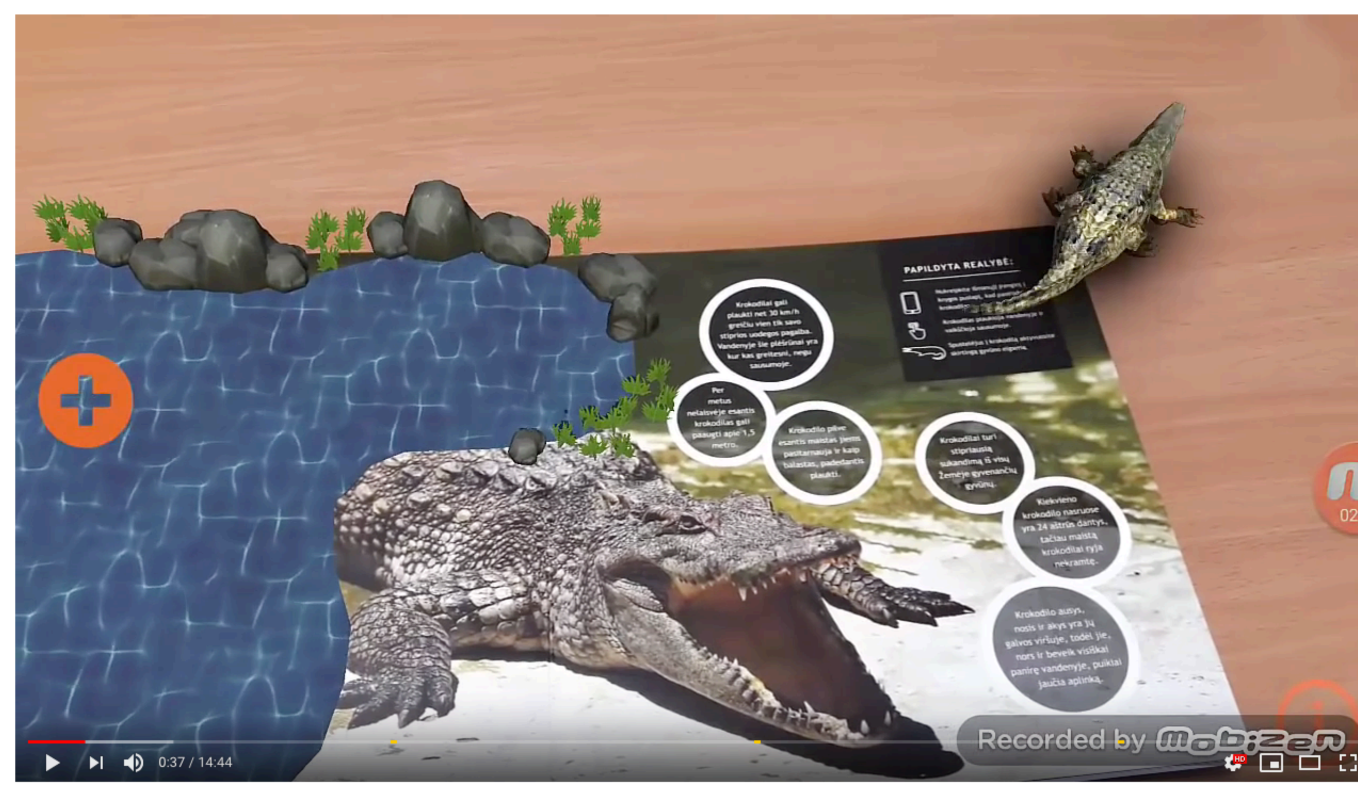
Tangible augmented reality

- Combine AR and tangible
- Virtual objects attached to tangible objects
- Visual markers on tangible objects (tags)
- Video image where digital imagery inserted at the same location and 3D orientation as the visual marker

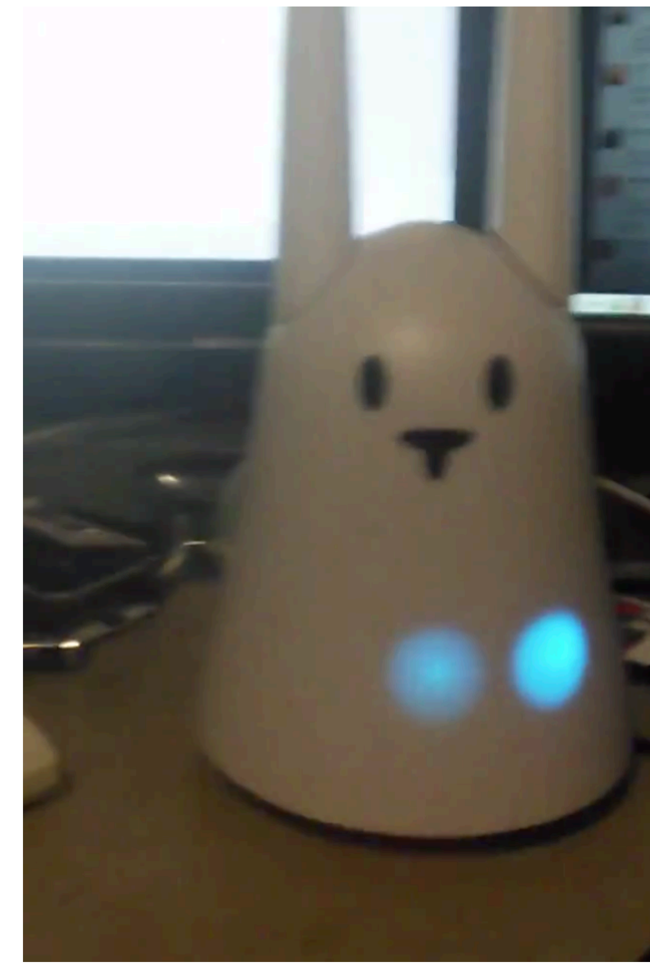


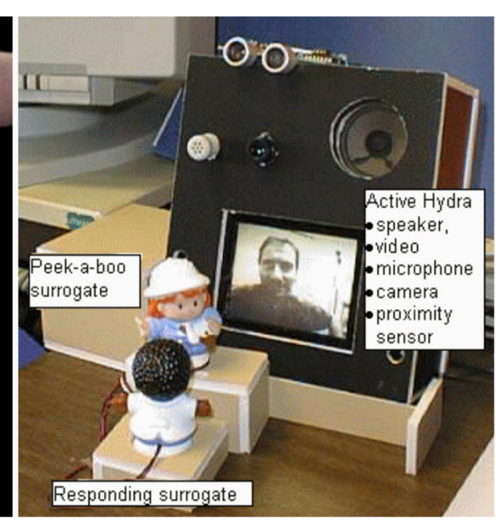
Tangible tabletop interaction

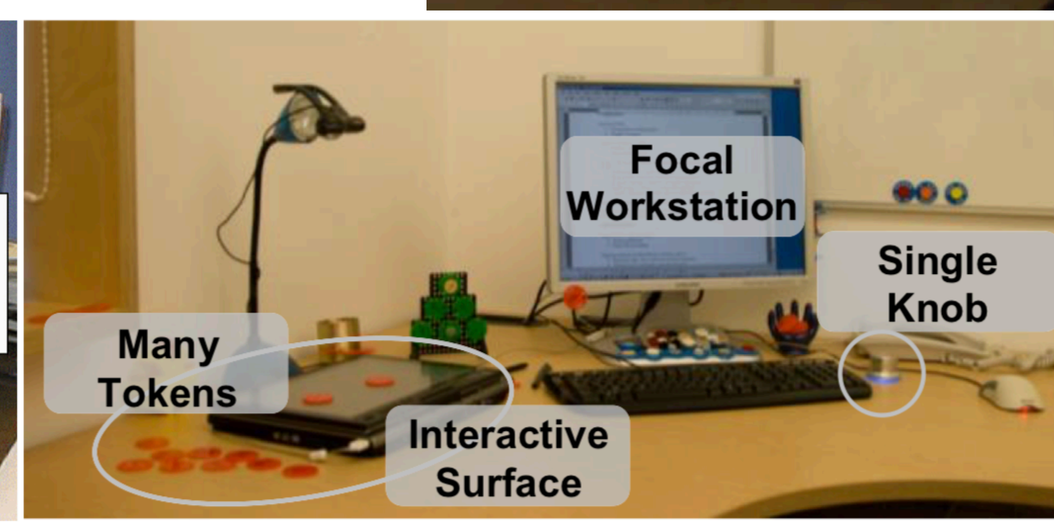
- Combines interactive multitouch surfaces and TUIs
- Camera + projector + translucent screen
- iPad version

Ambient displays

- flower that blooms to convey the availability of a work colleague
- user’s proximity to and handling of a figurine affect the fidelity of audio and video in a media window
- nabaztag bunny
- peripheral (and thus ambient) interaction with tangibles
- Interactive Pillows







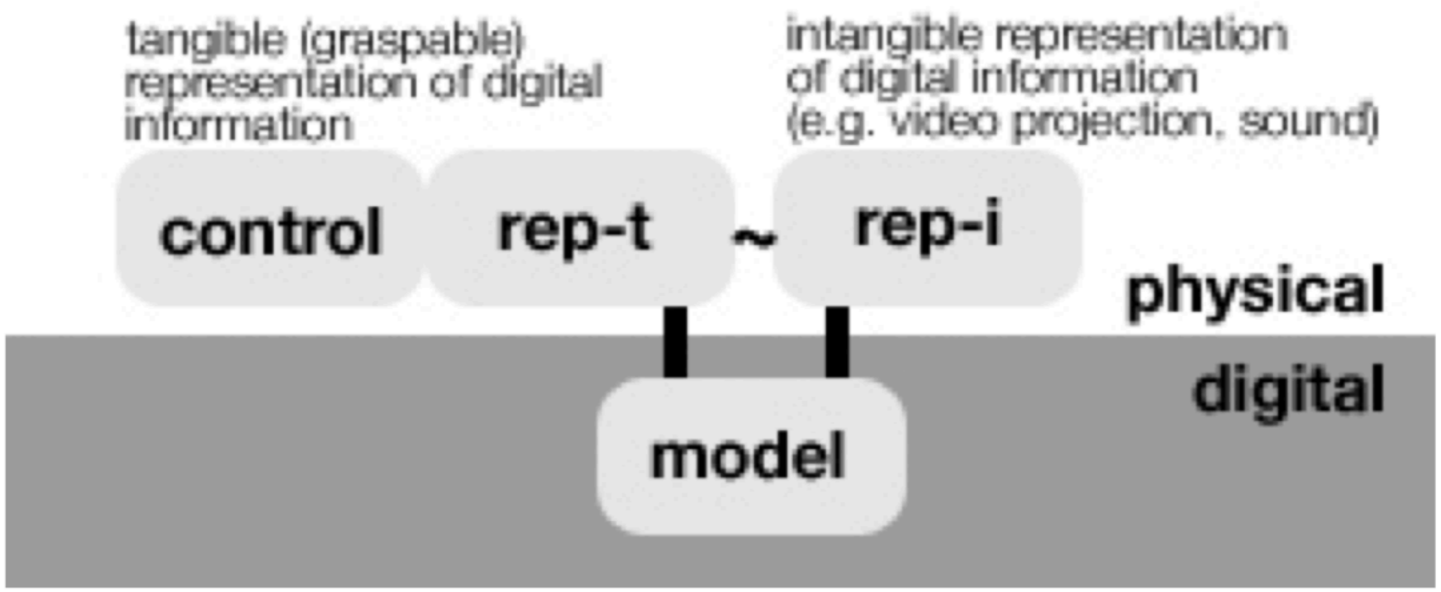
Tangible reminders and tags

- placing a particular object in proximity of a reader
- e.g. placing vacation souvenirs on a surface opens an associated photo collection
-

Model

MCRit

- Model-Control-Representation (intangible and tangible)
- integration of physical representations and control in tangible user interfaces



MCRit

- tangible objects are coupled via computerized functionality with digital data (computational coupling);
- the tangible objects represent the means of interactive control. Moving and manipulating objects is the dominant form of control;
- the tangible objects are perceptually coupled with digitally produced representations (e.g., audio and visuals);
- the state of the tangible objects embodies core aspects of the entire system’s state (representational significance). (the system is thus at least partially legible if power is cut).

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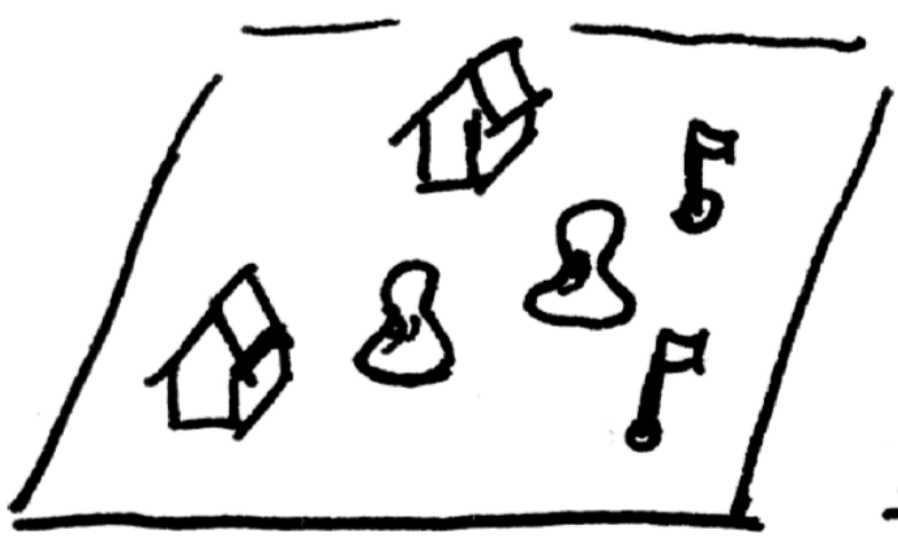
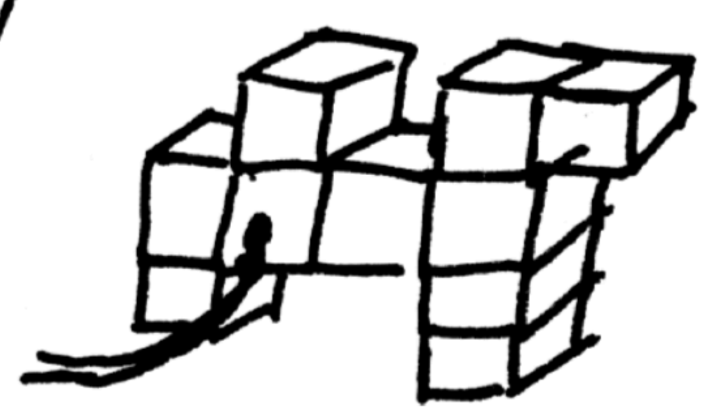
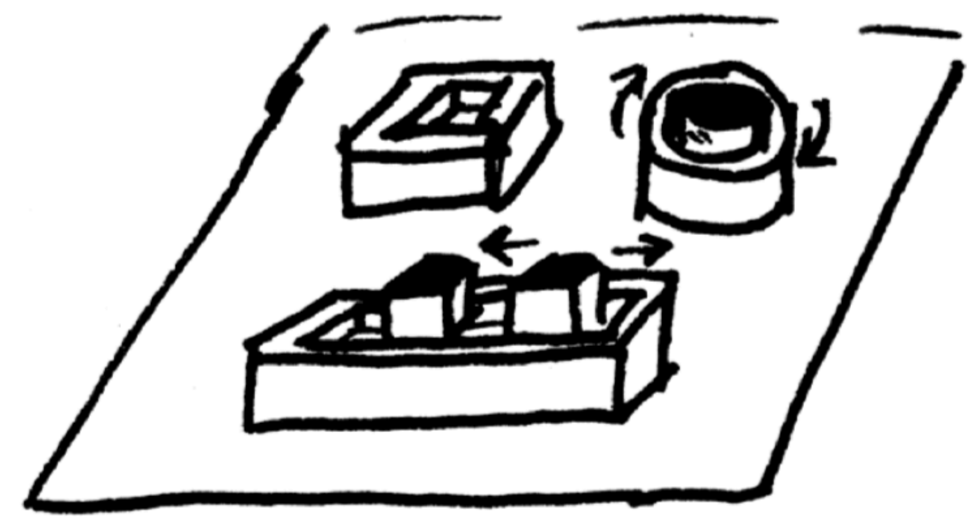
Classification of TUIS

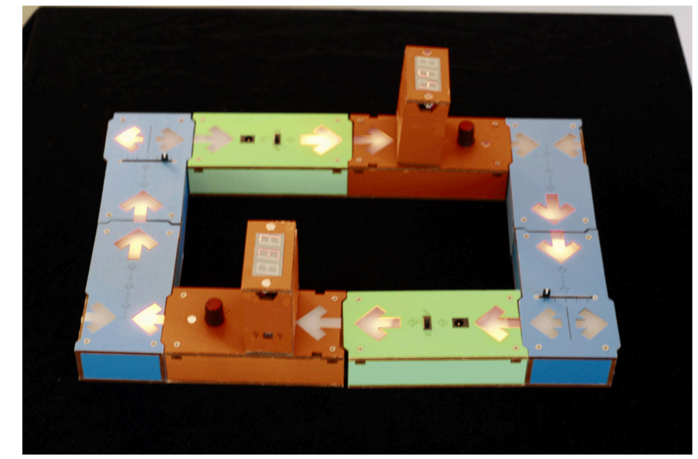
- interactive surfaces
- constructive assembly
- token+constraint

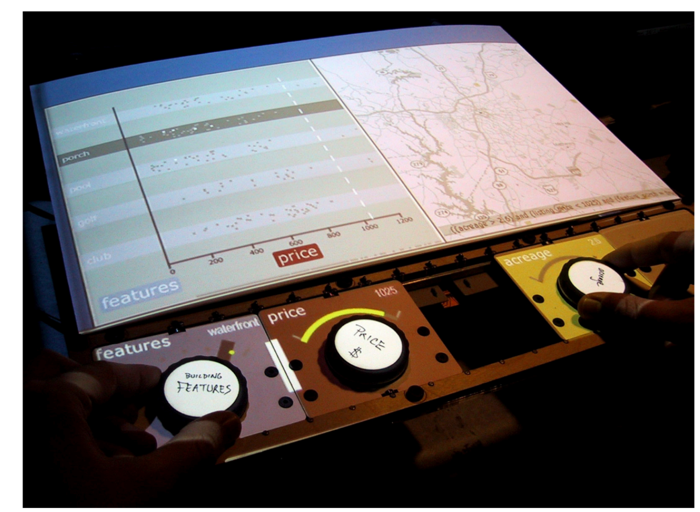




- Specification of complex commands (abstract, concatenated, or acting on a set of objects) generally is a weak point of all direct manipulation interfaces.
- TUIs are further weak in undoing mistakes as there is no undo function; the previous system state has to be remembered and manually reconstructed.

Application domains

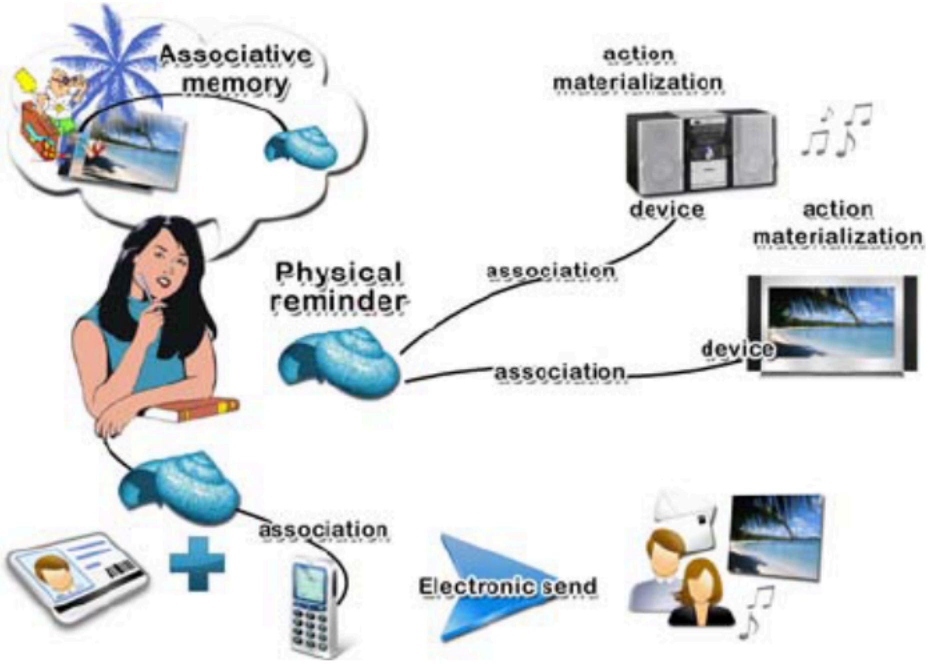
- Learning
- Problem Solving and Planning
- Information Visualization
- Tangible Programming
- Entertainment, Play, and Edutainment





Application domains /2

- Music and Performance
- Social Communication
- Tangible Reminders and Tags



Technologies

- RFID
- Computer vision
- Microcontrollers, Sensors, and Actuators

Properties /1

- Physical properties sensed. What physical properties can be sensed using a particular technology?
- Cost. What is the relative cost of the different components comprising a sensing technology?
- Performance. Is the system efficient in terms of processing and response times? What factors affect the system's efficiency?
- Aesthetics. To what extent does a sensing technology affect the appearance of an object? Can the user identify which objects or properties are sensed and which are not?

Properties /2

- Robustness and reliability. Can the system perform its required functionality for a long period of time? Can the system withstand changing conditions?
- Setup and calibration. What is required to get the system in a usable mode?
- Scalability. Can the system support an increasing number of objects or users?
- Portability. To what extent does a sensing technology com- promise the portability of a system?

Table 7.1. Comparison of TUI implementation technologies.

Property	RFID	Computer Vision	Microcontrollers
Physical properties sensed	Identity, presence.	Identity, presence, shape, color, orientation, position, relative position, and sequence.	Light intensity, reflection, motion, acceleration, location, proximity, position, touch, temperature, gas concentration, radiation, etc.
Cost	Tags are cheap and abundant. The cost of readers varies, but is generally inexpensive (short distance readers).	Fiducial tags are practically free. The cost of high-quality cameras continuously decreases. A high-resolution projector is relatively expensive.	Generally inexpensive. The cost of sensors and actuators vary according to type.
Performance	Tags are read in real time, no latency associated with additional processing.	Dependent on image quality. Tag-specific algorithms are typically fast and accurate. A large number of tags or low-quality image take longer processing. Motion blur is an issue when tracking moving objects.	Generally designed for high-performance. Stand-alone systems typically perform better than computer-based systems.

Table 7.1: Comparison of TUI implementation technologies.

Property	RFID	Computer Vision	Microcontrollers
Aesthetics	Tags can be embedded in physical objects without altering their appearance.	Fiducial marker can be attached to almost any object (ideally to its bottom).	Sensors and actuators can be embedded within objects. Wires may be treated to have a minimal visual affect.
Robustness and reliability	Tags do not degrade over time, impervious to dirt, but sensitive to moisture and temperature. Nearby technology may interfere with RFID signal. Tags can only be embedded in materials opaque to radio signals.	Tag-based systems are relatively robust and reliable. However, tags can degrade over time. Detection only within line of sight.	Typically designed for robustness and reliability. Batteries need to be charged. The robustness and reliability of sensors and actuators vary. Wiring may need to be checked.
Setup and Calibration	Minimal. No line of sight or contact is needed between tags and reader. The application must maintain a database that associates ID with desired functionality.	Address a variety of factors including occlusion, lighting conditions, lens setting, and projector calibration.	Connect microcontroller to computer; wire sensors and actuators; embed hardware in interaction objects; fabricate tailored interaction objects to encase hardware.
Scalability	The number of simultaneously detected tags is limited by the reader. No practical limitation on the number of tagged objects.	The maximal number of tracked tagged objects depends on the tag design (typically a large number).	Typically constrained by the number of I/O ports available on a microcontroller.

Limitations

- scalability (small data sets, space, no wildcards…)
- versatility (single use)
- malleability (objects are rigid and static; no undo; no history)
- user fatigue (size, weight, …)

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