Instrumented Environments

Andreas Butz, butz@ifi.lmu.de, www.mimuc.de

Fri, 12:15-13:45, Theresienstr. 39, Room E 045

Special Lecture on 07.07.

- Visit by Bill Buxton and Abigail Sellen (Microsoft Research Cambridge)
- Both working on interaction with Instrumented Environments
- Expect a Guru-level presentation!
  - Detailed topic yet TBD
- Bring friends!
  - Possibly in a bigger room --> TBD

Low level context recognition

..on the other end of the scale..

Low level context recognition
(Cakmakci et al. 2002)

- Design “context aware hardware”
- Enhance wearable computing
- Detect simple user activities, like sitting, walking, looking at the watch

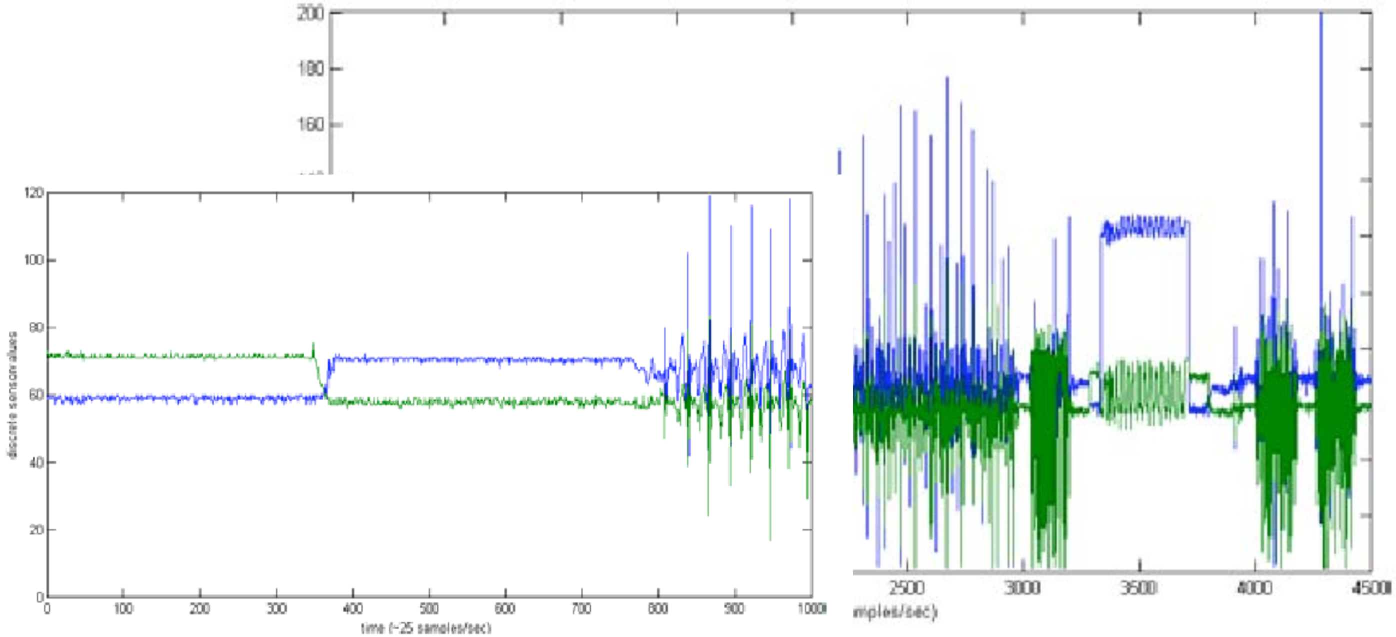
Low level context recognition

- Use statistical modeling techniques from robotics to determine context
- Use accelerometers to record movement changes
- Apply Bayes rule to determine probability of certain contexts:

$$p(context \mid sensordata) = \frac{p(sensordata \mid context) * p(context)}{p(sensordata)}$$

Low level context recognition

- First simple Experiment: Detect whether users are sitting, standing and walking



Acceleration over 4500 data points during the experiment

Use the first 1000 data points for learning

Low level context recognition

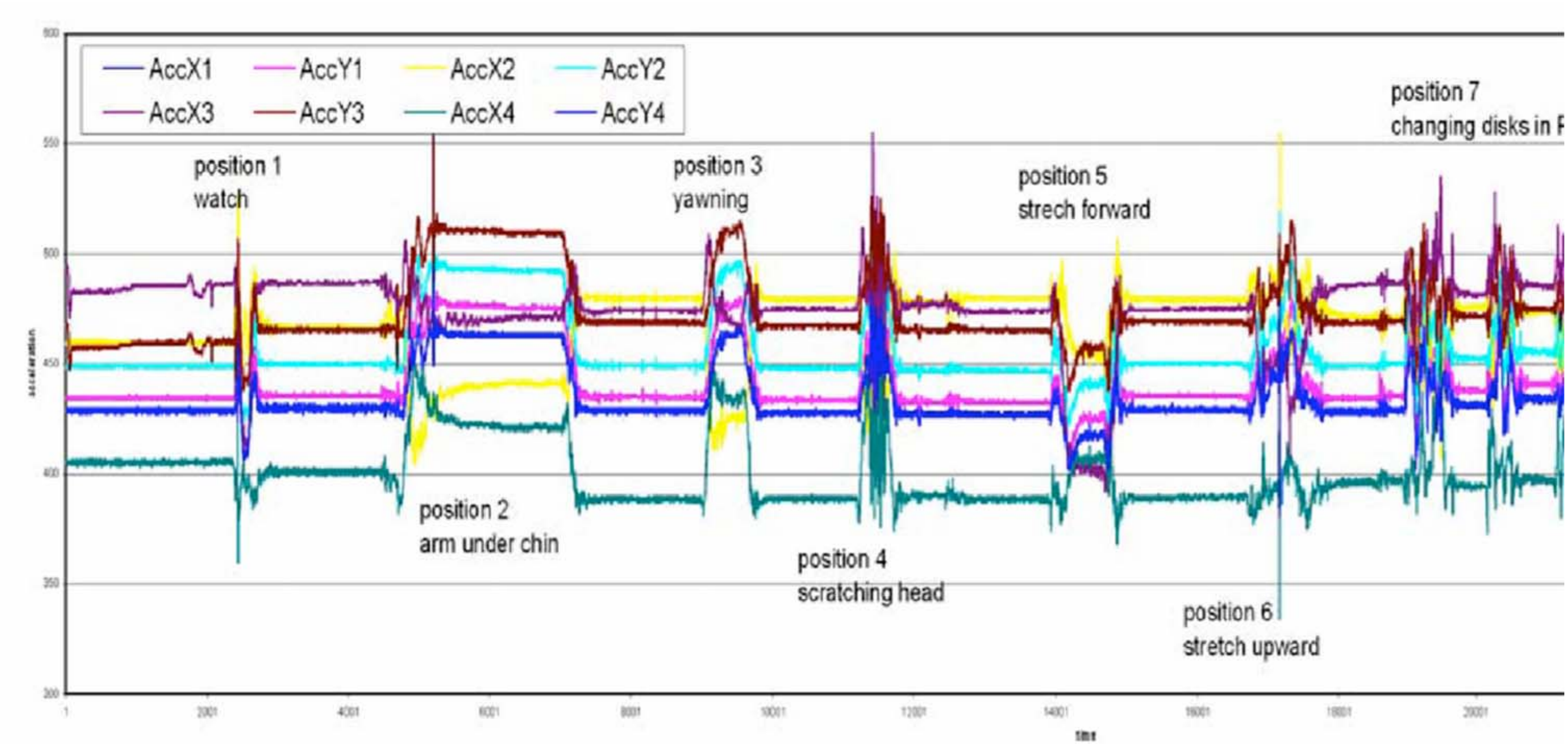
- Results of recognition

Activity	Recognition rate
Sitting (occurs 3 times during the experiment)	95.66%
Standing (occurs 2 times during the experiment)	80%
Walking (occurs 9 times during the experiment)	93.11%

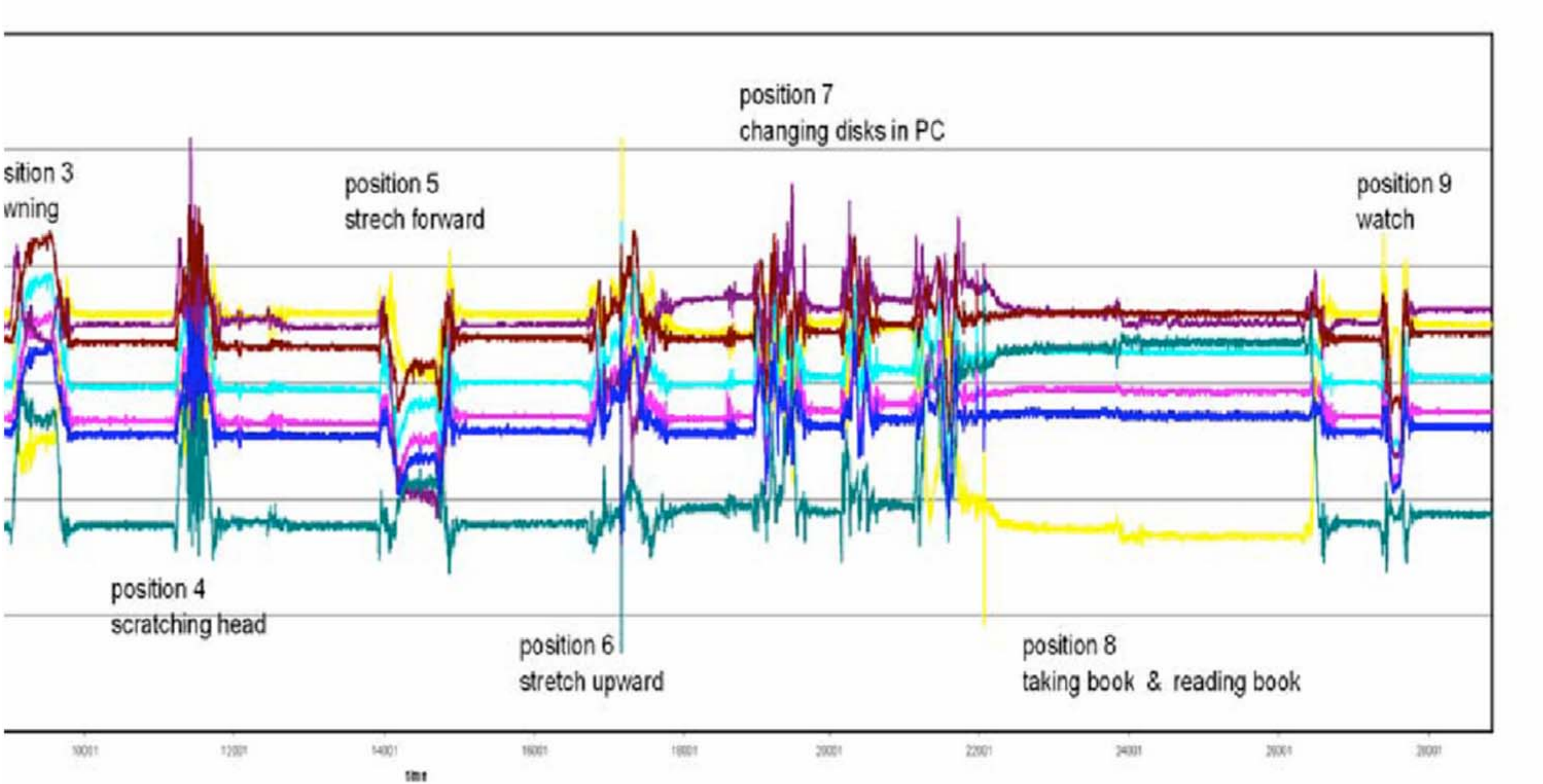
Low level context recognition

- 2nd experiment: Detect when users glance at their watch
- Idea: reduce power of watch (e.g. toggle display) during use
- Extremely important for a wristwatch computer (IBM WWC: ARM7 processor, 8Mb flash memory, 8Mb of DRAM, serial, IRDA, and expansion interfaces).

Low level context recognition



Evaluation set in a blind experiment



position 7
changing disks in PC
sition 3
wning
position 5
strech forward
position 9
watch
position 4
scratching head
position 6
stretch upward
position 8
taking book & reading book

Low level context recognition

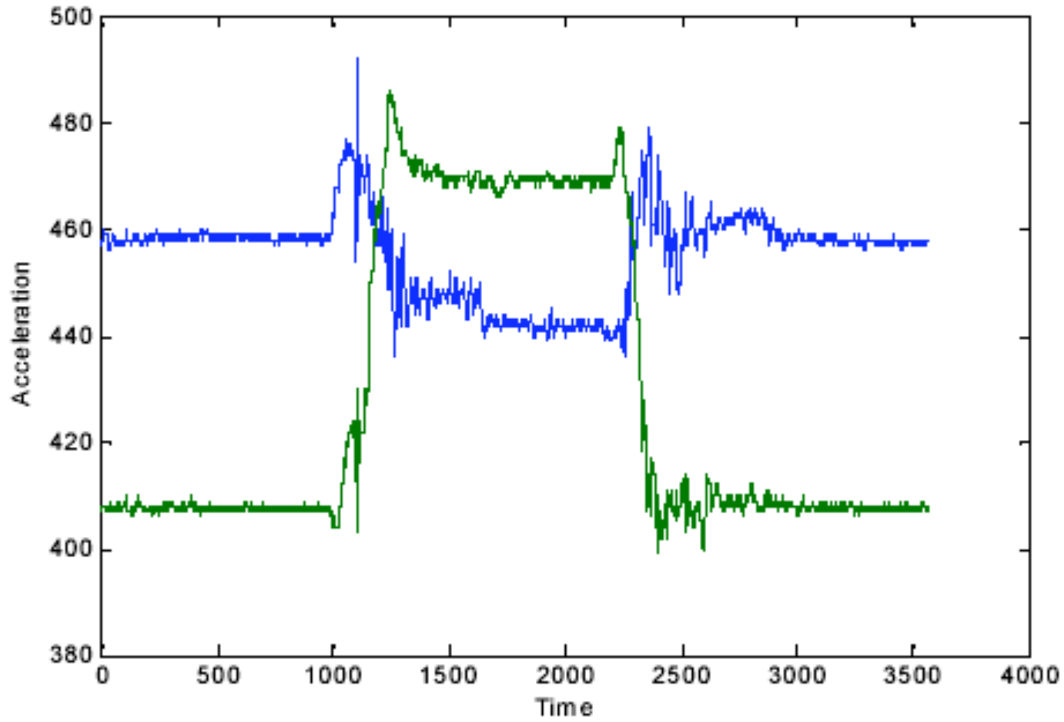
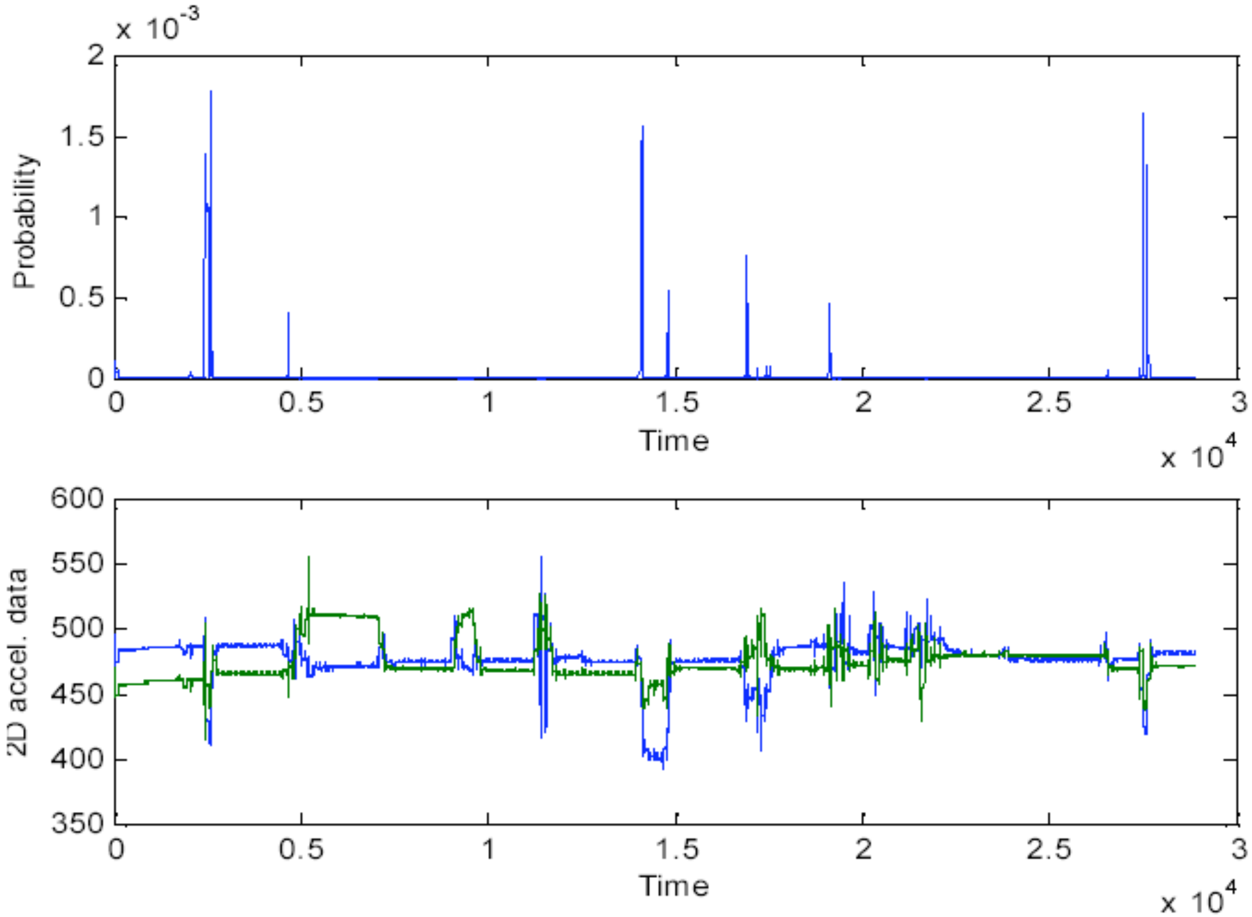


Figure 4. A typical example of training data for looking the watch gesture.

Use a single hypothesis approach to model “wrist watching”
(Only one well defined class)

Low level context recognition



Results:
Probability of certain data points belonging to a wrist watch action

Distributed context modeling

...For instrumented cities?!?..

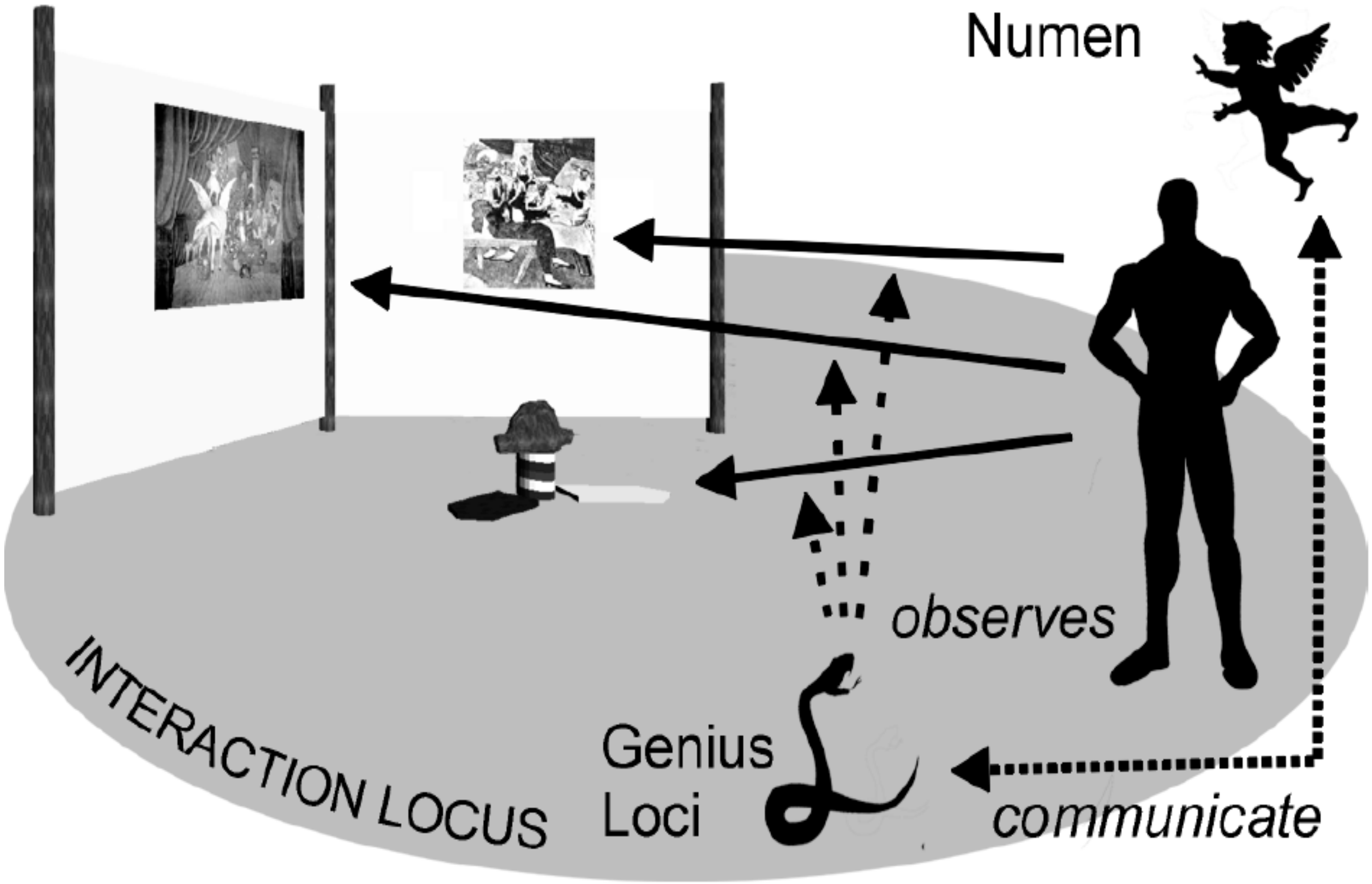
Distributed context aware interaction
(Celentano et al. 2002, 2003)

- Problem: interaction in large intelligent environments
- Solution: use agents to structure the problem space
  - Interaction Locus *IL* (3d-space) and the User
  - Agents: Genius loci and User's numen
- Target Scenario: intelligent museum guide

Distributed context aware interaction

- Genius loci:
  - (lat.), Geist des Ortes
  - Knows about displays and interaction possibilities of the interaction locus
- User’s numen
  - Numen (lat.), göttl. Wesen, Gottheit ohne persönl. Gestalt.
  - Knows about the interests and profile of the user and his exploration history

Distributed context aware interaction



Distributed context aware interaction

- Communication protocol integrates knowledge and is started when the user enters the *IL*
  1. Genius Loci (GL) starts the dialog and contacts the user’s numen (UN)
  2. The UN explains the user’s interest and the GL adapts the properties of the interaction
  3. The GL learns user preferences and interaction styles
  4. When leaving the IL the GL informs the UN about his inferences

Context Shadow: Organizing Contexts
(Jonsson 2002)

- Problem: How can a huge context be structured and managed?
- Solutions: Design of a searchable topology
- Provide a JAVA API that provides easy access to sensor and personal information with the help of a blackboard architecture

Context Shadow: Organizing Contexts

- Goals of Context Shadow:

1. Support for context aware service discovery.
2. Organization of services and context information in meaningful collections.
3. Context information for applications derived from sensors and other services
4. Refinement of context information.

Context Shadow: Organizing Contexts

- Entities on the blackboard
  - Context servers (CS) that represent persons, locations and groups
  - CS contain information about context and links to other CS
- Implement CS with the help of TSpaces from IBM

TSpaces (Lehmann et al., 1999, IBM)

- TSpaces is network middleware for ubiquitous computing
- A network communication buffer with database capabilities
- Implemented in JAVA
- Communication via Tuples that are read and written to “spaces”

Cross references with Context Shadow

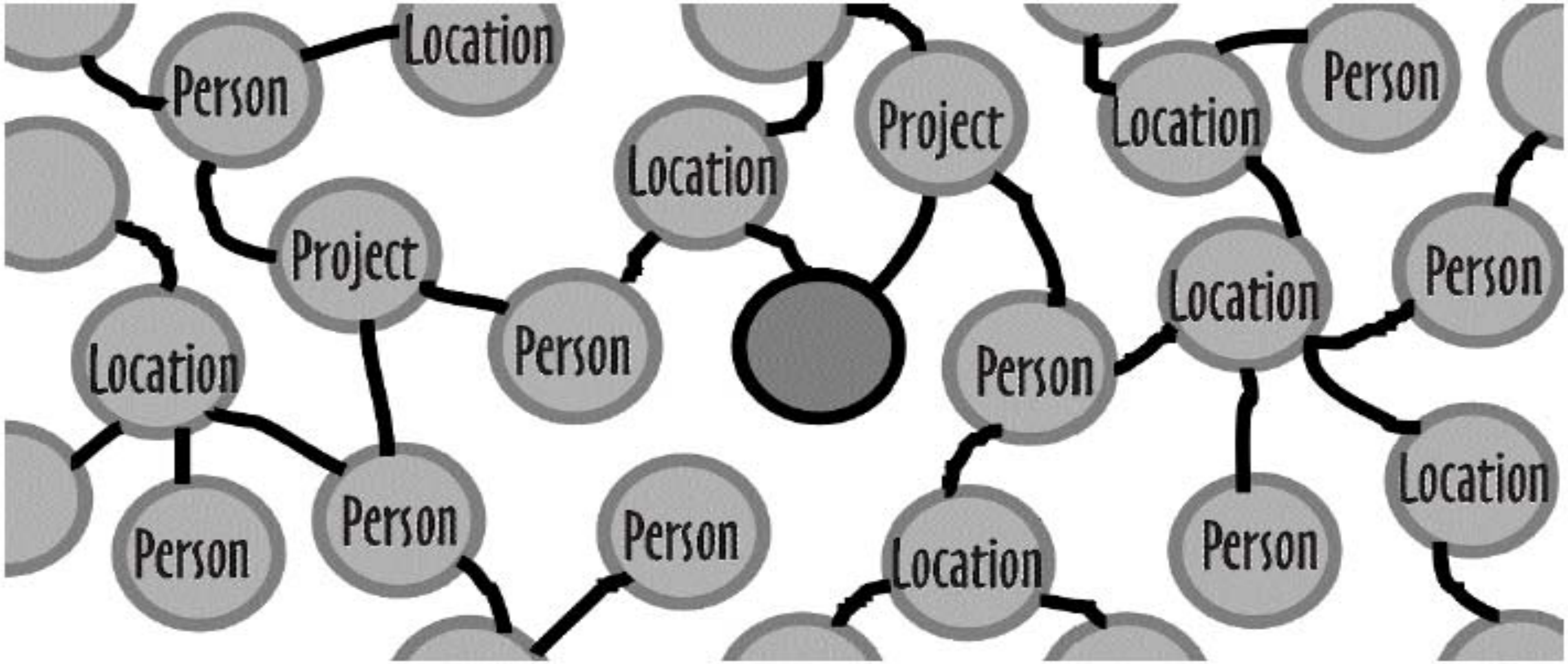


Figure 1. The linked context servers create a searchable space, where the topology of the space is part of the context information.

Example: representing spatial relations

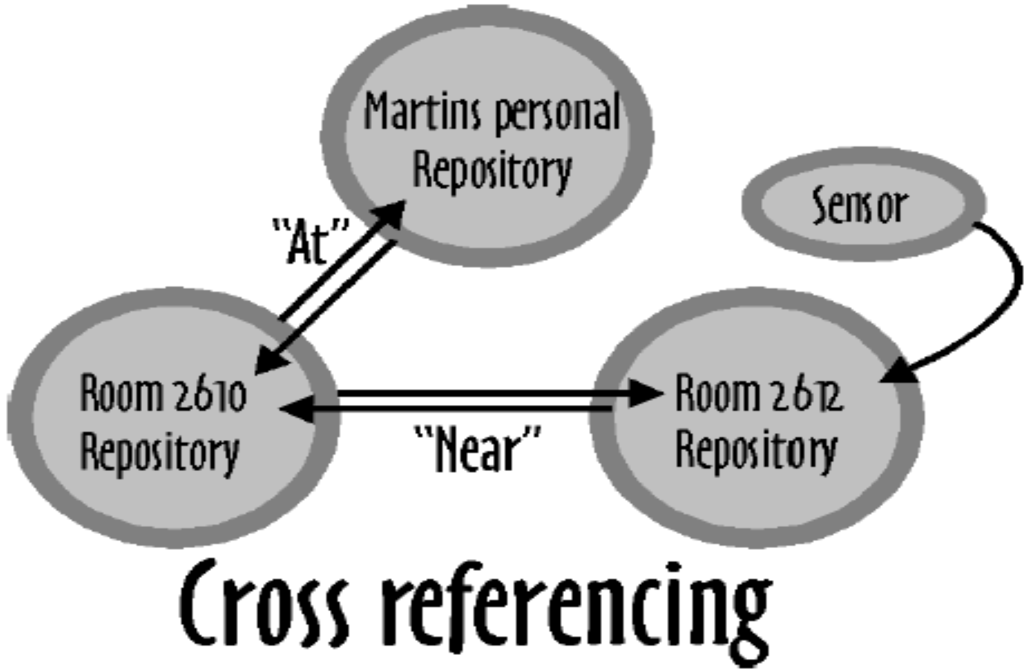


Figure 2. The context servers are linked with references. By following the links it is possible to acquire context information from other context servers than your starting point.

Example: Discover resources

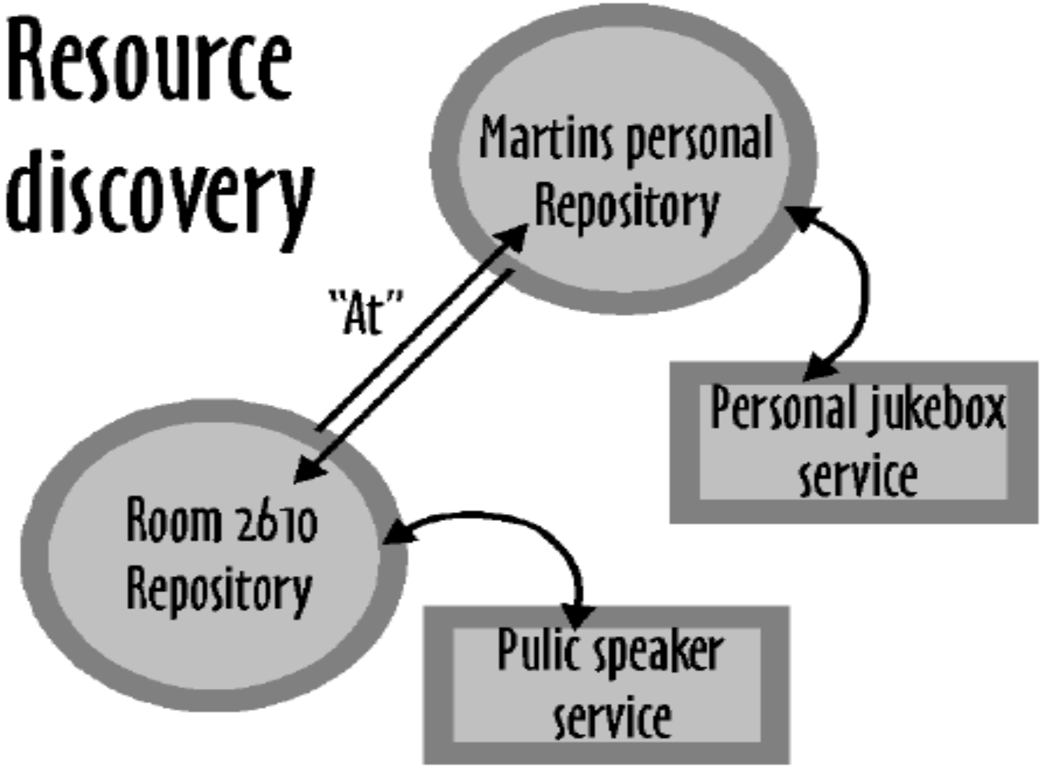


Figure 3. Using Context Shadow, a *jukebox service* finds a *speaker service* at the users current location.

Applications of Context Shadow

- 1. Example: Messenger services
  - Detects resources in the environment
  - Renders messages on appropriate medium
    - Wall displays
    - Public audio
    - Private displays
- 2. Example: Tools for local collaboration
  - Detect JINI services in the environment that are relevant to certain people
  - Support working groups that have gathered by providing last documents

SW infrastructure wrap-up

- No single all-purpose infrastructure (Ubicomp-OS ;-)
- Some basic structures used in many variations
  - Blackboard architectures
  - Agent-based systems
  - Pipe-and-filter architectures
  - Service-oriented architectures

Interaction in instrumented environments

Major interaction paradigms

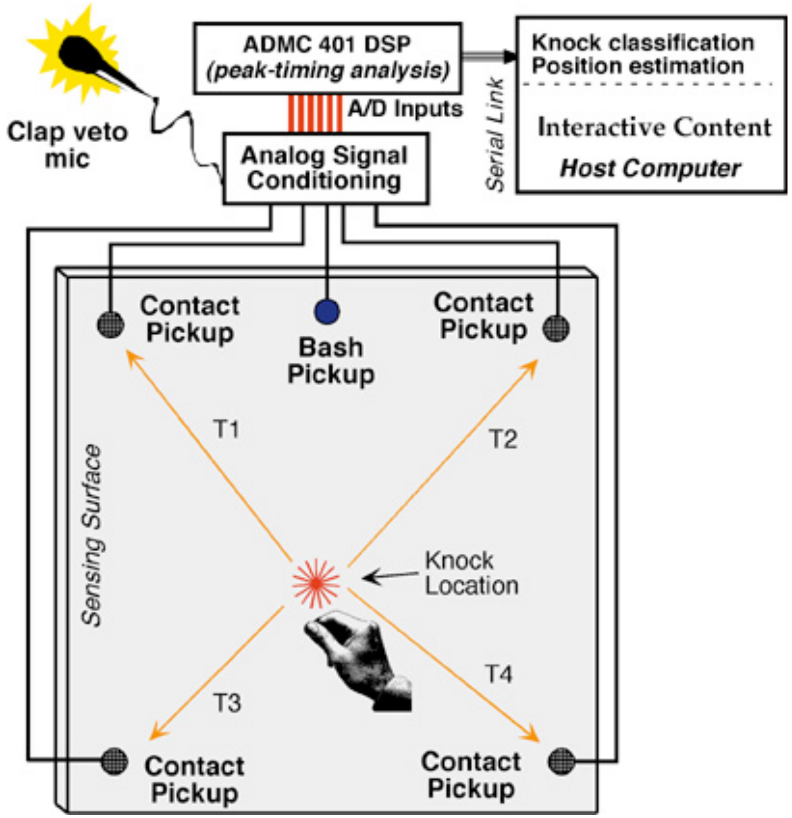
- direct physical interaction
- remote interaction
- implicit interaction
- tangible interaction
- ambient Uis
- interface agents
- interaction models
  - strictly tool-based
  - automation, assisted living
  - proactivity, intelligent agents

Direct physical interaction

- Touch screens
  - Simple finger buttons (as on ATM machines)
  - Pen-based control of a desktop GUI
  - Also used in fluidum brainstorming demo
- Interactive surfaces
  - Interaction with fingers on everyday surfaces
  - Sensing technology embedded or camera-based interaction (finger recognition)
  - Example: window tap interface

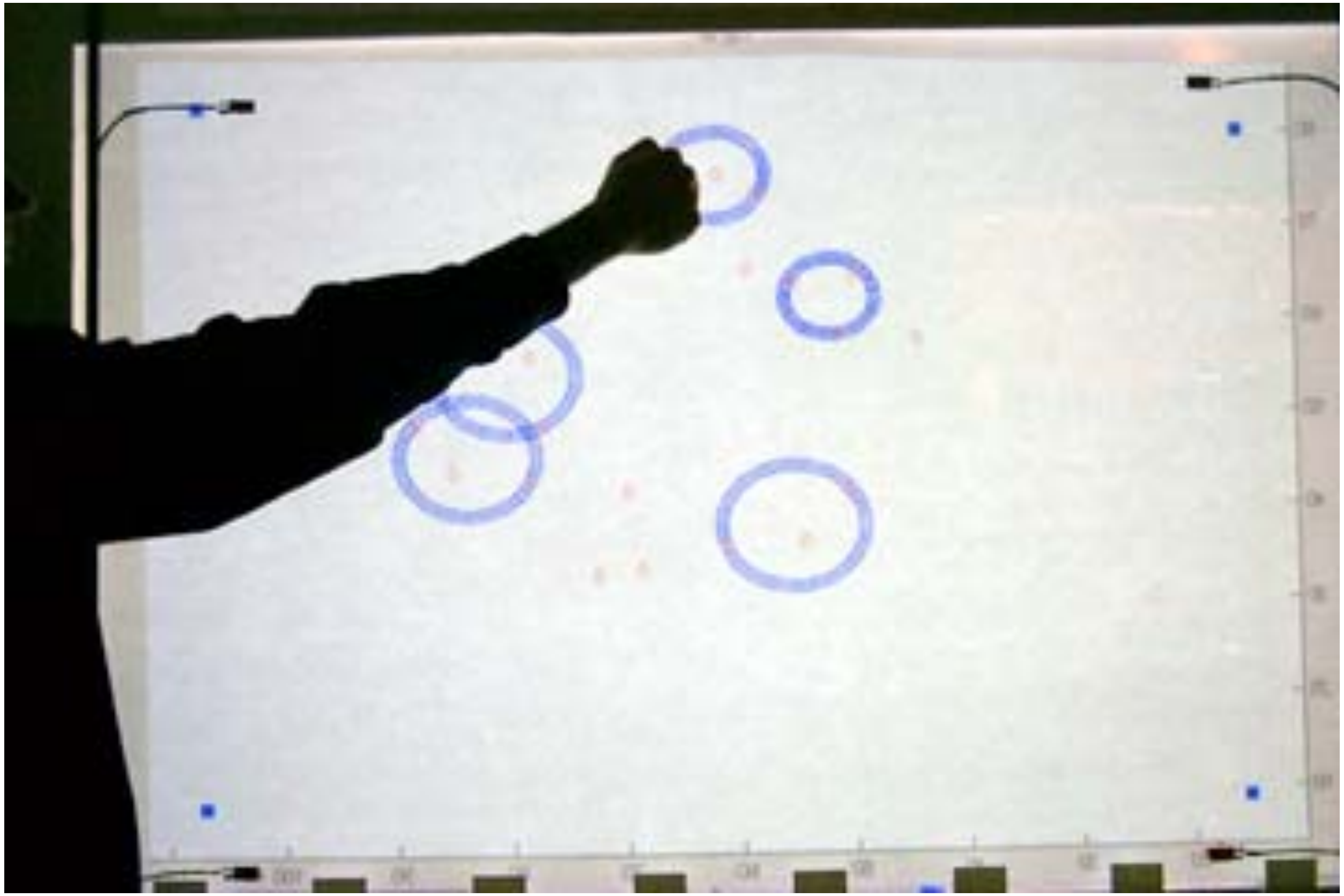
Example: Window Tap Interface

- locates the position of knocks and taps atop a large sheet of glass.
- piezoelectric pickups
  - located near the sheet's corners
  - record the structural-acoustic wavefront
  - relevant characteristics from these signals,
    - amplitudes,
    - frequency components,
    - differential timings,
  - to estimate the location of the hit
  - simple hardware
  - no special adaptation of the glass pane
  - knock position resolution of about s=2 cm across 1.5 meters of glass



http://www.media.mit.edu/resenv/Tapper/

Example: Window Tap Interface



http://www.media.mit.edu/resenv/Tapper/

Example: Window Tap Interface

- http://www.media.mit.edu/resenv/Tapper/

DMI: what is „Direct" ??

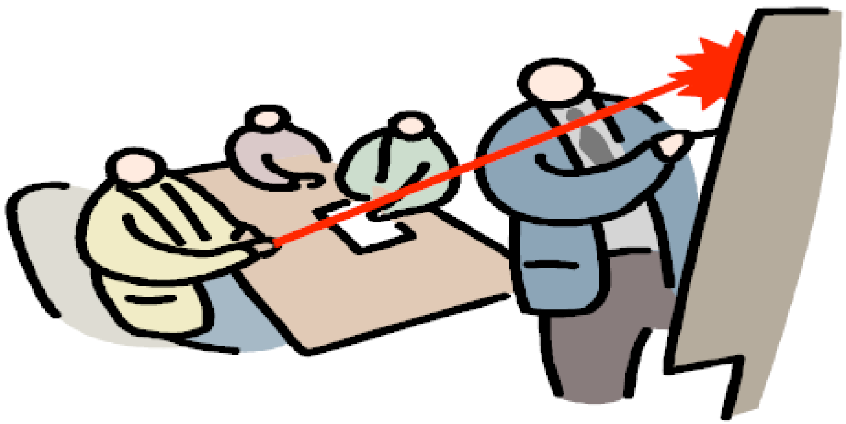
- Definition by Shneiderman:
  - continuous representation of the object of interest,
  - physical actions or labeled button presses instead of complex syntax,
  - rapid incremental reversible operations whose impact on the object of interest is immediately visible.
- Stems from a time when command line interfaces were the rule (1983)
- Mouse interaction = direct interaction?
- Touch screens = more direct?

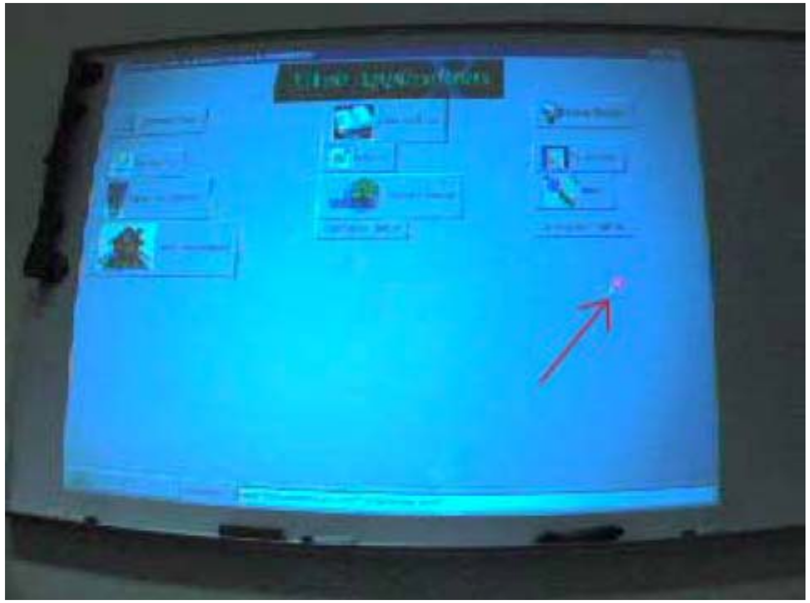
Remote interaction

- Laser pointer interaction
  - E.g., Olsen & Nielsen, CHI 2001
- Gesture interaction
  - E.g., Vogel & Balakrishnan, UIST 2005
- Mobile phone interaction
  - Markers
  - Motion
- Pointing, scanning, touching
  - E.g., Välkkynen et al. PI03

Laser Pointer Interaction

[Olsen & Nielsen, CHI 2001]





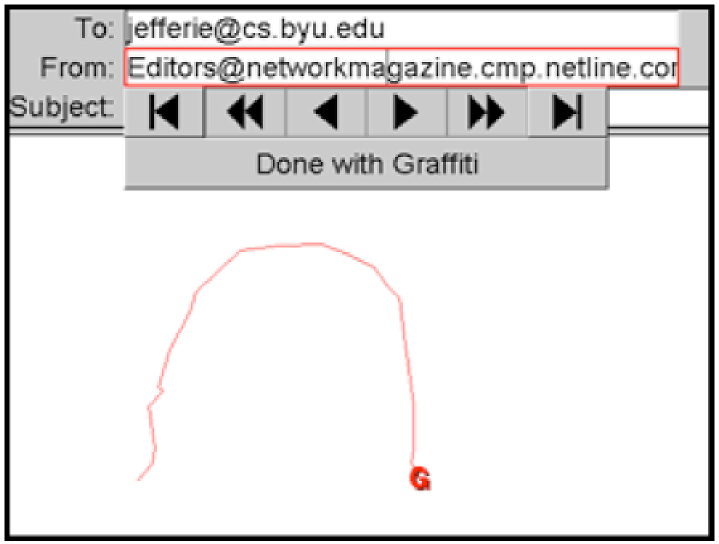
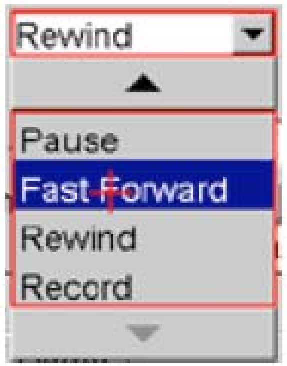
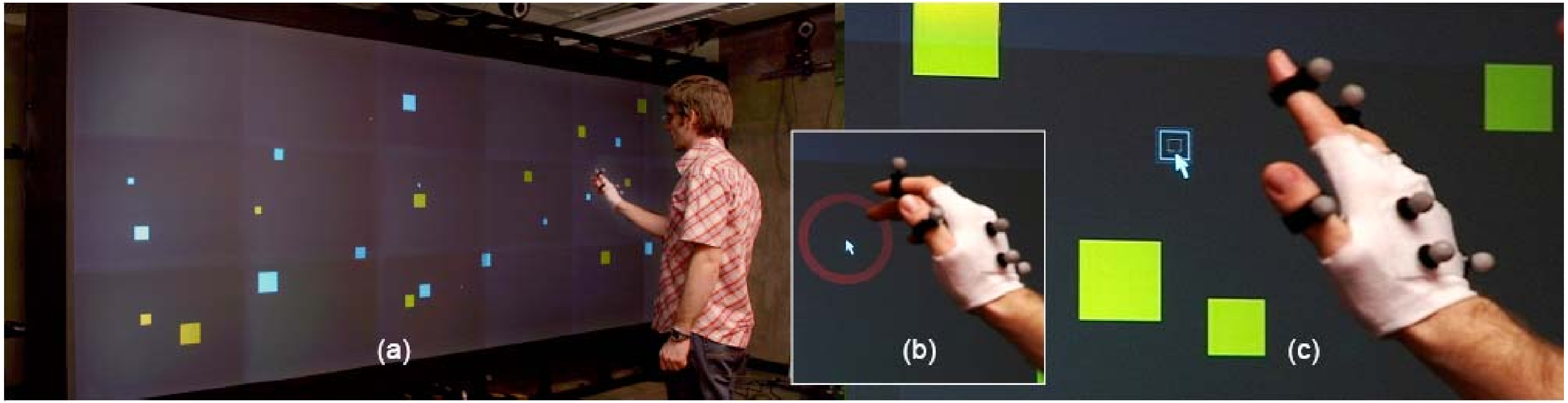


Figure 9 - Text Entry



Distant Freehand Pointing and Clicking [Vogel & Balakrishnan, UIST 2005]



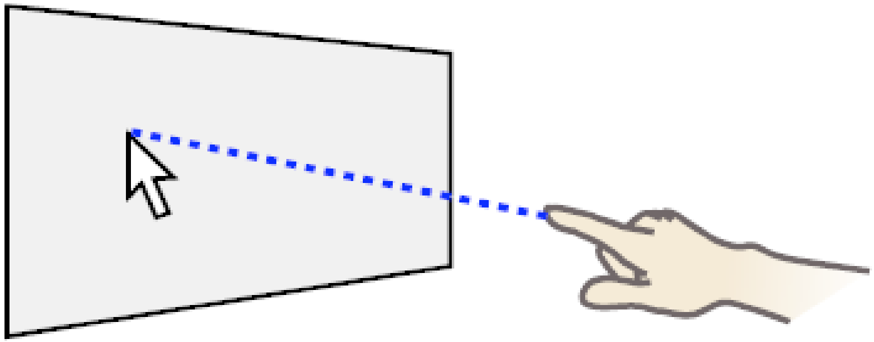


Figure 5. RayCasting. A ray extends from the tip of the finger and the cursor is positioned where it intersects with the large display surface.

Kickass Kung Fu (Perttu Hämäläinen)

http://www.kickasskungfu.net/

Implicit interaction

- Interaction is not done explicitly
  - Just as a side effect of other actions
  - Might be unnoticed by user
- Example RFID shopping assistant
- Example media cup

RFID shopping assistant

http://www.misch.net/ssa/



- Tagged objects in a shopping shelf
- Antenna registers when object is taken out
- Antenna in cart registers when object is put in cart
- Detected interactions:
  - Inspecting an object → give additional info
  - Inspecting several objects → compare
  - Decision to buy an object → advertise additional objects

Mediacup

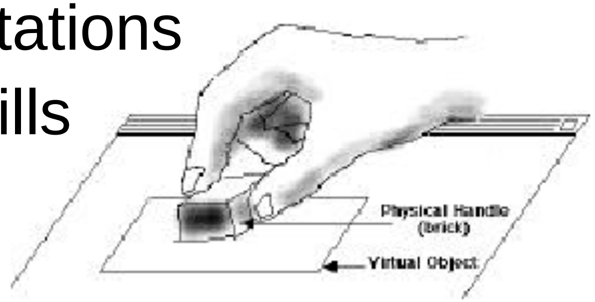
- Cup sensing temperature, weight and movement
- Location of cups detected
- Detected interaction:
  - Presence of multiple people in a room → mark room as occupied

Tangible User Interfaces

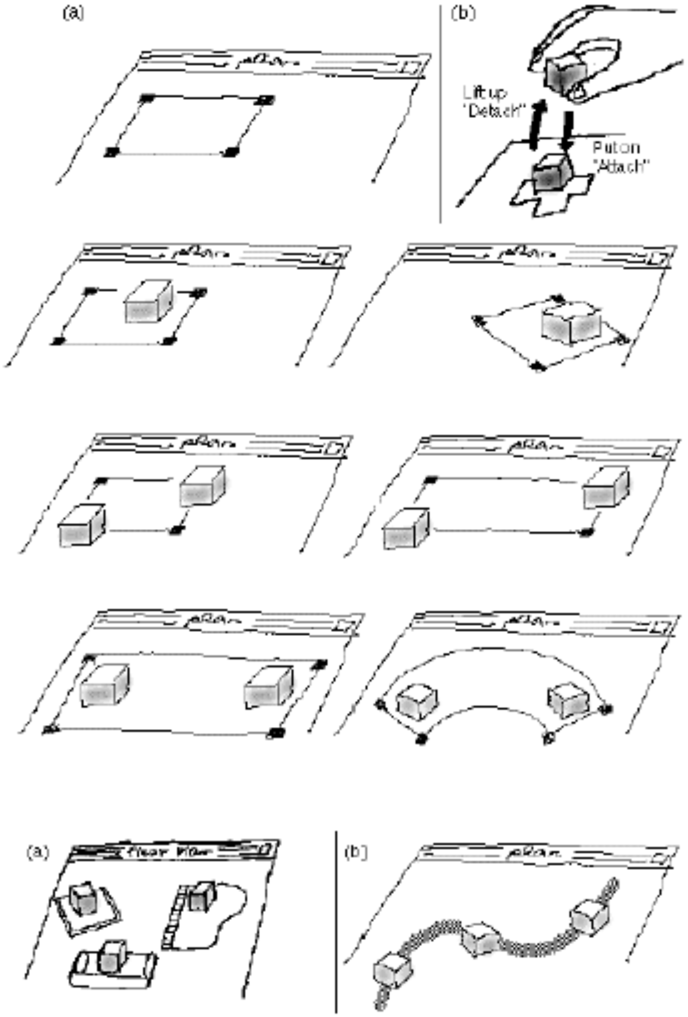
General purpose TUI frameworks

Bricks: Graspable User Interfaces (Fitzmaurice, Ishii, Buxton, CHI 95)

- specialized, context sensitive input devices
- interface elements more "direct" and more "manipulable" by using physical artifacts
- parallel input specification by the user
  - improving the expressiveness or the communication capacity with the computer
- encourages two handed interactions
- leverages our everyday skills of prehensile behaviors for physical object manipulations
- externalizes internal computer representations
- takes advantage of spatial reasoning skills
- affords multi-person, collaborative use



Bricks: basic operations



- Select an object
- Move and rotate
- Scale and stretch
- Bend and deform
- Floor planning, curve drawing

Bricks application: GraspDraw

- Drawing application
- On active desk
  - Rear-projection display
  - Transparent digit. Tablet
  - Magnetic tracker for bricks
- Two bricks for input
  - „Anchor“ and „actuator“

Bricks: Design Space

Brick's internal ability

Inert (dumb, only external physical shape)

Can exhibit **simple** expressions and has some internal logic (sensors, motors, indicator lights)

Smart (microprocessor, sensors, programmable)

Input & Output

Input - Properties sensed
Position (x, y, z)
Orientation (pitch, yaw, roll)
Audio (microphone)
Temperature
Tactile/Pressure (squeeze)
Light (photoelectric cell)
Visual (mini camera)

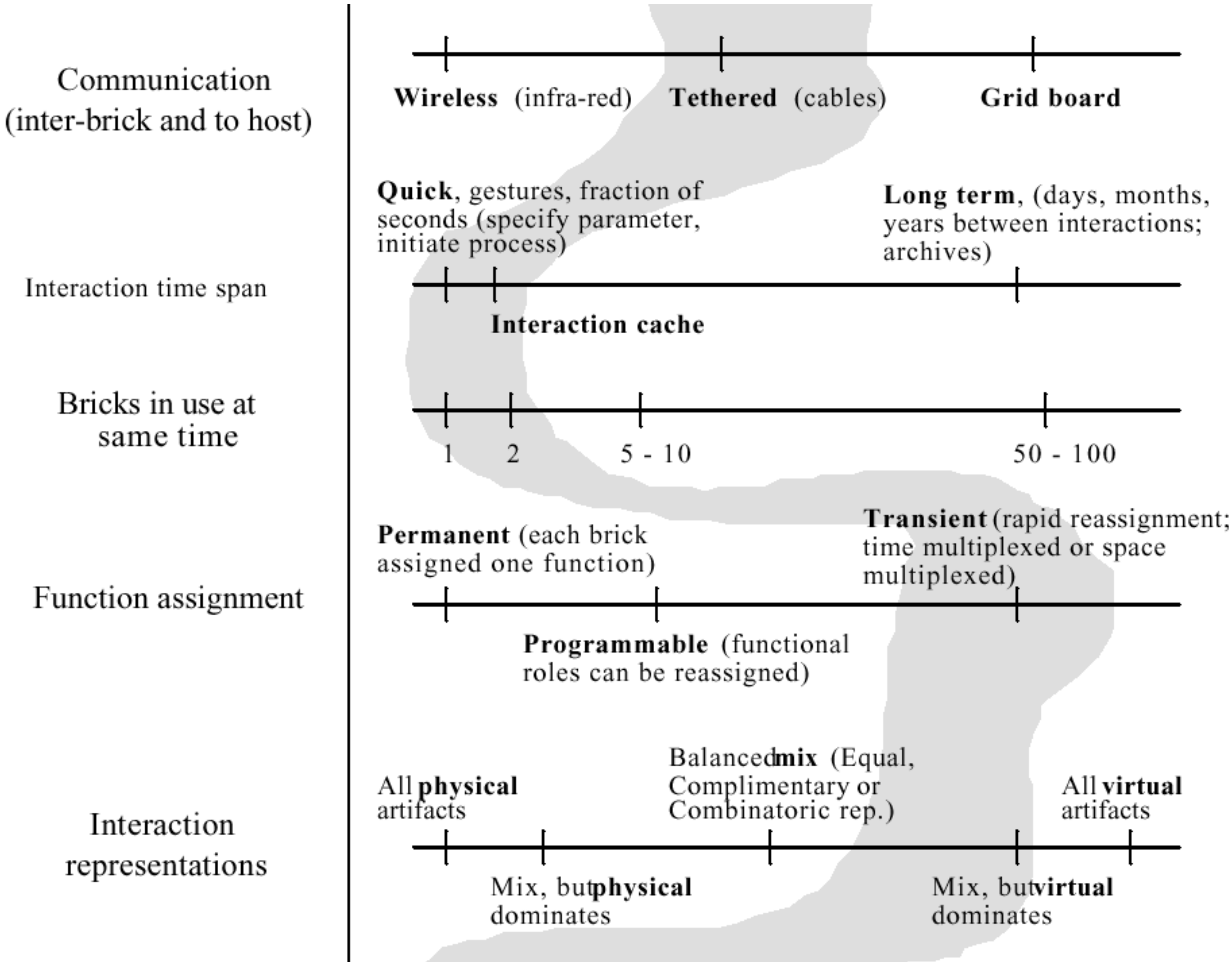
Output - Properties displayed
Position (self-propelled)
Orientation (self-propelled)
Audio (speaker)
Tactile (force feedback)
Light (LED indicator lights);
Visual (LCD display screen)

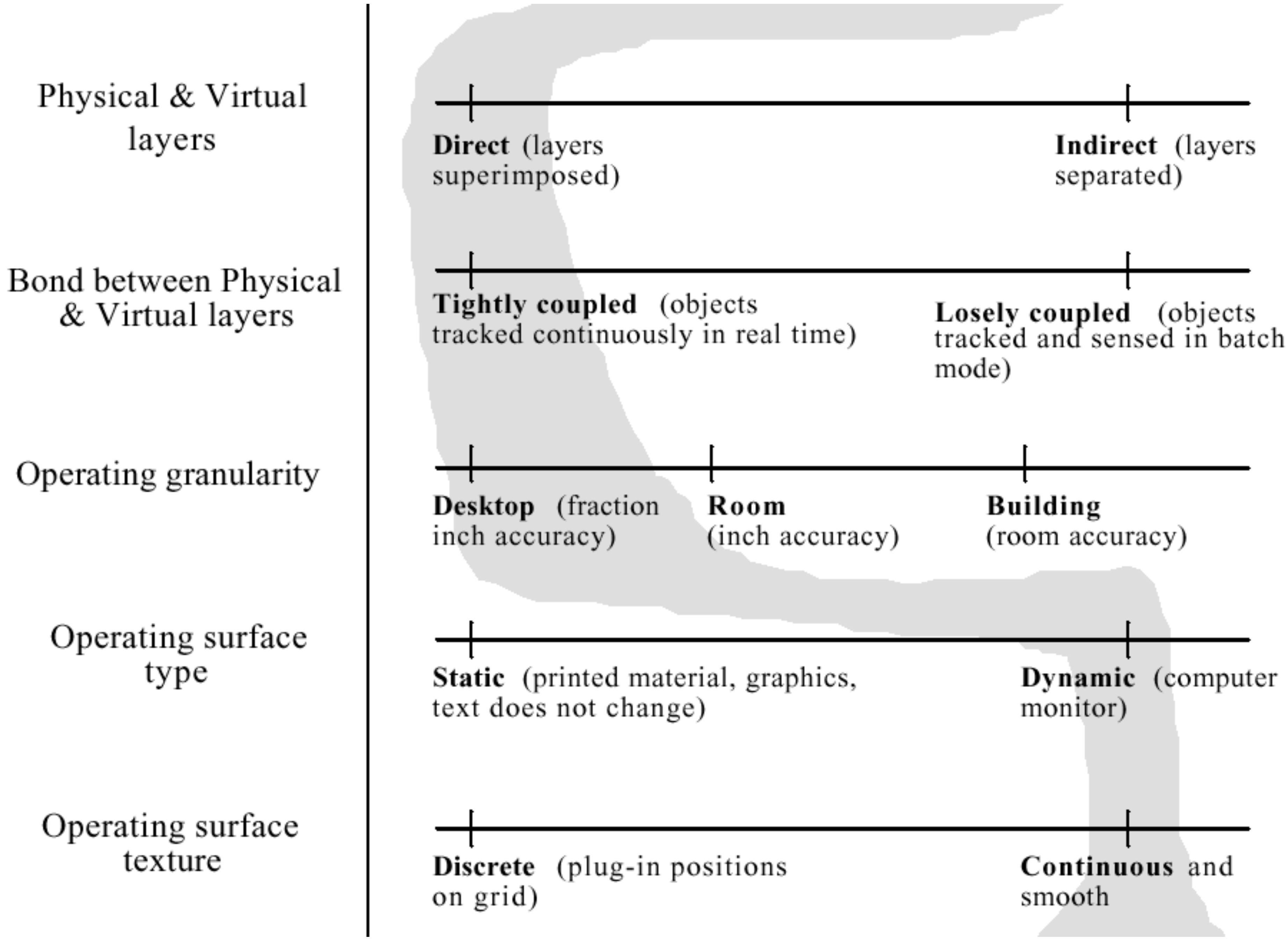
Spatially aware

Unaware , works in isolation

Mutual awareness (aware of each other)

Aware of surroundings (sensing of environment pl other bricks)


Communication (inter-brick and to host)
Wireless (infra-red)
Tethered (cables)
Grid board
Interaction time span
Quick, gestures, fraction of seconds (specify parameter, initiate process)
Long term, (days, months, years between interactions; archives)
Interaction cache
Bricks in use at same time
1
2
5 - 10
50 - 100
Function assignment
Permanent (each brick assigned one function)
Transient (rapid reassignment; time multiplexed or space multiplexed)
Programmable (functional roles can be reassigned)
Interaction representations
All physical artifacts
Balanced mix (Equal, Complimentary or Combinatoric rep.)
All virtual artifacts
Mix, but physical dominates
Mix, but virtual dominates


Physical & Virtual layers
Direct (layers superimposed)
Indirect (layers separated)
Bond between Physical & Virtual layers
Tightly coupled (objects tracked continuously in real time)
Losely coupled (objects tracked and sensed in batch mode)
Operating granularity
Desktop (fraction inch accuracy)
Room (inch accuracy)
Building (room accuracy)
Operating surface type
Static (printed material, graphics, text does not change)
Dynamic (computer monitor)
Operating surface texture
Discrete (plug-in positions on grid)
Continuous and smooth

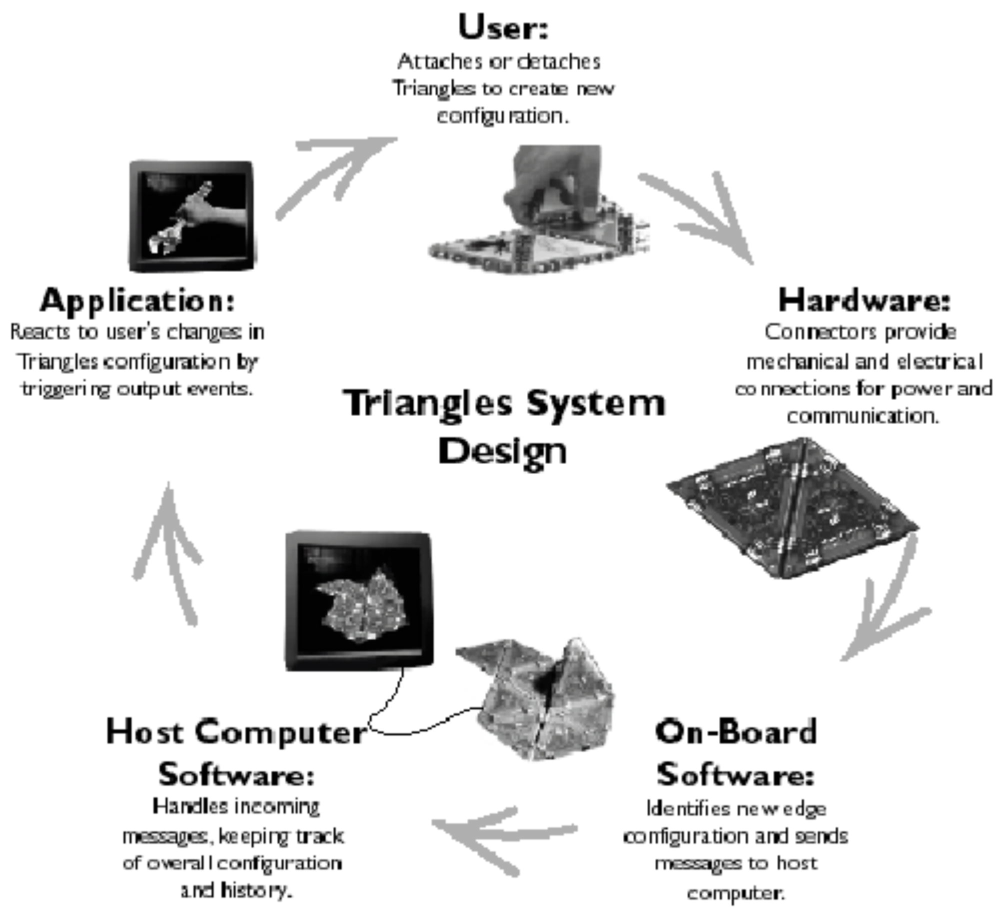
Triangles

(Gorbet, Orth, Ishii, CHI 98)

- Set of identical, flat plastic triangles
  - Each with a processor and a unique ID
  - Magnetic edge connectors
- Can be rearranged in 2D and 3D
  - Keep track of their connections
  - Transmit their configuration to a PC
- Building blocks for topographies
  - Immediate physical interaction
  - Spatial language

photo: Webb Chappell

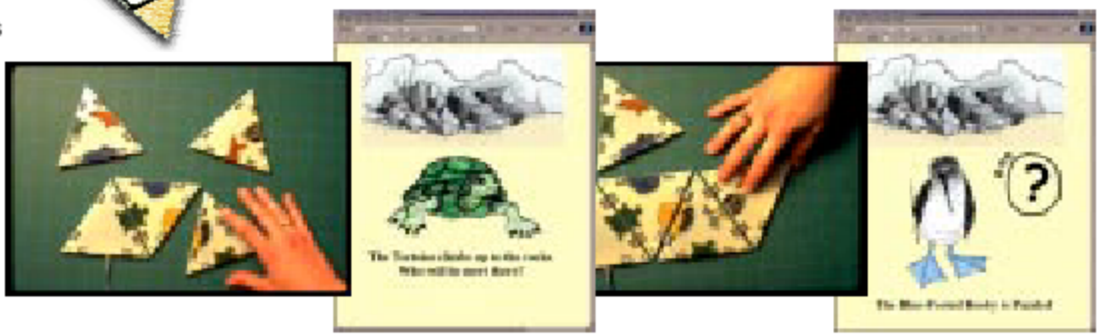
Triangles: System overview



Triangles: Example applications

Fig. 8: The *Cinderella 2000* Triangles

Non-linear storytelling



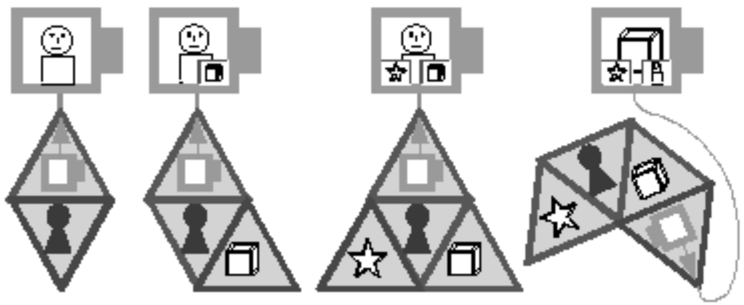


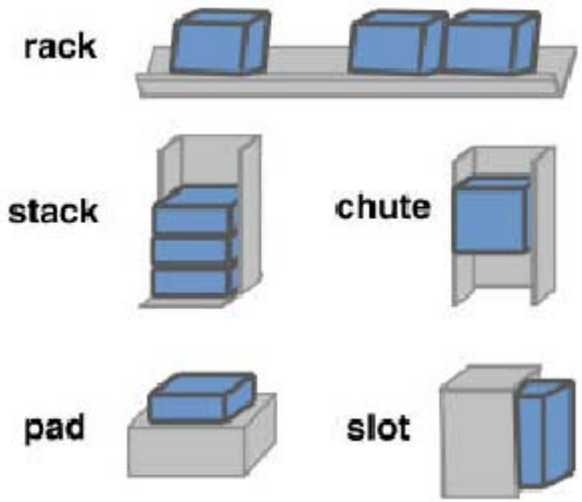
Fig. 9: *TriMediaManager*

Media Management

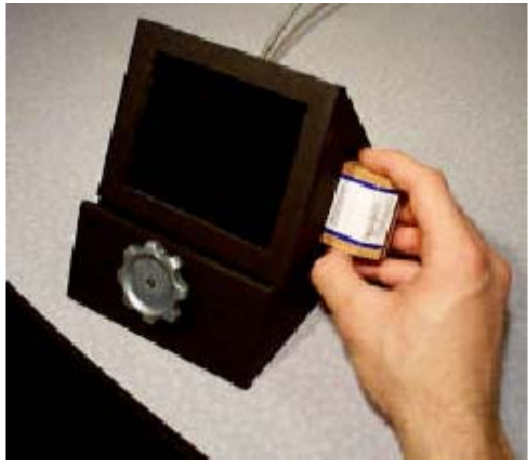
MediaBlocks

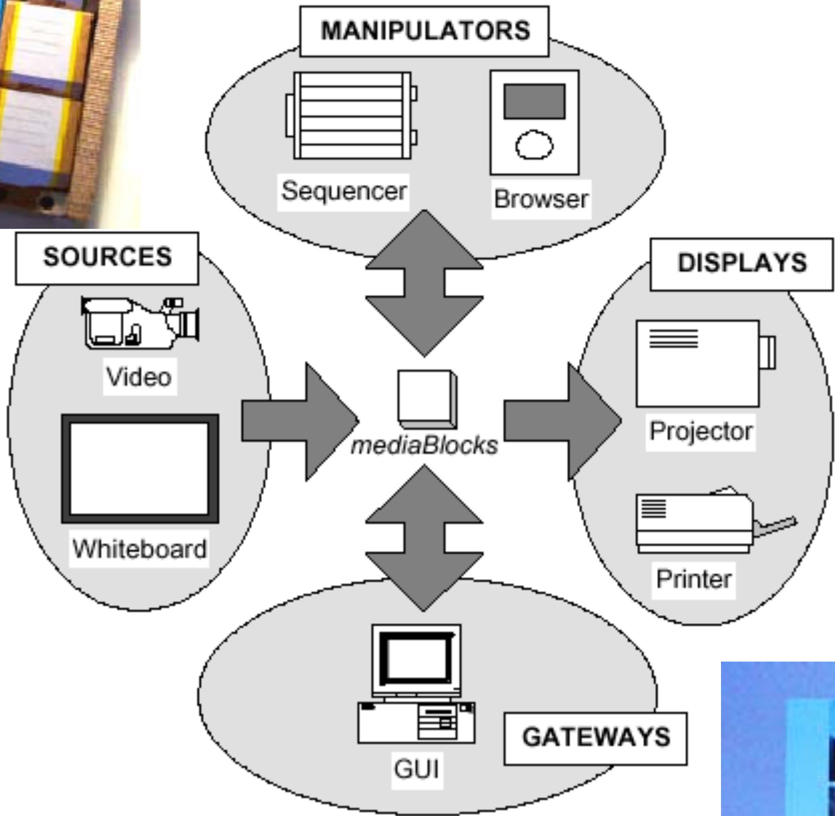
(Ullmer, Ishii, Glas, SIGGRAPH 98)

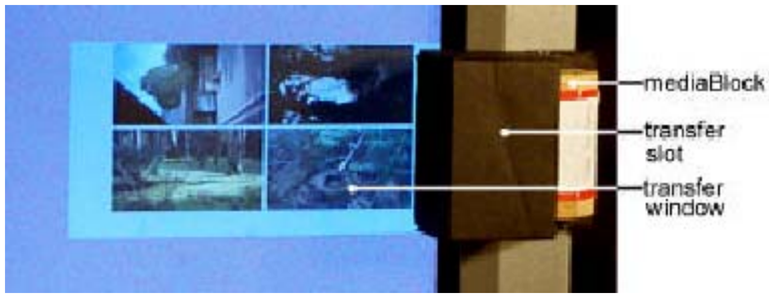
- Physical objects representing digital information: **phicons**
- No actual information stored on the blocks
- Various containers with different physical constraints



MediaBlocks (contd.)



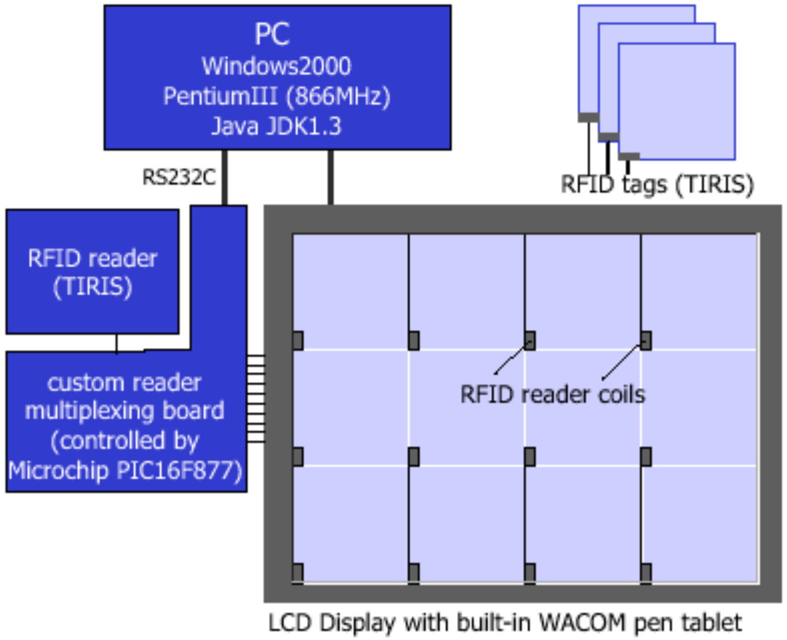




DataTiles

(Rekimoto, Ullmer, Oba, CHI 01)

- Transparent plastic tiles
  - On a flat panel screen
  - Sensed by RFID tags
  - Provide groves for pen
  - Can be spatially arranged
- Different tile types
  - Application tile
  - Container tile
  - Portal tile
  - Parameter tile



DataTiles (contd.)

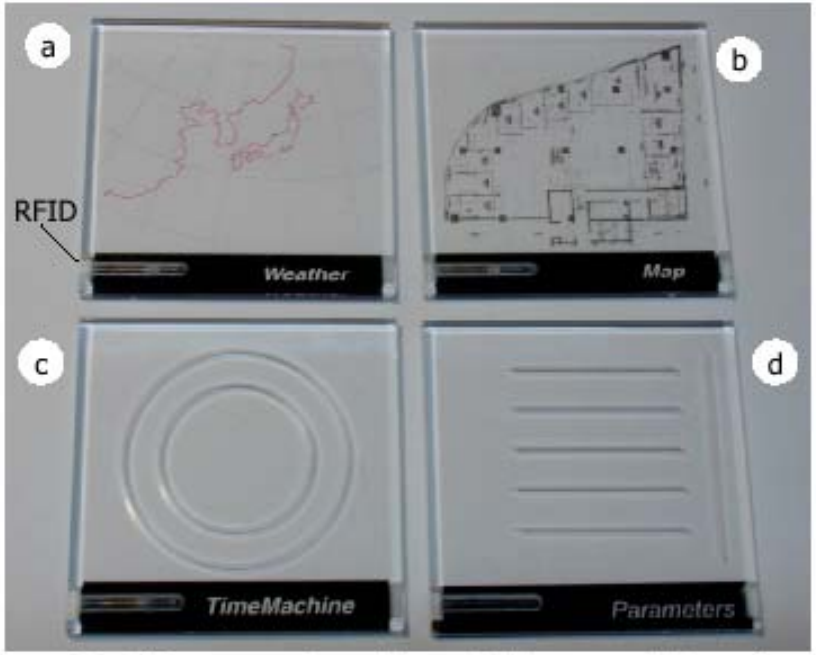


Figure 3: Tile examples. (a) and (b): partially printed tiles, (c) and (d) tiles with "grooves".

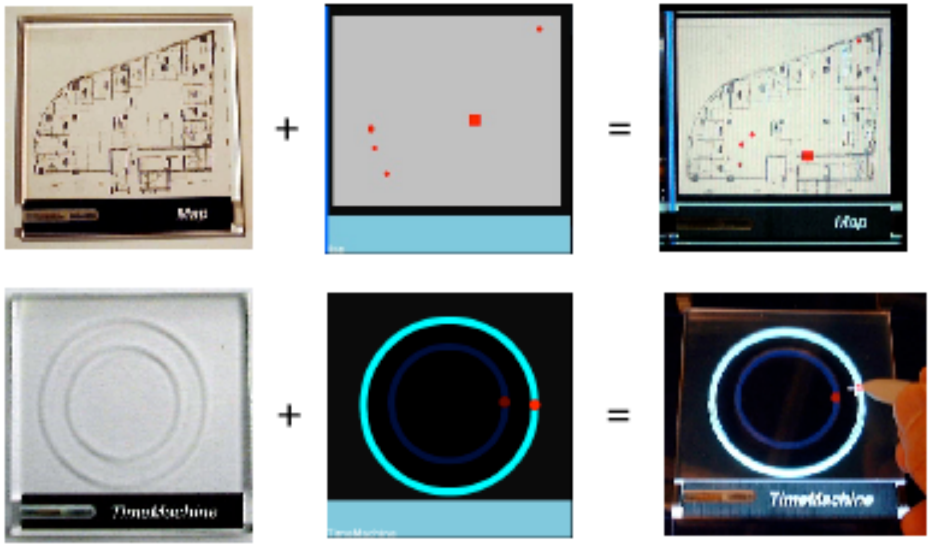


Figure 4: Combination of physical tiles and graphical information. Above: high-resolution printed information can be augmented by displayed graphics. Below: combination of physical grooves and graphical information creates a GUI widget with passive haptics.

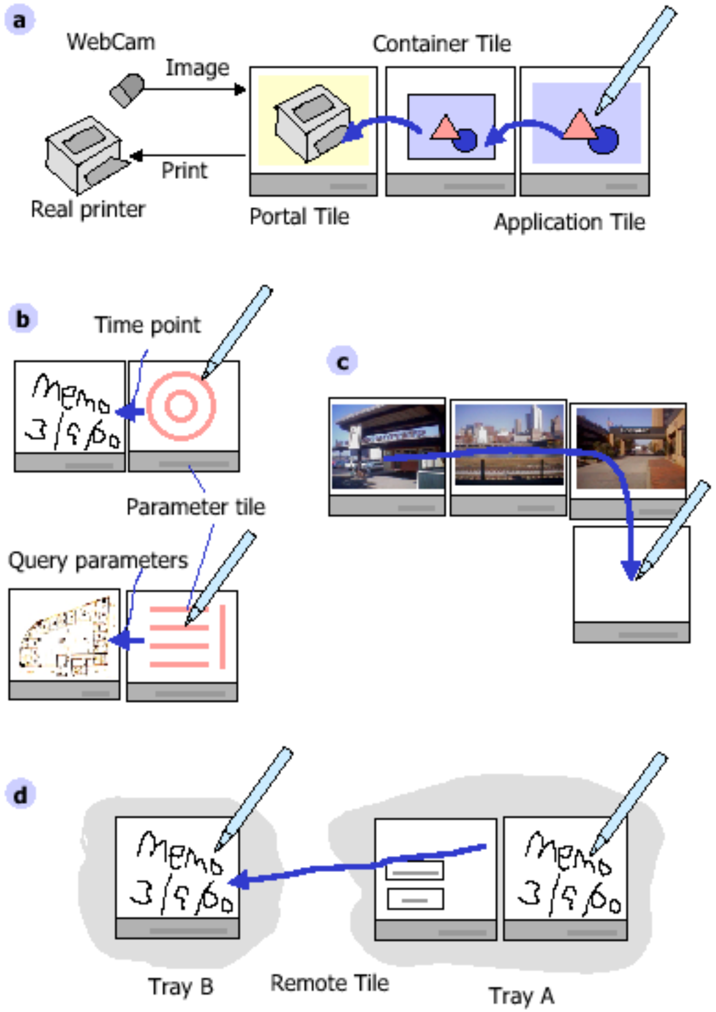


Figure 5: Examples of tiles and tile combinations. (a) An image from an application tile (right) is stored in a container tile (middle), and then transmitted to the portal tile. The portal tile represents a real world object (a printer in this example). (b) Parameter tiles can be used to specify various types of parameters. (c) Concatenates three video clips and stores item in a container tile. (c) Remote tiles are used to connect distributed tile trays. In this example, a shared drawing environment has been constructed.

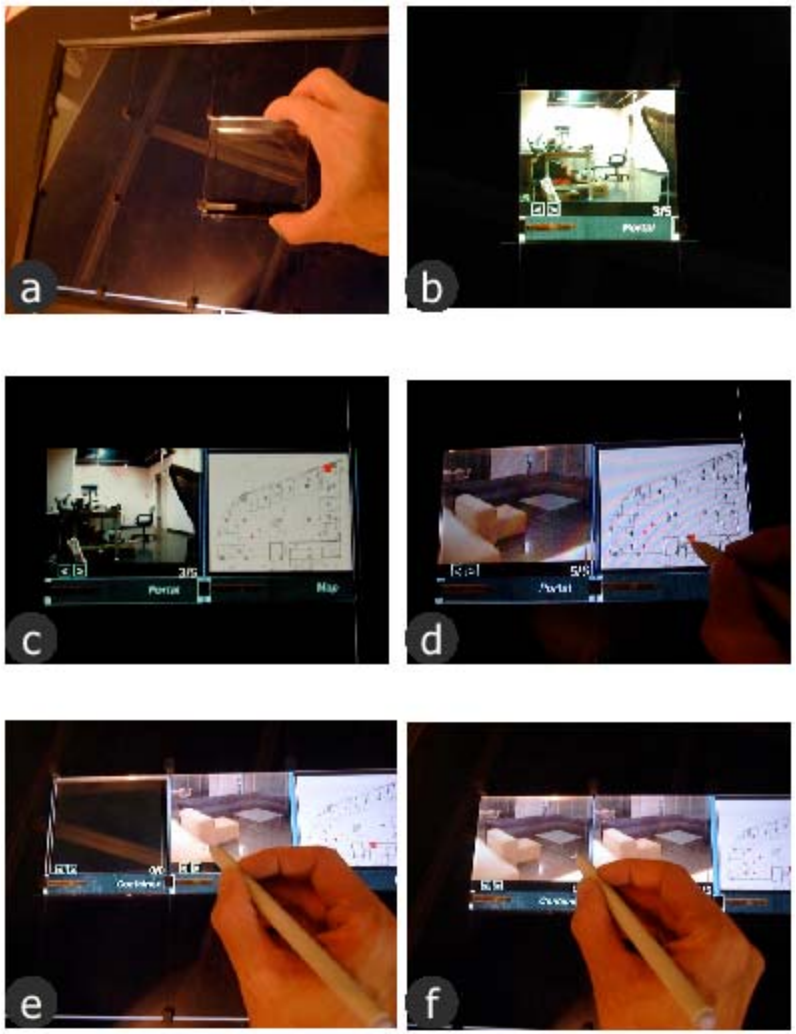


Figure 6: Examples of tile combination: (a) When a user places a portal tile on the tray, (b) an associated webcam image appears on the tile. (c) Then the user places a map tile, and the map displays locations of webcams. (d) The user clicks on a spot on the map to select another webcam. (e, f) Then the user makes an inter-tile gesture (from portal tile to the container tile) to store a snapshot image in the container tile.

DataTiles (contd.)

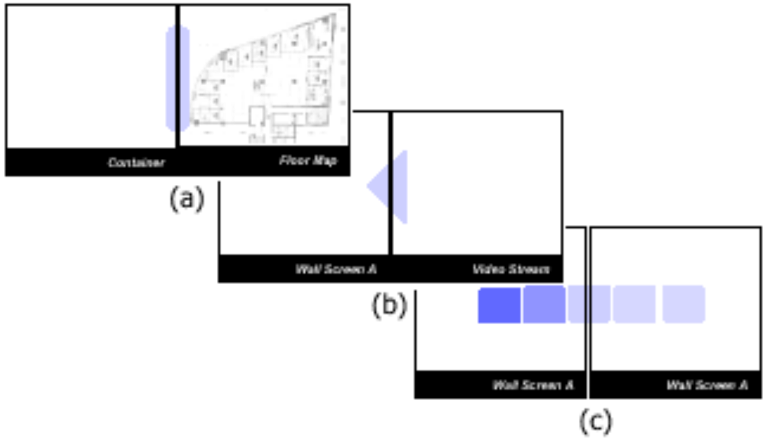


Figure 8: Several visual feedback approaches for indicating connection types. (a) one-way discrete data transmission from right to left, (b) one-way continuous data transmission, and (c) bi-directional continuous connection using animations.

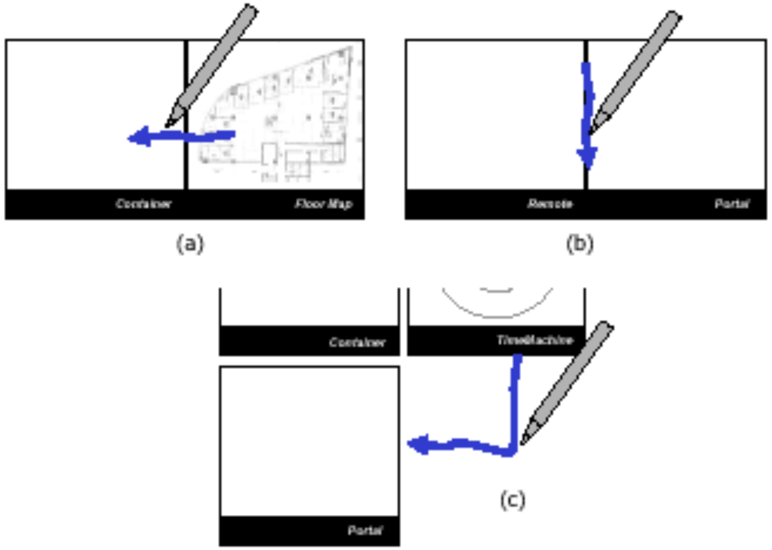
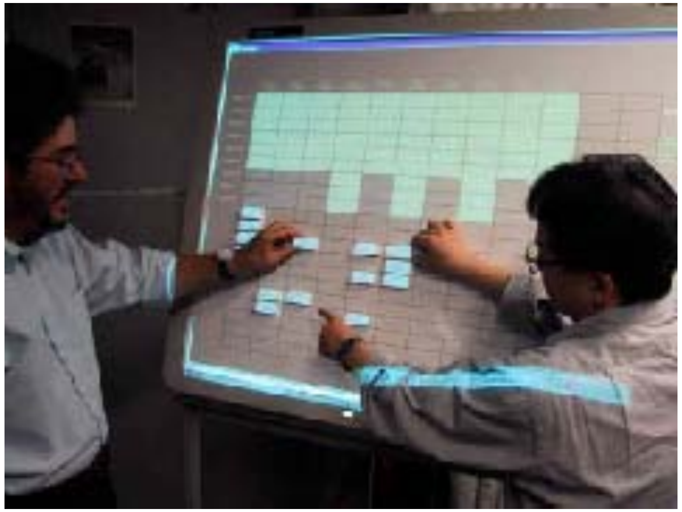


Figure 9: Inter-tile gestures by a pen to control a data connection between two adjacent tiles. (a) triggers a discrete data transmission, (b) suspends a continuous data transmission, and (c) connects two disjoint tiles. (Note: During these operations, the pen tip must be sufficiently close to the tile surfaces to be sensed, but need not touch them.)

SenseBoard

(Jacob, Ishii, Pangaro, Patten, CHI 02)

- TUI for organizing information on a grid
- Combines physical manipulation with a computer
  - Physically: arranging cards
  - Computer: arranging icons
- Get the best from both worlds
- Example: organize conference into sessions

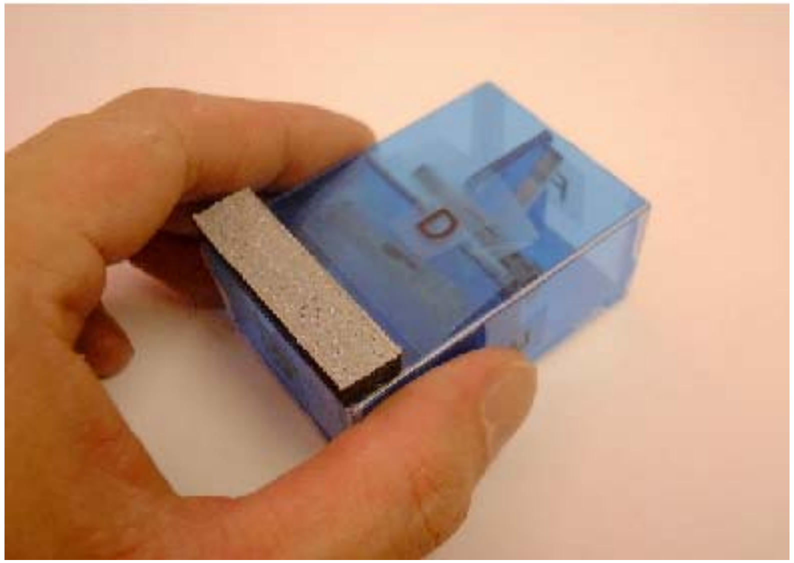


- Other tasks: arrange songs in a playlist, newspaper articles, slides for a talk, ideas from a brainstorming, emails, bookmarks, notes,...

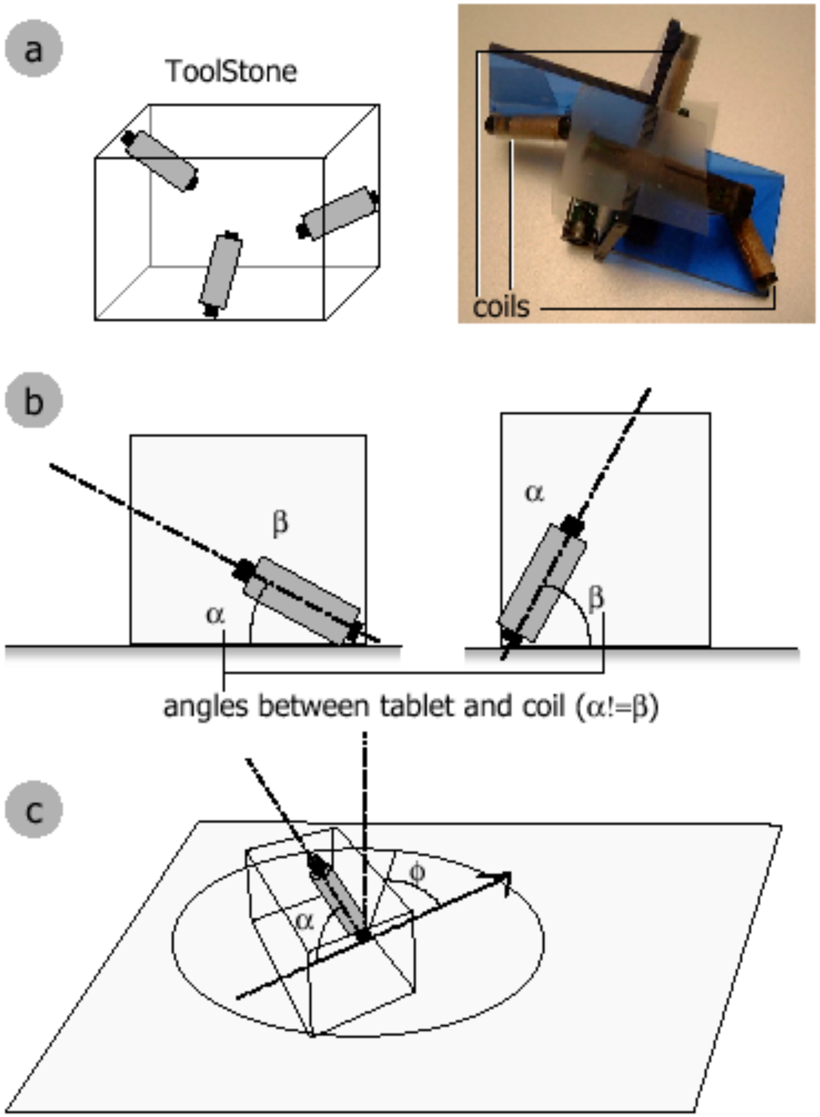
ToolStone

(Rekimoto, Sciammarella, UIST 00)

- Universal 6 DOF input device
- Works on a Wacom pen tablet
- Can be used together with pens



ToolStone working principle



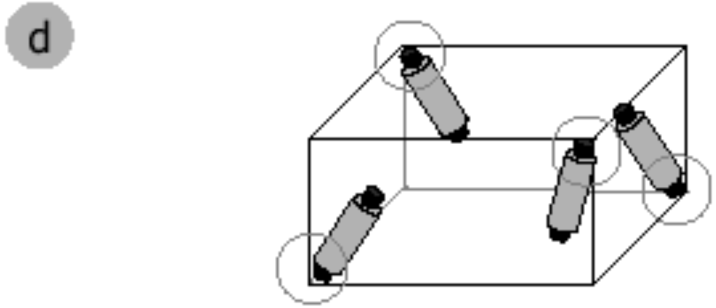


Figure 12: Detection of the touching face and orientation: (a) Inside the ToolStone: Three WACOM coils are embedded, and only one of them will be close enough to the tablet surface when the ToolStone is placed on the tablet. (b) When a coil touches the tablet, it can be identified by its unique resonance value. Two faces that share the same coil can be distinguished by comparing the tilt values (α and β). (c) Once the touching face is known, the orientation of the ToolStone can be determined from the orientation angle of the coil (ϕ). (d) An alternative sensor configuration with coils at the four corners of the device. Two of these coils are in contact with the surface when one face is placed on the tablet.

ToolStone interaction

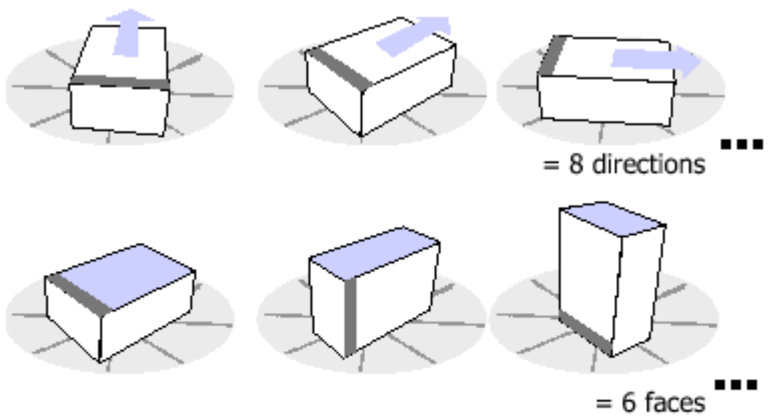


Figure 6: Selecting multiple functions by rotating and flipping the ToolStone: The combination of eight directions and six faces allows a user to quickly select 48 different functions (e.g., toolpalettes) with a single physical action.

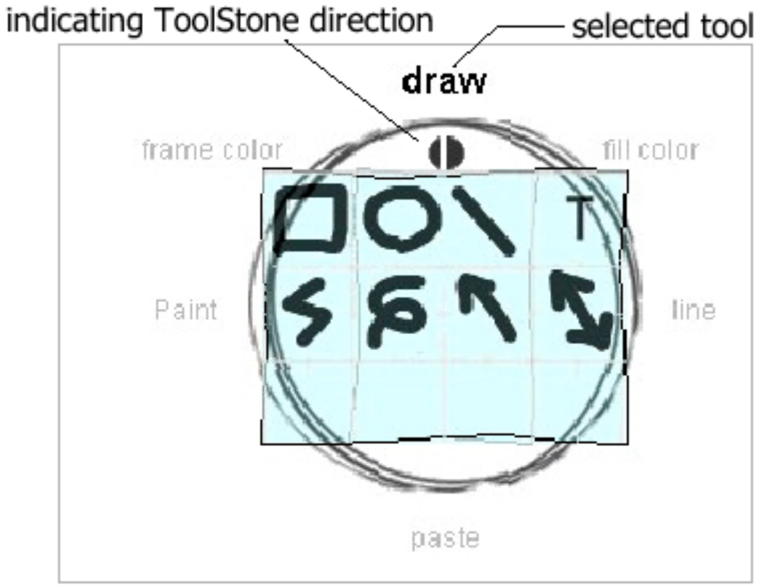


Figure 7: Example of a selected toolpalette: A dial and labels around the tool palette indicate available functionalities attached to the same face. The currently selected one is shown in bold. The selected toolpalette acts as a ToolGlass sheet.

ToolStone interaction

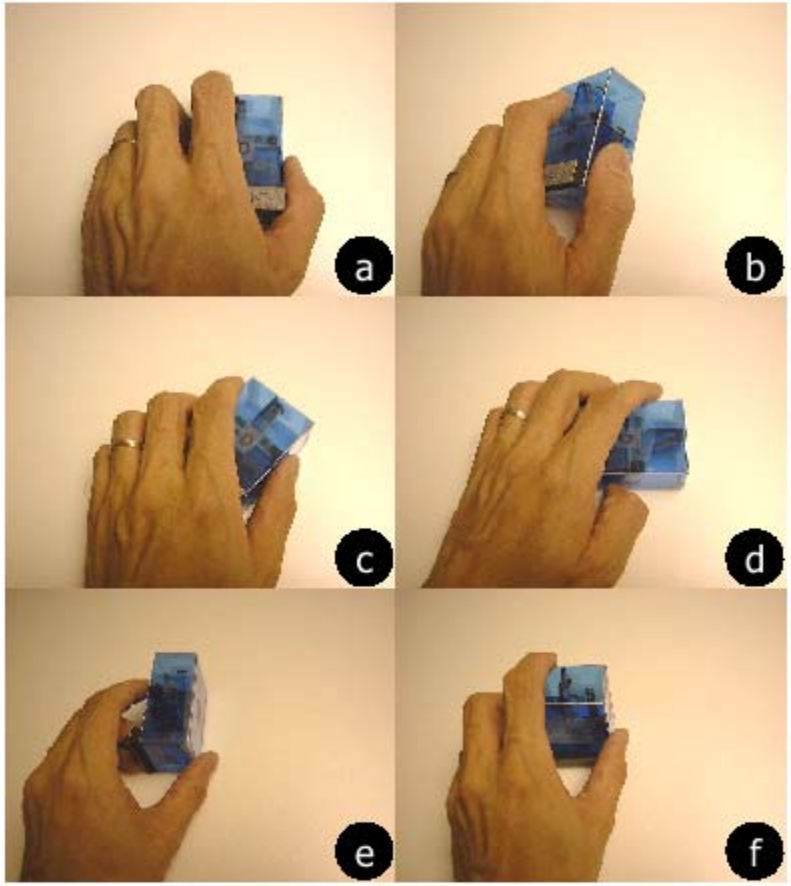


Figure 5: Several possible ways of holding the ToolStone: (a) Normal mode (Note: a projection attached near the lower edge of the upper face can be felt by the hand). (b) Tilting while one edge is contacting the tablet (c, d) Rotating, and (e, f) Flipping to select other faces.

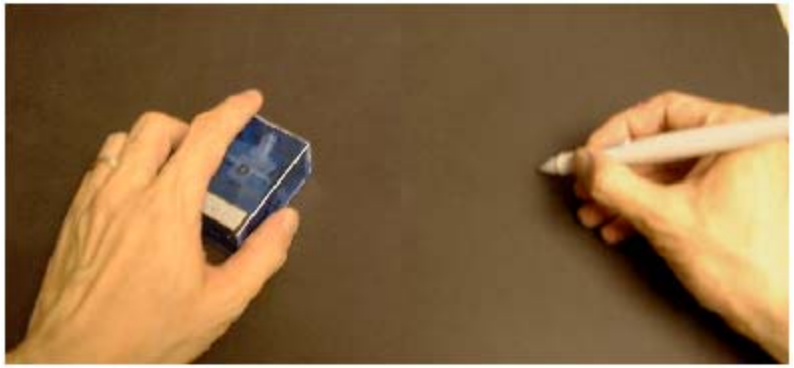


Figure 4: Bimanual interaction with the ToolStone.

Figure 8: A ToolStone device with labels on each face. A (novice) user would be able to visually inspect available commands by physically turning the device.

ToolStone interaction

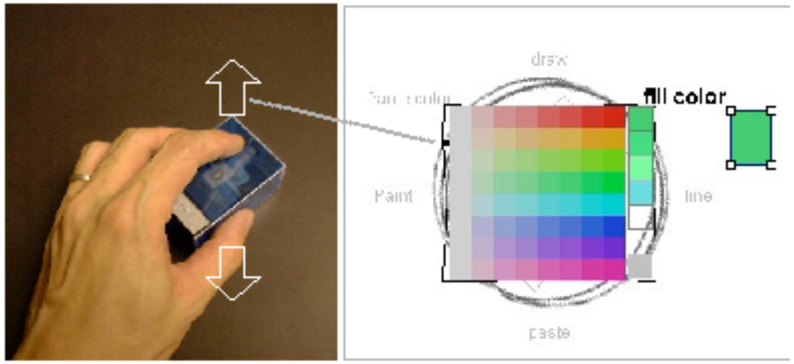


Figure 9: A color selection tool example: ToolStone's vertical motion controls the brightness parameter of the color space, while two other parameters (hue and saturation) are mapped according to the x and y axes of a 2D palette. A user can dynamically navigate though the color space before selecting a color instance. Note that the direction of the ToolStone is used to select the color selection tool.

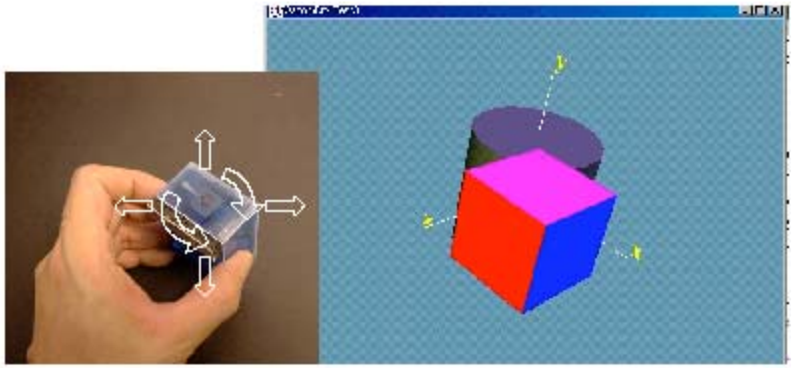


Figure 10: MDOF movement of the ToolStone can be mapped for 3D object control.

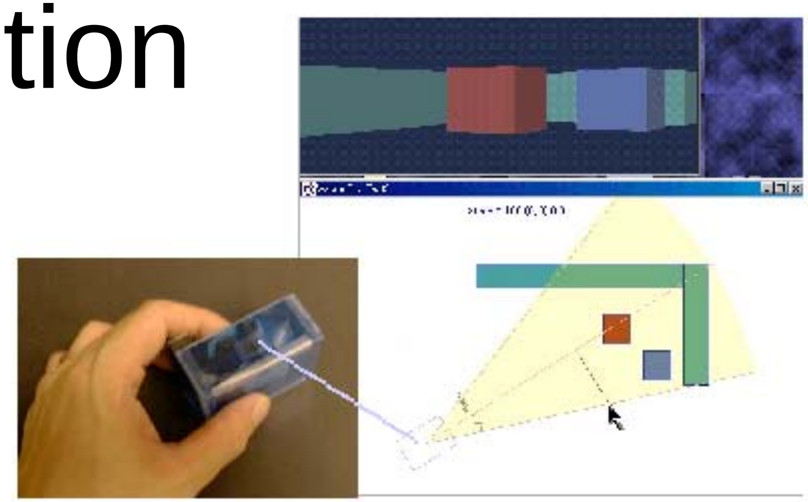
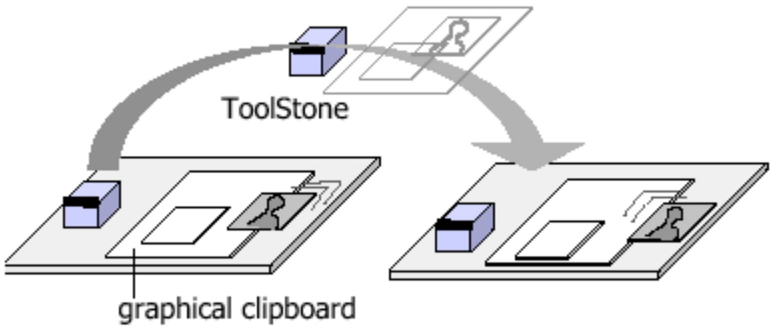
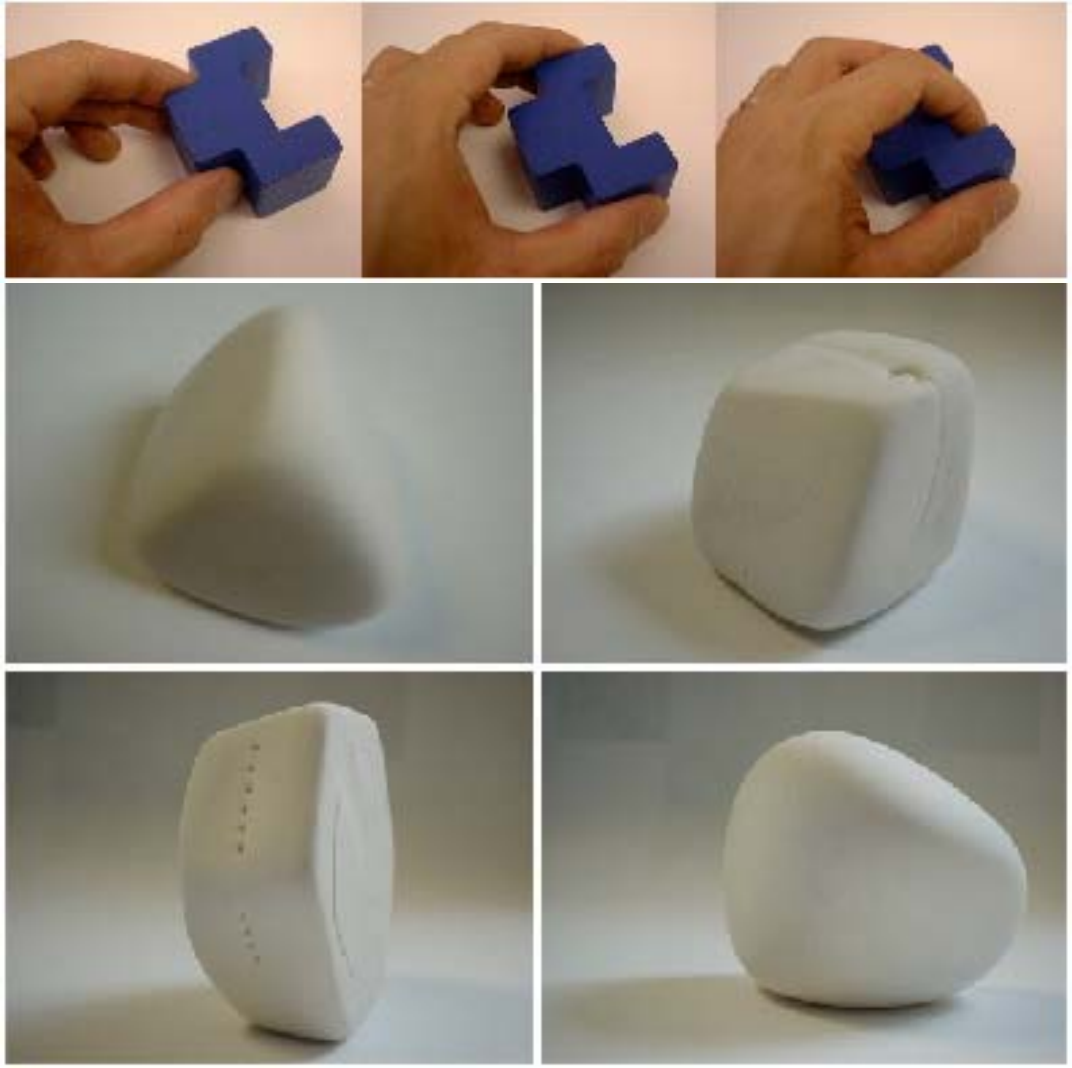


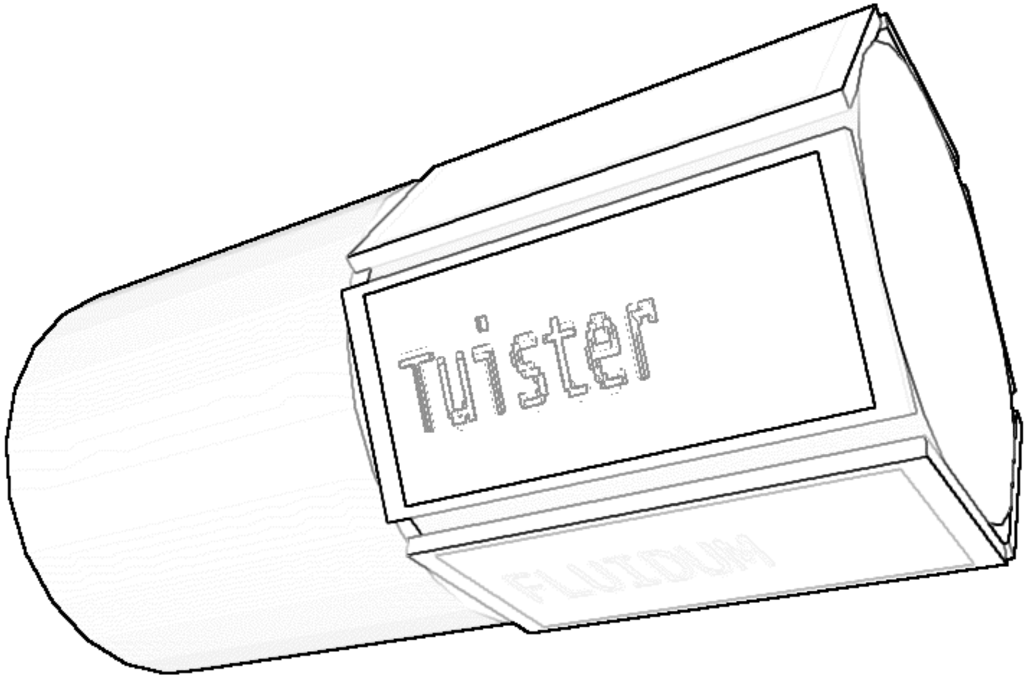
Figure 11: A user is manipulating a virtual camera of a 3D world. While the non-dominant hand is used to control the camera's position and orientation, the user can also change the field of view by dragging a viewing area (projected as a filled arc) with the dominant-hand's pointing device. Note that the pointing device is also used to change the viewing angle of the camera.

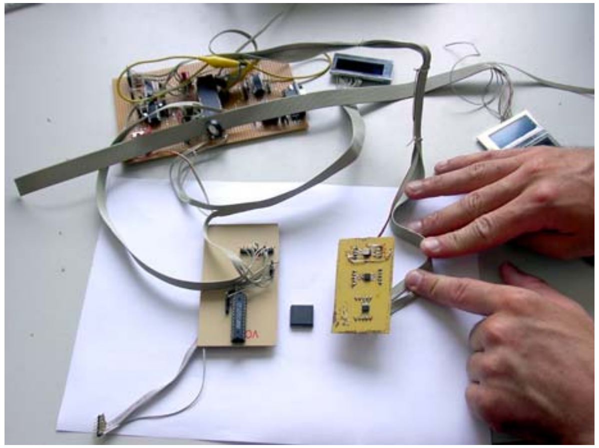


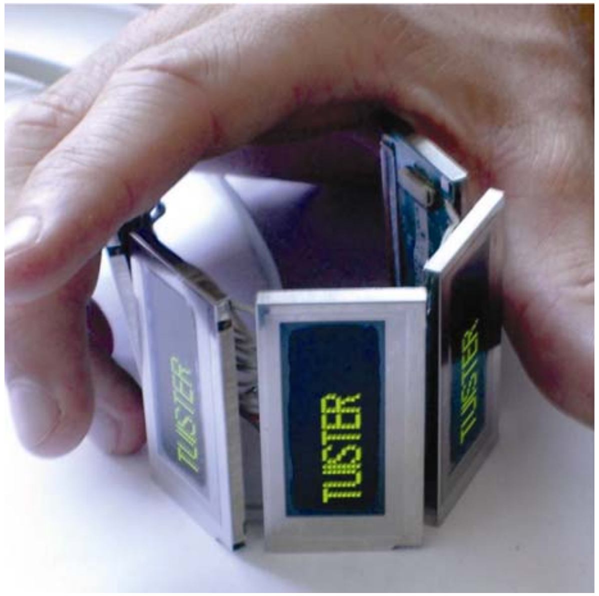
ToolStone design variations



TUISTER

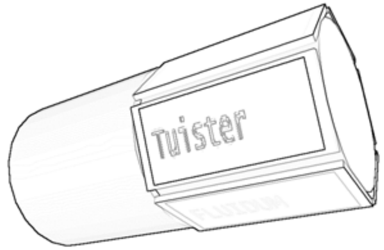




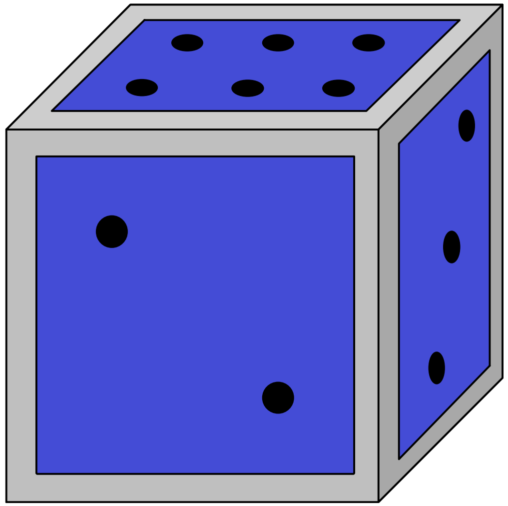


- Interaction object, two-handed, 1DOF each
- Gravitation, magnetic and rotation sensors
- 6 organic Displays
- Serial/BT connection to the environment

Initial Idea

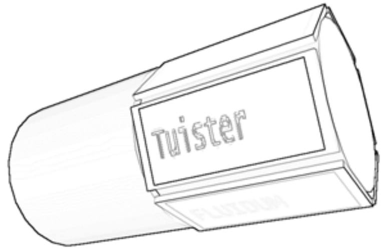


- Build a TUI with built-in display
  - Orientation sensitive
  - Direct feedback
  - Standalone operation



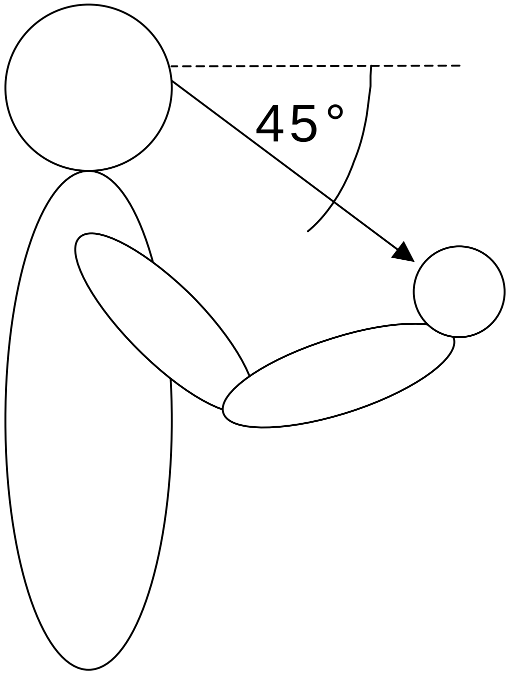
- Technical problems
  - No square organic (OLED) displays
- Cognitive issues
  - Different ways to any side
  - Action history?
  - Display orientation?

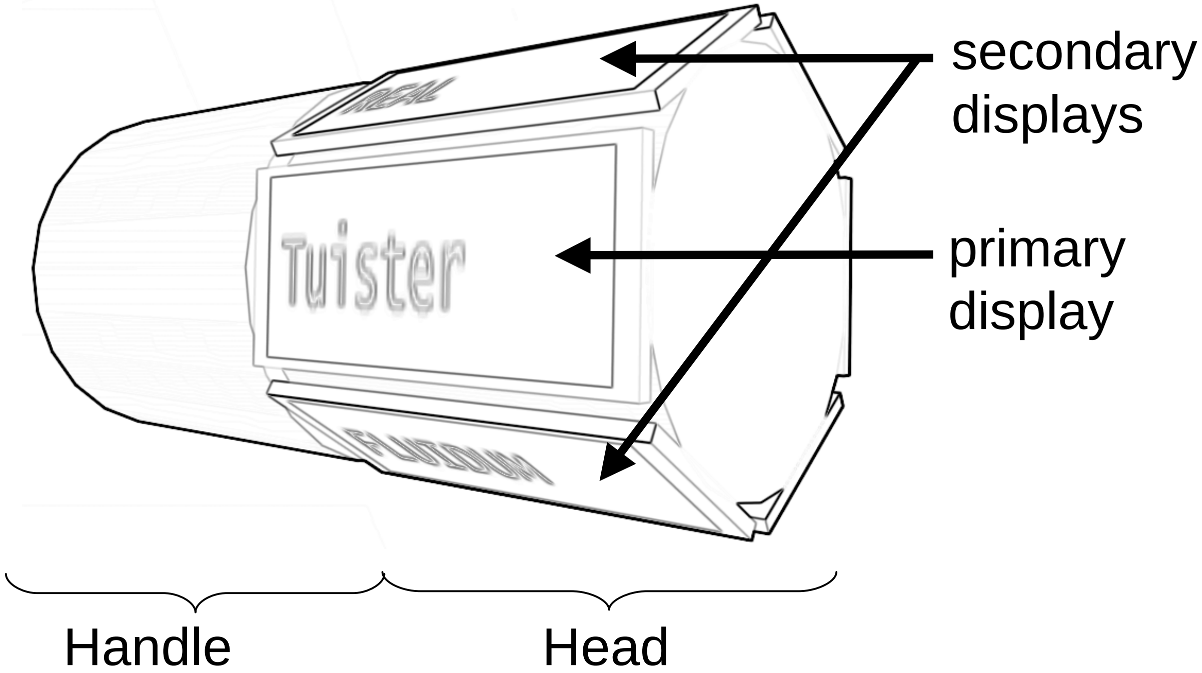
Conceptual Design



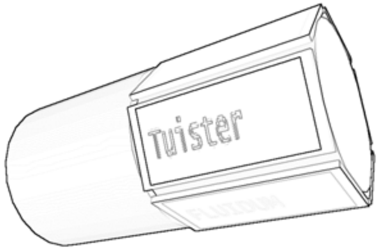
Determination of the primary display by two assumptions:
- Text must be upright
- User looks down about 45°

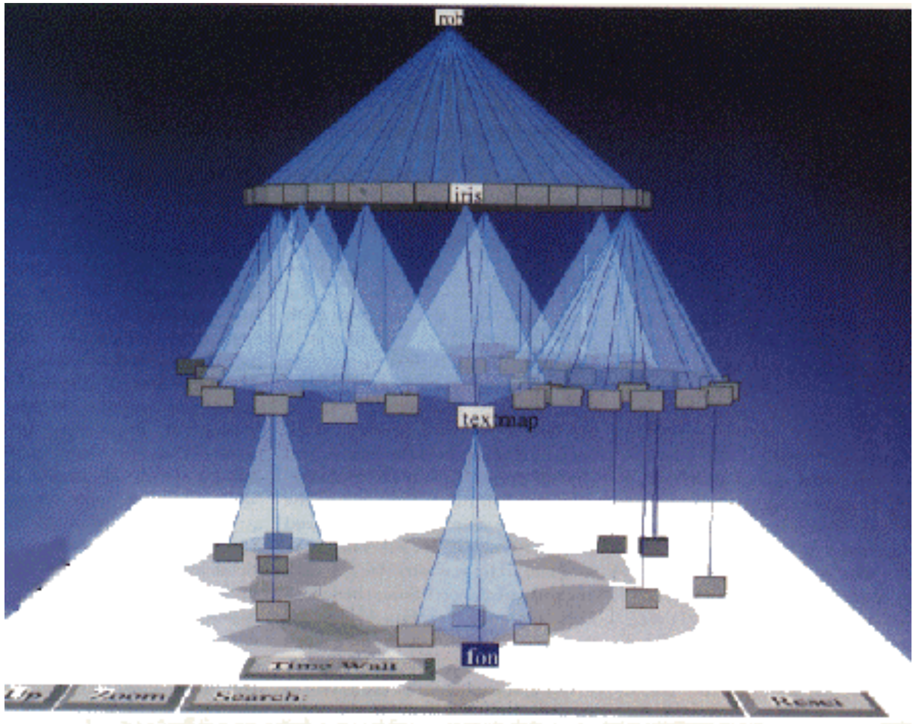
Sensors for orientation:
2x 2D acceleration
3x 1D magnetic
1x relative rotation

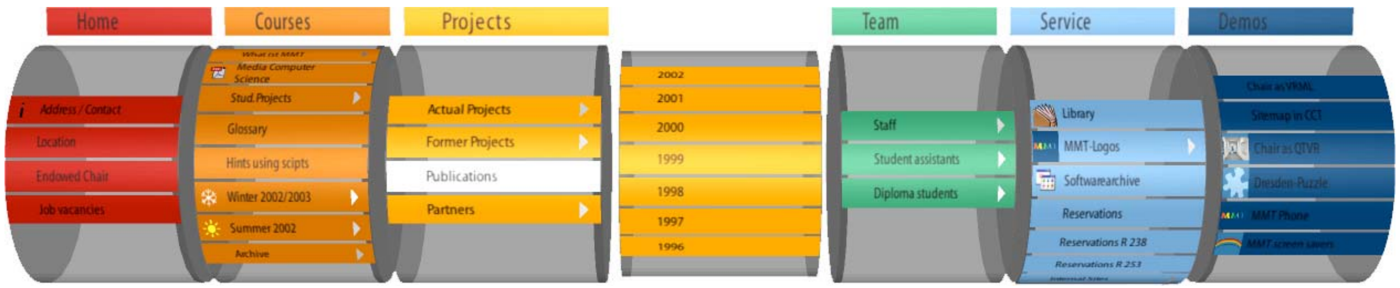




Intuition: Cone/Lyber trees





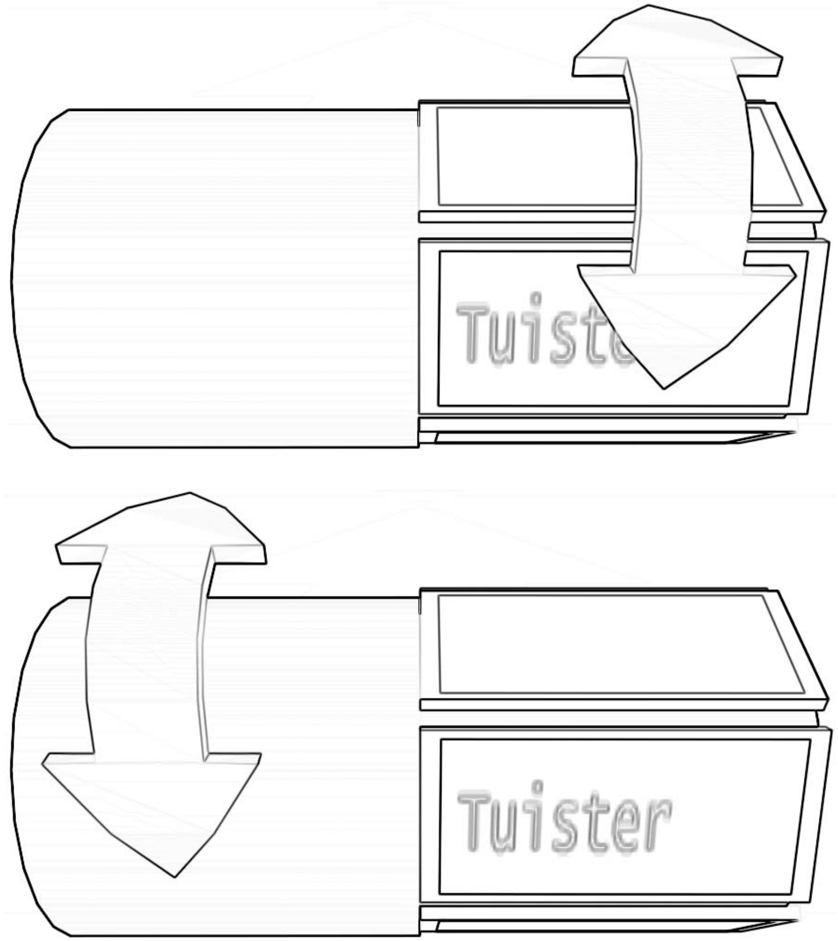


Two types of rotation

- Rotating the head
  - Direct physical manipulation
  - Choice within one menu level
  - Context via secondary displays

- Rotating the handle
  - Metaphor: (un-)fastening a screw
  - Clockwise = fastening = down
  - Counterclockwise = up
  - Choice of the menu level

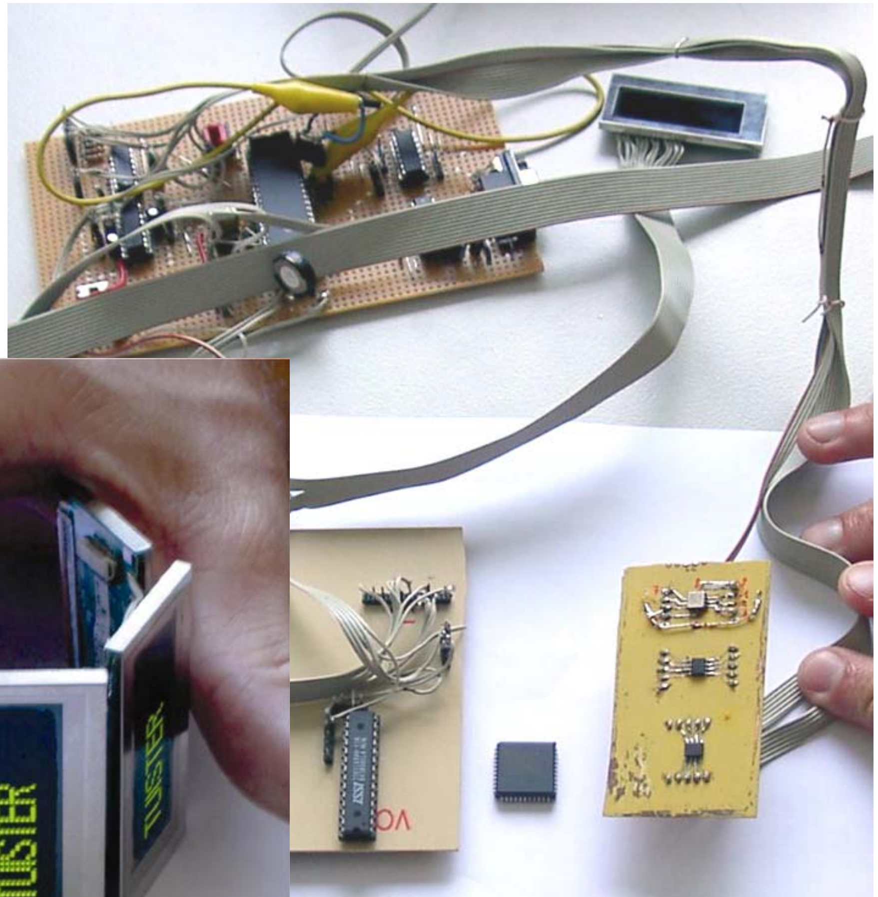
- Rotation by hand: few entries
- Free spin: for long menus



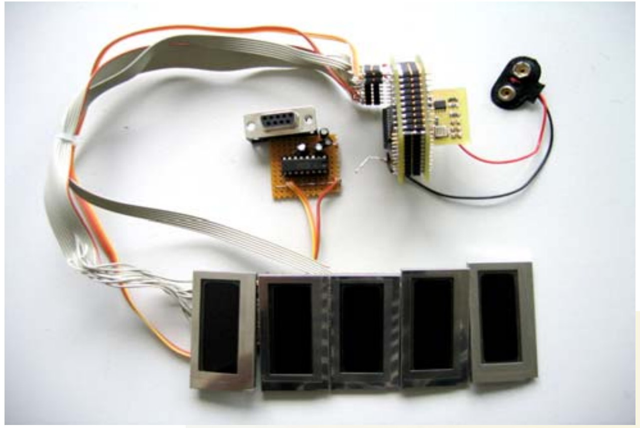
Paper Prototype

- Useful for discussing the concept
- No technical restrictions ;-)
- Close to the intended size

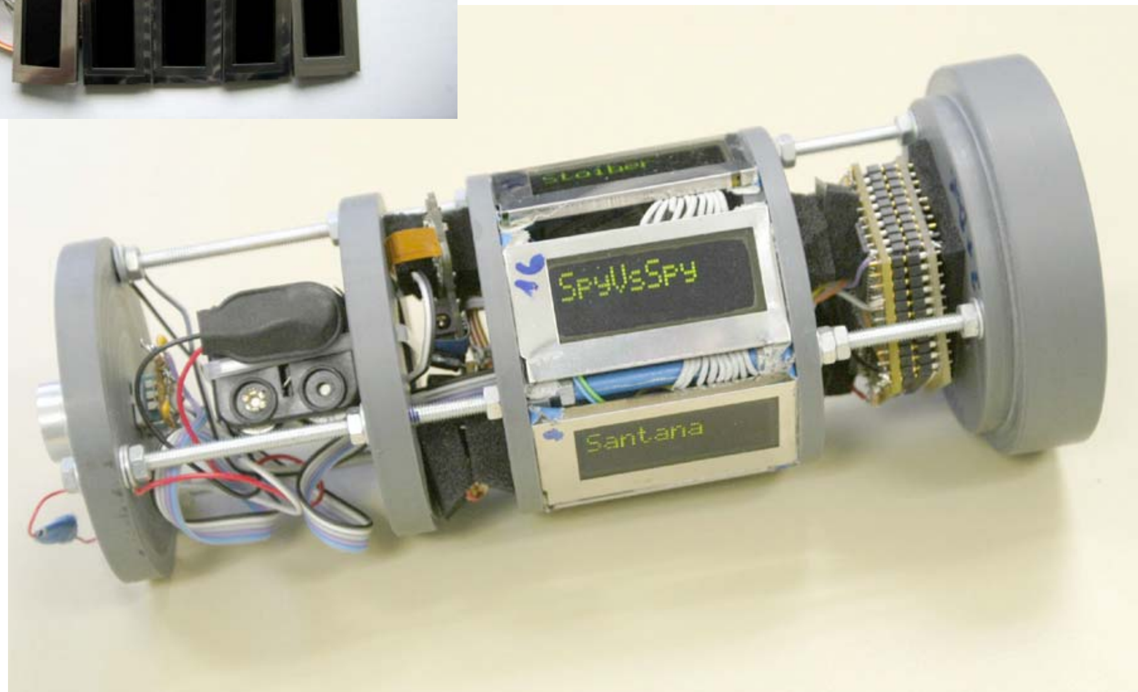
Electronic Prototype



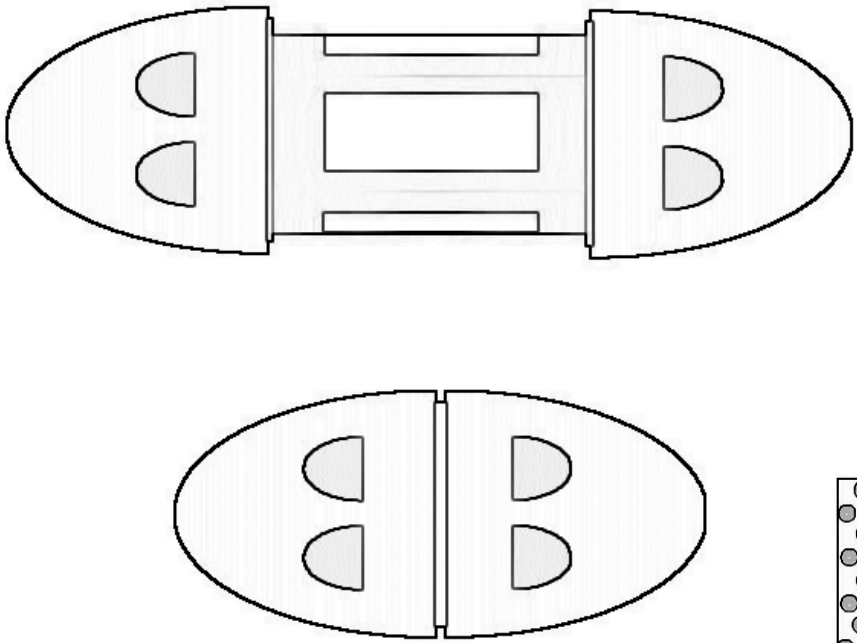
First Functional Prototype

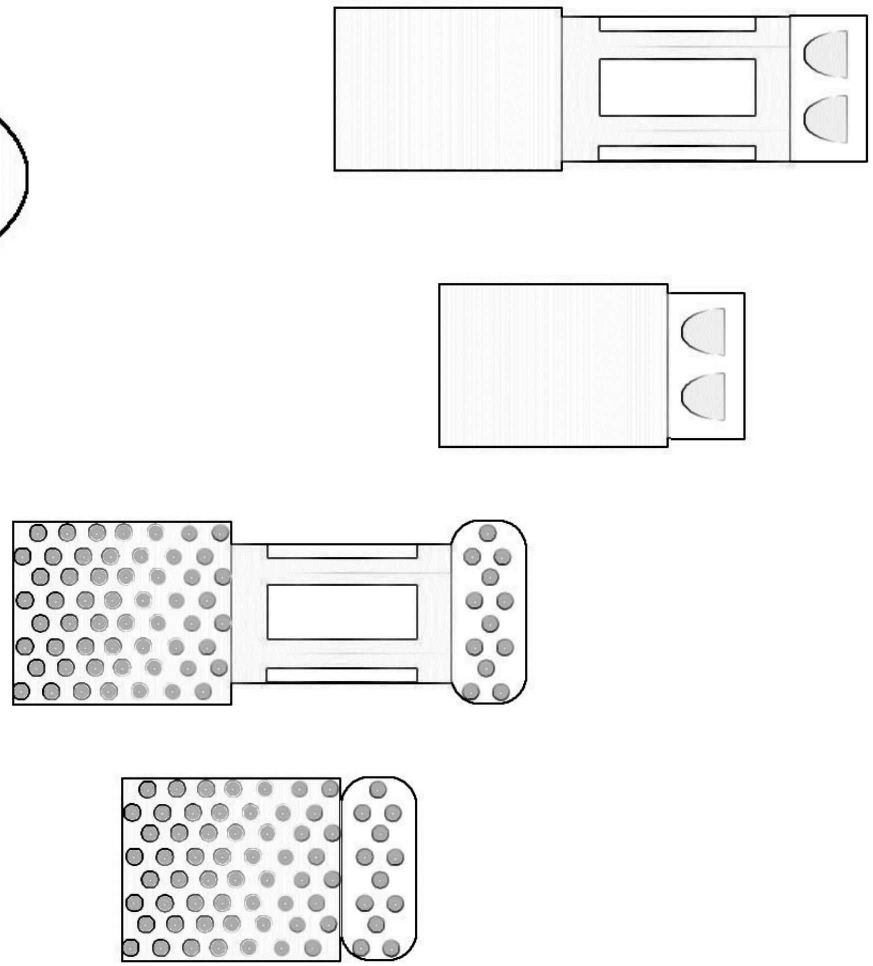


- printed circuit boards
- bluetooth connection
- XML hierarchy descriptions
- mechanics very bulky



Alternative Physical Designs





Courtesy of:
Altmayer Design

Generalization of the Concept

2 / 2

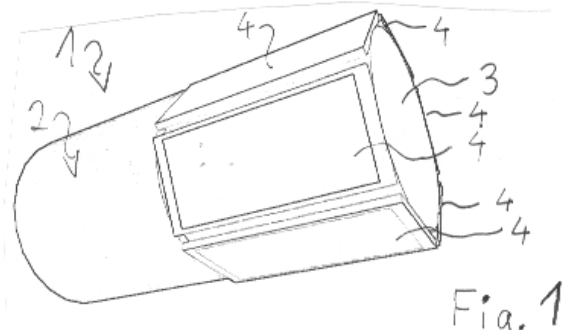


Fig. 1

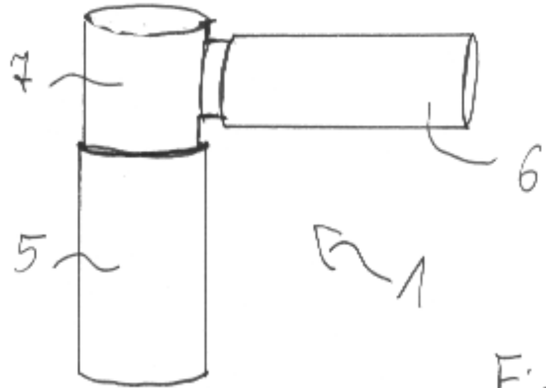


Fig. 3

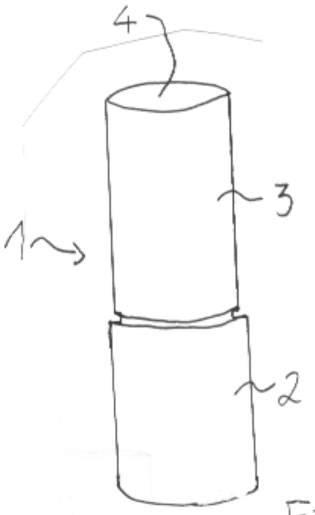


Fig. 2

Abstraction of conceptual design
Also includes display on front side
Also includes non-coaxial designs

German Patent in 2003

Tuister: Current prototype

Available Project/Diploma thesis

- Take the existing prototype
  - Build new case with minor design flaws fixed
- Take existing interactions
  - Determine details, such as exact angles, thresholds, etc.
  - Design a comparative study and evaluate
- Find new interactions
  - Specific application scenarios
  - Beginner/experienced interaction