Vorlesung
Mensch-Maschine-Interaktion

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Chapter 4
Analyzing the Requirements and Understanding the Design Space

The solution space

- What technologies are available to create interactive electronic products?
  - Software
  - Hardware
  - Systems
- How can users communicate and interact with electronic products?
  - Input mechanisms
  - Options for output
- Approaches to Interaction
  - Immediate "real-time" interaction
  - Batch / offline interaction

Motivation: 1D Pointing Device

- Interface to move up and down
- Visualization of rainforest vegetation at the selected height
- Exhibition scenario
- Users: kids 4-8

Motivation: 1D Pointing Device
Example: Computer Rope Interface

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- Visualization of rainforest vegetation at the selected height
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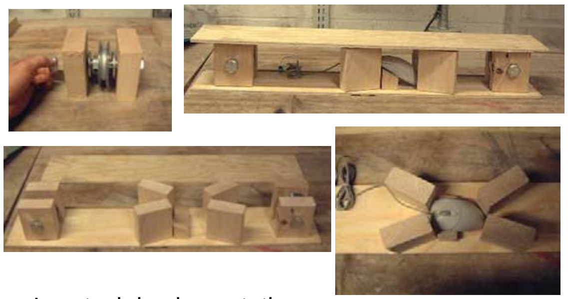
http://web.media.mit.edu/~win/Canopy%20Climb/Index.htm

Example: Computer Rope Interface

http://web.media.mit.edu/~win/Canopy%20Climb/Rope%20Interface%20Export2.avi
http://web.media.mit.edu/~win/Canopy%20Climb/Treemovie.avi

Example: Computer Rope Interface



- Low tech implementation
- Mouse scrolling

Basic Input Operations

- Text Input
  - Continuous
    - Keyboard and alike
    - Handwriting
    - Spoken
  - Block
    - Scan/digital camera and OCR
- Pointing & Selection
  - Degree of Freedom
    - 1, 2, 3, 6, <more> DOF
  - Isotonic vs. Isometric
  - Translation function
  - Precision
  - Technology
  - Feedback
- Direct Mapped Controls
  - Hard wired buttons/controls
    - On/off switch
    - Volume slider
  - Physical controls that can be mapped
    - PalmPilot buttons
    - "internet-keyboard" buttons
    - Industrial applications
- Media capture
  - Media type
    - Audio
    - Images
    - Video
  - Quality/Resolution
  - Technology

Complex Input Operations

- Examples of tasks
  - Filling a form = pointing, selection, and text input
  - Annotation in photos = image capture, pointing, and text input
  - Moving a group of files = pointing and selection
- Examples of operations
  - Selection of objects
  - Grouping of objects
  - Moving of objects
  - Navigation in space

Basic Output Operations / Option

- Visual Output
  - Show static
    - Text
    - Images
    - Graphics
  - Animates
    - Text
    - Graphics
    - Video
- Audio
  - Earcons / auditory icons
  - Synthetic sounds
  - Spoken text (natural / synthetic)
  - Music
- Tactile
  - Shapes
  - Forces
- Further senses
  - Smell
  - Temperature
  - …
- Technologies
  - Visual
    - Paper
    - Objects
    - Displays
  - Audio
    - Speakers
    - 1D/2D/3D
  - Tactile
    - Objects
    - Active force feedback

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Design Space and Technologies

Why do we need to know about technologies?

- For standard applications
  - Understanding the differences in systems potential users may have to access / use once software product
- For specific custom made applications
  - Understanding options that are available
  - Creating a different experience (e.g. for exhibition, trade fare, museum, …)

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Pointing Devices with 2DOF

- Pointing devices such as
  - Mouse
  - Track ball
  - Touch screen
  - Eye gaze
  - …
- Off the desktop other technologies and methods are required
  - Virtual touch screen
  - Converting surfaces into input devices
  - Smart Board
  - Human view
  - …

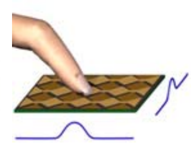
Classification of Pointing devices

- Dimensions
  - 1D / 2D / 3D
- Direct vs. indirect
  → integration with the visual representation
  - Touch screen is direct
  - Mouse is indirect
- Discreet vs. continuous
  → resolution of the sensing
  - Touch screen is discreet
  - Mouse is continuous
- Absolute vs. Relative
  →movement/position used as input
  - Touch screen is absolute
  - Mouse is relative

Examples of Pointing Devices (most with additional functionality)





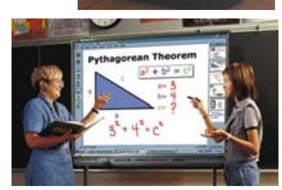




Virtual Touch Screen

- Surfaces are converted into touch screens
- Image/video is projected onto the surface
- Using a camera (or other tracking technology) gestures are recognized
- Interpretation by software
  - simple – where is someone pointing to
  - complex – gestures, sign language
- application
  - Kiosk application where vandalism is an issue
  - Research prototypes …

Smart-Board





- Large touch sensitive surface
- Front or back projection
- Interactive screen

Smart-Board
DViT (digital vision touch)

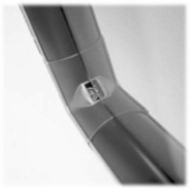


Figure 1: DViT Technology Camera

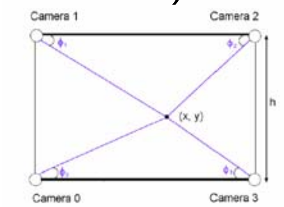
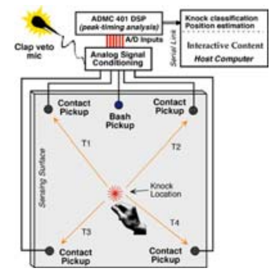


Figure 2: Camera Identification of a Contact Point

- Vision based, 4 cameras, 100FPS
- Nearly on any surface
- More than one pointers
- http://www.smarttech.com/dvit/index.asp

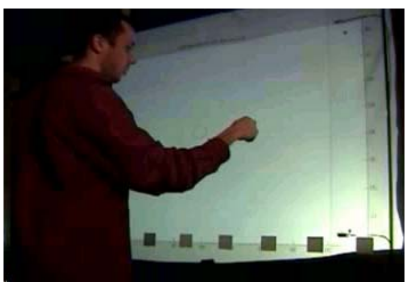
Example: Window Tap Interface

- 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

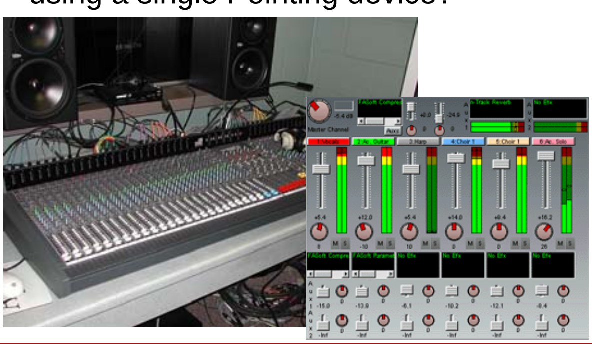


http://www.media.mit.edu/resenv/Tapper/

Example: Window Tap Interface

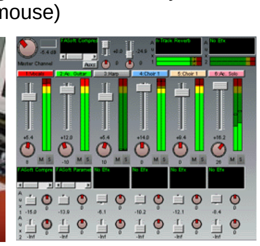
- http://www.media.mit.edu/resenv/Tapper/

What is the drawback of 2D interaction using a single Pointing device?



Basic Problem with a single 2DOF Pointing Device

- With 2DOF most often time multiplexing is implied!
- One operation at the time (e.g. slider can be only be moved sequentially with the mouse)



Game Controllers

Force feedback
more degrees of freedom
time-multiplex is an issue

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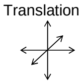
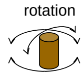
3D Input 6 DOF Interfaces

- 3D input is common and required in many different domains
  - Creation and manipulation of 3D models (creating animations)
  - Navigation in 3D information (e.g. medical images)
- Can be simulated with standard input devices
  - Keyboard and text input (6 values)
  - 2DOF pointing device and modes
  - Gestures
- Devices that offer 6 degrees of freedom
  - Criteria
    - Speed
    - Accuracy
    - Ease of learning
    - Fatigue
    - Coordination
    - Device persistence and acquisition
  - Little common understanding

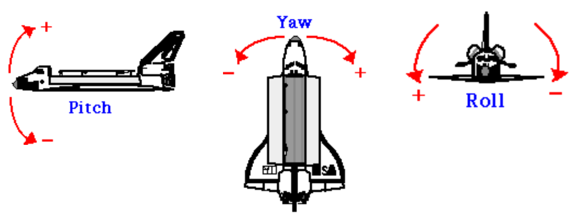
Translation



rotation



Basic Terms: different rotations

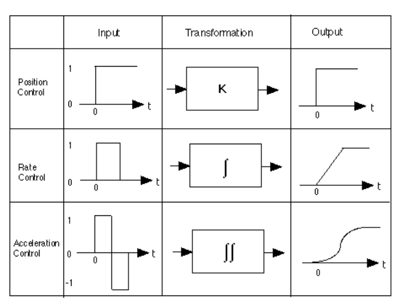


http://liftoff.msfc.nasa.gov/academy/rocket_sci/shuttle/attitude/pyr.html

6DOF

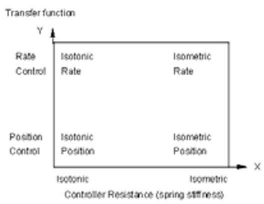
- Controller resistance
  - Isotonic = device is moving, resistance stays the same
    - Displacement of device is mapped to displacement of the cursor
  - Elastic
  - Isometric = device is not moved
    - Force is mapped to rate control
- Transfer function
  - Position control
    - Free moving (isotonic) devices – device displacement is mapped/scaled to position
  - Rate control
    - Force or displacement is mapped onto cursor velocity
    - Integration of input over time -> first order control

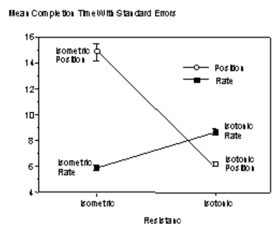
Analysis of Position versus Rate Control



http://vered.rose.utoronto.ca/people/shumin_dir/papers/PhD_Thesis/Chapter2/Chapter23.html

Performance depends on transfer function and resistance





http://www.siggraph.org/publications/newsletter/v32n4/contributions/zhai.html

Controller resistance

- **Isometric**
  - pressure devices / force devices
  - Infinite resistance
  - device that senses force but does not perceptibly move
- **Isotonic**
  - displacement devices, free moving devices or unloaded devices
  - zero or constant resistance
- **Elastic**: Device's resistive force increases with displacement, also called spring-loaded
- Viscous: resistance increases with velocity of movement,
- Inertial: resistance increases with acceleration

Flying Mice (I)

- a mouse that can be moved and rotated in the air for 3D object manipulation.
- Many different types…
- flying mouse is a free-moving, i.e. *isotonic* device.
- displacement of the device is typically mapped to a cursor displacement.
- Such type of mapping (transfer function) is also called *position control*.


(a)


(b)


(c)

http://www.almaden.ibm.com/u/zhai/papers/siggraph/final.html

Flying Mice (II)

- The advantages of these "flying mice" devices are:
  - Easy to learn, because of the natural, direct mapping.
  - Relatively fast speed
- disadvantages to this class of devices:
  - Limited movement range. Since it is position control, hand movement can be mapped to only a limited range of the display space.
  - Lack of coordination. In position control object movement is directly proportional to hand/finger movement and hence constrained to anatomical limitations: joints can only rotate to certain angle.
  - Fatigue. This is a significant problem with free moving 6 DOF devices because the user's arm has to be suspended in the air without support.
  - Difficulty of device acquisition. The flying mice lack persistence in position when released.

- The form factor of devices has a significant impact on the pointing performance. E.g. Fingerball vs. glove

http://www.almaden.ibm.com/u/zhai/papers/siggraph/final.html

Stationary devices (I)

- devices that are mounted on stationary surface.
- Have a self-centering mechanism
- They are either *isometric* devices that do not move by a significantly perceptible magnitude or *elastic* devices that are spring-loaded.
- Typically these devices work in *rate control* mode, i.e. the input variable, either force or displacement, is mapped onto the velocity of the cursor.
- The cursor position is the integration of input variable over time.


(a)


(b)


(c)

Stationary devices (II)

- isometric device (used with rate control) offers the following advantages:
  - Reduced fatigue, since the user's arm can be rested on the desktop.
  - Increased coordination. The integral transformation in rate control makes the actual cursor movement a step removed from the hand anatomy.
  - Smoother and more steady cursor movement. The rate control mechanism (integration) is a low pass filter, reducing high frequency noises.
  - Device persistence and faster acquisition. Since these devices stay stationary on the desktop, they can be acquired more easily.
- isometric rate control devices may have the following disadvantages:
  - Rate control is an acquired skill. A user typically takes tens of minutes, to gain controllability of isometric rate control devices.
  - Lack of control feel. Since an isometric device feels completely rigid

Multi DOF Armatures

- multi DOF input devices are mechanical armatures.
- the armature is actually a hybrid between a flying-mouse type of device and a stationary device.
- Can be seen as a are near isotonic - with exceptional singularity positions - position control device (like a flying mouse)
- has the following particular advantages:
  - Not susceptible to interference.
  - Less delay: response is usually better than most flying mouse technology
  - Can be configured to "stay put", when friction on joints is adjusted and therefore better for device acquisition.
- drawbacks:
  - Fatigue: as with flying mouse.
  - Constrained operation. The user has to carry the mechanical arm to operate, At certain singular points, position/orientation is awkward.
- This class of devices can also be equipped with force feedback, see later Phantom Device

Technology Examples Data Glove

- Data glove to input information about
  - Orientation, (roll, pitch)
  - Angle of joints
  - Sometimes position (external tracking).
- Time resolution about. 150...200 Hz
- Precision (price dependent):
  - Up to 0,5 ° for expensive devices (> 10.000 €)
  - Cheap devices (€100) much less

Technology Examples 3D-Mouse

- Spacemouse und Spaceball:
  - Object (e.g. Ball) is elastically mounted
  - Pressure, pull, torsion are measured
  - Dynamic positioning
- 6DOF

http://www.alsos.com/Products/Devices/SpaceBall.html

Technology Examples 3D-Graphic Tablet

- Graphic tablets with 3 dimensions
- Tracking to acquire spatial position (e.g. using Ultrasound)

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Force Feedback Mouse

- Pointing devices with *force feedback*:
  - Feeling a resistance that is controllable
  - Active force of the device
  - Common in game controllers (often very simple vibration motors)
- Examples in desktop use
  - Menu slots that snap in
  - feel icons
  - Feel different surfaces
  - Can be used to increase accessibility for visually impaired
- Logitech iFeel Mouse http://www.dansdata.com/ifeel.htm

Phantom – Haptic Device

- high-fidelity 3D force-feedback input device with 6DOF
- GHOST SDK to program it

www.sensable.com

PHANTOM® Omni™ Haptic Device

Specification: PHANTOM® Omni™ Haptic Device

Footprint (Physical area device base occupies on desk)	6 5/8 W x 8 D in. ~168 W x 203 D mm.
Range of motion	Hand movement pivoting at wrist
Nominal position resolution	> 450 dpi. ~ 0.055 mm.
Maximum exertable force at nominal (orthogonal arms) position	0.75 lbf. (3.3 N)
Force feedback	x, y, z
Position sensing [Stylus gimbal]	x, y, z (digital encoders) [Pitch, roll, yaw (± 5% linearity potentiometers)
Applications	Selected Types of Haptic Research and The FreeForm® Concept™ system

Examples:

Programming Abstractions for haptic devices

- GHOST SDK
  http://www.sensable.com/products/phantom_ghost/ghost.asp
- OpenHaptics™ Toolkit
  http://www.sensable.com/products/phantom_ghost/OpenHapticsToolkit-intro.asp
  - toolkit is patterned after the **OpenGL® API**
  - Using existing OpenGL code for specifying geometry, and supplement it with OpenHaptics commands to simulate haptic material properties such as friction and stiffness

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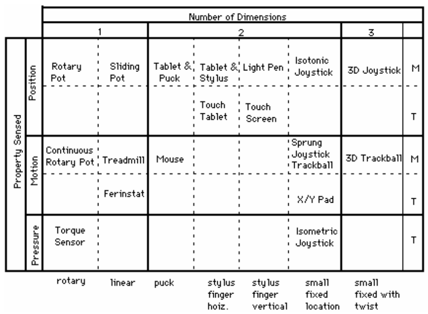
Taxonomy for Input Devices (Buxton)

- continuous *vs* discrete?
- agent of control (hand, foot, voice, eyes ...)?

- what is being sensed (position, motion or pressure), and
- the number of dimensions being sensed (1, 2 or 3)

- devices that are operated using similar motor skills
- devices that are operated by touch vs. those that require a mechanical intermediary between the hand and the sensing mechanism

Taxonomy for Input Devices (Buxton)



http://www.billbuxton.com/lexical.html

Buxton, W. (1983). Lexical and Pragmatic Considerations of Input Structures. *Computer Graphics*, 17 (1), 31-37.

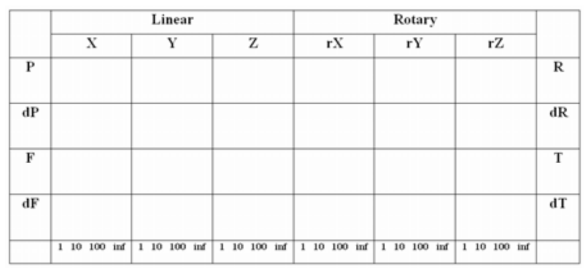
"…basically, an input device is a transducer from the physical properties of the world into the logical parameters of an application."
(Bill Buxton)

Physical Properties used by Input devices (Card91)

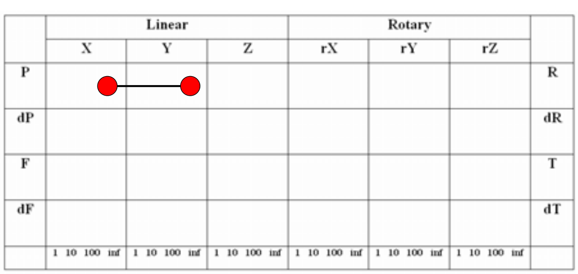
	Linear	**Rotary**
Position		
Absolute	P (Position)	R (Rotation)
Relative	dP	dR
Force		
Absolute	F (Force)	T (Torque)
Relative	dF	dT

Card, S. K., Mackinlay, J. D. and Robertson, G. G. (1991).
A Morphological Analysis of the Design Space of Input Devices.
ACM Transactions on Information Systems 9(2 April): 99-122
http://www2.parc.com/istl/projects/uir/pubs/items/UIR-1991-02-Card-TOIS-Morphological.pdf

Input Device Taxonomy (Card91)

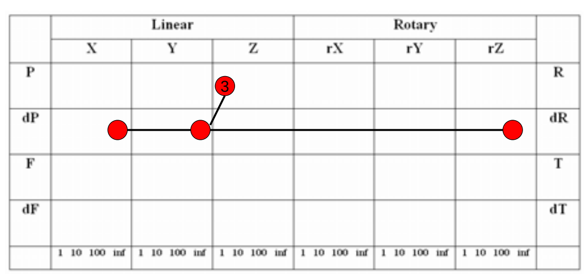


Input Device Taxonomy (Card91)



- Example: Touch Screen

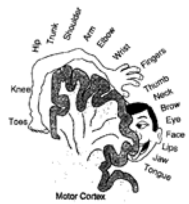
Input Device Taxonomy (Card91)



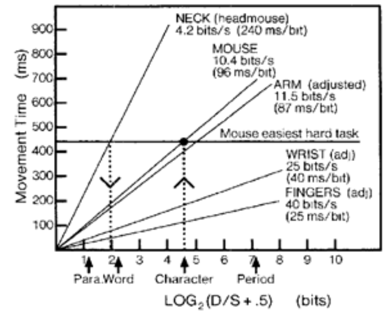
- Example: Wheel mouse

Design Space for Input Devices

- Footprint
  - Size of the devices on the desk
- Bandwidth
  - Human – The bandwidth of the human muscle group to which the transducer is attached
  - Application – the precision requirements of the task to be done with the device
  - Device – the effective bandwidth of the input device



Movement time for Different Devices / Muscle Groups (Card91)



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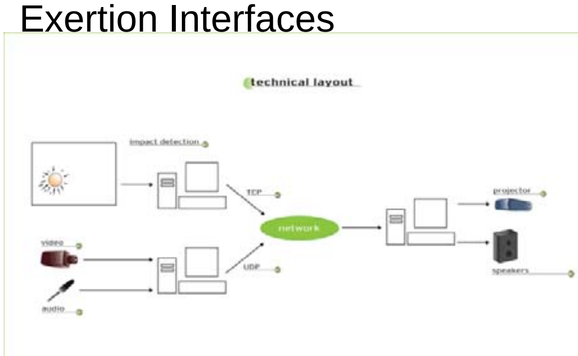
Exertion Interfaces

Video

http://www.exertioninterfaces.com/technical_details/index.htm

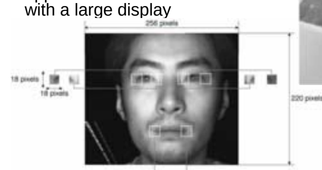
Exertion Interfaces



http://www.exertioninterfaces.com/technical_details/index.htm

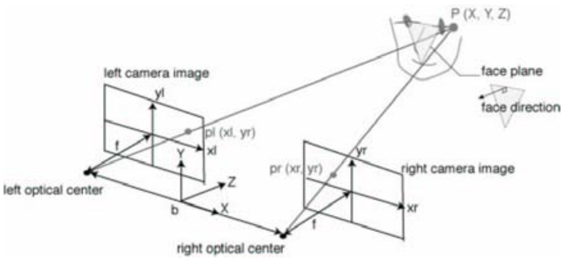
Example: Vision-Based Face Tracking System for Large Displays

- stereo-based face tracking system
- can track the 3D position and orientation of a user in real-time
- application for interaction with a large display



http://naka1.hako.is.uec.ac.jp/papers/eWallUbicomp2002.pdf

Example: Vision-Based Face Tracking System for Large Displays



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Input beyond the screen

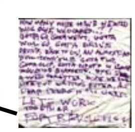
- Capture (photo, tracking)
- Interactive modeling

Capture Interaction

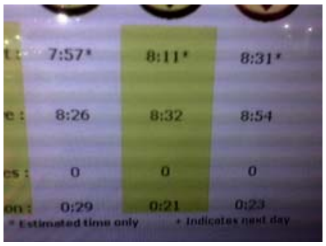
- Mimio
  - Tracking of flip chart makers
  - Capture writing and drawing on a large scale
- PC Notes Taker
  - Capture drawing and handwriting on small scale

Photo Capture

- Write on traditional surfaces, e.g. blackboard, white board, napkin
- Capture with digital camera



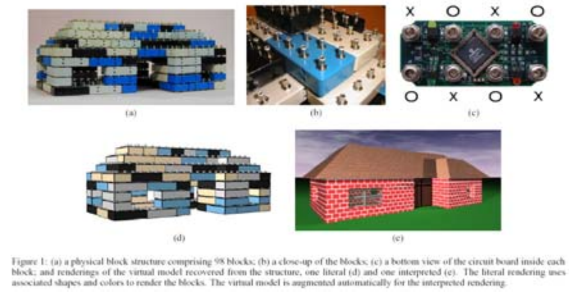
ne Capture



- New applications due the availability of capture tools
  - Paper becomes an input medium again (people just take a picture of it)
  - Public displays can be copied (e.g. taking a picture of an online time table on a ticket machine)

Interactive Modelling (Merl)

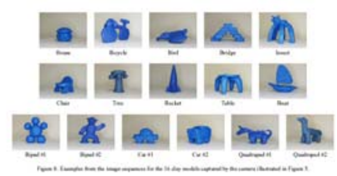
http://www.merl.com/papers/TR2000-13/

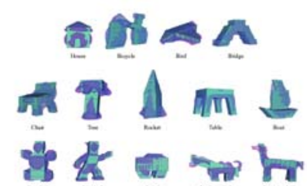


Interactive Modelling (Merl)

http://www.merl.com/papers/TR2000-13/

Interactive Modelling Cont. (Merl)





http://www.merl.com/papers/TR2000-13/

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