Vorlesung Mensch-Maschine-Interaktion

Albrecht Schmidt
Embedded Interaction Research Group
LFE Medieninformatik
Ludwig-Maximilians-Universität München
http://www.hcilab.org/albrecht/

Chapter 4
Analyzing the Requirements and Understanding the Design Space

- 4.1 Factors that Influence the User Interface
- 4.2 Analyzing work processes and interaction
- 4.3 Conceptual Models – How the users see it
- 4.4 Analyzing existing systems
- 4.5 Describing the results of the Analysis
- 4.6 Understanding the Solution Space
- 4.7 Design Space for Input/Output, Technologies

What do we need to Analyze?

- In the Analysis everything that has a potential impact on the solution should be accessed and investigated.
- Most importantly we have to look at
  - Users and their strength and limitations
  - Requirements imposed by the tasks that are to be supported
  - The available options for the implementation of a system (e.g. technologies)
  - The border conditions for development and deployment

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What is relevant?
What do we need to analyze?

- **Goals** of the project
- **People** involved in the operation of the system that is to be build
- **Processes** that are improved, changed, or replaced
- **Economic** constraints
- **Organizational** constraints and company/customer policies

→ Usually there is a trade-off between different factors

Identifying the Goals of a development or project

- Why is a new software or system created?
- What is the main purpose?
  - Replace or improve on an existing system
  - Streamline operation and optimize work processes
  - Introduce a new process or a new option for a process
- In what context is this developed
  - during continued operation
  - In a restructuring phase
  - In a start-up phase of a company or operation
- What is the role of the software/system
  - Driver for restructuring
  - Only one issue within a set of changes made in the organization
- How important is the system to the customer
  - Mission critical, essential for sustaining business
  - Just a nice additional piece to have

Understanding the people involved

- Who are the people involved
  - Who are the decision makers
  - Who are the users
  - What relationship exists between users
  - What relationship exists between users and decision makers
  - What roles do users have (customer, administrator, controller, supervisor, …)
  - What tasks (in the real world and in the system) are preformed by the user
  - Why do people use a system and what is their motivation
- Remember Shneiderman’s 1st principle: “Recognize User Diversity”

Processes

- By introducing or changing software we affect processes in the real world, e.g.,
  - People will be able to do certain tasks they could not do before
  - Certain tasks will be automatically done without user involvement
  - Specific tasks will be speeded up and others may be slowed down
  - The quality of tasks and operations will be improved
  - **Certain processes become traceable and people can be made accountable**
  - Some operation will be made easier others will be more complicate
- Often related to rationalization of the workflow
- Change is not always welcome by everyone

Economic constraints

- Only a certain budget is given
- Only a certain time for the introduction / change is available

- Objective: a product that is desirable and viable and buildable
  - What do people desire?
  - What will sustain a business?
  - What can be build?

- Software development and the creation of the user interface is one piece in a complex development!

Organization constraints Company policies

- How is the customer (e.g. company or organization) organized?
  - How are “chains of command”?
  - Who will decided in the end?
  - What is the relationship between the customer and the user?
- Can (potential) users be brought into the project?
- Is user centered design possible?
- Is clear information about the users available?
- Is the project secret?

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Methods for Analysis

- Methods for analysis can also be used in different phases of a project
  - During analysis to establish requirements
  - During design to decide on alternatives
  - During prototyping to assess different solutions
  - After Implementation to test if the requirements are met
  - In operation to improve the product and to create ideas for the next version
- The methods are often appropriated/tailored to fit a certain development, e.g.
  - How many users to involve
  - Where to carry out the interview
- Similar to other fields, e.g. market research

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Focus Group – Basics

- Informal group gathering
  - 6 to 12 people
  - Focus on a specific topic
  - Group discussion as means of communication
- Gather qualitative date from a group of people
- Get indication how people think and feel
- Collecting **opinions, attitudes, feelings, perceptions, and ideas**
- Get examples and rich descriptions
- Understand why people act or react in a certain way
- Can be used in different project phases, not suitable for formal evaluation

Creating a Focus Group

- Selecting people for a focus group
  - Balance between similarity and productive heterogeneity
  - Usually not representative
  - In general do not mix people that are at different levels in company hierarchy
  - In general do not mix people that have very opposite views
  - Do not set up a group where everyone has the same views
  - Diversity is useful
  - Too small groups do not generate a discussion, too large groups make it hard to involve all participants
- Consider having different focus groups to get information from different angles
  - One group with men and one with women
  - One with managers and one with sales staff
- Expected group dynamics and behavior should allow a constructive discussion

Planning a Focus Group Discussion

- Organize a appropriate location and time slot (1-2 hours)
- Prepare a set of open ended questions and discussion points (4 to 10 questions)
- Set questions that to allow group dynamics and spontaneity
- Focus groups can take place once or can be run as a program of focus group sessions
- Invite participants individually and explain the concept of the focus group and its purpose
- Prepare material that makes the discussion more tangible (e.g. product prototypes, concept video)
- Prepare for recording the session

Running a Focus Group Session

- Moderator keeps the group focused and the discussion moving
- Start with an introduction and provide name tags to participants
- Explain the rules of the discussion (e.g. confidentiality)
- Start with simple non-controversial questions
- Pose open-ended questions
- Avoid question that lead to specific answers
- Allow for diverse opinions and for equal opportunities in the discussion
- Encourage each participant to express their own point of view
- Consensus between participants is not required
- Capture or record the session (video, audio, note taking)


FOCUS GROUP
...AND SO WE'VE DECIDED TO AWARD FEWER MILES FOR DISCOUNT FARES: WHAT DO YOU THINK?
I'M NOT SURE THAT'S SUCH A GOOD IDEA!
SO...THAT'S ONE VOTE FOR "NO"...
ZZZZT!
WHAT DO THE REST OF YOU THINK?
SUPER!
GREAT!
YOU DA MAN!

Pros and Cons of Focus Groups

- Advantages
  - Wide range of information
  - In-depth information (Why user …)
  - Possibility to explore related topics or go into more detail
  - Cheap and easy to do
- Disadvantages
  - Sampling of participants is not random nor representative
  - The moderator plays a significant role and can influence the results
  - No quantitative information can be gathered
  - Findings can not be easily generalized

When to use Focus Groups?

- Generating ideas for a new product or a product improvement
- Comparison of two or more candidate designs for a product
- Explore and generate a hypotheses for a following study

- http://www.soc.surrey.ac.uk/sru/SRU19.html
- http://www.bren.ucsb.edu/academics/courses/281/Readings/whatarefocusgroups.pdf
- http://www.useit.com/papers/focusgroups.html
- http://www.usabilitynet.org/tools/focusgroups.htm
- http://www.humanfactors.com/downloads/sep04.asp

Focus Groups – Discussion

- Should focus groups be used?
- What focus groups would be appropriate?
- What are the requirements for the moderator?

- Image you have the following project to do…
  - Football championship web page for mobile device access (reporting of the daily results)
  - Micro-payment service on the website of Bravo-TV
  - Information web site on social benefits of the city council of Munich
  - Introduction of advertising on the university main website
  - Age verification (e.g. over 18) on web sites
  - Pay-per-view provision of adult content on mobile devices
  - Streaming video (e.g. selected TV shows) on a mobile Phone

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Contextual Enquiry

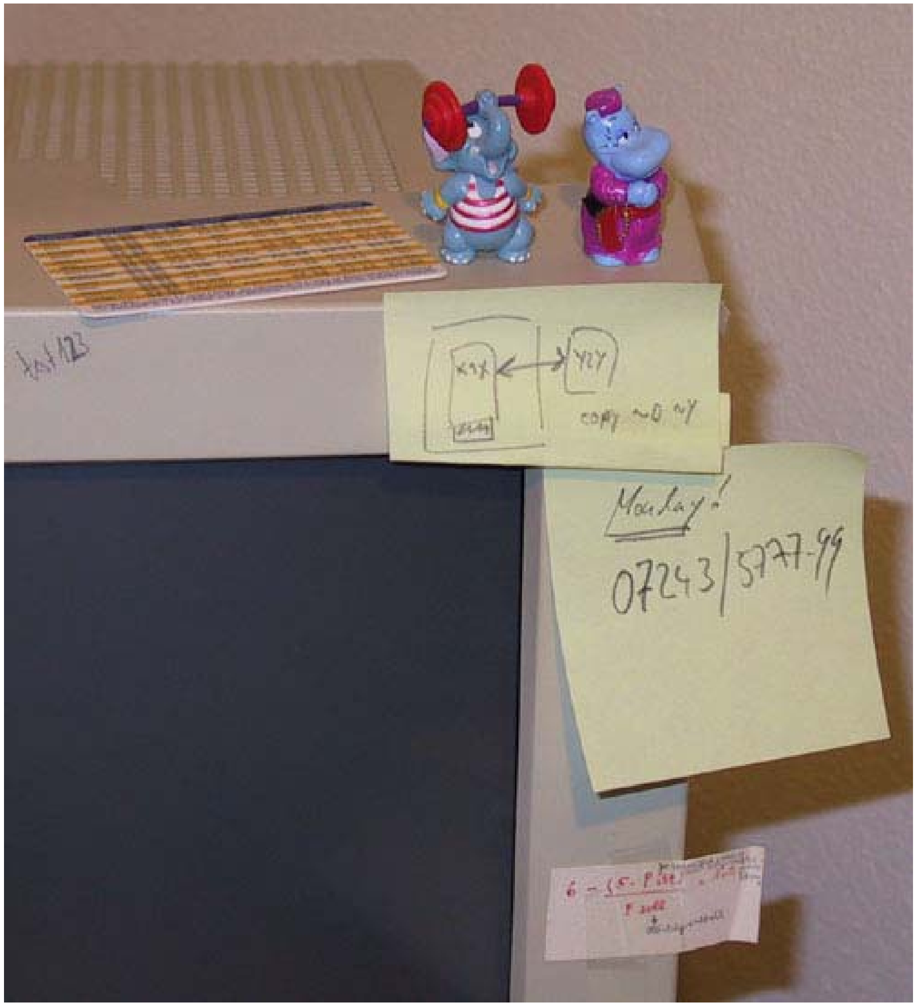
- Investigating and understanding the users and their environment, tasks, issues, and preferences
- Analyzing users' needs
- Related to task analysis
- Done by visits in context
- Observing and interviewing users in their environment while they do their work

- Further Information:
  http://www.infodesign.com.au/usabilityresources/analysis/contextualenquiry.asp
  http://www.infodesign.com.au/usabilityresources/analysis/userprofileforms.asp
  http://www.sitepoint.com/article/contextual-enquiry-primer

Ethnographic Observation in HCI Contextual Enquires

- Learning about the way user's work in the users workplace
- Understanding the work practices and why certain tasks are performed
- Master – apprentice relationship
  - User (master) teaches the observer (apprentice) what they do and how they do it
  - master explains while working
  - Validate your observation by re-phrasing and discuss interpretations made
  - apprentice asks whenever it is not clear
- This method allows to understand how people work and **why** it is done in a certain way
- The observer must be prepared before the interview (understand the language)
- Limit the time of contextual interviews

Ethnographic Observation in HCI Interviews



- Prepare a set of questions beforehand (e.g. what do you want to know from the user)
- Tell people what are you doing
- Use capture (audio/video) if your communication partners agree
- If applicable capture (take photos/video) material they use in their work (e.g. a manual, a checklist, the post-its around the screen)
- Be nosy … ask for details
- If possible summaries what your interview partner told you (to minimize misunderstandings)

Collecting Ideas from People in the context of their everyday life

Figure 1. A cultural probe package.

- Cultural Probes
- Package of materials, e.g.
  - Postcards
  - Disposable camera
  - Maps
  - Photo Album
  - Media diary
- Instructions for actions to be taken
- To provoke (contextual) inspirational responses from the users
- Over a period of time
- User centered inspiration

Gaver, W., Dunne, T., Pacenti, E.: Design. Cultural probes, Interactions, 6(1), 1999

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What and when to observe

From chapter 12
www.id-book.com

- Goals & questions determine the paradigms and techniques used.
- Observation is valuable any time during design.
- Quick & dirty observations early in design
- Observation can be done in the field (i.e., field studies) and in controlled environments (i.e., usability studies)
- Observers can be:
  - outsiders looking on
  - participants, i.e., participant observers
  - ethnographers

Frameworks to guide observation

From chapter 12
www.id-book.com

- \- *The person*. Who?
  \- *The place.* Where?
  \- *The thing.* What?

- The Goetz and LeCompte (1984) framework:
  \- *Who* is present?
  \- What is their role?
  \- *What* is happening?
  \- *When* does the activity occur?
  \- *Where* is it happening?
  \- *Why* is it happening?
  \- *How* is the activity organized?

The Robinson (1993) framework

From chapter 12
www.id-book.com

- *Space*. What is the physical space like?
- *Actors*. Who is involved?
- *Activities*. What are they doing?
- *Objects*. What objects are present?
- *Acts*. What are individuals doing?
- *Events*. What kind of event is it?
- *Goals*. What do they to accomplish?
- *Feelings*. What is the mood of the group and of individuals?

You need to consider

From chapter 12
www.id-book.com

- Goals & questions
- Which framework & techniques
- How to collect data
- Which equipment to use
- How to gain acceptance
- How to handle sensitive issues
- Whether and how to involve informants
- How to analyze the data
- Whether to triangulate

Data collection techniques

From chapter 12
www.id-book.com

- Notes & still camera
- Audio & still camera
- Video
- Tracking users:
  - diaries
  - interaction logging

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Adapted from PREECE ROGERS SHARP

Participant observation & ethnography

- Participant observation is key component of ethnography
- Must get co-operation of people observed
- Informants are useful
- Data analysis is continuous
- Questions get refined as understanding grows
- Reports usually contain examples

Data analysis

- *Qualitative data - interpreted* & used to tell the 'story' about what was observed.
- *Qualitative data - categorized* using techniques such as content analysis.
- *Quantitative data* - collected from interaction & video logs. Presented as values, tables, charts, graphs and treated statistically.

Adapted from PREECE ROGERS SHARP

Interpretive data analysis

- Look for key events that drive the group's activity
- Look for patterns of behavior
  - Critical incident analysis
  - Content analysis
  - Quantitative analysis - i.e., statistics
- Test data sources against each other - triangulate
- Report findings in a convincing and honest way
- Produce 'rich' or 'thick descriptions'
- Include quotes, pictures, and anecdotes
- Software tools can be useful

What do you think?

Key points

- Observe from outside or as a participant
- Analyzing video and data logs can be time-consuming.
- In participant observation collections of comments, incidents, and artifacts are made. Ethnography is a philosophy with a set of techniques that include participant observation and interviews.
- Ethnographers immerse themselves in the culture that they study.

Ethnographic Observation in HCI

- Traditional ethnographers immerse into other cultures over a extended period (weeks, month, years) and thereby study and understand the culture

- Ethnographic observations in HCI are a means of data collection
- Usually observing potential users (typical users) over a period of hours, days, or weeks. Include critical times (e.g. shift change)

- Goal
  - Acquire information that is required to create user interfaces and interaction mechanisms suitable
- Risk
  - Misinterpretation of observations (often due to a luck of insight)
  - Changing peoples behavior, disrupt processes
  - Overlooking / missing important facts

- Some problems occur infrequently – if you can not observe them conduct interviews

Guidelines for Ethnographic Observation in HCI (Shneiderman, chapter 3)

- Preparation
  - Understand the current system in the context of the organization and culture – don't be ignorant!
  - Describe the goals of the observation and prepare questions
  - Get permissions for observations and interviews
- Field Study
  - Establish contact, talk to people
  - Observe, interview, and collected data in situ
  - Document observations
- Analysis
  - Compile data, summaries and quantify
  - Provide interpretation of the data
  - Refine the goals and record issues about the process
- Reporting
  - Describe findings – possibly for different audiences

Observations & Protocols

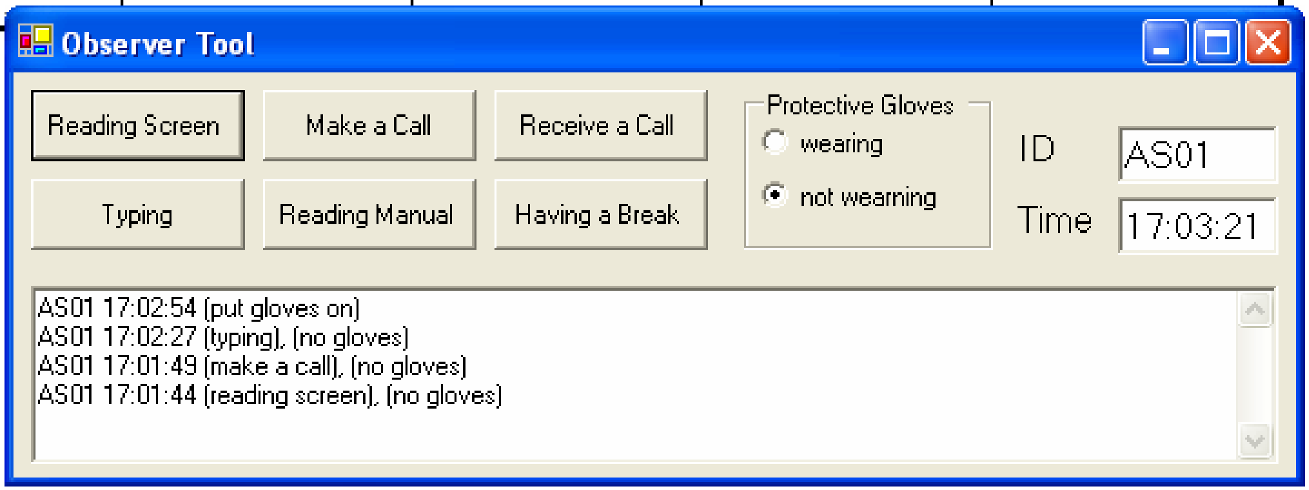
- Paper and pencil
  - Cheap and easy but unreliable
  - Make structured observations sheets / tool
- Audio/video recording
  - Cheap and easy
  - Creates lots of data, potentially expensive to analyze
  - Good for review/discussion with the user
- Computer logging
  - Reliable and accurate
  - Limited to actions on the computer
  - Include functionality in the prototype / product
- User notebook
  - Request to user to keep a diary style protocol

Structured observations

- Observation sheet

time	typing	reading screen	consulting manual	phoning	…
14:00		X		X	
14:01	X		X		
14:02	X				
14:03	X				
14:04				X	
…					

- Electronic version



Observations and Protocols

- What are observations and Protocols good for?
  - Demonstrating that a product improves productivity
  - Basis for qualitative and quantitative findings

- Hint
  - Minimize the chance for human error in observation and protocols
  - Most people are pretty bad at doing manual protocols
  - Combine with computer logging
    - Log what you get from the system
    - Observer makes a protocol on external events

Ethnographic Observation in HCI
Video Observation

- Capture work practices on video (consider legal and ethical issues)
- User's view often provides significant insight
- Asking user's to talk (to describe) while doing a task provides generally a lot of useful information
- Raw material alone is of little value – need for analysis
- Analyzing video observations is hard and time consuming!
- Users may not like it! If they agree a person observing them they still may disagree to be videoed

Video Observation (1)

Camwear from http://www.mydejaview.com

- Observation is done with one or more cameras
- Cameras provide pictures of regions important to the task
- Camera attached to the user may be use
  - Camera embedded into glasses
  - Allow the observer to see “through the eyes” of the user
- Different view points simultaneously
  - Camera overlooking the workplace
  - Camera looking from the screen to the user
  - Camera capturing what the user sees

Video Observation (2)

- Can be used
  - When only the user can be present
  - In dangerous environments
  - When many users interact and tasks are complex
  - When only selective data is required
  - For tasks that are done very quickly or hard to observe
- To speed up analysis the captured video material should be time stamped and correlated with other events
  - E.g. only look at the video from the moment when a “new mail arrived” notification is issued till the user enters the email client
- Analysis of raw material is very time consuming!
  - 3h to 20h for 1h recording
  - Automatically annotate video recordings (time stamps)

Using further Sensors for Observation

- To ease the analysis it is helpful to automatically detect interactions of interest, e.g.
  - When did the person leave the room?
  - When did the person get something out of the shelf?
  - When did the person meet another person?
  - Where did the person go?
- Such information can be obtained using sensor systems, e.g.
  - RFID-Tags and readers
  - Activity sensors
  - Location tracking systems
- Depending on the requirements a technology should be selected. Currently most of these technologies are very new or still research prototypes

Scenario for combined analysis

- Camera
- Sensors (e.g. motion, touch, rfid, …)
- Logfile of the interactive devices (e.g. key-logger, application logger)

- Log all the data (video, sensors, key input) with time stamps

- Use sensor information to find the video scenes that are of interest, e.g.
  - Get me all video scenes that show what the user is doing before she/he switches to application X
  - Show me all sequence where users have to input a password

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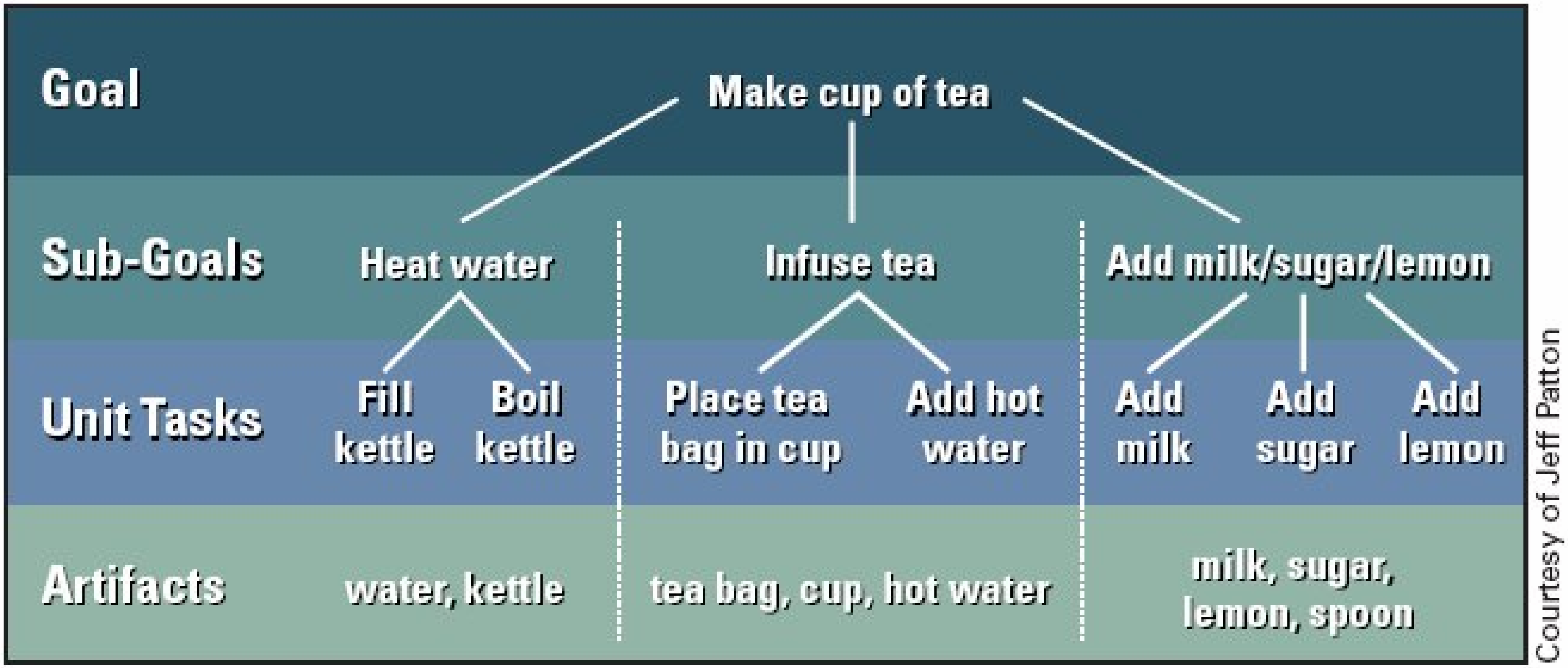
Task Analysis - Motivation

- Basically it is about all the actions performed by the user to accomplish a task
  - Its is about what we can observe
  - It is not really about the mental model
- Example – setting up a video projector:
  - unpacking the projector and placing it on the table
  - connecting the power cable to the projector and the socket
  - connecting a data cable between projector and computer
  - switching on the projector
  - waiting for the projector to be ready
  - switching the computer to dual screen mode
- Some issues
  - There is no single way to do that…
  - Granularity and details
  - Order of action

Task Analysis - Example



see: William Hudson. HCI and the web: A tale of two tutorials: a cognitive approach to interactive system design and interaction design meets agility. interactions Volume 12, Number 1 (2005), Pages 49-51

Task Analysis – High level Questions

- How do users know their goal is attainable?
- How do users know what to do?
- How will users know they have done the right thing?
- How will users know they have attained their goal?

William Hudson. HCI and the web: A tale of two tutorials: a cognitive approach to interactive system design and interaction design meets agility. interactions Volume 12, Number 1 (2005), Pages 49-51

Wharton, C., Rieman, J., Lewis, C., & Polson, P. (1994). The cognitive walkthrough method: A practitioner's guide. In J. Nielsen & R. L. Mack (eds.). Usability inspection methods. New York, NY: John Wiley.

What can we examine in Task Analysis?

- Input to the computer (keyboard, mouse, etc.)
- Physical actions, e.g. head movement, turning on the chair to reach for a document, lifting the mouse
- Perceptual actions, e.g. recognizing things that appear on the screen, finding a tool again
- Cognitive actions
- Mental actions and decision making
- Memory recall

Task analysis
Set of basic questions

- Who is going to use the system? .
- What tasks do they now perform?
- What tasks are desired?
- How often are the tasks carried out?
- What time constraints on the tasks?
- What knowledge is required to do the task?
- How are the tasks learned?
- Where are the tasks performed (environment)?
- What other information and tools are required to do the task?
- What's the relationship between user & data?
- What is the procedure in case of errors and failures?
- Multi-user system: How do users communicated (CSCW Matrix)?

Task Analysis – Basics

- Analyze what the user has (or users have) to do in order to get a job done
  - What (physical) actions are done?
  - What cognitive processes are required?
- The task analysis is usually in the context of an existing system or for a established procedure
- The information flow is discovered
  - What information is used?
  - What information is created?
  - Also you ask with regard to the information: how, where, when, by whom, …
- Usually the information flow is essential when creating or changing a system
- The analysis is most often hierarchical
  - Task → sub task → sub sub task …

Task Analysis – Goals

- Find the tasks and actions that must be supported by a system
- Rank tasks and actions according to the requirement
- Identify the critical information flow in the system
- Understand how a task is composed of sub tasks
  - The relationship between tasks and sub tasks
  - The rational of task composition
  - The order of sub tasks (e.g. has the order significance or not)
- Specify which functions need to be include in the system/user interface that allow to do the overall task efficiently and with minimal effort for the user
- The description of tasks can be used to benchmark the system (it must at least support those tasks)

Task Analysis – How To?

- Task decomposition is at the center of the method
  - Identify high level tasks
  - Break them down into the subtasks and operations
- Task flows and alternatives
  - Identify for elementary subtasks their order (task flow)
  - Identify alternative subtasks
  - Understand and document decision processes (how are alternative subtasks chosen?)
- Present the result of the task analysis as chart
  - Charts may have different levels (overview and detailed subtasks)
  - Show sequences, alternatives, ordering in the diagram
- Questions that help in decomposition of tasks
  - How is the task done?
  - Why is the user doing this task?

See also: http://www.usabilitynet.org/tools/taskanalysis.htm

Task Analysis – Steps

- Starting the analysis
  - Specify the main task
  - Break down into 4 - 8 subtasks. The subtasks should be described as objectives - Should cover the whole main task
  - Draw subtasks as a layer. Make a plan how subtasks are connected.
- Progressing the analysis
  - Decide on the level of detail (detailed: keystroke-level - higher: general tasks)
  - Decide for each task if the analysis should be continued
  - Number boxes according levels
- Finalize the analysis
  - Check decompositions - all alternatives covered
  - Show the decomposition to an expert (evaluation - assessment)

From http://www.uwasa.fi/~mj/hci/hci7.html

Hierarchical Task Analysis

- Identify the goals the user wants to achieve
- Relate the goals to tasks (and potentially planning) done by the user
- Task decomposition
  - Ordering
  - Alternative plans

- How to limit the tasks to consider?
  - Defining a threshold based on probability of the task and cost in case of failure
  - If (failure_cost(task) * probability(task)) < threshold
    do not further consider this task

- For a detailed discussion on Task Analysis (hierarchical task analysis, knowledge based analysis, entity-relationship based technique, see Dix et. al – chapter 7)

Alternatives

- Task decomposition
  - Top-down approach
  - Breaking tasks into sequences of actions
- Knowledge based analysis
  - Bottom-up approach
  - Grouping simple actions and objects into classes by similarity
- Entity Relationship based analysis
  - Bottom-up approach
  - Defining objects, actors, actions and their relationship

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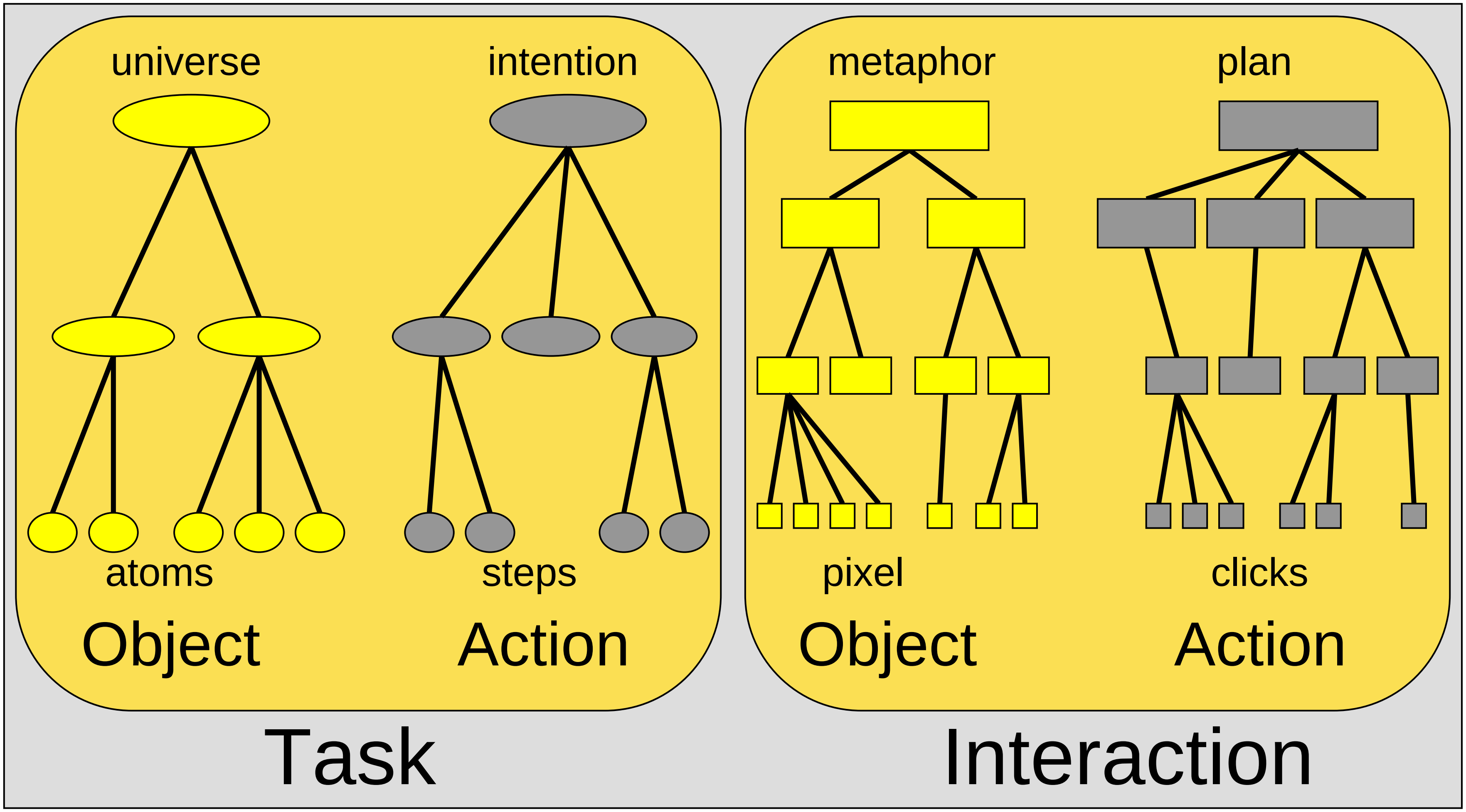
Object-Action Interface Model (OAI)

- Targeted at GUIs and applications in real world domains

- Steps
  1. Understanding the task, including
     - Universe of the real world, objects, atoms
     - Actions user can apply to objects, intention to steps
  2. Create a metamorphic representation of interface objects and actions
     - Object representation – metaphor to pixel
     - Actions – from plan level to specific clicks

Object-Action Interface Model (OAI)



Example

Chapter 4
Analyzing the Requirements and Understanding the Design Space

- 4.1 Factors that Influence the User Interface
- **4.2 Analyzing work processes and interaction**
  - 4.2.1 Focus groups
  - 4.2.2 Contextual enquiry
  - 4.2.3 Observational Studies and Video Analysis
  - 4.2.4 Task Analysis
  - 4.2.5 Object-Action-Interface Model
  - **4.2.6 Diary studies**
- 4.3 Conceptual Models – How the users see it
- 4.4 Analyzing existing systems
- 4.5 Describing the results of the Analysis
- 4.6 Understanding the Solution Space
- 4.7 Design Space for Input/Output

diary study

(usability glossary from www.usabilityfirst.com)

- A study that asks people to keep a diary, or journal, of their interactions with a computer system, any significant events or problems during their use of a system, or other aspects of their working life.
- A diary typically asks a user to record the date and time of an event, where they are, information about the event of significance, and ratings about how they feel, etc.
- An interesting alternative for making diary entries is to give users a tape recorder and a list of questions, so that users don't need to write things down as they encounter them.

Diary study - Discussion

- … your current homework includes a diary study

- What is a diary study good for?
- What are potential problems with this study type?
- How can technologies such as voice recorders, cameras, mobile phones help?

Image from: John Rieman. The diary study: a workplace-oriented research tool to guide laboratory efforts. Proceedings of the SIGCHI conference on Human factors in computing systems. pp 321-326. 1993.

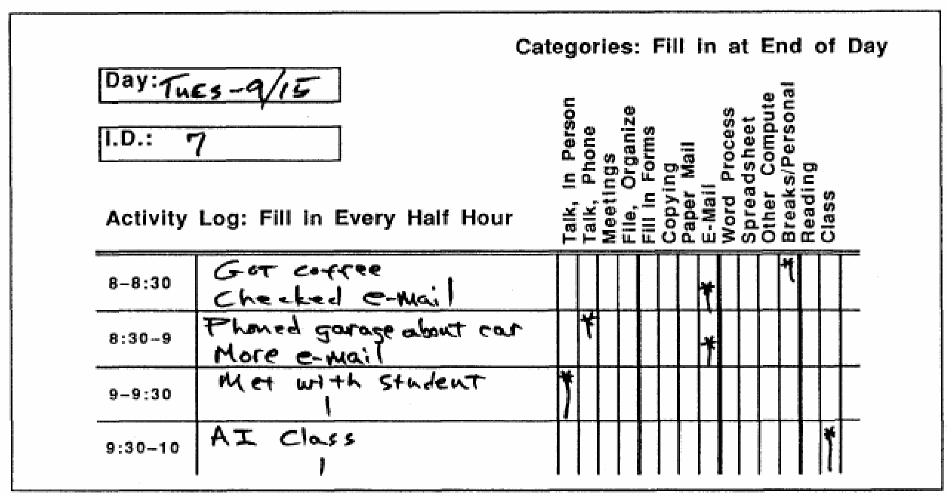


Figure 1. The beginning of a diary log sheet for one day. The participant records activities on the left as the day proceeds. The researcher assigns categories during the end-of-day debriefing.

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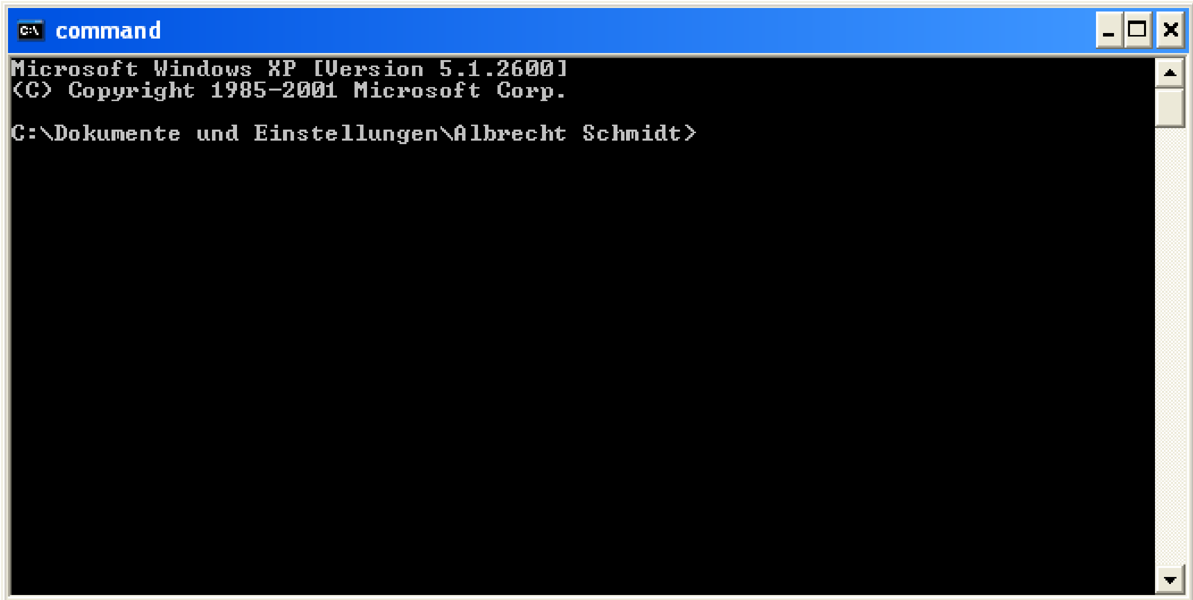
Motivation
Conceptual Models

- How do you figure out that those objects are not usable?
- How do you do it for software?

Images from: D. Norman, The Design of everyday things.

Background: The Psychology of Everyday Things (Norman 2002, Chapter 1)

- Not primarily aimed at computer science problems but with technologies (web, interactive media, embedded computers) moving into everyday life of most people it becomes highly relevant!
- Terms: Perceived and Real Affordances
  - Affordances determine the range of possible - usually physical - actions by a user on an system/object.
  - Perceived Affordances are the actions perceived by a user that appear to be possible.
  - Example: certain materials afford/support certain forms of vandalism (e.g. glass is smashed, wood is carved, graffiti appears on stone)
- This is also applicable to digital materials and designs.


command
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.
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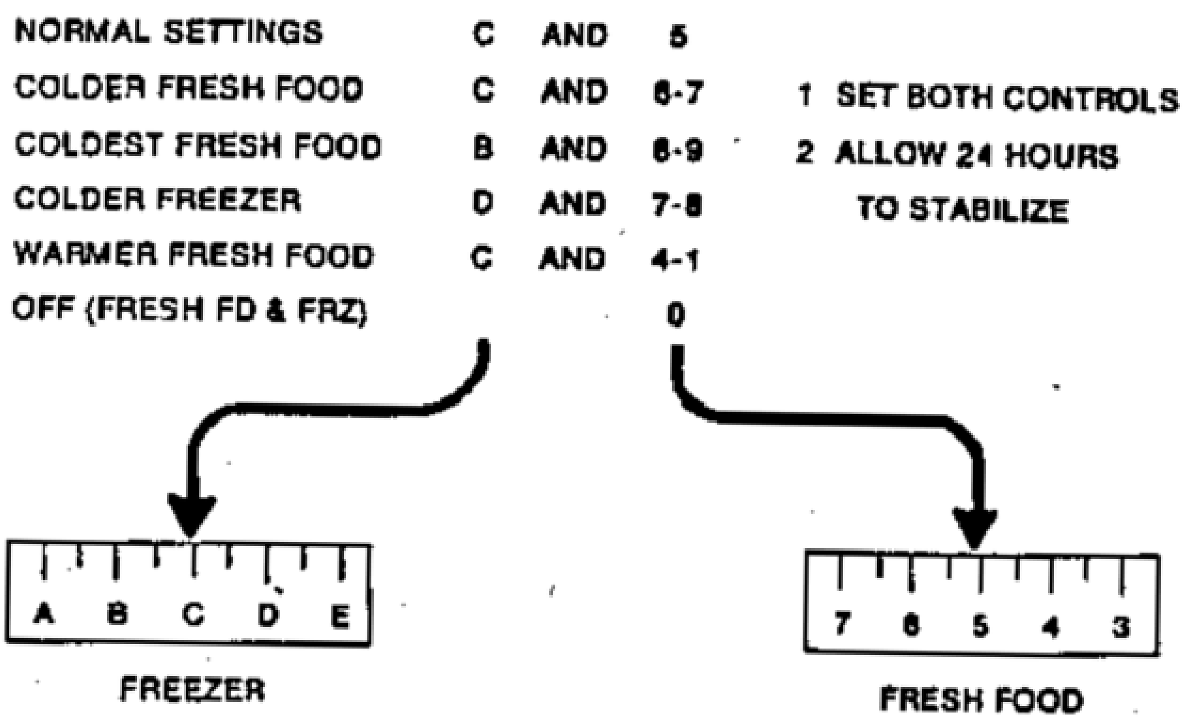
metabo

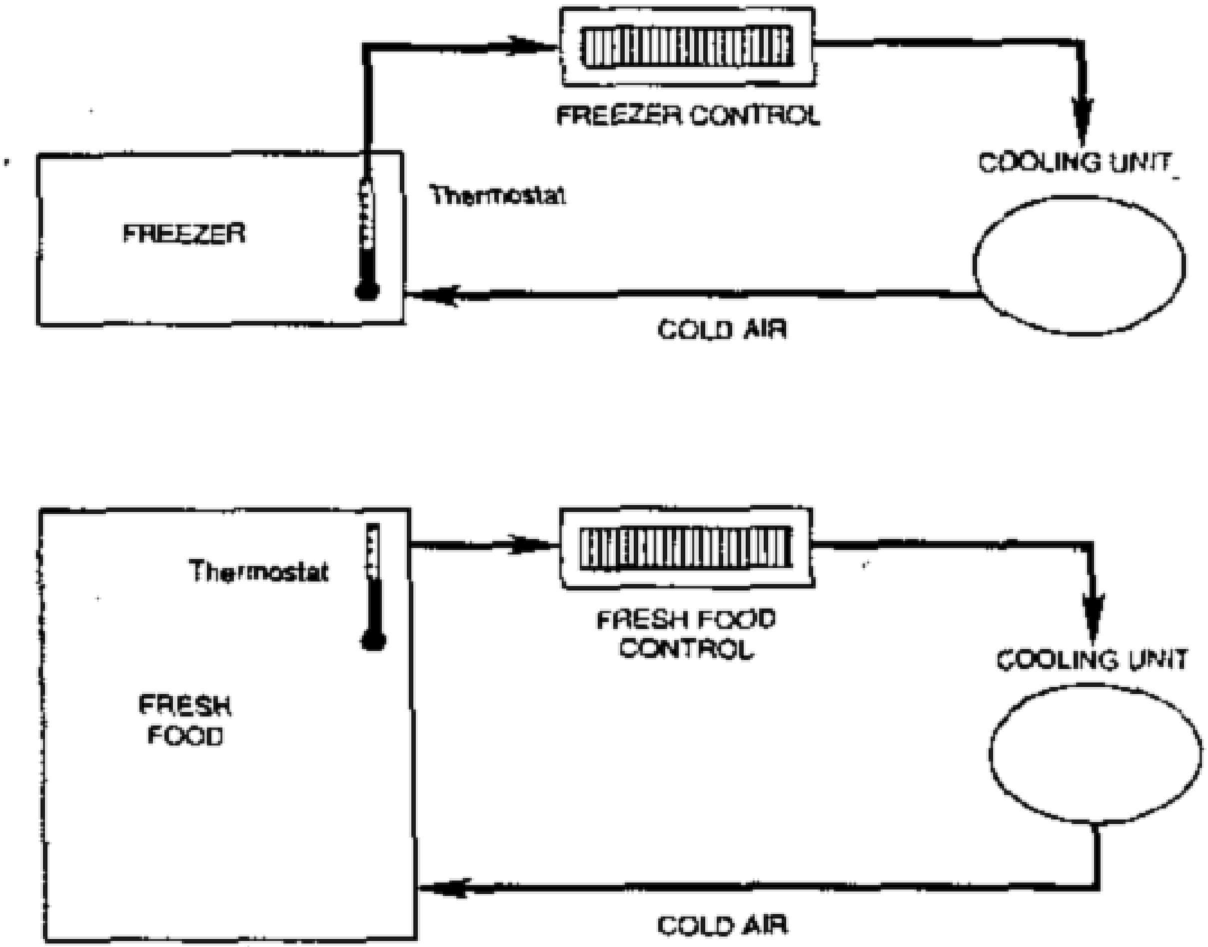
Explaining Conceptual Models Example –Refrigerator

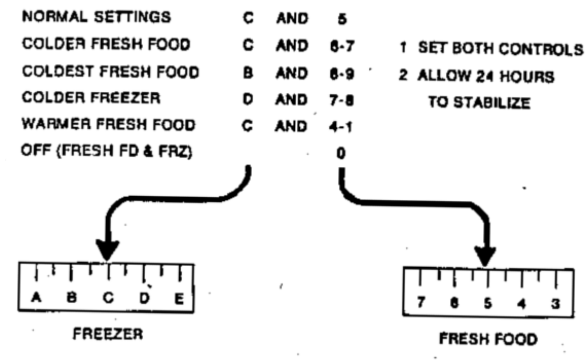


- 2 controls
- Freezer
- Fridge

From D. Norman, The Psychology of Everyday Things.

Example – Refrigerator Conceptual Model 1

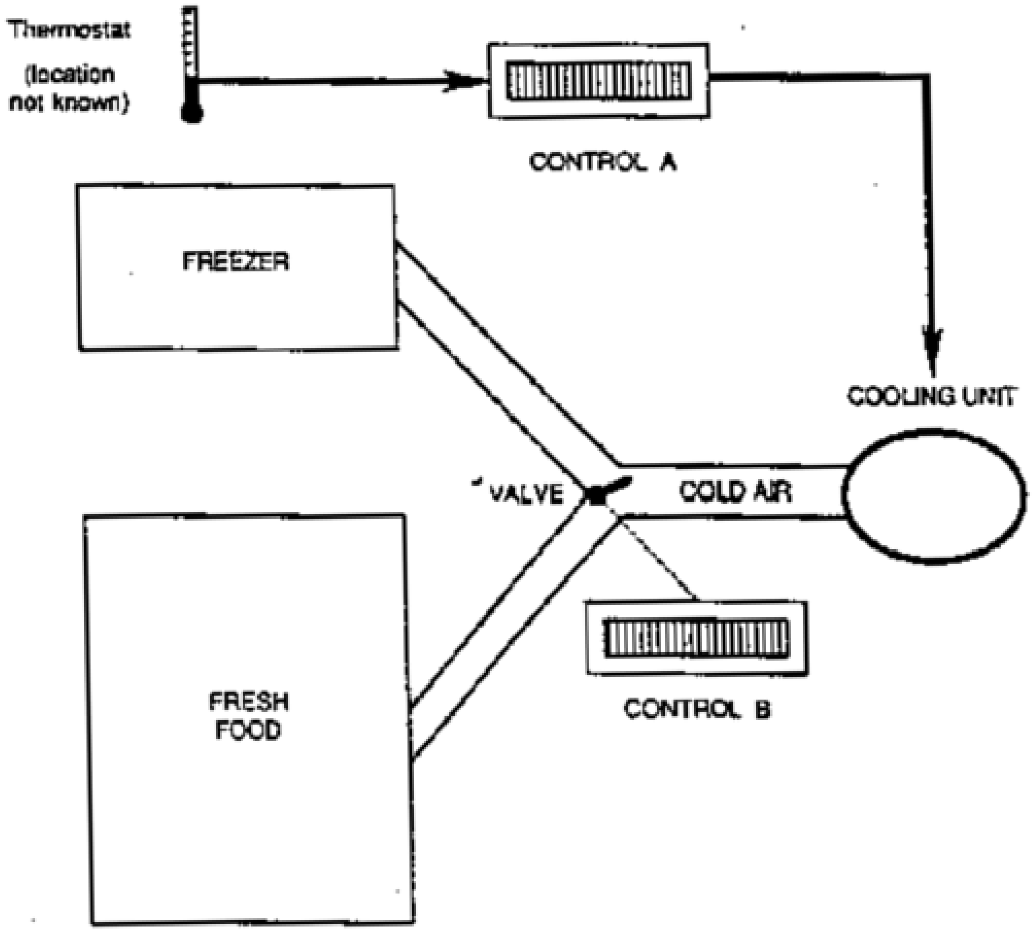


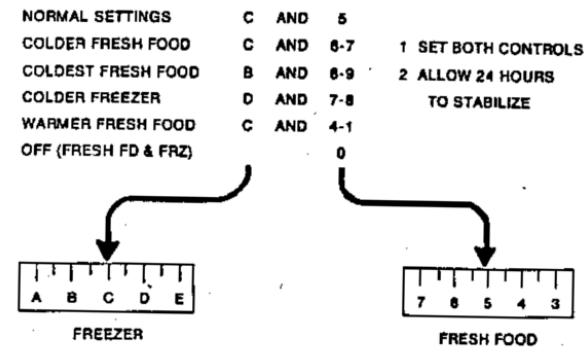


- Idea 1:
  2 cooling units
- One control each

From D. Norman, The Psychology of Everyday Things.

Example – Refrigerator Conceptual Model 2





- Actual design – one cooling unit
- Controls have different functions

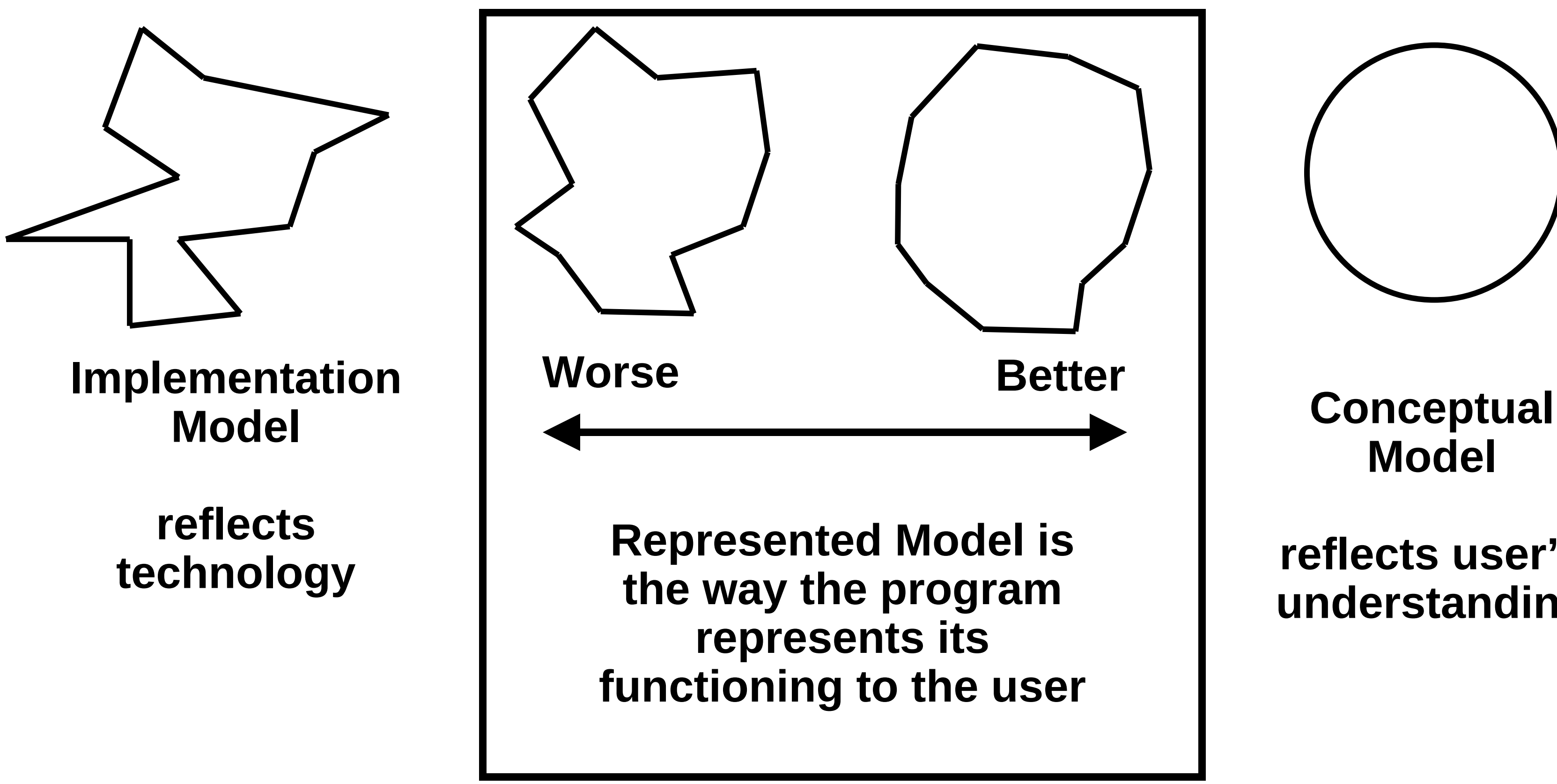
From D. Norman, The Psychology of Everyday Things.

Informal Exercise: Understand Conceptual Models

- Talk to “non-technical” people and try to understand their conceptual model for the following systems
  - Ordering a book from an online bookshop
  - Finding and reading information on the WWW on a particular topic using a search engine
  - Sending an email to someone who is traveling

- Hints to the conceptual model are often provided by
  - Observing what constraints on usage people apply (e.g. you have to do step x before step y)
  - How people explain errors (e.g. assuming the mental model does no include DNS – it is interesting to find out how people explain errors cause by failure of this component)

Implementation, Represented, Conceptual Model



From A. Cooper, About Face 2.0

Example: ‘Geldkarte’ - Difference between the Conceptual Model and Implementation Model

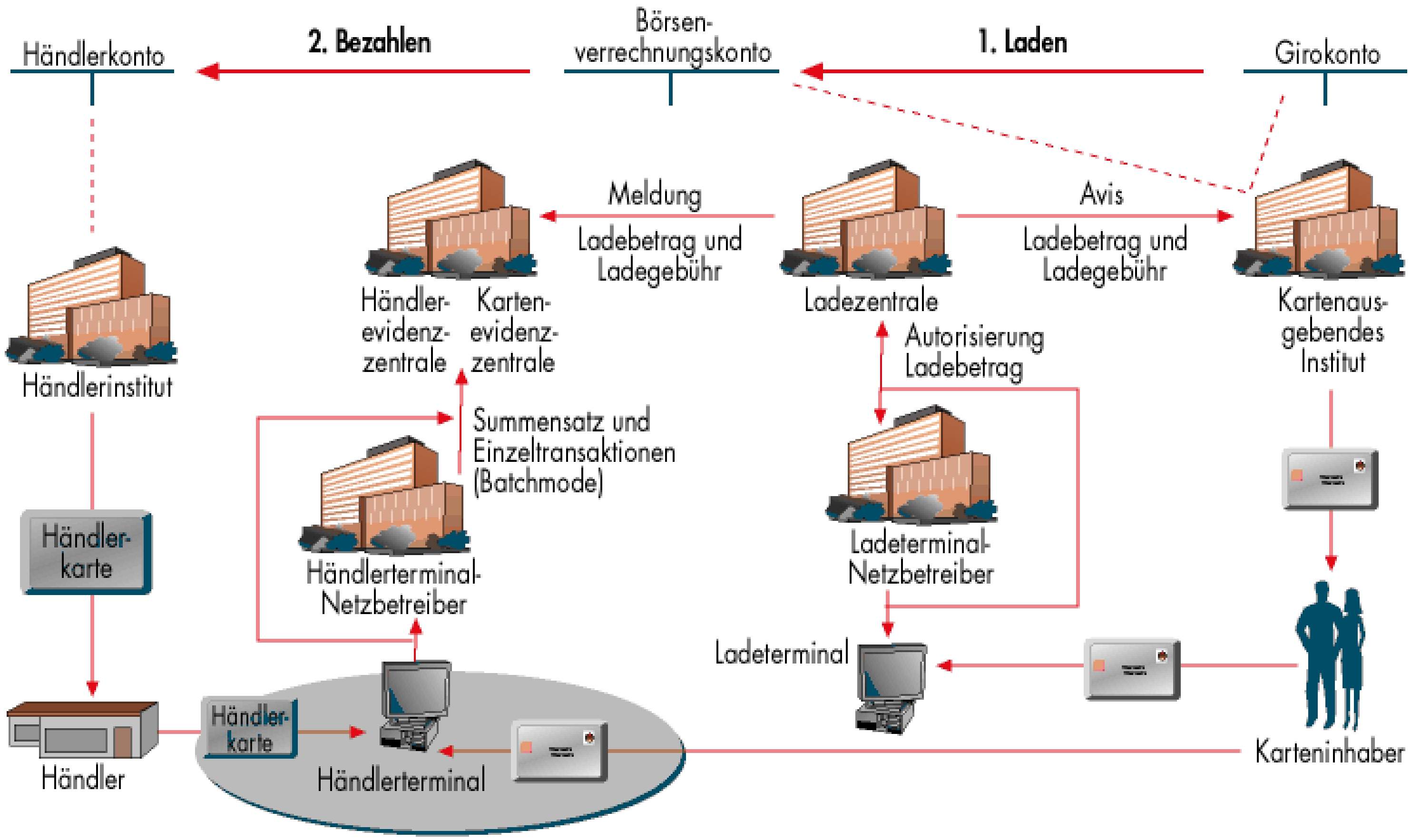
- Store cash on the card

- Pay with the card

Conceptual Model – by the user

Example: ‘Geldkarte’ - Difference between the Implementation Model and Conceptual Model

Some aspects of the implementation model



From IX-Article: Chipgeld by Hans-Bernhard Beykirch, http://www.heise.de/ix/artikel/1998/12/148/

Models – Human and Computer

- Applications work on an Implementation Model
- They were designed after a Conceptual Model
- Users operate on their Mental Model
- The user interface translates between models

- Provocative Statement from A. Cooper
  "Computer literacy is nothing more than a euphemism for making the user stretch to understand an alien logic rather than having software-enabled products stretch to meet the user's way of thinking"

Implementation Model

- Model how a product is implemented
- Implementation details
  - data structures
  - control flow
  - functional components
- Constraints for the implementation, e.g.
  - remote data access vs. local data access
  - different ways to access records in a database depend on the existents of an index
- Terminology
  - terms/wording used reflect on technology
  - example – see error messages on various systems

Mental & Conceptual Model

- From the user's point of view
  - the explanation how something works
  - describing the basic properties and possible behaviour
  - the basis on which assumptions and predictions about the system and its behaviour are made
- Technically this is
  - in most cases a simplification of the underlying technology and
  - will most likely not reflect the correct mechanism or the actual implementation
- From the developers/designer point of view
  - how will the system appear to the user
  - how will the user understand the process
  - a conceptual description of the system at high level
- For the user the conceptual model is a psychological shorthand to understand how they can interact with a system

Conceptual Model
A Definition and its Significance

- A conceptual model is "the proposed system in terms of a set of integrated ideas and concepts about what it should do, behave and look like, that will be understandable by the users in the manner intended"
(Preece, Rogers & Sharp, 2002, Interaction Design, Wiley, p 40)

- "The most important thing to design is the user's conceptual model. Everything else should be subordinated to making that model clear, obvious and substantial. That is almost exactly the opposite of how most software is designed."
(David Liddle, 1996, Design of the conceptual model. In T. Winograd, (editor), Bringing Design to Software. Reading, MA: Addison-Wesley, p17)

Why is this a big issue new with digital products?

- For simple mechanical systems/processes the conceptual model and implementation model are very similar, e.g.
  - Hammer
  - Power drill
- For digital systems the implementation model is often very complex
  - Many components, often distributed
  - The service provided is a result of contributions from different parts
  - The digital components are not visible – even when you open the device
- Users still have a simple conceptual models to operate digital products
  - Based on what they see and their experience gained in use
  - By the control options they are given
  - By the behaviour and reactions they observe
  - By what they have learned about the system

How to get a Conceptual Model? 1st Analyse Problem Space

- Understand and analyse the problem space
  - Make problems of existing solution explicit (e.g. list of issue)
  - Why did you characterize them as problem? (because of intuition, reports, user studies, experiments?)
  - How does the envisioned concept solve the problem better? (is it faster, easier to use, easier to deploy, more fun?)
  - How would you see people using it with their current way of doing things?
  - How will it support people in their activities?
  - Will it really help them?
  - Would the envisioned solution introduce new problems? Which?
- Understanding the problem space leads to ideas about
  - What type of device/technology may be appropriate
  - What functionality is required under what conditions
  - What interaction metaphors can be used

How to get a Conceptual Model? 2nd Understand the User's Goals

- What is the user (or are the users) trying to achieve
  - What is the final goal?
  - Are there intermediate goals?
  - Are there conflicting goals and trade-offs?
  - If multiple users - how are their goals related?
- Understand the tasks involved
  - What tasks and subtasks are carried out?
  - Why is the user doing these tasks?
  - How is this related to a potential solution?
  - Will the solution eliminate task and still reach the goals?
- Relate the user's goals and tasks to the business model of the envisioned solution
  - Especially for service oriented digital products
  - Are there conflicts of interest between provider and consumer (e.g. quick answers and hence short connection time may conflict with a business model based on connection time, see WAP pages)

How to get a Conceptual Model? 3rd Make an Explicit Model

- Based on the analyses of the problem space and goals, identify
  - appropriate interface
  - Interaction methods and metaphors
  - Interaction paradigms
- Make the conceptual model explicit
  - Describe scenarios in detail and the use of the products
  - Storyboarding and videos
  - Sketching out ideas, design sketches
  - Put the solution into the wider context (e.g. an application on the mobile phone in the context of phone usage in general, what happens if a call comes in while you use the application?)
  - Create prototypes
    - low fidelity, e.g. paper prototypes, digital mock-ups (e.g. Flash examples, HTML-Forms with no Backend)
  - Documentation and training material

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Analyzing existing systems

- Observe usage manually → observation
- Monitor usage automatically
  - Use functions/mechanism included in products, e.g.
    - Log files for using web applications
  - Use additional software to monitor usage
    - Key logger
    - Proxy server
    - Screen capture tool
  - Extend the software that is used to track/analyze usage
  - Typical questions
    - What applications are used in the work process
    - How often is application X or function Y used
    - What files are accessed during the work process

- Tools, e.g.
  - analog - Web analysis software
    http://www.analog.cx
  - Filemon – logging files used
    http://www.sysinternals.com/Utilities/Filemon.html

User studies on existing systems

- Carry out user studies / controlled tests on the existing software
  - Provides understanding of the current system
  - Show opportunities for improvements
  - Base line to compare the new development
    - Ease of use
    - Speed for defined tasks
    - Frequency of errors
    - Effort for training
- Focus of the analysis depends on how the approach for the new development
  - Upgrading/improving the current system
  - Redesigning the system/software
  - Restructuring the work process and introduction of new software

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Result of the analysis

- Definition of Requirements
- Clear description of
  - Goals of the user when operating the system
  - Tasks that need to be support
  - Context of use (technical, social)
  - Description of potential users
  - Side conditions
- Application / system concept
  - Description of the conceptual model
  - Concept design, sketches, video → design phase
  - Scenarios based on the contextual observation

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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

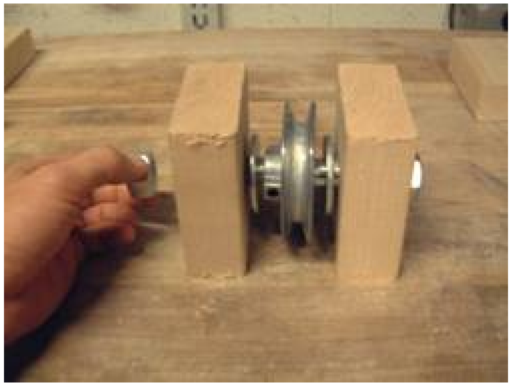
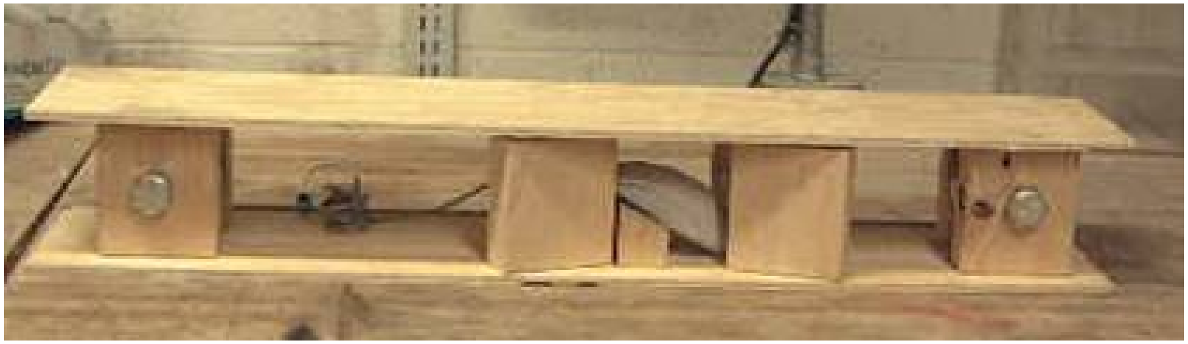
- Interface to move up and down
- Visualization of rainforest vegetation at the selected height
- Exhibition scenario
- Users: kids 4-8

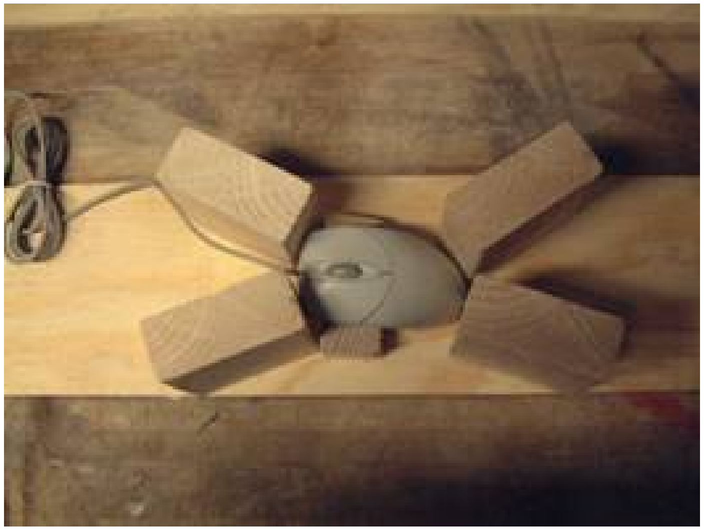
http://web.media.mit.edu/~win/Canopy%20Climb/Index.htm

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



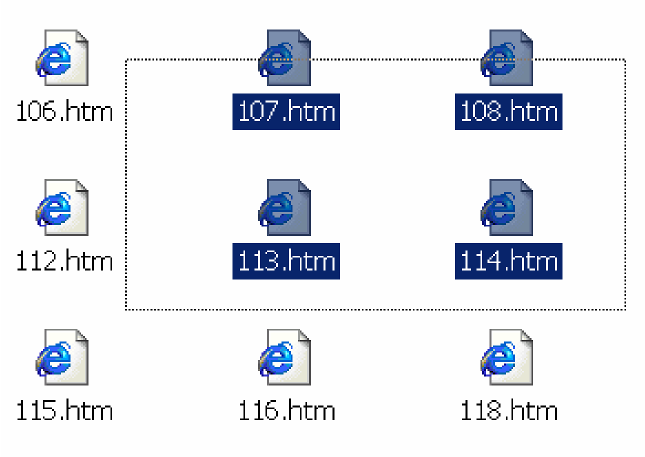
- Low tech implementation
- Mouse scrolling

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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  - 4.7.4 Force feedback
  - 4.7.5 Further forms of input and capture
  - 4.7.6 Visual and audio output
  - 4.7.7 Printed (2D/3D) output
  - 4.7.8 Further output options
  - 4.7.9 User interfaces for authentication

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
  - …

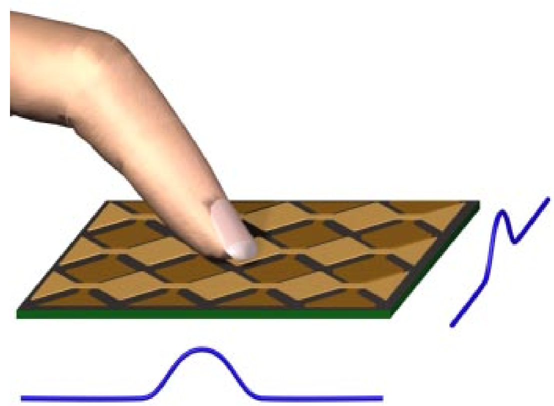
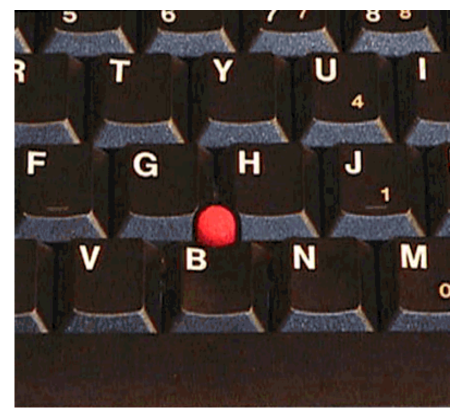
Classification of Pointing devices

- 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)



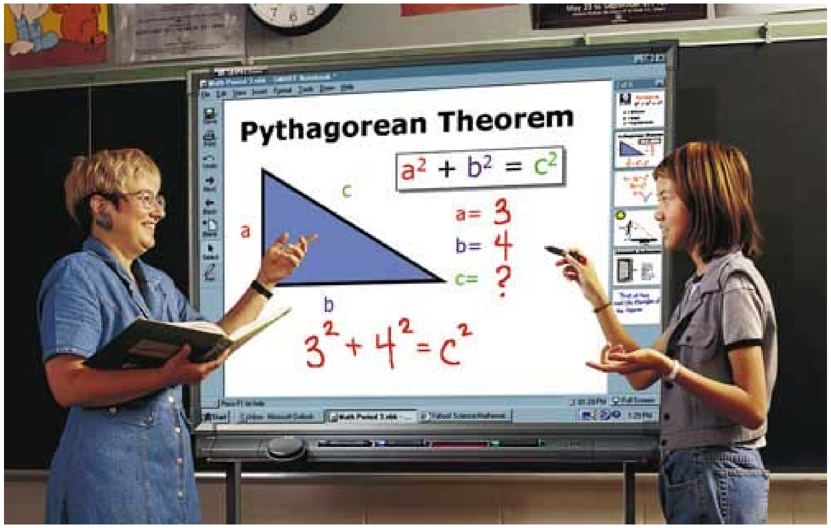


Virtual Touch Screen

- 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

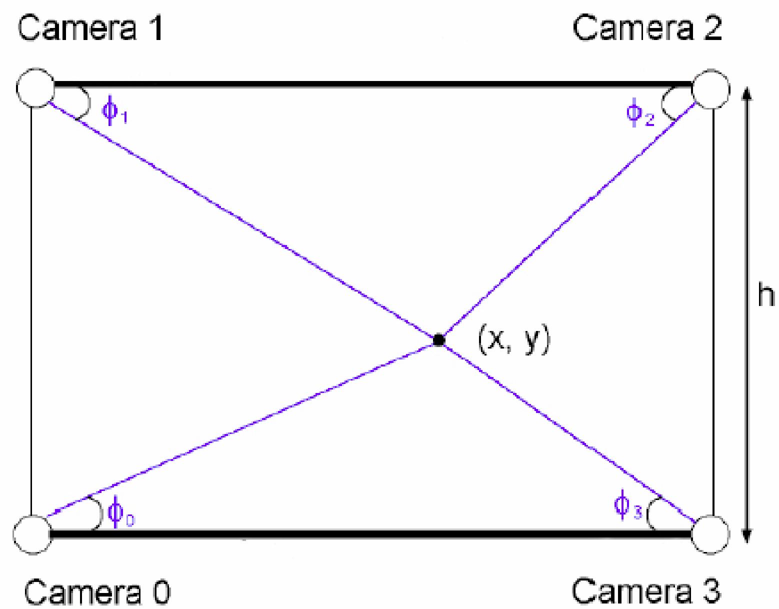


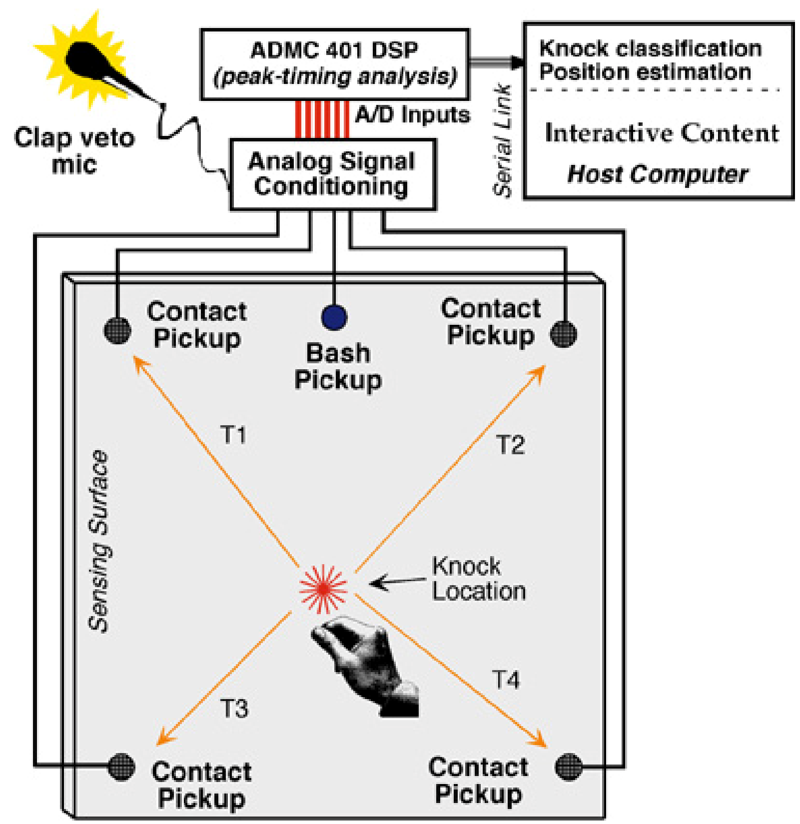
Figure 2: Camera Identification of a Contact Point

- 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/



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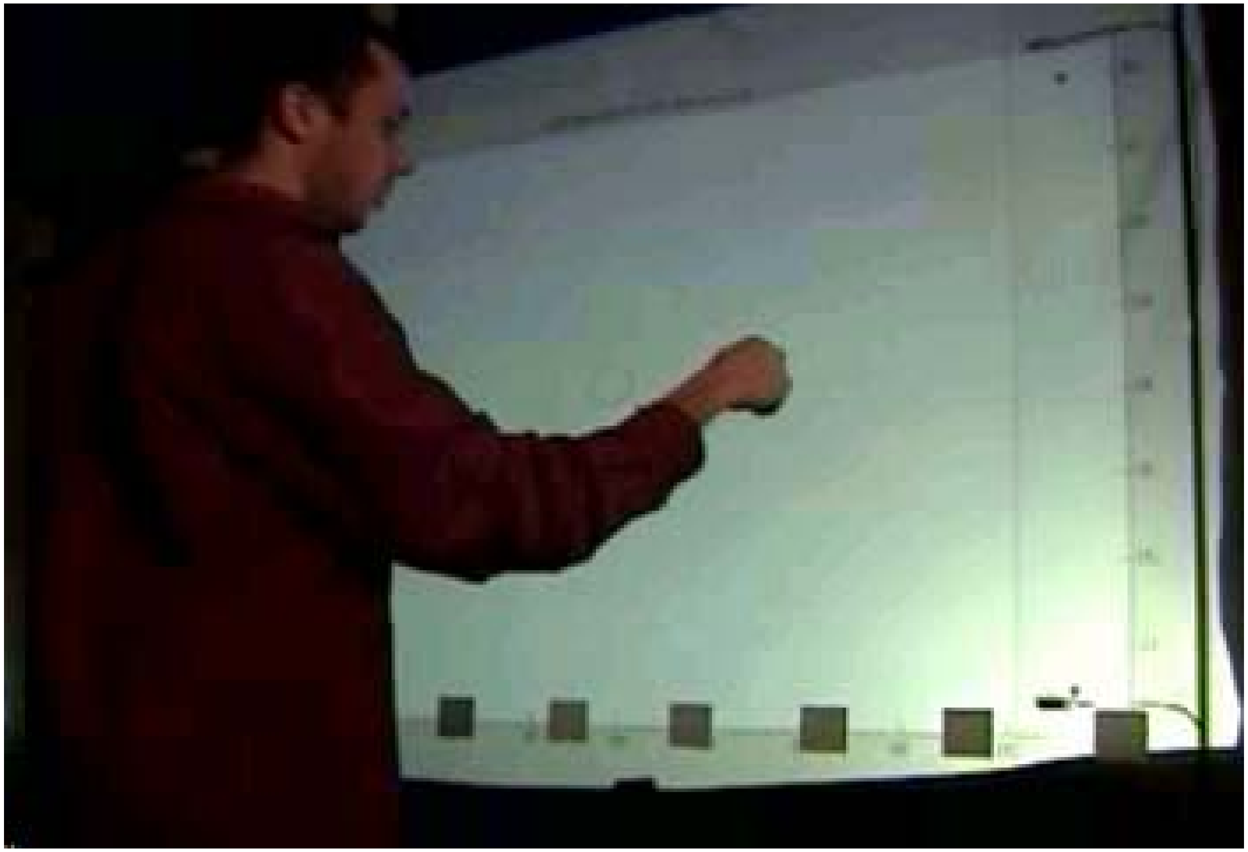
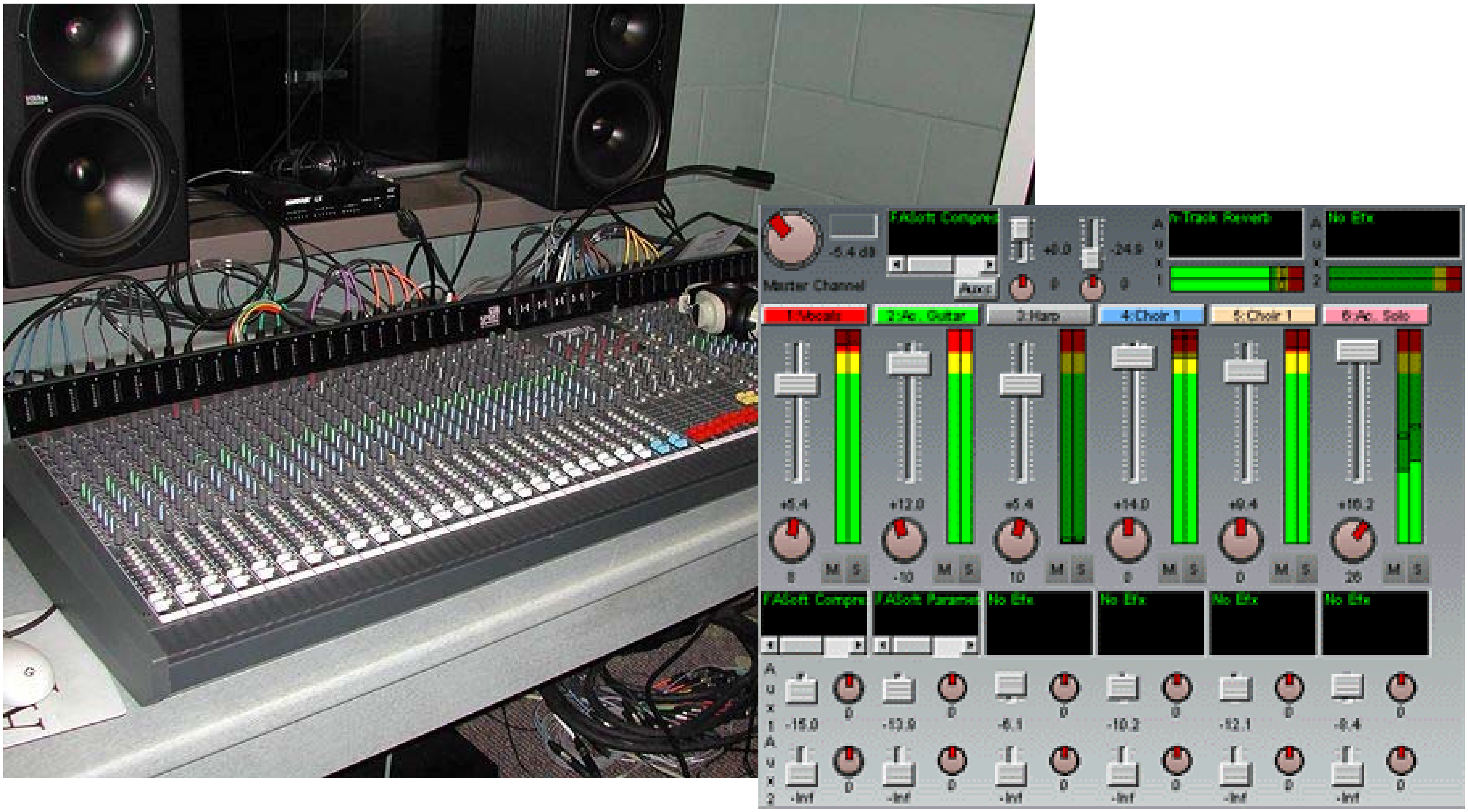


http://www.media.mit.edu/resenv/Tapper/

Example: Window Tap Interface

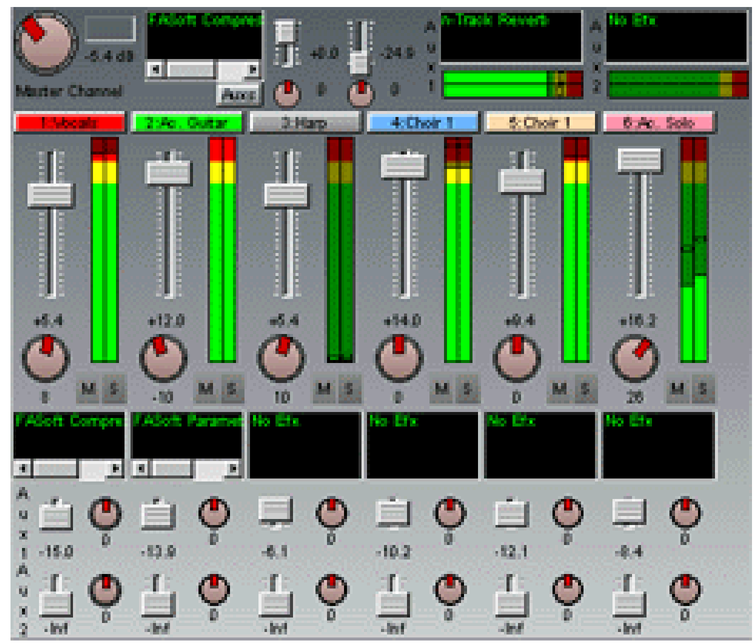
- http://www.media.mit.edu/resenv/Tapper/

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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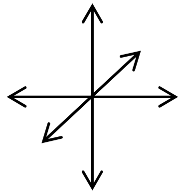
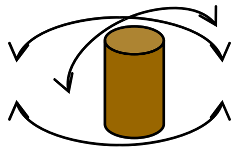
3D Input
6 DOF Interfaces

- 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

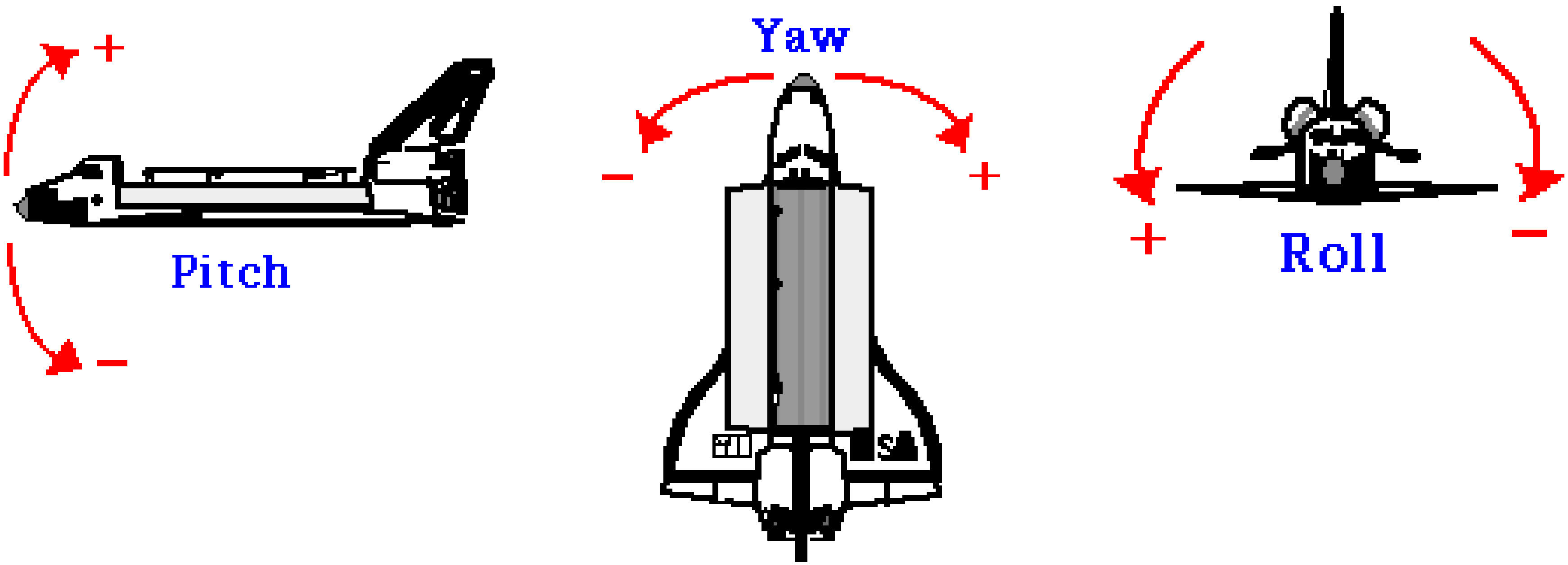
Translation



rotation



Basic Terms: different rotations

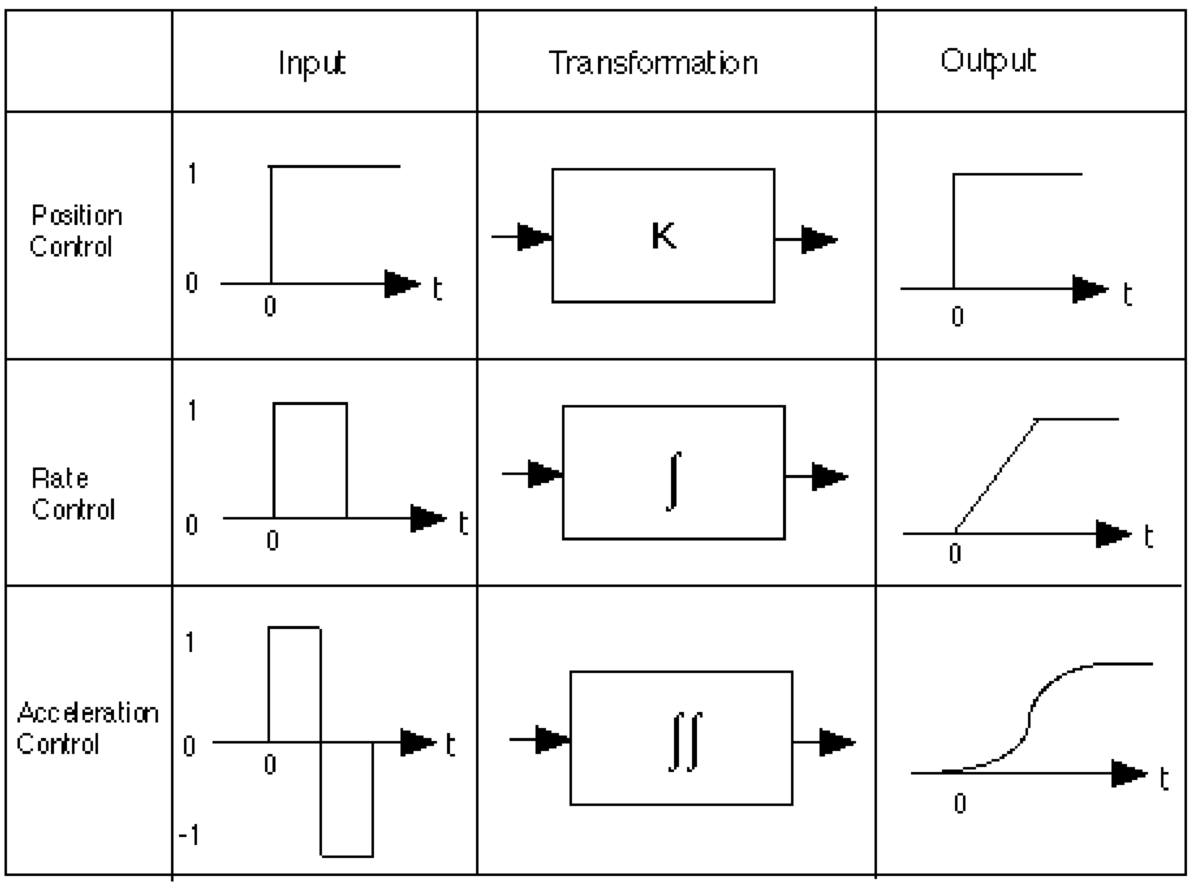


http://liftoff.msfc.nasa.gov/academy/rocket_sci/shuttle/attitude/pyr.html

6DOF

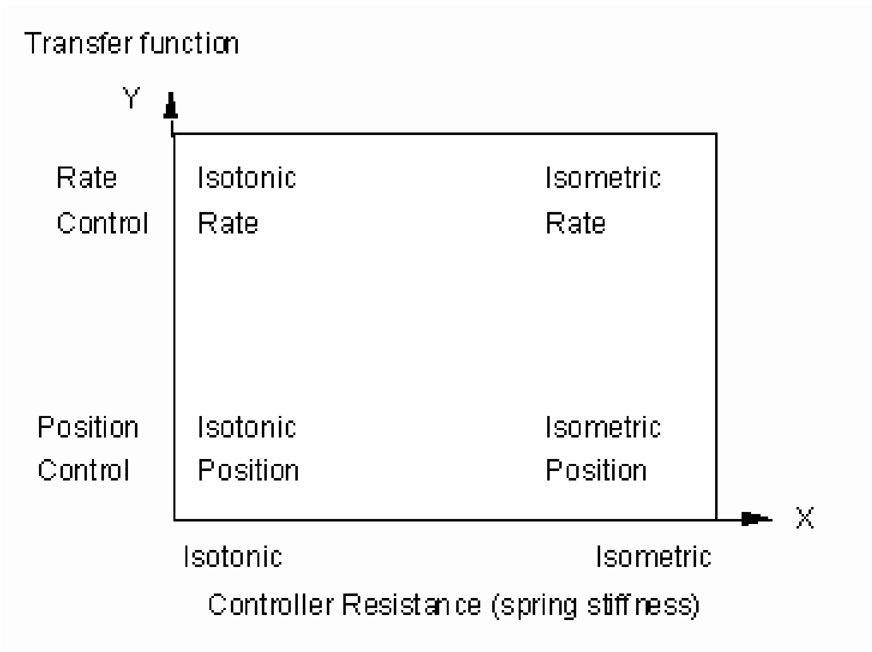
- Controller resistance
  - Isotonic = device is moving, resistance stays the same
    - Displacement of device is mapped to displacement of the cursor
  - Elastic
  - Isometric = device is not moved
    - Force is mapped to rate control
- Transfer function
  - Position control
    - Free moving (isotonic) 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

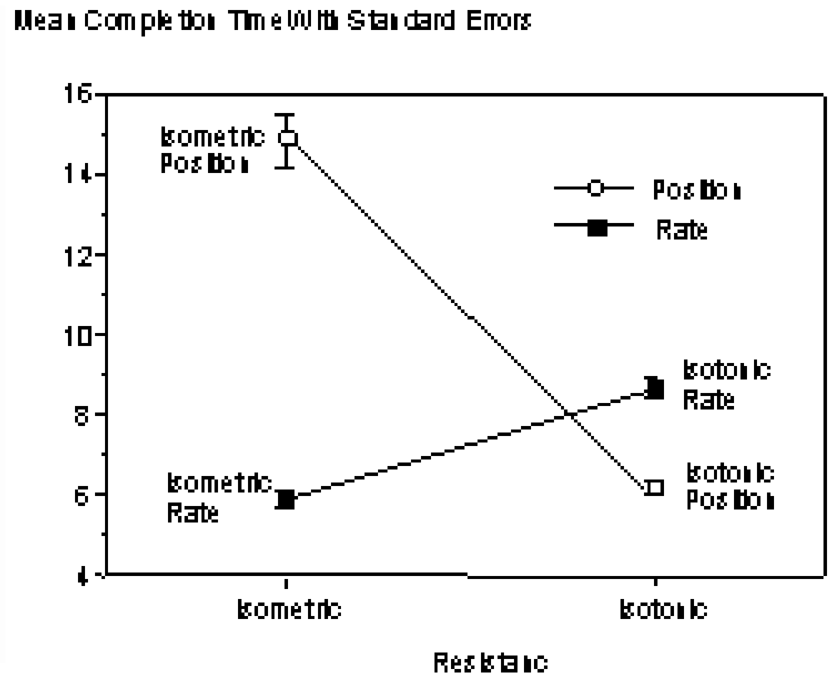
Analysis of Position versus Rate Control



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

Performance depends on transfer function and resistance

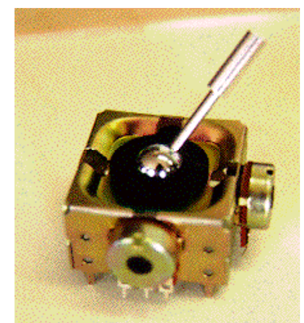




http://www.siggraph.org/publications/newsletter/v32n4/contributions/zhai.html

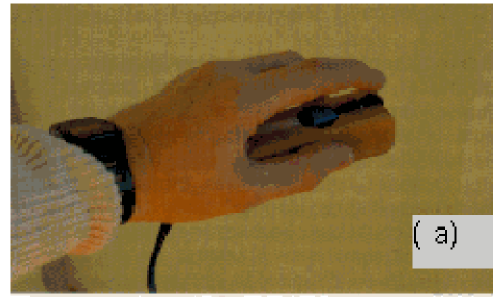
Controller resistance

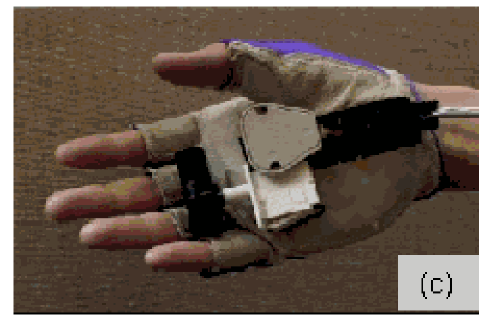
- **Isometric**
  - pressure devices / force devices
  - Infinite resistance
  - device that senses force but does not perceptibly move
- **Isotonic**
  - displacement devices, free moving devices or unloaded devices
  - zero or constant resistance
- **Elastic**: Device's resistive force increases with 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*.



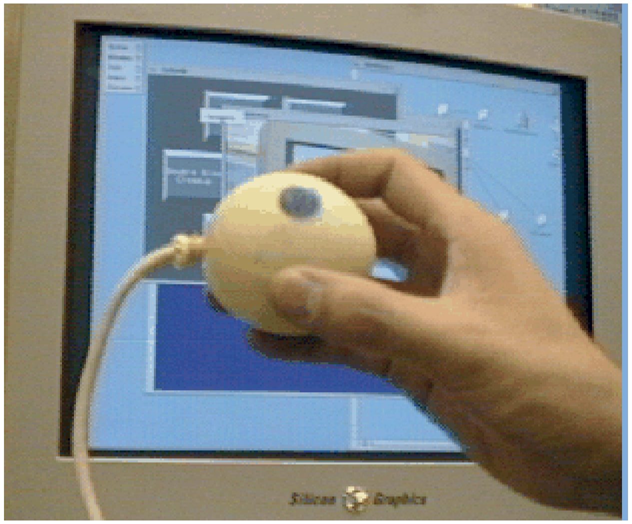


http://www.almaden.ibm.com/u/zhai/papers/siggraph/final.html

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.

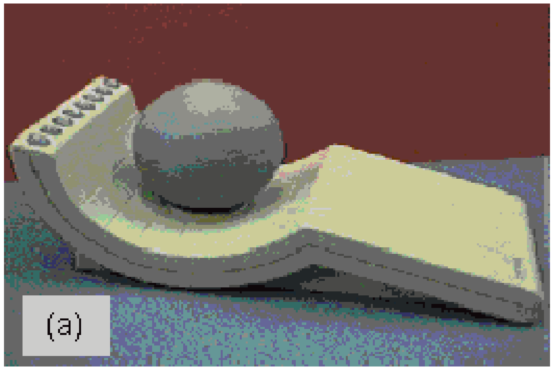
http://www.almaden.ibm.com/u/zhai/papers/siggraph/final.html

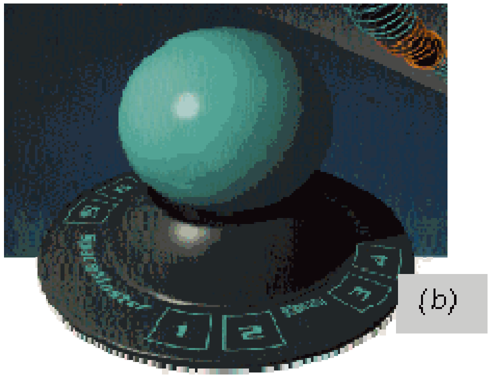


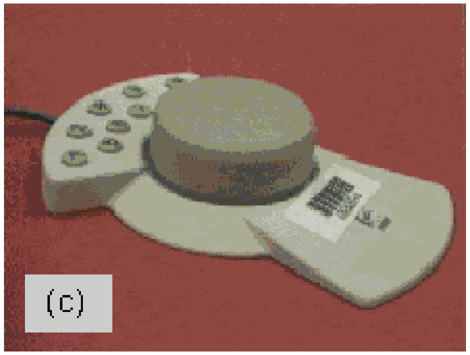
- The form factor of devices has a significant impact on the pointing performance. E.g. Fingerball vs. glove

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.







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)

Chapter 4
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  - 4.7.2 3D input
  - **4.7.3 Force feedback**
  - 4.7.4 Input device taxonomy
  - 4.7.5 Further forms of input and capture
  - 4.7.6 Visual and audio output
  - 4.7.7 Printed (2D/3D) output
  - 4.7.8 Further output options
  - 4.7.9 User interfaces for authentication

Force Feedback Mouse

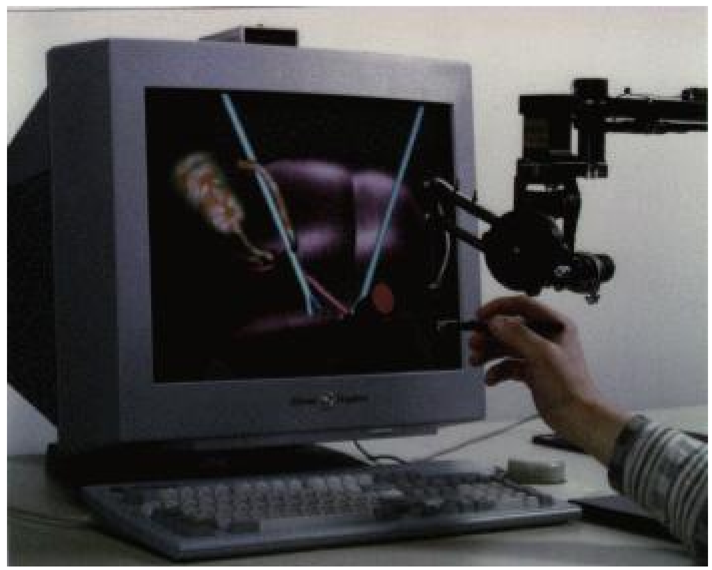
- Pointing devices with *force feedback*:
  - Feeling a resistance that is controllable
  - Active force of the device
  - Common in game controllers (often very simple vibration motors)

- 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)

	Number of Dimensions							
Property Sensed	1		2				3	
Position	Rotary Pot	Sliding Pot	Tablet & Puck	Tablet & Stylus	Light Pen	Isotonic Joystick	3D Joystick	M
Position				Touch Tablet	Touch Screen			T
Motion	Continuous Rotary Pot	Treadmill	Mouse			Sprung Joystick Trackball	3D Trackball	M
Motion		Ferinstat				X/Y Pad		T
Pressure	Torque Sensor					Isometric Joystick		T
	rotary	linear	puck	stylus finger hoiz.	stylus finger vertical	small fixed location	small fixed with twist	

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)

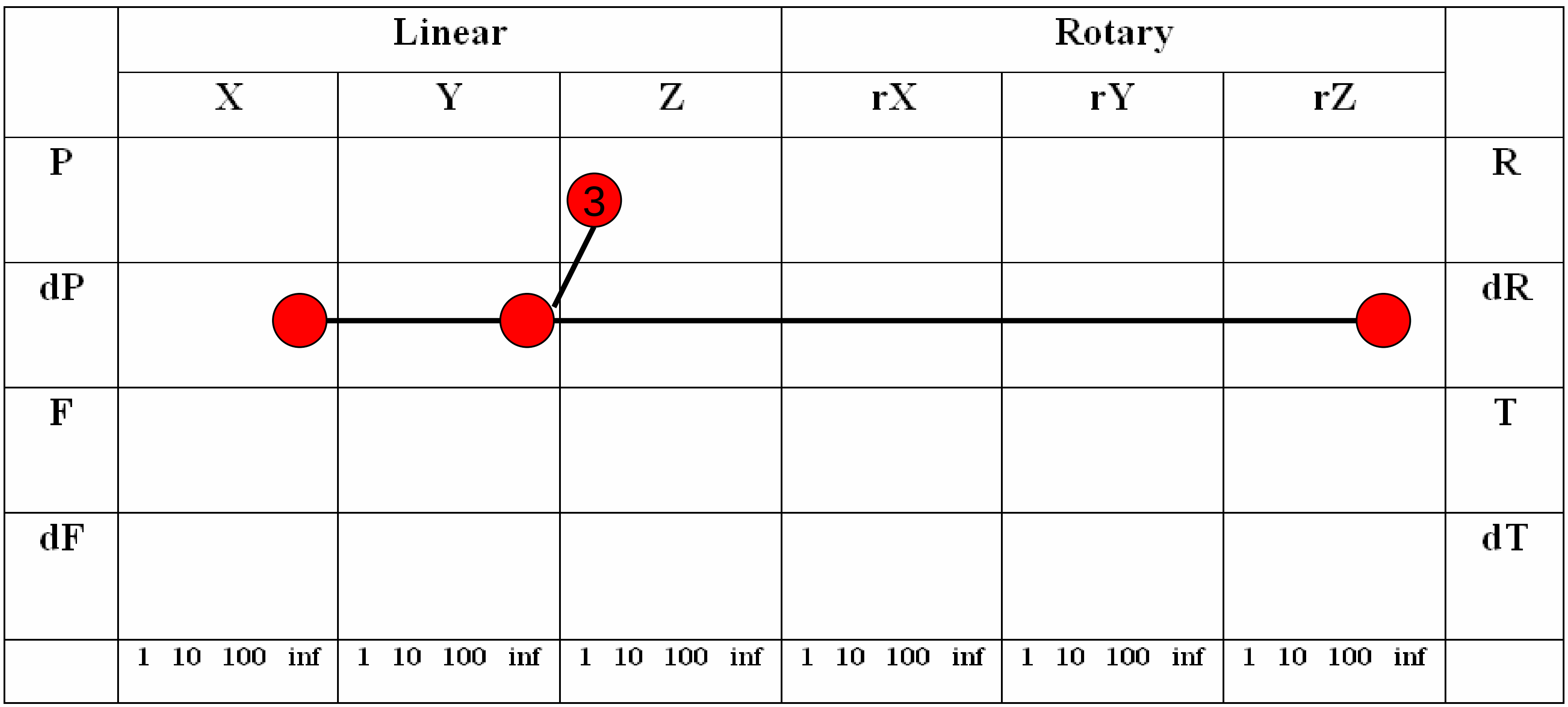
	Linear			Rotary			
	X	Y	Z	rX	rY	rZ	
P							R
dP							dR
F							T
dF							dT
	1 10 100 inf	1 10 100 inf	1 10 100 inf	1 10 100 inf	1 10 100 inf	1 10 100 inf	

Input Device Taxonomy (Card91)

	Linear			Rotary			
	X	Y	Z	rX	rY	rZ	
P							R
dP							dR
F							T
dF							dT
	1 10 100 inf	1 10 100 inf	1 10 100 inf	1 10 100 inf	1 10 100 inf	1 10 100 inf	

- Example: Touch Screen

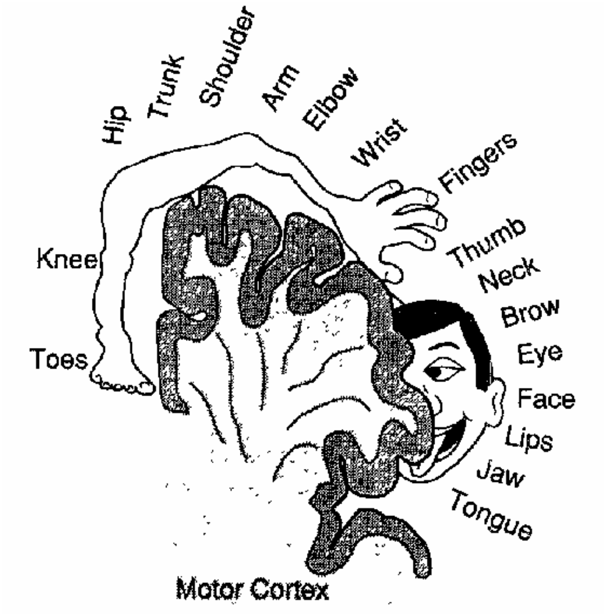
Input Device Taxonomy (Card91)



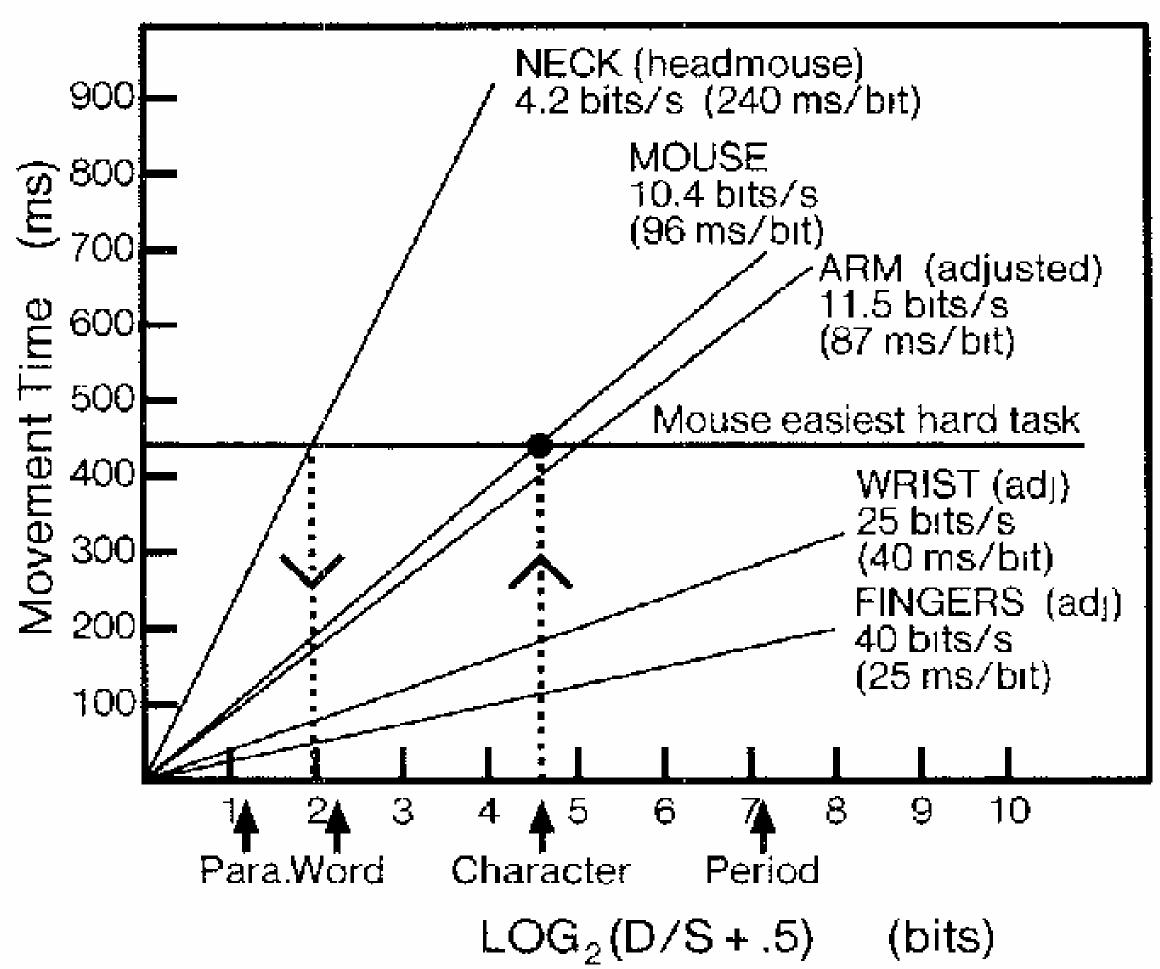
- Example: Wheel mouse

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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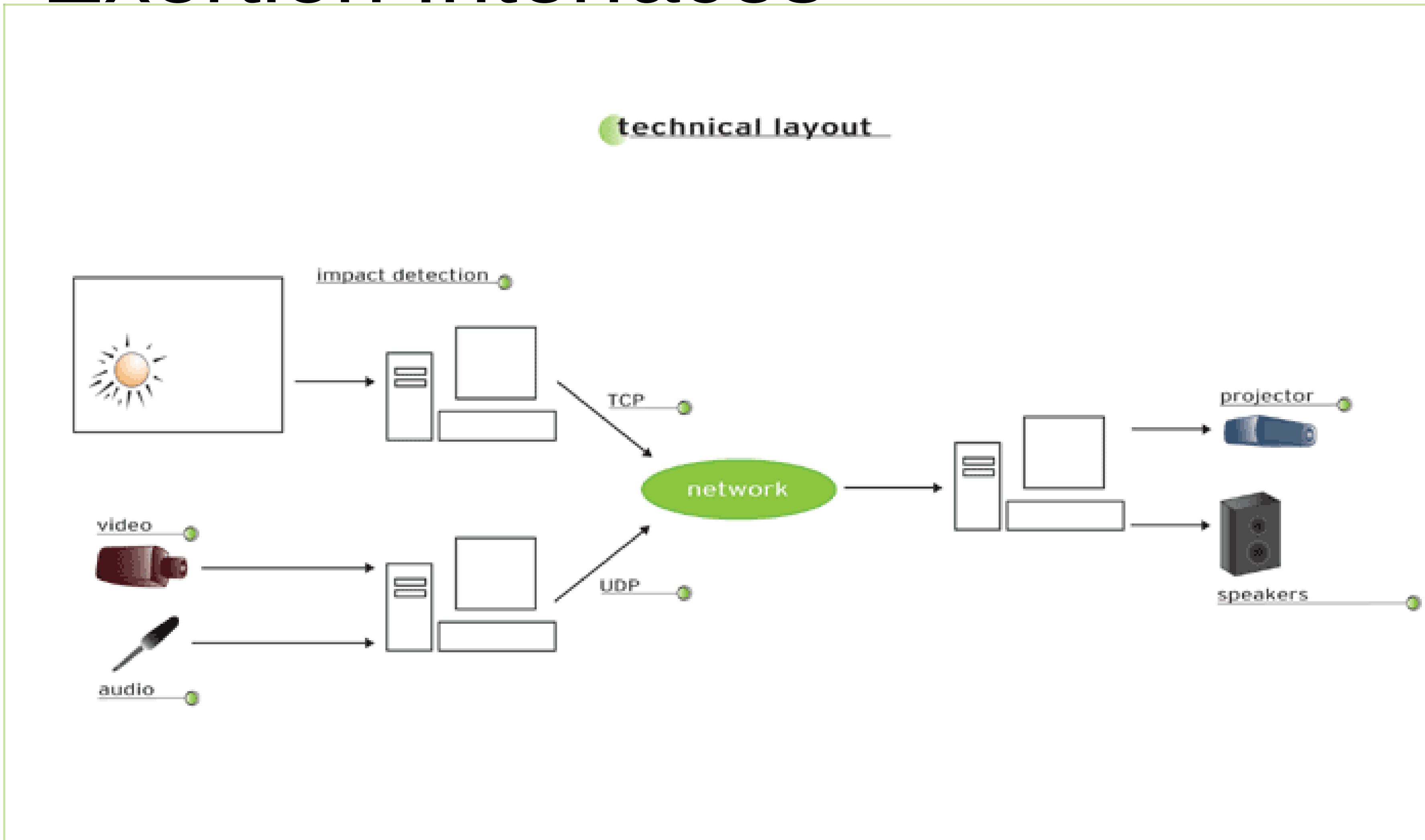
Exertion Interfaces

Video

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

Exertion Interfaces



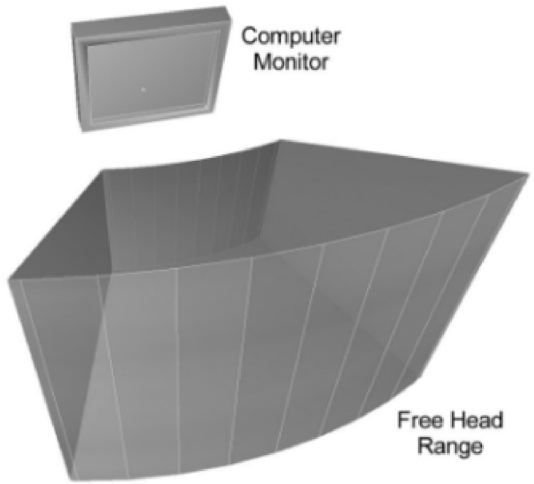
http://www.exertioninterfaces.com/technical_details/index.htm

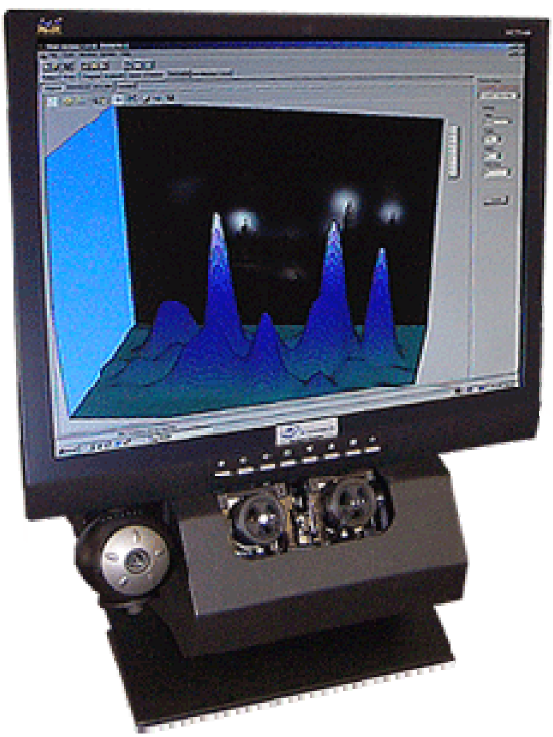
Eye Tracker
see exercise for details

- ERICA
  http://www.eyeresponse.com/
- Eye gaze system used in the exercise

Eye Follower (video)

- Free Head Motion
- Automatic Eye Acquisition
- Binocular Eyetracking
- High Gazepoint Tracking Accuracy

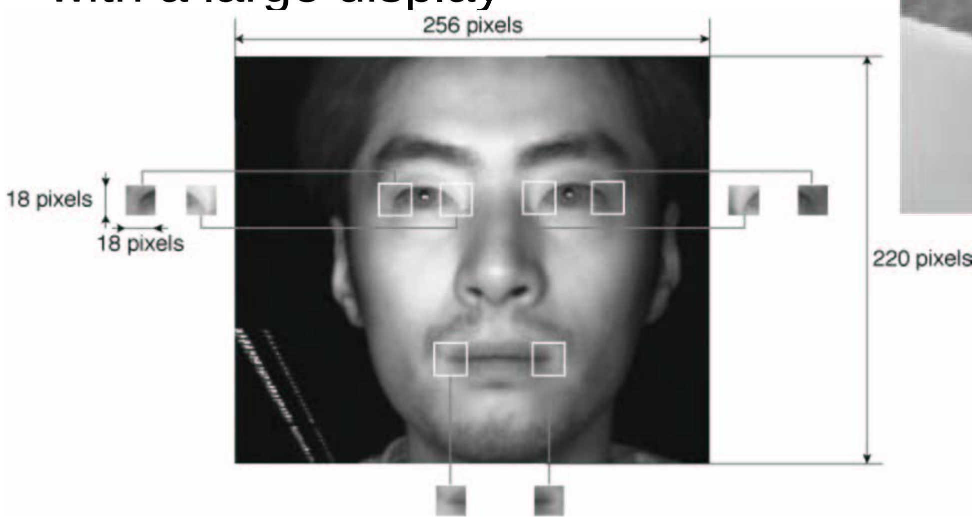


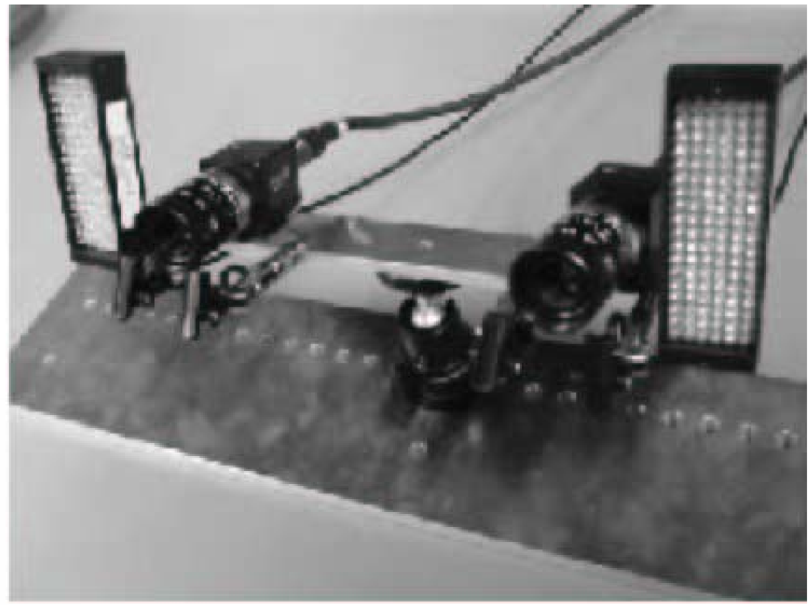


http://www.eyegaze.com/

Example: Vision-Based Face Tracking System for Large Displays

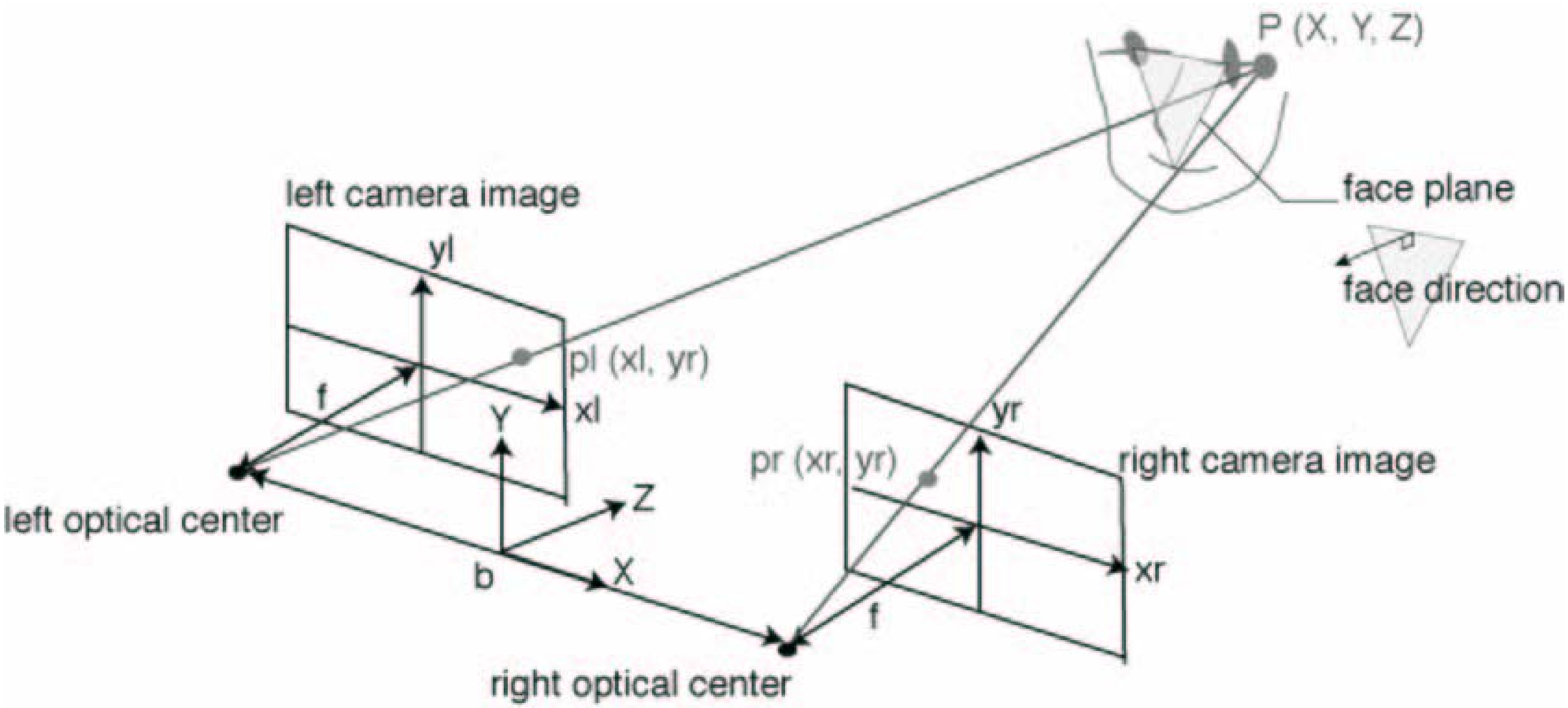
- stereo-based face tracking system
- can track the 3D position and orientation of a user in real-time
- application for interaction with a large display





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

Example: Vision-Based Face Tracking System for Large Displays



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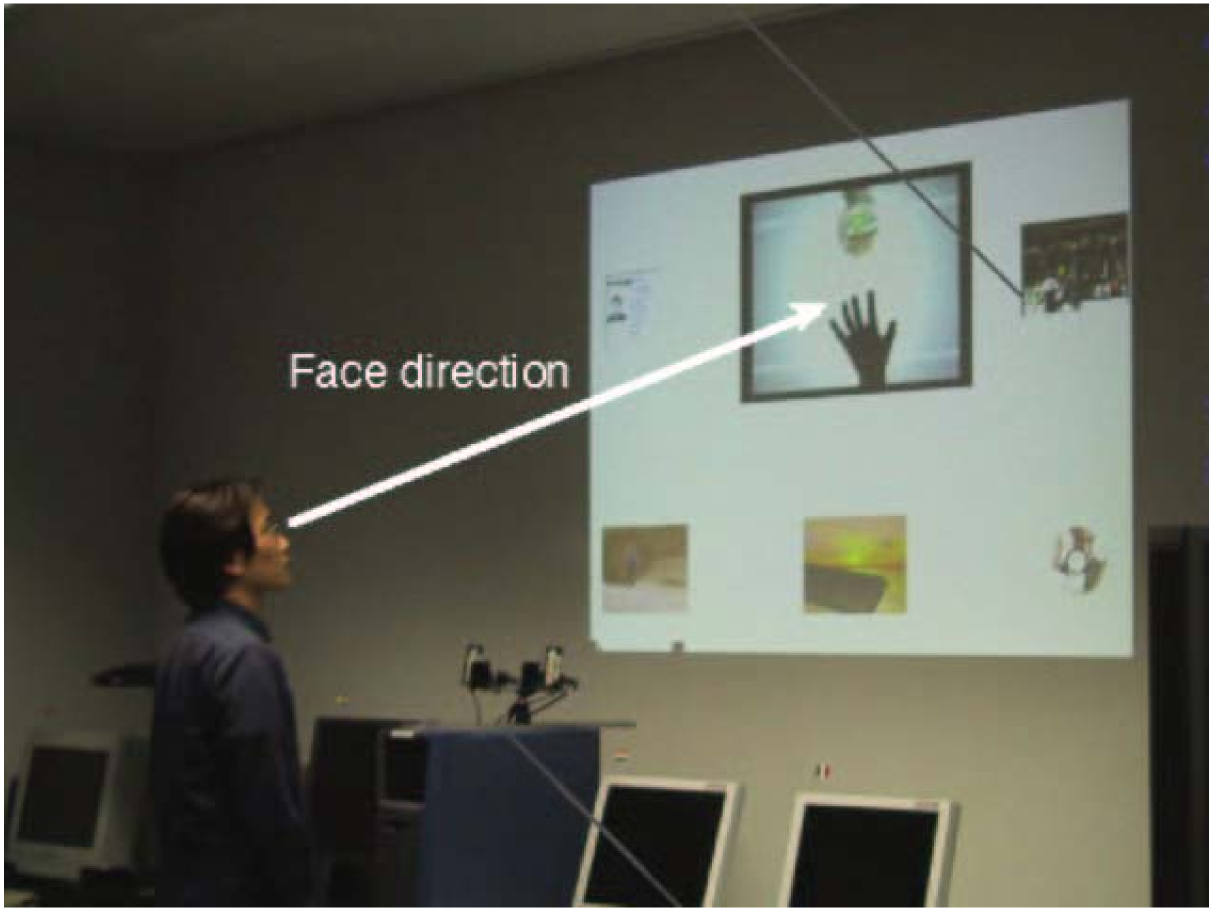


http://naka1.hako.is.uec.ac.jp/papers/eWallUbicomp2002.pdf

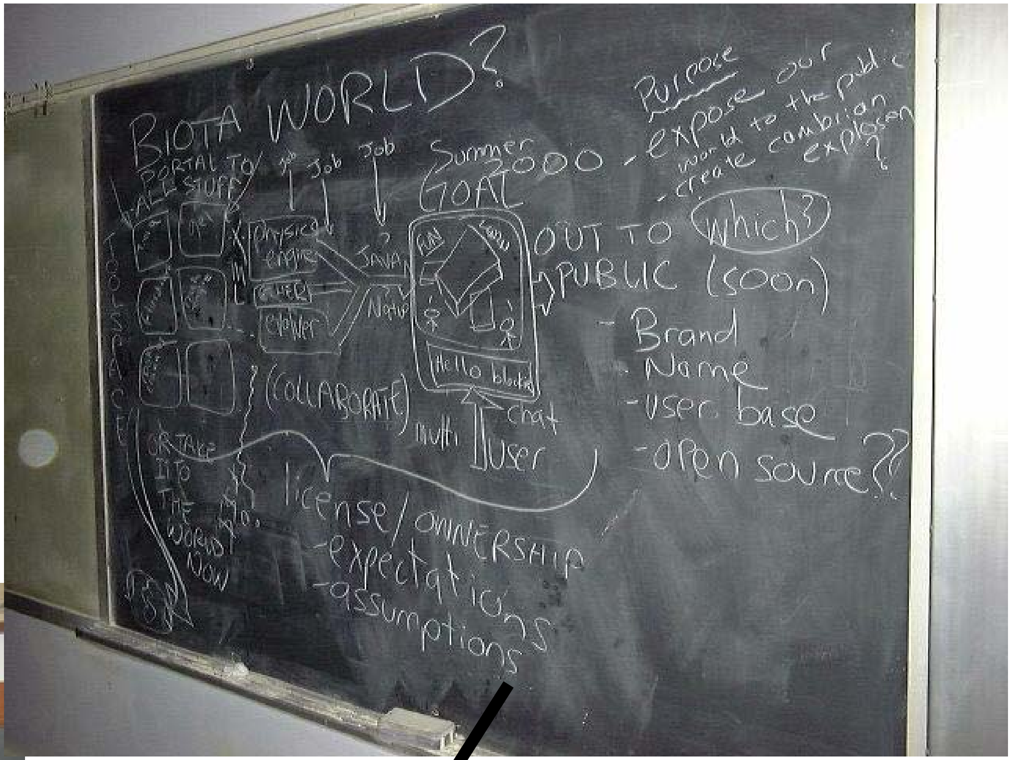
Input beyond the screen

- Capture (photo, tracking)
- Interactive modeling

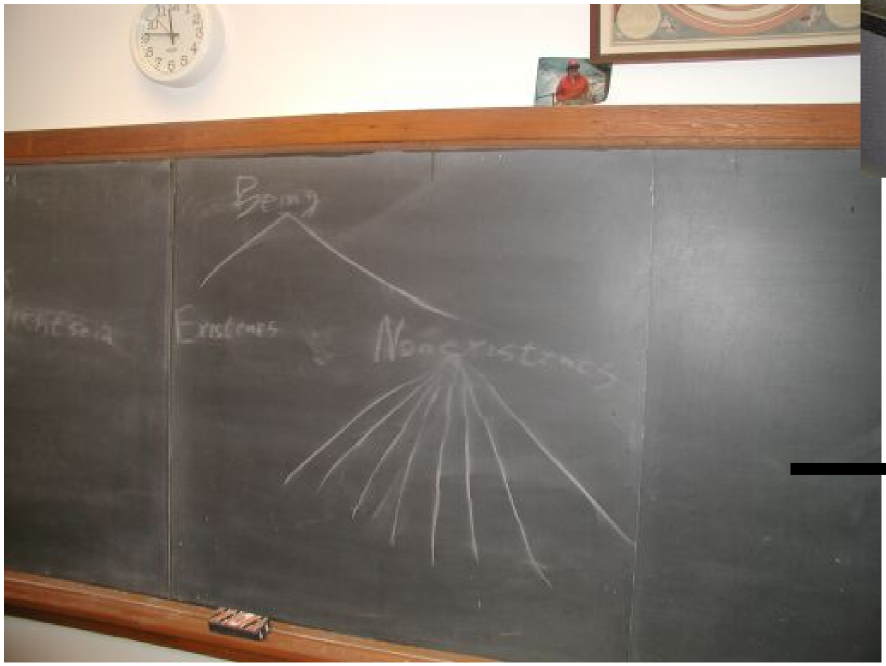
Capture Interaction

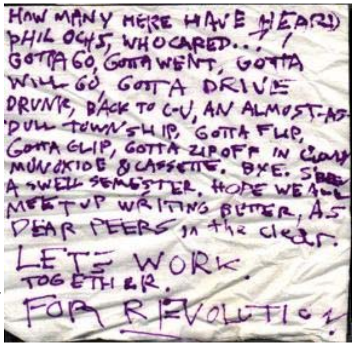
- Mimio
  - Tracking of flip chart makers
  - Capture writing and drawaing on a large scale
- PC Notes Taker
  - Capture drawing and handwriting on small scale

Photo Capture

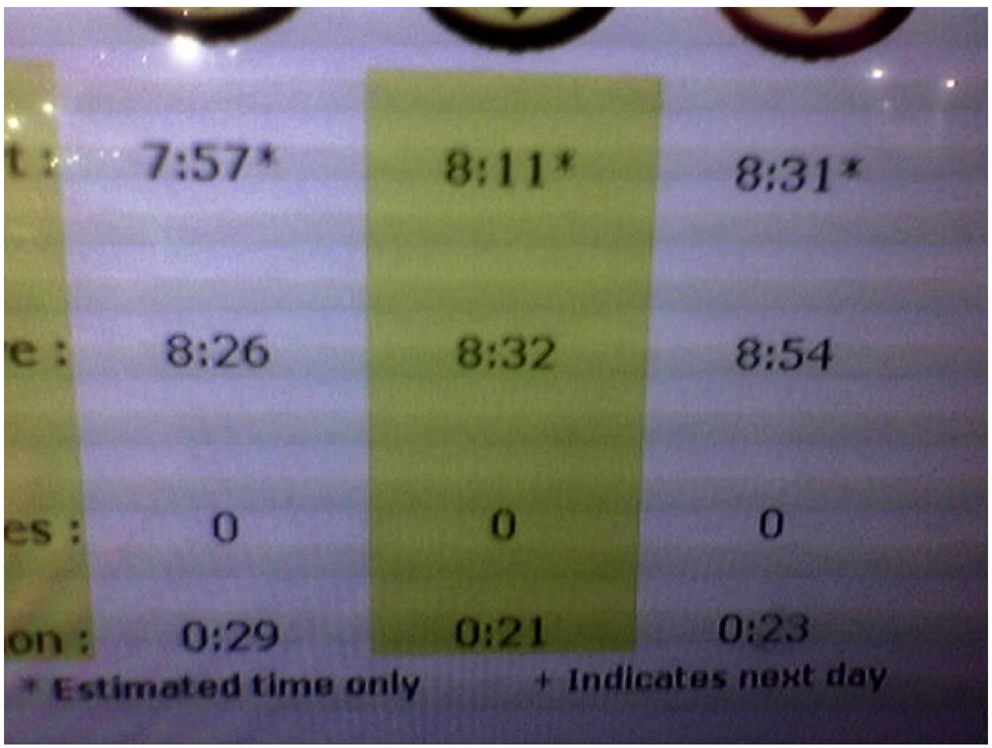


- Write on traditional surfaces, e.g. blackboard, white board, napkin
- Capture with digital camera





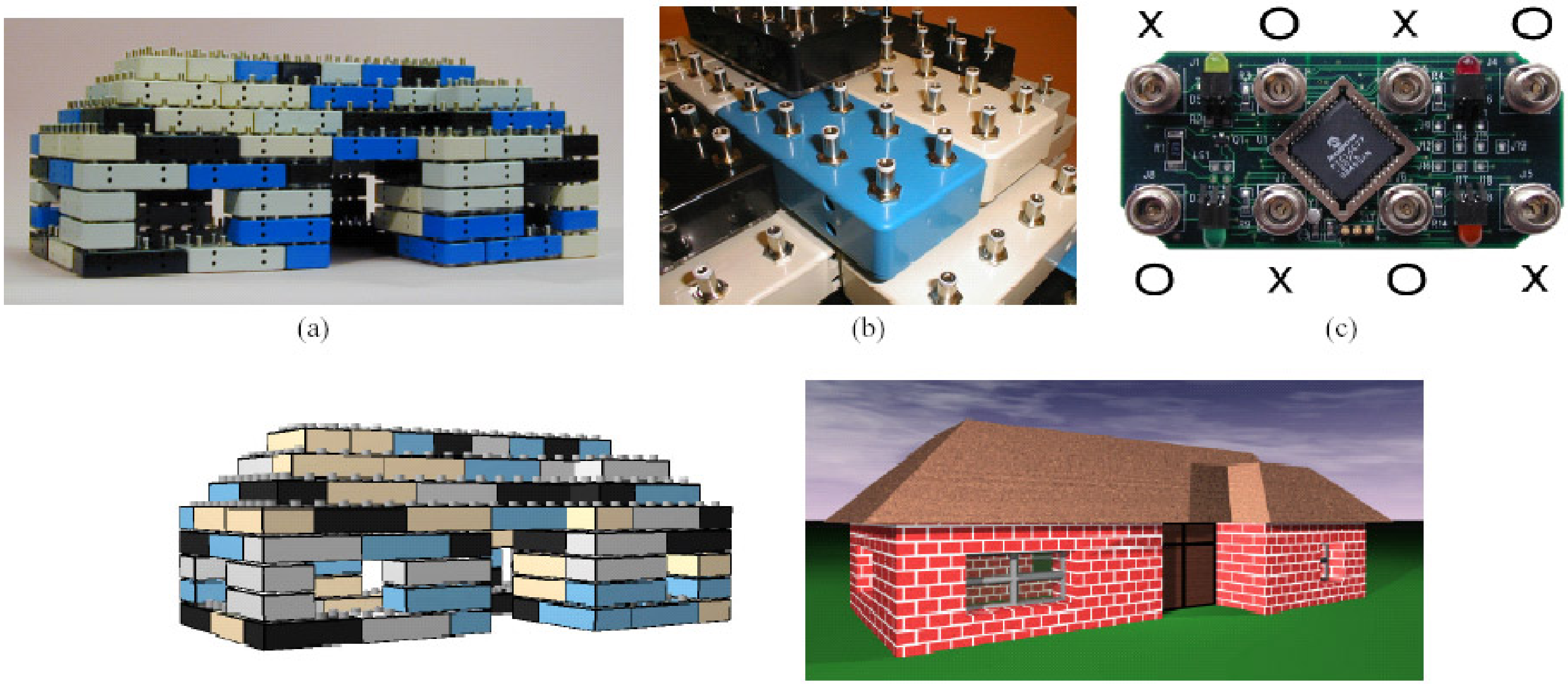
ne Capture



- 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/



(a) (b) (c)

(d) (e)

Figure 1: (a) a physical block structure comprising 98 blocks; (b) a close-up of the blocks; (c) a bottom view of the circuit board inside each block; and renderings of the virtual model recovered from the structure, one literal (d) and one interpreted (e). The literal rendering uses associated shapes and colors to render the blocks. The virtual model is augmented automatically for the interpreted rendering.

Interactive Modelling (Merl)

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

Figure 4: (a) a model of a castle comprising 118 blocks, and (b) an interpreted rendering of it. The automatic enhancements in this graphical interpretation include the addition of turrets, roofs, windows, archways, a portcullis, and a flagpole in appropriate locations, as well as the selection of suitable surface properties and features for all the geometry. The 560-block model in (c)—a 12-inch ruler is included to show scale—was built as a challenging virtual environment for Quake II, the data format for which is another output option in our system. Applying the same interpretive style to this larger model to get the rendering in (d) requires changing only one numerical parameter indicative of building scale: it specifies the smallest number of blocks in the structure that can constitute a distinct architectural feature.

Interactive Modelling Cont. (Merl)

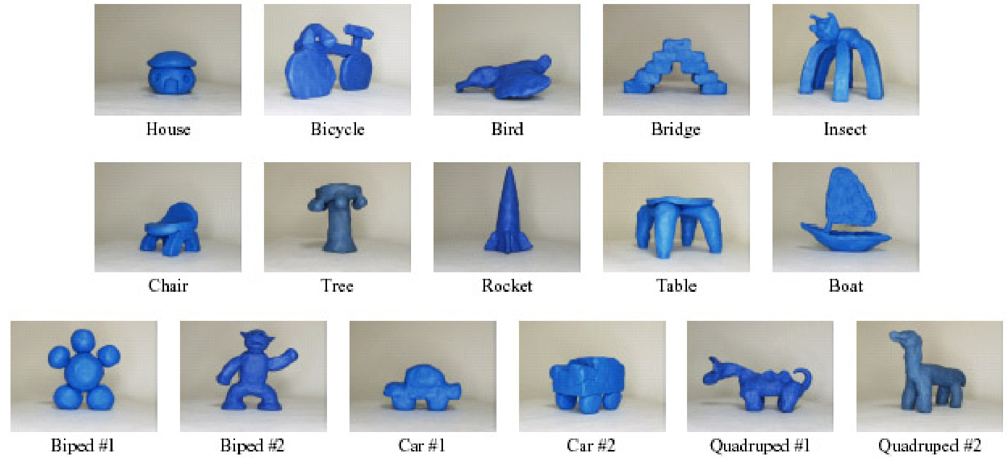
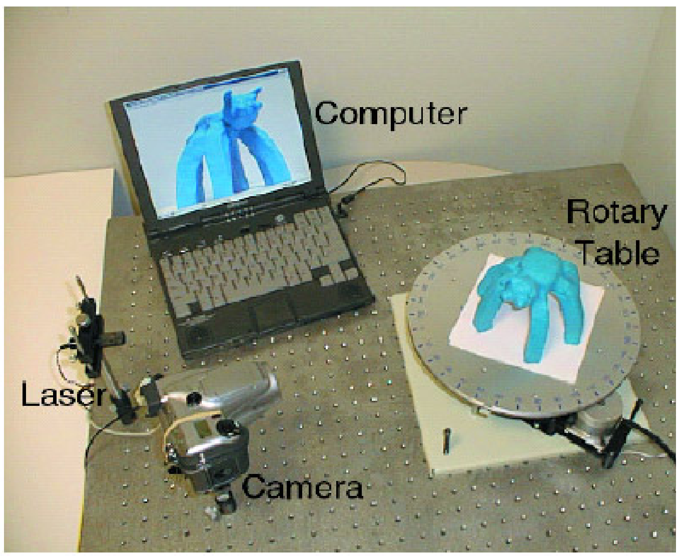
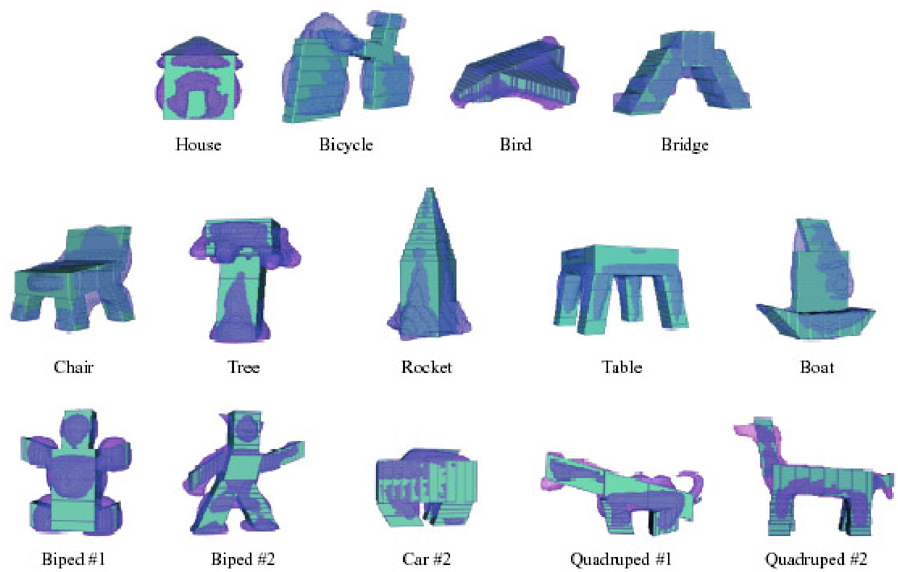


Figure 8: Examples from the image sequences for the 16 clay models captured by the camera illustrated in Figure 5.





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

Media Capture
Text

- Legacy content (documents, books)

- Technologies for capture
  - Scanner
  - Digital photo camera
  - Results in a bitmap of the text

- Technology for recognition / transformation into text
  - OCR (optical character recognition)
  - Recognize text and format
  - less storage required (if only textual content is of value)
  - Allow search in archived documents

Media Capture
Still images, graphics

http://www.reflecta.de

- Drawing (e.g. cartoon, caricature)
  - Artistic interpretation
  - Digital input (pen, tablet, mouse?)
  - Analog creation and digitizing
- Photo capture (chemical) and digitizing
  - High resolution (e.g. photo for a 4m x 8m poster or A1 Poster with 100dpi)
- Legacy content (e.g. slides, photos, book pages)
- Technologies for still image digital capture
  - Scanner
  - Digital photo camera

Scanner, examples

- Xerox DigiPath Network Scanner
  - Up to 65 pages per minute
  - Automatic duplex
  - document handler with a 100-sheet capacity

- Polaroid SprintScan 120
  - optical resolution 4000 dpi
  - medium-format film scanner
  - E.g. theoretical 6cm x 9cm ~ 9400 pixel x 14000 pixel = 126 Mega Pixel
  - 6cm x 6cm scan about 1 minute

Media Capture Video

- Record on photographic film and subsequent digitizing

- Digital capture, examples
  - DV (e.g. Canon XL1 DV)
  - Betacam digital (Sony Betacam SX Camcorder)
  - D1 (8-bit uncompressed digital)

- Capture analog video signal
  - Digitizing legacy content

http://videoexpert.home.att.net/artic3/256atab.htm
http://www.belle-nuit.com/dv/dvddix.html
http://www.jamesarnett.com/2-1-6-4.html

Chapter 4
Analyzing the Requirements and Understanding the Design Space

- 4.1 Factors that Influence the User Interface
- 4.2 Analyzing work processes and interaction
- 4.3 Conceptual Models – How the users see it
- 4.4 Analyzing existing systems
- 4.5 Describing the results of the Analysis
- 4.6 Understanding the Solution Space
- **4.7 Design space for input/output, technologies**
  - 4.7.1 2D input
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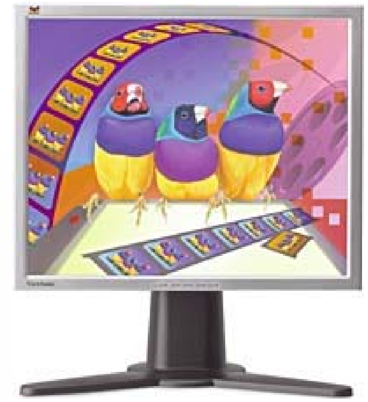
  - 4.7.3 Force feedback
  - 4.7.4 Input device taxonomy
  - 4.7.5 Further forms of input and capture
  - **4.7.6 Visual and audio output**
  - 4.7.7 Printed (2D/3D) output
  - 4.7.8 Further output options
  - 4.7.9 User interfaces for authentication

TFT LCD Screens



- Typical color resolution 640x480 to 1920x1200
- ~ 85 pixel/inch
- viewing angle to 170°
- pivot function (90° rotation)

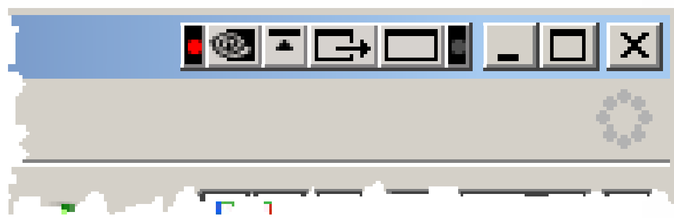
- More on the basic technology
  - http://electronics.howstuffworks.com/lcd.htm
  - http://www.pctechguide.com/07panels.htm

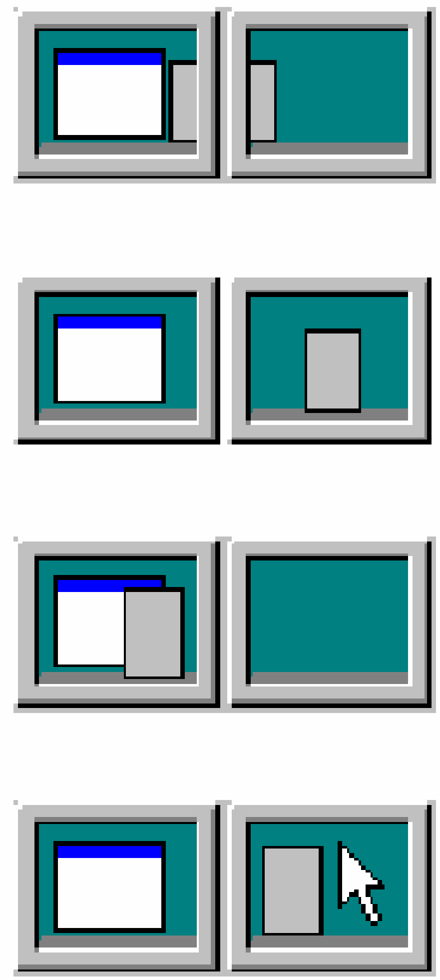
Multiple Screens

- Increased screen real estate
- Connected to one computer (one keyboard and one mouse)
- Screen arrangements with standard hard- and software
  - Dual display
  - Triple display
  - Quad display
- Application areas
  - CAD
  - Software development
  - Media production
  - Financial software
  - Comparison tasks
  - Customer info & adverts
  - Time tables

Multi-screen problems & solutions

- Dialog box appears on the boarder between the screens
  - Position in new screen
  - Position in application screen
  - Position at the cursor





- What is the meaning of maximizing a window
  - Within the current screen
  - overall
- Losing the cursor
  - Example of a solution: High density cursor
    http://www.patrickbaudisch.com/projects/highdensitycursor/

More on Multi Displays

Hutchings, D., Smith, G., Meyers, B., Czerwinski, M., & Robertson, G. (2004).

Display space usage and window management operation comparisons between single monitor and multiple monitor users.

In Proceedings of the working conference on Advanced Visual Interfaces, AVI 2004, p. 32-39.

Multi-screen problems & solutions drag and drop over screen borders

- Scenario:
  - Multiple touch screens (e.g. smart boards) are connected to become “one” display
  - Drag-and-drop does not work over borders

- Suggested solution – move possible targets to the object that is dragged
- Drag-and-Pop

  http://www.patrickbaudisch.com/projects/dragandpop/

Hi-Resolution Grayscale Displays

- Use for medical imaging, radiology
- Image presentation according to DIN 6868-57
- Calibration software

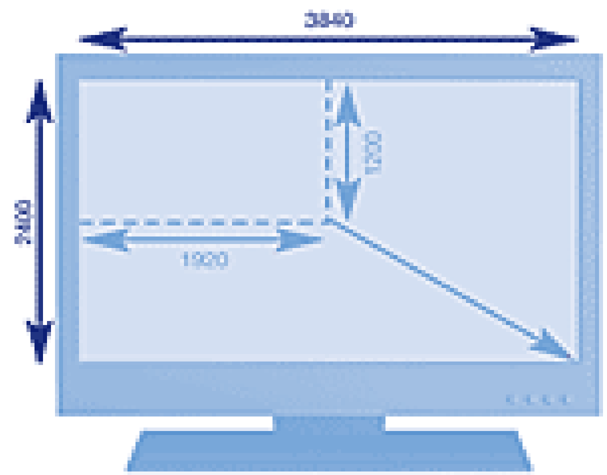
- E.g. Eizo RadiForce G51
  - 21.3" monochrome LCD
  - 5 mega pixel
  - 2560 × 2048 pixel
  - 154 pixel/inch
  - 10-Bit simultaneous grayscale display

Hi-Resolution Color Displays

- Application examples
  - Medical imaging
  - CAD and construction
  - Digital content creation
  - Geophysical imaging

- E.g. IBM T221 Flat Panel Monitor.
  - 3840x2400 pixel
  - 9.2 million pixel
  - 22.2" TFT LCD
  - 204 pixels/inch

- Resolution close to a photo



Hi-Resolution Displays Potential Problem

- Often standard software is designed for different resolution (e.g. 90 pixel/inch)
  - controls are too small
  - fonts are hardly readable in normal size
- Approach
  - Design software independent of actual screen resolution and adapt to system characteristics at run time
  - Design for the specific characteristics of the output device

Context & Focus
Baudisch et al.

- Central area is a high resolution display
- Peripheral area is low resolution and provides context

- http://www.patrickbaudisch.com/projects/focuspluscontextscreens/

Context & Focus
Baudisch et al.

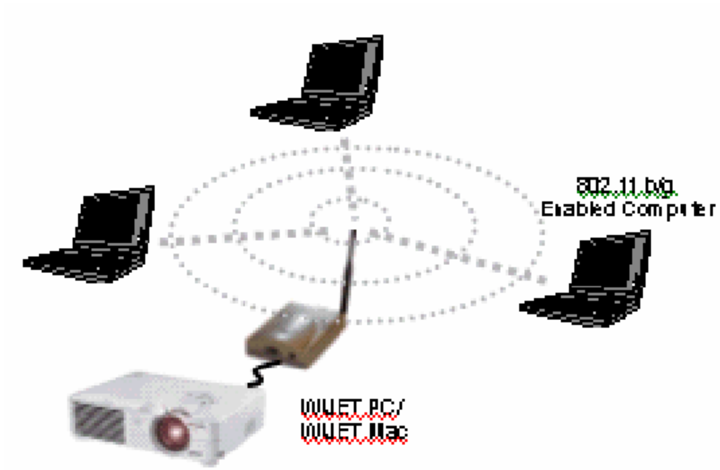
- Central area realized as TFT screen
- Periphery is projected
- Helps with task where context does provide important information

Projectors

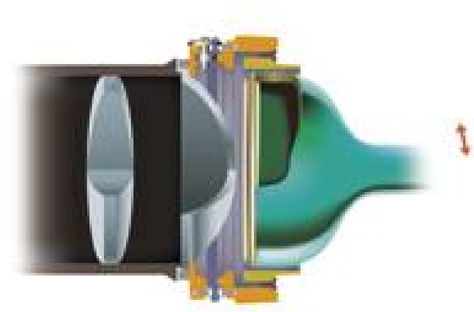
Projectors

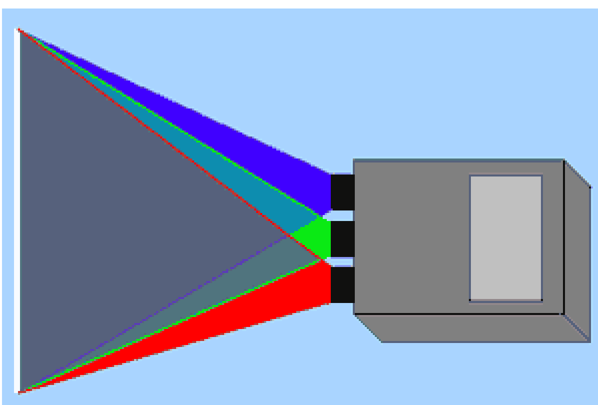
- Key Criteria
  - Resolution
  - Brightness
  - Weight
  - Noise
  - Lens
  - Image correction
  - Projection distance
  - Connections
  - Lamp life time

- E.g. Toshiba TLP-T720U
  - Wireless 802.11B
- E.g. WiJET
  - http://www.otcwireless.com/802/wijet.htm



CRT projector

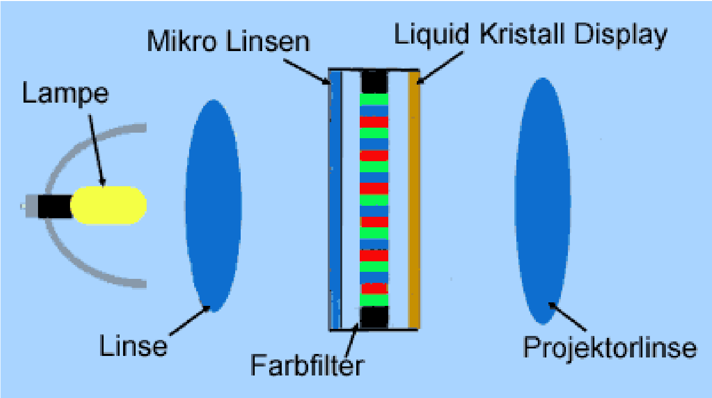




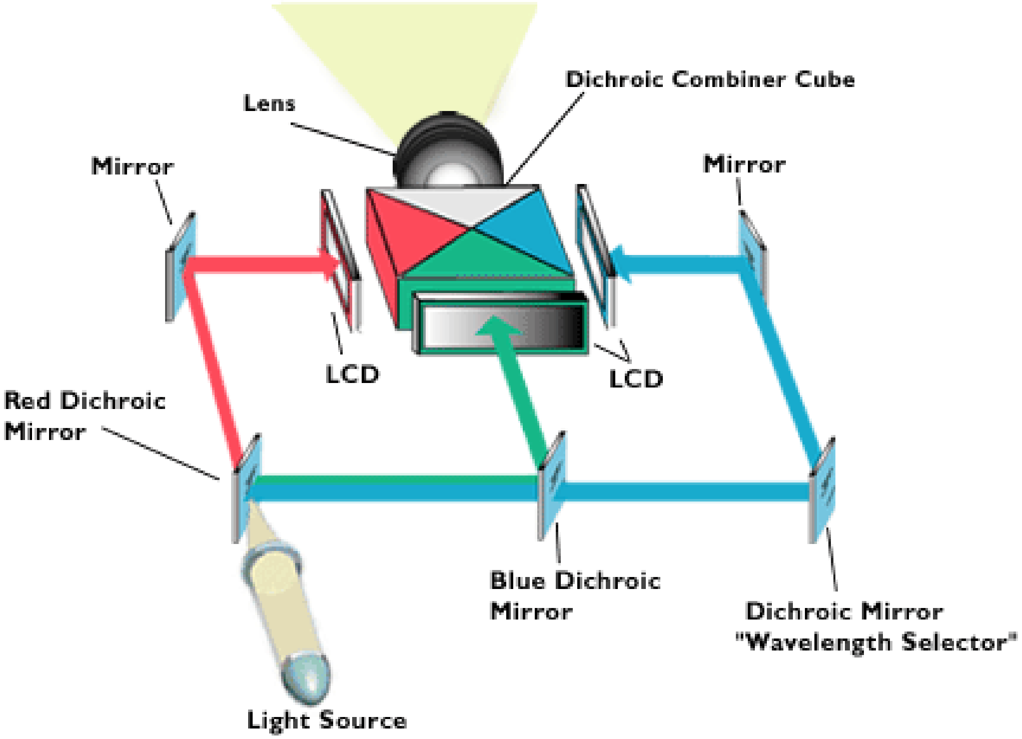
- Use R,G+B CRTs as light sources
- Good black areas
- Low brightness
- Fast
- Need to calibrate convergence!

www.projektoren-datenbank.com/rohre.htm

LCD projector

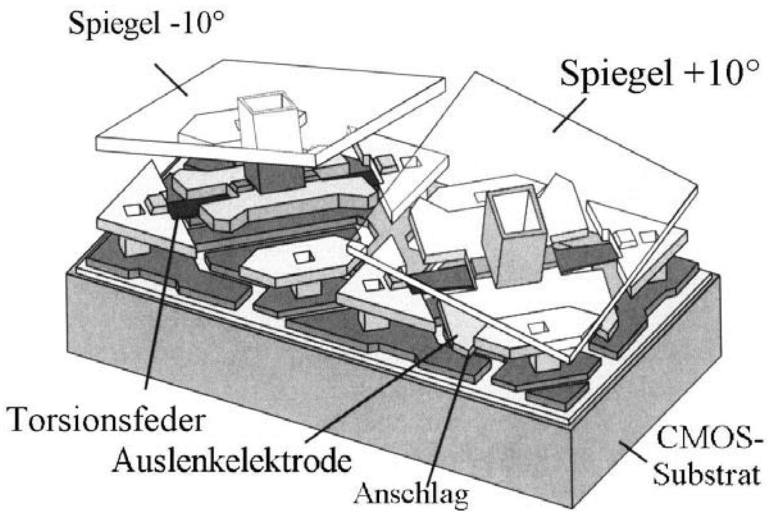


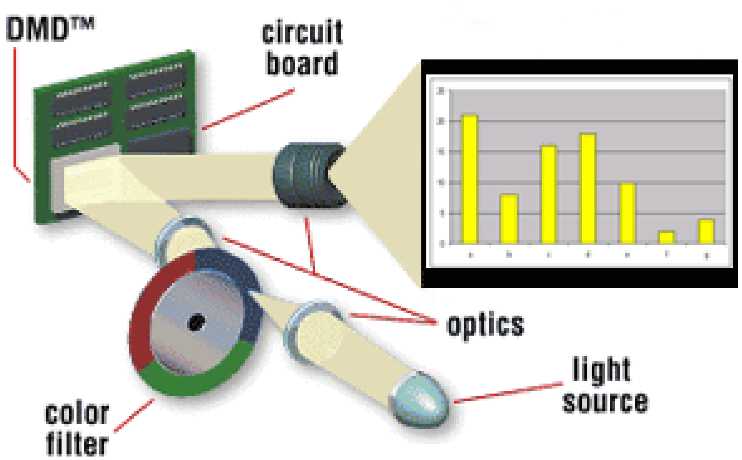
www.projektoren-datenbank.com/lcd.htm

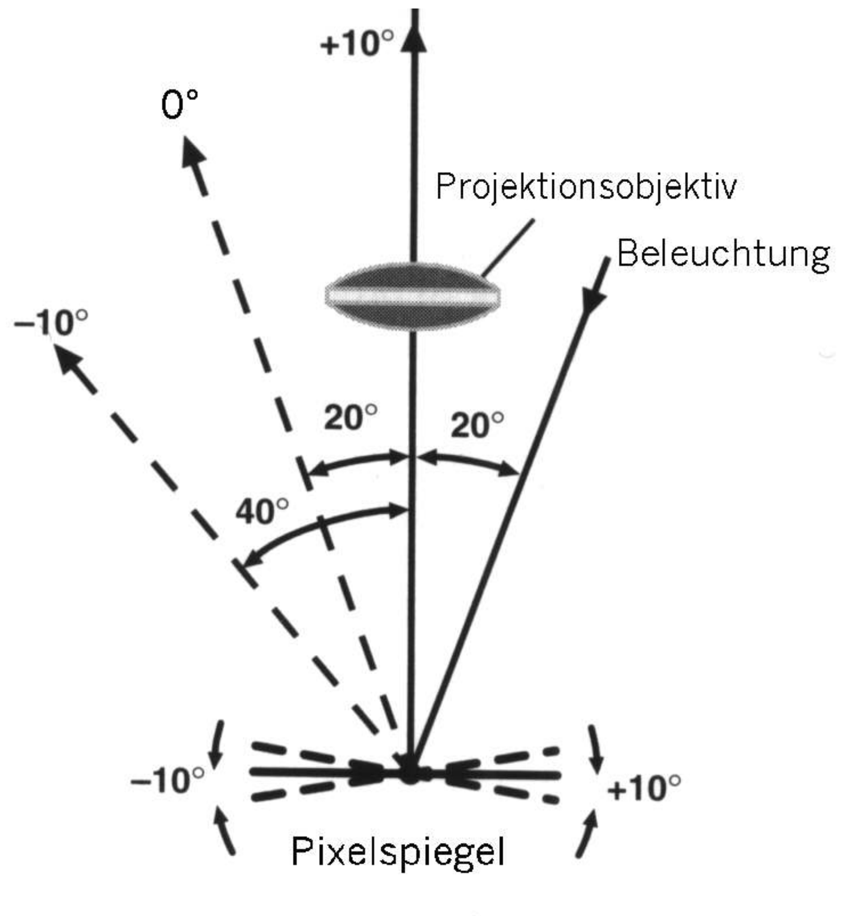


www.projectorpoint.co.uk/projectorLCDvsDLP.htm

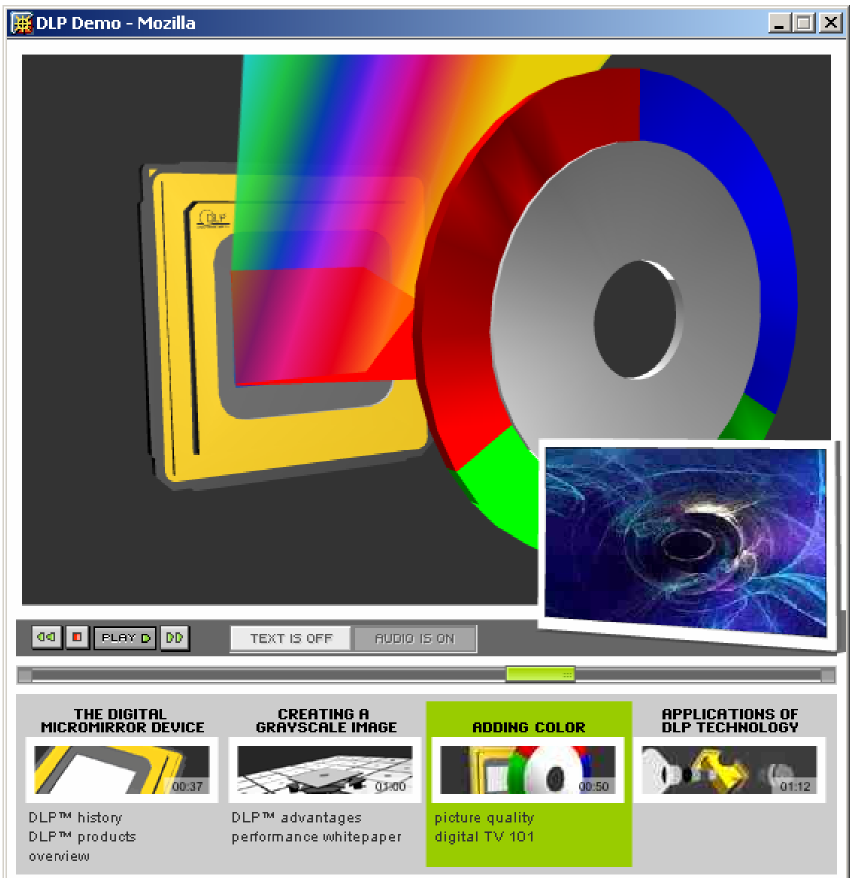
DLP projector

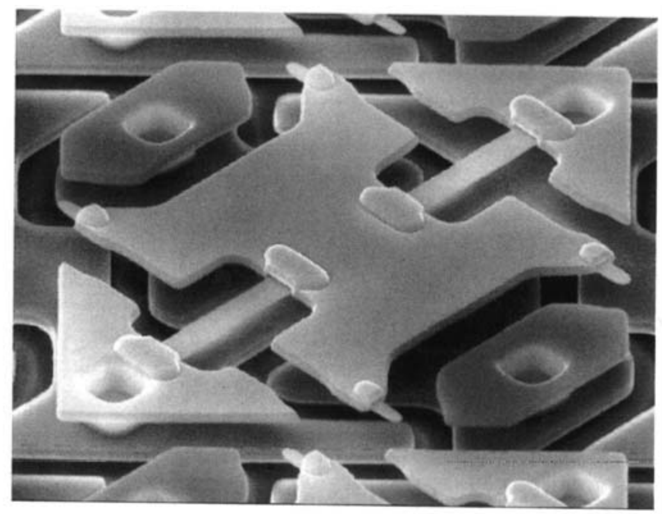






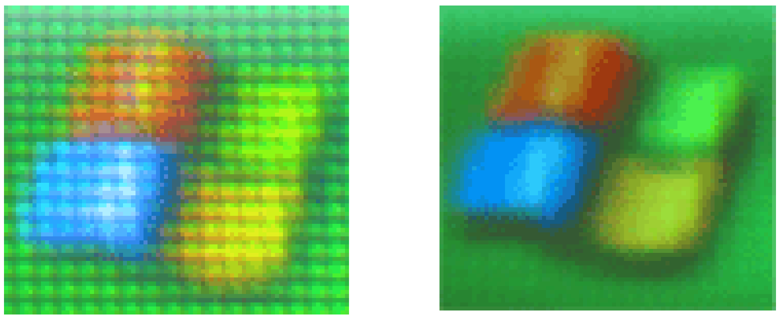
DLD projector (movie)





http://www.dlp.com/

Technological side effects



LCD DLP

(image is a magnified portion of the start up icon)

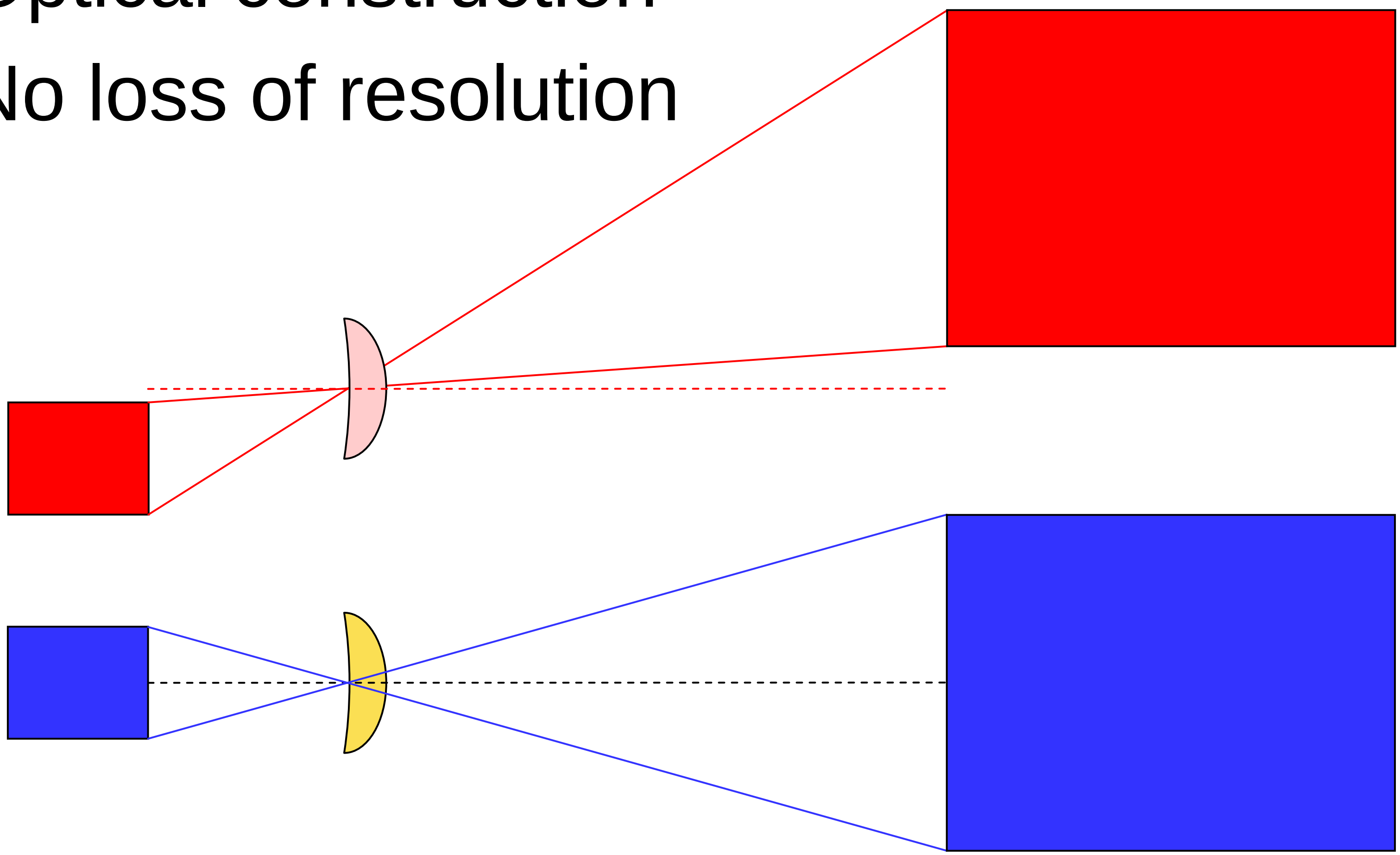
www.projectorpoint.co.uk/projectorLCDvsDLP.htm

- Screen door effect
  - Caused by LCDs
  - Less prominent in DLP

- If a DLP projector is moved, color seams appear

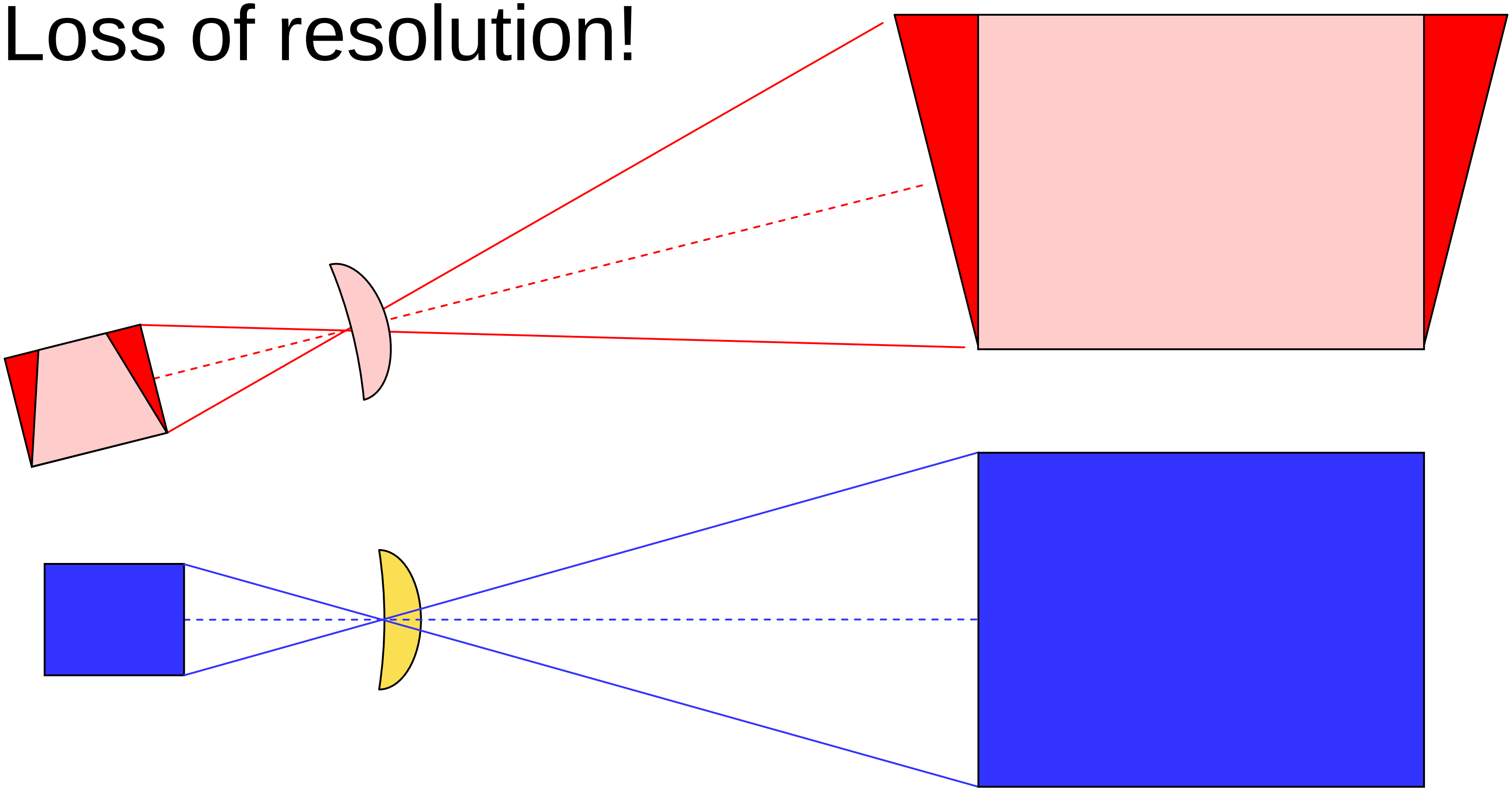
Lens shift

- Optical construction
- No loss of resolution

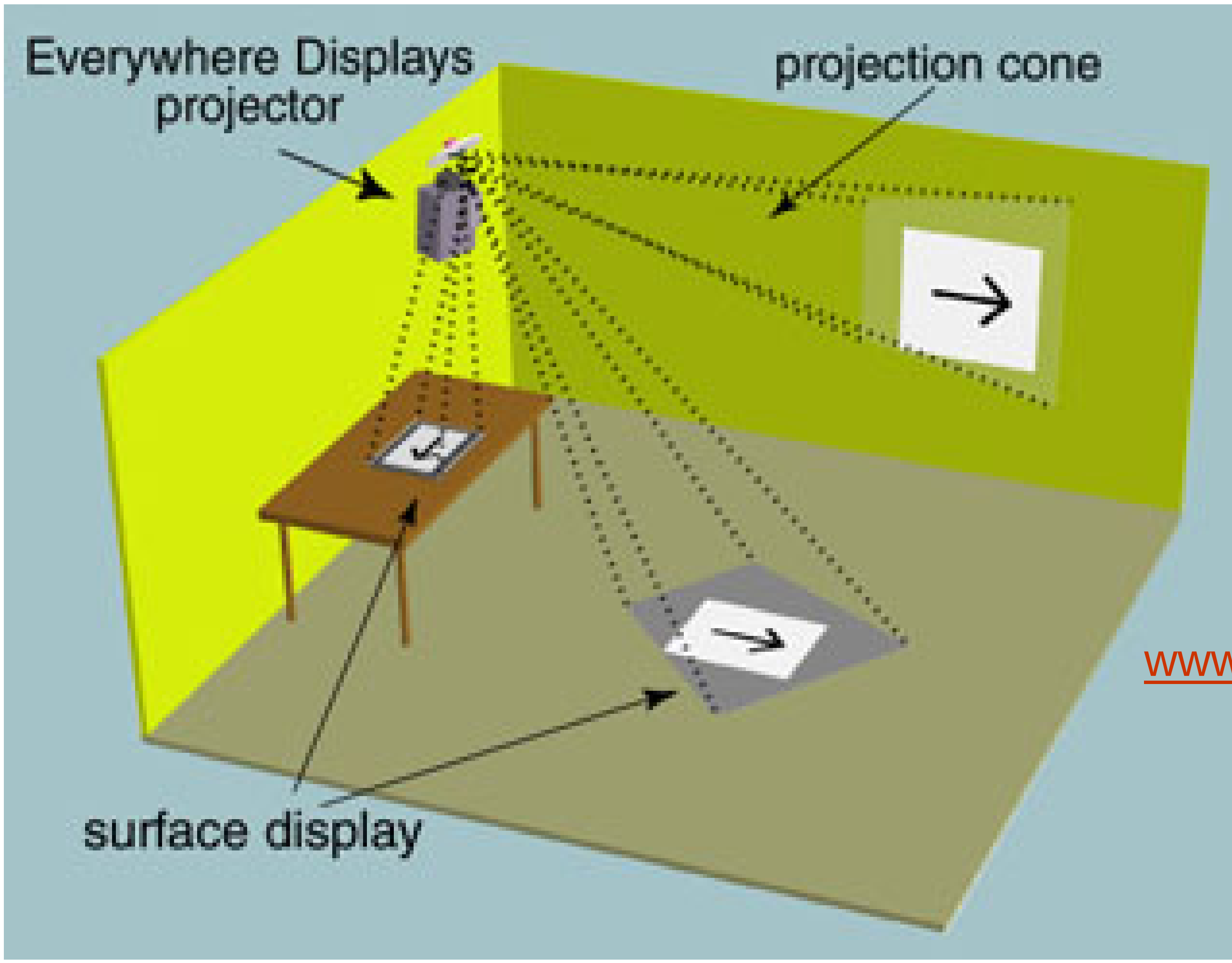


Keystone correction

- Computed correction
- Loss of resolution!



The Everywhere Display



Claudio Pinhanez

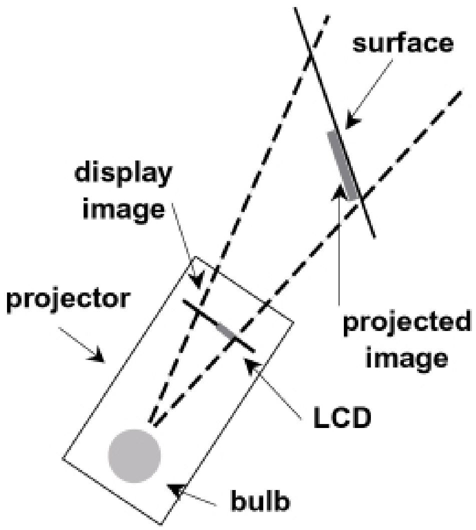
www.research.ibm.com/ed/

Everywhere display (cont.)

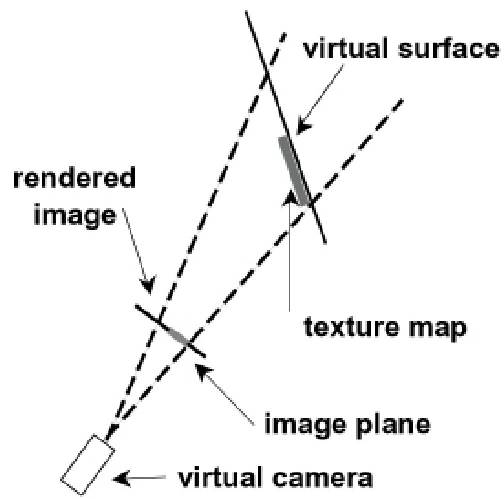
Components: a projector, a camera and a rotating mirror

Everywhere display (cont.)

- Correct distortions
  - Use the fact that camera and projectors are geometrically the same (optically inverse)
- Use standard HW components
  - 3D-Graphics board and VRML-world



REAL WORLD

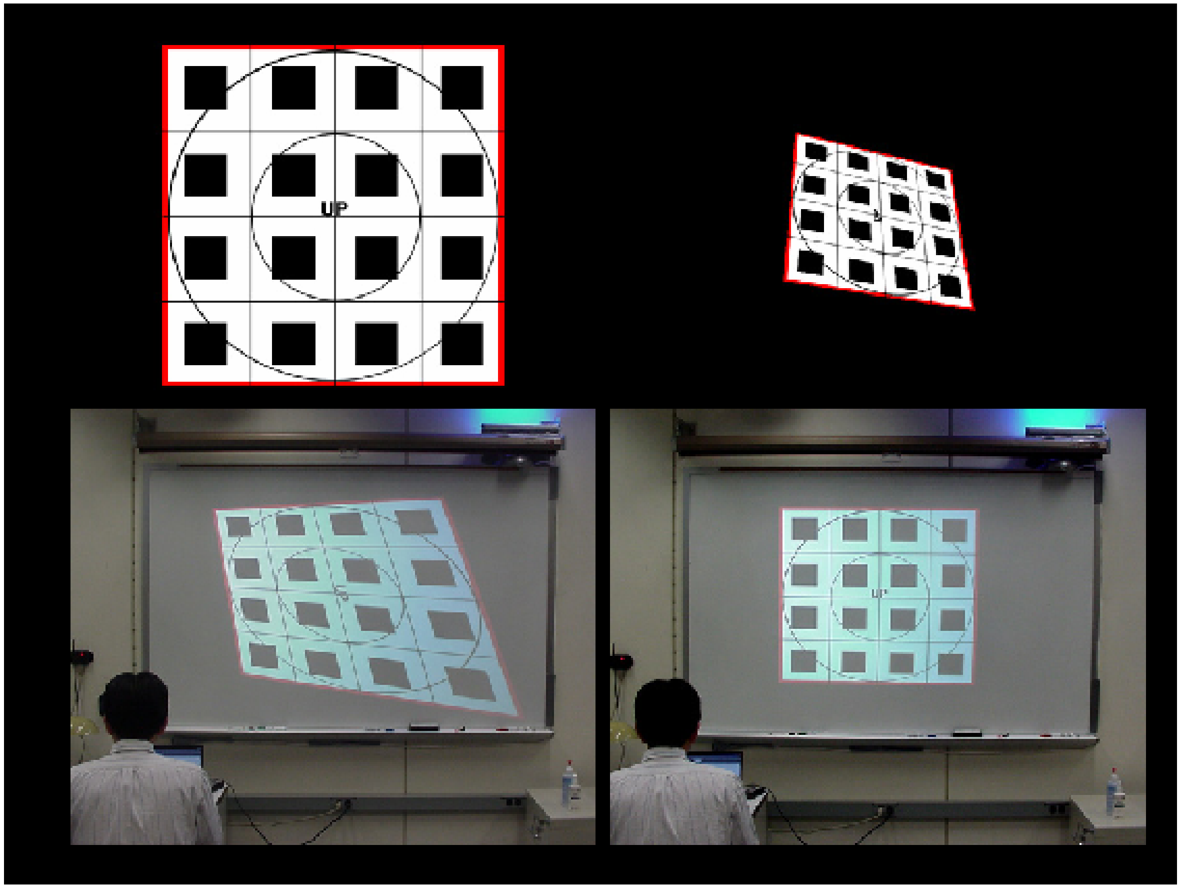


VIRTUAL 3D WORLD

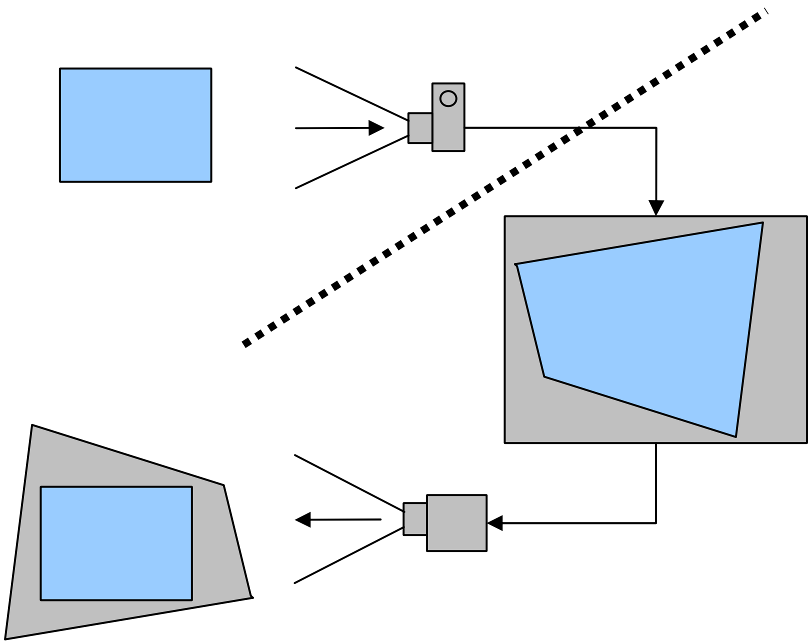
Everywhere Displays Project (IBM)

http://www.research.ibm.com/ed/

- Correct image distortion



Undistorting the projected image



- Place original image in the 3D model
- Camera image shows it distorted
- Project the distorterd image from 3D model with the real projector

– Distortions cancel each other out IF virtual camera and physical projector are in the same location

Everywhere display (cont.)

BLUESPACE office scenario

Albrecht Schmidt
Embedded Interaction Research Group
University of Munich, Germany

Everywhere Displays Project (IBM)

Applications

http://www.research.ibm.com/ed/

SearchLight: Basic Idea

- Build a search function for physical objects
- A tool for directing the user’s attention
- No 3D model of the environment

Ideas for realization:

- Optical markers for object recognition
- Highlighting by a projected spot

Step 1: Room Scanning

- Projector/camera unit moving and taking pictures
  - Until the whole room is covered
  - Neighbouring pictures slightly overlap
- Recognized marker IDs are stored with:
  - pan/tilt values when taking the picture
  - position of the marker in the picture

Step 2:
Showing objects

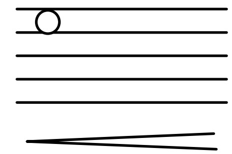
- Retrieve object's marker ID
- Move unit to stored pan/tilt position
- Project a spot around the marker's position

Audio

Sound and Audio

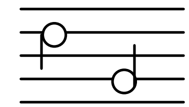
Create

note, getting louder



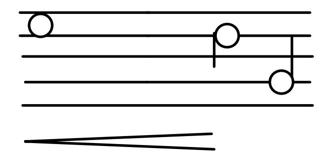
File

high-low note



Create file

create icon followed by file icon



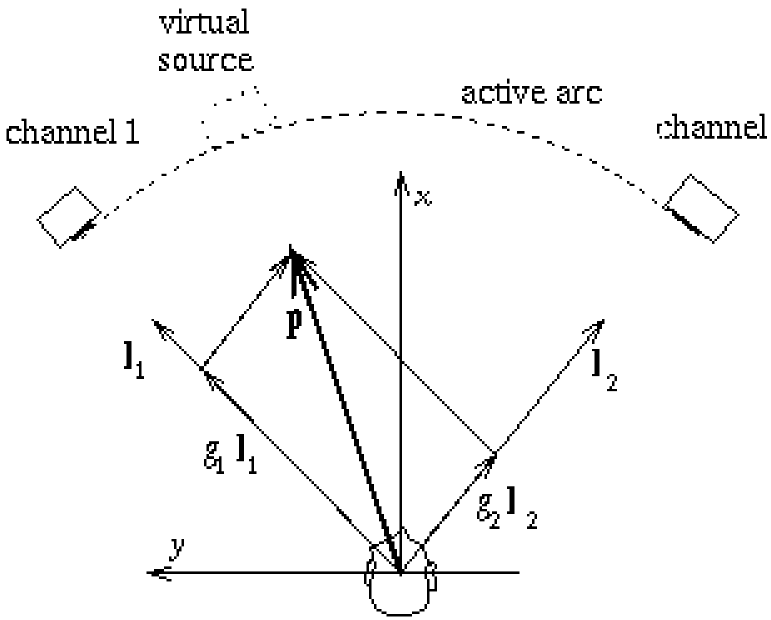
- Variety of options
  - Beep to multi-channel spatial audio
  - Different technologies
- Output of
  - Information (e.g. click, notification)
    - Auditory icons (e.g. sound for throwing a document away)
    - Earcons – conveying complex information
  - Captured media (e.g. songs, music, films, speeches)
  - Synthesized media (music, spoken text)

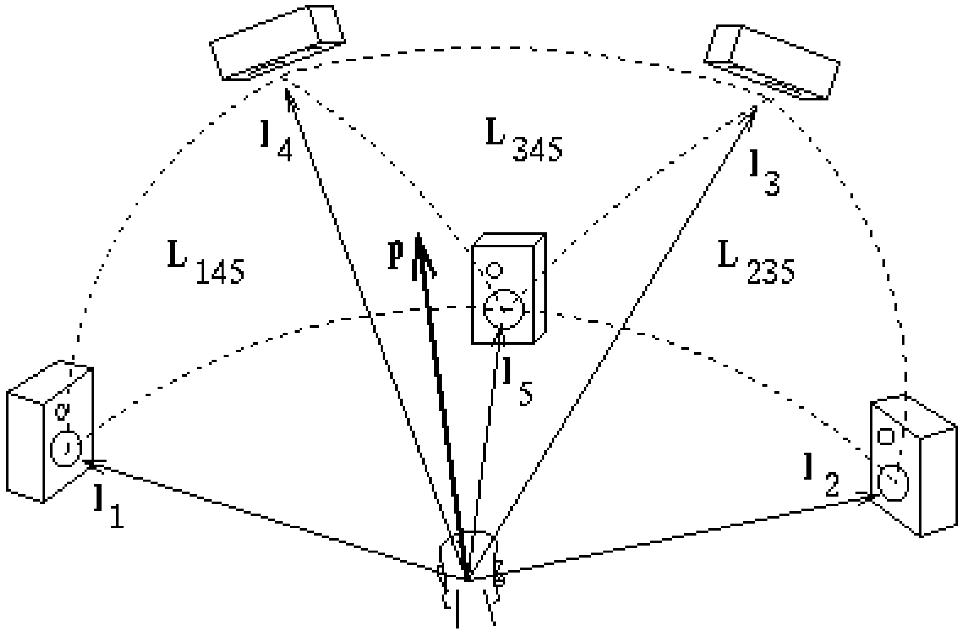
Spatial Audio with headphones

- Principle of spatial audio is simple: if the sound waves arriving at your eardrums are identical to those of a real audio source at a particular position, you will perceive that sound as coming from a source at that particular position.
- Because people only have two ears, you only need two channels of sound to create this effect, and you can present this sound over ordinary headphones. It is possible to recreate the effects of the ears and upper body on incoming sound waves by applying digital filters to an audio stream; True binaural spatial audio, when presented over headphones, appears to come from a particular point in the space outside of the listener's head. This is different from ordinary recorded stereo, which is generally restricted to a line between the ears when listened to with headphones
- Headphones are used because they fix the geometric relationship between the physical sound sources (the headphone drivers) and the ears. Headphones also eliminate crosstalk between the binaural signals. With additional signal processing, we can conceivably compensate for these effects, allowing spatial audio to be presented over free field speakers. However, to compensate for the effects of speakers, the spatial audio system must have knowledge of the listener's position and orientation with respect to the speakers

http://www.cc.gatech.edu/gvu/multimedia/spatsound/spatsound.html

Vector Based Amplitude Panning





$$\underset{\rightarrow}{p} = g_1 l_1 + g_2 l_2 = Lg$$

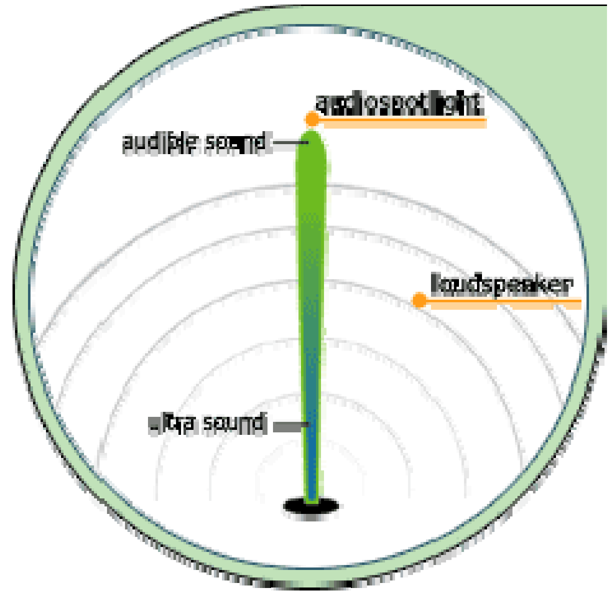
$$g = p^T L^{-1}$$

$$\underset{\rightarrow}{p} = g_1 l_1 + g_2 l_2 + g_3 l_3 = Lg$$

$$g = L^{-1} p^T$$

http://www.acoustics.hut.fi/research/abstracts/vbap.html

Audio Spotlight
(BBC Video)



- Directed ultra sound is generated
- Transformed in the air in audible sound
- Generates a sound only at a predictable location

http://www.holosonics.com/

Albrecht Schmidt
Embedded Interaction Research Group
University of Munich, Germany

3D

Stereo photography stereo vision is not new…

http://www.stereoblick.de/

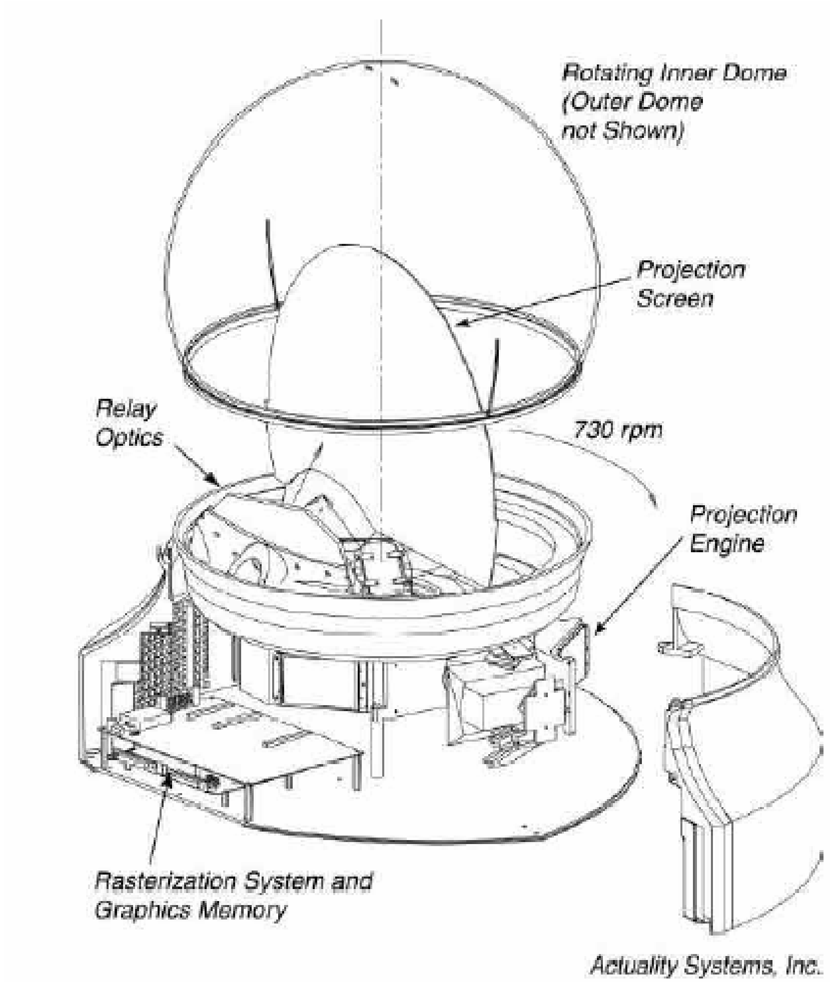
Volumetric 3-D Display

- Creating a volume image – like an objects "Volume-filling imagery "
- Many simultaneous viewers
- Multiple viewpoints,
- Autostereoscopic

- E.g. Perspecta™ 3D
  - Swept-screen multiplanar volumetric display
  - 198 2-D slices
  - 768 x 768 pixel slice resolution
  - 100 million voxels
  - 24 Hz volume refresh
  - 10" diameter spherical image
  - 8 colors at highest resolution
  - Viewing Angle: 360º horizontal, 270º vertical

http://actuality-systems.com/

Theory of operation
high speed projection (5000 fps)



http://actuality-systems.com/

Separate displays for each eye

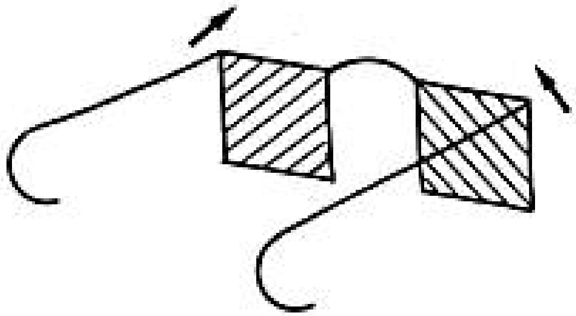
- Stereoscopic 3D computer imaging
- Separate displays
- E.g. i-glasses SVGA
  - Resolution: 800 x 600
  - Pixels: 1.44 Million per Display
  - Field of View: 26 Degrees Color Depth: 24 Bit
  - Refresh Rate: 120hz

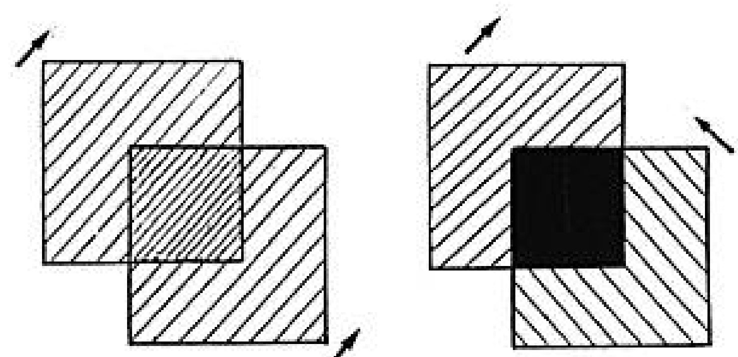
Electro optical shutter

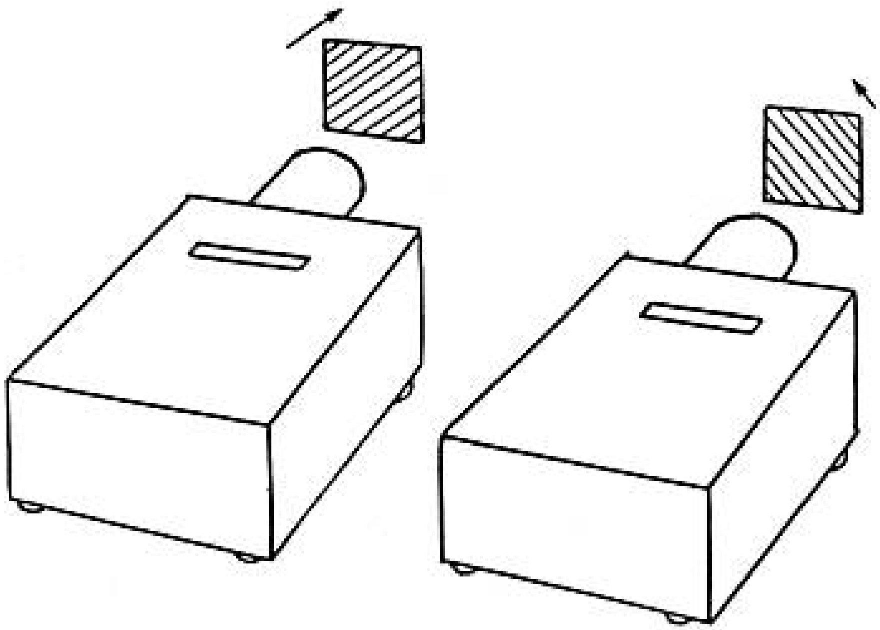
- E.g. CrystalEyes
  - electro-optical shutters
  - wireless active eyewear
  - infrared emitter is placed at the monitor and broadcasts synchronization information to the eyewear.
  - The system works seamlessly so the user sees stereoscopic image

http://www.stereographics.com/support/hp-paper.htm

Linear polarization filters and spectacles for 3D projection







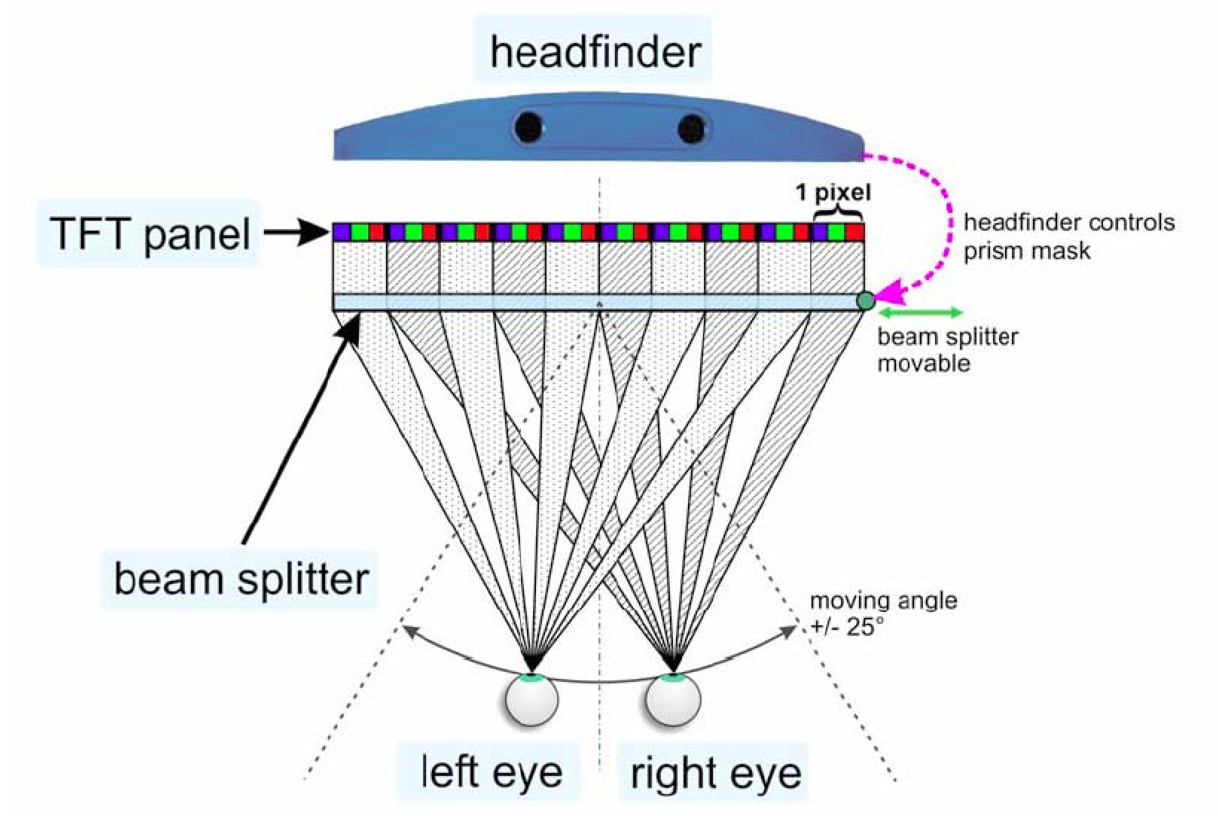
Dresdener 3D Display

- Auto stereoscopic display
- no special glasses
- high resolution
- Full brightness display
- tracking system that allows the user to move naturally while working but without losing the 3D effect.

http://www.seereal.com

Dresdener 3D Display basic Technology

- Tracking of users position
- camera or infrared (requires reflector) based
- Moveable prism provided two views
- Alternating columns for left and right eye



http://www.seereal.com

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  - 4.7.8 Further output options
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Printing & Printers

- Printing text, graphics, and photos
- Total cost - dependent on usage/user profile
  - printer price
  - materials (e.g. paper, ink, toner, energy)
  - maintenance (e.g. changing of paper in a ticket machine)
- Hardware
  - Media size and type, e.g. paper A4, CD, card board, envelops
  - Media handling, e.g. paper container, rolls and cutting
  - Speed – e.g. pages/minute, characters per second, sq ft/h
  - Resolution – typically dpi (dots per inch)
  - Colors
  - Print technology e.g. laser, dot-matrix, ink-jet, thermo
  - Connectivity e.g. network, USB, …
  - Size, weight, noise, …
- Software
  - Printer language, e.g. PS (postscript), HPGL (Hewlett-Packard Graphics Language, plotter), PCL (printer command language), GDI (Graphical Device Interface)

Some Printing Technologies

- laser (black/white and color)
  - creating standard documents
  - office use
  - high resolution
- dot-matrix
  - Point of sale
  - Ticket printers
  - Multiple copies (e.g. carbon copy slip for credit card payment)
- Thermo printer
  - Point of sale
  - Ticket printers
  - Mobile printers

Albrecht Schmidt
Embedded Interaction Research Group
University of Munich, Germany

Adobe Postscript

- PostScript is a programming language optimized for printing graphics and text
- device independent description
- Instructions for drawing curves, lines, text in different styles, scaling, …
- stack-based, e.g. “**`12 134 mul`**”

```
%!
% Sample of printing text

/Arial findfont     % Get the basic font
72 scalefont               % Scale the font to 20 points
setfont                    % Make it the current font

newpath                    % Start a new path
50 200 moveto              % Lower left corner at (100, 200)
(Hello World!) show        % Typeset "Hello, world!"

showpage
```

2D Printer

- Different technologies, e.g.
  - Laser (B/W and Color)
  - Ink jet
  - Plotter

- Postscript as language

- Not just paper, e.g.
  - Laser cutter
  - Sewing machine

Albrecht Schmidt
Embedded Interaction Research Group
University of Munich, Germany

Stereolithography

- The Stereolithography process is basically performed in the following way:
  - Create a 3D model with CAD software.
  - Stereolithography software slices up model into layers; about 5-10 layers per millimeter.
  - 3D printer (Stereolithography machine) "paints" one of the layers by exposing the liquid polymer in the tank to the laser and hardens it.
  - The platform drops down into the tank layer by layer until the model is completedStereolithography Machine

- There are 4 main parts of the Stereolithography Machine:
  - Liquid Photopolymer Tank: holds liquid plastic sensitive to ultraviolet light
  - Perforated Platform: the platform is immersed in the tank and can be moved up and down as the process is performed.
  - Ultraviolet Laser: transforms the liquid polymer into the 3D object.
  - Computer: controls the laser and movement of the platform during the printing process.

http://www.what-is-injection-molding.com/stereolithography.aspx

Stereo-litho-graphy

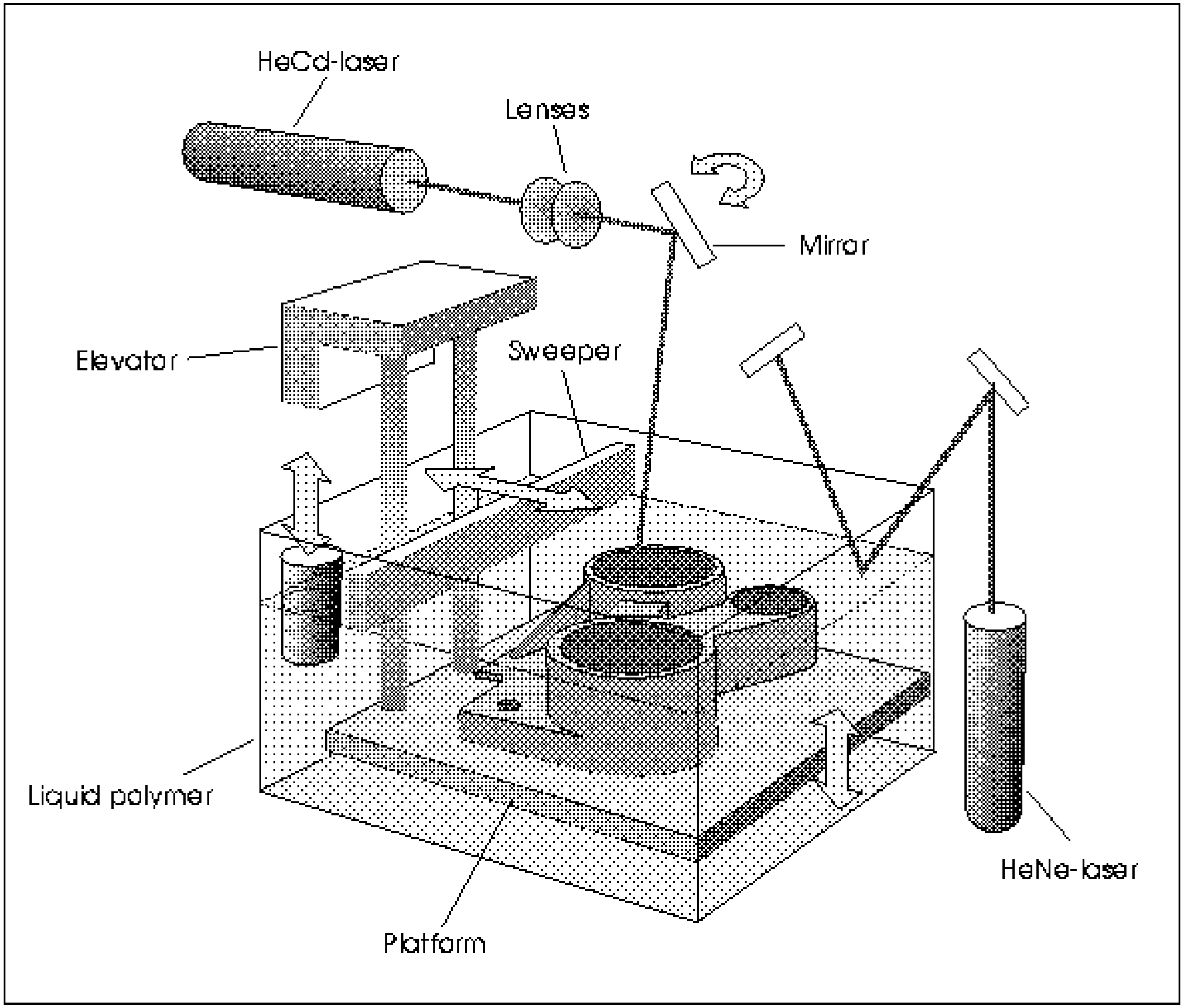
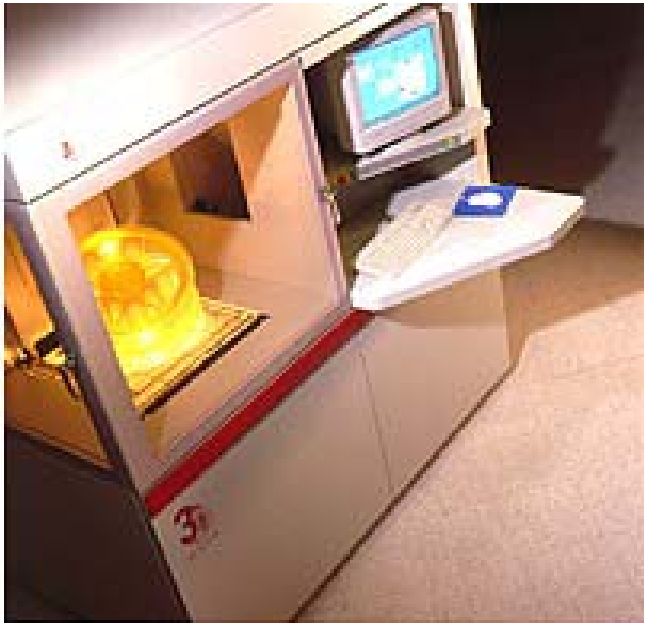


FIGURE 1. A schematic drawing of an SLA.

http://www.cs.hut.fi/~ado/rp/subsection3_6_1.html

Stereolithography Example System



- http://www.3dsystems.com/products/sla/tour/movtest.asp
- SLA 7000
  - Layer thinkness 0.025 mm – 0.127mm
  - Maximum drawing speed: 2.54 m/sec - 9.52 m/sec
  - Max part weight 68 kg (150 lb)
  - Max build envelope 508 x 508 x 584 mm
- http://computer.howstuffworks.com/stereolith3.htm

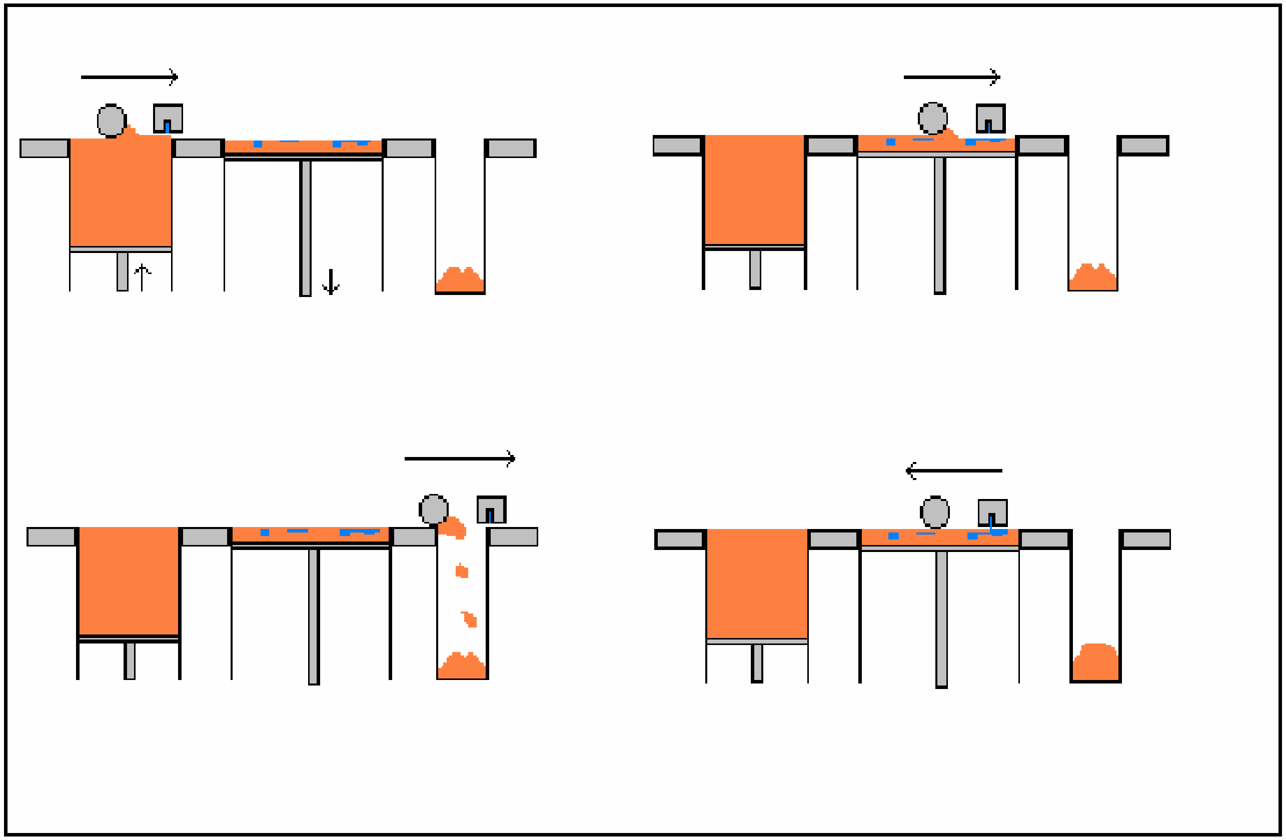
3D Printer

- *Printing in layers*
- *Different materials*
- *Different colors*
- *Build Speed:*
  - *2-6 layers per minute*
- *Build Volume:*
  - *203 x 254 x 203 mm*
- *Layer Thickness:*
  - *0.076-0.254 mm)*
- *Different formats, e.g. VRML import*

- *http://www.zcorp.com/products/printersdetail.asp?ID=2*
- *video*

3D Printer basic principle

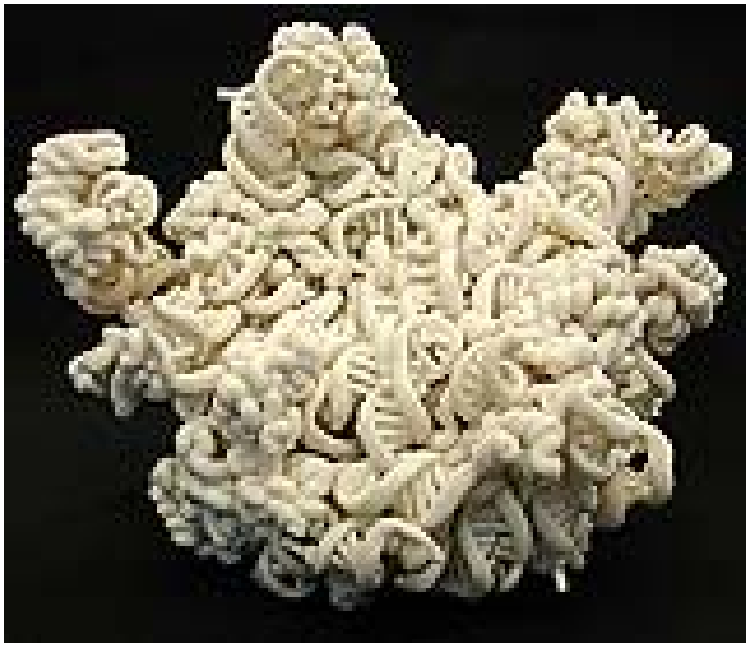
- Powder is spread in a thin layer
- Print head spray the binder on the particles
- Repeat for each layer

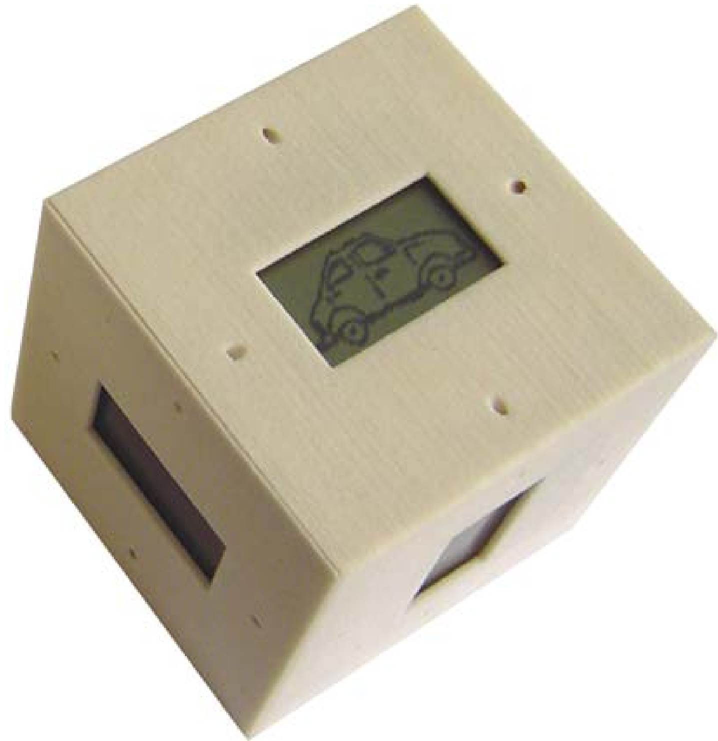


http://www.fmf.uni-freiburg.de/service/sg_surface/pfister-project.pdf

Albrecht Schmidt
Embedded Interaction Research Group
University of Munich, Germany

3D Printer (example printout)





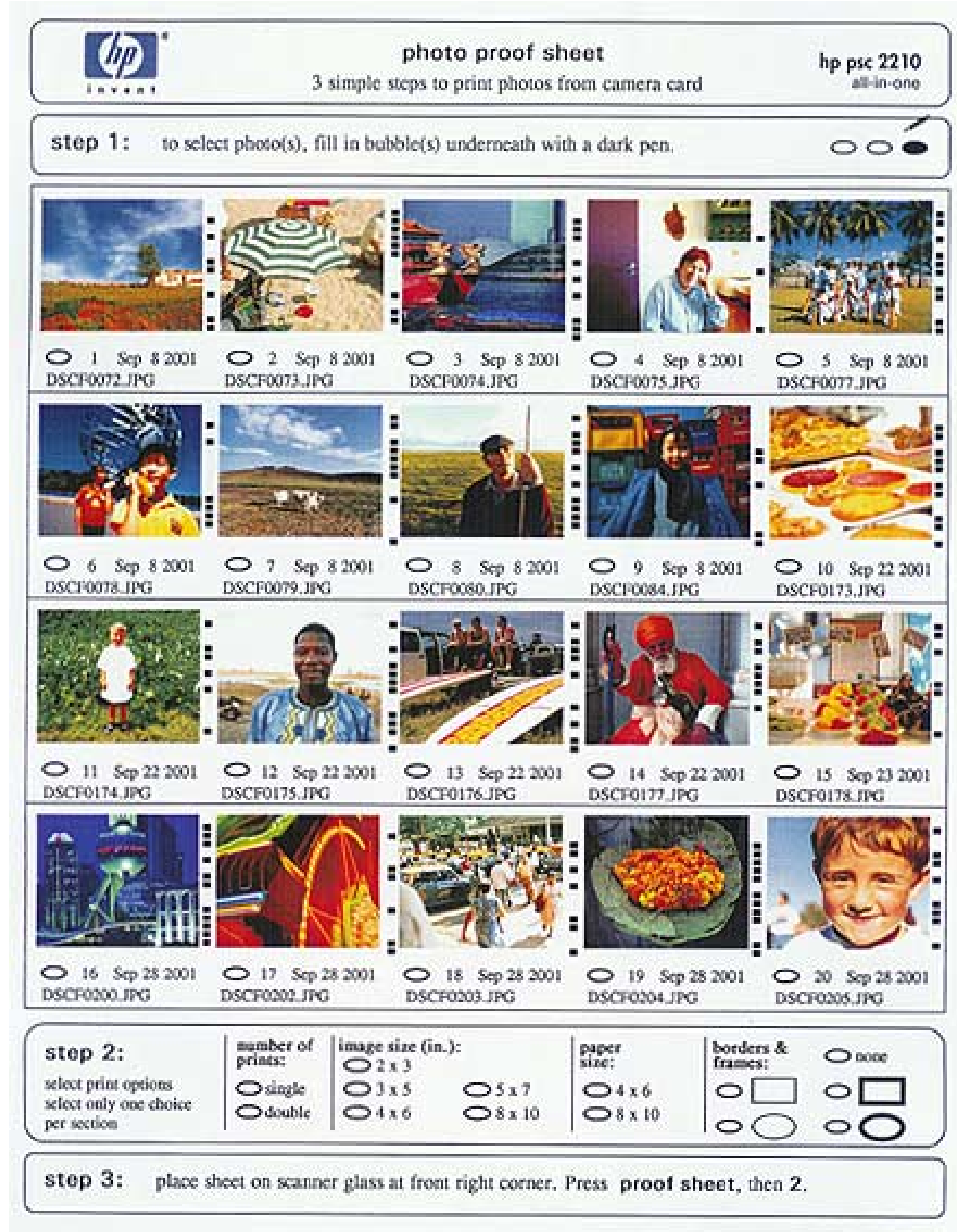
- 3D Ribosome-Model
  http://www.biol.ethz.ch/dienstleistungen/digitalwerkstatt
- Interaction cube, hcilab.org

Human Computer Interaction with Paper?

- Paperless office has not yet happened!
- Advances in technology makes it easier to use paper as interaction media
  - Printing as output mechanism
  - Scanning as input mechanism
- Paper as a temporary interface
  - Multi-step process, e.g.
    - print out a check list on paper
    - user interacts with the checklist on paper
    - scan & recognize interaction and create a database entry
  - for specific scenarios this can be a state of the art solution
- Research (e.g. Xerox) and products (e.g. HP printers)

Paper interface for photo printing

- E.g. HP PSC 2210 all-in-one
- Steps
  - Insert memory card
  - print proof sheet (index)
  - Select on paper
  - Scan selection
  - Get your selection printed

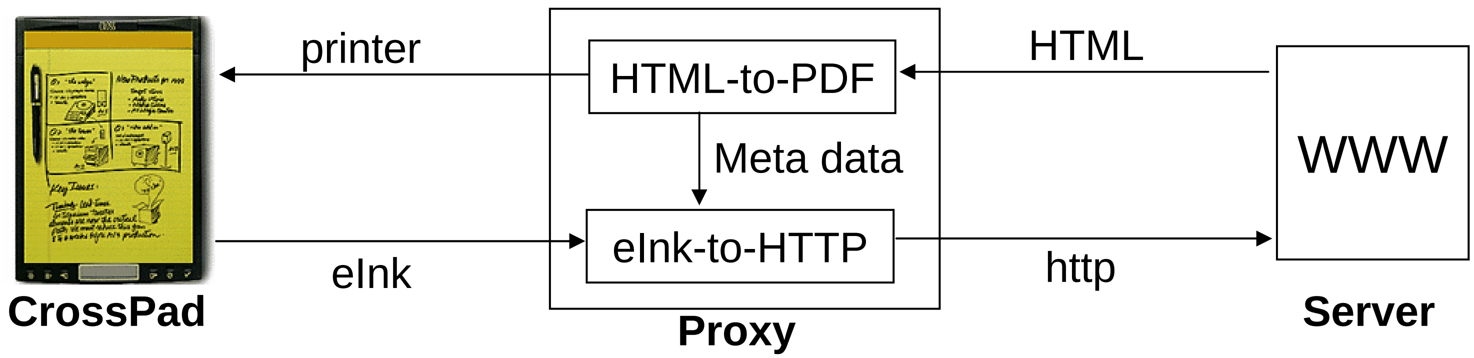


Paper as input medium
(University of Karlsruhe & SAP cooperate research, 2000)

http://www.comp.lancs.ac.uk/~albrecht/pubs/pdf/gellersen_mc2001_paper2webl.pdf

Paper-to-Web

- **Using the CrossPad as Client for paper based input**
- **Transparent proxy between CrossPad and Web Server**
  - Conversion of web forms (HTML) into print documents
  - Recognition of handwriting and marks in the paper forms and conversion



Application, Results

- **Test in different domains (interviews, inventory)**
- **Usability: unobtrusive, transparent, custom interface (additional: paper copy)**

Chapter 4
Analyzing the Requirements and Understanding the Design Space

Alternative Lo-Fidelity Output Devices

- Visual
  - analogue representations:
    dials, gauges, lights, etc

- Auditory
  - beeps, bongs, clonks, whistles and whirrs
  - used for error indications
  - confirmation of actions e.g. key click

Albrecht Schmidt
Embedded Interaction Research Group
University of Munich, Germany

Incense Clocks

- […One is a 19th-century Chinese fire clock (a slow fuse lights successive compartments, one at a time) the other an incense clock. Each new smell (another incense) marks a passage of time.] (http://www.thisislimitededition.co.uk/printversion.asp?ID=142)

http://www.nawcc.org/museum/nwcm/galleries/asian/incense.htm

Aromatic Output for HCI

- From: Joseph "Jofish" Kaye, Making scents: aromatic output for HCI, Interactions, Volume 10, Number 1 (2004), Pages 48-61
- Humans use their sense of smell
  - Is food save to eat?
  - Is there danger due to a fire?
  - Relationships
- An almost entirely unexplored medium in HCI
  - There are reasons for this: technical difficulties in emitting scent on demand,
  - chemical difficulties in creating accurate and pleasant scents

Physiology and Chemistry of Smell

- A thousand different kinds of olfactory receptors in our nose, and it is thought that each can sense a single kind of chemical bond in a molecule
- No abstract classification
  - Examples: how does mint taste? It tastes like …mint
  - Compared to colors: green vs. spinach colored
- Rapidly acclimatized
  - Less than 1 minute
- Human Olfactory Bandwidth
  - … hard to tell
  - Perfumers and florist can distinguish many different smells - potentially thousands

Technology

- Explored in movie theaters and VR… but not really successful
- Different technologies

www.scentury5d.com/

See for examples: http://www.aromajet.com/game.htm and J. Kaye, Making scents: aromatic output for HCI

Ideas in Smell Output, Open Questions

- Olfactory Icons
  - Smell a shot fired each time you press the trigger in Quake
- Ambient Notification
  - Smell of rose to notify you of a date

The question of what information should be displayed is fundamental. Olfactory display is useful for slowly-moving, medium-duration information or information for which an aggregate representation is slowly changing.

Further UIs…

- Bio sensors for
  - Stress level
  - Excitement
  - Tiredness
- Other sensors
  - Acceleration
  - Proximity
  - Force
  - Weight

→ See advanced topics in HCI

Chapter 4
Analyzing the Requirements and Understanding the Design Space

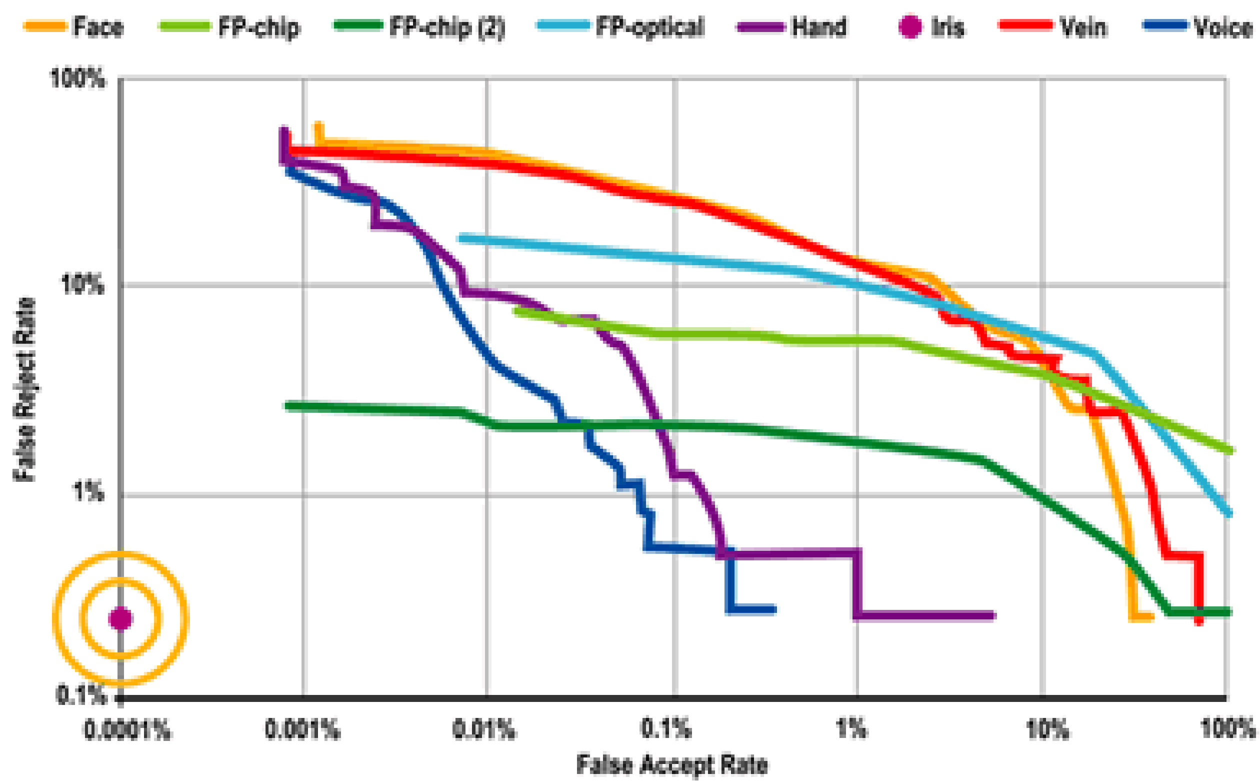
- 4.1 Factors that Influence the User Interface
- 4.2 Analyzing work processes and interaction
- 4.3 Conceptual Models – How the users see it
- 4.4 Analyzing existing systems
- 4.5 Describing the results of the Analysis
- 4.6 Understanding the Solution Space
- **4.7 Design space for input/output, technologies**
  - 4.7.1 2D input
  - 4.7.2 3D input
  - 4.7.3 Force feedback
  - 4.7.4 Input device taxonomy
  - 4.7.5 Further forms of input and capture
  - 4.7.6 Visual and audio output
  - 4.7.7 Printed (2D/3D) output
  - 4.7.8 Further output options
  - **4.7.9 User interfaces for authentication**

User Interfaces for Authentication

- Categories
  - Password based
  - Token based – ID and Authentication in one go
  - Biometric – ID and Authentication in one go
  - Recall, recognition based, e.g. Images
- Parameters
  - False acceptance rate (FAR) – accepting user who should not be allowed in
  - False rejection rate (FRR) – rejecting user who should get in
- High FRRs reduce usability
- High FARs reduce security
- Trade-Off between FAR and FRR

Examples of Biometric Authentication

- Fingerprint
- Hand geometry
- Iris / Retina
- Voice
- Face
- Signature



Detection error trade-off: Best of 3 attempts

careful… data is from a company selling a iris scanner!

Source: http://www.argus-solutions.com/iris_howitworks.htm

Selected Issues with Biometric Authentication

- How to use it
  - What to do? Instructions?
  - Feedback: Did it work? What went wrong?
- User acceptance
  - Data protection, privacy
  - Related to use (hygienic, convenience, …)
- Usability
  - Speed (total operation time), reliability
  - Finger: what finger, position, where is the sensor?
  - Iris: height adjustment, which eye, user distance
- Further issues
  - Cultural issues: e.g. Veil and face recognition?, Gloves and Finger print?
  - Injuries: e.g. burns on finger
  - Changes in appearance: contact lenses, make-up, …

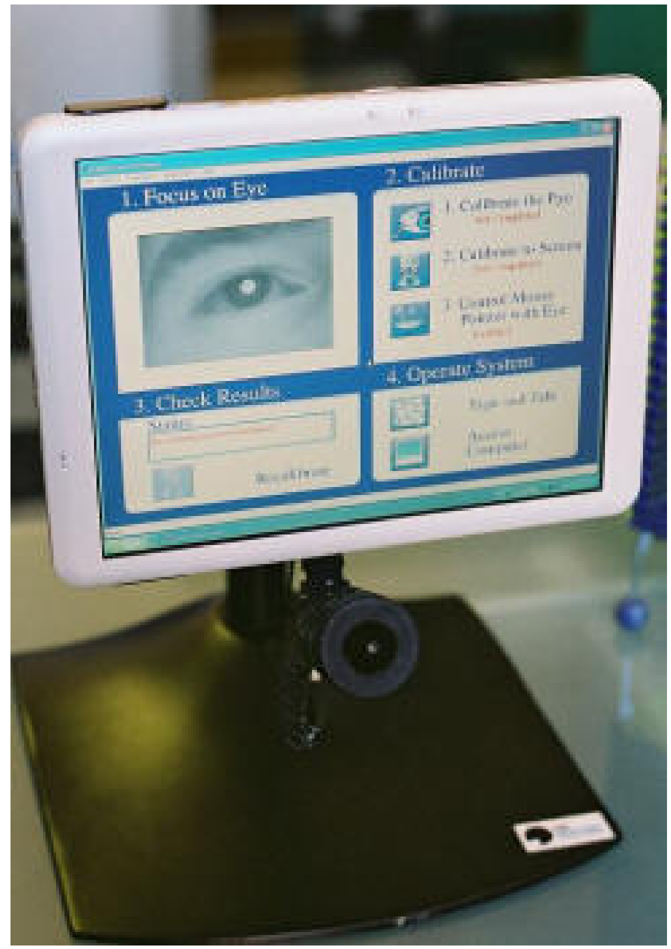
Recall Based Authentication

- Dhamija, R. (2003). Déjà Vu: Using Images for User Authentication. Project Homepage, visited 2004-02-15. http://www.sims.berkeley.edu/~rachna/dejavu/
- A. Schmidt, T. Kölbl, S. Wagner, W. Straßmeier (2004). Enabling Access to Computers for People with Poor Reading Skills. User Interfaces for All (UI4ALL), Wien, June 2004

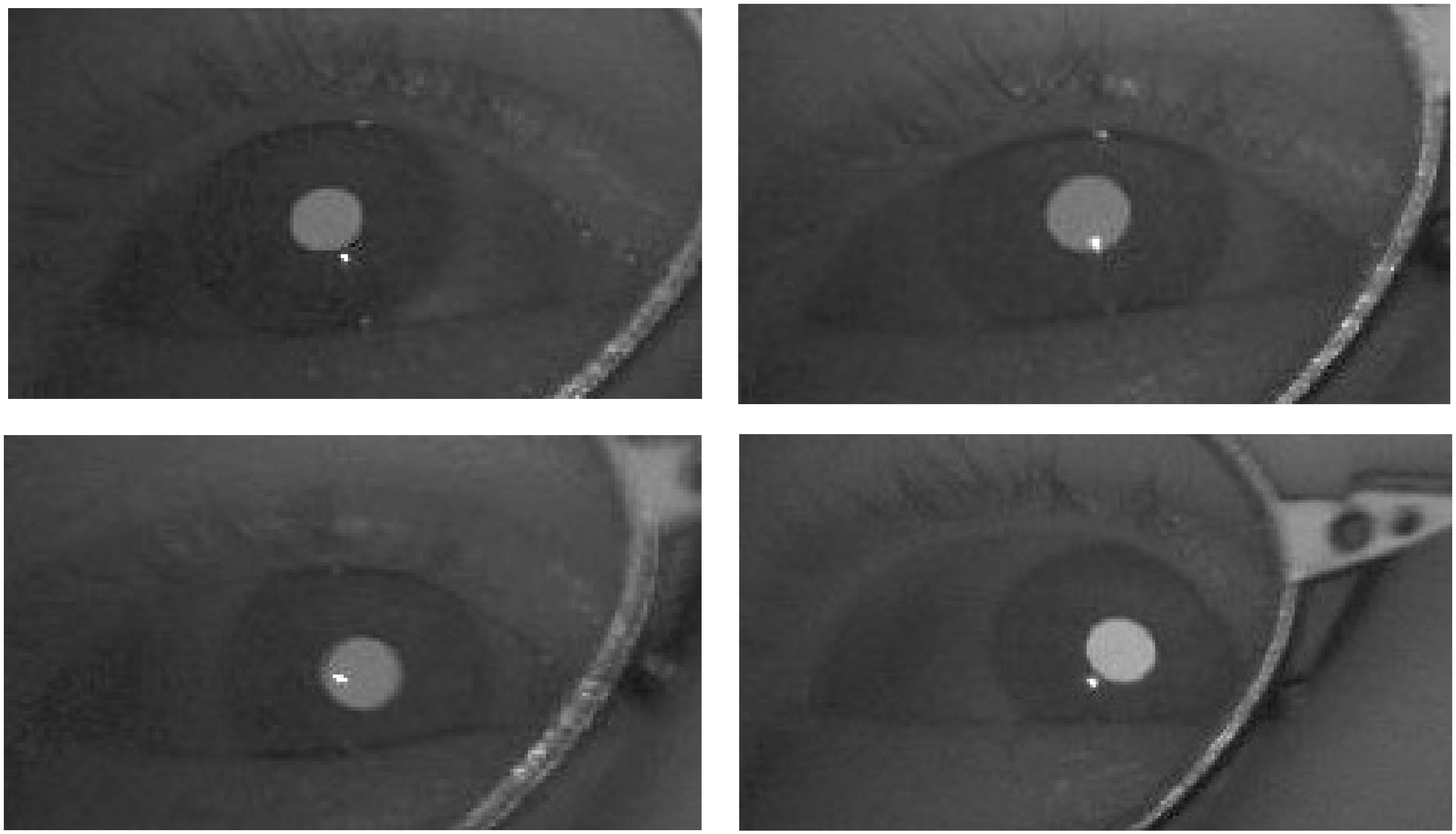
Chapter 4: Appendix - Exercise Eye-Tracking

Eye Tracker

- ERICA
  http://www.eyeresponse.com/
- Eye gaze system used in the exercise



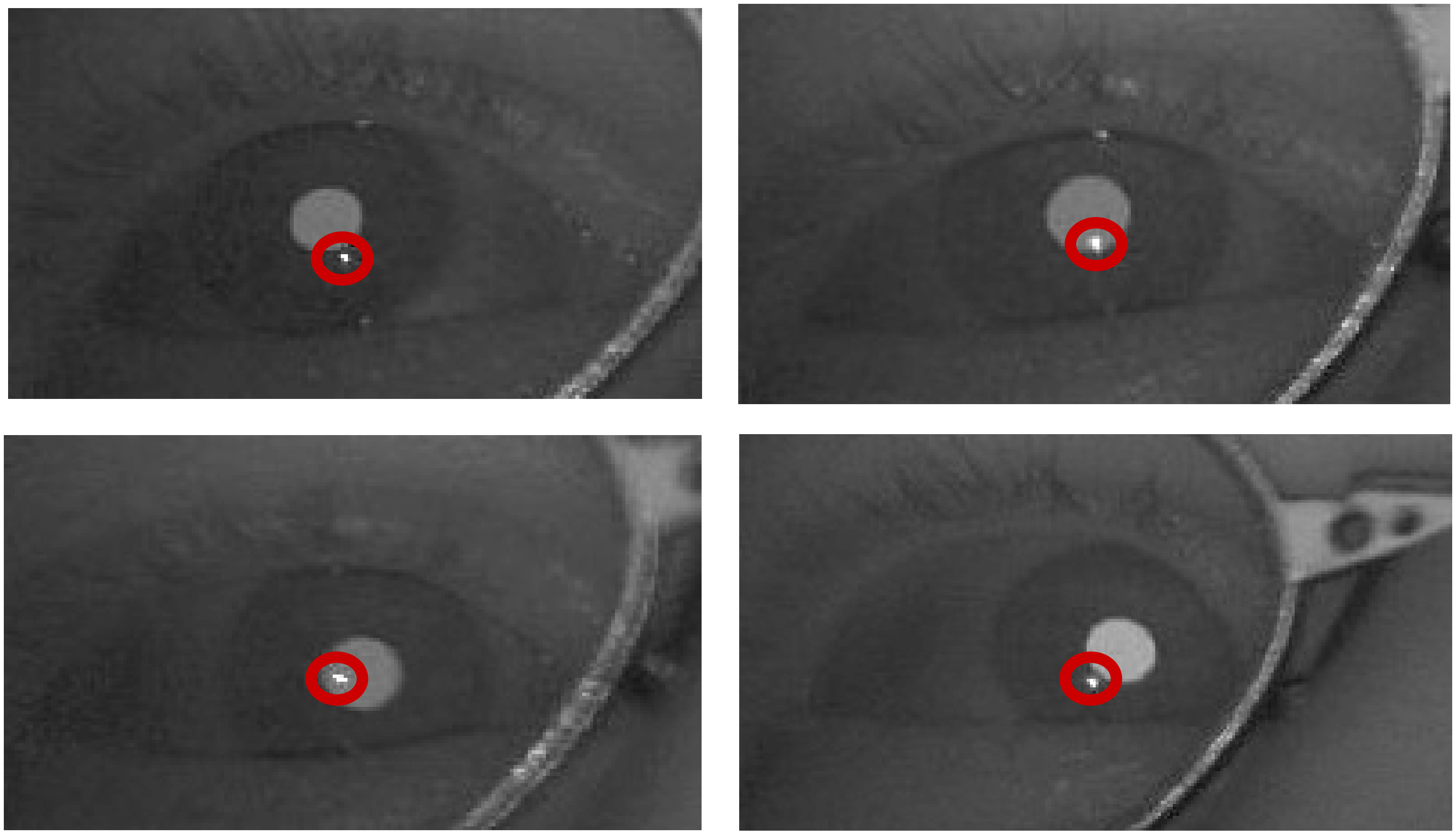
Eye Gaze / Eye Tracker



- Reflection (glint) and eye movement

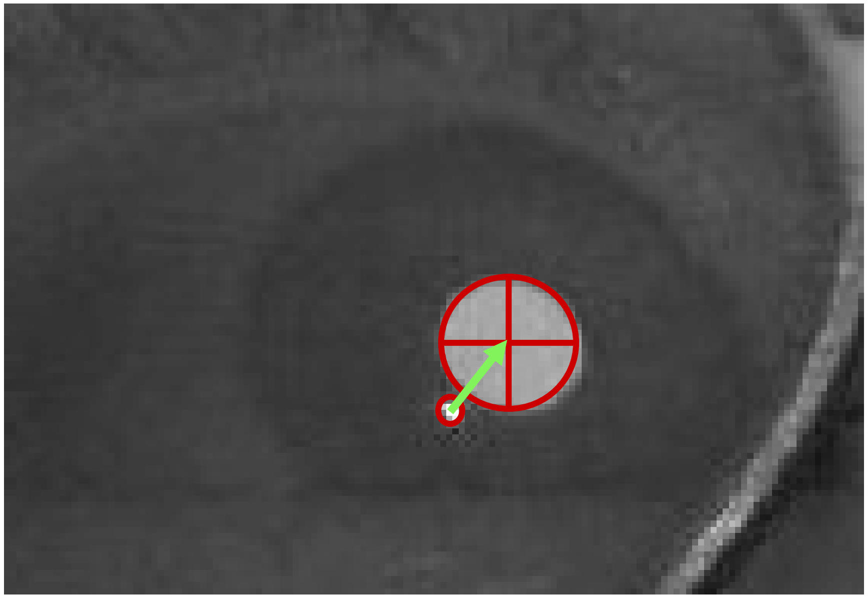
Albrecht Schmidt
Embedded Interaction Research Group
University of Munich, Germany

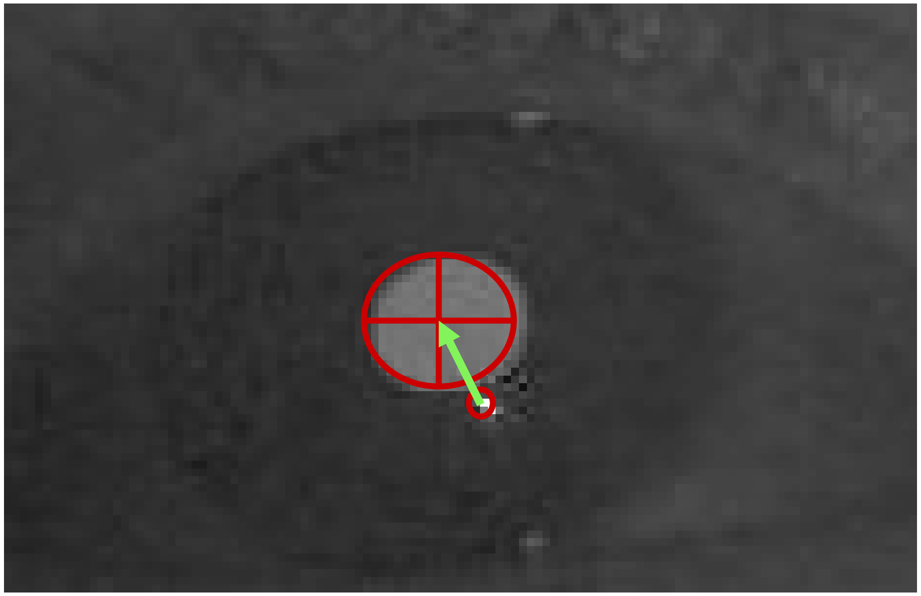
Eye Gaze / Eye Tracker



- Reflection (glint) and eye movement

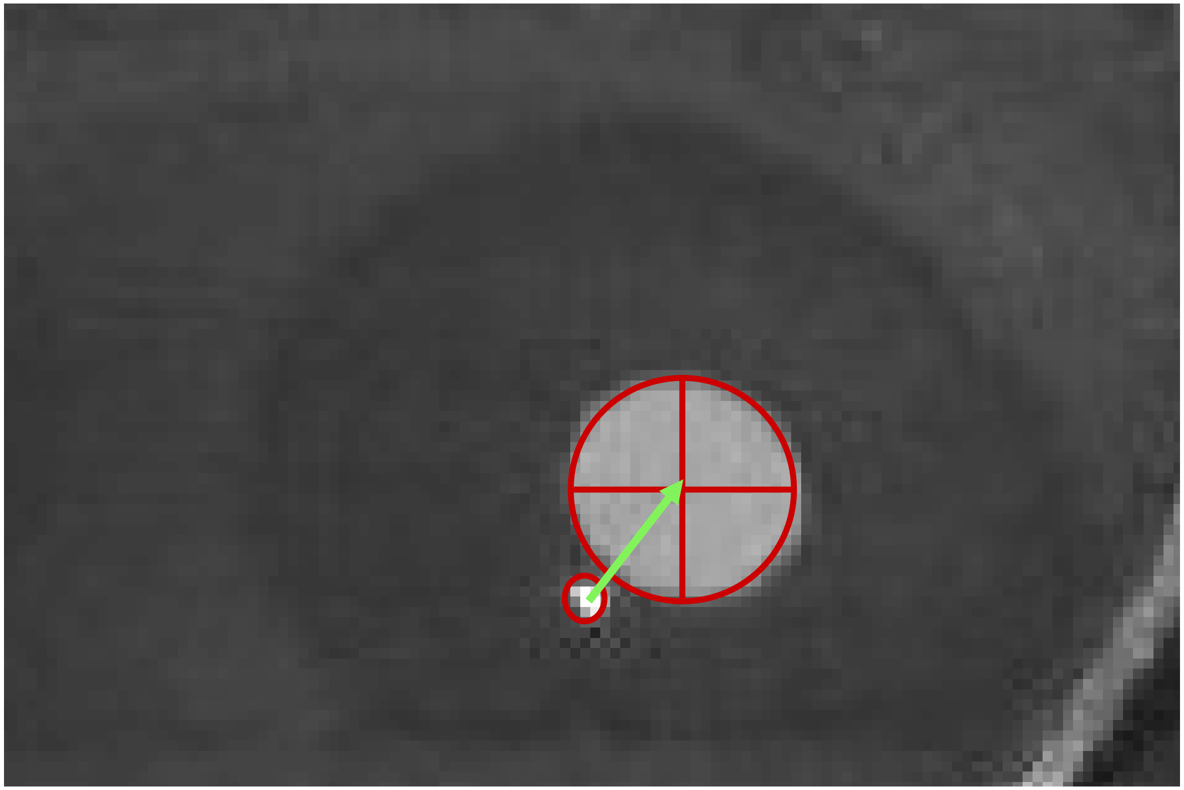
Eye Gaze / Eye Tracker



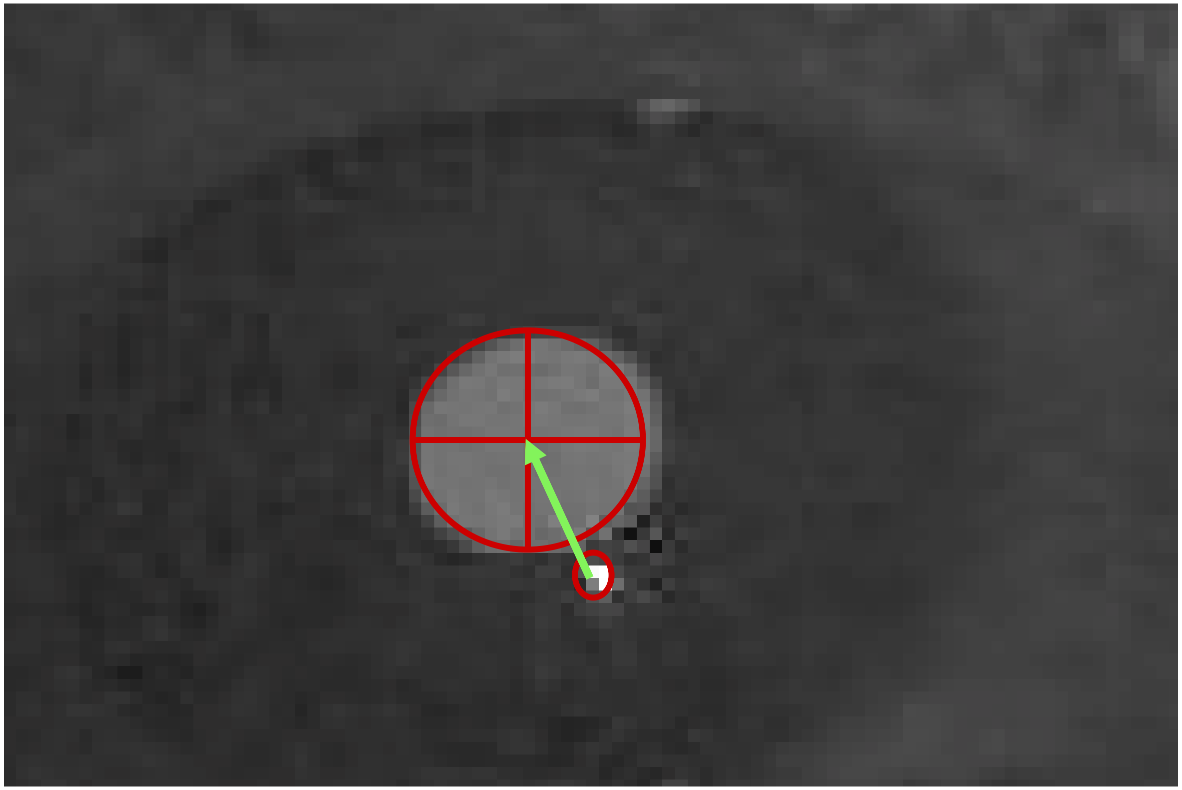


- Measuring the direction and distance between glint and center of the pupil

Eye Gaze / Eye Tracker



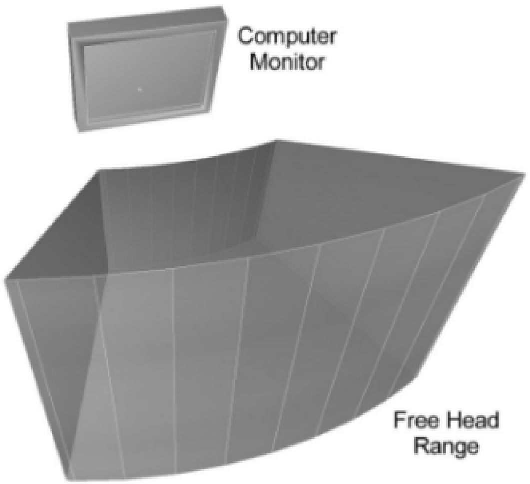
Eye Gaze / Eye Tracker

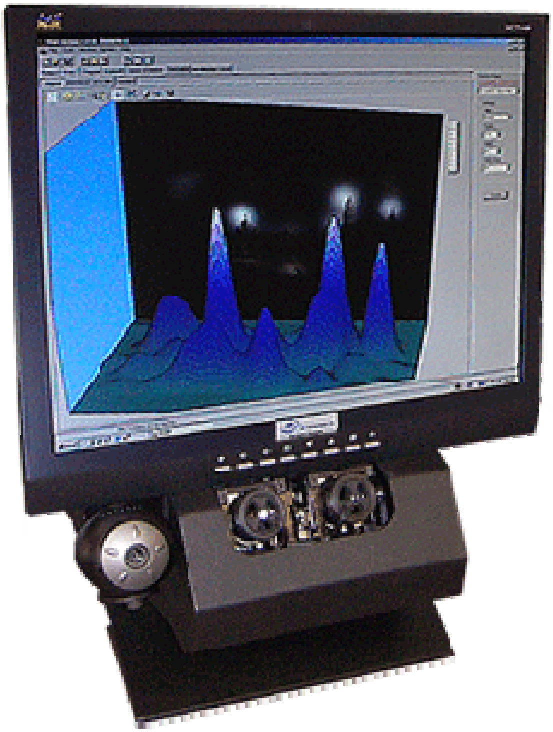


Eye Follower (video)

- Free Head Motion
- Automatic Eye Acquisition
- Binocular Eyetracking
- High Gazepoint Tracking Accuracy

http://www.eyegaze.com/





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