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Schloss Dagstuhl,
Germany

Embedded Interaction

Summer School on Wireless Sensor Networks and Smart Objects

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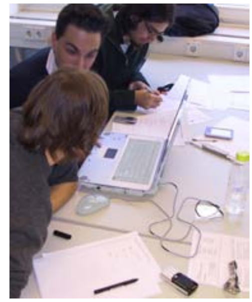
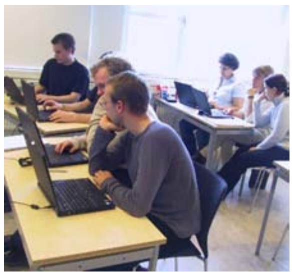
Overview

- Interaction with Information
- Defining HCI
- Development Process
- Traditional Interaction Models
  Modeling Interaction of System
- Selected Methods
  Prototyping & Wizard of Oz
- Implicit Interaction –
  Back to Smart Objects and Environment
- Interaction is Interaction in context
- Experimental research

Is interaction with information…

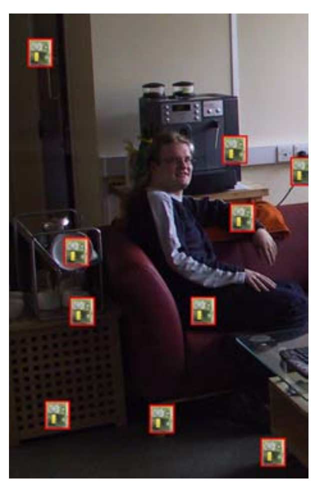
- ubiquitous,
- invisible and unconscious,
- intuitive and simple?



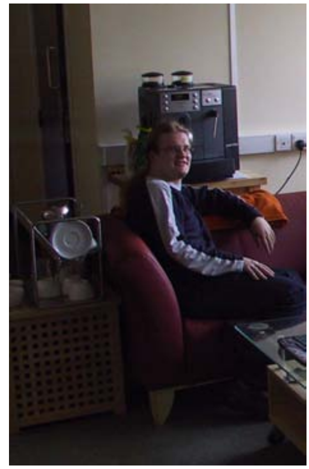


Yes and No!

Future Interactive computing environments



Future Interactive computing environments



Defining HCI

Human Computer Interaction (HCI)

- *"Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them"*
  (working definition in the ACM SIGCHI Curricula for HCI)

- Computer science view point:
  "Interaction between one or more humans and one or more computational machines"

HCI - An Interdisciplinary Area

- **Computer Science**
  application design and engineering of human-computer interfaces

- **Psychology**
  the application of theories of cognitive processes and the empirical analysis of user behavior

- **Sociology and Anthropology**
  interactions between technology, work, and organization

- **Design and Industrial Design**
  creating interactive products

Utility, Usability, Likeability

- **Utility**
  a product can be used to reach a certain goal or to perform a certain task. This is essential!
- **Usability**
  relates to the question of quality and efficiency. E.g. how well does a product support the user to reach a certain goal or to perform a certain task.
- **Likeability**
  this may be related to utility and usability but not necessarily. People may like a product for any other reason…

What is Usability

Usability 101 by Jakob Nielson

- *"Usability is a quality attribute that assesses how easy user interfaces are to use. The word 'usability' also refers to methods for improving ease-of-use during the design process."*
- Usability has five quality components:
  - **Learnability**: How easy is it for users to accomplish basic tasks the first time they encounter the design?
  - **Efficiency**: Once users have learned the design, how quickly can they perform tasks?
  - **Memorability**: When users return to the design after a period of not using it, how easily can they reestablish proficiency?
  - **Errors**: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
  - **Satisfaction**: How pleasant is it to use the design?

Why is Usability Important?

- Improving usability can
  - increase productivity of users
  - reduce costs (support, efficiency)
  - increase sales/revenue (web-shop)
  - enhance customer loyalty
  - win new customers
- Several case studies that show the benefit of usability
- Usability is often considered as sign of quality
- Working with users can create ideas for new products, e.g. "similarities" feature at amazon.com

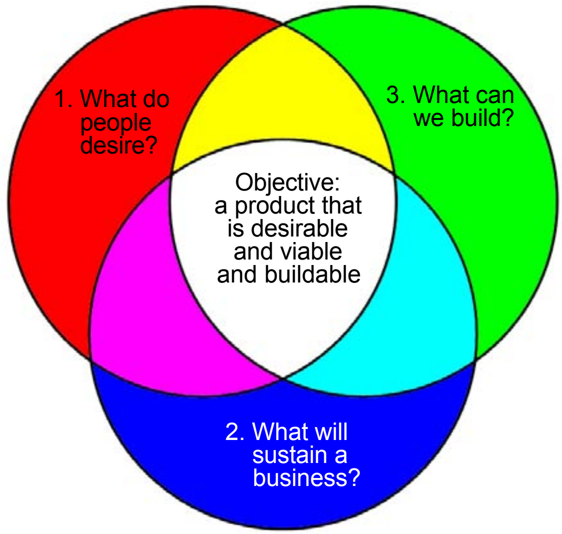
How to Achieve Usability

(high level overview – more details later)

- Identify what utility and usability for the product means
  - main purpose of the product
  - anticipated users, target audience
  - compare with similar/competitive products (if applicable)
- Common effort in the design and development process
  - trade-offs between design, engineering, and usability
- Iterative evaluation
  - usability testing with different methods at various stages of the development process
- Improvement after product release
  - monitoring user behavior
  - evaluation of changes to the product (e.g. adding a new feature to a web shop)

Building Successful Digital Products

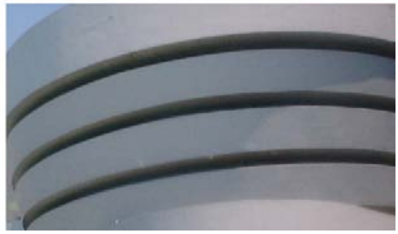
- tension
  - different objectives
  - different design goals
- step by step 1-2-3
- solution
  - Products in the overlapping space



From A. Cooper, About Face 2.0

Development Process

What the User Sees



- Users see only what is visible!

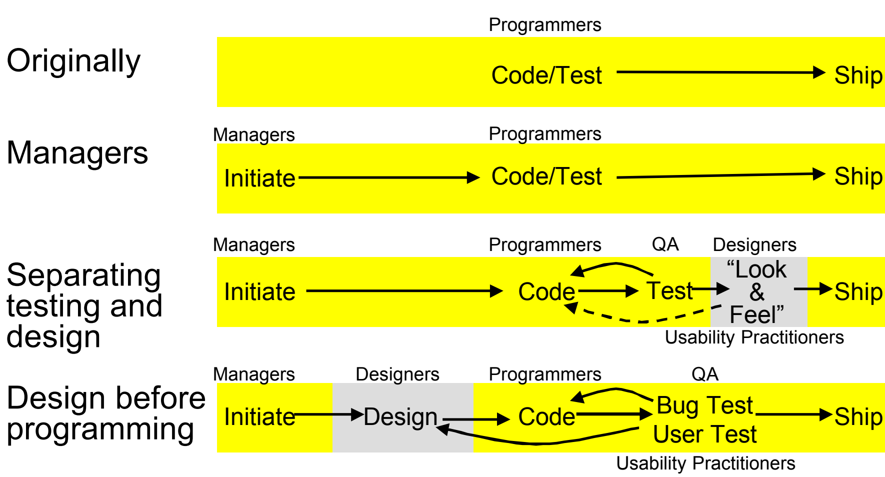
What the Developer Knows

- Users see only what is visible!
- users have little idea about:
  - architecture,
  - state transitions,
  - dependencies
  - application context
  - system restrictions
  - …

HCI is Central to the Design and Development Process

- … even if done unconsciously. Decisions made in the development process are likely to influence how a product can be used.
- thinking about the user interface when a first version of a product is finished is to late!
- good user interfaces – and often good products – are a joined effort of all participants in the design and development process
- similar to building a house… the interior designer can't solve problems caused by bad engineering.

Evolution of the Software Development Process



From A. Cooper, About Face 2.0

Interaction Models
Modeling Interaction of System

Understandability and Usability

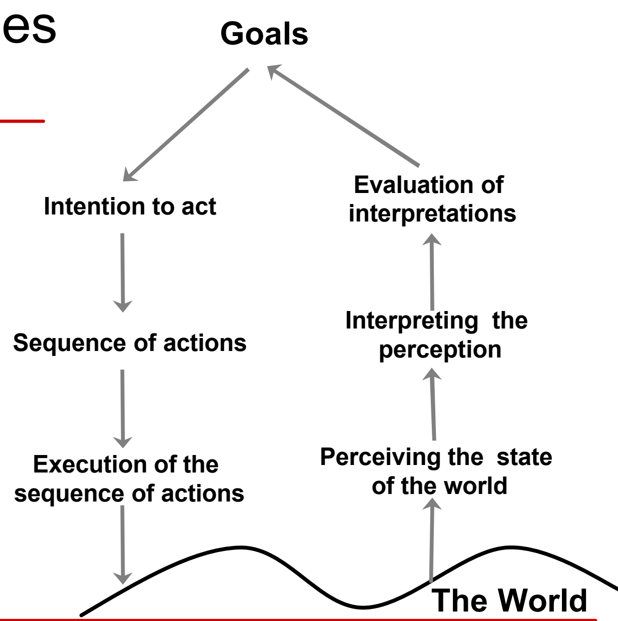
- Principles of Design (Norman, 2002)
  1. Provide a good conceptual model
  2. Make things visible
- A conceptual model is used to predict the effect of actions performed. The conceptual model is based on:
  - Affordances - basic properties of the device/system
  - Constraints - possible actions that can be performed
  - Mapping - Relationship between controls and outcome
  - Experience - knowledge acquired that is related to the domain
- Visibility relates also to mappings and feedback
  - Provide a control for each function (direct mapping)
  - Make actions and reactions visible (feedback)

Background: The Psychology of Everyday Action (Norman 2002, Chapter 2)

- People are blaming themselves for problems caused by design
  - If the system crashes and the user did everything as he is supposed to do the developer/system is blamed
  - If the system crashes and the user operated the system wrongly the user is blamed
- People have misconceptions about their actions
  - The model must not be fully correct – it must explain the phenomenon
- People try to explain actions and results
  - Random coincidence may lead to assumptions about causality

Seven Stages of Action

1. Forming a goal
2. Forming an intention
3. Specifying an action
4. Executing the action
5. Perceiving the system state
6. Interpreting the system state
7. Evaluating the outcome



Norman 2002

Gulf of Execution

- The difference between the intentions and the allowable actions is the Gulf of Execution
  - How directly can the actions be accomplished?
  - Do the actions that can be taken in the system match the actions indented by the person?
- Example in GUI
  - The user wants a document written on the system in paper (the goal)
  - What actions are permitted by the system to achieve this goal?
- Good design minimizes the Gulf of Execution

Norman 2002

Gulf of Evaluation

- The Gulf of Evaluation reflects the amount of effort needed to interpret the state of the system how well this can be compared to the intensions
  - Is the information about state of the system easily accessible?
  - Is it represented to ease matching with intensions?
- Example in GUI
  - The user wants a document written on the system in paper (the goal)
  - Is process observable? Are intermediate steps visible?
- Good design minimizes the Gulf of Evaluation

Norman 2002

Implications on Design

- Principles of good design (Norman)
  - Stage and action alternatives should be always visible
  - Good conceptual model with a consistent system image
  - Interface should include good mappings that show the relationship between stages
  - Continuous feedback to the user
- Critical points/failures
  - Inadequate goal formed by the user
  - User does not find the correct interface / interaction object
  - User many not be able to specify/execute the desired action
  - Inappropriate / mismatching feedback

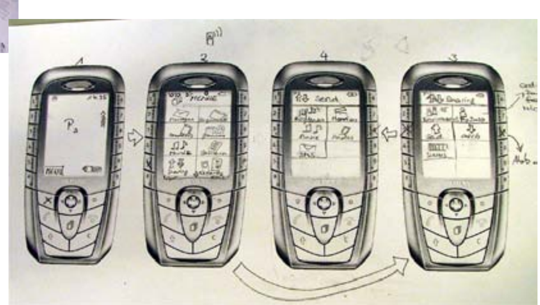
Selected Methods
Prototyping & Wizard of Oz

Design Cycles & Prototyping

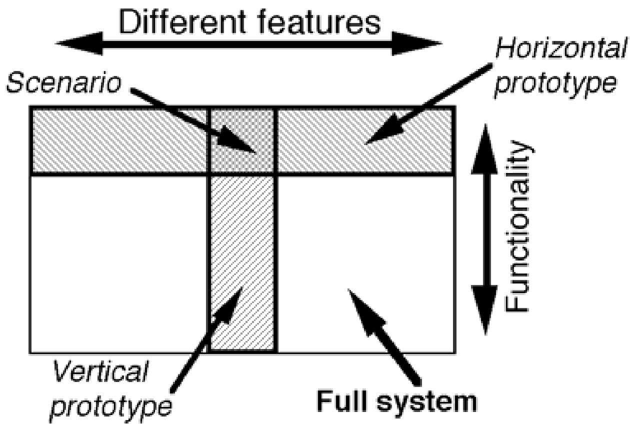
- Creating prototypes is important to get **early** feedback
  - from the project team (prototypes help to communicate)
  - from potential users
- Different types of prototypes
  - Low-fidelity prototypes (e.g. paper prototypes, sketches)
  - Hi-fidelity prototypes (e.g. implemented and semi-functional UI, could look like the real product)
  - Fidelity is referring to detail
- Tools & Methods
  - Sketches & Storyboards, Paper prototyping
  - Limited functionality simulations
  - Wizard of Oz

Sketches & Storyboards

- Storyboards as in movies
  - A picture for each key scene
- Sketch out the application
  - Key screens
  - Main interaction
  - Important transitions
- Helps to communicate and validate ideas
  - Easy to try out different option, e.g. document base vs. application based
- Ignore details, e.g.
  - what font to use, how icons will look like



Addition – about Prototypes



- http://www.useit.com/papers/guerrilla_hci.html

Minimize the time for design Iterations Make errors quickly!

- Idea of rapid prototyping
- Enables the design team to evaluate more design options in detail
- If you go all the way before evaluating your design you risk a lot!
- Sketches and paper prototypes can be seen as a simulation of the real prototype

- Without paper prototyping:
  - Idea – sketch – implementation – evaluation

Slow Iteration

- With paper prototyping:
  - Idea – sketch/paper prototype – evaluation – implementation - evaluation

Quick Iteration **Slow Iteration**

Wizard-of-Oz

- "The man behind the curtain"
- Basically don't not implement the hard parts in the prototype – just let a human do
- Typical areas
  - Speech recognition, Speech synthesis
  - Annotation
  - Reasoning
  - (Visual) Perception
- Provides the user with the experience without extensive implementation effort for the prototype

Back to Smart Objects and Environment

Implicit Interaction

Interacting with disappearing computers

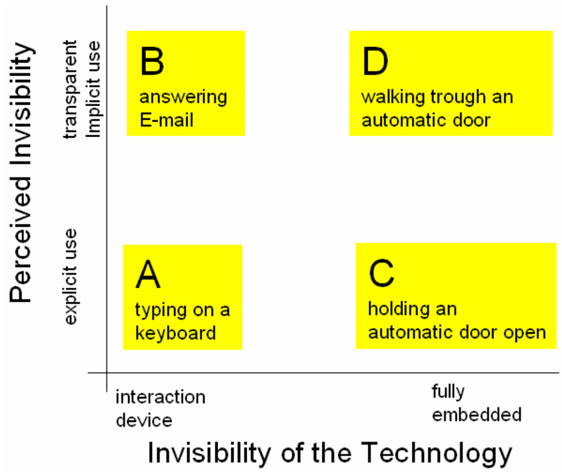
- Disappearing is NOT only
  - Very small systems
  - Computers and devices invisibly embedded in the environment
  - Computers disguised as everyday objects
- Perceiving computers as “invisible”
  - Dependent on previous knowledge of the user
  - Related to the user’s expectations
  - Is subjective and varies
- **Interaction with information** means that the user focuses on the primary task. The user is not aware that she or he is operating a distributed set of connected computers.

Interaction – motivation sensor controlled automated door

- Implicit use:
  go through the door
- No thought on sensors, actuators, and control.

- Explicit use:
  open the door for deliveries
- Manipulating the sensor to get the desired effect
- Explicit use requires an understanding of the conceptual model of the user interface!

Transparency and embedding



- Physical embedding does not ensure transparent use.
- Physical embedding is no prerequisite for transparent use.

A extended design space for interactive systems

		mode of interaction	
		explicit	implicit
modality	command line		
	GUI & direct manipulation		
	gestures		
	tangible and physical UIs		

Implicit interaction

Implicit Human-Computer Interaction (iHCI)

- iHCI is the interaction of a human with the environment and with artefacts which is aimed to accomplish a goal. Within this process the system acquires *implicit inputs* from the user and may present *implicit output* to the user.

Implicit Input

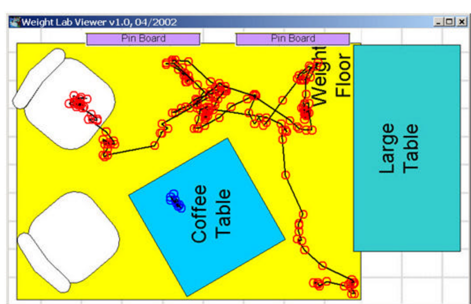
- Implicit input are actions and behaviour of humans, which are done to achieve a goal and are not primarily regarded as interaction with a computer, but captured, recognized and interpret by a computer system as input.

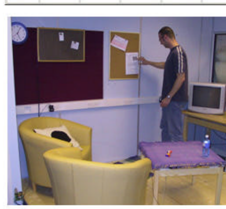
Implicit Output

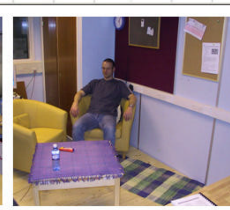
- Output of a computer that is not directly related to an explicit input and which is seamlessly integrated with the environment and the task of the user.

Implicit and explicit interaction Experiment

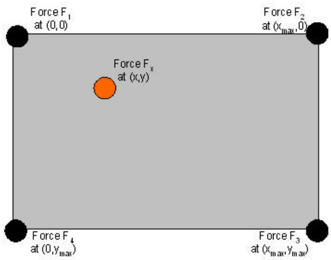
- Environment with surfaces that are load sensitive
- Tables with 4 load cells
- Recognition of implicit and explicit interaction

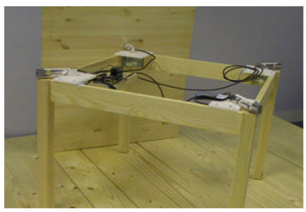


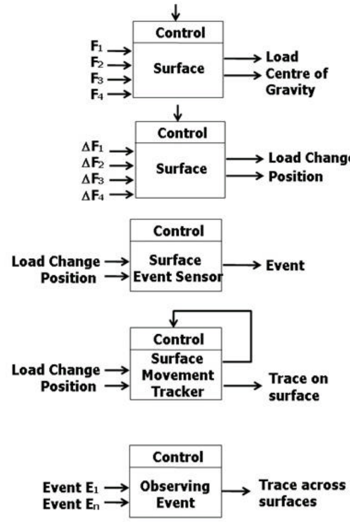




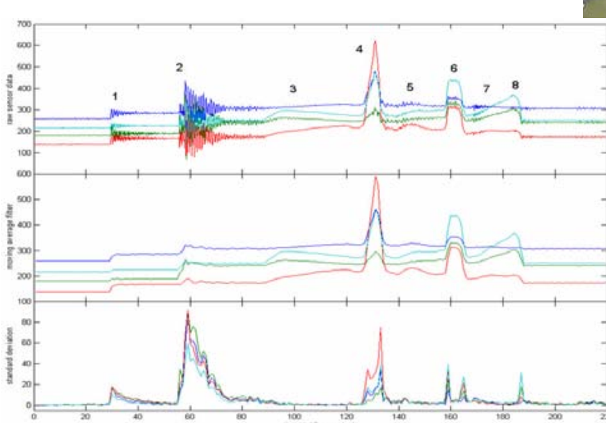
Implicit and explicit interaction
Sensing details



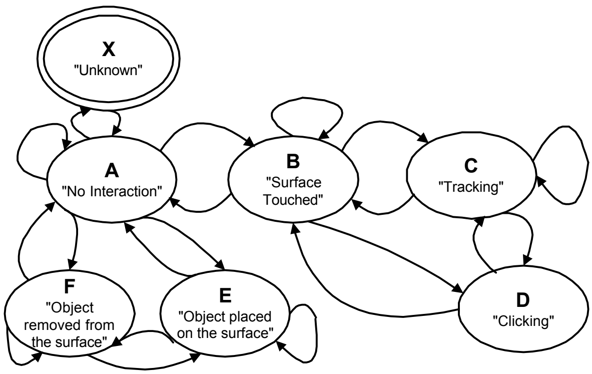




Implicit and explicit interaction
Interaction Events



Implicit and explicit interaction interaction model



- Conditions for transitions

X→A:

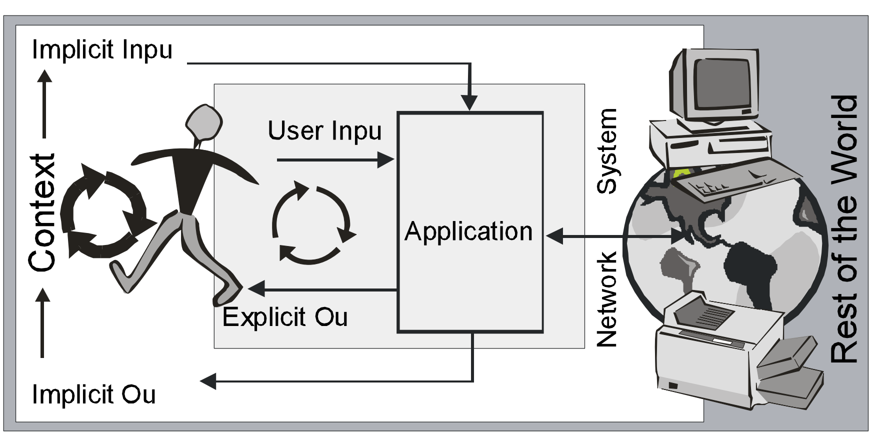
$$\sum_{i=1..4}\sum_{j=(t-n)..(t-1)} \left|(F_i(t)-F_i(j))\right| < e$$

C→D, B→D:

$$\sum_{j=(t-n)..(t-1)} \left|(F_x(t)-F_x(j))\right| > d \wedge$$

$$\sum_{j=(t-n)..(t-1)} \left|(p(t)-p(j))\right| < e$$

A revised model for human computer interaction



Interaction is Interaction in context

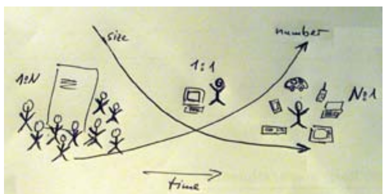
Interaction is interaction in context

- The computer is a part of our world.
- Living in a modern world is interaction with an I/O subsystem of a distributed embedded computer.

*"The real power of the concept comes not from any one of these devices; it emerges from the interaction of all of them. The hundreds of processors and displays are **not a "user interface"** like a mouse and windows, **just a pleasant and effective "place" to get things done**." (Mark Weiser, 1991)*

How are new interfaces related to pervasive computing?

- Powerful and small processors
- Nearly limitless memory
- Ubiquitous networks
- Novel display technologies



- **Sensors**
  - Acquiring different parameters in the real world
  - E.g. activity, context
- **Actuators**
  - Computer controlled devices
  - Components in buildings and engineering
- **Production technologies**
  - individualization
  - E.g. 3D printing

New Production Technologies can change the use of technology

- Similar to a laser printer
  - Paper is still one of the most important user interfaces
  - print → read → dump
- 3D-print
  - Interaction devices with a specific form factor
  - Custom made – even if you only need for one task

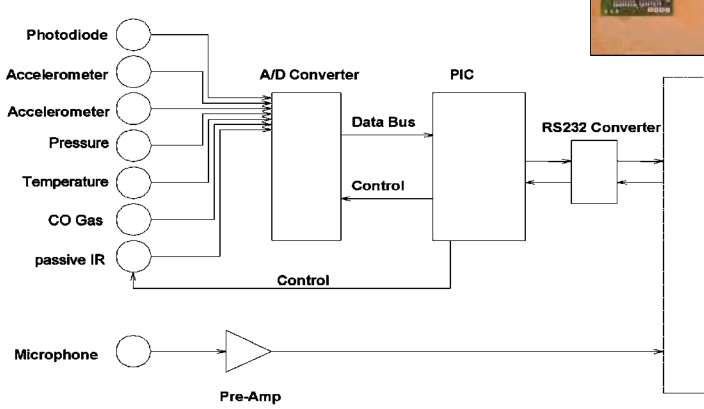
Vision: embed technology components into custom-made short-lived cases

Context-Aware Phone
Project TEA

Perception – even if simple – is a key issue for making smart devices

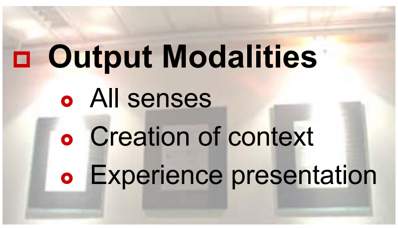
- Phone acts context dependent
- Recognizes contexts
  - "in the user's Hand"
  - "on a surface"
  - "in a bag"
  - …
- Algorithms with minimal processing

Context-Aware Phone
Basic Hardware



The world becomes the user interface

- Everyday objects and environments allow new way for interaction with information
- Pervasive technologies (e.g. RFID) have the implication that interaction in the real world is at the same time interaction in the data world
- User experience is a central issue
- Focus is on information not on the device



- **Output Modalities**
  - All senses
  - Creation of context
  - Experience presentation

- **Input Modalities**
  - Allow expressiveness of humans
  - Perception
  - Acquisition of context

The Basic Questions

Where do we create information?

- How to acquire and understand it?
- How to represent and store it?
- How to distribute and use it?

Where do we use information?

- How to display information?
- What to present?
- Where and when to show information?

Experimental research

Experimental research

- New tools for interaction with information, new forms of interaction
  - Understanding information creation and information access in context
  - Concept and design
  - Implementation and test
  - Evaluation with users
  - Formulating conclusions

- Step by step identifying new “Widgets” in the real world
- Finding design parameters for those “Widgets”

- In my view experimental research (building functional prototypes) is the only way to get the foundations…

Experience…

- requires engaging with the world around us
- is not theoretical

DistScroll - concept interaction with one hand

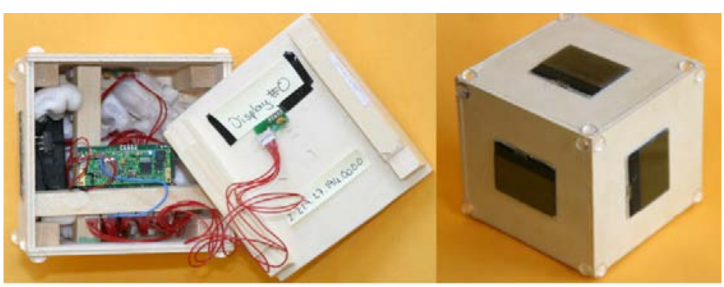
- Mobile devices are used in many different contexts.
- How can you interact with one hand, how to interact when wearing gloves?
  - Navigation based on distance to the body and using one button to make a selection
- … what comes after the idea?

DistScroll
interaction with one hand

- …finding generic parameters for this type of interaction device
- „Fitts‘ Law“ for this type of interaction
- Interesting parameters, e.g.
  - How many menu items?
  - What distance interval to the body?
- Steps
  - Identification of parameters
  - Implementation
  - User studies
  - Creating guidelines

Interaction Cube

Example of a physical user interface

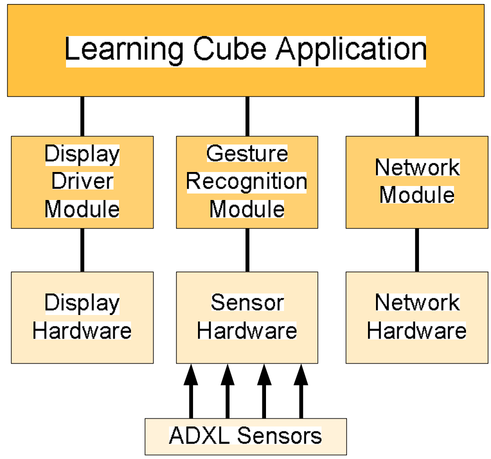


- Complete “computer”
- 6 Displays, one on each side
- Integrated wireless communication
- Sensors to acquire information on gestures and movement

Interaction Cube

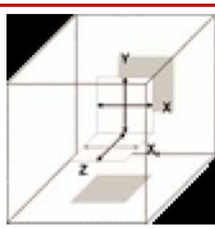
System architecture

- Abstraction from hardware
- Middleware for handling interaction
- Application is independent from actual hardware
- Application describes interaction with information

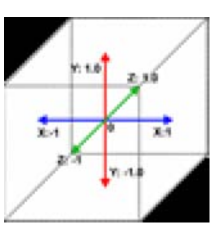


Interaction Cube

Sensors and input

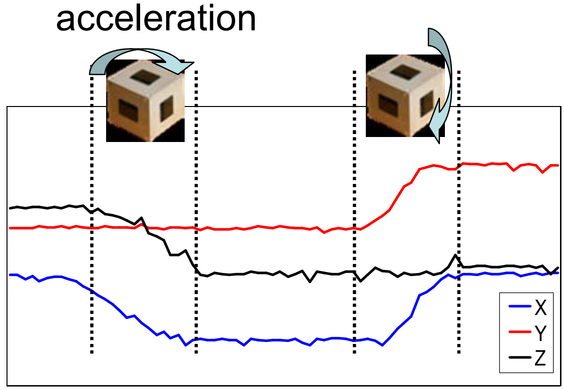


Physical arrangement



Abstracted Model

- Gestures (implicit and explicit) are recognized from acceleration

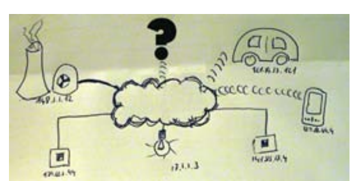


Interaction Cube
initial results from user studies

- Quiz as application
- Explorative user interface
- Physical activity required
  - Shaking / movement
  - Becomes an additional design parameter
- Children understand the UI based on the affordances
- UI supports cooperation

Problems with Pervasive User Interfaces

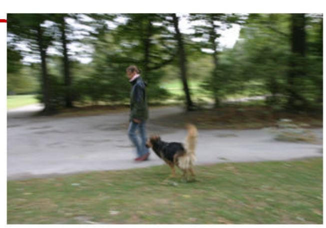
- Virtually no constraints anymore
- Distribution of control (no single focus)
- Interaction with a variety of applications
- Difficulties with the presentation of feedback
- User may not be aware that she or he is interaction with a system
- Communication of the conceptual model to the user

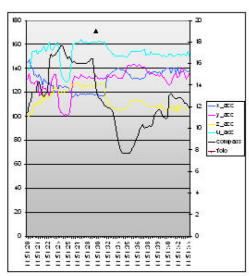


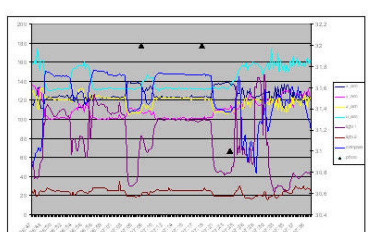
Tools for analyzing interaction
Tools to enhance “real world tools”

- Example Photography
- Custom made sensor box attached to a camera
- Recording additional information while “working”
- Study with 5 photographers

Tools for Analyzing Interaction







Selected research challenges

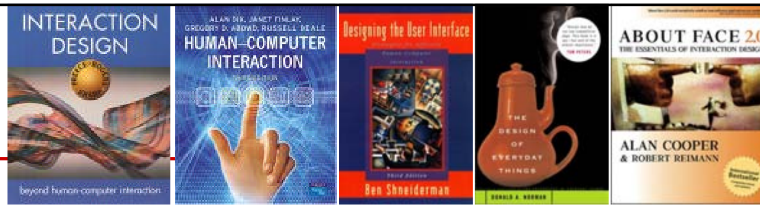
- Physical effect of interaction does not allow to "undo" operations
- Massive distribution and redundancy of user interface components
- Finding, classifying and analyzing a minimal and comprehensive set of real world widgets
- Levels of abstraction and architectures for pervasive user interfaces
- Development support for building pervasive user interfaces

Conclusion




- Information is created and use in context
- A move from device centric interaction to information centric interaction is inevitable
- Pervasive computing technologies allow the creation of new tools for interaction
- Implicit and explicit interaction co-exists
- Central Design principles
  - Appropriate abstraction between components
  - Allow implicit and explicit interaction
  - Provide hints for the user to acquire a model
- Experimental approach to user interface research

Some Books



- Jennifer Preece, Yvonne Rogers, Helen Sharp (2002). Interaction Design. ISBN 0471492787
- Alan Dix, Janet Finlay, Gregory Abowd and Russell Beale. (2003) Human Computer, Interaction (third edition), Prentice Hall, ISBN 0130461091
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