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Ubiquitous Computing – Computing in Context

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1

Outline

- Ubiquitous Computing
  – influential visions
- Context and interaction
- A bottom-up approach to Ubicomp
- Load sensing
  – a prototyping case study
- The need for a platform
  – Smart-Its

2

Ubiquitous Computing

- Influential Visions …
  – Ubiquitous Computing (Mark Weiser, 1991)
  – The Invisible Computer (Don Norman, 1998)
  – Disappearing Computer (European IST, 2000)
- … and many related ideas
  (often looking at specific issues)
  – Appliance Computing
  – Pervasive Computing
  – Situated Computing
  – Ambient Intelligence
  – Calm Computing
  – Ambient Displays
  – Context-Aware Computing
  – …

3

Weiser: Ubiquitous Computing

- *"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."*
- *"Such a disappearance is a fundamental consequence not of technology, but of human psychology. Whenever people learn something sufficiently well, they cease to be aware of it. […] in this way are we freed to use them without thinking ..."*
- *"… use the term "embodied virtuality" to refer to the process of drawing computers out of their electronic shells. The "virtuality" of computer-readable data […] is brought into the physical world."*

4

Norman: The Invisible Computer

- *"The proper way, I argue, is through the user-centered, human-centered, humane technology of appliances…"*
- *"[…] the primary motivation behind the information appliance is clear: simplicity. Design the tool to fit the task so well that the tool becomes part of the task, ..."*
- *"Making a proper information appliance has two requirements: the tool must fit the task and there must be universal communication and sharing."*

5

IST-Call: Disappearing Computer

- *"A vision of the future is one in which our world of everyday objects and places becomes infused and augmented with information processing and exchange. In this vision, the technology providing these capabilities is unobtrusively merged with real world objects and places, so that in a sense it disappears into the background, taking on a role more similar to electricity - an invisible pervasive medium."*
- *"Artefacts will be able to adapt and change, not just in a random fashion but based on how people use and interact with them. […], resulting in an everyday world that is more 'alive' and 'deeply interconnected' "*

6

Ubiquitous Computing is Computing in Context

Observations
- Computing has moved beyond the desktop and becomes part of everyday environments
- Real world artefacts are augmented with computers
- No "computer users" anymore - user experience becomes a central concern (the challenge has moved beyond task efficiency)

Challenges
- How to allow access always and everywhere
- Enabling transparent use of technology
- Compatibility with everyday life
- Resolving the mismatch between traditional HCI and the vision of invisible computing

Opportunities
- Context as a rich source of information is available
- New interfaces and ways for interaction become feasible
- Implicit Interaction can reduce the complexity of interfaces

7

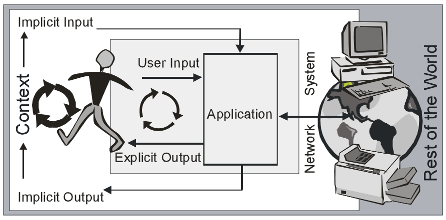
Context & Interaction

- Understanding Context
  - **Context n 1:** discourse that surrounds a language unit and helps to determine its interpretation [syn: linguistic context, context of use] **2:** the set of facts or circumstances that surround a situation or event; "the historical context" *(Source: WordNet ® 1.6, http://www.cogsci.princeton.edu/~wn/)*
  - **Context**: That which surrounds, and gives meaning to, something else. *(Source: The Free On-line Dictionary of Computing, http://foldoc.doc.ic.ac.uk/foldoc/)*
- Invisibility vs. traditional explicit human computer 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.

8

iHCI



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.

9

A Bottom-up Approach to Ubicomp I

Context is anchored in Artefacts

- Modelling and acquiring context on entity level
  - More general properties
  - Flexible and simple model
  - Open and extensible
  - Exploiting domain knowledge
- Augmenting artefacts with
  - Sensing
  - Processing
  - Communication
- Context – on artefact level – is related to interaction with the artefact
- Combining context on a higher level

10

A Bottom-up Approach to Ubicomp II

Towards a Methodology
- Analysing artefacts
- Prototyping context-aware artefacts
- Understanding and recording issues that are coming up when building such systems
- "Confronting" people (e.g. designer & ethnographers) with these artefacts (version 0.001)
- Deployment in a living lab environment
- Facilitating everyday environments
- Recording use – and learning from it

Evaluation
- Finding the right questions: What is the goal?
- Evaluation in context

11

Why Prototyping?

Hypothesis
Prototypes are essential to learn and understand ubiquitous computing

From the idea to knowledge
- Prototyping is central to hallmark Ubicomp research (e.g. ParcTab, ActiveBadge)
- Learning occurs when
  - an idea is transferred into a prototype
  - people are getting the prototype to work
  - prototypes are used to communicate and inspire
  - prototypes are deployed in a living lab
  - studies using the created prototypes
- From the understanding of the prototypes more general concepts evolve
  - models, patterns, architectures, etc.
  - finally the understanding to make products …

12

A Case Study: Load Sensing Surfaces

Context Acquisition in Everyday Environments
- Information about users, environments, and interaction

Including the Design Perspective (Human in the loop)
- Focus on foreground activity
- Interaction with accustomed physical environments
- Exploiting rich affordances of physical artefacts and structures that incorporate surfaces

Challenges
- Everyday environments are not controlled setting
- Unobtrusive and robust implementation

13

Context Acquisition Based on Load Sensing

Surfaces are everywhere
- Surfaces have a purpose & properties
- Centres of interaction

Major research challenge – compatibility with everyday life

Why Load Sensing technology?
- Gravitational forces apply to all physical objects
- Human interaction results in changes in the weight distribution
- Load changes are closely related to our understanding of events in the physical world
- Robust an mature technology
- Low cost technology
- Preserving privacy

Related Work

Ubicomp draws from technologies used in labs
- Put technologies into a different use context
- New use contexts create new challenges
  - Robustness
  - Price
  - Usability
- Opens new directions, new uses

Biomechanics
- Medicine – gait analysis, joint angles
- Sports – shoe traction, optimized training

Ubicomp research "floors"
- ORL active floor [Addlesee,97] – identify and track people, game control [Headon,01]
- Georgia Tech, Smart Floor [Orr,00] – identify and track people

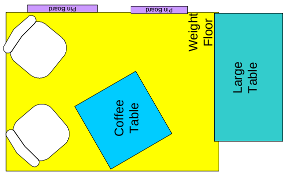
Interaction
- Magic Carpet [Paradiso,97] – input device for performances
- [Konomi,99] i-Land – bridge mechanism – using physical artefacts to transport data

15

Weight Lab

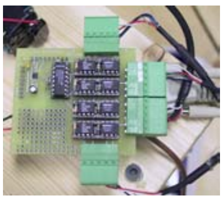
Augmented surfaces
- Floor: 240 x 180cm, up to 800kg load

- Large table: up to 200kg
- Coffee table: up to 8kg, highly sensitive
- Shelves



16

Artefacts Become Wireless Sensors



- Smart-Its sensor AddOn board
- 16 Bit DA
- Instrumentation Amps
- Wireless

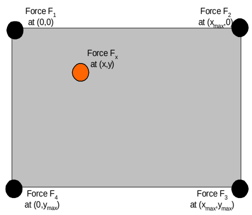
17

Basic Calculations

Weight
- Subject or object anywhere on the surface

Centre of gravity
- 2D position
- overall arrangement

Position on a surface
- 2D position
- Single subject / object



$$F_x = F_1 + F_2 + F_3 + F_4$$

$$F0_x = F0_1 + F0_2 + F0_3 + F0_4$$

$$x = x_{max} \frac{(F_2 - F0_2) + (F_3 - F0_3)}{(F_x - F0_x)}$$

$$y = y_{max} \frac{(F_3 - F0_3) + (F_4 - F0_4)}{(F_x - F0_x)}$$

18

Experiment I: Position on a Surface

Setup

- Table – 135x75
- Six positions
- Different objects placed, one at the time
- Measuring forces and calculating position

Findings

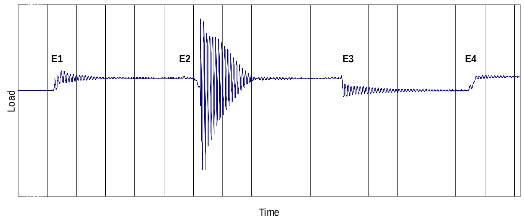
- About 2% of the dimension without calibration
- Repeated real world environment (34kg pre-load)
- Same result

19

Interaction Events

beyond weight and position

- Object put down (E1, E4)
- Object removed (E3)
- Object moved
- Object knocked over (E2)



20

Experiment II: Interaction

Setup

- Different event types
  - Put down
  - Pick up
  - knock over
- 500 ms Time window
- Simple time domain analysis
- Clear table and occupied surface

Results

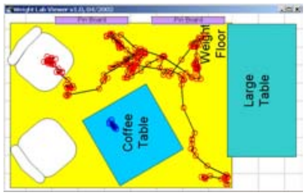
- Events recognized
  - 94% clear table
  - 96% preloaded table

21

Multiple Surfaces

Primitives

- Disappear
- Appear
- Correlation



Exploring applications

- Don't leave things behind
- Single person tracking


22

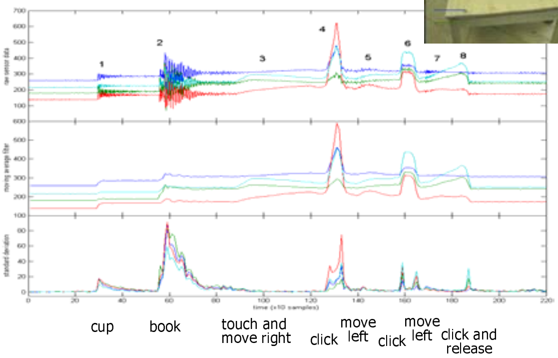
Recognizing Situations

23

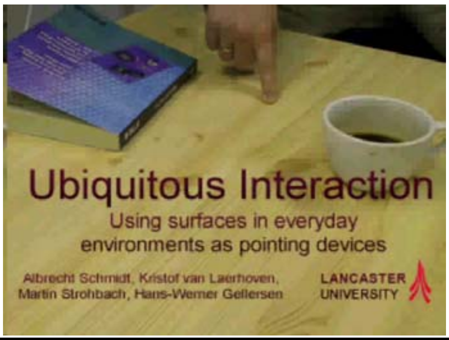
Load Sensing Data I

24

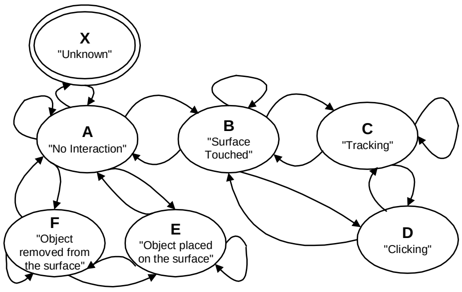
Load Sensing Data II



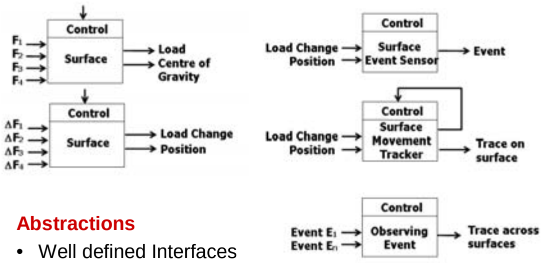
Using Surfaces in Everyday Environments as Pointing Device I



Using Surfaces in Everyday Environments as Pointing Device II



Load Sensing Primitives



Abstractions

- Well defined Interfaces
- Easing further developments
- Similar to Computer Vision

Follow up 1: Augmented Commerce

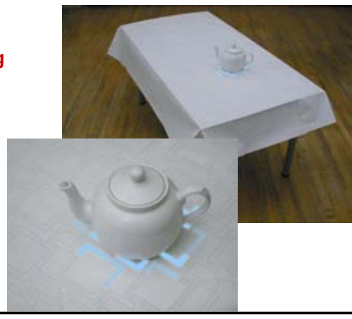
Retail learns from E-Commerce

- Load sensing in shelf
- Detecting interaction, e.g.
  - Product selected
  - Putting things back in the shelf
- Physical recommender systems
  - Non personalized recommendations
  - Item related recommendations
  - Feedback

Follow up 2: New Designs (in cooperation with Royal College of Art, London)

A series of design using load sensing technologies

- History table
- Drift table
- Key table
- Arm chair racing



Load Sensing: Lessons Learned

About Load Sensing
- Can be realized unobtrusive
- Usable in everyday settings
- Robust, proven technology
- Low complexity
- Simple to integrate
- Evaluation in different ways
- New application domains and scenarios based on primitives

About prototyping
- Valuable, allows new insight
- Chance inventions / side findings
- It is expensive and time consuming
- The wheel is reinvented over and over
- Need for building blocks and platform

31

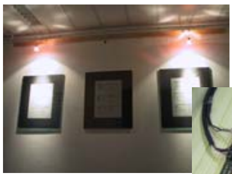
Smart-Its – A new Computing Platform

Means for exploring applications

- Building scenarios
  - Rapid-prototyping of context-aware computing applications
  - Assessing the potential as an enabling technology for ubiquitous computing in various application domains
- Why a new computing platform?
  - Investigating the difference between Smart-Its and an iPAQs with Bluetooth and a sensor board.
  - Price, size and power consumption matters now – even if the future brings it anyway!
- Understanding and refining the requirements

32

Prototypes…



Similar for
- Central processing
- Wireless communication
- Debugging I/O

… but differ in
- Sensing
- Actuators

33

Smart-Its Idea and Objectives

- Sensing, processing and communication
- Enabling technology to make everyday objects smarter
- Post-it metaphor
- Building context aware applications

- Developments
  - Hardware
  - Communication
  - Firmware & software
  - Backend
- Objective
  - Simple (development and use)
  - Robust
  - Extensible
  - Cheap

34

Smart-Its Platform

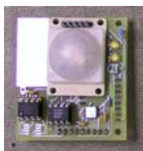
All base boards
- Microcontroller
- Ram
- Analog Inputs
- Digital I/O
- Wireless communication
- All boards are software and hardware compatible

- Small portable unit
  - 45mm x 50mm x 19mm
  - 29g with battery
- Base station and debug unit
  - 55mm x 70mm x 29mm
  - 110g with 4x AAA
  - RS232 connector
  - DC Power Connector

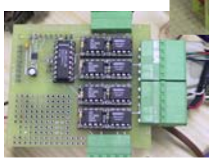
35

New Sensor boards Add-Ons to the core smart-It

- Hardware
  - Much simpler
- Software
  - Build upon frameworks
- Communication
  - Basic functions available



Examples
- General sensors
- Vision / Camera
- Load sensing
- Weather board
- Motion sensing
- Actuator boards
- …



36

Hardware
DIY Approach

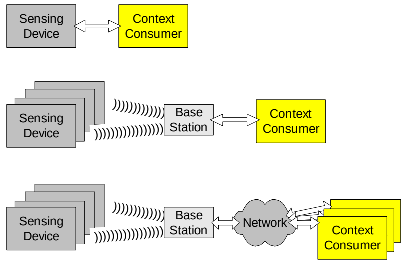
Selected requirements
- Understandable with a CS background
- Minimal electronics skill
- It is a tool
- Similar to electronic kits
- Easing embedding of sensors and actuators
- Reusable
- Basic hardware and software should run within a week for most scenarios

Beyond rapid prototypes
- All components as CAD unit
- Different physical shapes (of the same HW) are easy to do
- Software compatible to modules

37

Software
Context Acquisition Systems

Architectures & Software Frameworks

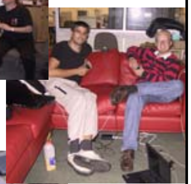


38

Platform Evaluation
Prototyping Exercise I

Evaluation Method
- Developers Workshop (DC Atelier)
- 2,5 days hands-on

Results
- Prototypes & Demonstrators
  - Smart Ball
  - Wireless Gesture Remote Control
  - Singing Smart-It
  - Wireless RFId Sensor
  - Wireless Gesture Joystick
- Value of implementation

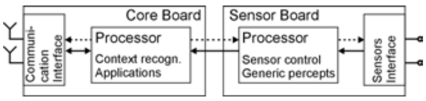


39

Prototyping Exercise - Impressions

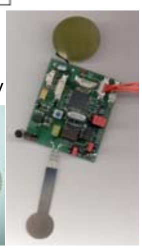
40

Further Routes in Smart Its



ETH Zurich
- Bluetooth node
- Interoperability

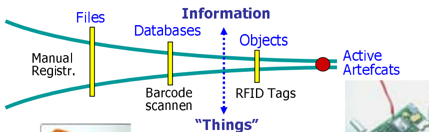
TecO, Uni KA
- Minimal size
- Minimal energy



41

Smart Its: Long Term Vision

Toward tighter integration of „things" with information



Barcodes
Explicit Registration

RF Identification
Implicit, unintentional

Active Artefacts
Dynamic state
Self-controlled presence

42

Conclusions

Issues discussed

- Ubiquitous Computing, Context & Interaction
- Prototyping is an important research method
- Case study: load sensing
  → prototyping is valuable but expensive
- Smart-Its
  → towards a platform to make prototyping affordable
- Evaluation in context

[Weiser,91]

- *"They [Ubiquitous Computing technologies] weave themselves into the fabric of everyday life until they are indistinguishable from it."*

To advance Ubiquitous Computing

- ***We have to weave technologies into the fabric of everyday life until they are indistinguishable from it***.

43

Acknowledgements

- Equator IRC, EPSRC
  (http://www.equator.ac.uk)

- Smart-Its Project
  (http://www.smart-its.org)
  Disappearing computer initiative of the European commission

Software & "Hardware" available at

`http://www.comp.lancs.ac.uk/~albrecht/`

44

Questions?

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45