

iNTRODUCTION

Some Statements about Ubiquitous Computing (GI Computer Zeitung, No. 24, June 10th 2003)

„Through the progress in microelectronics and communication technology the vision of a comprehensive computerization of the world and its items seems to be realistic.

Barely visible microelectronic components can be produced cost effectively and million-fold embedded into the environment.

This allows for a fine-granular supervision of various problems.“

Prof. Friedemann Mattern (ETH Zurich)

„In the production plant of the future a smart tool can sensor its own configuration, the degree of abrasion and its position.

A machine will plan an order by contacting tools in the near environment and choosing the most appropriate.

Billions of sensors will soon permanently measure the world's status building a digital world model as a global information space in analogy to the WWW (e.g. 3-D street maps with visualizations of mobile objects and their context (velocity, temperature, height, etc.))“

Prof. Kurt Rothermel (Uni Stuttgart)

iNtRODUctiON

Some Statements about Ubiquitous Computing (GI Computer Zeitung, No. 24, June 10th 2003)

„Ubiquitous Computing is the logical next step in development in business information processing.

It closes the gap between information systems and reality.

Storage system order new products,
the shopping bag sums the prices,
the blood bottle announces its expiration date
the car wheel signals low pressure“

Prof. Elgar Fleisch (Uni St. Gallen)

„I want to grasp my PDA in a shopping mall, ask for a shop or an ATM and get a map and navigation guidance.“

Steven Shafer (Microsoft Research)

iNTRoDUCtiON

Some Statements about Ubiquitous Computing

„... an attempt at a violent technological
penetration of everyday life.“

Agustin A. Araya (San Jose State University)

„... the feverish dream of spokes and spies
– to plant a „bug“ in every object –
has been enlarged and re-shaped into the millennial dream of
ubiquitous computing“

Stephen Talbott (Author)

„... we have to do with a project, trying to achieve allness,
standing also near to totalitarianism. “

Natascha Adamowsky (Humboldt-University, Berlin)

THE ViSiON

What is ,ubiq-ui-tous'?

(Merriam Webster Online, <http://www.m-w.com>)

Main Entry: **ubiq-ui-tous**

Pronunciation: yü-'bi-kw&-t&s

Function: *adjective*

Date: 1837

: existing or being everywhere at the same time : constantly encountered :

- **ubiq-ui-tous-ly** *adverb*

- **ubiq-ui-tous-ness** *noun*

Synonyms:

omnipresent, allover, universal, constantly available

pervasive to the point of subconscious

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The Vision of Ubiquitous Computing

- ❑ The term ‚Ubiquitous Computing‘ was invented by Marc Weiser in 1988.



Marc Weiser (1952-1999)

„Ubiquitous Computing enhances computer use by making **computers available throughout the physical environment**, while making them **effectively invisible** for the human user.“

- ❑ Weiser was a chief technologist at Xerox PARC (Palo Alto Research Center), one of the most important research centers worldwide
- ❑ The PARC researchers invented Personal Computers, Mouse, Windows, Bitmap terminals, Icons, Laser Printer and many more ...



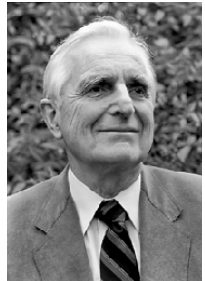
<http://www.parc.xerox.com/>

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Influences:

- ❑ Vannevar Bush (1890-1974): „As we may think“
 - *The Atlantic Monthly*; July, 1945; Vol. 76, No. 1; pp 101-108.
 - This article was written to trigger the peaceful research after World War II
 - Bush described a theoretical machine he called a “*memex*,” It was based on a table with ‘dry photographs’ and allowed the user to store and retrieve documents linked by associations
 - Can be seen as the vision of the Web

- ❑ Douglas Englebart (Born 1925)
 - Was influenced by Bush
 - Wanted to use technology to augment human intellect.
 - He saw technology, especially computers, as the answers to the problem of dealing with the ever more complex modern world
 - He performed early experiments on hypertext as „highly interconnected narratives“ at Stanford Research Institute



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Influences:

□ J.C.R. Licklider (1915-1990)

- Psychologist and Acoustician
- Headed early ARPA computer projects
- Started the area of computer interface design in 1960 with a paper called 'Man-Computer Symbiosis'
- His ideas foretold of graphical computing, point-and -click interfaces, digital libraries, e-commerce & online banking,
- Thought about software that would exist on a network and migrate to wherever it was needed (web services of today?)



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Influences: Myron Krueger – Responsive Environments

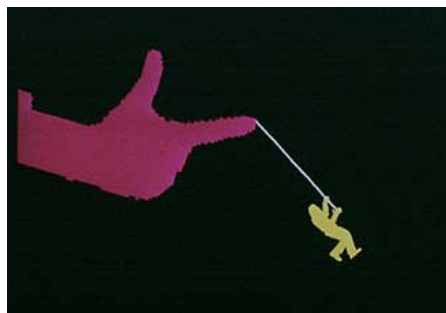
- ☐ *In the environment, the participant is confronted with a completely new kind of experience. He is stripped of his informed expectations and forced to deal with the moment in its own terms. He is actively involved, discovering that his limbs have been given new meaning and that he can express himself in new ways. He does not simply admire the work of the artist; he shares in its creation.,, (MyronKrueger 1977)*
- ☐ Originally trained as a computer scientist, Myron Krueger, under the influence of John Cage's experiments in indeterminacy and audience participation, pioneered human-computer interaction in the context of physical environments.
- ☐ Beginning in 1969, he collaborated with artist and engineer colleagues to create **artworks that responded to the movement and gesture of the viewer through an elaborate system of sensing floors, graphic tables, and video cameras.**
- ☐ At the heart of Krueger's contribution to interactive computer art was the notion of the artist as a "composer" of intelligent, real-time computer-mediated spaces, or "responsive environments".

Source: <http://www.artmuseum.net/w2vr/timeline/Krueger.html>

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▣ Influences: Myron Krueger – Responsive Environments

- ❑ Krueger "composed" environments, such as **VIDEOPLACE** from 1970, in which the computer responded to the gestures of the audience by interpreting, and even anticipating, their actions. Audience members could "touch" each other's video-generated silhouettes, as well as manipulate graphical objects on the screen



- ❑ Basic elements of Ubiquitous Computing are already visible:
 - System recognizes events in the real world (context)
 - System processes the events in some meaningful way
 - System produces some form of effective feedback to the real world
- ❑ A **relationship between real and virtual world** is established

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Mark Weiser's Vision

- ❑ Weiser tried to implement his vision in the **ParcTab Ubiquitous Computing Experiment** as a first testbed
 - „... emphasizing context, sensitivity, casual interaction and spatial arrangement of computers“
- ❑ **Good Technology is invisible**
 - „As inexpensive computers add limited intelligence to a wider variety of everyday products, a new model of computing becomes possible“
 - „Invisible technology stays out of the way of the task“
 - „Bad technology draws intention to it“
 - „Today's computers are mostly not invisible“
- ❑ **New model of usage**
 - „A return to the whole person“
 - „Rational analysis is only a small part of the succesful person“
 - „Planning is only a small part of thinking and work“

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Mark Weiser's Vision

- ❑ Weiser used the **written text as an example** of a good invisible technology
 - Written text is everywhere
 - You don't have to concentrate on the reading process
 - Information input is automatic and intuitive (after learning to read ...)
- ❑ **Computers as good tools**
 - Don't need explicit attention, but instead are hidden in the background
 - Usage is tailored and adapted to the tasks, optimized and obvious
 - Simple tool for direct usage
(Computer as secondary artifact)
 - „Tools are not invisible in themselves, but are part of a context of use“
They have to be aware of the context

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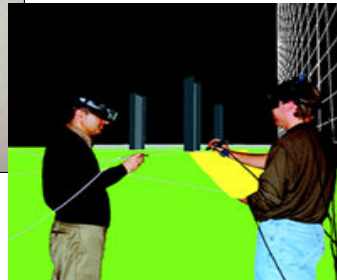
Virtual Reality

Making the reality invisible
and integrating the human in the
(enormous) computer apparatus

Goal: **Create new reality**



Today: Cave



Future: Holodeck?



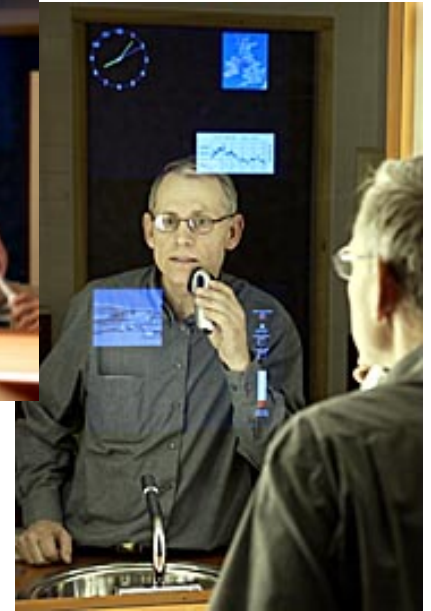
Ubiquitous Computing

Making the computer invisible
and integrating the computer in the
(enormous) surrounding context

Goal: **Improve existing reality**



Future?



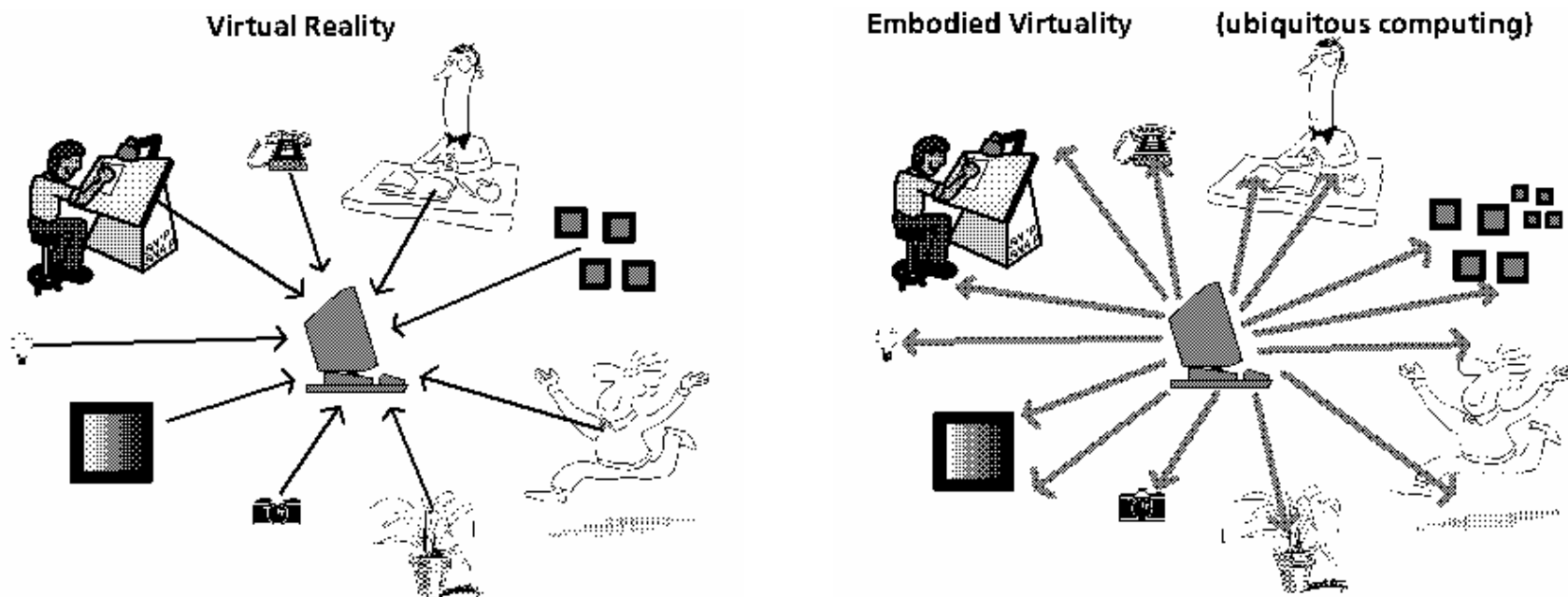
Today: Philips HomeLab
Mirror with integrated Displays



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Weiser's Definitions

- ☐ Ubiquitous Computing is the inverse of Virtual Reality
- ☐ In VR humans are just sensor machines without context
- ☐ Ubiquitous Computing is more like **Embodied Virtuality**
- ☐ Computers are embedded in artifacts of the world (pervasive computing)

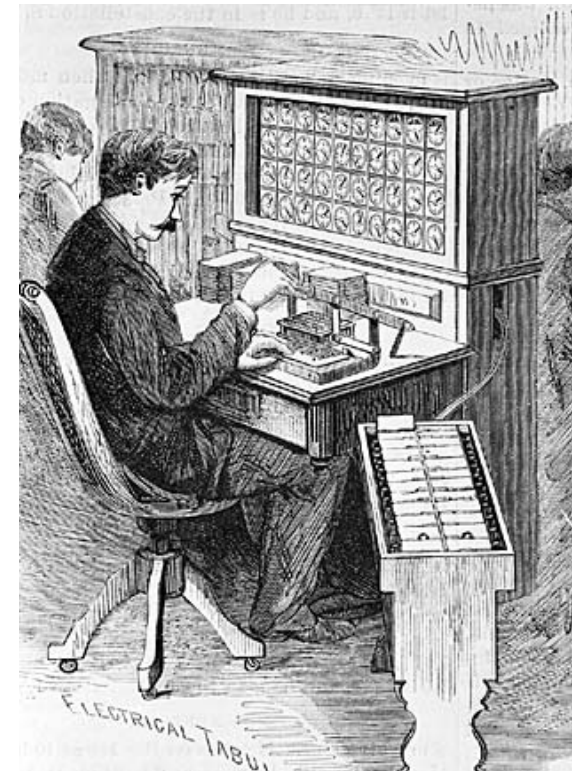


Source: <http://www.ubiq.com/hypertext/weiser/VRvsUbi.gif>

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▣ Era 0 – Human Computers (~300 - 1960)

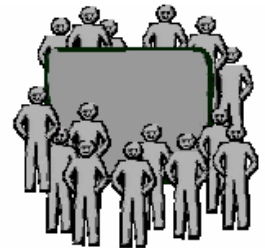
- ❑ Paradigm: Human beings perform calculations using some simple machines (predominantly women)!
- ❑ "Computer" was originally a job title to describe those human beings whose job it was to perform the repetitive calculations required to compute such things as navigational tables, tide charts, and planetary positions for astronomical almanacs.
- ❑ Electronic computers (and the earlier mechanical computers) were given this name because they performed the work that had previously been assigned to people.



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Era 1 – Mainframes (~1960-1980)

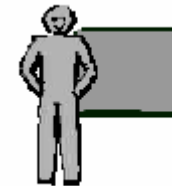
- ☐ Paradigm: Humans share a rare and expensive resource
- ☐ Central, „powerful“ and expensive computer
- ☐ Many users access a single computer from „dumb“ terminals
- ☐ Computers not easily accessible
- ☐ Mainly used in enterprise environments
- ☐ Users: Experts
- ☐ Usage: Explicit, well-prepared



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Era 2 – Personal Computers (~1980-1990)

- ☐ Paradigm: Each human has its own desktop computer
- ☐ „Powerful“ and relatively inexpensive computer
- ☐ Used for word processing, personal applications, video, audio, etc.
- ☐ Users: Everybody, supported by experts
- ☐ Usage: Direct



IBM 5150 (1981)



Commodore C64 (1982)

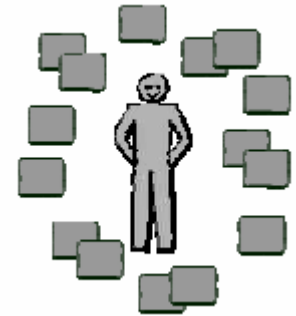


Amiga 500 (1984)

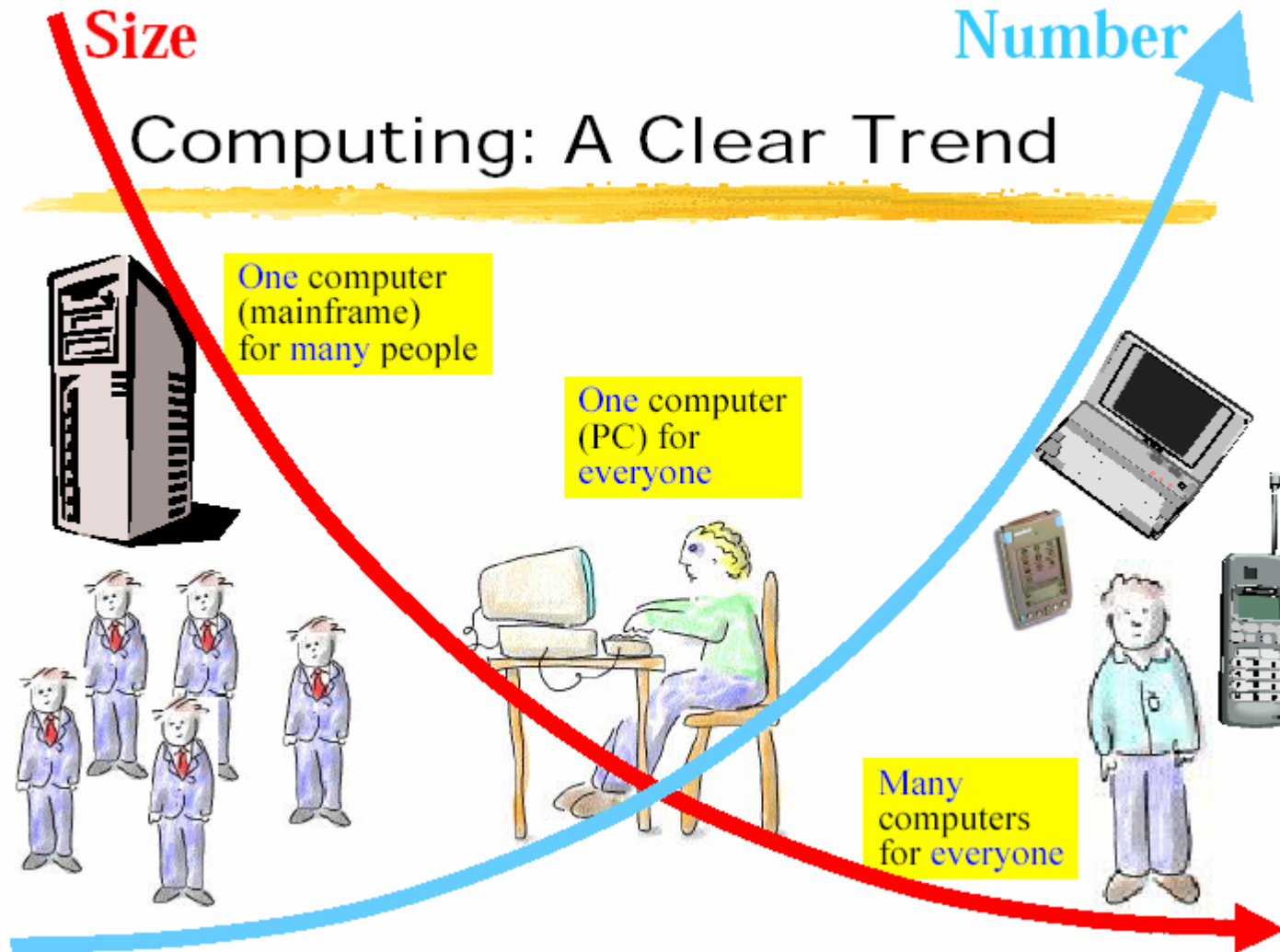
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Era 3 – Post PC (~1990-future)

- ❑ Paradigm: Each humans has a collection of computers
- ❑ Explosion in number and variety of computing devices
- ❑ Inexpensive devices vary in complexity and functions
- ❑ Computers become mobile and sometimes „invisible“
- ❑ User: Everybody
- ❑ Usage: Implicit



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Source: Friedemann Mattern (ETH Zurich)

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The Vision of Ubiquitous Computing



Marc Weiser in 1988:
„The most profound **technologies**
are those that **disappear**.
They weave themselves into the
fabric **of everyday life** until they
are **indistinguishable** from it.“

- ❑ Amazing vision, if you consider:
Gopher : 1991, Windows 3.1 : 1992, Netscape 1.0 : 1994
- ❑ Small, lightweight, cheap, mobile processors, and sensors
 - in almost all everyday **objects** → **Pervasive Computing**
 - on your **body** → **Wearable Computing**
 - embedded in the **environment** → **Sensor Networks**

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Pervasive / Ubiquitous Computing



image source: "Die Zeit"

- Information technology will be **everywhere**



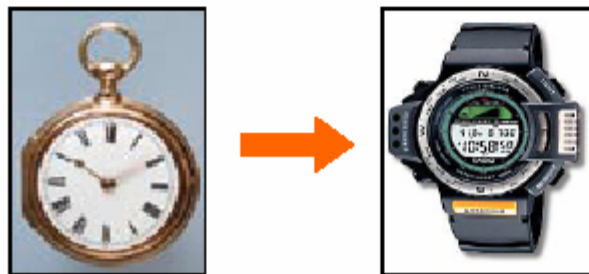
- Everyday objects will become **smart**
 - embedded processors
- ...and they will all be **interconnected**
 - wireless communication

Source: Friedemann Mattern (ETH Zurich)

THE ViSiON

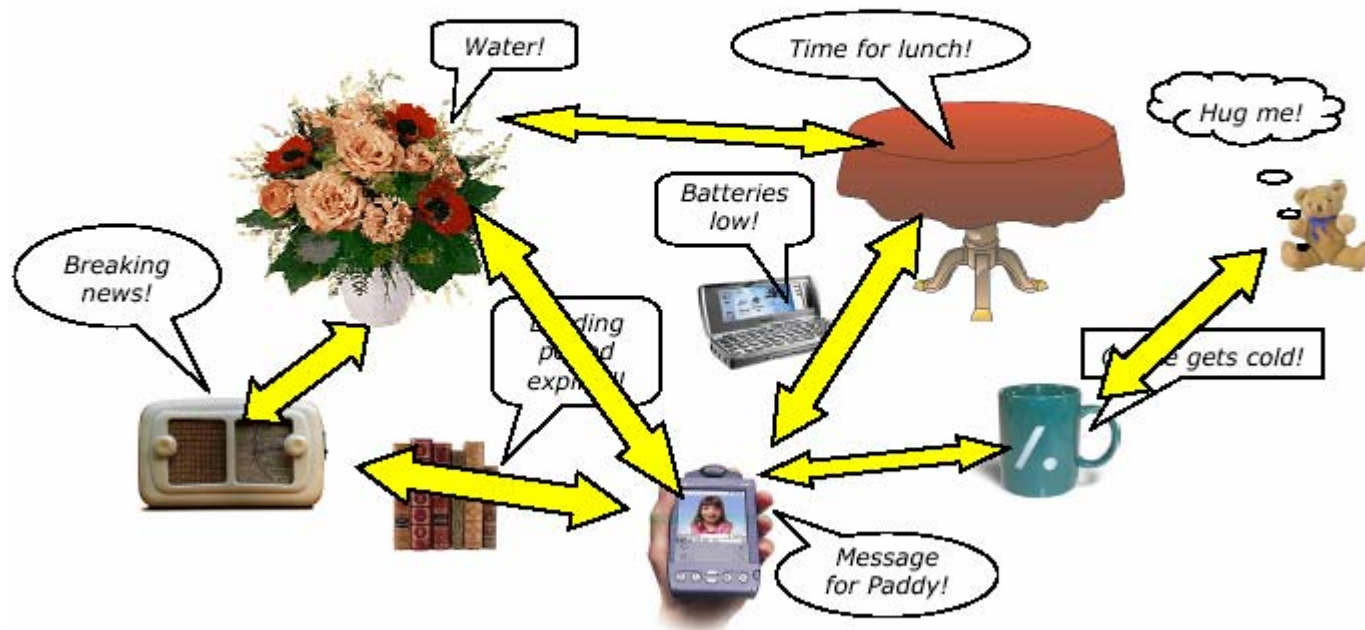
Everything Smart? From Smart Devices...

- **Electronic devices** such as mobile phones, cameras, or CD players have become "**smart**" in recent years
- They offer **new functions** to the user that have been impossible previously



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...to Smart Everyday Objects

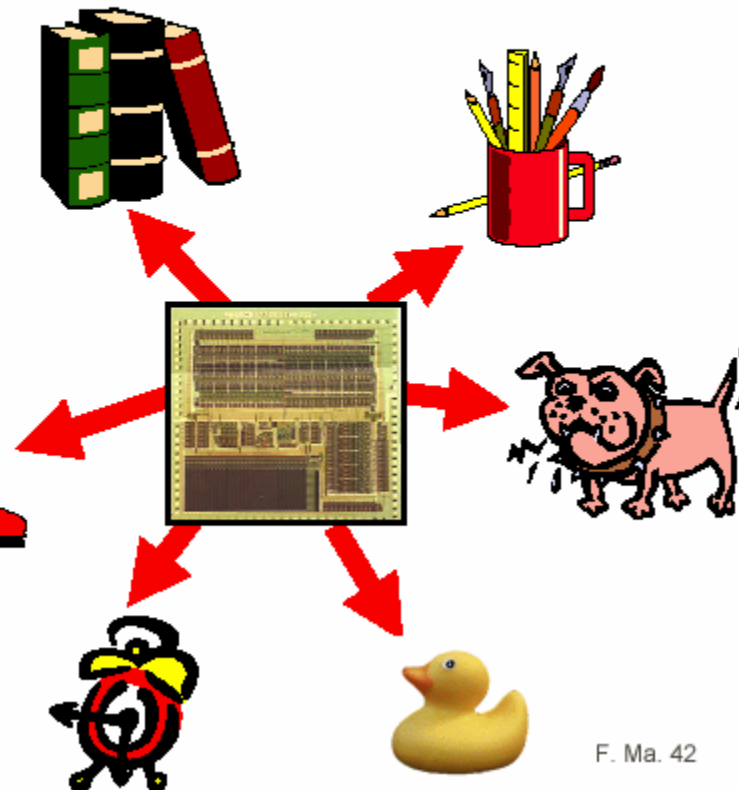


Everything Connected?

Embedded Computing Enables „Cooperating Smart Things“

Real world objects are enriched with information processing capabilities

- **Embedded processors**
 - in everyday objects
 - small
 - cheap
 - lightweight
- **Wireless communication**
 - spontaneous networks
- **Sensors**

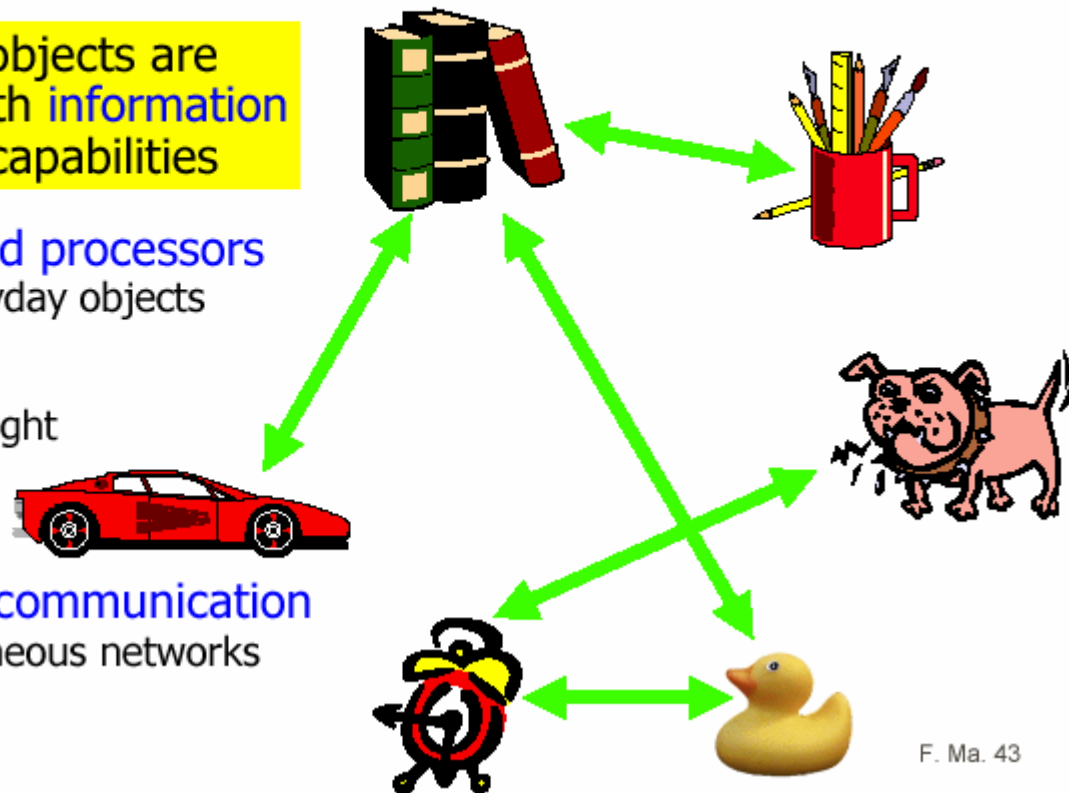


F. Ma. 42

Embedded Computing Enables „Cooperating Smart Things“

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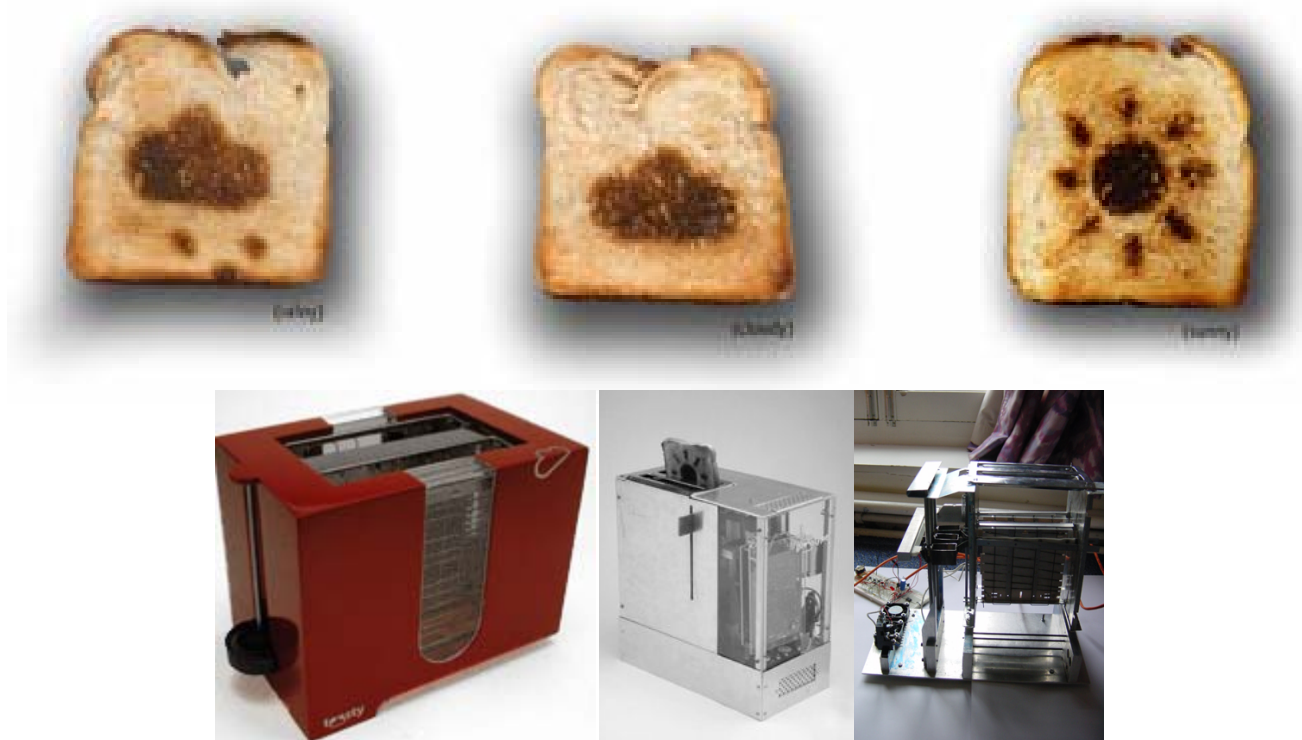


F. Ma. 43

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Example: Smart Toaster

- ❑ Developed by Robin Southgate as a master thesis at Brunel University, UK
- ❑ The Java-equipped toaster dials a freephone number to get the weather forecast and burns the appropriate symbol on a piece of toast.
- ❑ Could also be used for reminders, commercials, etc.

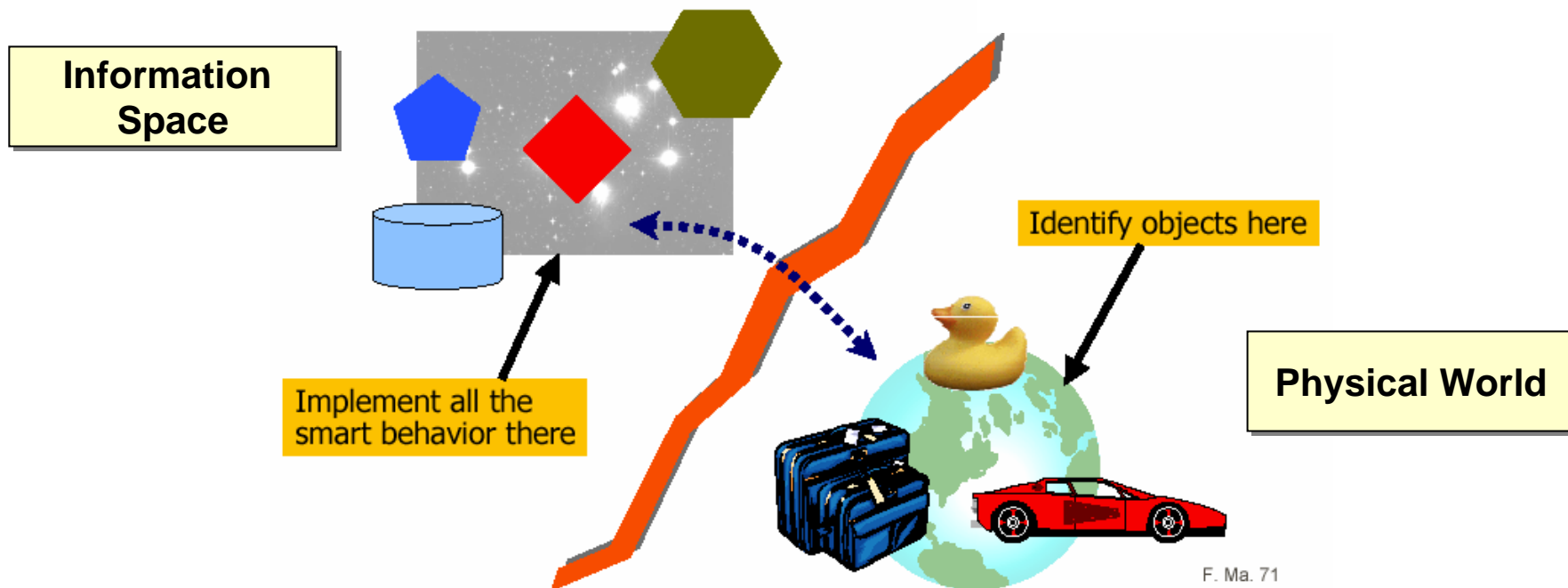


Source: <http://www.dancing-man.com/robin/webhome/report2.htm>

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The big divide - Media Gap

- ❑ How can meta information for real objects be created in the virtual world?



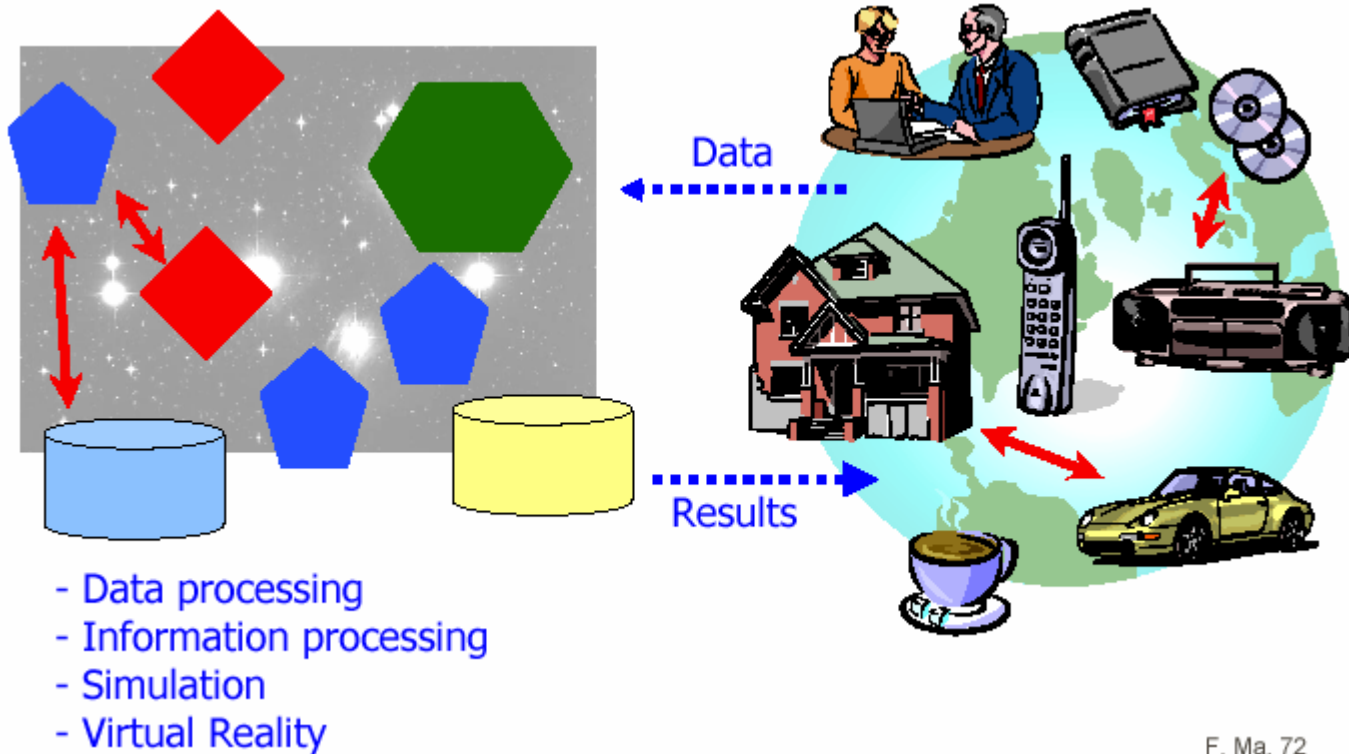
- ❑ How can consistency be ensured?
- ❑ So far: manual data acquisition
(too slow, too expensive, too error-prone)

Source: Friedemann Mattern (ETH Zurich)

THE ViSiON

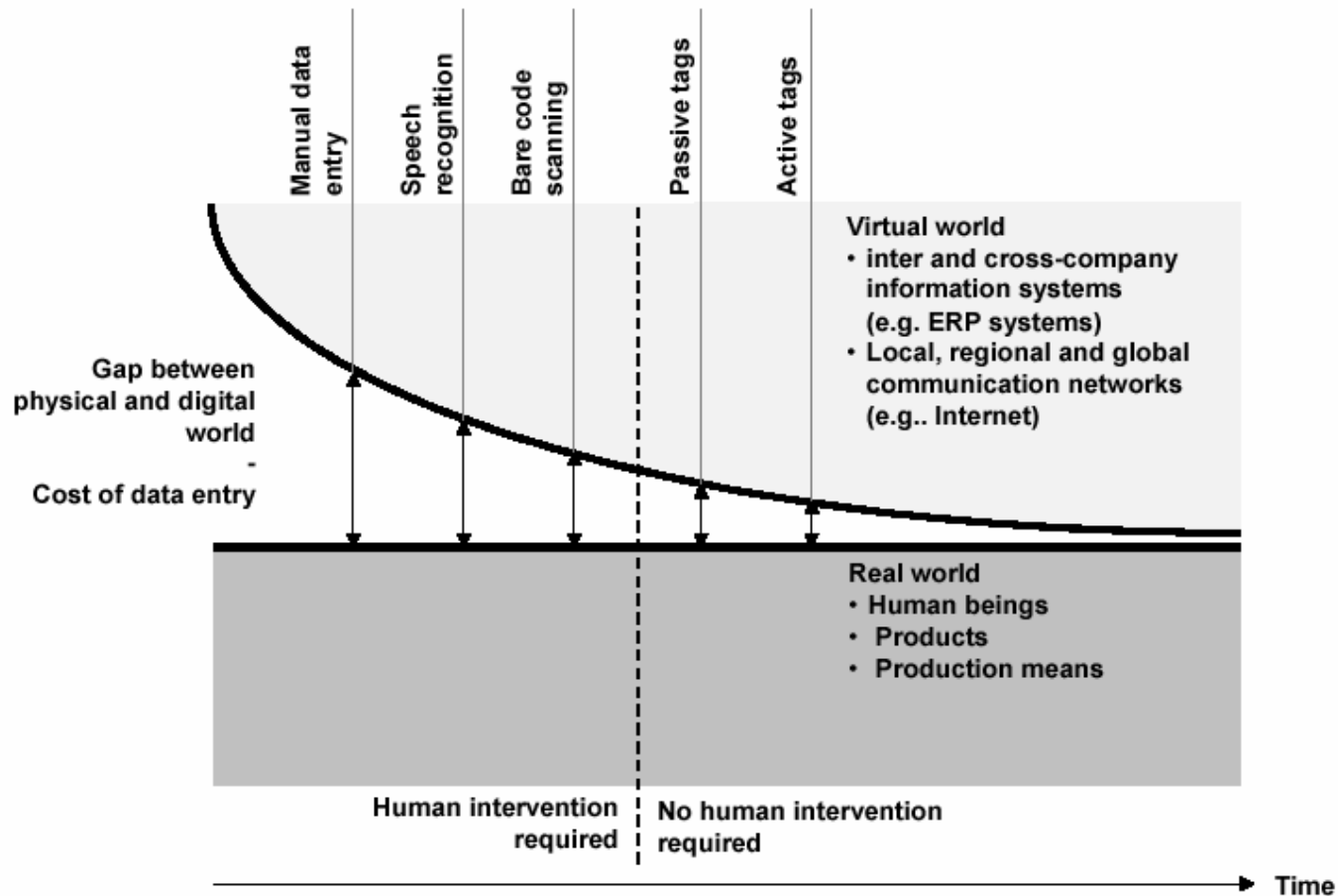
■ The big divide - Media Gap

- It all started with data processing



THE ViSiON

■ The big divide - Media Gap



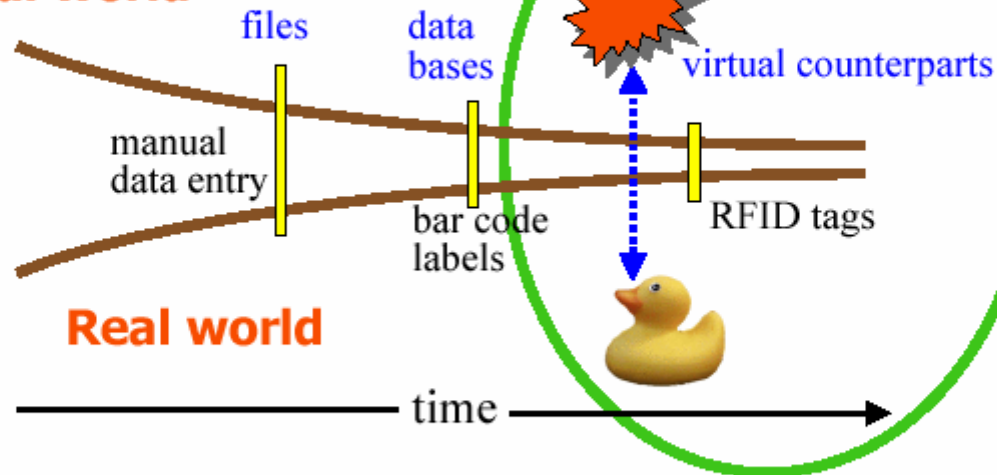
Source: Elgar Fleisch: Business Perspective of Ubiquitous Computing

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■ The big divide - Media Gap

Narrowing the Gap

Virtual world



- Extend the **integration depth**
 - tie up smart things automatically with **information systems**
 - avoid **media breaks** and input **errors**
 - **timely** information

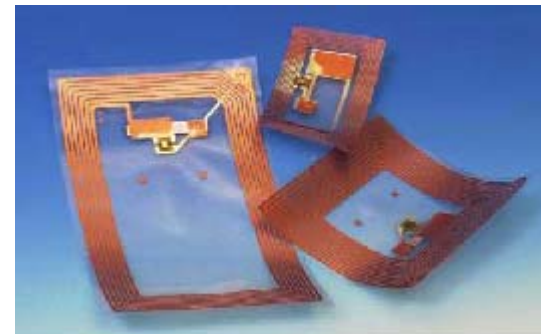
F. Ma. 74

Source: Friedemann Mattern (ETH Zurich)

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One Solution: Smart Labels

- ☐ Identification through distance
IC with RF-transponder
- ☐ Wireless energy supply
magnetic fields using induction (~1m)
- ☐ Small memory (~100 Bytes)
ROM or EEPROM (rewritable)
- ☐ Costs: ~ €0.1 ... €1 (disposal after use)
- ☐ Flexible (integrated in paper)



Chip (without antenna):
~ 2 x 2 mm x 10 μ m
can be integrated into
paper of 80 μ m

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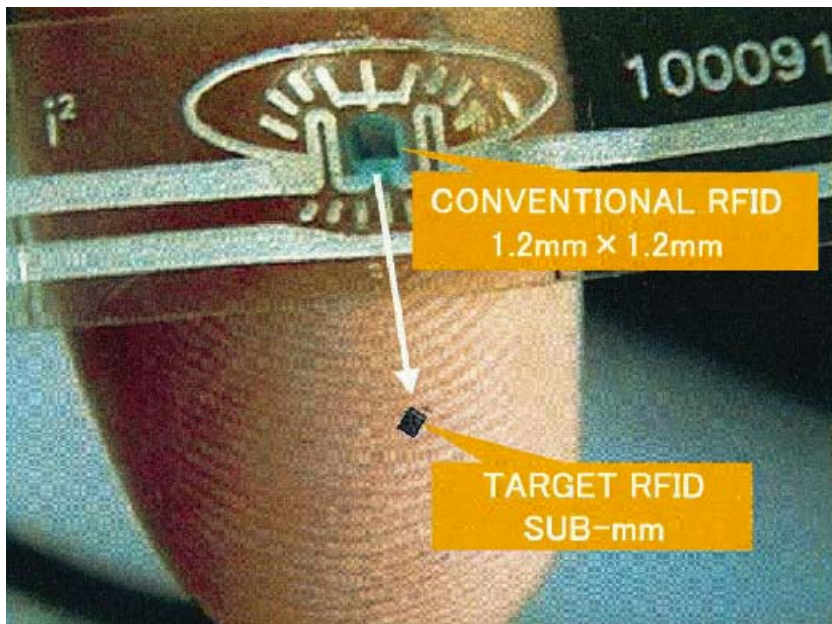
One Solution: Smart Labels

- Can be easily and invisibly integrated into everyday products



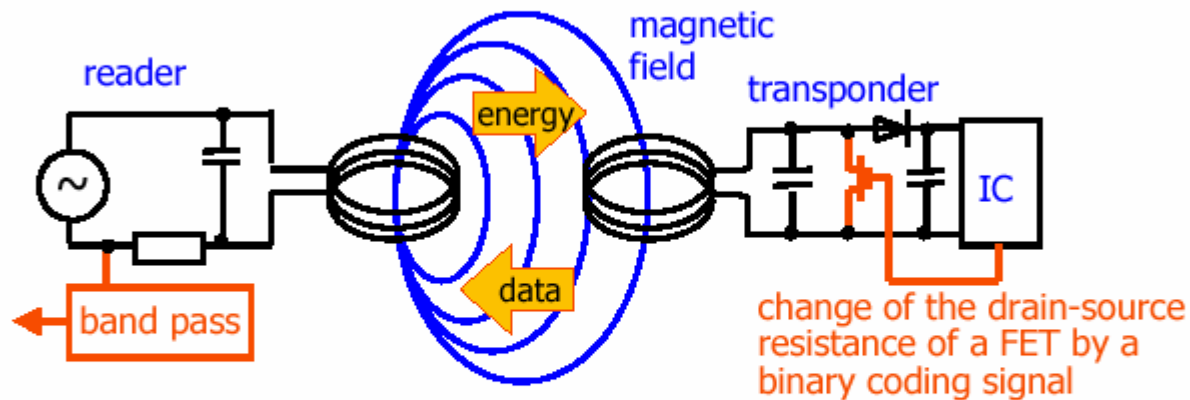
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Advanced RFID chips in preparation



Source: Hitachi

Load Modulation



- Transponder **absorbes** some **energy** of the magn. field
- Turning on and off a **resistor** in the **oscillating circuit** of the transponder yields a small voltage change at the antenna of the reader
 - typically only ~ 10 mV for a reader antenna with 100 V (i.e., 80 dB signal-"noise" ratio)

F. Ma. 81

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Ski Ticket



RFID tags in wrist belts

F. Ma. 84

Source: Friedemann Mattern (ETH Zurich)

Andreas Schrader

UBIQUITOUS COMPUTING

RFIDs in Logistics

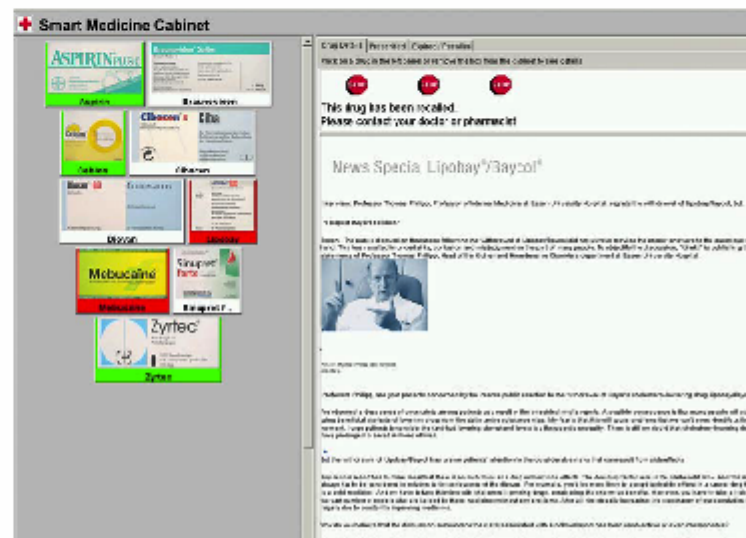
- Product tracking
- Realtime inventory
- Fast check in and check out process
 - unload of an entire truckload takes 30 min (instead of 150 minutes)
- Optimization of shelf life time



THE ViSiON

Smart Medical Cabinet

- Tagging of medicine packages with RFID labels
- Automatic **content monitoring** and display of related information:
 - prescription
 - expiry date
 - drug recalls
- Optional:
 - alerts via **SMS**
 - **spoken language** to help **blind persons** to take the right medicine („talking medicine“)

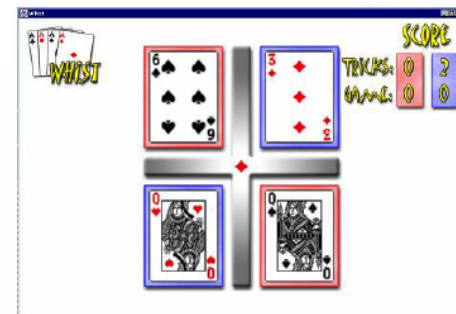


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Example: Smart Playing Cards (ETH Zurich)

□ Kay Römer: Smart Playing Card, A Ubiquitous Computing Game, UbiComp 2001.

- Support people playing a **card game** by an unobtrusive smart environment
 - playing cards equipped with **RFID labels**
 - RFID **antenna** is placed under the table
- Features:
 - count **score**
 - determine **winner**
 - **hints** for beginners
 - **cheat** alarm
- Display:
 - wireless **PDA**
 - nearby screen
- Demo game „Whist“

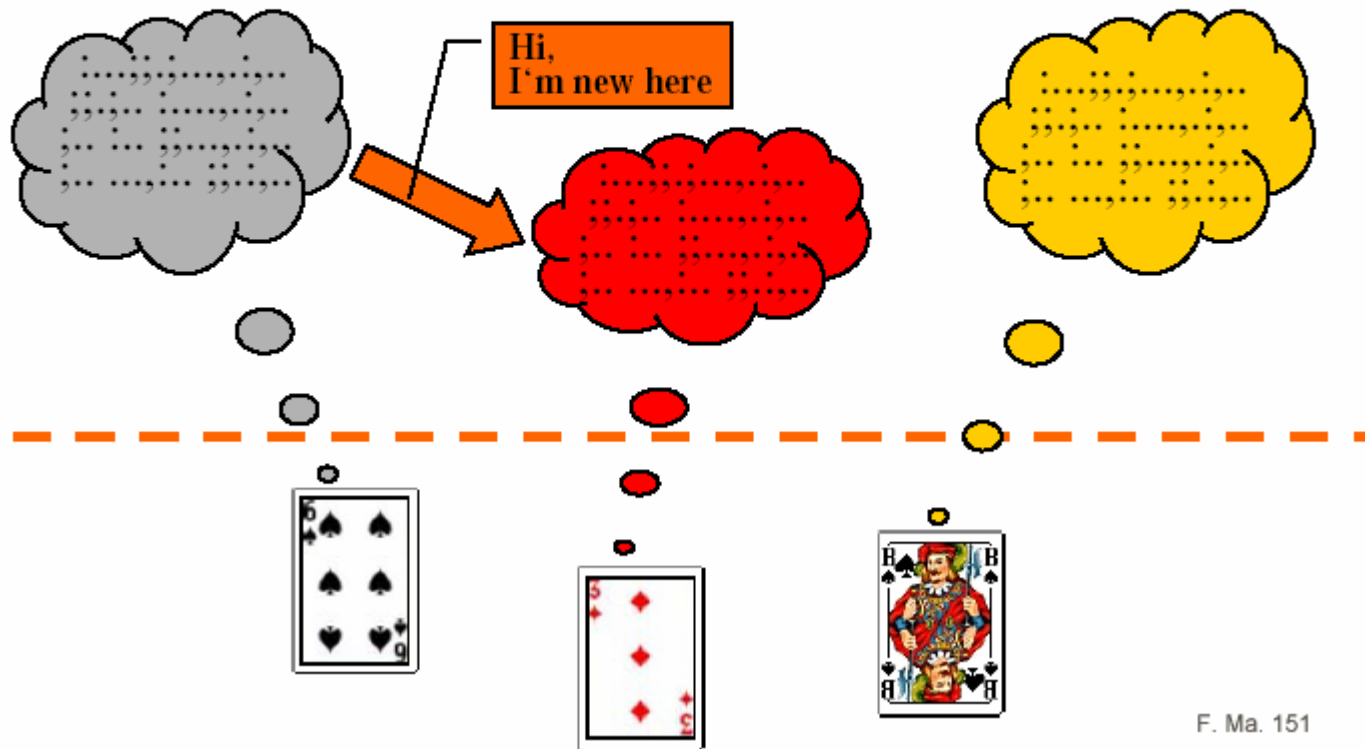


But: RFID is not a perfect technology!

- ☐ Christian Floerkemeier, Matthias Lampe (ETH Zurich):
Issues with RFID Usage in Ubiquitous Computing Applications
PERVASIVE 2004, LNCS 3001, pp. 188-193, Vienna, April 2004.
- ☐ A card game was used for measurements.
- ☐ Cards were placed in heap, spread-out, stack or in the hand.
- ☐ Result: Stack and Hand was almost completely wrong.
- ☐ Problems:
 - Collision Detection (slots are too short)
 - Tags placed in proximity detune the resonance circuit away from the 13.56MHz
Resonance can also increase the induced current by amplification
 - Tag misalignment. Planar tags in magnetic fields have a null plane
- ☐ Possible Improvements:
 - Increase RFID system performance (higher frequency, specialized tags)
 - Increase redundancies (multiple antennas, multiple tags on same card, add. sensors)
 - Adapt applications (play card one-by-one, etc.)
- ☐ Conclusion:
Perfect system not yet available (e.g. water is a big problem for RFIDs!)

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Card Proxies as Virtual Counterparts



F. Ma. 151

Source: Friedemann Mattern (ETH Zurich)

Andreas Schrader

UBIQUITOUS COMPUTING

Cards as Personalities



Alice in Wonderland

- What do playing cards **remember**?
 - all their games?
- What do they **communicate**?
- How do they **react** to msgs?

Cards as Personalities (2)



Alice in Wonderland

- When are msgs **created**?
 - How are msgs **relayed**?
 - How do playing card proxies **interact** with a global (distributed?) game controller?
- General **infrastructure**

THE ViSiON

Example: Cooltown (HP Labs Palo Alto, since 2001)

- ☐ Kindberg T. et.al.: *People, Places and Things: Web presence for the Real World*. HP Laboratories Technical Report HPL-2000-16.
- ☐ Create ,**web presence**‘ for people, places and things
- ☐ <http://www.cooltown.com>

Example: The Portolano project (University of Washington)

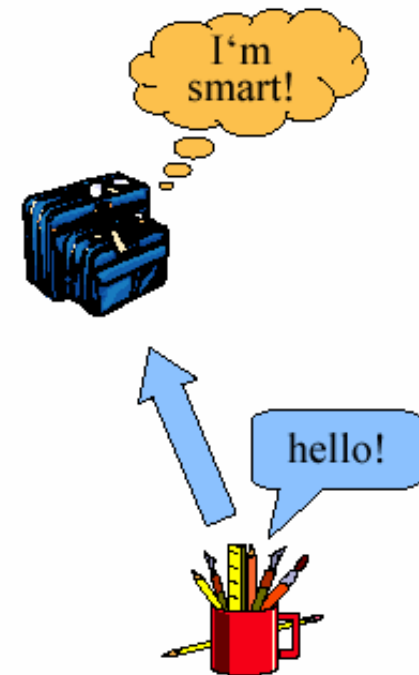
- ☐ Data shadows could be attached to daily life objects
- ☐ <http://portolano.cs.washington.edu/>

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Smart Labels are not really Smart Objects yet

Smart Objects

- Can **remember** pertinent events
 - they have a **memory**
- Show **context-sensitive behavior**
 - they may have **sensors**
 - location / situation awareness
- Are **responsive**
 - communicate with their environment
 - networked** with other smart objects

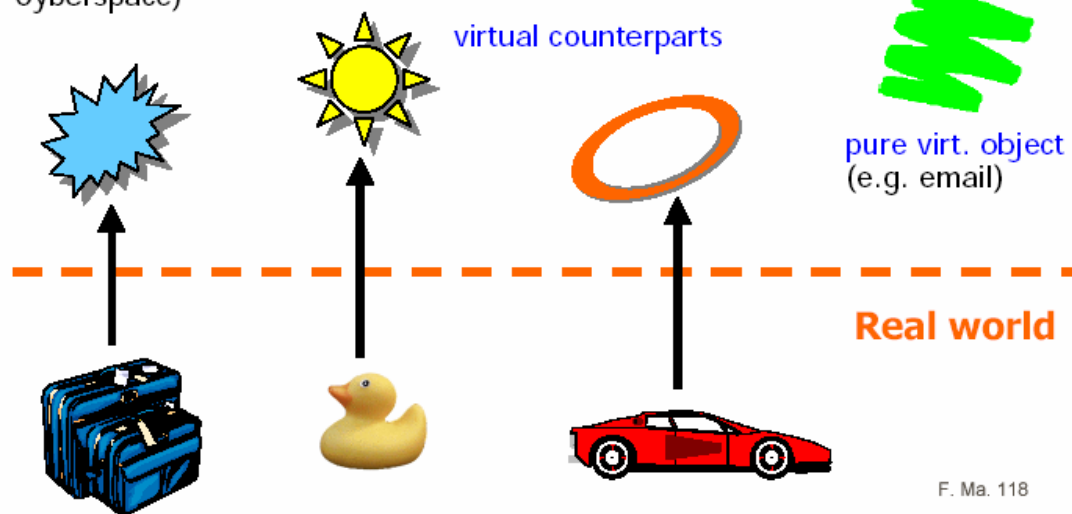


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Proxies: Active Data Shadows

- ☐ Real-world objects should be represented by **virtual world counterparts**
- ☐ Not necessary one-to-one only, also pure virtual objects possible
- ☐ The virtual world should follow an object-oriented approach
- ☐ Virtual objects reflect status and relations of the real-world objects

Virtual world
(Internet,
Cyberspace)



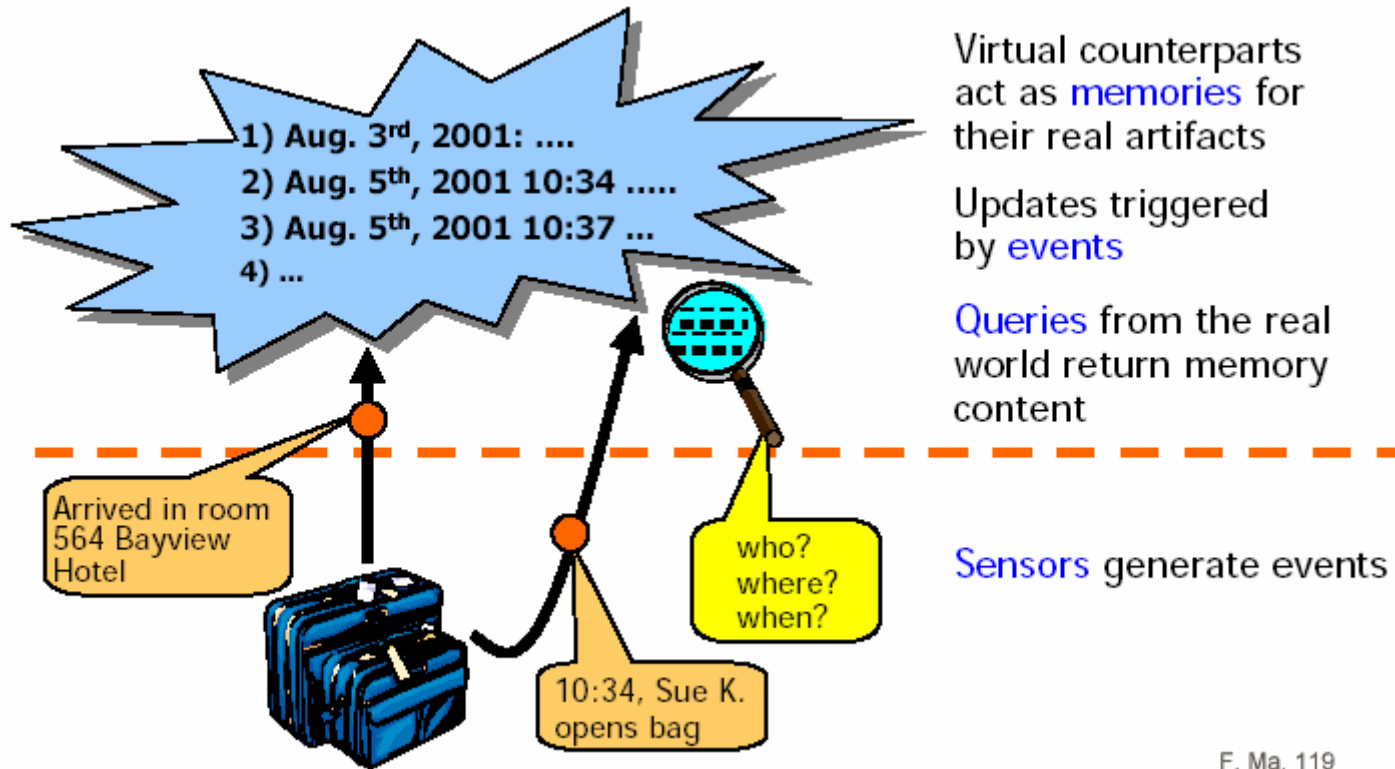
Proxy Objects are

„**Data Shadow**“
(passive)
„**Guardian Angel**“
(active)

F. Ma. 118

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Proxies: Active Data Shadows

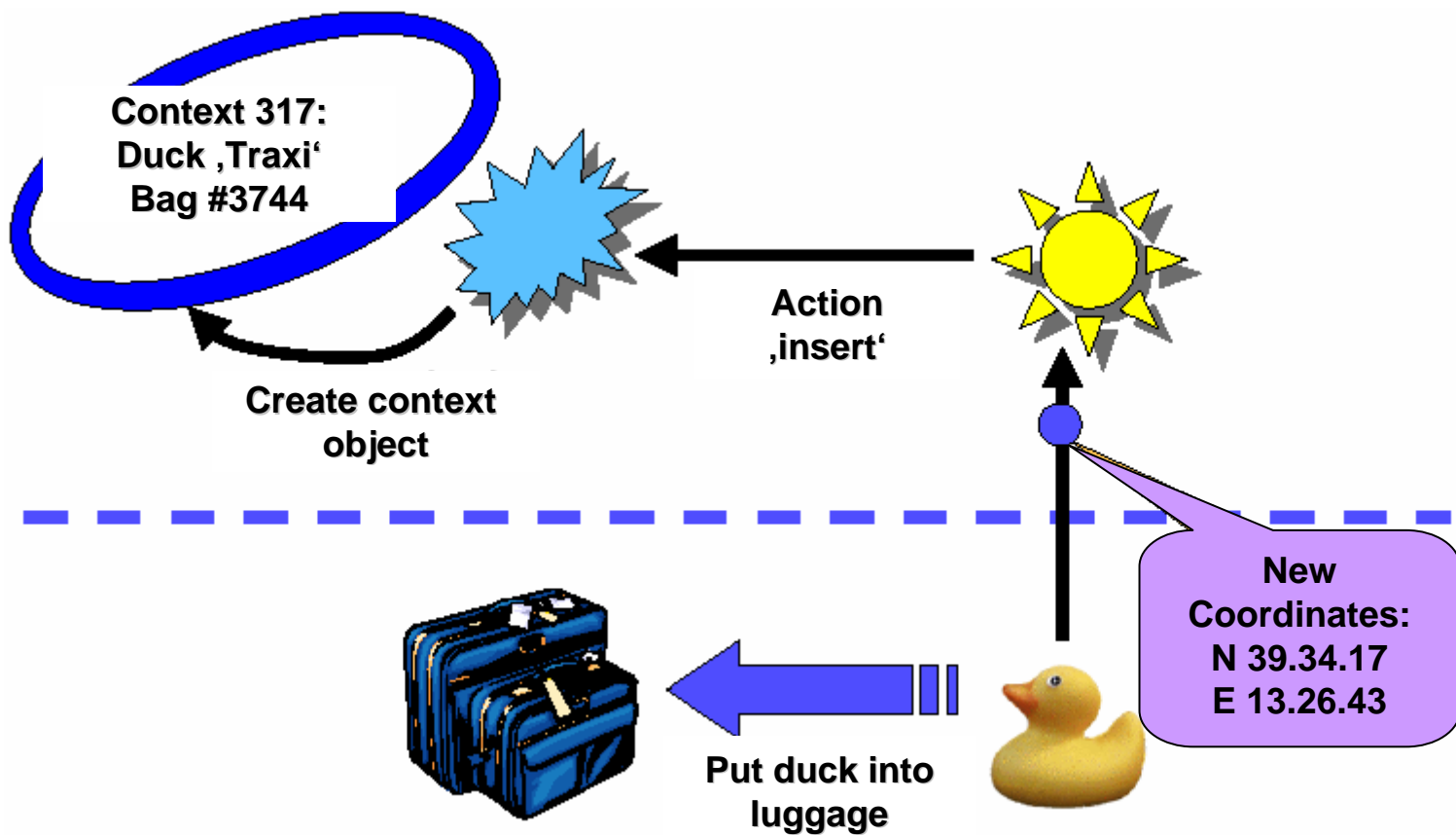


F. Ma. 119

Source: Friedemann Mattern (ETH Zurich)

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Proxies: Active Data Shadows





Summary:

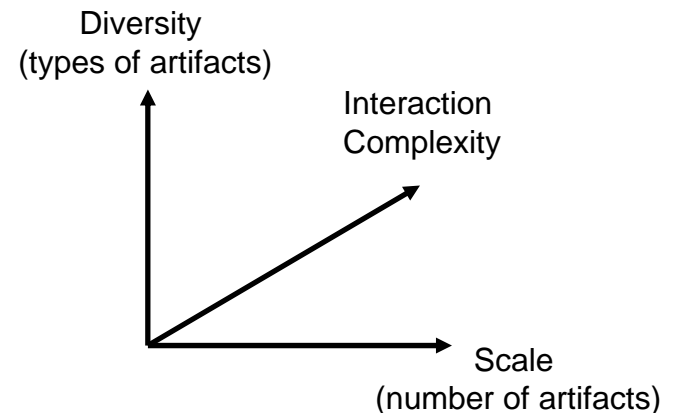
- ❑ **Media Gap** between real and information world.
Attributes of real world must be sensed and tracked.
Can be closed with smart labels creating smart things, but also with other sensors systems (e.g. cameras, microphones, etc.)
- ❑ **Data Shadows** represent real-world objects in the virtual information world.
Passive shadows just deliver information to sensors.
- ❑ **Virtual Proxies** (active data shadows) increase smart objects with memory and processing capabilities.
Smartness is created through context awareness.
- ❑ **Examples:**
 - Media Cups (TeCo Karlsruhe)
 - RFID Chef (ETH Zürich)

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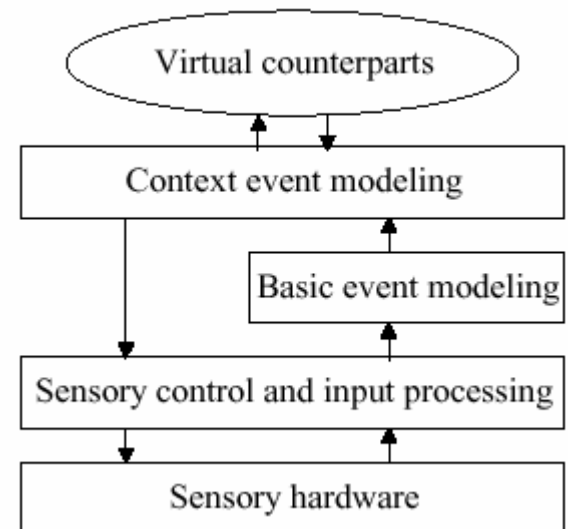
Smart Environments

- ❑ Smart Items need smart environments
- ❑ According to Mattern (Zurich) applications involving smart things can be characterized along three axis:
- ❑ Many-to-many interactions both **between artifacts of the same type** as well as **between artifacts of different types** need to be addressed
- ❑ Artifacts need to exchange information with the environment
- ❑ Therefore: **Interaction Infrastructures** are needed



Smart Environments

- ☐ Event-based structures would allow for generating, receiving, combining, filtering and aggregating events
- ☐ Multi-level context events, event sequences, access to event arguments, and extensions of the event space should be supported
- ☐ Sensory control and input processing allows for tracking hardware events (also sensor fusion)
- ☐ Basic event modeling prevents flickering effects of shortly lost or detected items and aggregates hardware events into system events
- ☐ Content event model creates system view states (e.g. list of ingredients changed)



Why Infrastructures at All?

- Consider infrastructures in the **real life**
 - examples: **electricity**, roads,...
 - just there or even **invisible**
 - “**open** platform”
 - makes life **easy** (e.g., deployment of new services)
- **Internet** infrastructure
 - Domain Name System (**DNS** registry)
 - **services**: cooperating **routers**, time servers,...
 - IP, TCP,...: common formats / **protocols**
 - **Web** standards (platform for other applications)

Extend the Internet
to everyday objects

Why Infrastructure for Smart Objects?

How do we organize billions of mobile smart objects that are highly dynamic, short living,...?

- **Guarantee**

- security
- privacy
- availability
- reliability

for applications built with smart objects

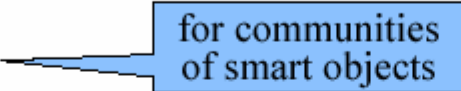
- **Provide services**

for smart objects

- location („where am I?“)
- context („are we in a meeting?“)
- event delivery („tell me when... happens“)
- brokering („find something that...“)
- directory
- registry
- ...

F. Ma. 100

More Infrastructure Tasks

- Enable  for communities of smart objects
 - spontaneous **networking**
 - **cooperation** among smart objects
 - **communication**
 - **mobility**
 - **service creation**
 - service **discovery** ("is a service available that ...?")
 - ...
- Challenge for practical computer science research!
-
- Facilitate linking the **real world** to the **virtual world**



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- ❑ **Edward O. Thorp: The Invention of the First Wearable Computer**
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UbiComp 2001
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- ❑ **The Portolano Project (University of Washington)**
<http://portolano.cs.washington.edu/>
- ❑ **The Cooltown Project (HP)**
<http://www.cooltown.hp.com>
- ❑ **Wearable Computers**
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