

# Ubiquitous Computing

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Most Slides courtesy of Prof. F. Mattern: Lecture Series *Ubiquitous Computing*, ETH Zurich

## Computer 1975



Computer by Large Industry Conglomerate

SIEMENS

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## Computer 1990



Computer by Business Machines Manufacturer

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## Computer 2005



Computer by Entertainment Industry Player

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## Computer 2009

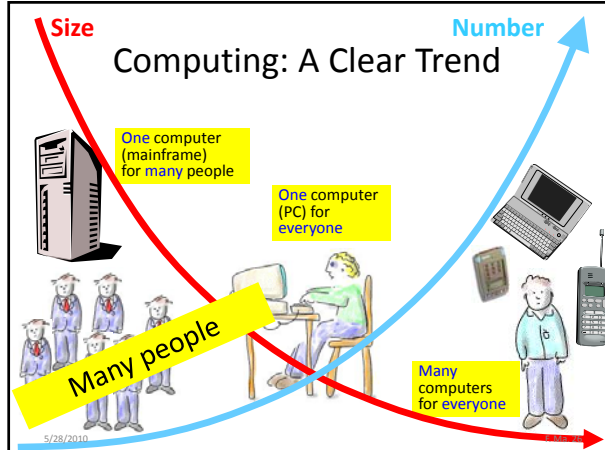


Computer Manufacturer that now dominates Music and Books publishing

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25

## Computing: A Clear Trend



### Computing: A Clear Trend

Number ↑

And the future? →

Internet of Things?

smart dust?

computer or one

Many computers for everyone

Size

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### A Short History of the Computing Metamorphosis

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### The Computer as a Calculator

Computer as a Calculator

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### The Computer as a Data Processor

„If it should ever turn out that the basic logics of a machine designed for the numerical solution of differential equations coincide with the logics of a machine intended to make bills for a department store, I would regard this as the most amazing coincidence that I have ever encountered.“

— Howard Aiken, 1956 ("MARK I")

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### The Computer as a Personal, Interactive Tool

Computer as a Personal, Interactive Tool

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### The Computer as an Information Device

Computer as an Information Device

BTX, Germany (1983-2001)

Minitel, France (1982-1999)

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### The Computer as a Toy



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35

### The Computer as a Communication Device



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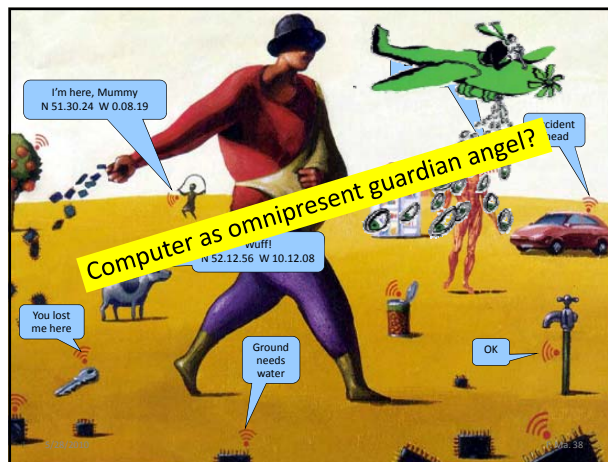
### Soon: The Computer as...

...an invisible and omnipresent background assistance?



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### The Vision of Ubiquitous Computing



„The most profound technologies are those that **disappear**. They weave themselves into the fabric of **everyday life** indistinguishable from it.“

Mark Weiser (1952 – 1999), XEROX PARC

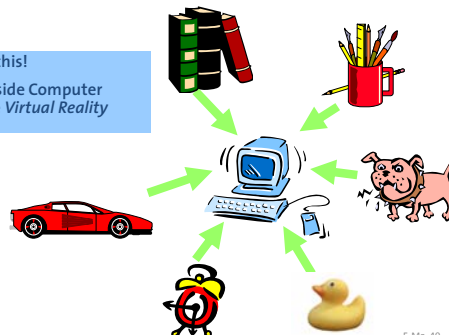
- Basic Motivation of Ubiquitous Computing
  - Integrating computers with *intuitive* user interfaces
  - The computer as a tool for the *everyday, everywhere*
  - Things are *aware of each other* and the environment

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### Instead of „World inside the Computer“...

Not like this!  
World inside Computer would be Virtual Reality



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### „Computer in the World“

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### A Vision Of The Future: The Smart Grid

Is this a realistic vision?

- Appliances **negotiate** energy needs w/ utilities
  - Freezer waits until electricity is **cheap**, then cools
  - Washing machine starts laundry **an hour later**
  - Energy provider can **avoid high energy demand**

Image Source: NIST 42

### Another Vision Of The Future (in 1955)

„This particularly streamlined model from the year 1975 is an elegant two-seater with a **nuclear powered engine in the back...**“

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### Forecasting is Hard...

<ul style="list-style-type: none"> <li>• Moon Colonies                             <ul style="list-style-type: none"> <li>– → too expensive?</li> </ul> </li> <li>• Sub-aquatic Cities                             <ul style="list-style-type: none"> <li>– → ... + not comfy?</li> </ul> </li> <li>• Flying Cars                             <ul style="list-style-type: none"> <li>– → ... + too dangerous?</li> </ul> </li> <li>• Video Phone                             <ul style="list-style-type: none"> <li>– → is Skype finally it?</li> </ul> </li> <li>• Home-PC                             <ul style="list-style-type: none"> <li>– I think there is a world market for maybe 5 computers. <small>Thomas Watson, CEO of IBM, '43</small></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Maglev Trains                             <ul style="list-style-type: none"> <li>– → too expensive?</li> </ul> </li> <li>• Supersonic Flight                             <ul style="list-style-type: none"> <li>– → the Concorde, and then?</li> </ul> </li> <li>• Nuclear Fusion                             <ul style="list-style-type: none"> <li>– → too optimistic?</li> </ul> </li> <li>• Households Robots                             <ul style="list-style-type: none"> <li>– → getting there (Roomba)?</li> </ul> </li> <li>• SMS                             <ul style="list-style-type: none"> <li>– By-product of mobile telephony, success without advertising</li> </ul> </li> </ul>
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### Ubiquitous Computing

## TECHNOLOGY DRIVERS (FIVE TRENDS)

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### 1. Moore's Law (1965)

- Processing speed and storage capacity double every 18 months
  - „cheaper, smaller, faster“
- Exponential increase
  - will probably go on for the next 10 years at same rate

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### Consequence: Very Small Chips



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### Consequence: Entire Libraries on a Stick



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## 2. Progress in Communication Technology



Nostalgia

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## Soon: Ubiquitous Connectivity

- **Wireless** (and very cheap) access to the Internet
  - At any place
  - Without manual configuration („instant on“)
  - Real-world objects can access services on the Internet
- Everything could be connected together, even objects **without a power source**
  - Contact-less chip cards
  - Radio Frequency Identification (RFID)
  - Near Field Communication (NFC)

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## Communication by Touching



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## Communication by Touching



### Near Field Communication

Short-range interaction with handheld devices (~ 10 cm)




NFC/RFID tag

mobile phone, camera, PDA,...

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## Communication by Touching



Owner:  
Heinz Lieb  
Bought on  
12 Sep 2007

**Intuitive way of interaction**

- access content and services by **touching** other smart objects ("magic touch")



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## Communication by Touching



**Intuitive way of interaction**

- access content and services by **touching** other smart objects ("magic touch")



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## 3. New Materials



Smart Paper


**Flexible Low-Power Displays**

Flexible Organic LEDs

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## Smart Paper, Electronic Ink

Pigments keep orientation even after power is cut → Low-power displays



**Micro capsules**

Positively charged white pigment chips

Clear fluid

Top transparent electrode

Negatively charged black pigment chips


Bottom electrode

0.2 mm

No backlight (readable in sunlight!)

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## Smart Paper, Electronic Ink



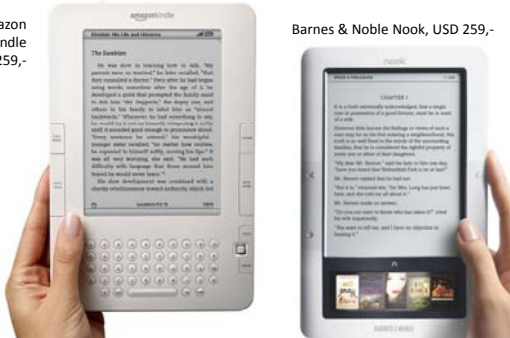
**New Materials**

E-Ink, 2001 E-Ink, 2005 F. Ma. 59

## E-Books (2009)

Amazon Kindle USD 259,-

Barnes & Noble Nook, USD 259,-



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### Flexible Displays: The PC of the Future?



But what about its energy source?  
(Fuel cells)

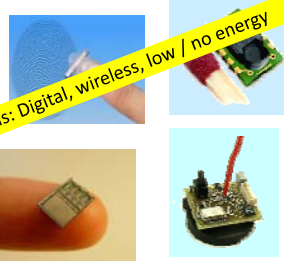
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### 4. Better Sensors

- Miniaturized cameras, microphones,...
- Biometric sensors
- Sensors for
  - temperature, humidity, acceleration,...
- Location sensors
  - e.g., GPS

Trends: Digital, wireless, low / no energy



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### Example: Fingerprint Sensor

- CMOS silicon chip
- Thermal imaging
- 0.4 mm x 14 mm sensing area
- Finger "sweeping" interface

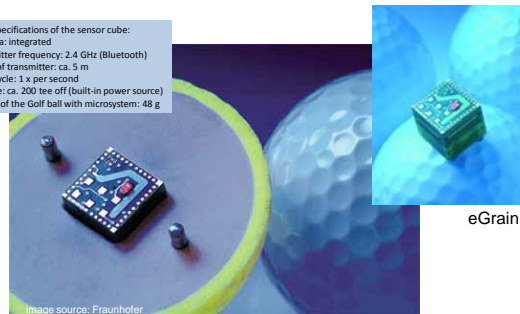


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### Example: Instrumenting a Golf Ball with Wireless Sensors

Technical specifications of the sensor cube:  
 \* Antenna: integrated  
 \* Transmitter frequency: 2.4 GHz (Bluetooth)  
 \* Range of transmitter: ca. 5 m  
 \* Clock cycle: 1 s per second  
 \* Lifetime: ca. 200 tee off (built-in power source)  
 \* Weight of the Golf ball with microsystem: 48 g



eGrain

Image source: Fraunhofer

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64



© MIMOSA project

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### Example: Passive Radio Sensors

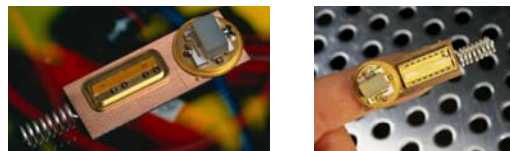


Image source: Siemens

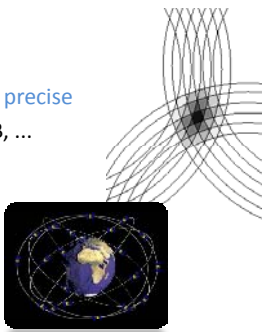
- No external power supply
  - energy from the actuation process
  - piezoelectric and pyroelectric materials transform changes in pressure or temperature into energy
- Can be read wirelessly (from up to 20 m) by reflecting RF signal
  - E.g., tire pressure sensor

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## 5. Localisation


- Technology improves
  - smaller, cheaper, more precise
  - GPS, A-GPS, WiFi, UWB, ...
- New Applications
  - Finding friends
  - Finding lost objects
  - Finding cool places



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## What should (or wants to) be localised?

- Keys, pets, luggages, parcels, containers, weapons, rental cars, cars that haven't paid road toll, expensive things (theft), toxic products,...
- Children?
- Unfaithful Spouse?
- Foreigners with Visa?
  - For their own safety...



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## Where Does All the Technological Progress Lead To?



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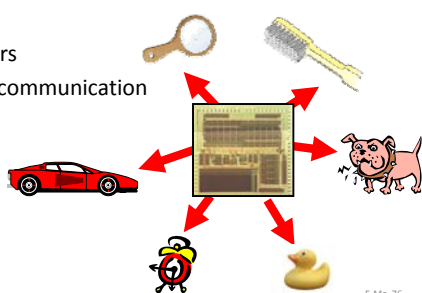
Vision

## SMART OBJECTS

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## Embedded Processors Allow for Cooperating Smart Objects

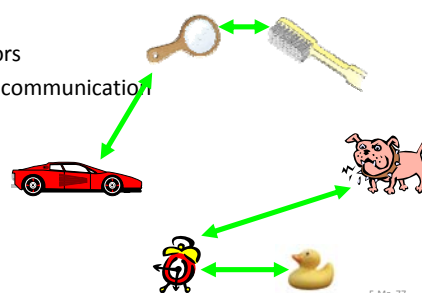
- Small, cheap, integrated
  - sensors
  - processors
  - wireless communication



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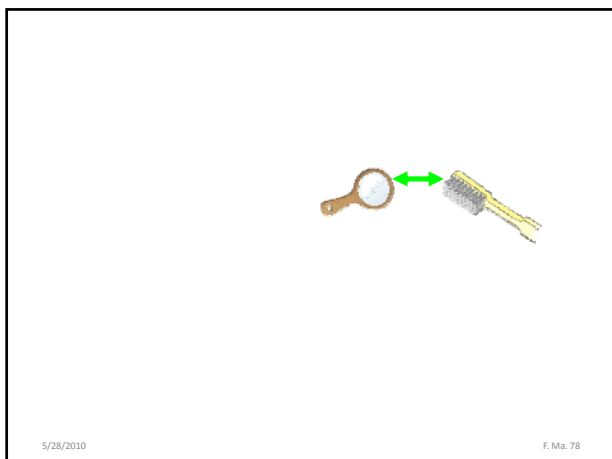
## Embedded Processors Allow for Cooperating Smart Objects

- Small, cheap, integrated
  - sensors
  - processors
  - wireless communication



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### Cooperating Smart Everyday Things?

When the **tooth brush** communicates with the bathroom **mirror**

- animated **cartoon** appears on the mirror
- brushing the teeth becomes a **computer game**, the tooth brush becomes a **joy stick**
- high-score lists, collect rewarding **points**,...

Image source: Philips F. Ma. 79

### Cooperating Smart Objects: Workplace Safety

When entering a confined space:

- Is **breathing apparatus** detected?
- Is there a **permit to work**?
- Is there **more than one person** present?
- Do those present have valid **training certificates**?

Source: BP F. Ma. 80

Vision 2

## SMART PEOPLE

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### Smart Glasses

You could wear a pair of glasses with a small amount of **face recognition** built-in, look at a **person**, and his **name** would pop up in a balloon above his head. You could know instantly who the person is, even if you don't immediately recognize him. I look at my **tree**, and a little balloon pops up saying, "**Water me**," I look at my **dog**, it says, "**Take me out**," or I look at my **wife**, it says, "Don't forget my **birthday!**"

M. Satyanarayanan (CMU)

Eyeglass with tiny laser and mirrors projects an image directly onto the retina

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### Smart Glasses Yesterday

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### Smart Glasses Today

Smart Glasses as a Fashion Item?

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Smart Glasses Close-Up

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### Smart Glasses Tomorrow?

Invisible Smart Glasses?

5/28/2010 <http://spectrum.ieee.org/biomedical/bionics/augmented-reality-in-a-contact-lens/0> 89

## SUMMING UP

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### Ubiquitous Computing

- Things, places and routines are increasingly being computerized, digitized
- Exciting consequences!
- Huge informatics challenges
  - Infrastructure
  - Usability
  - Security & Privacy

Tomorrow's Lecture!

5/28/2010 92