Vom Verschwinden des Computers

Die Vision des Ubiquitous Computing

Friedemann Mattern

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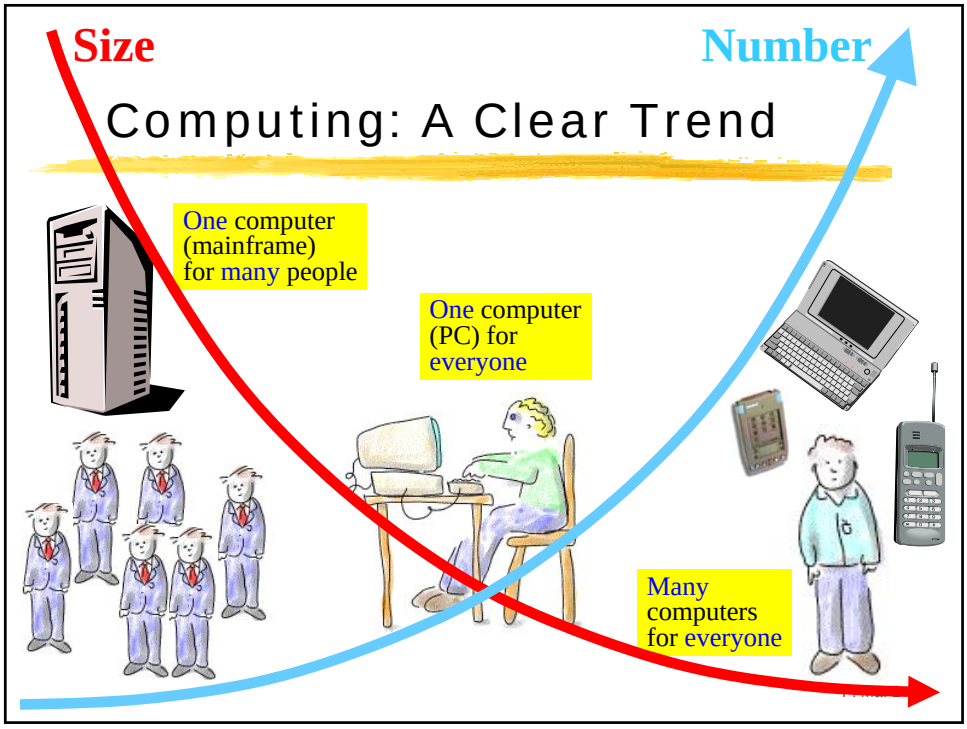
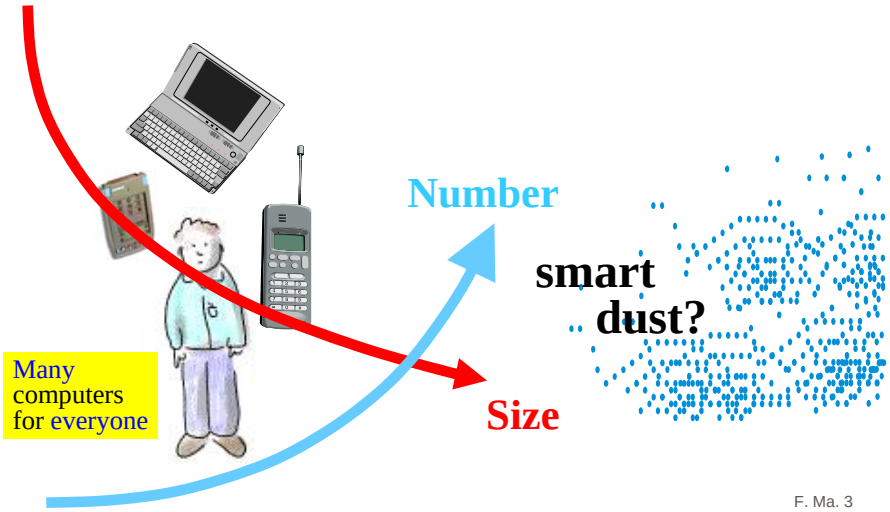
ETH Eidgenössische Technische Hochschule Zürich

Berlin **Mai 2003**

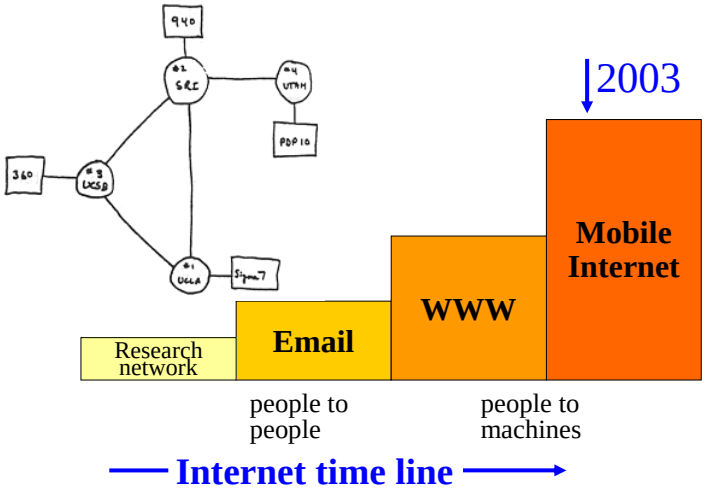


The Trend... What's Next?



F. Ma. 3

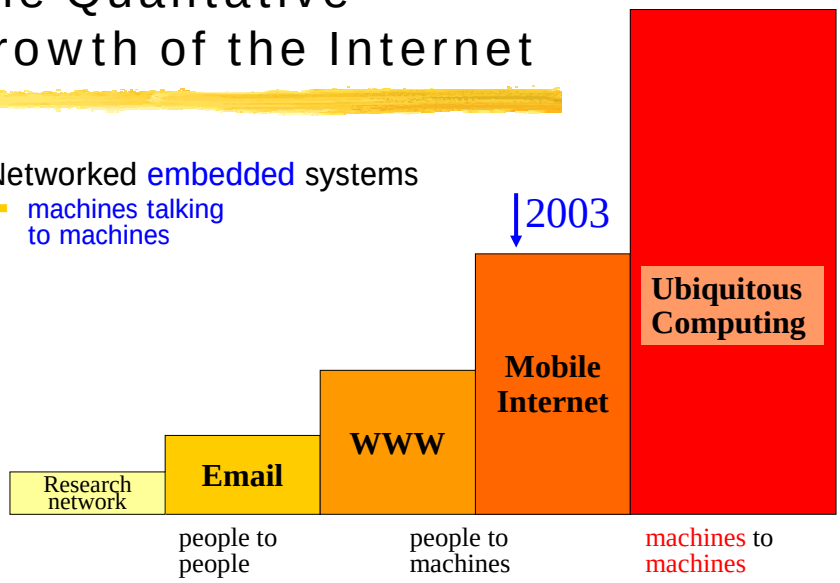
The Qualitative Growth of the Internet



F. Ma. 4

The Qualitative Growth of the Internet

- Networked embedded systems
  - machines talking to machines



F. Ma. 5

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

F. Ma. 6

Outline

- 4 Technology Trends
- The Vision
- Real World meets Cyberspace
- Consequences

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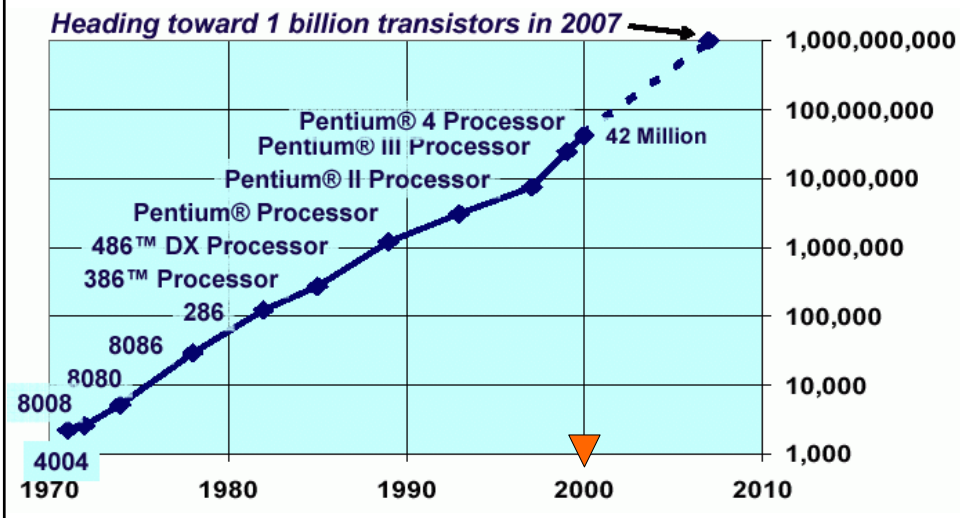
F. Ma. 7

1. Moore's Law (1965)

"It's been 18 months and my computer's power hasn't doubled."

F. Ma. 9

1. Moore's Law (1965)



Moore's Law
Electronics, April 19, 1965

Cramming more components onto integrated circuits

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

By Gordon E. Moore

Director, Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.

F. Ma. 12

Cramming more...

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment.

F. Ma. 13

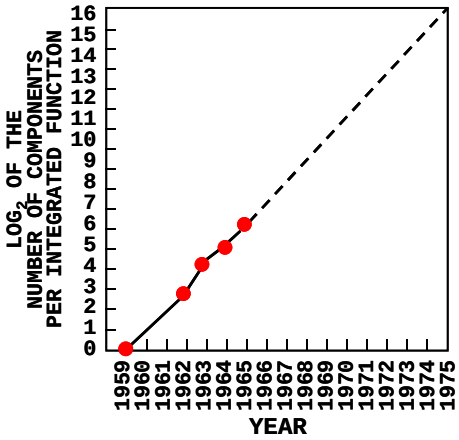
Cramming more...

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment.

F. Ma. 14

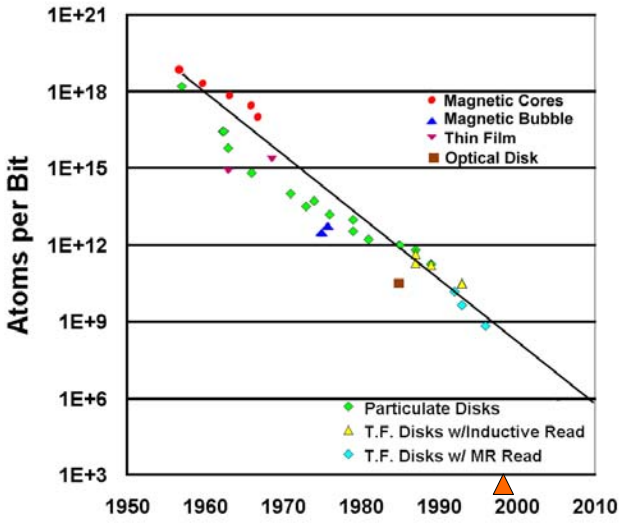
Cramming more...

- „...factor of two per year...“
- „...by 1975, the number of components per integrated circuit ... will be 65,000“



F. Ma. 16

Storage Density Trend



Generalized Moore's Law:

Most important technology parameters double every 1 – 3 years:

- computation cycles
- memory
- magnetic disks
- bandwidth

Problems:
- increasing cost
- energy

F. Ma. 18

2. Progress in Communication Technologies

Nostalgia

- Fiber optics: from Gbit/s to Tbit/s
- Wireless
  - mobile phone: GSM, UMTS
  - wireless LAN (> 10 Mbit/s)
  - Bluetooth
- Body area networks

F. Ma. 20

Telecommunication and Information Everywhere – an Old Vision

O, du göttliches Telephon, was bist du eine praktische Erfindung! Da kann man in der Kneipe die Vorlesung hören und braucht das Trinken nicht zu versäumen.

Carl Stauber (1882):
„Die Zukunft des Telefons“

F. Ma. 22

Picture Phone – Vision and Reality

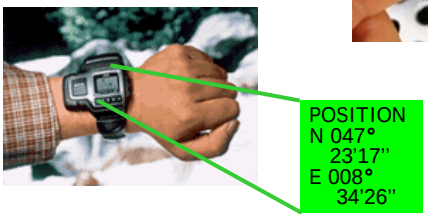
„Hello, Dorothy... You're looking well!"
A vision in 1929 (from a journal ad)...

...and reality some 70 years later

F. Ma. 23

3. Better Sensors

- Miniaturized cameras, microphones,...
- Fingerprint sensor
- Radio sensors
  - without power supply
- Location sensors
  - e.g., GPS
- ...



F. Ma. 25

4. New Materials

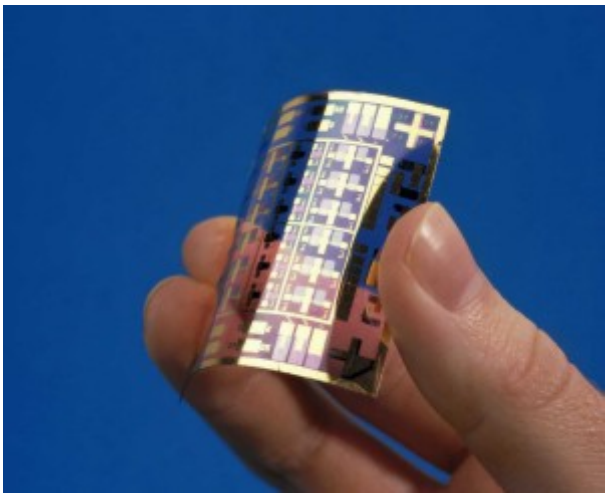
- Whole eras named after materials
  - e.g., „Stone Age“
- More recently: semiconductors, fibers
  - information and communication technology

first transistor, 1947

- Organic semiconductors
  - → change the external appearance of computers
- „Plastic“ laser
  - → opto electronics, flexible displays,...
- ...

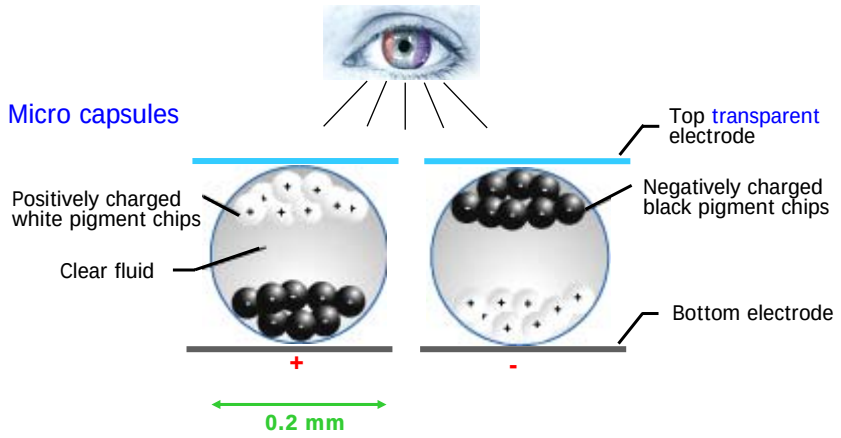
F. Ma. 29

Example: Flexible Substrates



F. Ma. 30

Smart Paper, Electronic Ink



F. Ma. 32

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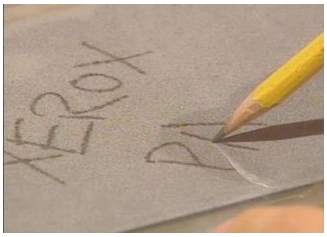

An electronically charged pencil rotates the “pixels”

F. Ma. 33

All Trends Together Lead to a New Era

- Progress in
  - computing speed
  - communication bandwidth
  - material sciences
  - sensor techniques
  - computer science concepts
  - miniaturization
  - energy usage
  - battery technique
  - display technologies
  - price
  - ...

→ Ubiquitous Computing

F. Ma. 34

Outline

- 4 Technology Trends
- The Vision
- Real World meets Cyberspace
- Consequences

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F. Ma. 35

The Vision

„In the 21st century the technology revolution will move into the everyday, the small and the invisible...“

Mark Weiser (1952 – 1999), XEROX PARC

- Small, lightweight, cheap, mobile processors and sensors
  - in almost all everyday objects („embedded computing“)
  - on your body („wearable computing“)
  - embedded in the environment („sensor networks“)

F. Ma. 37

The Vision

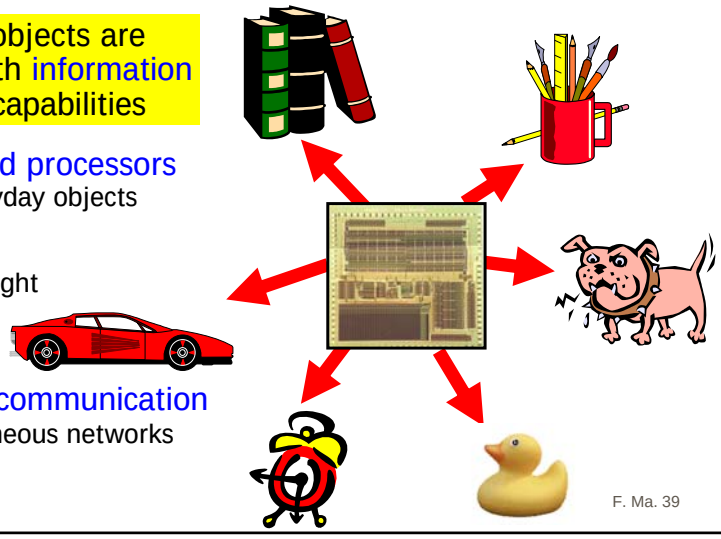
- in almost all everyday objects („embedded computing“)

F. Ma. 38

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. 39

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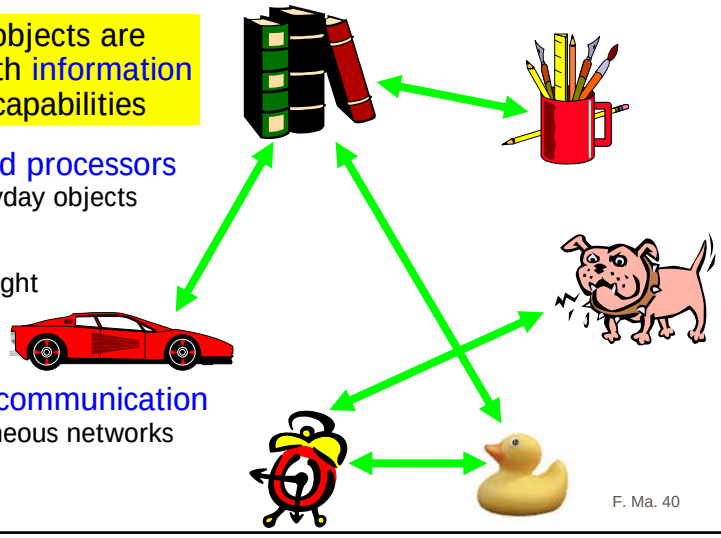

F. Ma. 40

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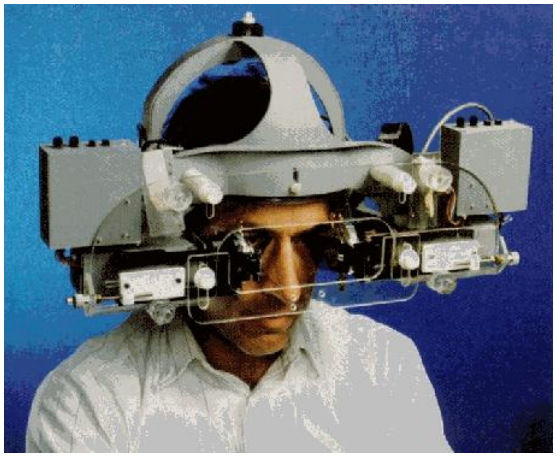
F. Ma. 42

- on your body („wearable computing“)

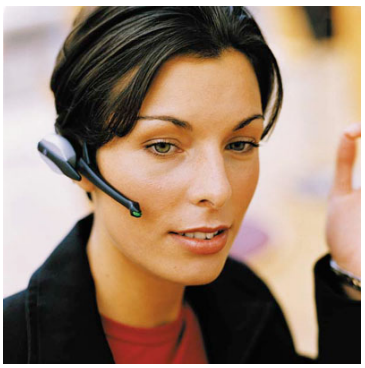
F. Ma. 43

Wearable Yesterday



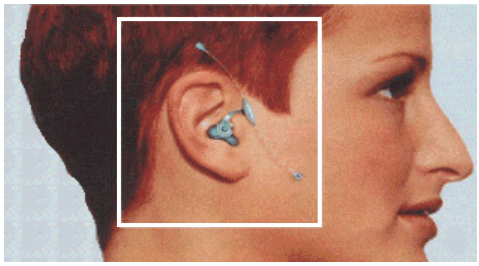
F. Ma. 44

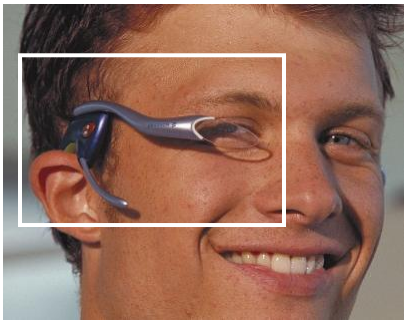
Wearables Today



F. Ma. 45

Ubiquitous Information with Tomorrow's Wearables?





- Headsets of mobile phones as jewellery?

F. Ma. 46

Retina Eyeglass Display?

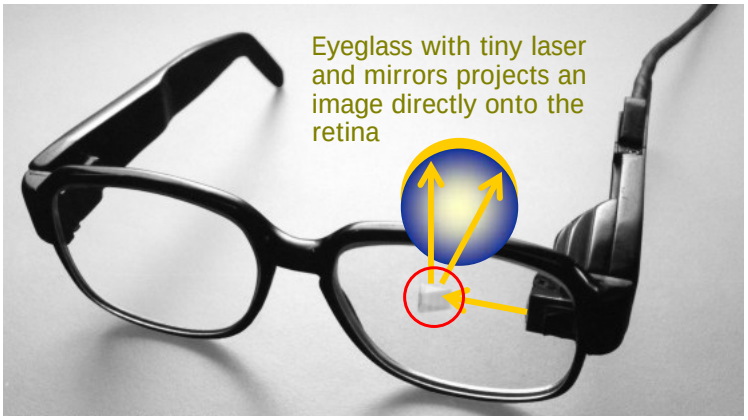


image source: Microoptical Corporation

F. Ma. 47

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!" I'm being facetious here, but there are more serious possible applications for this kind of technology.“ M. Satyanarayanan (CMU)

F. Ma. 48

The Vision

„In the 21st century the technology revolution will move into the everyday, the small and the invisible...“

Mark Weiser (1952 – 1999), XEROX PARC

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F. Ma. 49

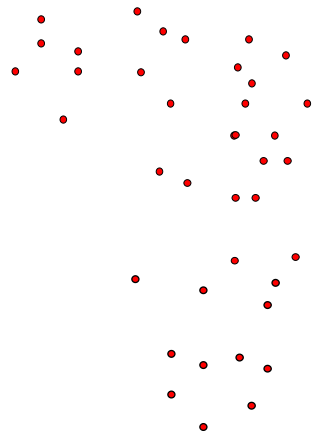
The Vision

- embedded in the environment („ sensor networks“)

F. Ma. 50

Wireless Sensor Networks

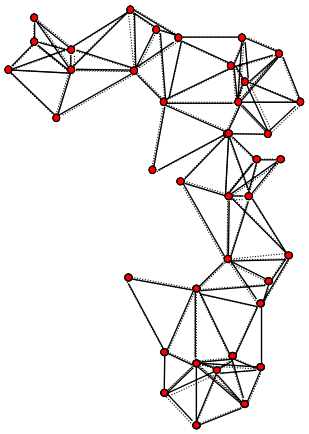
- Embed numerous distributed devices to monitor the physical world



F. Ma. 51

Wireless Sensor Networks

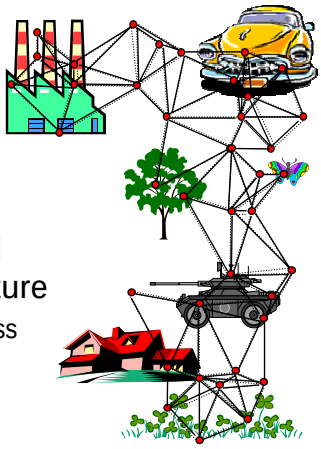
- Embed numerous distributed devices to monitor the physical world
- Network these devices so that they can coordinate to perform higher-level tasks



F. Ma. 52

Wireless Sensor Networks

- Embed numerous distributed devices to monitor the physical world
- Network these devices so that they can coordinate to perform higher-level tasks
- Combine sensing, communication and computation into a complete architecture
  - possible by advances in low power wireless communication technology
  - MEMS bringing rich array of cheap, tiny sensors

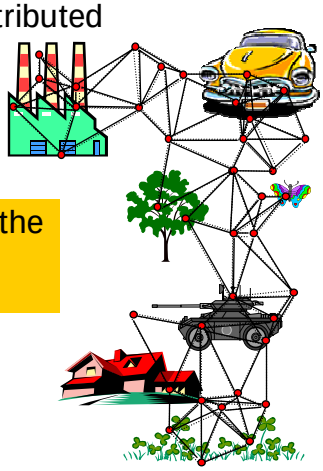


F. Ma. 53

Sensor Networks – Vision

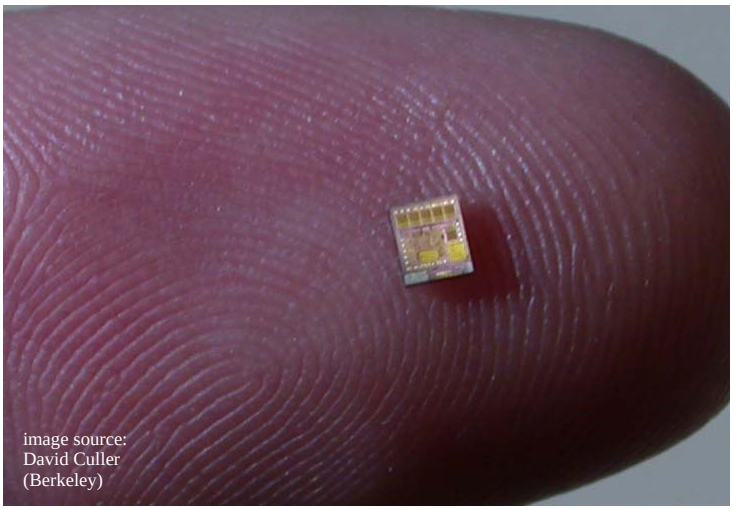
- Dense instrumentation by massively distributed networks of tiny processing elements
  - computationally-augmented environments („smart spaces“)
  - environmental, in situ monitoring
  - surveillance and security
  - military
  - emergency analysis
  - traffic monitoring
  - medical monitoring
  - condition-based maintenance
- SF
  - smart paint?
  - ingestible device networks?

Monitoring is the generic „killer application“



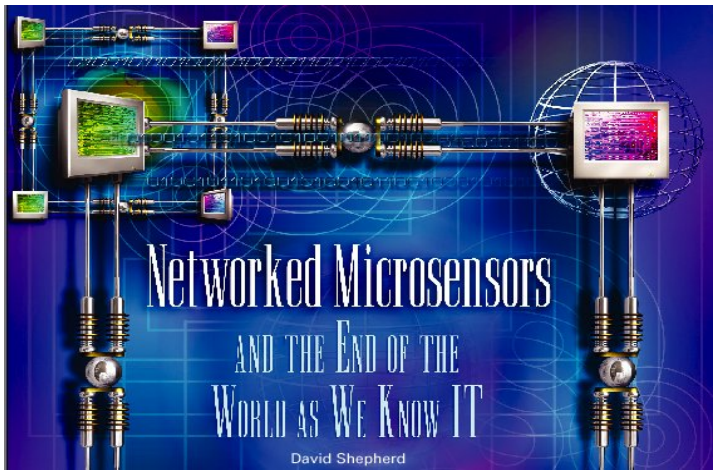
F. Ma. 55

A Sensor Node



F. Ma. 61

Networked Microsensors...



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...and the End of the World As We Know It

F. Ma. 63

Outline

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F. Ma. 64

Responsive Objects

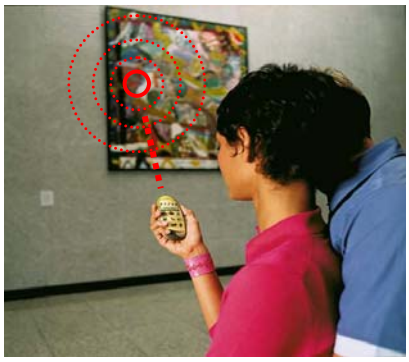
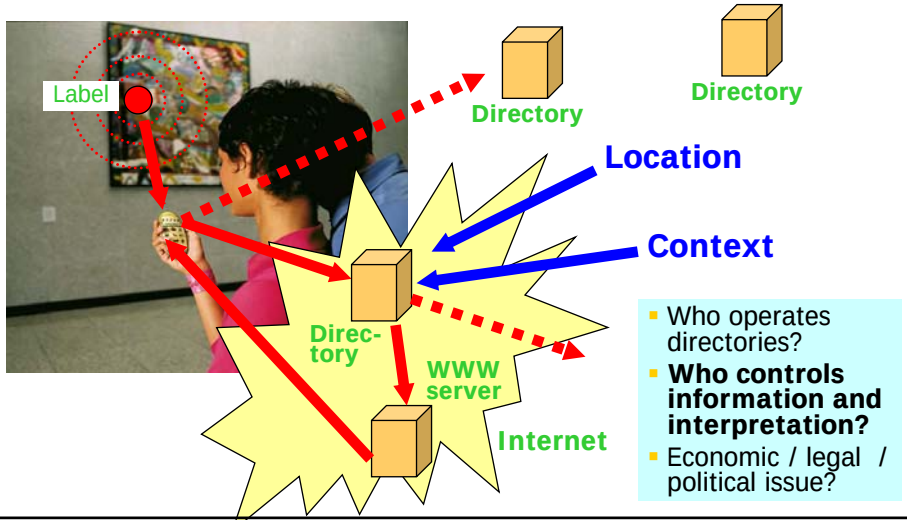


Image source: Nokia
Cf. Cooltown project (HP)

- An objects tells something about itself
  - e.g., by displaying a dynamically generated homepage
- Content
  - depends on cirmumstances such as context and privileges

F. Ma. 68

Responsive Objects

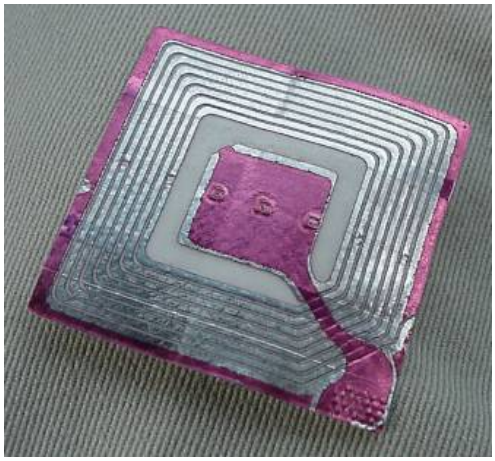


- Who operates directories?
- **Who controls information and interpretation?**
- Economic / legal / political issue?

Electronic Labels (RFID)

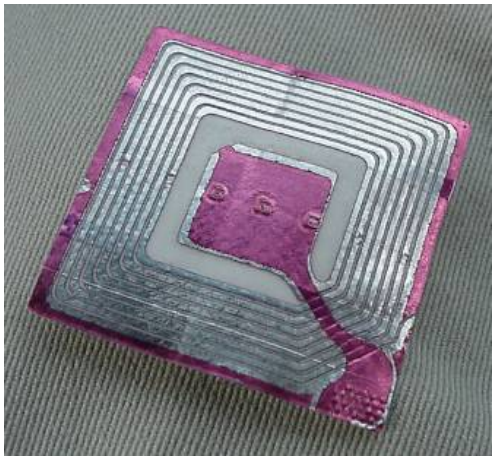
F. Ma. 71

Electronic Labels (RFID)



F. Ma. 72

Electronic Labels (RFID)



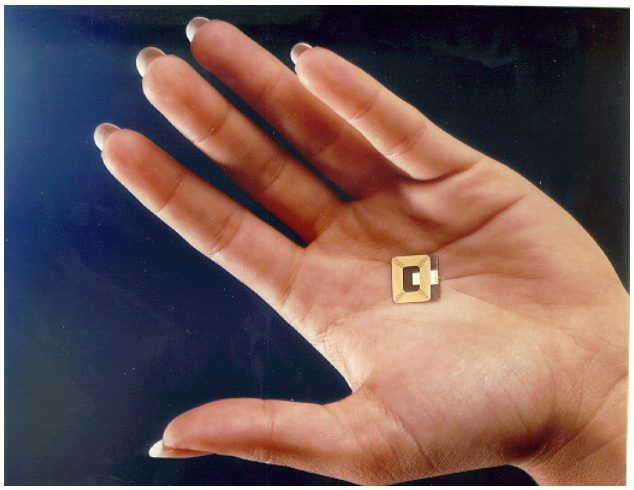
Identify objects from distance
- small IC with RF-transponder

Wireless energy supply
- magnetic field (induction)

Read and write a few 100 bits „over the air“
- ~ 1 m

F. Ma. 73

Small RFID Chips



F. Ma. 74

The μ-Chip

image source: Hitachi

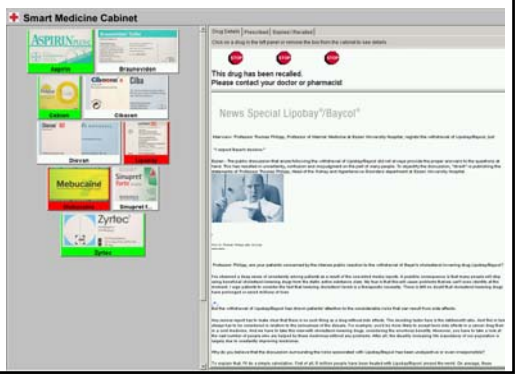
F. Ma. 75

Smart Playing Cards

- 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

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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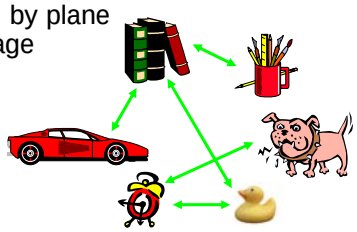
F. Ma. 89

Imagine an „Internet of Things“

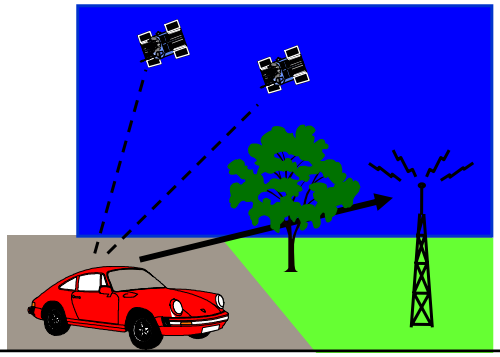
- Detailed and timely knowledge of product location and life cycles, individual and dynamic prices for goods,…
  - higher taxes if product is transported by plane
  - milk bottle reduces its price with its age

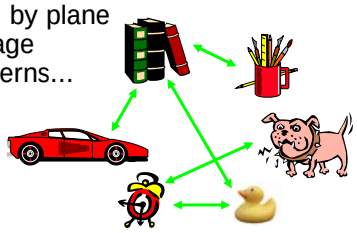


F. Ma. 91

Imagine an „Internet of Things“

- Detailed and timely knowledge of product location and life cycles, individual and dynamic prices for goods,...
  - higher taxes if product is transported by plane
  - milk bottle reduces its price with its age
  - car insurance depends on usage patterns...





F. Ma. 92

Privacy in a Ubicomp World?

- Privacy is already a concern with the WWW
  - what do they do with my personal data?
  - are my page visits and mouse clicks analyzed?
- Much more dramatic in a ubicomp world!
  - many events of very elementary actions are registered
  - could be assembled to perfect profiles

Bought on **20 Aug 2001**; last travel: to **London** Sep 2003; contained shirt no. 1342 and 1349; was in **Hotel Atlantic**, **room 317** on 17 Nov 2002 ...

- information fusion
- data mining
- search engines

F. Ma. 94

Privacy Challenges

- Unlimited coverage (sensors everywhere)
- Loss of awareness („invisible computing“)
- New types of data (location, health, habits, ...)
- More knowledge through context
- Explicit notice, consent by user difficult
- ...

- And what about trust?
  - trusting smart everyday things?

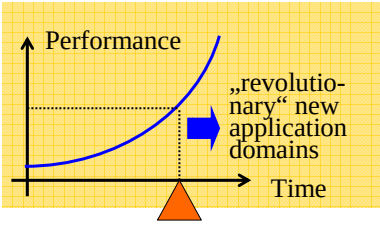
F. Ma. 95

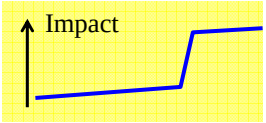
Ron Rivest: The Digital Revolution Reverses Defaults

- What was once private is now public
- What was once hard to copy is now trivial to duplicate
- What was once forgotten is now stored forever

General Impact: Evolution vs. Revolution

- Technology and science have a major impact on our society and the world we live
  - historically: industrialization, electricity, trains and automobiles, electronic mass media
  - implies therefore eventually also ethical questions
  - social adaptation to technical impacts needs some time since this is an evolutionary process (willingness to learn, generational aspects,...)





F. Ma. 100

Conclusions

- Ubiquitous computing technologies will have a major impact
- Economic, social, cultural, political consequences?
- Challenges
  - technical infrastructure
  - security, privacy, dependability

image: EU Disappearing Computer Initiative

*The Internet only connected computers, now we begin to **network all things***

F. Ma. 101

Total vernetzt

Friedemann Mattern (Hrsg.): *Total vernetzt – Szenarien einer informatisierten Welt.* Springer-Verlag, 2003

F. Ma. 102

Agenda

09:30 Gisbert Freiherr zu Putlitz: Begrüßung

09:35 Thomas Weber: Grußwort

09:45 Friedemann Mattern: Vom Verschwinden des Computers – Die Vision des Ubiquitous Computing

10:20 Kurt Rothermel: Digitale Weltmodelle – Grundlage kontextbezogener Anwendungen

10:55 Claudia Eckert: Mobil, aber sicher!

11:30 – 11:50 Pause

11:50 Günter Müller: Geduldige Technologien für ungeduldige Patienten

12:25 Elgar Fleisch: Betriebswirtschaftliche Anwendungen des Ubiquitous Computing – Beispiele, Visionen und Nutzenüberlegungen

13:00 – 14:30 Mittagspause

14:30 Ralf Guido Herrtwich: Kommunikation rund ums Automobil

15:05 Dieter Wybranietz: Die Zukunft der Telekommunikation – Convenience als Innovations- und Wachstumstreiber

15:40 Natascha Adamowsky: Totale Vernetzung – totale Verstrickung?

16:15 – 16:45 Pause

16:45 – 17:20 Christoph Hubig: Selbstständige Nutzer oder verselbstständigte Medien? – Die neue Qualität der Vernetzung

17:20 – 18:00 Alois Knoll: Zielvorstellungen und Ansätze für autonome „smarte“ Serviceroboter

18:00 – 18:30 Diskussion

19:30 Wolfgang Wahlster: Virtuelle Gesprächspartner – sprachverstehende und sprechende Computer im Alltag

Vom Verschwinden des Computers

Die Vision des Ubiquitous Computing

Friedemann Mattern

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