# Interacting with Smart Objects: Application Scenarios with the BTnode Platform

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Institute for
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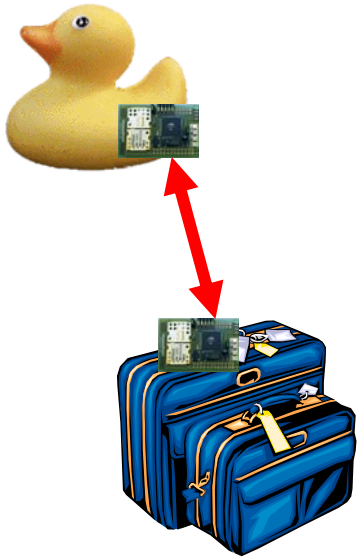
# Making Things Smart with Wireless Sensors



- smartits project (2001-2003)

  part of the European „Disappearing Computer“ initiative

- Goal: enable everyday objects as smart interconnected information artifacts
  - by attaching wireless sensors („Smart-Its“) to them
  - objects become self aware, context sensitive, cooperative

- Integration into background computing environment

# The NCCR „Mobile Information and Communication Systems“

- **N**ational **C**enter of **C**ompetence in **R**esearch
- First phase until 2005, planned total time: 10 years
- Focus: decentralized, self-organizing mobile networks

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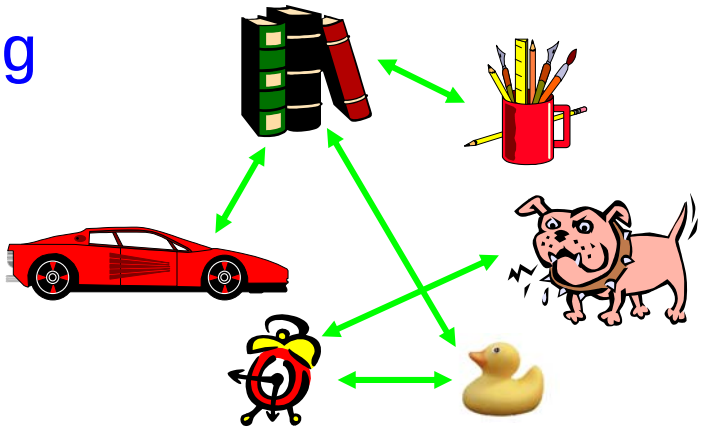
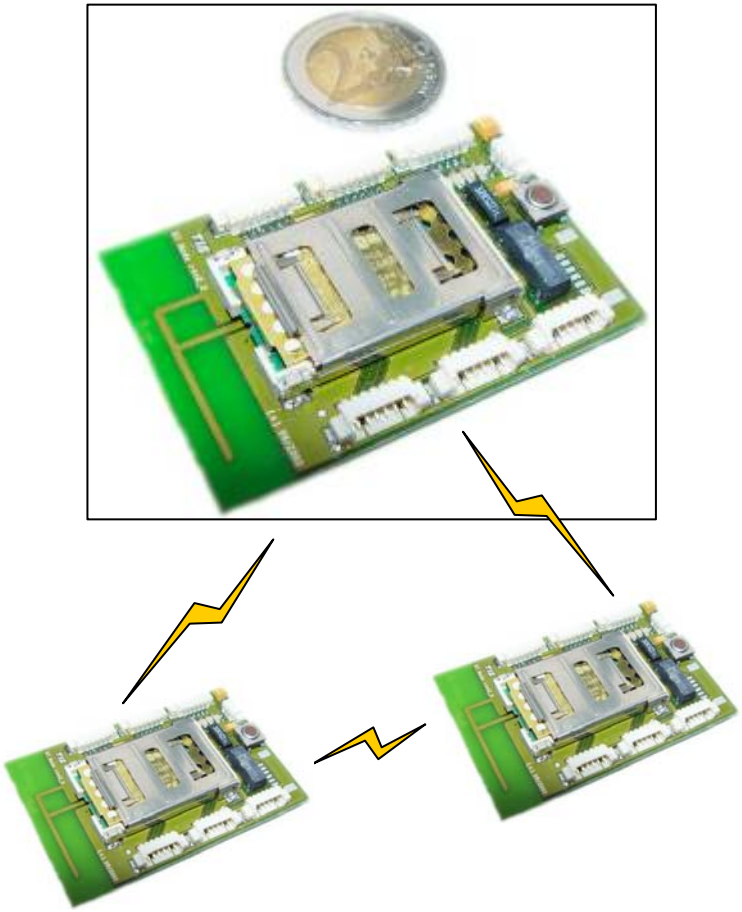
- Sub-project IP9 “Communicating Embedded Systems”
  - one out of 11 projects
  - Jan Beutel, Kay Römer, Roger Wattenhofer,...
  - BTnodes sensor node platform



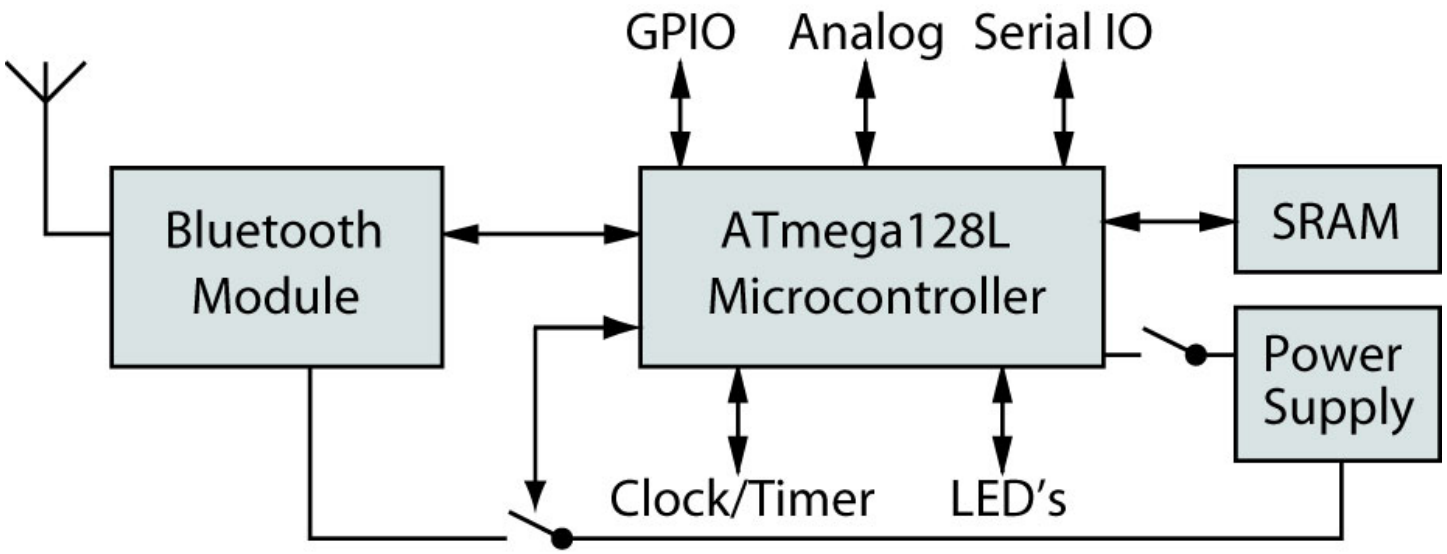
# BTnode – An Experimental Hardware Platform

- CPU: 8 bit RISC, 8 MIPS
- Generic sensor interfaces
- Communication: Bluetooth
- Lightweight event-driven OS
- Unit cost @ 200 units: $110



# BTnode architecture

**Lightweight wireless communication and computing platform based on a Bluetooth radio module and a microcontroller.**




**Bluetooth has the advantage of**

- availability today for experimentation
- compatibility to interface to consumer appliances
- an abstract, standardized high level digital interface

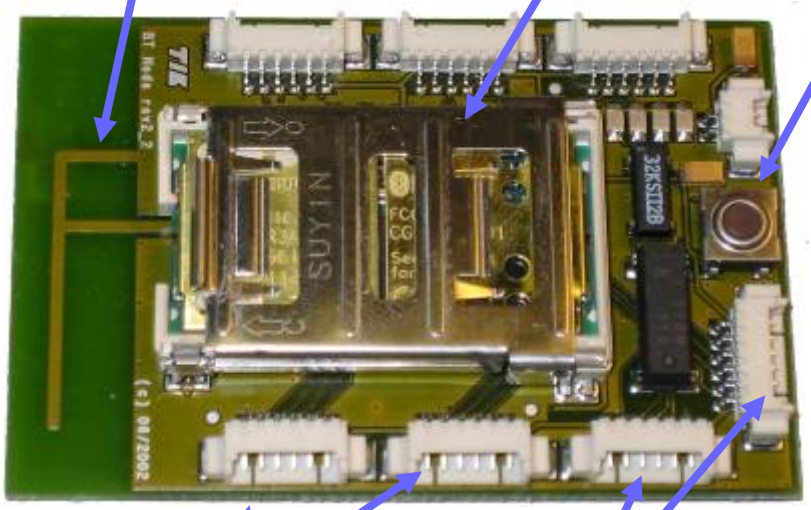
# BTnode – Some Hardware Details

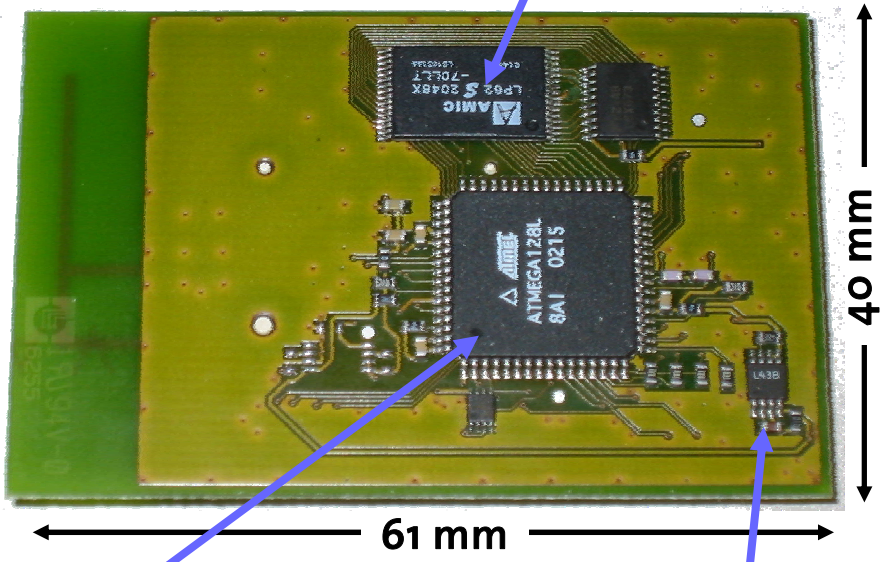
Integrated
PIFA antenna

**Communication**
Bluetooth module

LEDs,
Reset, Clocks

**Memory**
128 kB Flash, 244 kB
SRAM, 4 kB EEPROM






Generic sensor
interfaces

UART and I2C
data interfaces

**CPU**
Atmel ATmega 128L MCU
8-Bit RISC (max. 8 MHz ~8MIPS)

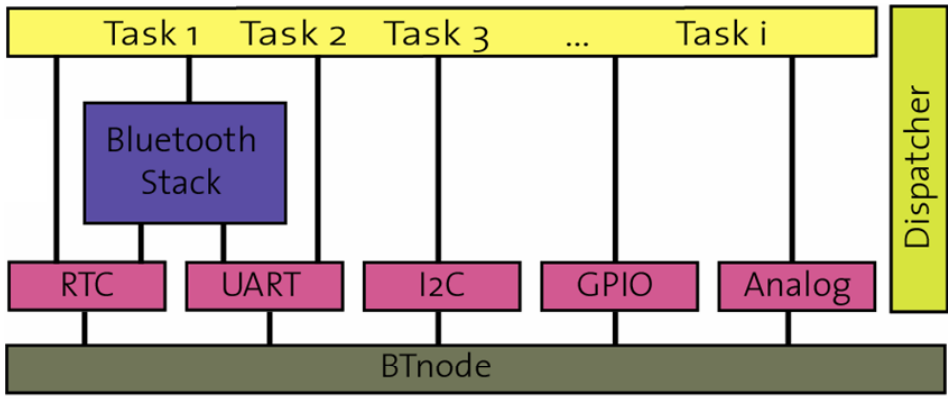
Power
management

12 cm³, 2 mW (low power) – 150 mW

# BTnode System Software

## Lightweight OS

- –event-driven application model
- –cooperative multithreading
- –device drivers (UART, RTC, ADC, ...)
- –static memory allocation
- –minimum memory footprint




## Programming

- –standard C language
- –high-level Bluetooth interface
- –system software available as library
- –emulation environment on Linux

# Event driven OS/application integration

**Approach common to embedded systems**

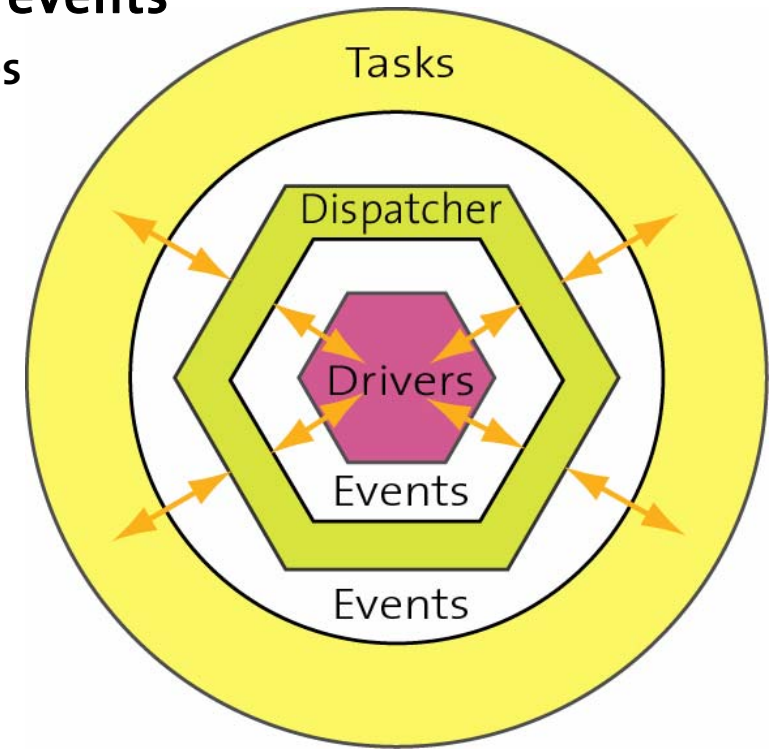
**Geared towards processing of external events**

- sensor values, data packets, state changes
- only one handler active at a time

**One application per system at a time**

- application resident in device
- no dynamic process model
- events triggered by OS/driver functions and applications

**No real-time OS knowledge necessary for application design**



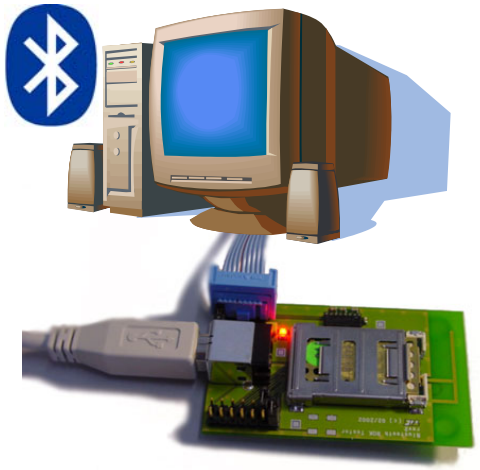
# Rapid prototyping – Linux emulation

**Native compilation and execution on Linux**

- using adapted drivers to match the host system
- with a serial Bluetooth device on a PC or iPAQ

**Bluetooth PC**

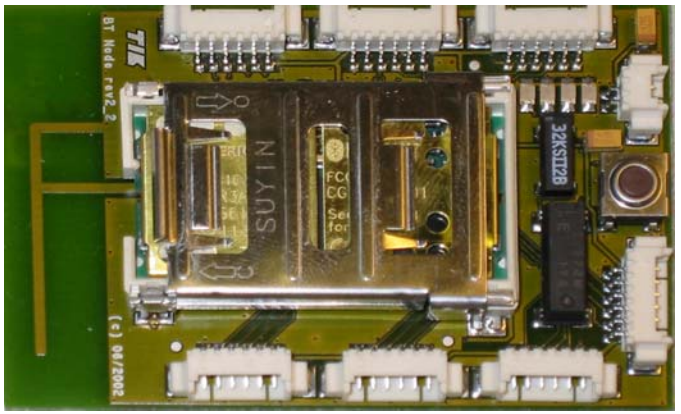
+ use unlimited resources of host
+ bridging networks
+ comfortable application debugging



≈

**BTnode**

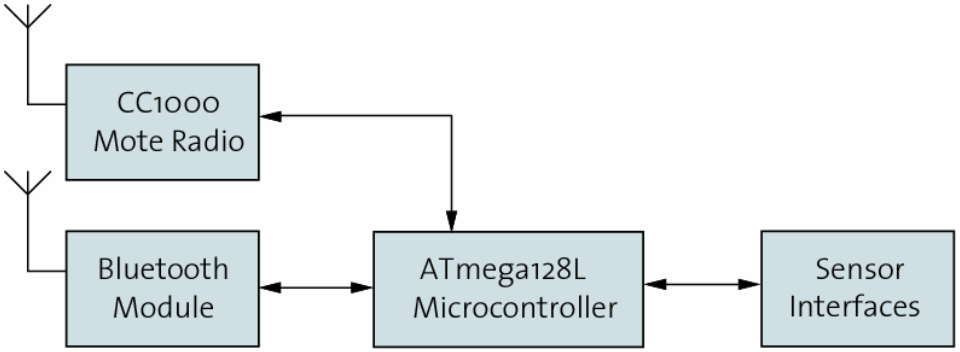
+ deployment platform
− slow upload necessary



# BTnode rev3 architecture

## Multiple radio frontend BTnode

- wake-up radio and low duty cycle power schemes

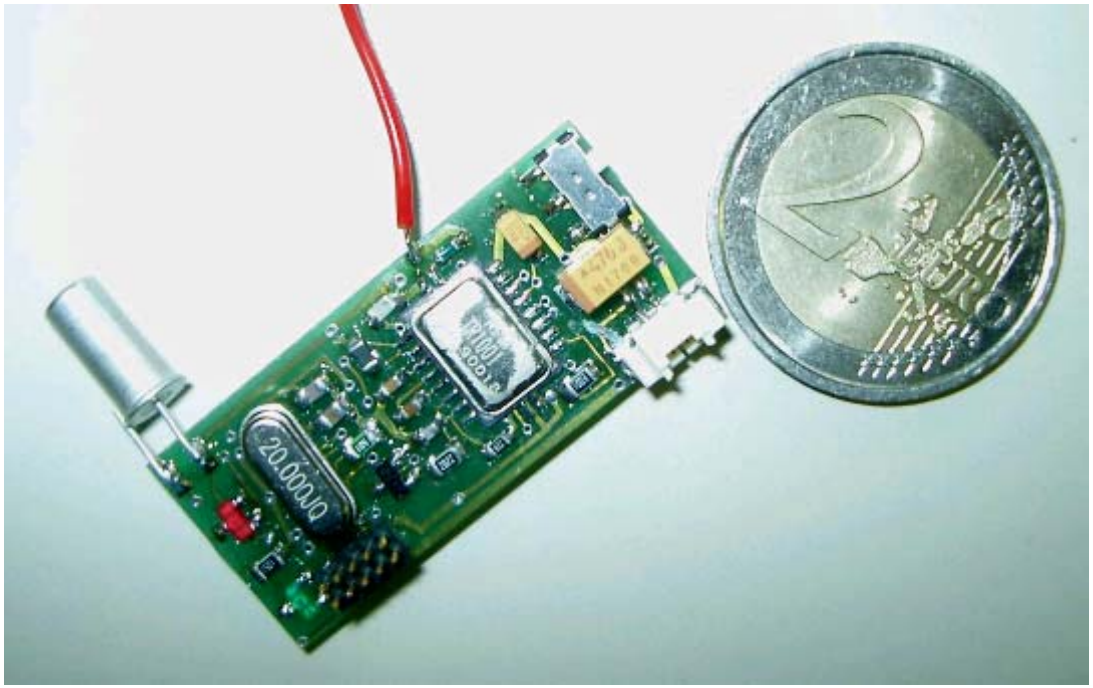



## Integrated modular extension port

## Integrated power management

- power supply (2x AA) or DC input
- main power switch and reset
- switchable supplies for subsystems
- power consumption 0.5-50 mA @ 3.3V (projected)

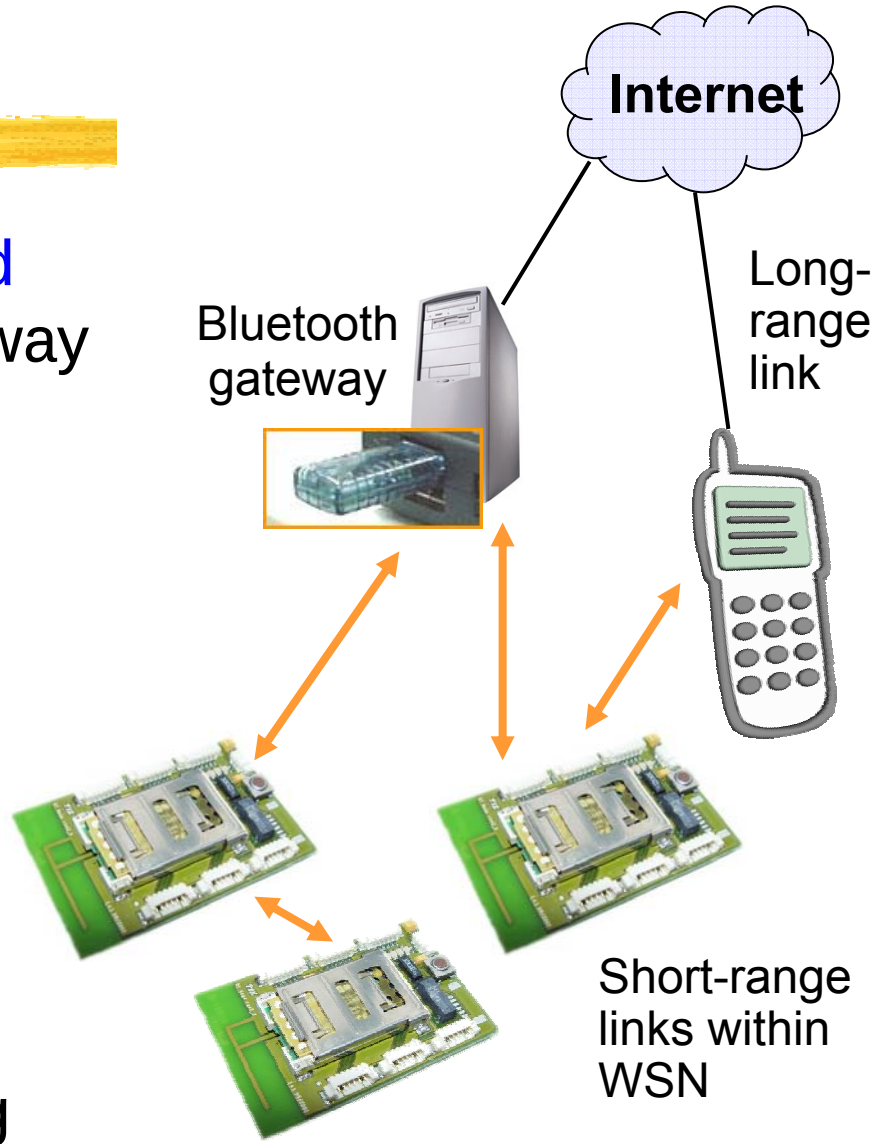
# Attachable Sensor Module




**TeCO, University of Karlsruhe**

# BTnode Backend Connectivity

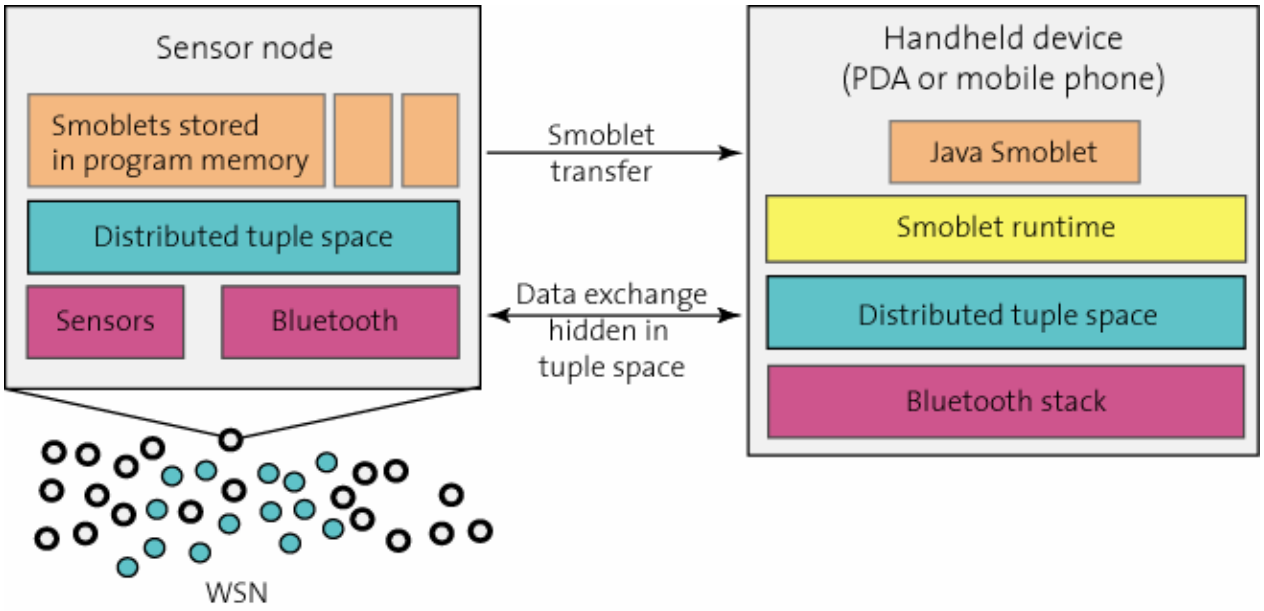
- Easy access to background infrastructure via BT-gateway
  - GSM
  - SMS short text services
  - WLAN
  - Internet
  - ...
- Easy to integrate with commodity devices
- Simplifies development, monitoring and debugging



# BTnode – Easy Integration with User Interface Devices

# Outsourcing of Computations as a System service

- BTnodes have limited resources
- Outsource computations on nearby more powerful devices
- Mobile code is executed on remote device
  - PDA, mobile phone, laptop computer...



# An Early Application of BTnodes: Smart Products

- Acceleration sensor
- Temperature sensor
- Standard Bluetooth profiles for SMS, object push and RFCOMM

# Smart Products

Bluetooth

SMS via GSM

sensor event


user control


- The BTnodes act as “smart tags“ for valuable products
- Alert via SMS of sensor events such as shock or heat
- Interactive dialogue with the smart product

# Interacting with Smart Everyday Objects…

# (1)
# …Using Sensors

# Interacting with Disappearing Computers?

- Hold two artifacts (with attached Smart-Its) together – and *shake!*

# Interacting with Disappearing Computers?

- Hold two artifacts (with attached Smart-Its) together – and *shake!*

# Shaking Two Objects Together Establishes a ”Friendship”

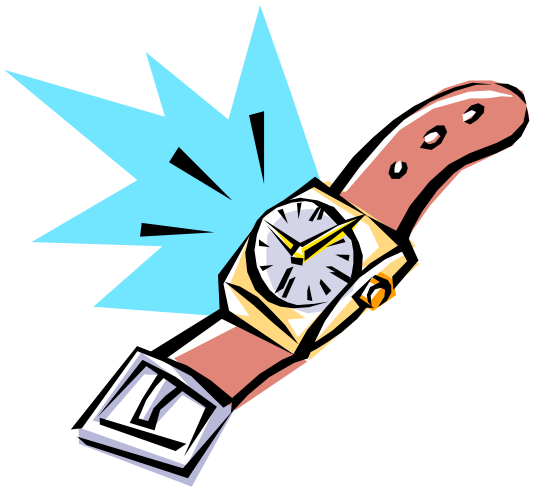
- The shaking motion establishes a shared context (i.e., acceleration pattern) that no other devices will have


- After the shared context has been established, the two devices can open a direct communication link

# Crying When Lonely

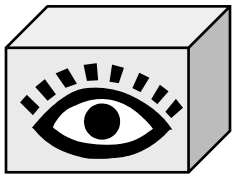
- If the two objects are too far apart (e.g., radio communication breaks down), the user is notified with an audible ”beep”

# Application:
# Credit Card and Wrist Watch

- Shake together before first use (establish friendship)
- Credit card will only work when in proximity of watch

# Another Application: Poor Man's Theft Alarm

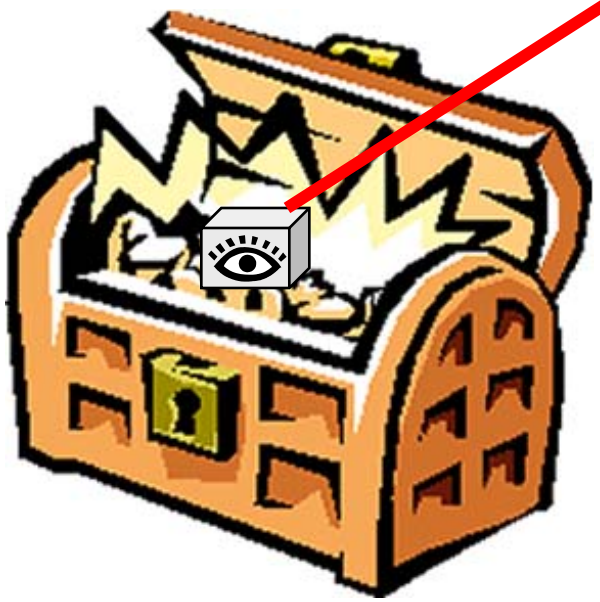


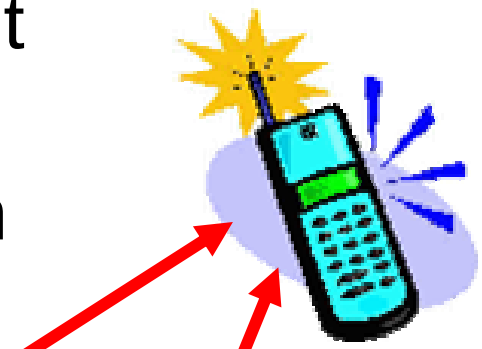
Sensor Cube

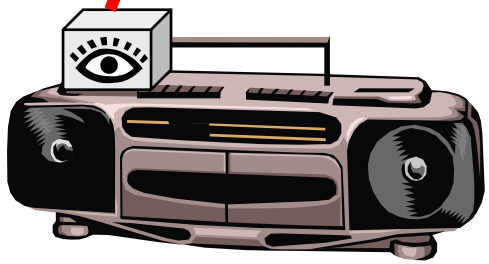
- Many mobile phones will be equipped with motions sensors
  - interaction feature for games
- Shake sensor cube together with phone to activate the cube
  - no bottons etc. on the cube
  - "location limited channel"
  - feedback via phone
  - configuration via phone

# Poor Man's Theft Alarm

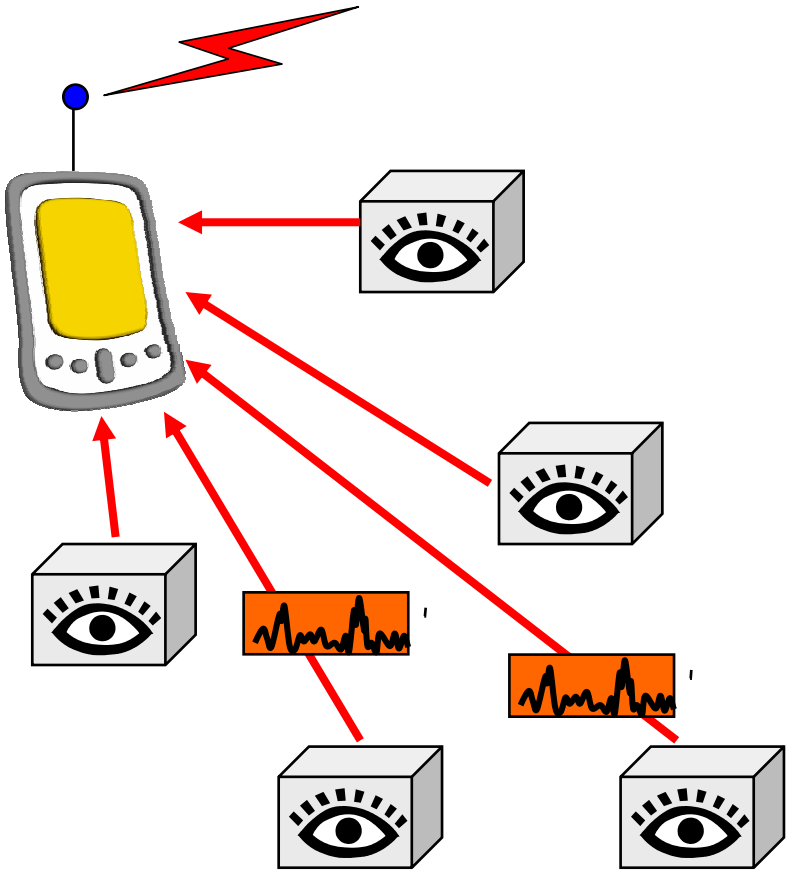
- Place cube on object to be protected
- Receive alarm when cube is moved







# Poor Man's Theft Alarm



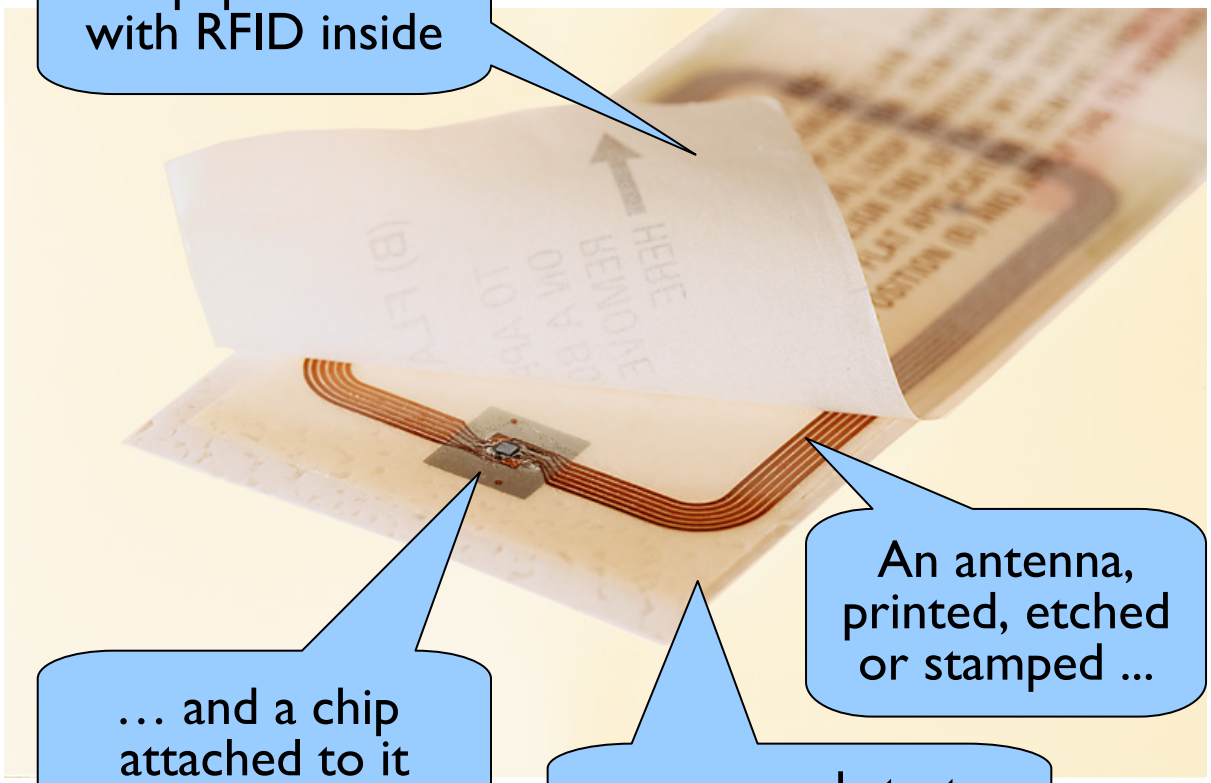
- Spontaneous networking with gateway station?
- Raise alarm only when two or more sensor cubes report motion?
- Deactivate when owner is nearby?

# Interacting with Smart Everyday Objects…

# (2)

# …Using RFID

# Making Things Smart with 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“

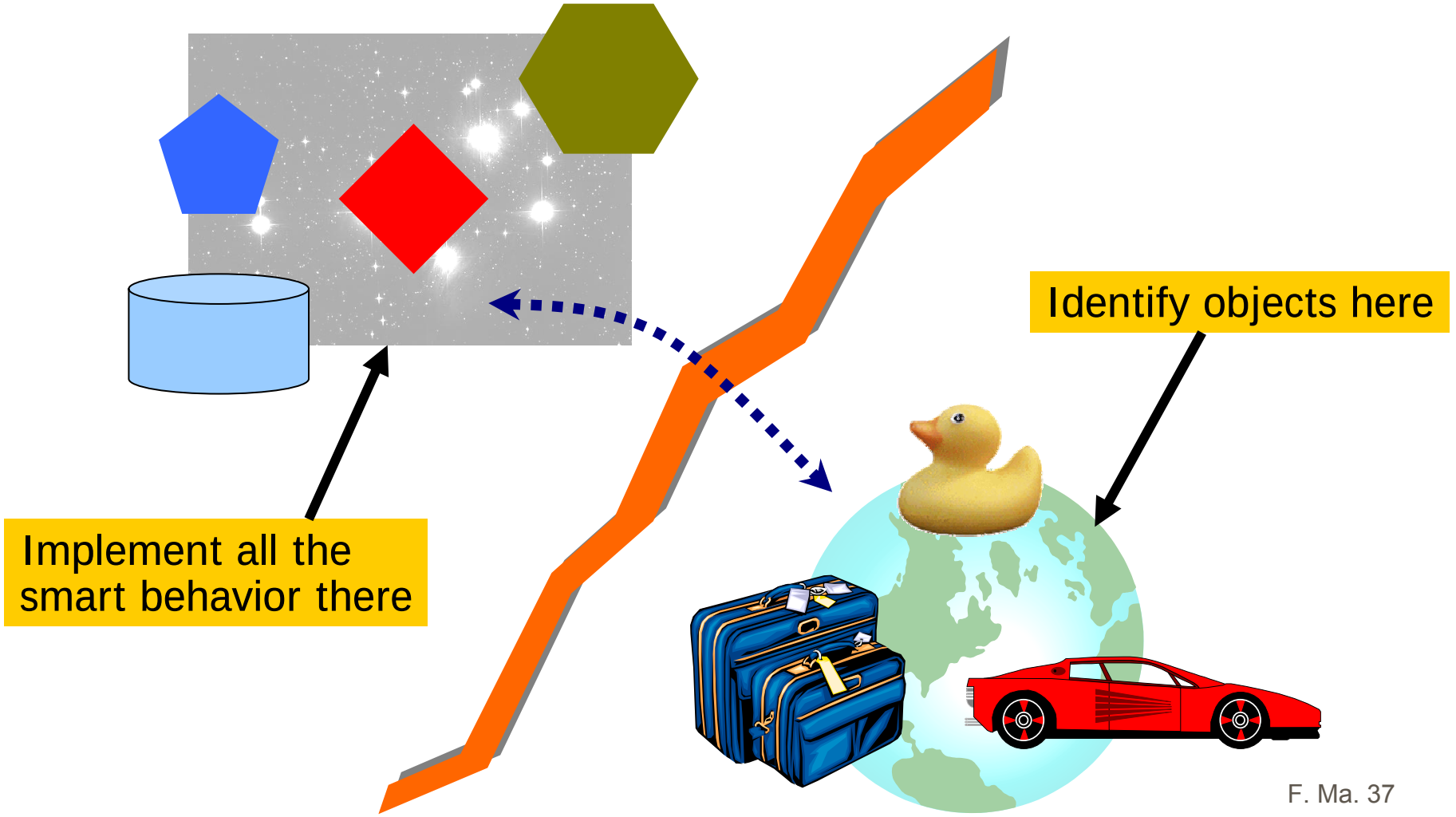
- ~ 1 m

# Smart Playing Cards

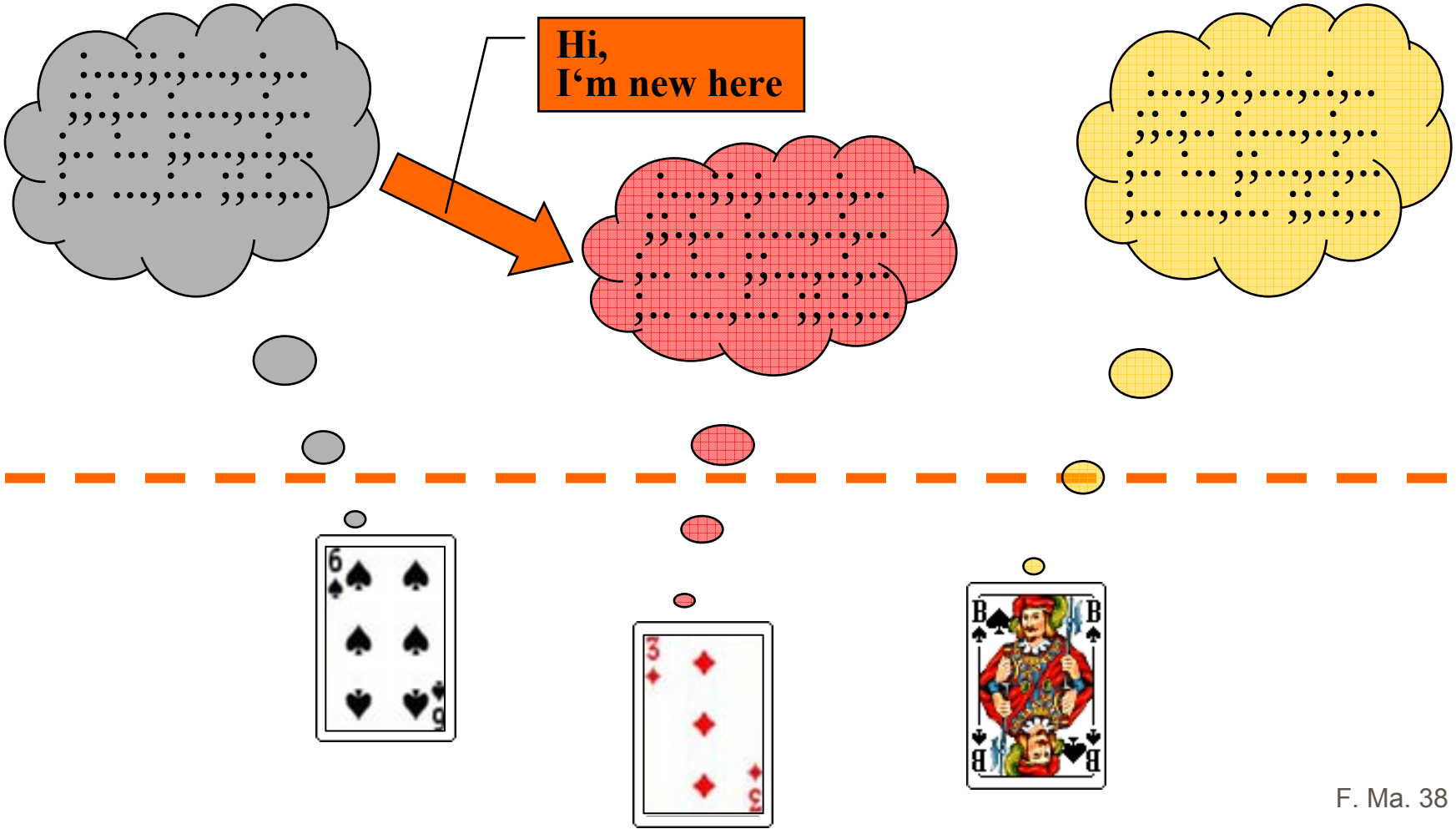

- Playing cards have RFID labels
  - reader antenna is placed under the table
  - wireless transmission to player‘s PDA

- Features:
  - count score
  - hints for beginners
  - determine winner
  - cheat alarm

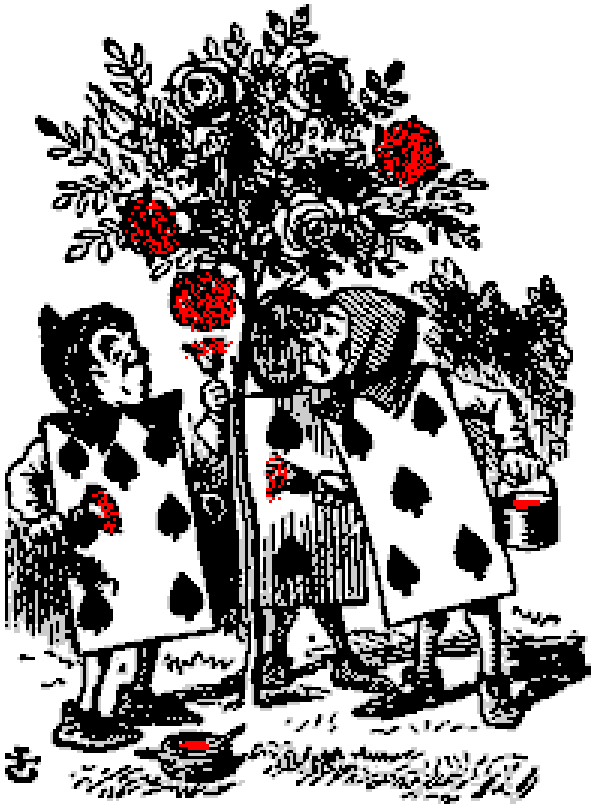
# Simulating Smart Objects with "Virtual Counterparts"



# Virtual Counterparts of Playing Cards



# Cards as Personalities

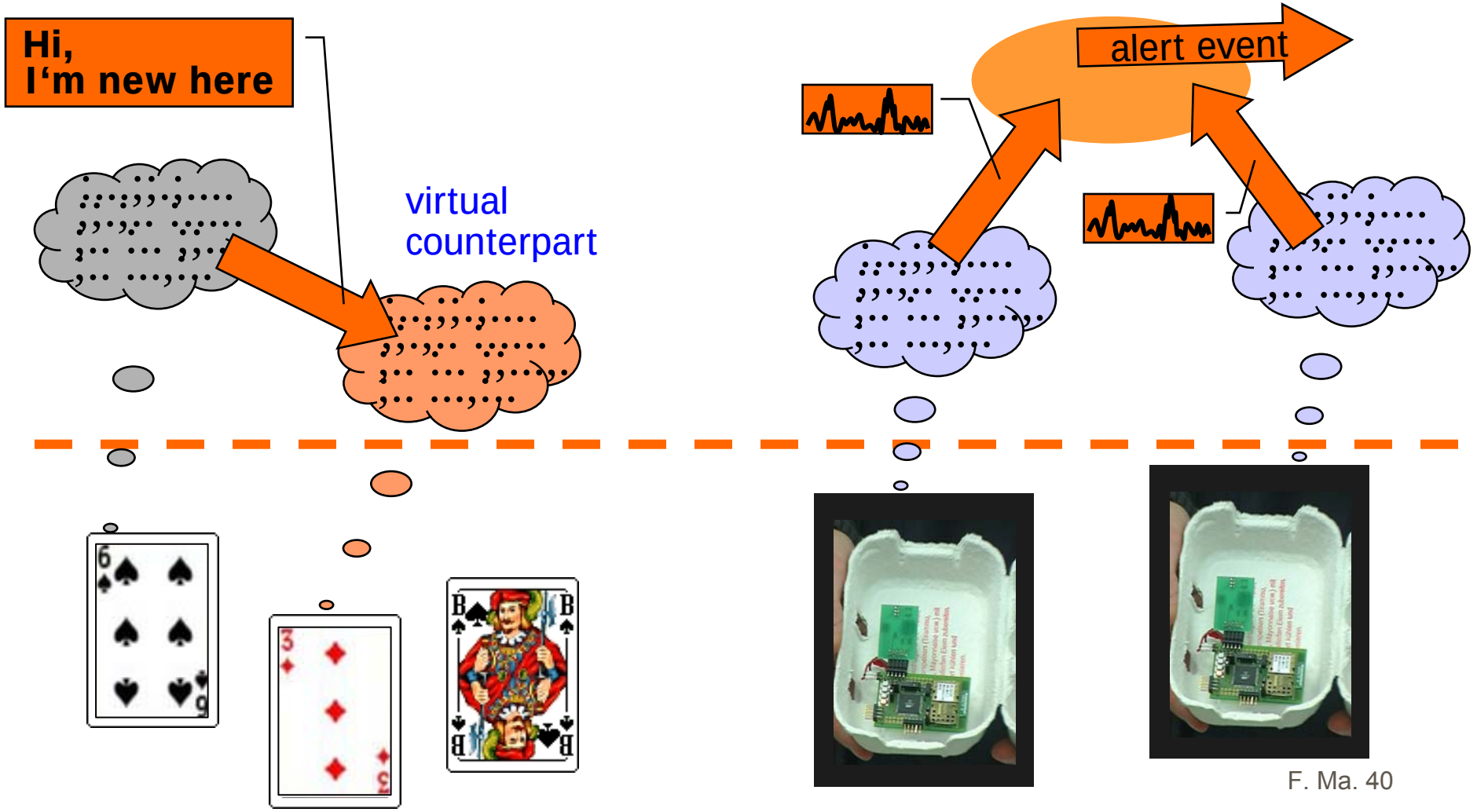


Alice in Wonderland

- Do playing cards have a memory?
- What do they communicate?
- How do they react to msgs?
- How do playing cards interact with a backend system?

➔ General infrastructure

# Software Infrastructure for Smart Objects?



# Interacting with Smart Everyday Objects…

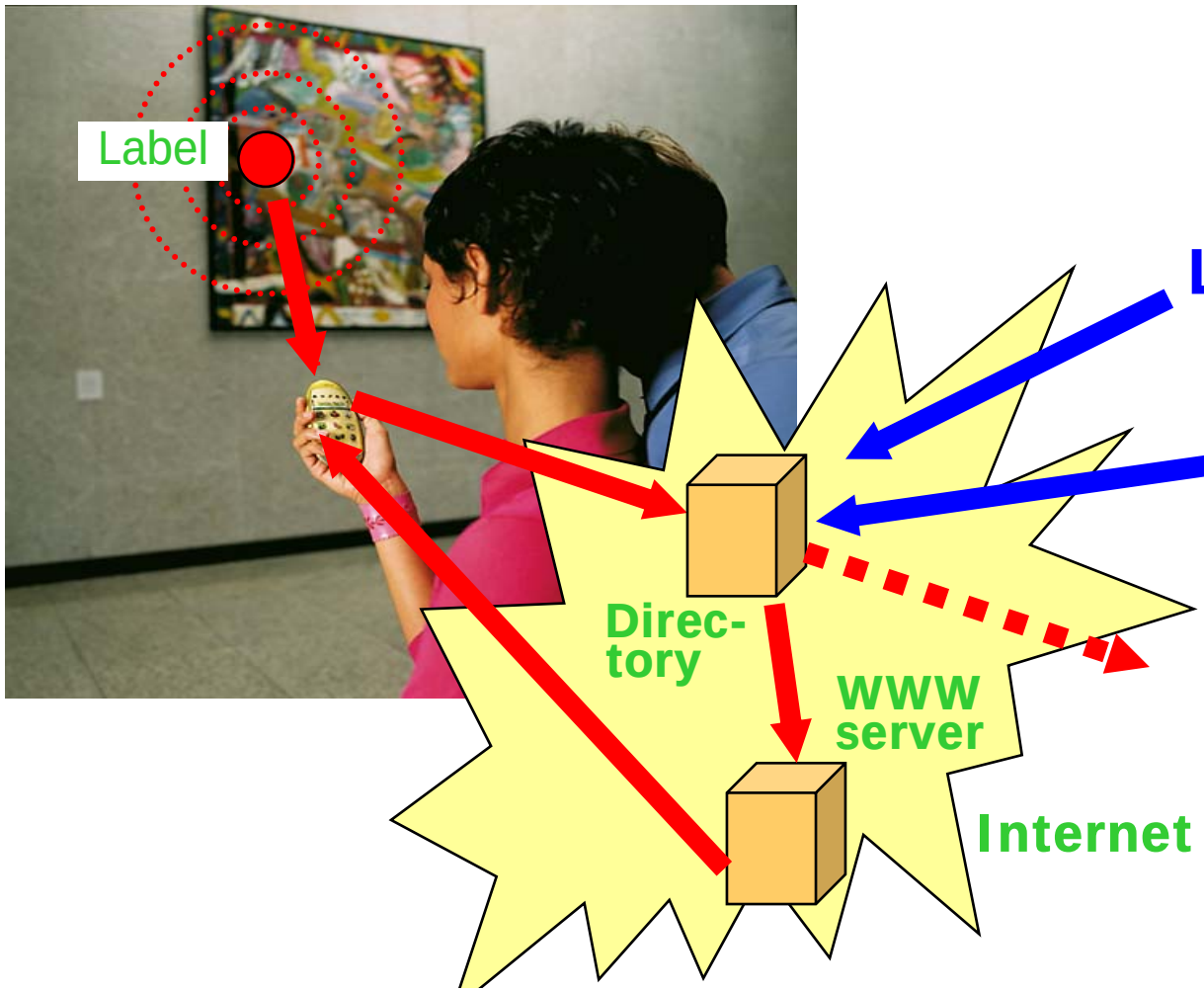
# (3)
# ...Using 2D-Labels

# Responsive Objects

Image source: Nokia
Cf. Cooltown project (HP)

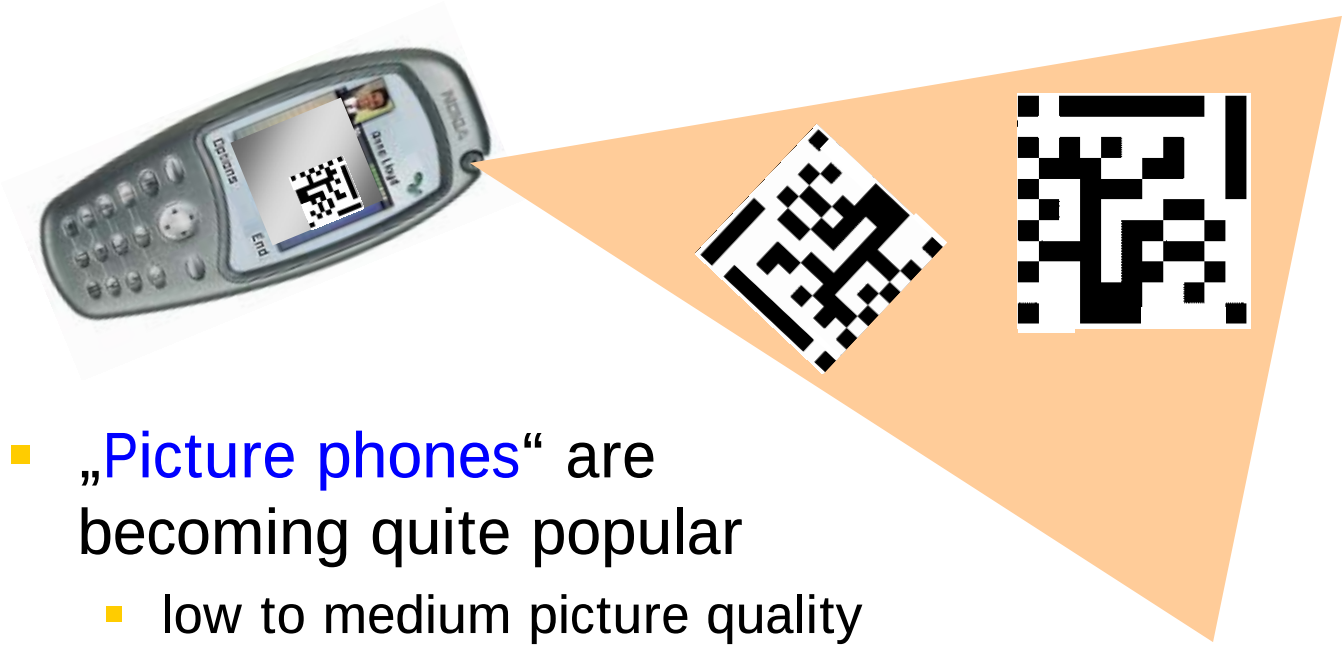
- An objects tells something about itself
  - e.g., by displaying a dynamically generated homepage
- Content
  - depends on circumstances such as context and privileges

# Responsive Objects




- Copy by reference instead of copy by value

# Object-Interaction with Camera-Equipped Mobile Phones



- „Picture phones“ are becoming quite popular
  - low to medium picture quality
  - typically 640 x 480 pixels
  - programmable

**Patents pending**

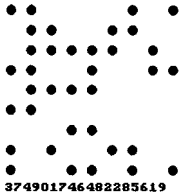
# Visual Codes

- Many different visual codes exists
- Differences in
  - application domain
  - number of encoded bits
  - robustness
- Low resolution CCD camera requires coarse grained code

Data Matrix

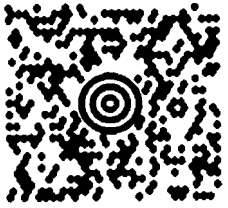
TRIPcode

PDF417



3749017464822856 19

Philips Dot Code



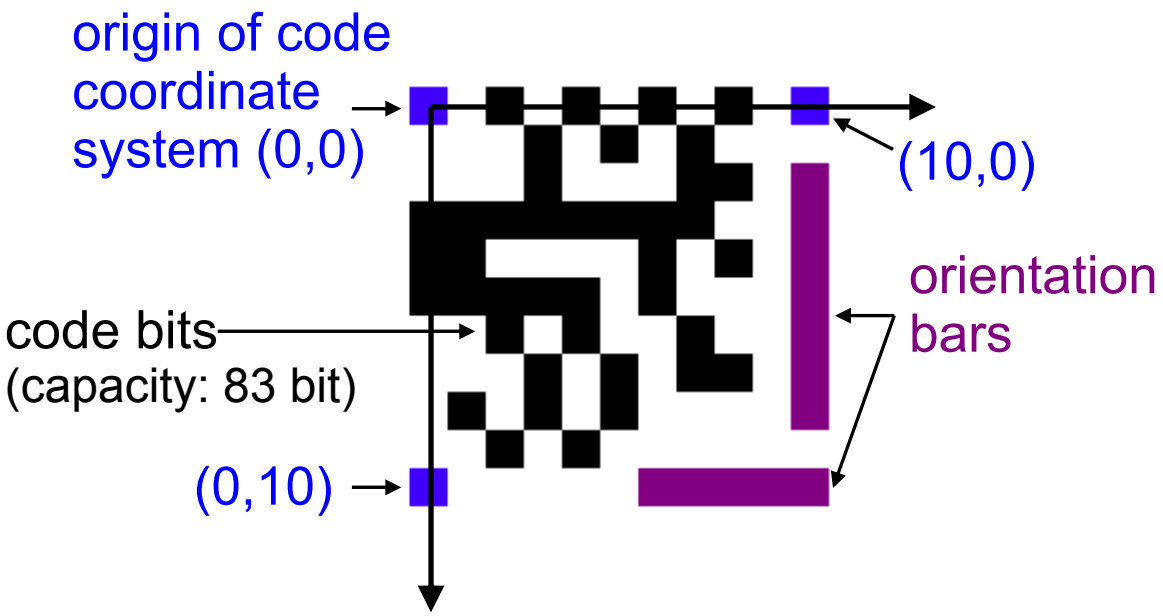
UPS MaxiCode

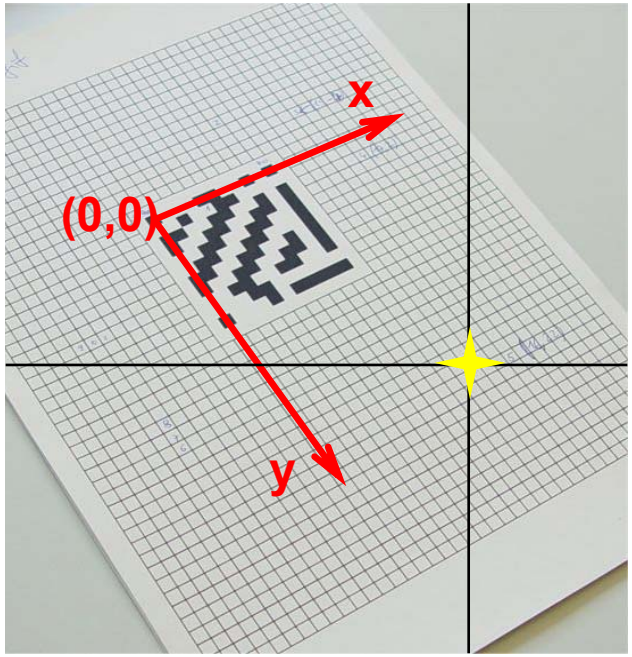
QR Code

CyberCode

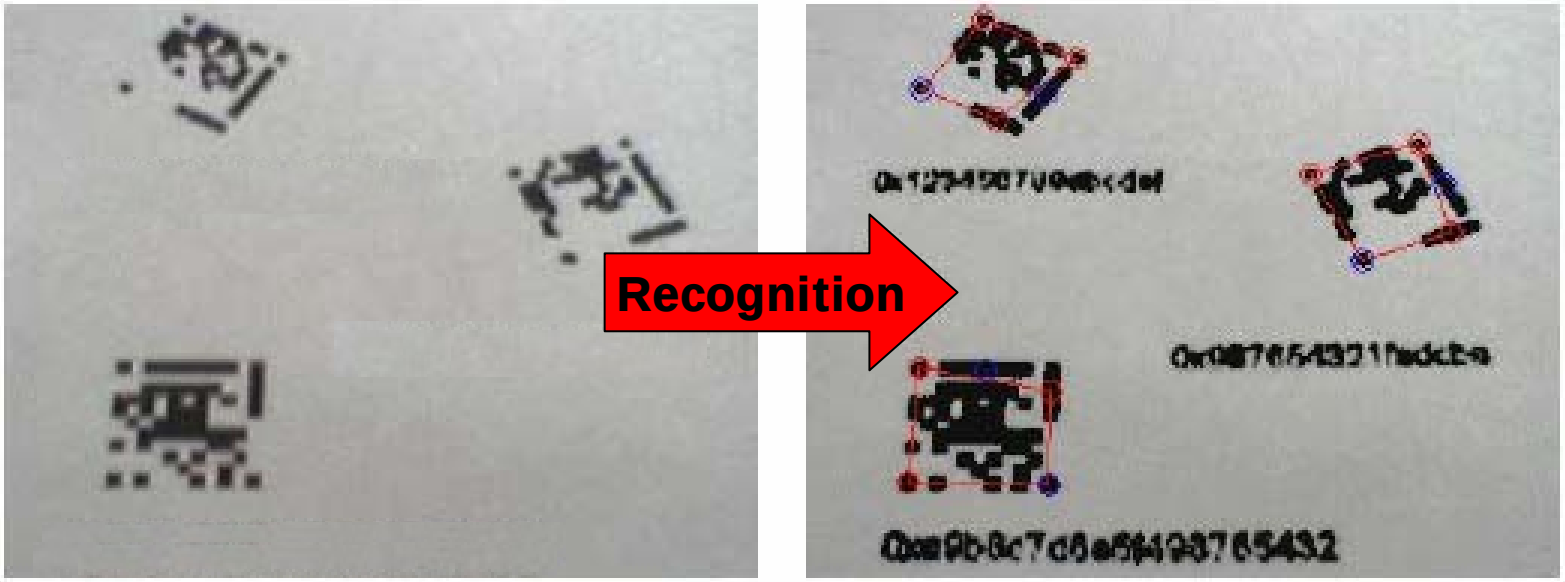
0073292

# Our Code (Suited for Low-Resolution CCD Cameras)

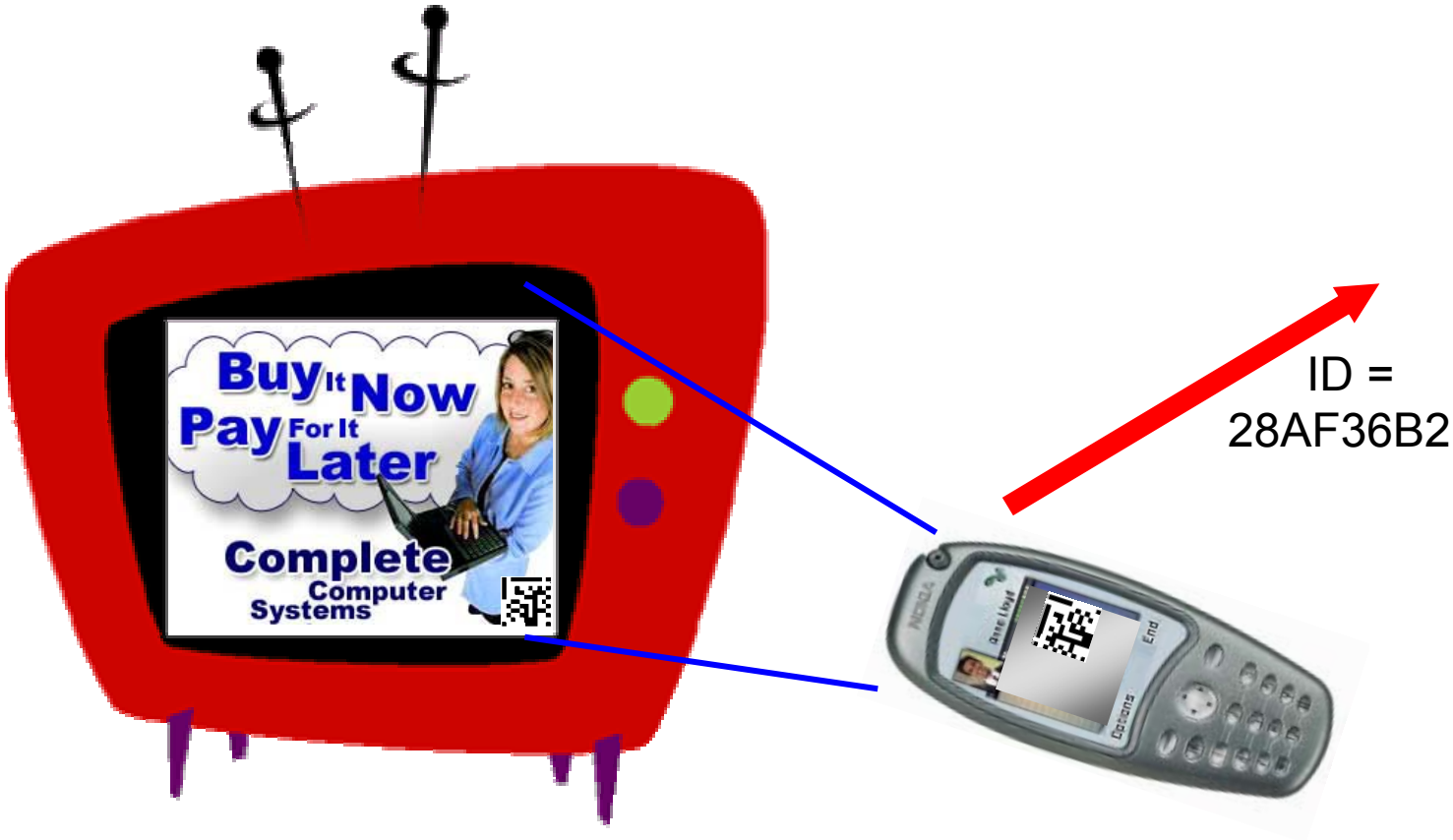


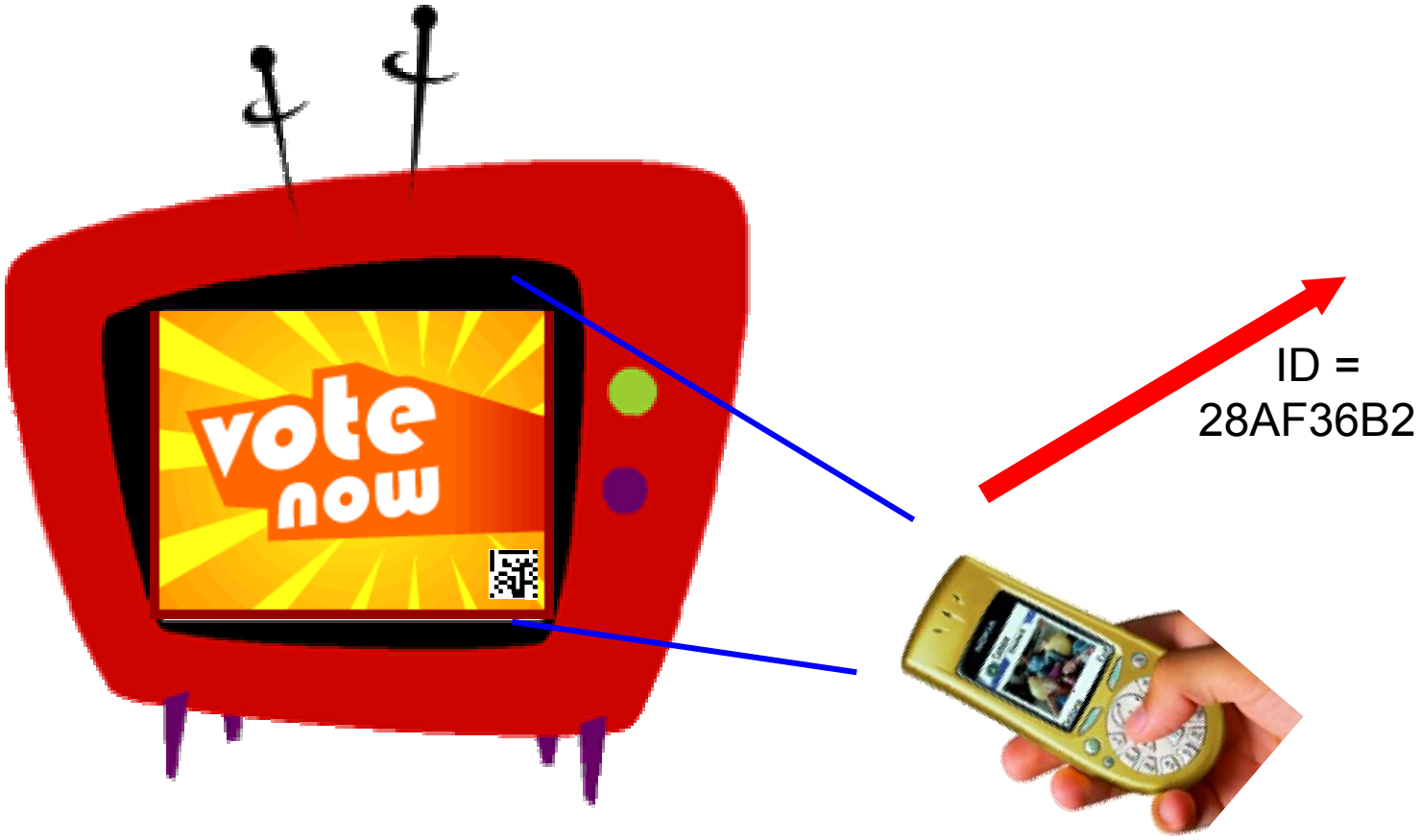
# Visual Code Recognition



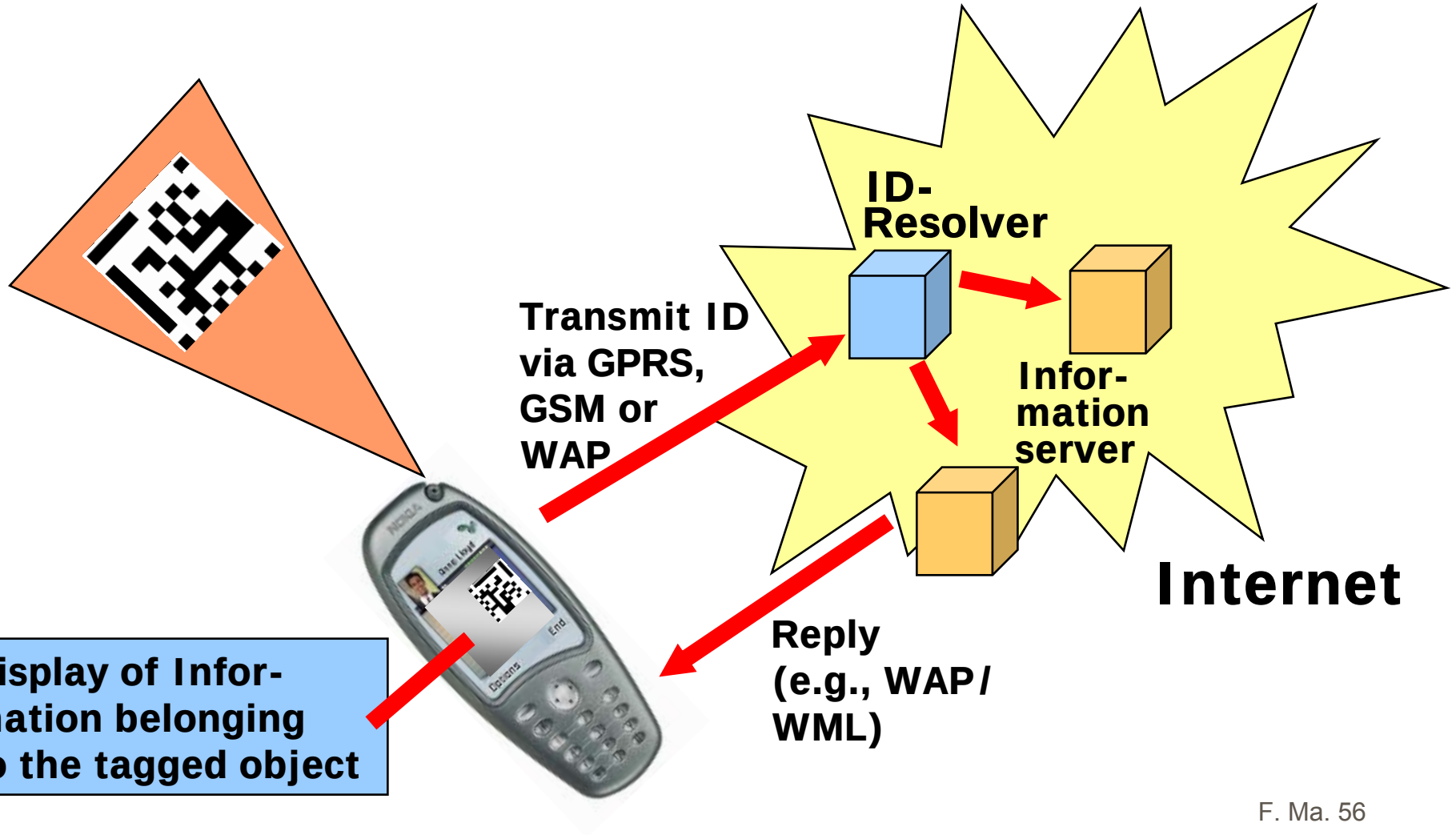
# Application: Buy Now



# Music Charts: Vote Now

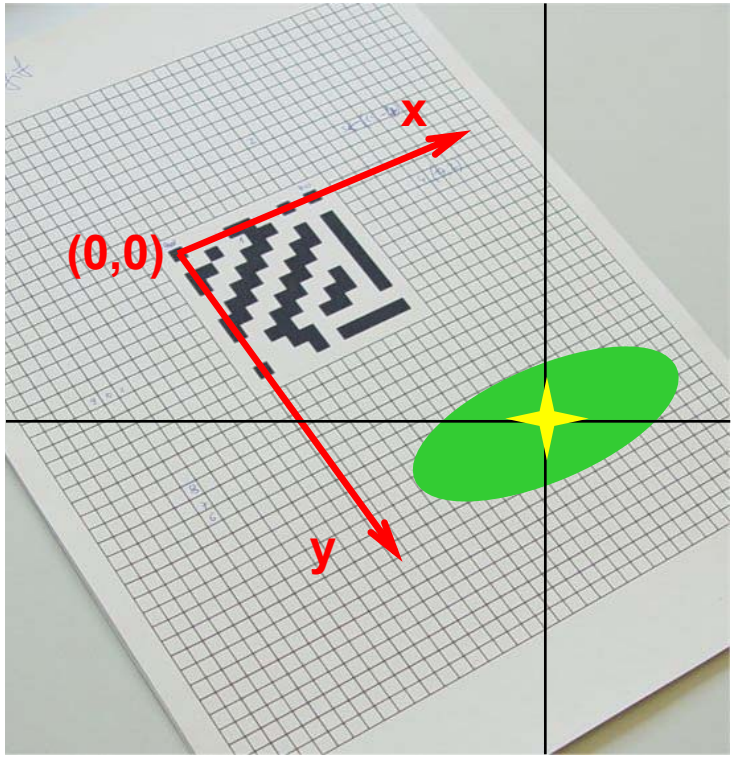


# „Talking Objects“ Simulated by a Backend Infrastructure

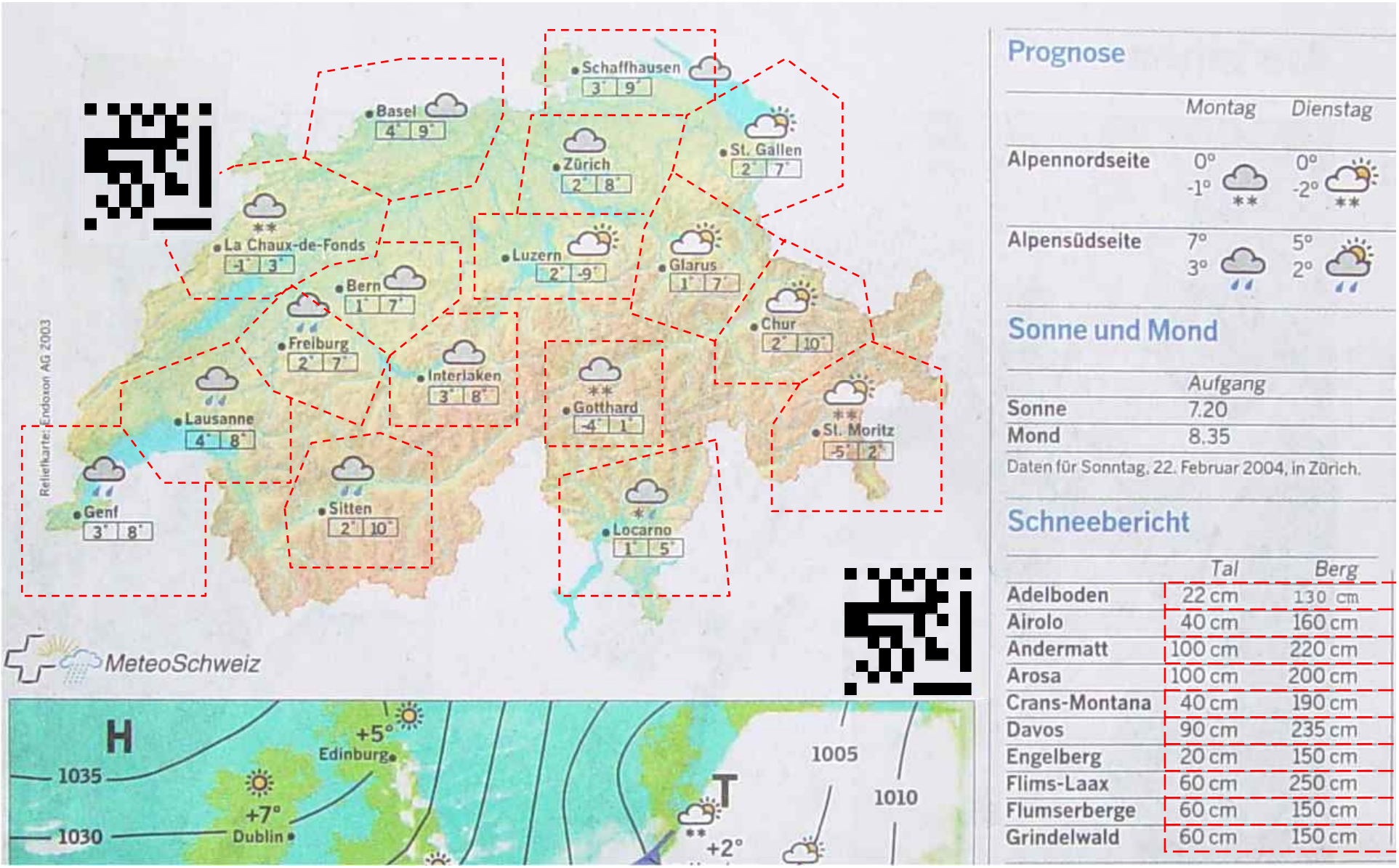


# Augmenting Paper with Hyperlinks

- Determine the coordinates of the camera focus
  - w.r.t the visual code origin
- Associate physical hyperlinks with image regions
- Augmented reality: the picture phone can follow the hyperlink, fetch the additional information via the wireless link and display it



# Item Selection with Relative Focus Position Determination




## Prognose

| | Montag | Dienstag |
|---|---|---|
| Alpennordseite | 0° -1° ** | 0° -2° ** |
| Alpensüdseite | 7° 3° | 5° 2° |

## Sonne und Mond

| | Aufgang |
|---|---|
| Sonne | 7.20 |
| Mond | 8.35 |

Daten für Sonntag, 22. Februar 2004, in Zürich.

## Schneebericht

| | Tal | Berg |
|---|---|---|
| Adelboden | 22 cm | 130 cm |
| Airolo | 40 cm | 160 cm |
| Andermatt | 100 cm | 220 cm |
| Arosa | 100 cm | 200 cm |
| Crans-Montana | 40 cm | 190 cm |
| Davos | 90 cm | 235 cm |
| Engelberg | 20 cm | 150 cm |
| Flims-Laax | 60 cm | 250 cm |
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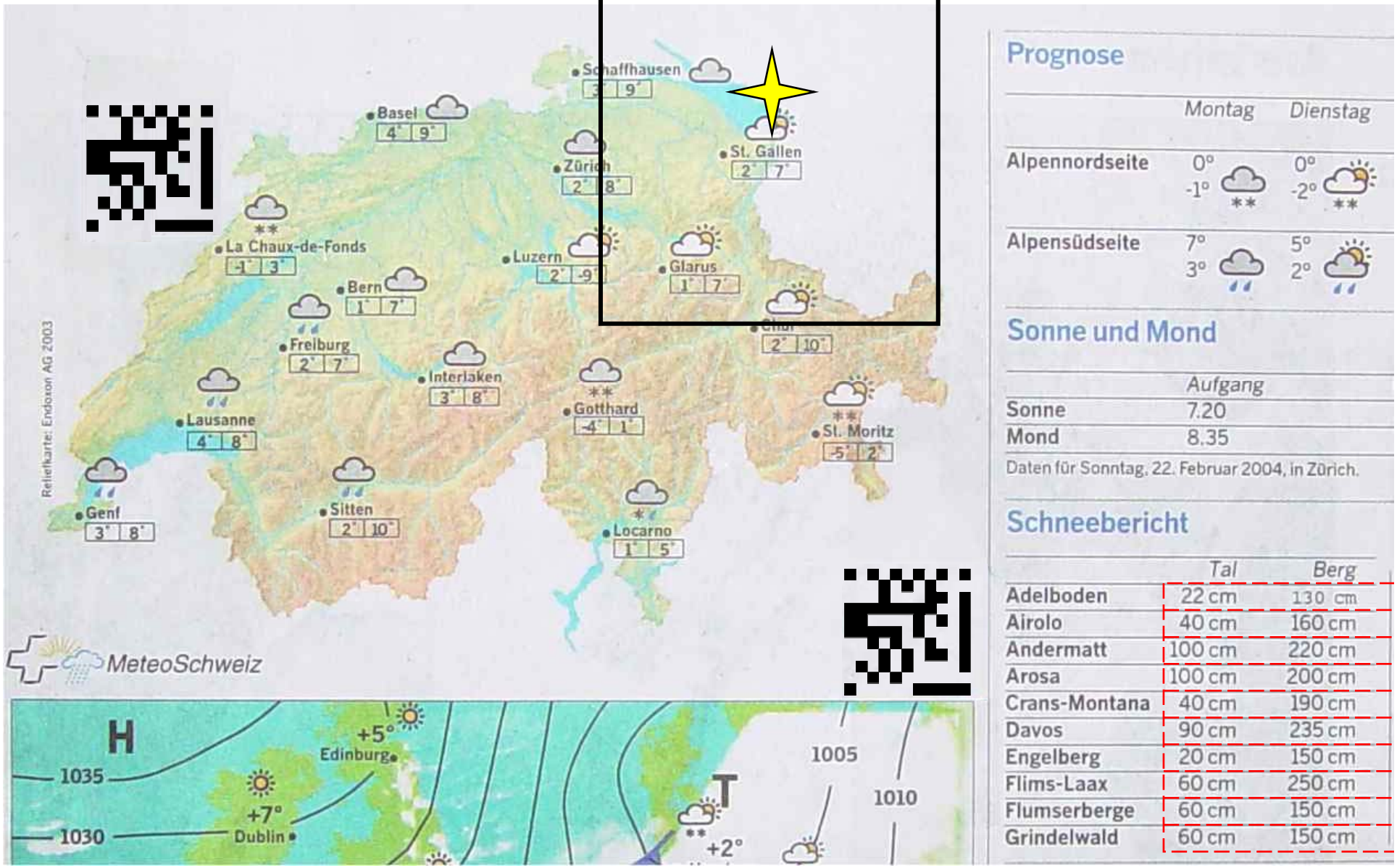


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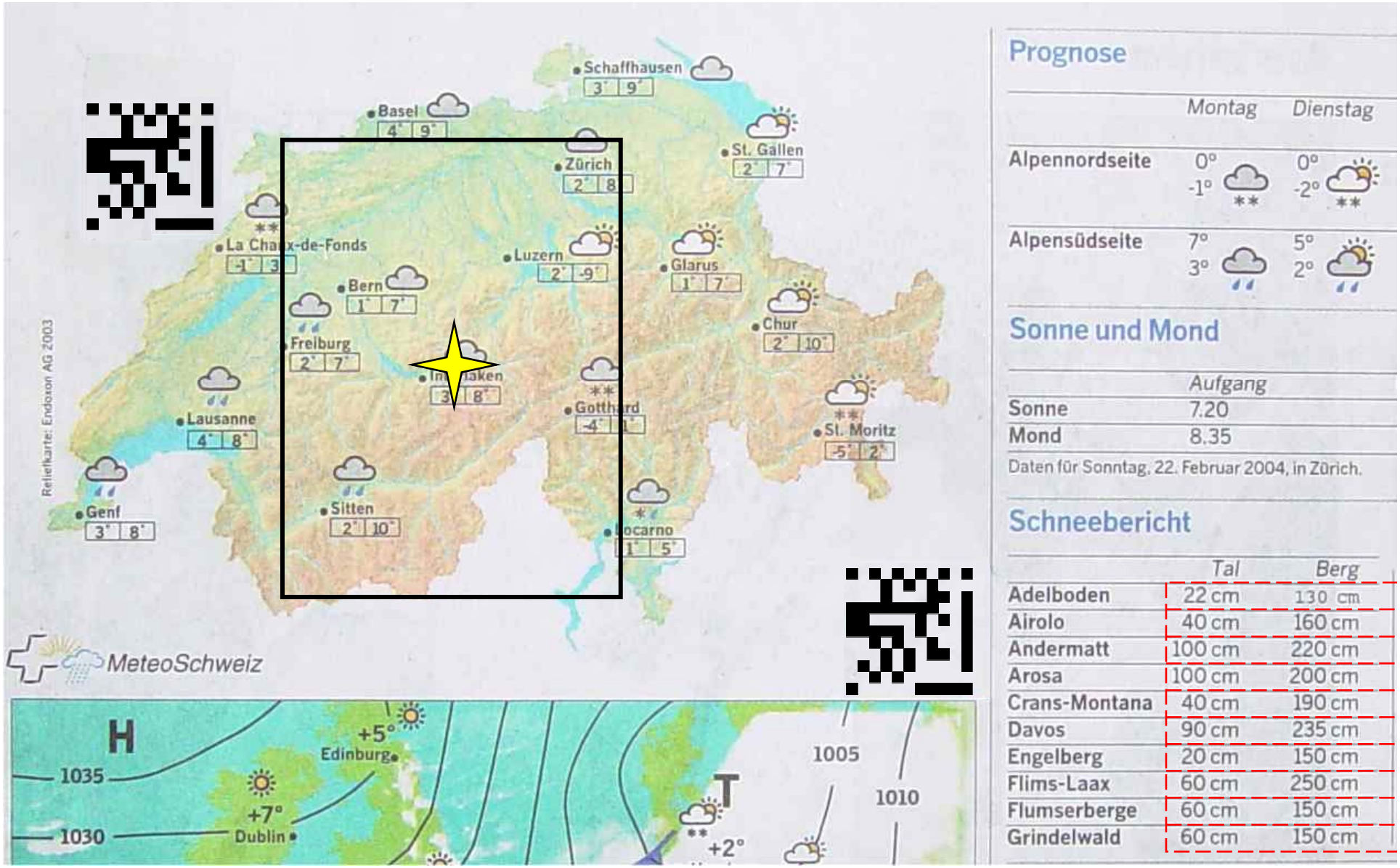


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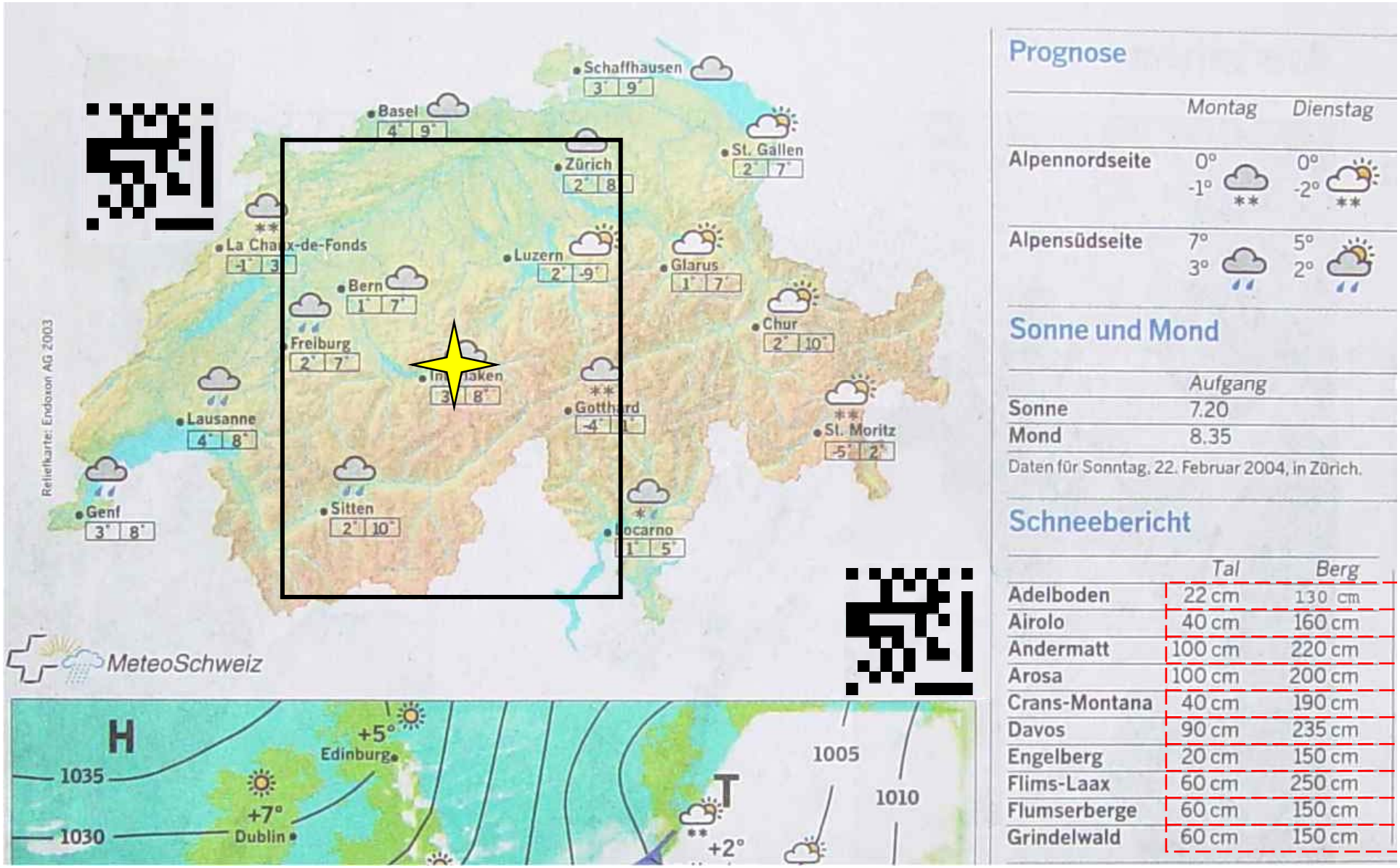


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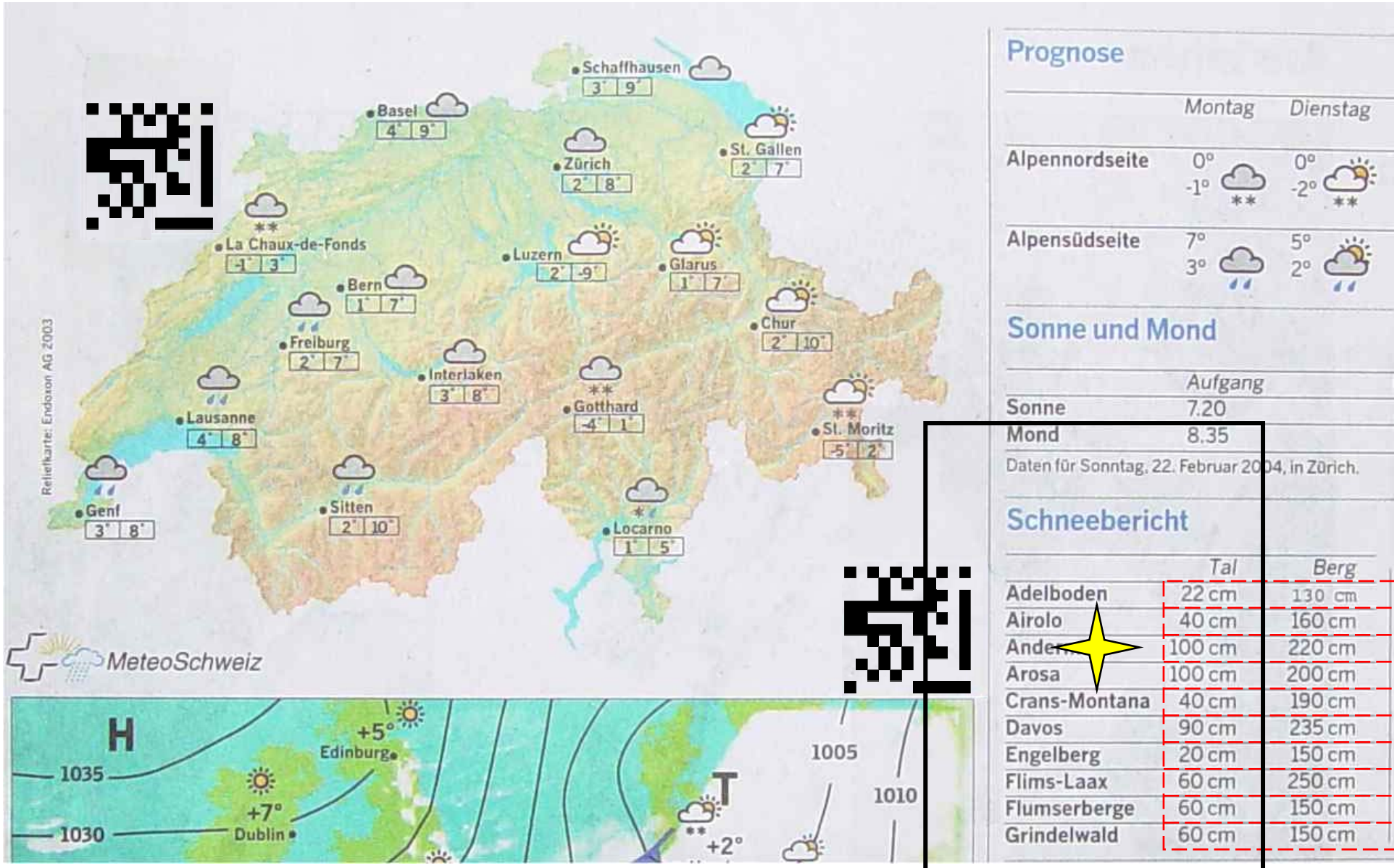
| Mond | 8.35 |

Daten für Sonntag, 22. Februar 2004, in Zürich.

## Schneebericht

| | Tal | Berg |
|---|---|---|
| Adelboden | 22 cm | 130 cm |
| Airolo | 40 cm | 160 cm |
| Andermatt | 100 cm | 220 cm |
| Arosa | 100 cm | 200 cm |
| Crans-Montana | 40 cm | 190 cm |
| Davos | 90 cm | 235 cm |
| Engelberg | 20 cm | 150 cm |
| Flims-Laax | 60 cm | 250 cm |
| Flumserberge | 60 cm | 150 cm |
| Grindelwald | 60 cm | 150 cm |

# Item Selection with Relative Focus Position Determination




## Prognose

| | Montag | Dienstag |
|---|---|---|
| Alpennordseite | 0° -1° | 0° -2° |
| Alpensüdseite | 7° 3° | 5° 2° |

## Sonne und Mond

| | Aufgang |
|---|---|
| Sonne | 7.20 |
| Mond | 8.35 |

Daten für Sonntag, 22. Februar 2004, in Zürich.

## Schneebericht

| | Tal | Berg |
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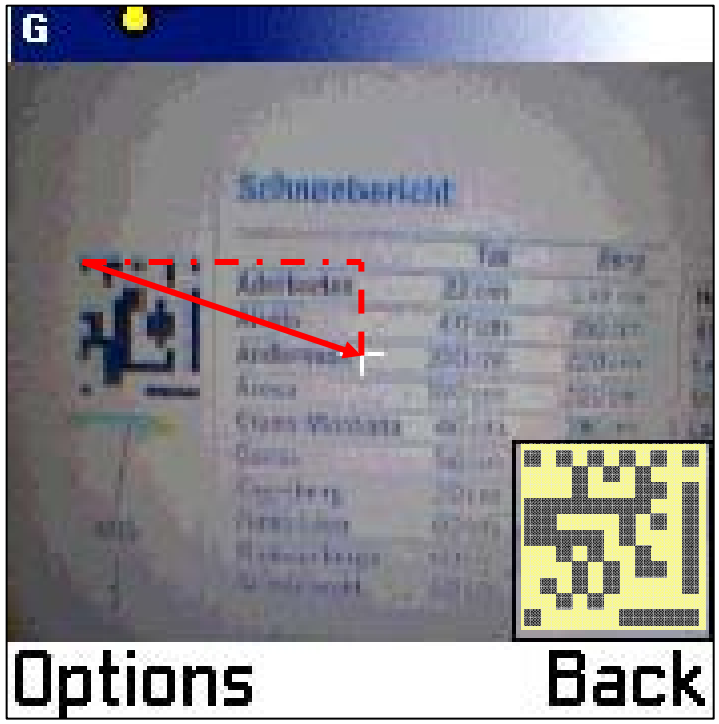
| Grindelwald | 60 cm | 150 cm |

# Item Selection: Current Snow Conditions in Andermatt

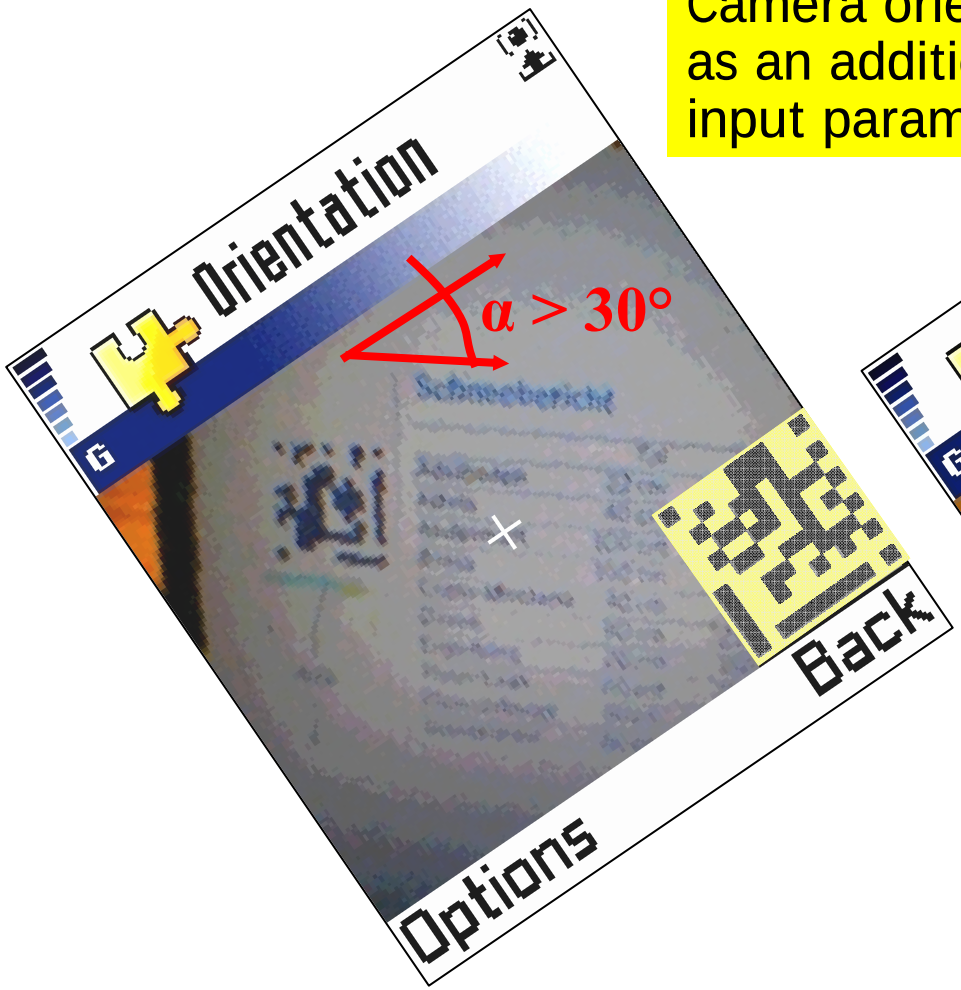
Original camera image




Augmented image

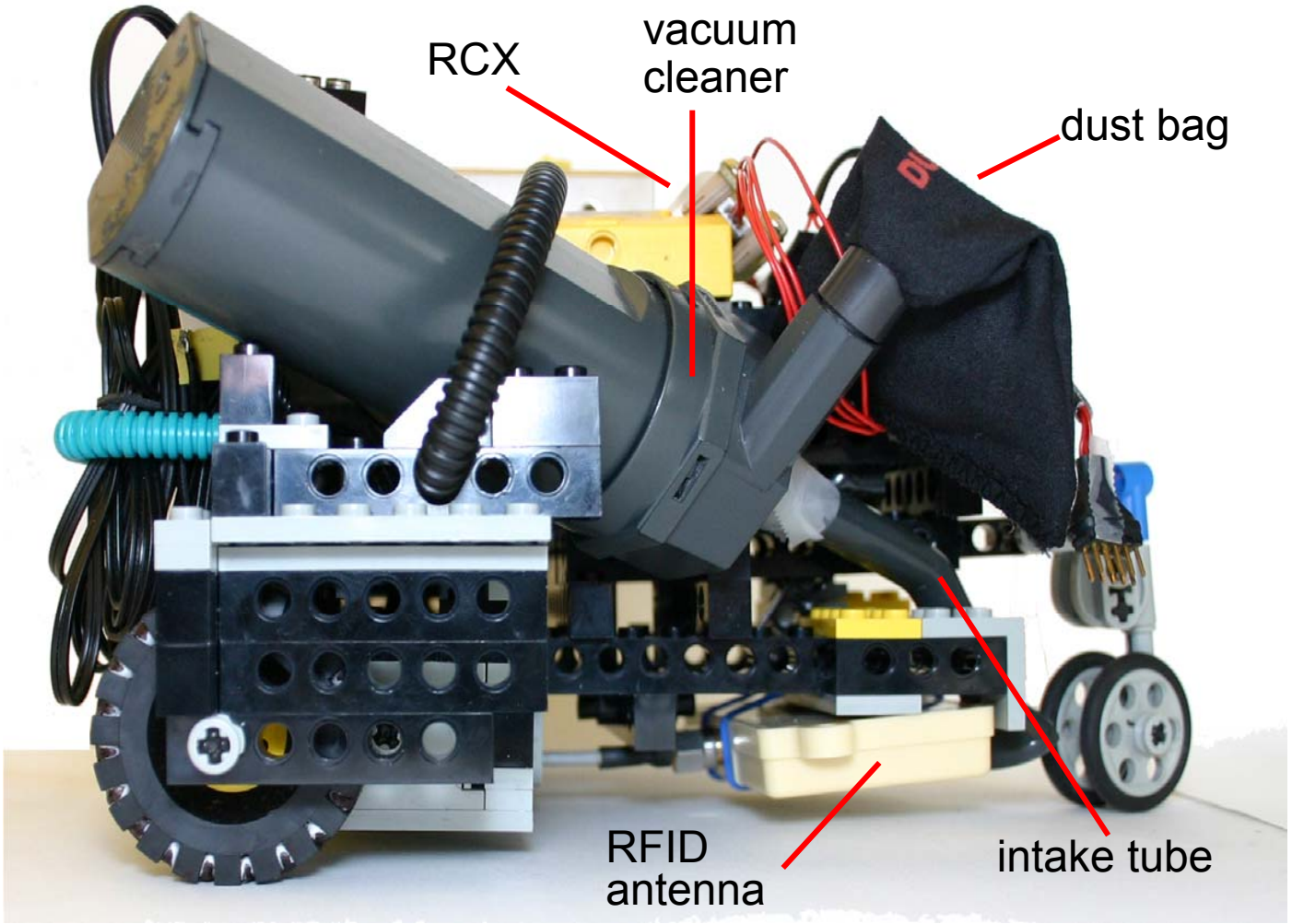
# Orientation Feature: Current Temperature in Andermatt

Camera orientation as an additional input parameter



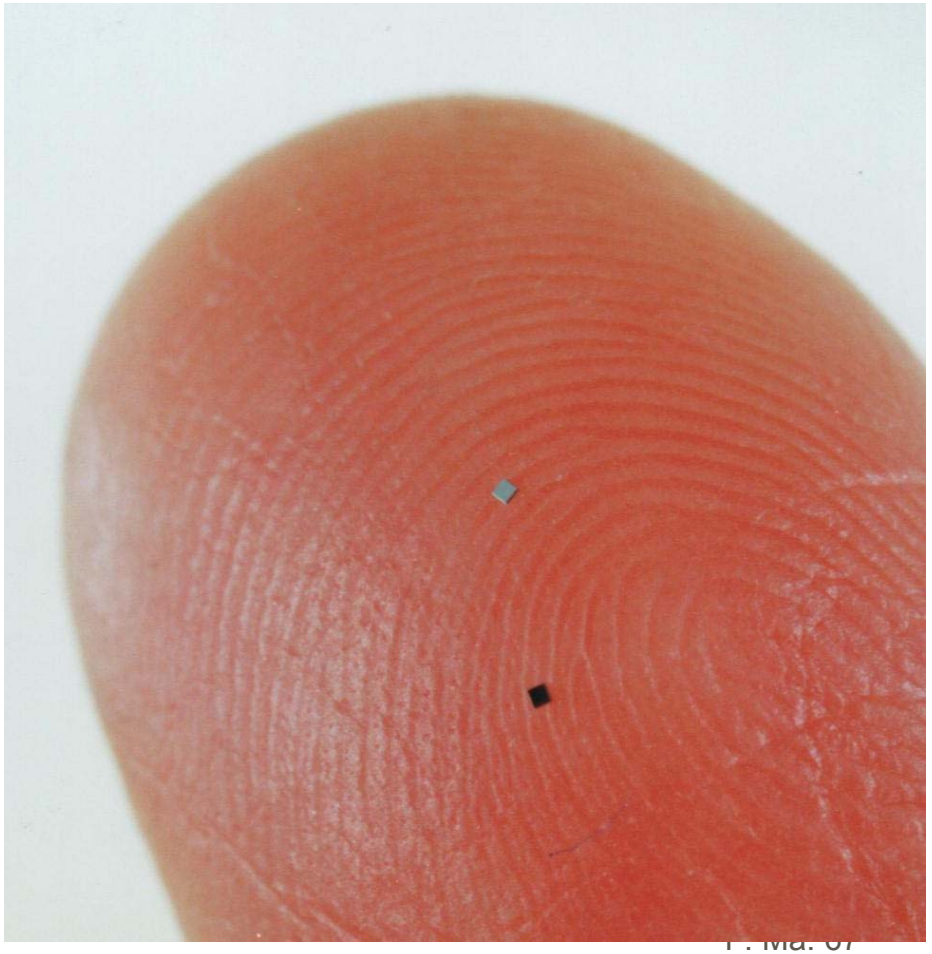

# Mobile Sensing of ‘Superdistributed’ RFID Tags

# RFID-based Smart Vacuum Cleaner

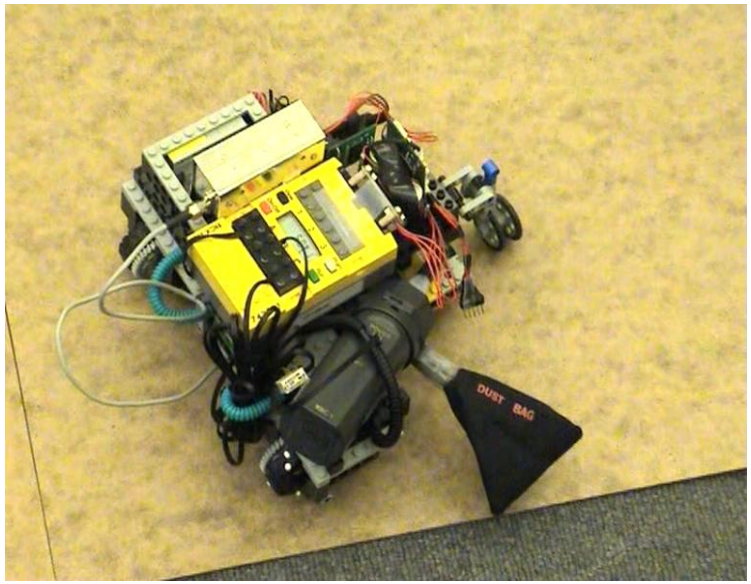


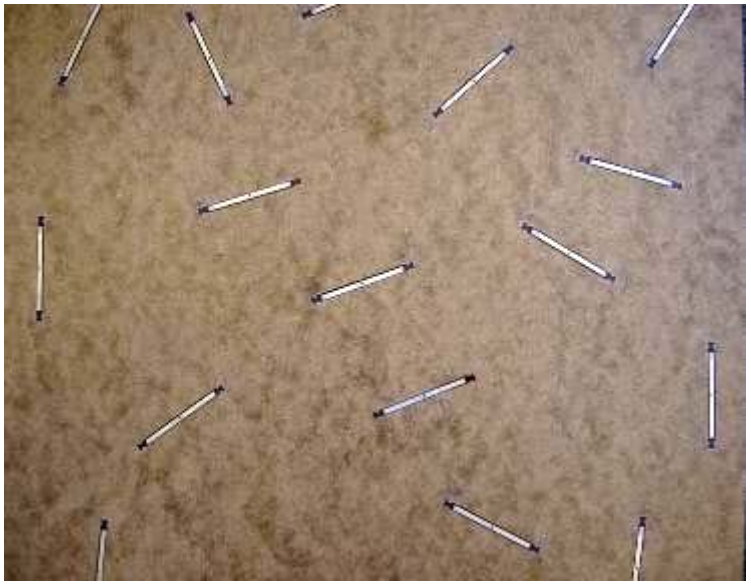
# µ-Chip (Hitachi)

- Size: 0.4 $mm^2$
- Carrier frequency: 2.45 GHz
- Operating distance: 0-25 cm
- Memory capacity: 128bit ROM
- Anti-collision: no
- Response time: 20 ms



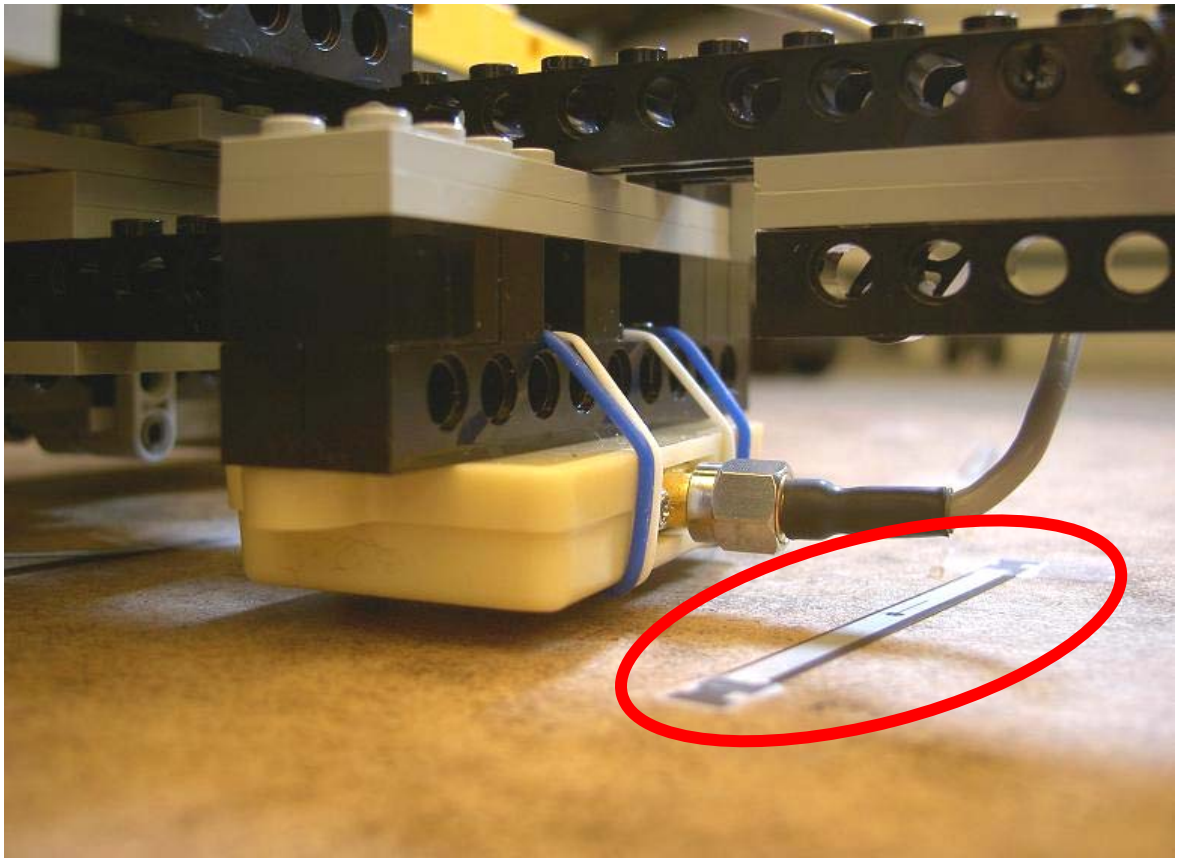
# RFID-based Smart Vacuum Cleaner



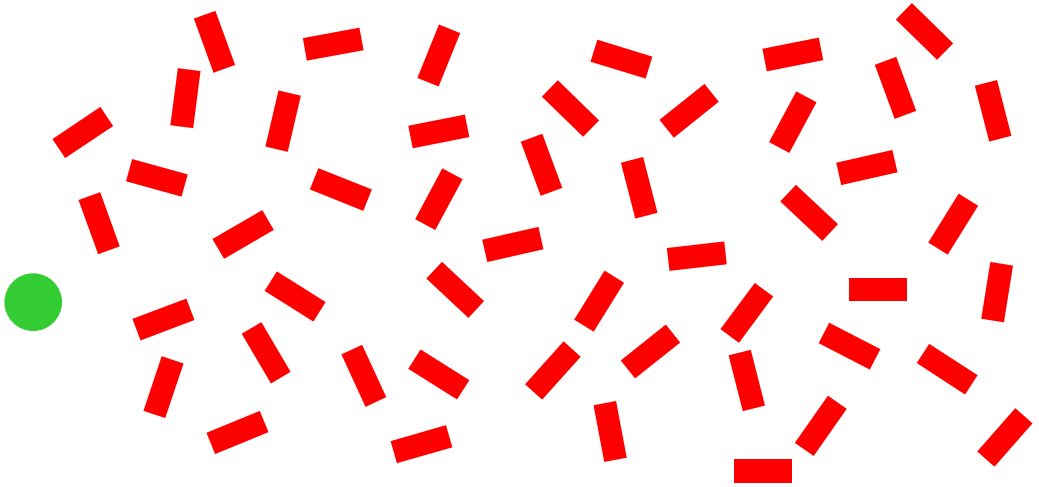



- Huge number of RFID tags fixed on the floor
- Robot carries a mobile RFID reader
- Robot learns its position (tag ID)

# Fixed RFID Tag and Mobile Reader Antenna

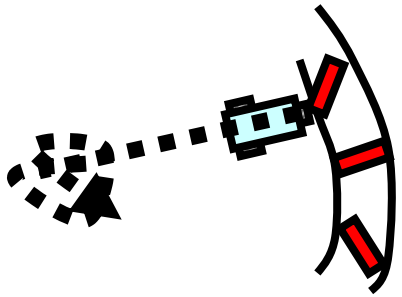


# Mobile Robot Positioning



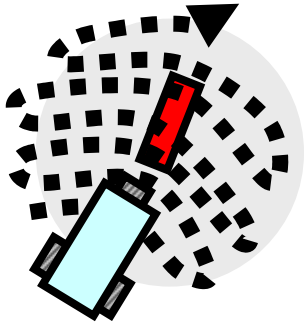
- Robot learns its position (tag ID)
- Knows the border, remembers its track,...
- Performs appropriate action (move, turn, clean,...) depending on the position

# Position Dependent Behavior



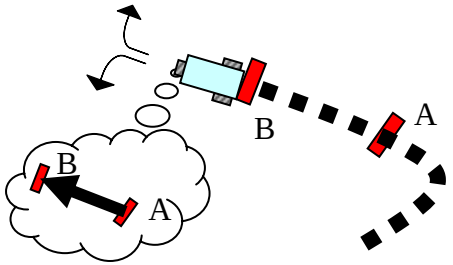
**Border case**

*Robot turns left or right when it senses a tag that is known to be a border tag*



**Cleaning mode**

*Robot performs cleaning action on a small area when it detects a "new" tag*




**Déjà-vu**

*Robot makes a turn when it detects the same two tags in a sequence*

# Conclusions

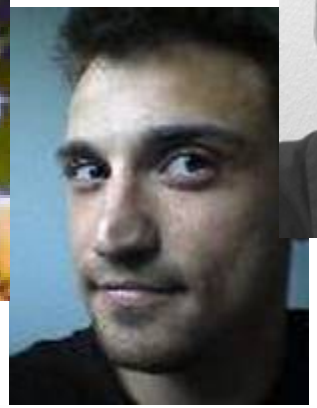
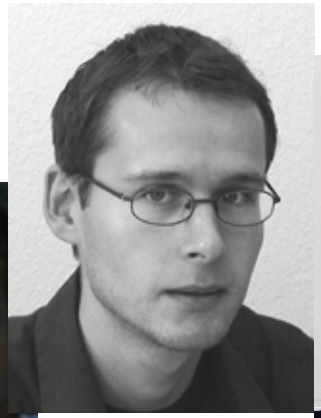
- Wireless sensors: not only to realize smart environments, but also to implement smart objects
- Use today‘s technology to prototype tomorrow‘s technology, applications, and scenarios

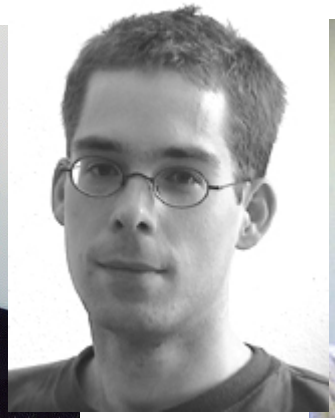
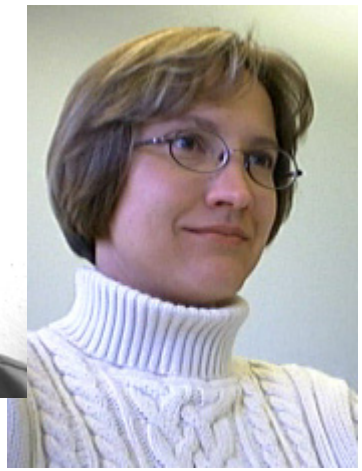
Jan Beutel, Oliver Kasten, Friedemann Mattern, Kay Römer, Frank Siegemund, and Lothar Thiele: **Prototyping Wireless Sensor Network Applications with BTnodes**, EWSN, Springer LNCS, 2004

# Acknowledgements


- BTnodes: Jan Beutel, Oliver Kasten, Frank Siegemund
- Smart Playing Cards: Kay Römer
- 2D-Codes: Michael Rohs
- Smart Vacuum Cleaner: Svetlana Domnicheva

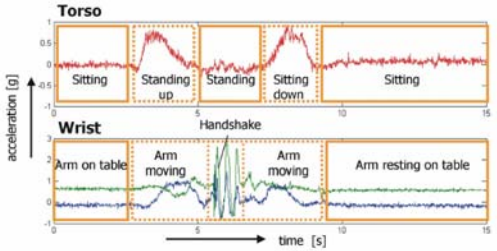


# Other BTnode Applications

- The Lighthouse location system [Roemer2003]
- Smart product monitoring [Siegemund2002]
- Bluetooth enabled appliances [Siegemund2003]
- Smart It's friends [Siegemund2003]
- XHOP/R-DSR multihop prototype [Beutel2002]
- Distributed positioning – TERRAIN implementation [Frey2003]
- Physical activity detection network [Junker2003]
- Better avalanche rescue through sensors [Michahelles2002]
- Wearable unit with reconfigurable modules [Plessl2003]
- Undergrad projects with Lego Mindstorms [Blum2003]
- ...




# Selected Publications from www.vs.inf.ethz.ch/publ/

- Michael Rohs, Beat Gfeller: Using Camera-Equipped Mobile Phones for Interacting with Real-World Objects. PERVASIVE 2004, to appear.
- Kay Römer, Thomas Schoch, Friedemann Mattern, Thomas Dübendorfer: Smart Identification Frameworks for Ubiquitous Computing Applications. Wireless Networks, Vol. 10 No. 6, December 2004.
- Jan Beutel, Oliver Kasten, Friedemann Mattern, Kay Römer, Frank Siegemund, Lothar Thiele: Prototyping Wireless Sensor Network Applications with BTnodes. 1st European Workshop on Wireless Sensor Networks (EWSN), Springer-Verlag, ISBN 3-540-20825-9, pp. 323-338, Berlin, January 2004.
- Kay Römer, Svetlana Domnitcheva: Smart Playing Cards: A Ubiquitous Computing Game. Journal for Personal and Ubiquitous Computing (PUC), Vol. 6, pp. 371-378, 2002.
- Lars Erik Holmquist, Friedemann Mattern, Bernt Schiele, Petteri Alahuhta, Michael Beigl, Hans-W. Gellersen: Smart-Its Friends: A Technique for Users to Easily Establish Connections between Smart Artefacts. Proc. Ubicomp 2001, LNCS No. 2201, pp. 116-122, Springer-Verlag, 2001.
- ...

# Interacting with Smart Objects: Application Scenarios with the BTnode Platform

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