Physical-Virtual Integration, Ubicomp Applications & Implications

Friedemann Mattern
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Outline

- The Vision
- Linking Atoms and Bits
- Bridging the Gap
- Our Contributions
- Applications
- Implications
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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

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.
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 ("ambient intelligence")
The Vision

- in almost all everyday objects ("embedded computing")
Embedded Computing Enables "Cooperating Smart Things"

Real world objects are enriched with information processing capabilities

1. Embedded processors
   - in everyday objects
   - small
   - cheap
   - lightweight

2. Sensors

3. Wireless communication
   - spontaneous networks
Cooperating Smart Things

I’m smart

hello!
The Vision

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Mark Weiser (1952 – 1999), XEROX PARC

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on your body ("wearable computing")
The Pioneers...
Life Recorder Concept  (Motorola)
- embedded in the environment ("ambient intelligence")
Ambient Intelligence

- Seamless environment of computing
- Gesture and speech control
- Adaptive, personalized, anticipatory

**Clothing** monitors heart-rate, respiration-rate and blood pressure, detects muscle fatigue,...

**Video wall** acts as virtual coach and communicates with other users for group workout sessions

**Camera** inserts user into the video to highlight exercise pattern and guide workout routines

image source: Phillips
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Linking **Atoms to Bits**

- Data processing
- Information processing
- Simulation
- Virtual Reality
Narrowing the Gap

Virtual world

Real world

manual data entry

files
data bases

bar code labels

--- time ---
Narrowing the Gap

Virtual world

Real world

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

- Connect the **real world** to the **digital world**
  - e.g., by using bar code readers or RFID readers

- e.g., transform number to an URL, return **associated Web page**

- identifies **object instance**, not object type (e.g., UPC)
What If Every Object Had Its Own Internet Home Page?

- Or even better - its own portal?
What If Every Object Had a Smart Proxy in the Internet?
Virtual Counterparts of Real World Objects

Virtual world

---

virtual counterparts

pure virt. object

Real world
Virtual Counterparts of Real World Objects

- **Virtual counterparts** represent their real-world artifacts in a virtual world
  - passive ("homepage")
    - e.g., HP's Cooltown project
  - active ("proxy") or
  - service interface ("portal")

- **Extend artifacts** by information processing facilities
  - embedded processors
  - sensors
  - tagging (bar code, RFID tags)
Virtual Counterparts as Artifact Memories

1) Aug. 3$^{rd}$, 2001: ..... 
2) Aug. 5$^{th}$, 2001 10:34 ..... 
3) Aug. 5$^{th}$, 2001 10:37 ...
4) ...

Virtual counterparts act as memories for their real artifacts

Updates triggered by events

Queries from the real world return memory content

Sensors generate events
Interactive Physical Objects

- Various techniques for identifying physical objects
  - “bridge” or at least “narrow” the gap

- Identification precondition for coupling of physical objects to virtual counterparts

- Need tools or means that
  - make virtual counterparts accessible or visible
  - allow for interaction with virtual counterpart

- Physical objects become "clickable" and interactive
  - „physical hyperlink“ (→ Cooltwon project, HP)
An Old Paradigm, But a New Quality

- **Classical paradigm**: mapping the real world through thoughts, ideas, data collections, bookkeeping, simulation, factory automatization...

- But provide a **new view**:
  - **everything** has a unique virtual counterpart
  - bridges are **ubiquitous**
  - interactions are **immediate**

- **Actions** in one world are **reflected** in the other
  - real transactions manipulate virtual objects ("sensors")
  - virtual actions trigger real-world actors ("actuators")
Structure of the „Shadow World“?

- **Architecture?** Elements? Principles?
  - do object relations reflect an **ontology**?
  - how are the **relations** represented?
  - when are **new objects** created?

- **What level of detail** is appropriate?
  - depends on purpose and application

- **Computer science** knows about engineering concepts for virtual structures!
  - design principles, object orientation
  - data structures, information systems
  - knowledge representation, semantics
  - ...
The Power of Name Resolving

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

Cf. Cooltown project (HP)
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Bridging the Gap Between the Real World and the Virtual World
“Historic” Example 1: “Bar-Mail“

- Barcode reader with memory
  - capacity to store 100 codes
- Stand-alone or connected to mobile phones
- Send codes via SMS to bar-mail server
  - www.bar-mail.org
  - server sends back e-mail
- Company founded 1997 with help from Ericsson
  - June 2000: Motorola investment
  - what happened to it?
- Filed for protection for “from atoms to bits and back again"
“Reading“ Tagged Artifacts – Barcodes as Physical Hyperlinks

Current technology:

- **Phone attachments**
  - scan document or artifact
  - retrieve content (e.g., via WAP)
  - possible use: show information content, store calendar entries, place calls, play tunes, ...

- **Memory scanners** (e.g., Symbol CS2000)
  - connect to PC
  - retrieve content from the Internet

- **Compact flash-card barcode scanners**
  - wireless content retrieval (WLAN, Bluetooth)
  - possible use with PDA etc.: show Web document,...
Example 2: „Cross Convergence“

- Mobile scanner and pen, $89.90
- Allows to link from a printed page directly to the Web
- Scans barcodes on printed material
- No wireless communication yet
  - data well hooks up to computer for information transfer
  - up to 100 scans between downloads
- First release shipped Oct. 2000
  - still available today?
Example 3: „CueCat“ – *First Tries with Business Models*

- **Bar code scanner** (shape of a *cat*)
  - LED based; attaches to the computer via the keyboard port

- **10 million free** scanners distributed in the US by the end of year 2000
  - 50 millions were planned for 2001
  - estimated cost of $ 5 - $ 10 per CueCat
  - someone willing to spend at least $ 0.5 Bio.

- Sends the **Web browser** directly to the „right“ location when scanning the bar code of an **ad in a magazine**

- **Video**
Mapping of Barcode to Web Page

User has to register to use the software.

Provider:
- Map barcode to URL
- Log user data
- Send targeted advertisements

User:
- barcode + CueCat serial number

Manufacturer, Advertiser, ...

Web page related to product or document:
- barcode + serial number + user data

1. User
2. Provider
3. Manufacturer, Advertiser, ...
4. User
Who?

- Who controls the information to be displayed?
- Who has the knowledge?
- Who „owns“ the mapping?
- What about privacy?
- Economic value?
“System and method for using an ordinary article of commerce to access a remote computer.”

NeoMedia Technologies, Inc., Fort Myers, FL
Issued / Filed Dates: Nov. 2, 1999 / Oct. 3, 1995
Patent US5978773

“System and method for using an ordinary article of commerce to access a remote computer.”

NeoMedia Technologies, Inc., Fort Myers, FL
Issued / Filed Dates: Nov. 2, 1999 / Oct. 3, 1995
A system and method for using identification codes found on ordinary articles of commerce to access remote computers on a network. In accordance with one embodiment of the invention, a computer is provided having a database that relates Uniform Product Code ("UPC") numbers to Internet network addresses (or "URLs"). To access an Internet resource relating to a particular product, a user enters the product's UPC symbol manually, by swiping a bar code reader over the UPC symbol, or via other suitable input means. The database retrieves the URL corresponding to the UPC code. This location information is then used to access the desired resource.
CueCat Revenue Model

- “Our revenue model is being the gate keeper between codes and their destination online”
  - software in the user’s computer links to the provider
  - code is encrypted by the scanner
  - scanner adds its serial number
  - provider keeps mapping from bar code to URL as its property

- Business risk: “Our right to keep information collected in our databases may be challenged in the future.”
CueCat Reverse Engineering

- Hackers know
  - how to decrypt the code
  - how to avoid sending the serial number

The CueCat dissected
CueCat Reverse Engineering

- **Hackers** know
  - how to **decrypt** the code
  - how to avoid sending the **serial number**

- **Provider** doesn’t like
  - reverse engineering
  - open bar code **directories** for products
  - **free applications** (e.g., download amazon.com information from ISBN numbers on books)
  - **LINUX drivers**

- „Our **revenue model** is being the **gate keeper** between codes and their destination online“
Many people believe that the reason for the XOR "encryption" is an attempt to bring the output of the CueCat under the Digital Millenium Copyright Act. Using/writing your own software for the cuecat would then be illegal.
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U.S. Congress passed the Digital Millennium Copyright Act on October 12, 1998.

It makes it a crime to circumvent anti-piracy measures built into commercial software. It outlaws the manufacture, sale, or distribution of code-cracking devices used to illegally copy software. It does permit the cracking of copyright protection devices, however, to conduct encryption research, assess product interoperability, and test computer security systems.
A Recent Example: The Anoto Pen

- Uses paper with a **pattern of small dots**, slightly dislocated from a strict grid
  - 2x2 mm determine exact location
  - appears as a faint grey shade on the paper

- **Pen calculates its position**
  - illuminates pattern with **infrared**
  - reads 100 picture frames / s
  - ink from pen not visible

- Sends the calculated positions to other devices via **Bluetooth**
  - together with the **pen ID** (useful in e-commerce, e.g. when ordering a product)
Anoto Pen
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Infrastructure for Smart Objects

“A Dancing Toaster” (Rich Gold, XEROX PARC)
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?

- Guarantee
  - security
  - privacy
  - availability
  - reliability

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

for applications built with smart objects

Friedemann Mattern
Why Infrastructure for Smart Objects?

- **Guarantee**
  - security
  - privacy
  - availability
  - reliability

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

How do we organize billions of mobile smart objects that are highly dynamic, short living,…?
More Infrastructure Tasks

- Enable
  - spontaneous networking
  - cooperation among smart objects
  - communication
  - mobility
  - service creation
  - service discovery ("is a service available that ...?")
  - ...

- Facilitate linking the real world to the virtual world

for communities of smart objects

Challenge for practical computer science research!
Open or Proprietary Infrastructure?

- Will we ever get a common infrastructure for smart objects?
  - scalable
  - extensible
  - ...

- Will it be open?
  - based on common, open standards
  - analogous to the Internet and its protocols
What Are We Doing at ETH?

- General infrastructure for Ubiquitous Computing
  - smart counterparts for real-world objects
  - event-based middleware for smart objects
- Communication and service environment for Smart-Its
  - → Oliver Kasten
- Privacy
  - → Marc Langheinrich
- Scenarios, social & economic consequences
  - → Vlad Coroama
Responsive objects interweave the physical campus infrastructure with the infostructure.

- DSG Conference: Apr 4 2002
- Flyer
- Official Announcements
- Student Ads
- Usage/Maintenance information
- Technical Equipment
- Occupancy, Reservations
- Rooms
- What?
- Where?
- Link?
- Who?
- When?
- Action?
- Until?
- How?

XML

→ Michael Rohs
Research Project „Living in a Smart Environment“

- **Vision** of an all-encompassing computarization and networking of „all“ objects soon feasible
  - could have dramatic **impact**

- **Consequences** of Ubicomp?
  - social
  - economic
  - privacy
  - perception of the world
  - everyday life, work, home,...

- What **possibilities** and alternatives do we have when shaping a „smart“ world?

- Gottlieb Daimler- & Karl Benz Foundation
- 7 groups (Germany, Switzerland)
- started Jan. 2002
- development of scenarios, showcases, prototypes

→ Vlad Coroama
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
Card Proxies as Virtual Counterparts

Hi, I'm new here

Friedemann Mattern
Cards as Personalities

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

Alice in Wonderland
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Friedemann Mattern, ETH Zurich
Ubicomp - Applications?

“We are always very bad at predicting how a given technology will be used and for what reasons”

-- Bran Ferren, Chief Disney Imagineer
Economic Impact of Ubicomp?
(„Couple E-business with Star Trek Technology“)

- Products that are fully integrated in information systems
  - e.g., supply chain optimization

- New digitally enhanced products
  - e.g., cooperating toys,…

- New services („e-utilities“)
  - e.g., management of smart devices at home, management of personal privacy,…
Economic Impact of Ubicomp?
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- New services („e-utilities“)
  - e.g., management of smart devices at home, management of personal privacy,...

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

- „Silent commerce“ (Intershop)
  - the ability of objects to conduct business transactions directly with other objects

- „Imagine that...“
  - your products, your inventory or any of your physical assets could sense the characteristics of their environment, know their location and tell you about it
  - your products were self monitoring and could tell you when they were about to go outside of acceptable boundaries for temperature
  - you could identify and track every product as it moves along your value chain, from the factory all the way to the consumer

...“ (Accenture)
Electronic Product Code (ePC)

- Identification of single object instances, not object classes
- Based on RFIDs
- Developed by MIT Auto-ID
- Cheap (goal: $0.05 per label)

```
01. 203D2A. 916E8B. 8719BAE03C
```

- Header 8 bits
- Manufacturer 24 bits
- Product 28 bits
- Serial Number 38 bits
The **M-Lab**

- „Mobility and Ubicomp Lab“
- ETH Zurich together with the University of St. Gallen (HSG)
  - collaboration with MIT Auto-ID Center (electronic product code,...)

- Identifying and designing effective **business applications** based on Ubicomp technologies
  - life sciences, automotive, retail and logistics,...
  - from ideas to **prototypes**

- Currently **7 industrial partners:**

  ![SAP](https://example.com/sap.png)
  ![VW](https://example.com/vw.png)
  ![UBS](https://example.com/ubs.png)
  ![Swisscom Mobile](https://example.com/swisscom.png)
  ![Novartis](https://example.com/novartis.png)
The M-Lab

- Ubicomp in healthcare
- Smart toolbox
- PML (Product Markup Language) together with MIT
- Spare part management with RFID
- Abstraction layer and programming library for different RFID systems
- ...

F.Ma. 69
Example of an Application Domain: Smart Toys

- **Communicate** with each other and with TV, Swatch,...

- **Internet** via game console, home PC, „home gateway“
- **Update** during the night via the Internet
  - e.g., stories from yesterday’s TV show for speaking dolls
Smart Toys

- Access to WWW and large external data bases
  - e.g., language dictionary
- Networked fan communities
  - „my toy“ --> marketing
- Remote execution server for compute intensive tasks
  - e.g., speech recognition
- Avatars for family members
- Babysitting, health monitoring
- New games when toys interact
Another Important Application Area: Healthcare

Wearables to collect medical data
Bodymedia

- Communication platform for wireless transmission of body function data
- Bodymedia translates raw sensor data to „lifestyle data“ (available on the Web)
Sensatex Smart Shirt

- Monitors continuously vital signs such as heart rate, temperature, respiration activity,...
- Wireless communication with the Sensatex Health Center
- Comprehensive notification and audit systems for doctors and patients, but also for sportsmen and workers
Talking Medicine

These are headache tablets. Take at most 4 per day.

Helps partially sighted and blind persons to take the right medicine
Other, Unconventional Applications?

“iGlassware”
System monitors fluid level of glasses through wireless connection and alerts wait staff when to ask for new drink order.

http://www.merl.com/projects/iGlassware/
Example of a Location-aware Application: The LEONIE System

The LEONIE Call Process

Position coordinates determined by GPS

Call by GSM if call released

SMS via GSM position transmission (regularly if requested, otherwise only the current position at call release + up to 23 last detected positions)

Positioning on a map

LEONIE Call Center

Customer Database

Call accepted with caller identification
Example: Insurance Companies

- **Autograph System**
  - pilot 1998/99, Houston, TX
  - insurance rates depend on *individual driving behavior* (when, where, how often?)
  - GPS sensors send data to a service center

- **Experience**
  - 25% average fee reduction for customers
  - particularly successful with company car fleets
Speed determination by GPS

\[ V = \frac{s}{t} \]
GPS System Used to Fine Driver for Speeding

HARTFORD, Conn. (AP, 07/03/2001) - The state Department of Consumer Protection is investigating a complaint against a rental car company that used satellite technology to track a New Haven customer's alleged speeding.

James Turner complained about Acme Rent-A-Car of New Haven for using his rented minivan's global positioning system to clock his speed. Acme billed Turner $150 for each of three alleged speeding violations last fall.

"It's a scary situation to be given speeding tickets by way of satellite, never having come into contact with a law enforcement agent," he said. "Who monitors this? Do they have someone in the back room monitoring where you go? I think there's some sort of privacy issues there."

Rental contracts inform potential customers about the global positioning systems, said Max Brunswick, a New Haven lawyer for Acme. ... Turner signed a contract stipulating that vehicles driven "in excess of posted speed limits" will be charged $150 each time, Brunswick said.

The devices also are intended to reduce car wrecks and track cars that customers fail to return, Brunswick said. Acme fines motorists who drive faster than 79 mph for two minutes or longer.
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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
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
- ...
TOM CRUISE
A STEVEN SPIELBERG FILM
MINORITY REPORT
Anderton (Tom Cruise) lives in a futuristic world (year 2054) that seems to respond to his every move.

A key plot element is that iris scanners are completely ubiquitous in the world.

„The futurists that I assembled around that table didn't agree with each other on every point, but one of the several things they did unanimously agree on was that the entire advertising industry is going to recognize us as individuals, and they're going to spot-sell to us“. (Spielberg)
Minority Report (Steven Spielberg, 2002)

- New user interfaces
- Customized, animated ads
- Anderton pours a bowl of cereals at home, triggering the animated characters to sing the product's theme song. Frustrated because he can't make the characters shut up, Anderton flings the box at the wall.
Who Owns the Key?

- Who knows the mapping from object IDs to data (such as a product homepage)?
  - copyright? trade secret? intellectual property?
  - can one own such mappings?
  - e.g., are phone book entries common knowledge?

- Commercial value!
  - linking bar codes on ads to the “right” web site
  - customer profiles when “clicking” real-world objects
Ubiquitous Computing Criticism

- E.g., loss of control and loyalty:
  - "My refrigerator ... would refuse to open at certain hours of the day, having talked to my bathroom scale."
  - "If I exceed the speed limit, my car reports me, and if I try to park illegally, it refuses to turn off or to let me open the door."
  - "I want to disengage these features, but the car comes with a shrink-wrap agreement whose legalese implies that the purchaser has only licensed its capabilities without any true ownership."
  - ...
  - "I feel surrounded by enemies and traitors."

- From: Robert Lucky: *Connections – Everything will be Connected to Everything Else*. IEEE Spectrum, March `99
Consequences?

Have you ever thought of the cultural consequences when every object around us is both smart and connected?

-- Bernard Goldbach: Just Turn Me Off
Two Worlds that Collide?

- If there is **tight interaction** between the physical and the virtual world – what happens?
  - what is gained?
  - what is lost?
Two Worlds that Collide?

- If there is tight interaction between the physical and the virtual world – what happens?
  - what is gained?
  - what is lost?

- Can we make a better world, or just better business?
- Which techniques are needed? Which are suitable?
- What are the limits?
Challenges for Computer Science: „Computing Without Computers“

- **Increasing importance of computer science**
  - information processing moves to the background
  - computerizing and networking „all“ objects
  - cs has competence in organizational issues of complex, dynamic information spaces
    - object orientation, knowledge representation, semantics,…
  - good engineering principles are important

- **New design issues**
  - energy efficiency
  - scalability, reliability
  - mobility, cooperation
  - usability
Challenges for Computer Science

As we approach 2001, we are in the **Information Age**, not in the **Space Age**!

Randy Katz, UC Berkeley
System architectures and platforms for pervasive computing
Middleware and pervasive computing infrastructures
Mobile, wireless, and wearable technologies
Innovative small computing and intelligent devices
Emerging applications and mobile business issues
Scenarios for information appliances
Service discovery protocols
Content distribution and delivery
User interfaces for invisible and embedded computing
Context awareness
Security and privacy issues

20 papers (out of 160 submissions)
Springer LNCS
12 short papers
Invited talks (Randy Katz, Ralf G. Herrtwich)
6 Tutorials
Exhibition
Conference dinner: boat tour on Lake Zurich
Physical-Virtual Integration,
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