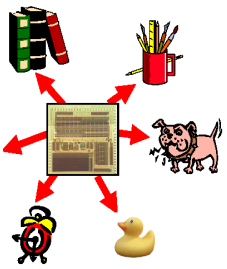
Challenges

Goals of Pervasive (Ubiquitous) Computing

- Invisible technology
- Integration of virtual and physical worlds ("embodied virtuality")
- Encompassing all parts of your life (home, office, commute, entertainment, shopping, medical, …)
- "Using a computer should be as refreshing as a walk in the woods"
- Make everyday objects "smart"

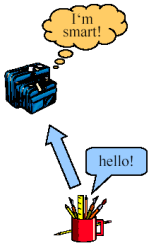
Smart Objects

- Real world objects are enriched with information processing capabilities
- Embedded processors
  - in everyday objects
  - small, cheap, lightweight
- Communication capability
  - wired or wireless
  - spontaneous networking and interaction
- Sensors and actuators

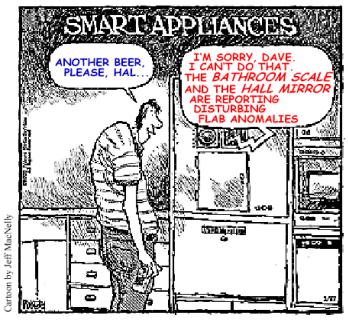


Smart Objects (cont.)

- Can remember pertinent events
  - They have a memory
- Show context-sensitive behavior
  - They may have sensors
  - Location/situation/context awareness
- Are responsive/proactive
  - Communicate with environment
  - Networked with other smart objects



Smart Objects (cont.)

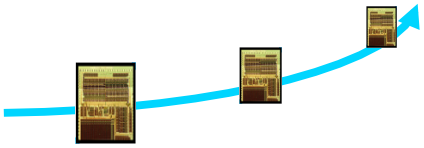


Pervasive Computing Enablers

- Moore's Law of IC Technologies
- Communication Technologies
- Material Technologies
- Sensors/Actuators

First Enabler: Moore's Law

- Processing speed and storage capacity double every 18 months
  - "cheaper, smaller, faster"
- Exponential increase
  - Being "replaced" with other technology, e.g., multiple cores

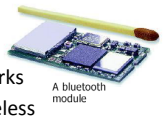


Generalized Moore's Law

- Most important technology parameters double every 1–3 years:
  - computation cycles
  - memory, magnetic disks
  - bandwidth
- Consequence:
  - scaling down

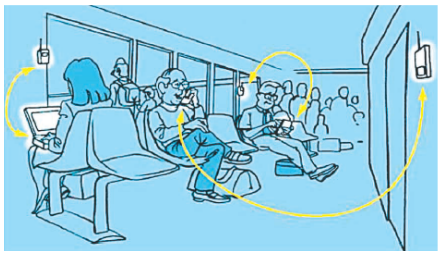
Second Enabler: Communication

- Wired
  - 1GB, 10GB Ethernet (100GB in development)
  - Optical fiber, powerlines, …
- Wireless
  - mobile phone: GSM, GPRS/EDGE, 3G, 4G
  - wireless LAN (> 10 Mb/s)
  - Bluetooth, Zigbee
- Body area networks, vehicular networks
- Constant connectivity, wired and wireless



A bluetooth module

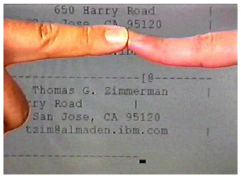
Ubiquitous Information



PAN: Personal area network

Body Area Networks

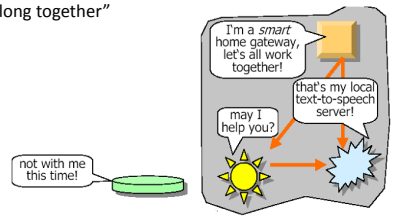
- Very low current (some nA), some kb/s through the human body
- Possible applications:
  - Car recognize driver
  - Pay when touching the door of a bus
  - Phone configures itself when it is touched



business card exchange (IBM)

Spontaneous Networking

- Objects in an open, distributed, dynamic world find each other and form a transitory community
  - Devices recognize that they "belong together"

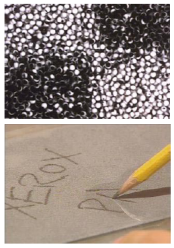


Third Enabler: New Materials

- Whole eras named after materials
  - e.g., "Stone Age", "Iron Age", "Pottery Age", etc.
- Recent: semiconductors, fibers
  - information and communication technologies
- Organic semiconductors
  - change the external appearance of computers
- "Plastic" laser
  - Opto-electronics, flexible displays,…
- Nanocomputing

Smart Paper, Electronic Ink

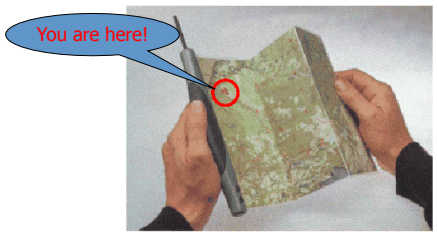
- Electronic ink
  - micro capsules, white on one side and black on the other
  - oriented by electrical field
- Potentially high contrast, low energy, flexible
- Interactive: writable with magnetic pen



An electronically charged pencil rotates the "pixels"

Interactive Map

- Foldable and rollable



Smart Clothing

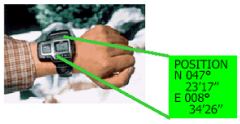
- Conductive textiles and inks
  - print electrically active patterns directly onto fabrics
- Sensors based on fabric
  - e.g., monitor pulse, blood pressure, body temperature
- Invisible collar microphones
- Kidswear
  - game console on the sleeve?
  - integrated GPS-driven locators?
  - integrated small cameras (to keep the parents calm)?

Smart Glasses

- "Visual information will be written directly onto our retinas by devices in our eyeglasses and contact lenses"
  -- Raymond Kurzweil

Fourth Enabler: Sensors/Actuators

- Miniaturized cameras, microphones,...
- Fingerprint sensor
- Radio sensors
- RFID
- Infrared
- Location sensors
  - e.g., GPS
- ...



Example: Radio Sensors

- No external power supply
  - energy from the actuation process
  - piezoelectric and pyroelectric materials transform changes in pressure or temperature into energy

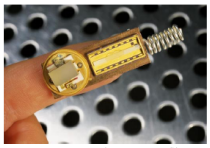
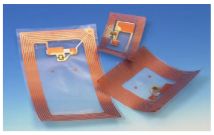


image source: Siemens

- RF signal is transmitted via an antenna (20 m distance)
- Applications: temperature surveillance, remote control (e.g., wireless light switch),...

RFIDs ("Smart Labels")

- Identify objects from distance
  - small IC with RF-transponder
- Wireless energy supply
  - ~1m
  - magnetic field (induction)
- ROM or EEPROM (writeable)
  - ~100 Byte
- Cost: couple of cents
  - consumable and disposable
- Flexible tags
  - laminated with paper



Chip (without antenna): ~ 2 mm x 2 mm x 10 µm (fits into 80 µm thick paper!)

Putting Them Altogether

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

- Enables new applications
- "Post-PC era" business opportunities
- Challenges for computer scientists, e.g., infrastructure

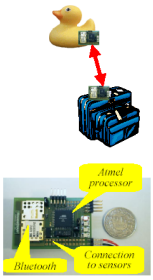
Example Projects

- ETH Zurich The Smart-Its Project
- *HP Cooltown project*
  http://www.youtube.com/watch?v=JwbTxkSSGG4
- AT&T Sentient System
- Berkeley's Wireless Sensor Network
- Intel Mote/RFID Project

Idea: Making Objects Smart

The Smart-Its Project

- Vision: make everyday objects as smart, interconnected information artifacts
  - by attaching "Smart-Its"
- Smart labels
  - Atmel microcontroller: (ETH Zurich) 4 MIPS, 128 kB flash



Magnifying Glass

- An object as a web link
  - e.g., by displaying a dynamically generated homepage
  - Contents may depend on circumstances, e.g., context and privileges
  - possibly mediated by different name resolvers
  - *HP Cooltown project*

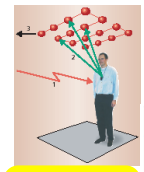
Smart Environment, Dumb Object

- A context-sensitive cookbook with RFID

Can be Context-Aware

- Properties of the ingredients
  - Check whether there is enough of an ingredient
  - Prefer ingredients with earlier best-before date
- Properties of the kitchen
  - Check whether required tools and spices are available
- Preferences and abilities of the cook
  - Prefers Asian dishes
  - Expert in vegetarian dishes

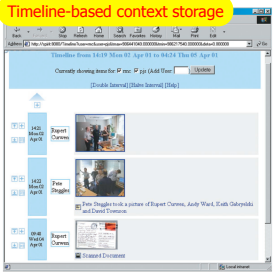
AT&T Sentient System



Location tracking

Position monitoring

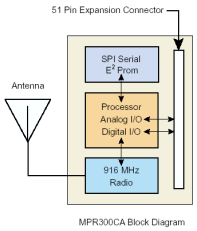
Timeline-based context storage



Berkeley's Wireless Sensor Network

- MICA Motes, sensors, and TinyOS:

MTS310CA Sensor Board



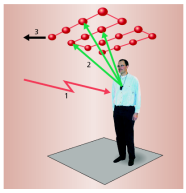
MPR300CA Block Diagram

Ubiquitous information and communication

- Technology has advanced towards ubiquitous computing
  - Global Positioning System (GPS)
  - Radio Frequency Identification (RFID)
- Striking developments
  - The emergence of the Web
    - A global information and service resource
  - Mobile telephony
    - Widespread adoption

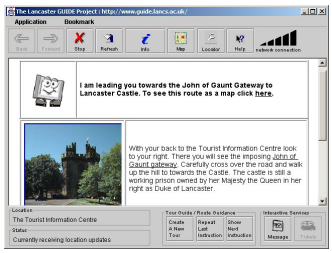
Active Bat System

- Conducted at AT&T Lab in Cambridge
- Indoor positioning system
  - Using sensor and badge



Lancaster's Guide System

- Provides visitors with tour guide information
  - Based on visitor's interest and movement
- Use
  - Tablet PC
  - WLAN deployed around major attractions



MediaCup Project

- University of Karlsruhe, Germany
- Cups equipped with sensors and wireless communications

Not used

Someone plays with the cup

Someone drinks

Research Challenges

- Scale: one size doesn't not fit all
- Configuration, programming
- Component interaction (self-configuring)
- Contextual sensitivity (what is context? how is it represented?)
- Appropriate management mechanisms
- User interfaces (input/output)
- Knowing when to act, react, interrupt, etc.
- Knowing what is good for people

Research Challenges

- Privacy
  - Empower users to evaluate tradeoff
  - Legislation needed
  - When should computer be visible/invisible?
  - Is it ok to give up this privacy in some settings (healthcare)?
  - Do we give the hackers too much power?
- Security
  - Constant monitoring takes away personal responsibility
  - What happens if I lose my data?

Research Challenges

- Concurrency
  - People multitask and rapidly switch task based on external unpredictable environment
  - Systems need to adapt to this opportunistic behavior and change accordingly
- Hard to evaluate ubicom systems
- Economic: one killer app? Or many small successful projects?