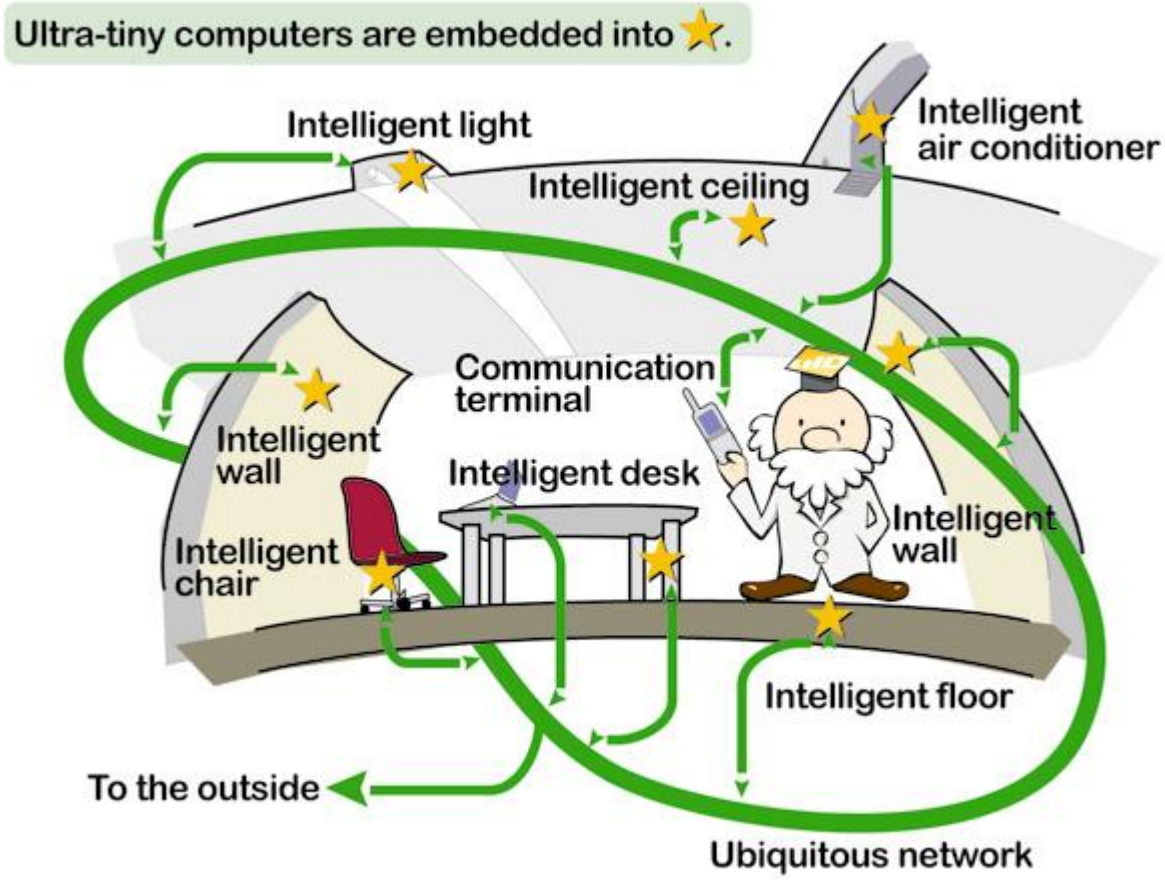
Ubiquitous Computing

Pervasive Computing, Ambient Intelligence

“The Third Era of Computing”
“Third Paradigm” (Alan Kay)

cf. Bell’s Law of Computer Classes


monitor III
Apple IIc
disk II
disk II



http://omarsbrain.wordpress.com/2010/08/10/ubiquitous-computing-and-ai/

But what is it really?

- No authoritative definition exists

Pervasive Computing

- Computer resources and services everywhere
- Impact of the **context** of man/machine
- Mobile and Fixed devices
- Relatively classical interface

Ambient Intelligence

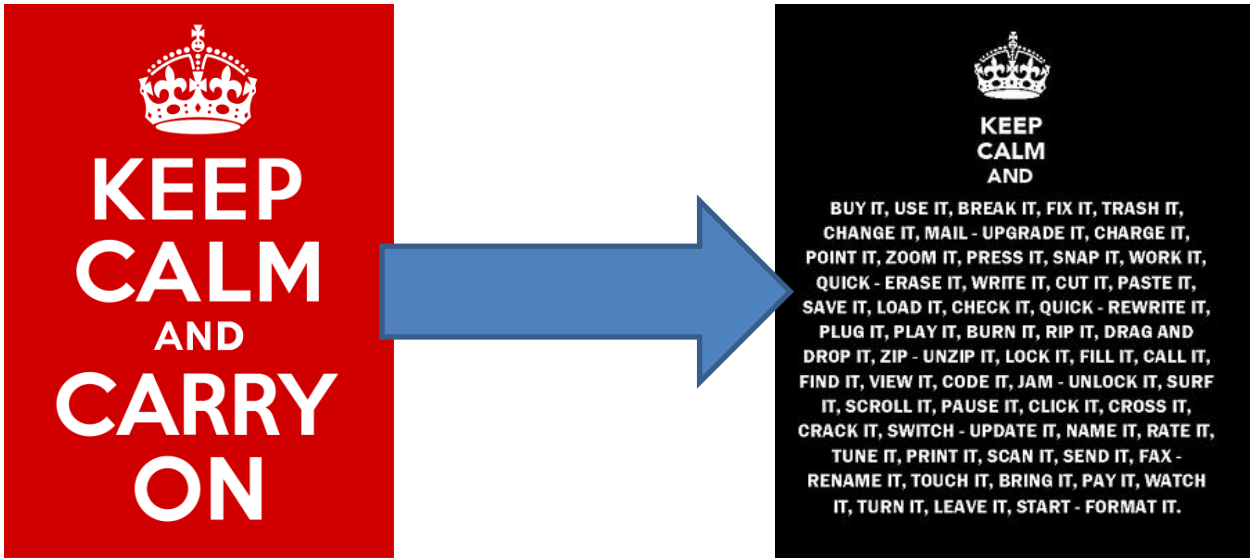
- Computers around us
- Reacting to who we are, what we do → Context awareness
- Controlling and informing: No ***explicit*** UI
- Less dependent on physical objects

UbiComp

- Combines features, adds own focus
- Computers:
  - on us
  - around us
  - everywhere
  - in every **thing**
  - react to us, by “telling” and “doing”
  - fade into the background

“Calm Technology” (Mark Weiser)

- Computing services/resources as a “utility”
  - Present, but not recognizable as computers
  - Easy peripheral attention / center of attention transitions
  - Rich peripheral information

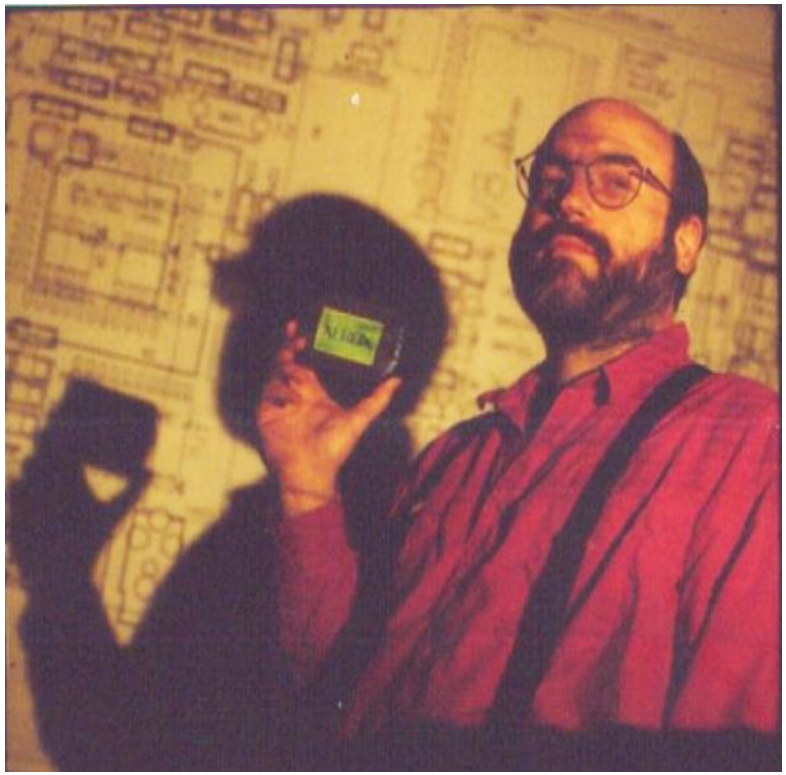


1940s

2020s?

Mark Weiser?

- “Father of UbiComp”
- Xerox PARC 87-94/96-99
- “tabs”, “pads” and “boards” (88-94)



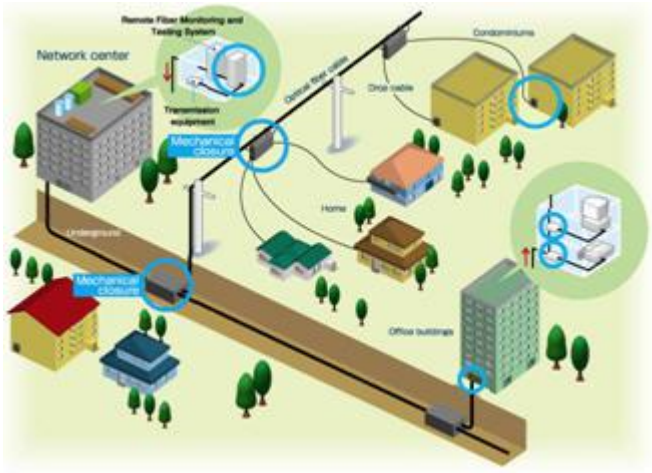
“Mark proudly holding a Tab”, from “The last Weiserama”, Xerox PARC
http://library.stanford.edu/weiser/weiserama/mark-tab.html

Enabling Factors

- Networks
  - wireless infrastructure
  - suitable protocols
- Miniaturization
  - of power sources
  - of computing devices
  - of sensors and actuators

Network Infrastructure

- Fiber to the Home, **GPRS**, UMTS, **LTE**, WiMAX
- Wi-Fi, Bluetooth, ZigBee, Powerline
- CCTV
- IPv6, Peer-to-Peer



http://www.fujikura.co.uk/fibre_optics/products/ftth/

Evolution of UMTS FDD and TDD
driven by data rate and latency requirements

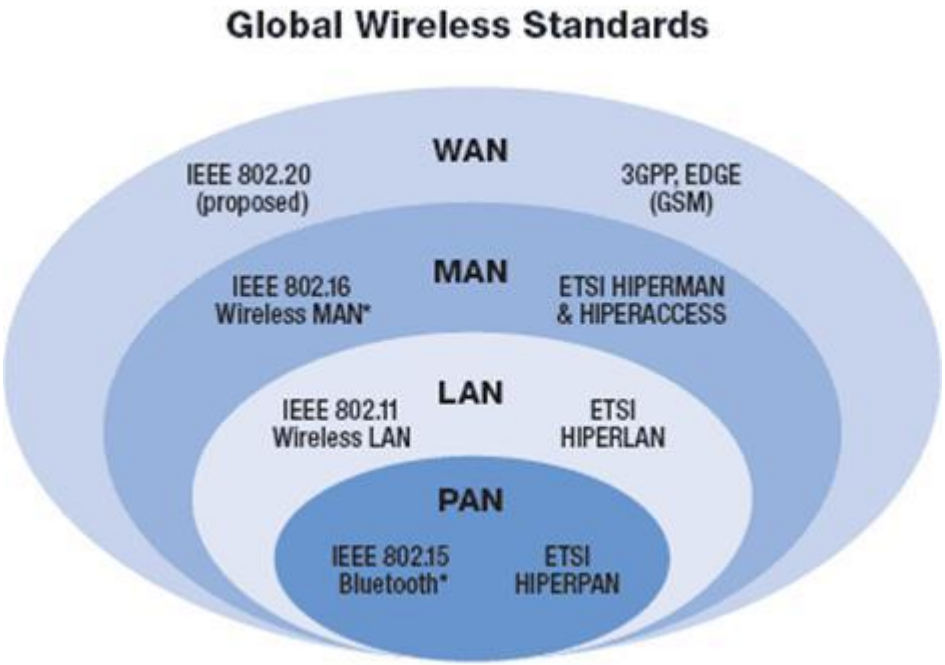
FDD evolution	WCDMA	HSDPA/ HSUPA	HSPA+	LTE and HSPA+	LTE-advanced
TDD evolution	TD-SCDMA	TD-HSDPA	TD-HSUPA	TD-LTE and TD-HSPA+	
3GPP release	3GPP Release 99/4	3GPP Release 5/6	3GPP Release 7	3GPP Release 8	3GPP Study Item initiated
App. year of network rollout	2003/4	2005/6 (HSDPA) 2007/8 (HSUPA)	2008/2009	2010	
Downlink data rate	384 kbps (typ.)	14 Mbps (peak)	28 Mbps (peak)	LTE: 150 Mbps* (peak) HSPA+: 42 Mbps (peak)	100 Mbps high mobility 1 Gbps low mobility
Uplink data rate	128 kbps (typ.)	5.7 Mbps (peak)	11 Mbps (peak)	LTE: 75 Mbps (peak) HSPA+: 11 Mbps (peak)	
Round Trip Time	~ 150 ms	< 100 ms	< 50 ms	LTE: ~10 ms	

*based on 2x2 MIMO and 20 MHz operation

http://hbougdal.blogspot.com/2011/05/evolution-of-umts-networks-and.html

Wireless Networks

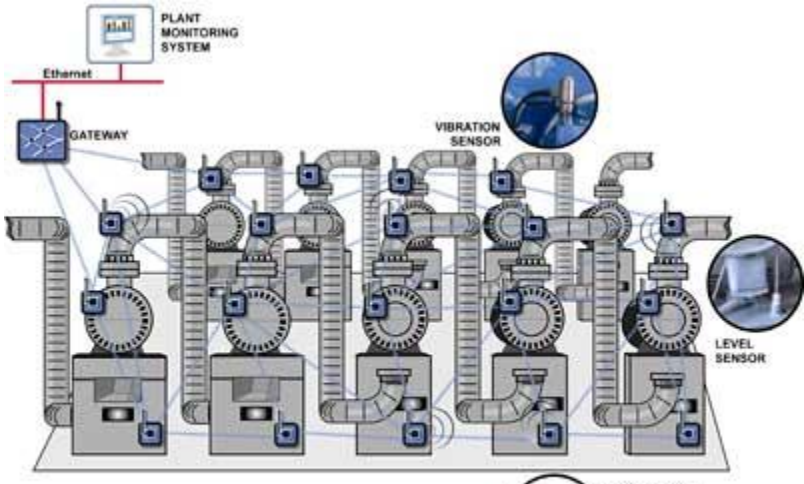
- Three levels: global / local / personal
- Different power requirements for the same bandwidth
- Different latencies
- Different costs of implementation



http://www.rfidc.com/docs/introductiontowireless_standards.htm

Wireless network structures

- Pseudo-tree: multiple base stations connected to a fiber/copper back-bone
- Mesh : multiple nodes with local interconnections
- Peer-to-Peer : dedicated, direct connection between two nodes
- physical vs. logical



"dust" (www.dustnetworks.com/ M2M mesh network, http://mobiledevdesign.com/hardware_news/wireless_mesh_networks/

‘Service Discovery’

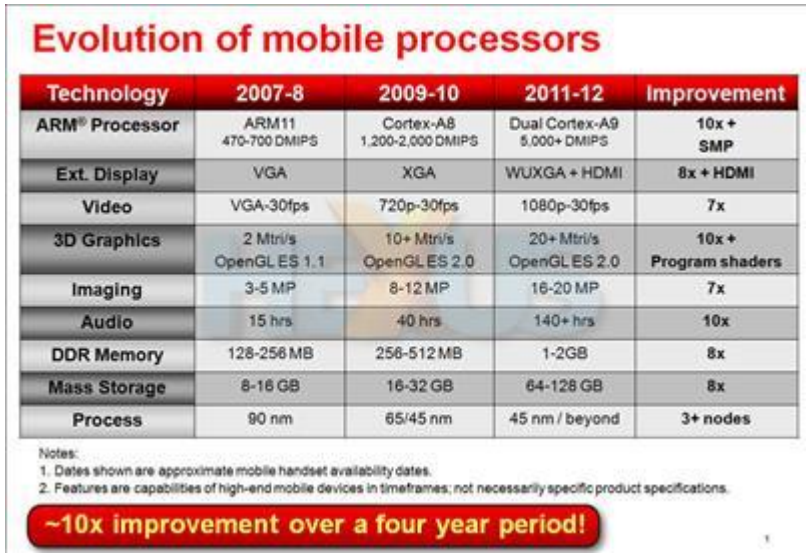
- Devices have capabilities
- …and data requirements
- Devices are transient
  - mobile
  - low cost
  - context dependant

“hot-pluggable”

- Semantic Web – Internet of **Things**

Silicon advancement

- **MORE POWER!** (Moore's Law)
- Higher power efficiency
- Smaller size
- Lower cost

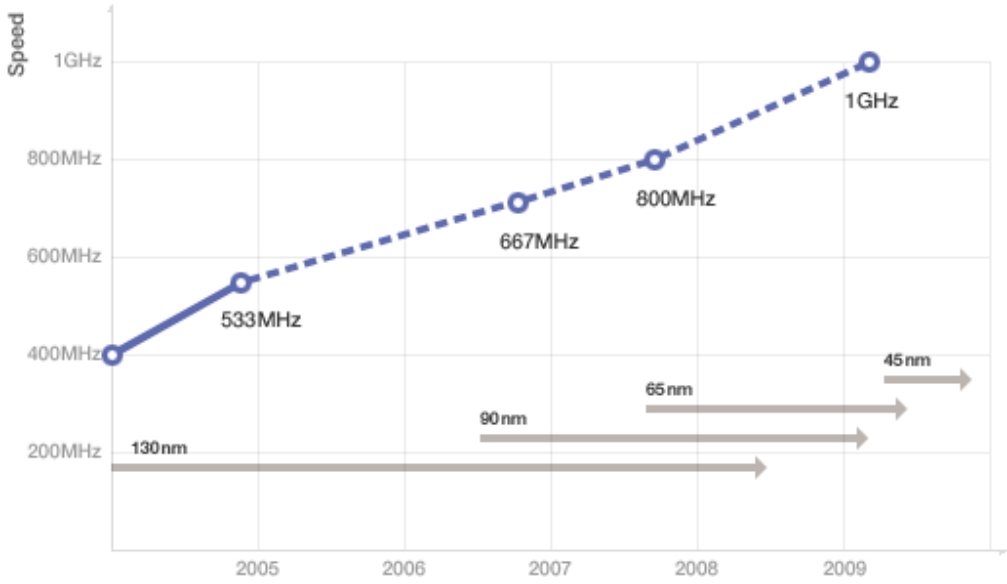


Evolution of mobile processors

Technology	2007-8	2009-10	2011-12	Improvement
ARM® Processor	ARM11 470-700 DMIPS	Cortex-A8 1,200-2,000 DMIPS	Dual Cortex-A9 5,000+ DMIPS	10x + SMP
Ext. Display	VGA	XGA	WUXGA + HDMI	8x + HDMI
Video	VGA-30fps	720p-30fps	1080p-30fps	7x
3D Graphics	2 Mtri/s OpenGL ES 1.1	10+ Mtri/s OpenGL ES 2.0	20+ Mtri/s OpenGL ES 2.0	10x + Program shaders
Imaging	3-5 MP	8-12 MP	16-20 MP	7x
Audio	15 hrs	40 hrs	140+ hrs	10x
DDR Memory	128-256 MB	256-512 MB	1-2GB	8x
Mass Storage	8-16 GB	16-32 GB	64-128 GB	8x
Process	90 nm	65/45 nm	45 nm / beyond	3+ nodes

Notes:
1. Dates shown are approximate mobile handset availability dates.
2. Features are capabilities of high-end mobile devices in timeframes; not necessarily specific product specifications.

~10x improvement over a four year period!

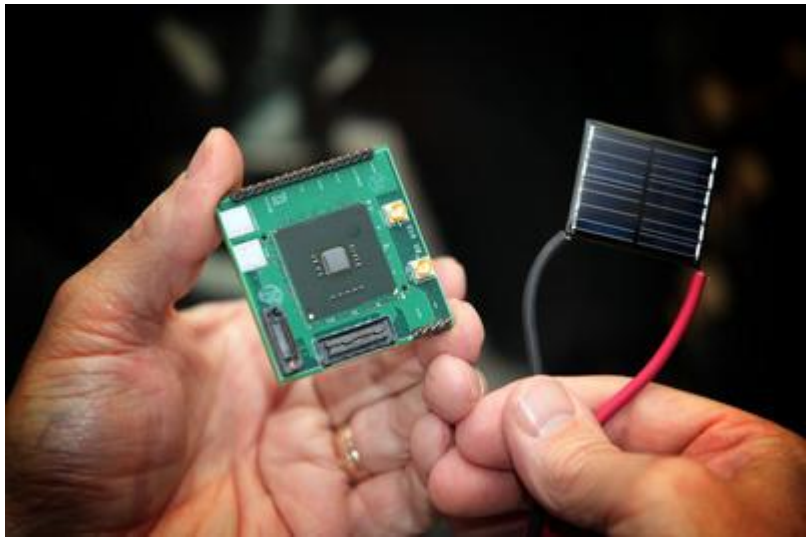


Samsung ARM roadmap (2008),
http://news.cnet.com/8301-13924_3-9865770-64.html

TI OMAP roadmap,
http://portals.hexus.net/?item=22195&page=2&id=microdirect

Power Advancements

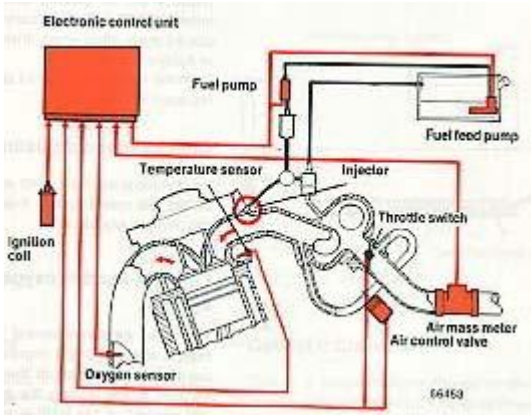
- Induction charging, passive ‘devices’ (RFID)
- Lithium Ion/Polymer rechargeable batteries
- Higher efficiency photovoltaic cells
- Body-heat powered devices
- Very small fuel cells
- Gait-powered devices
- Large power-bandwidth

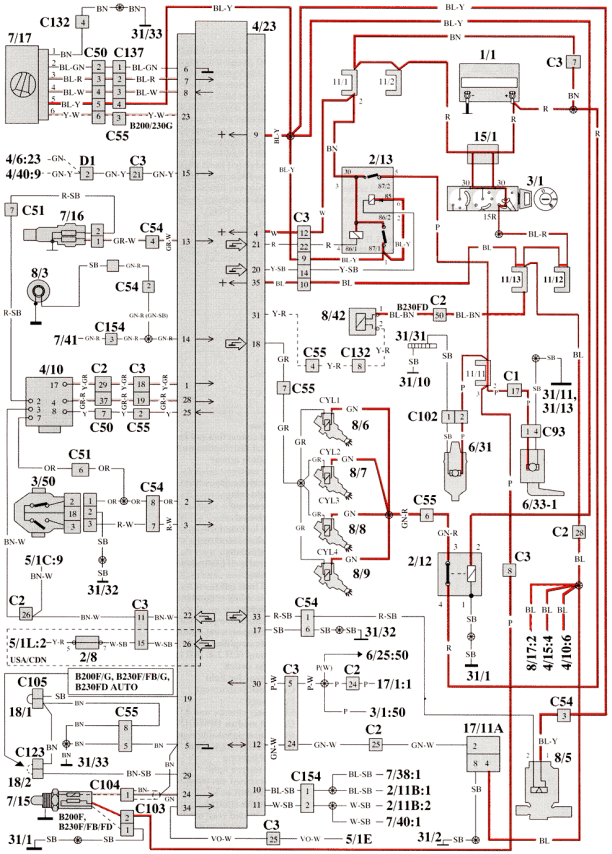


Intel Claremont experimental Near-Threshold-Voltage CPU,
http://blogs.intel.com/research/2011/09/ntvp.php

Embedded Computing

- Classically: Microcontrollers (µC) and lightweight general purpose CPUs/SoCs
  - single purpose/limited scope
- For UbiComp:
  - interconnected (ideally IPv6)
  - capable of broadcasting abilities
  - cheap
  - lightweight

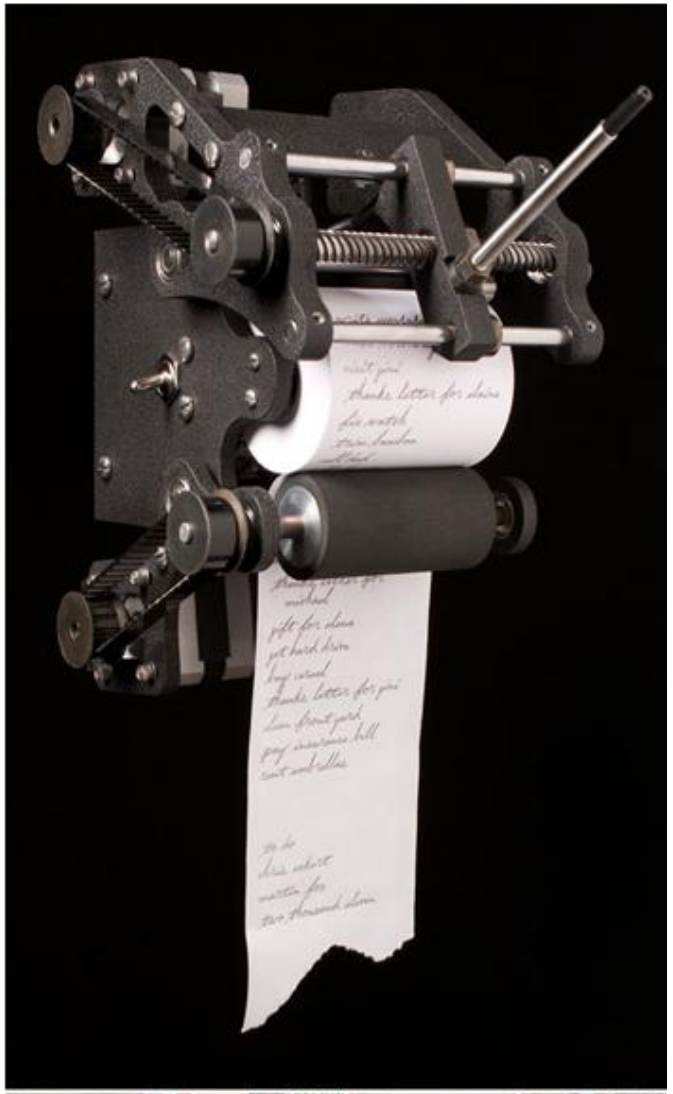


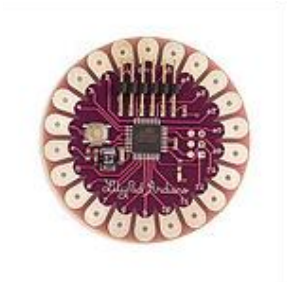


Bosch LH-jetronic 2.4 multiport fuel injection system, Volvo 940,
http://www.autoelectric.ru/auto/volvo/940/1993/940-93.htm
Volvo 240 owners manual, engine fuel system,
http://new.volvocars.com/ownersdocs/1986/1986_240/86240_03a.htm

Embedded Computing

- Compute capabilities and memory
- Sensors
- Actuators/Speakers/Lights/ Displays/Transmitters
- Interconnection
- Power Source
- Example: ARM, Arduino



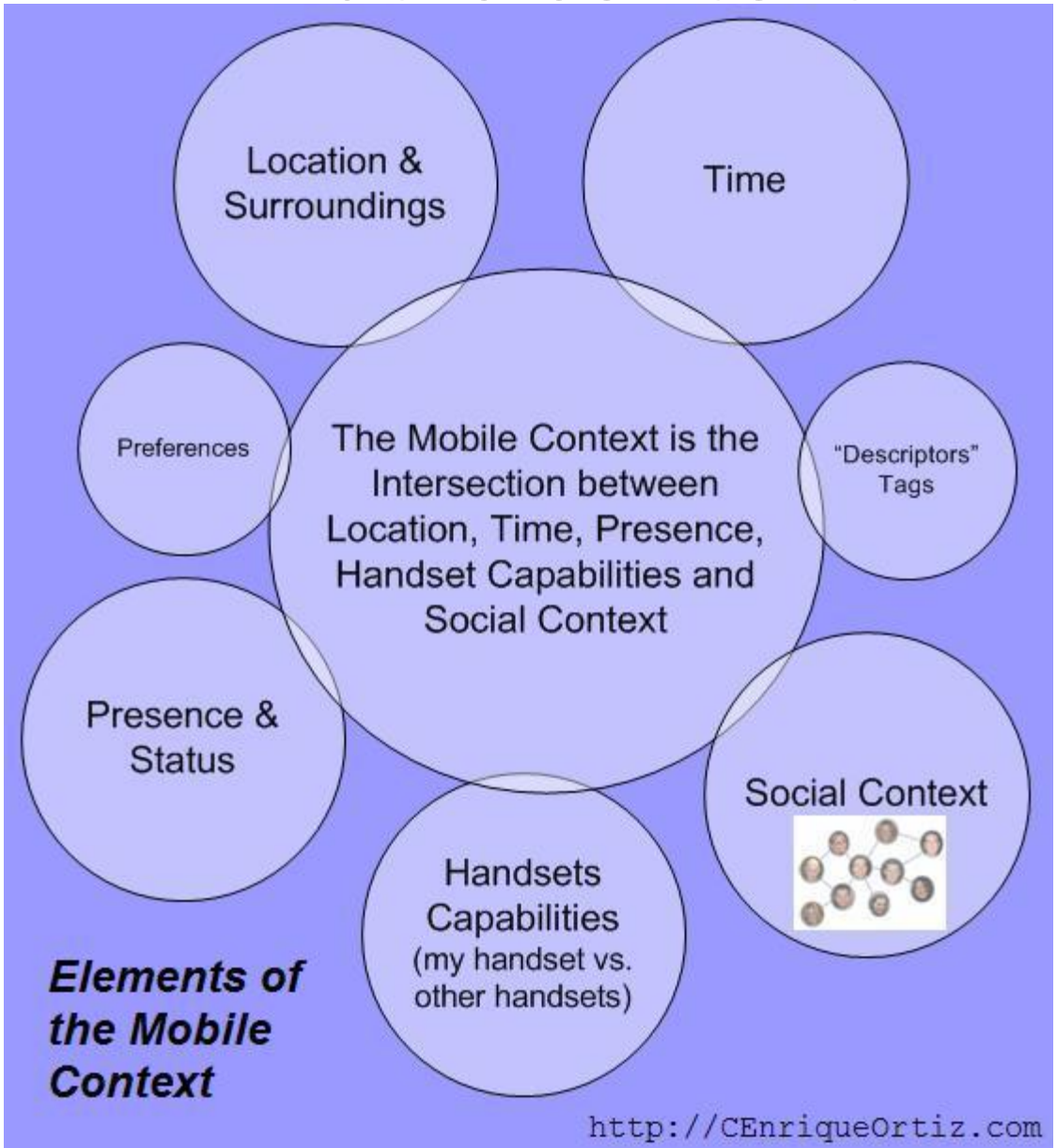


www.arduino.cc, “ToDo” by Chris Eckert, www.chriseckert.com

Context in Computing

- Context of an interaction
- Context of a device
- Context of a user
- …

What is context?



Context Sensing

- Locally embedded sensors
  - Radio sensors
  - Light sensors
  - MEMS (Force) Sensors
- Remote “sensors”
  - Weather
  - Traffic
  - Events
  - POI databases

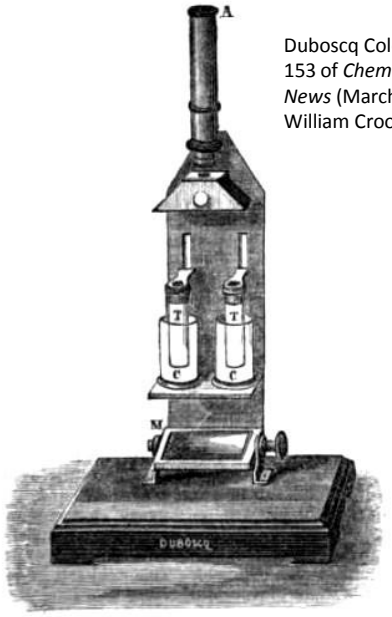
Radio Sensors

- GPS/GLONASS/Beidou/Galileo etc.
- Cellular Networks (3GPP/3GPP2)
- IEEE 801.11, 801.16, 802.15 wireless networks
- RFID/NFC
- AM/FM-Radio, UHF/VHF-TV
- Terrestrial dedicated positioning systems: ILS, TACAN, IFF, RADAR altimeters for aviation, RADAR beacons for shipping

Photon Sensors

- Video and still cameras (CCD or CMOS sensors)
- Diodes and other Luxmeters
- Proximity sensors: Active light sensors
- Colorimeters
- Motion detectors
- Thermometers

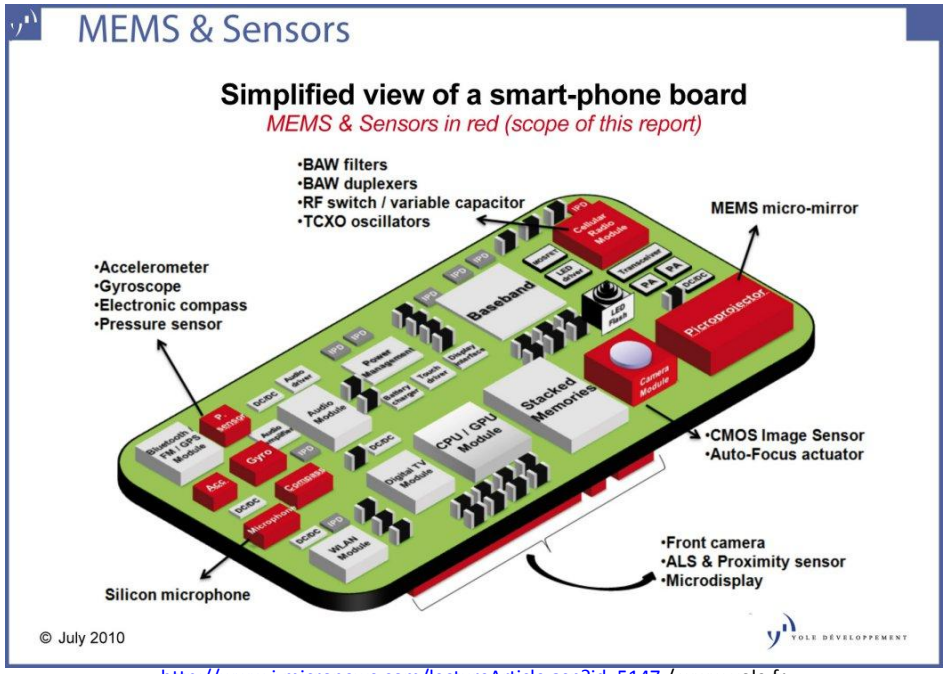
Galvanometric light meter



Duboscq Colorimeter, Page 153 of *Chemical News* (March, 1870), William Crookes, Editor

Force Sensors

- When embedded in ICs: MEMS
- Accelerometers
- Gyroscopes
- Magnetometers
- Baro(alti-)meters
- Thermometer
- Microphones
- Springs, torque meters, gravimeters, podometers, heart rate sensors,



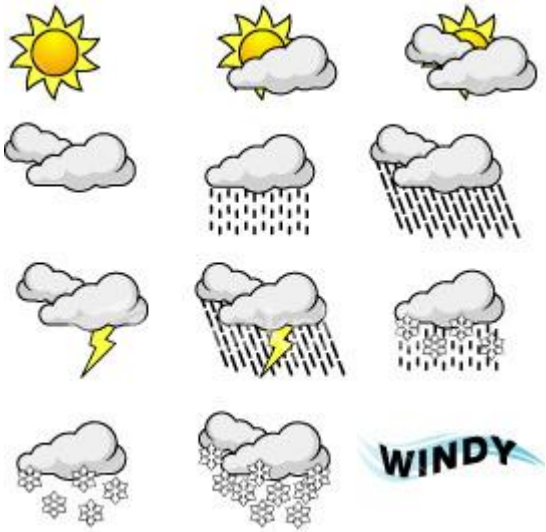
http://www.i-micronews.com/lectureArticle.asp?id=5147 / www.yole.fr

Miscellaneous Sensors

- Thermal diodes
- Geiger counters
- Dosimeters
- Voltmeter/Ampèremeter/Ohmmeter
- any more?

Meteorological Context Data

- Precipitation (mm, type)
- Cloud cover (%)
- Wind
  - speed(m/s)
  - direction(degrees)
- air pressure(hPa)
- temperature(degrees Celsius)
- view conditions (m)
- Humidity (%)



http://lingue.altervista.org/vocabulary_pictures_weather.htm

Meteorological Data Sources

- Guaranteed at airports
- In all major cities
- Harbors
- Aggregated and published by different web services, e.g. www.wunderground.com, www.worldweatheronline.com, www.yr.no, www.noaa.gov

Traffic Sensors

- Road traffic density (eg. bison futé), traffic events (eg. TMC)
- Airport flight plans and delays
- Train schedules …
- Ferry schedules …
- Public transit
- Car sharing, Car pooling
- Bike sharing

http://www.mtc.ca.gov/news/transactions/ta03-0406/511_driving_times.htm

Points of Interest

- Anything which has a physical position
- Landmarks
- Addresses
- People
- Places of public service
- Arbitrarily designated places
- Sources: Google places, OSM, user defined, social networks, service providers' web pages

image: http://izit.org/content/point-interest-675x506

Events

- Popular news
- Political situation and tension

  [www.uic.edu/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/3663/3040, First Monday vol 16, no 9]
- Cultural events (concerts, theater, cinema, etc…)
- Social events (parties, meetings,…)
- Personal events (scheduled appointments, holidays, birth of an infant,…)

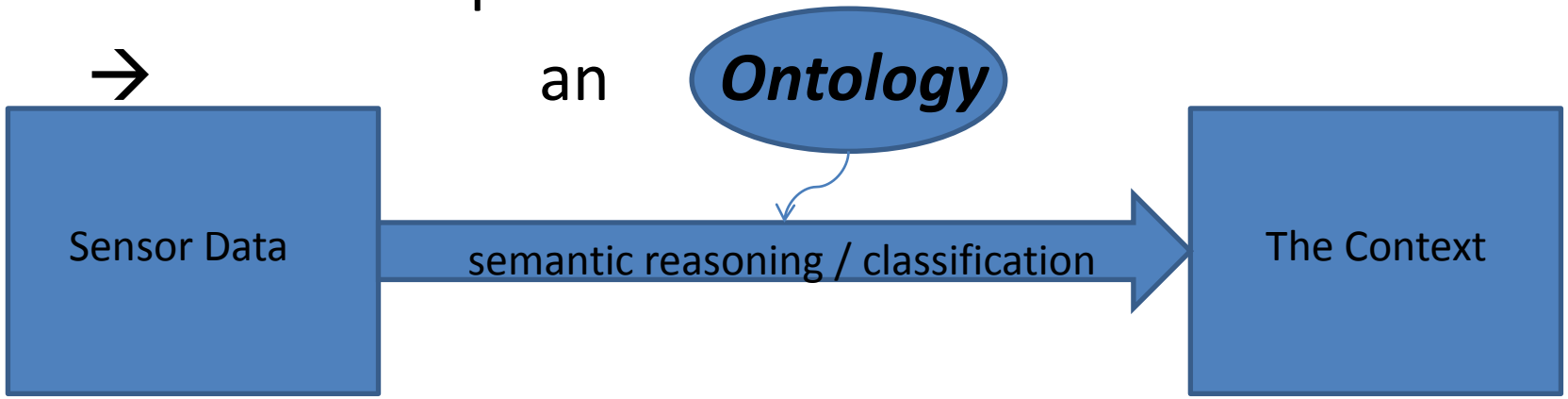
Challenges

- Technological
  - Improve existing tech (….)
  - Model context
  - Model, profile user
  - Fusion of the models
- Ergonomic
  - User Interfaces – design and development
  - Accessibility
- Social
  - Privacy
  - User acceptance

Context Semantics

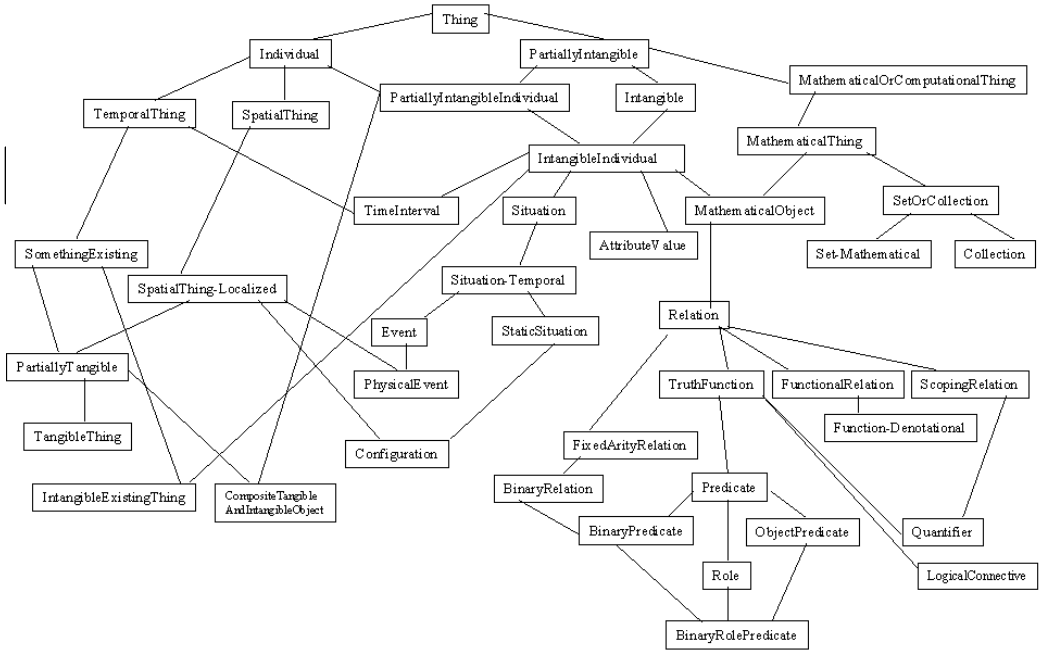
- Raw sensor values have no meaning
- We need to make sense:
  - Assign meaning to values → create “concepts”
  - Create relations between concepts
  - Describe capabilities of devices (sensors, effectors)
  - Describe capabilities of users

→ an ***Ontology***



Ontology

- A [formal, explicit] specification of a [shared] conceptualization. (Tom Gruber, also http://tomgruber.org/writing/ontology-definition-2007.htm)
- ex. Dublin Core (RDF, document metadata)
- ex. FOAF (Friend of a Friend – social network ontology, OWL DL)



On what basis?

- An ontology can be constructed using:
  - large databases
  - statistical information
  - machine learning
  - a priori heuristics
- This is hard to get “right”.

User profiling

- Exists on the “old web”
  - amazon, facebook, google etc.
  - cookies, clicks and User-Agent
  - individual and collaborative models
- Ubiquitous: Profile real world actions
  - Active research topic
  - derive habits and preferences from context
  - …and still log explicit interactions
  - collaborative methods require abstraction

Mobile Computing

- Precursor to “true” UbiComp
- Important part of Pervasive Computing
- Highly context dependent
- Applications
  - classic
  - context-enabled
- Limited by portability requirement

Mobile Platforms

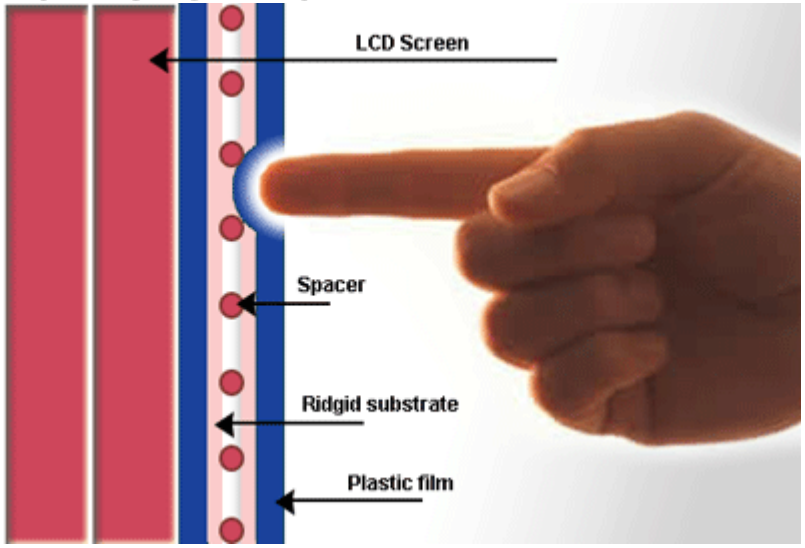
- At the base, highly integrated PC's
  - SoC = CPU + RAM + Graphics + Net + Audio + Bus
  - Display, flash storage, speaker
- with some specific features
  - vibrator
  - sensors
  - touch screen
  - often no relative pointing device

Mobile Interactions

- Size
  - keyboard text entry difficult (worse on soft-kb's)
  - held in hand – one handed interaction via thumb
  - fingers are large and obscure the screen
- Context
  - light/darkness
  - noise/conversation
  - vibrations/lack of skin-contact
  - focus of attention

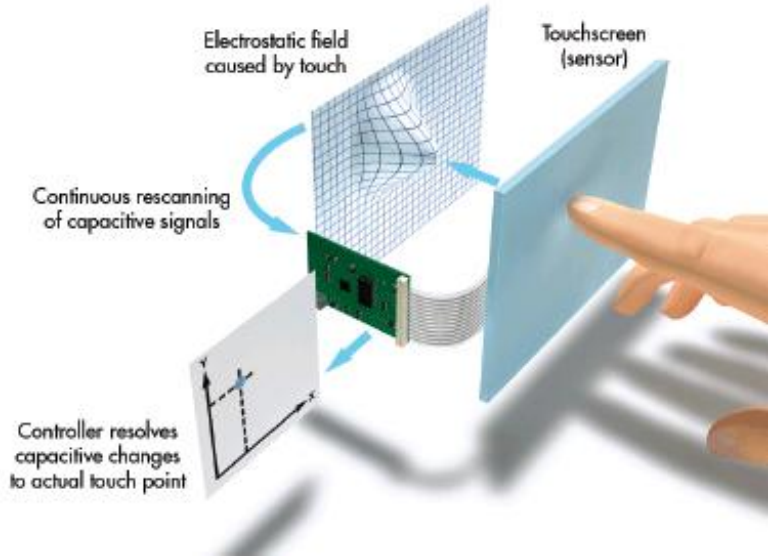
Touch Screens

- Resistive



http://www.screentekinc.com/resource-center/touch-screens.shtml

- Capacitive



http://www.telecomcircle.com/2010/03/touchscreen/

Touch Screen UI's

- Low precision pointing ("Fat-Finger-Syndrome")
- Occlusion (dependent of handedness)
- Prolonged Usage: Ergonomics ("Gorilla arm")
- Limited mechanic (haptic/kinesthetic) feedback
- No tactile feedback / no surface structures

Touch Screen UI's

- Typing aids:
  - Swype
  - vibration feedback
  - dictionaries
  - handwriting detection
- gestures
  - symbolic
  - direct manipulation

Tangible UIs

- Proximity based (ID-per-NFC/RFID/IRDA)
- Motion-based (3d symbolic/non-symbolic gestures)
- Direct physical feedback via vibration
- Image based: AR applications

Beyond Smart Phones

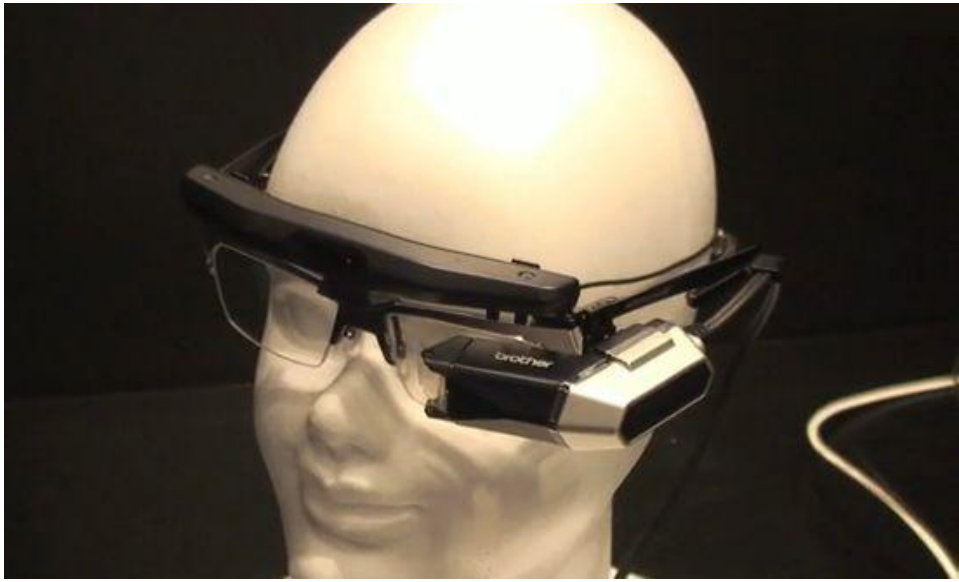
- Keyboards for one-handed operation

Twiddler (www.handykey.com), FrogPad (www.frogpad.com)

Beyond Smart Phones

- Head-mounted / helmet-mounted Displays

US Army Land Warrior



brother AiRScouter

Instrumented Spaces

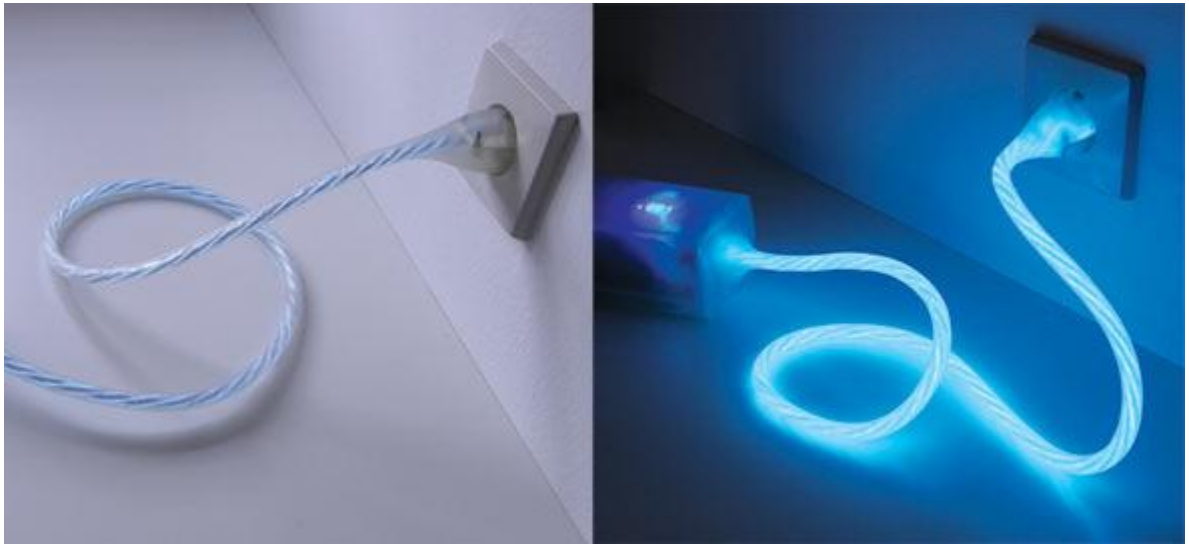
- Interact with mobile components

Ambient Interfaces

- Non-explicit information
- Suitable to notify changes, alerts
- Attention management

Dangling String, N. Jeremijenko

Nabaztag (Mindscape, Violet)



"Power-Aware Cord" - Anton Gustafsson and Magnus Gyllenswärd, CHI 2005

Nuage Vert, http://www.pixelache.ac/nuage-blog/index.php?option=com_content&task=view&id=14&Itemid=27

Privacy Issues

- Sensor logs and public networks…
- Who benefits?
- Services offered and data required
- Public key encryption and cryptographic trust
- How to manage dissemination?
- Track- and traceability
- Does it *really* matter?

Conclusion

- Why UbiComp? – Forget about the computer.
- What is UbiComp?
  - Interdisciplinary (Design, sociology, ethnology, interface, hardware, software, network, displays)
  - Developing (Mobile now, Ubiquitous tomorrow?)
- How?
  - Smart internetworked everything
  - Context and user profiling
  - Assure privacy