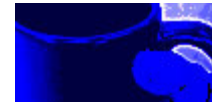


An Introduction to Ubiquitous Computing

Hans-W. Gellersen

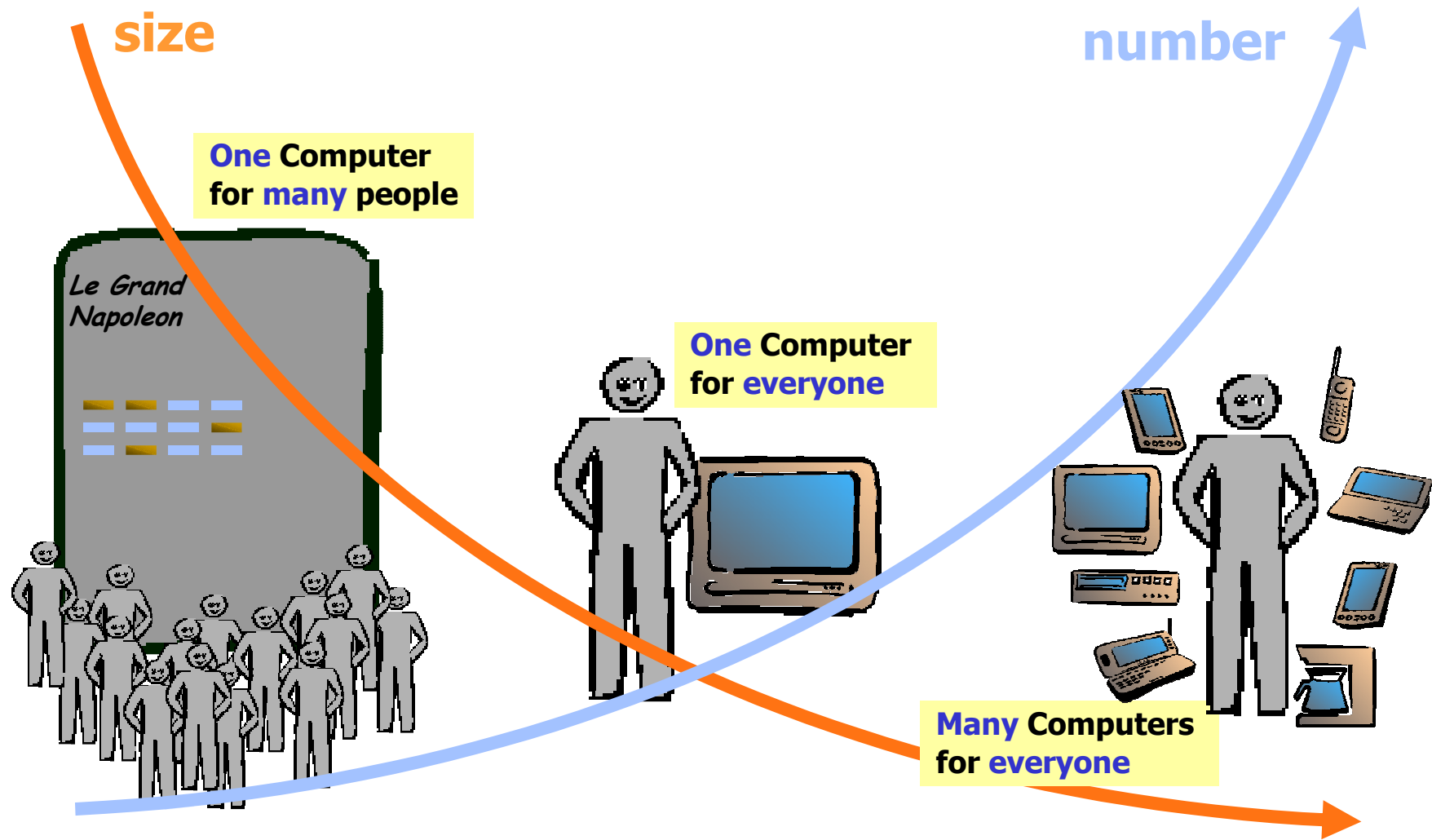


Lancaster University
Department of Computing
Ubiquitous Computing Research



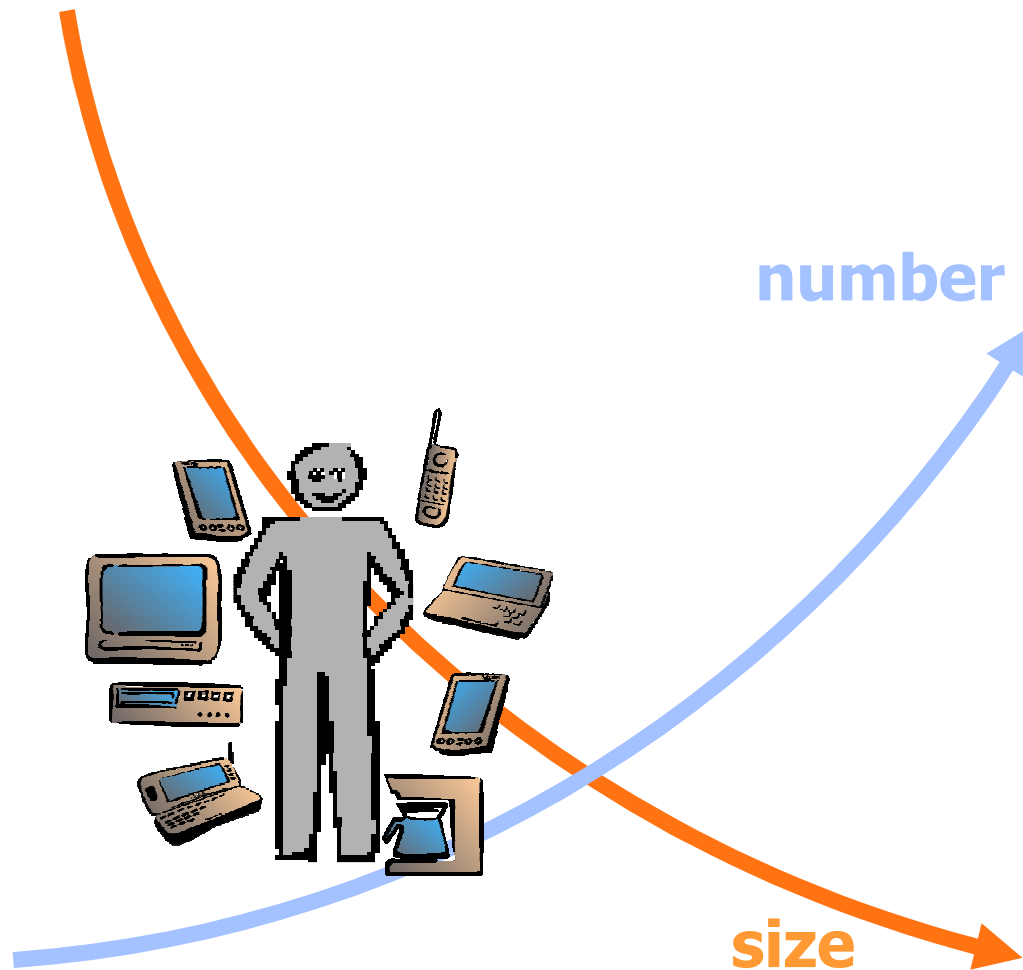
Computer Technology Trends

Computers: Size + Number



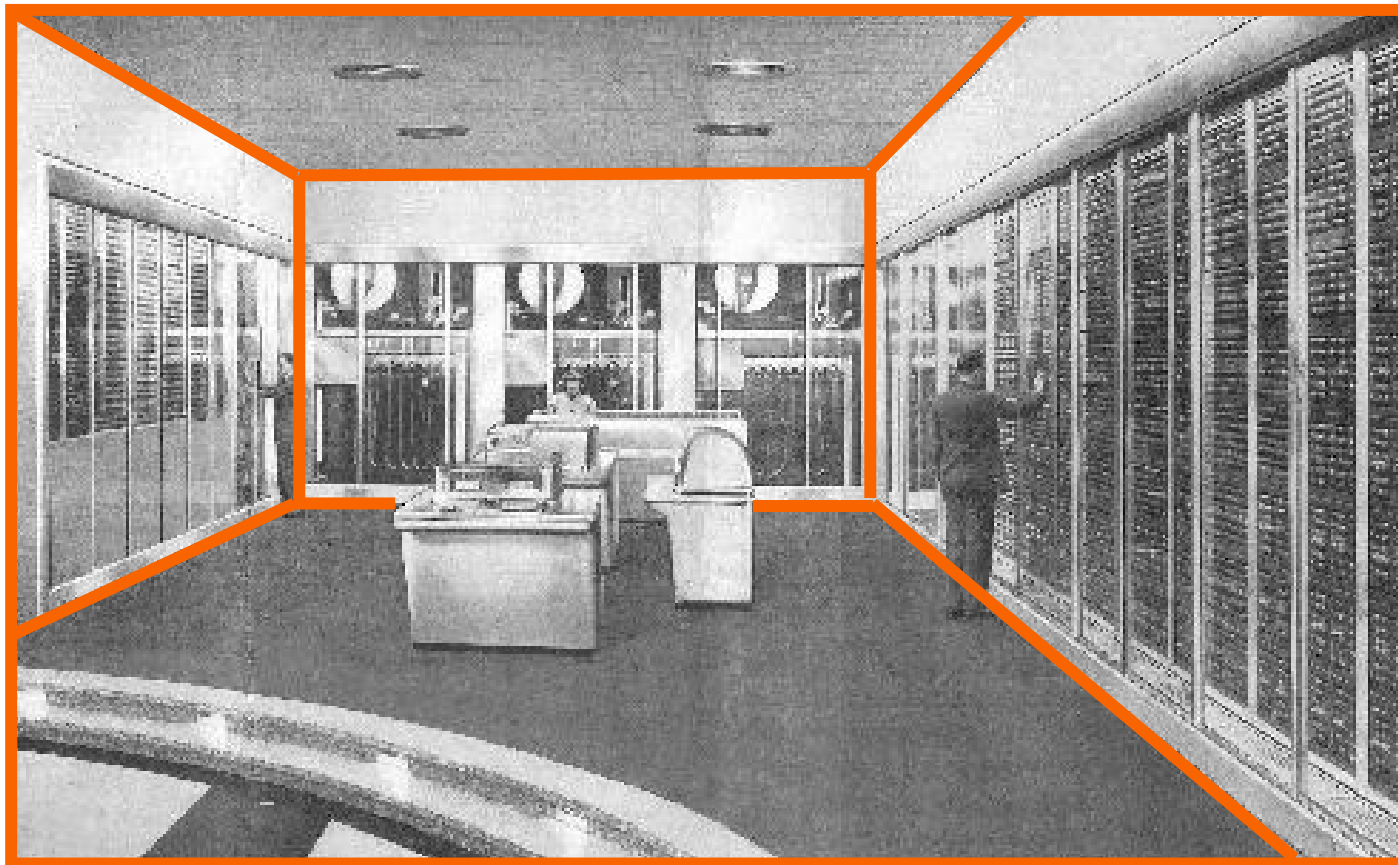
adapted from: F. Mattern, Dagstuhl 2002

Size + Number: What's next ?



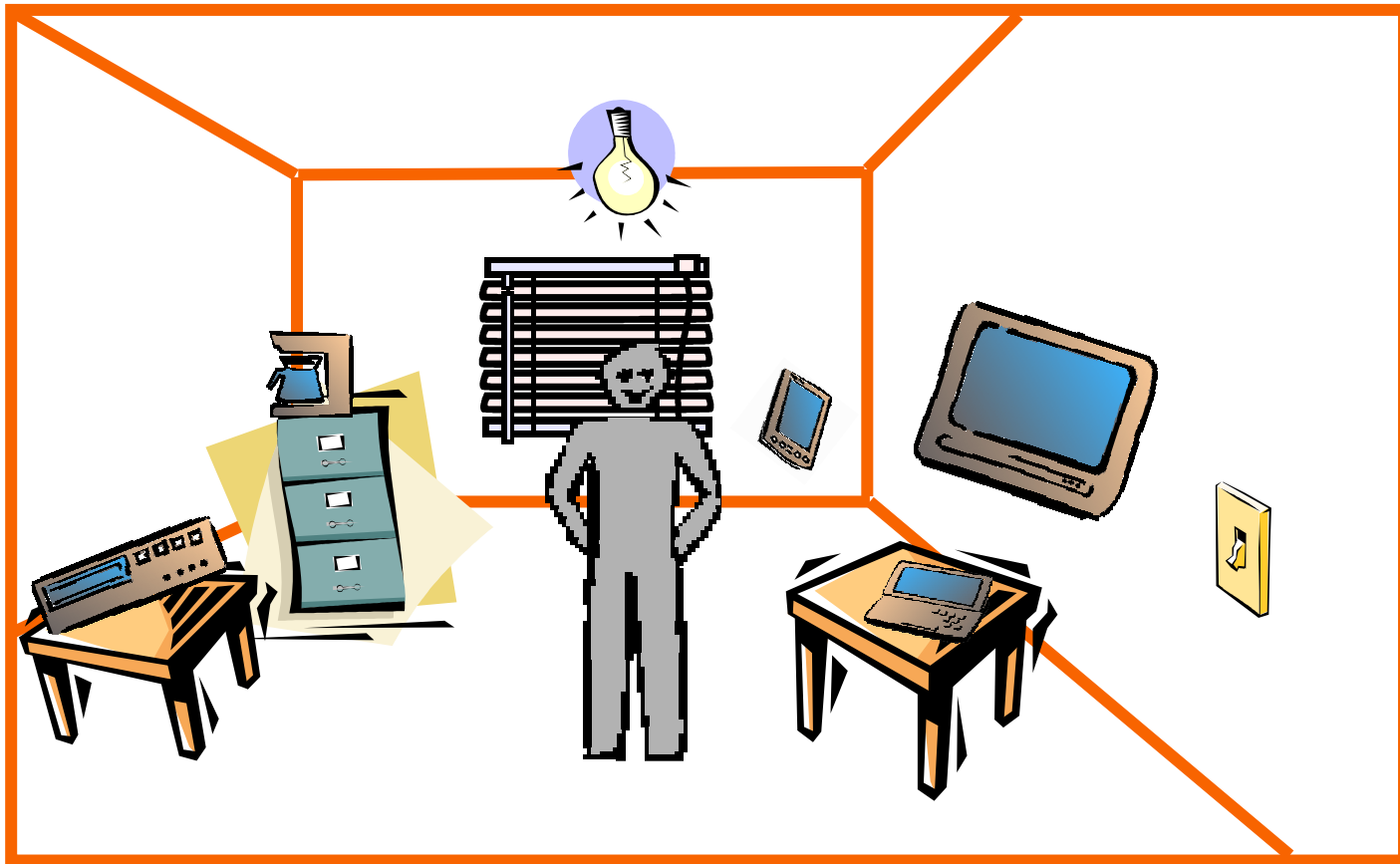
Coursework:
Fill this space!
Submit to
hwg@comp.lancs.ac.uk

Yesterday's Computers filled Rooms



IBM Selective Sequence Electronic Calculator, 1948

So will Tomorrow's!



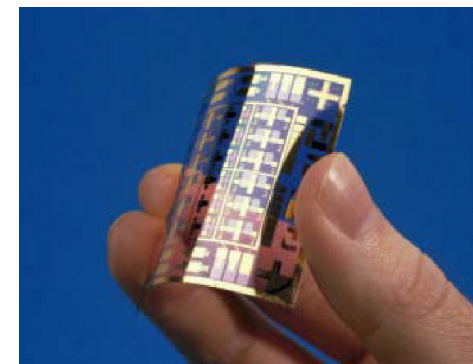
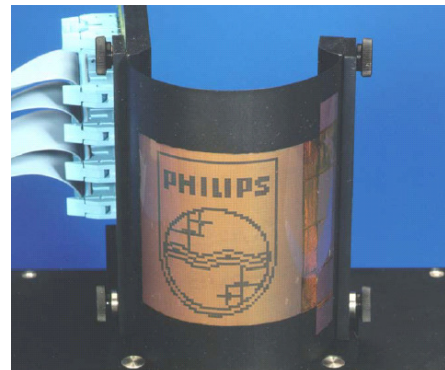
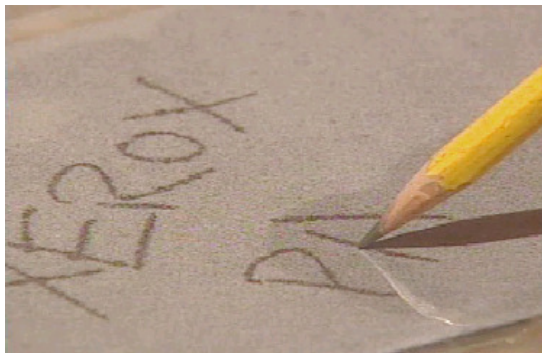
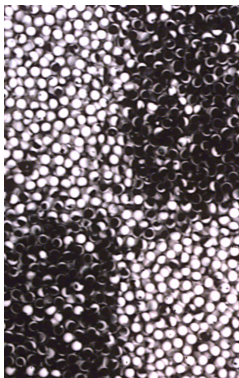
IBM Selective Sequence Electroinic Calculator, 1948

What makes this possible ?

- **Microprocessors** so small that they can be embedded in practically everything
- **Storage** so inexpensive and dense that it can be provided everywhere
- **Wireless networking** for inexpensive short-range connectivity
- **New materials** for new forms of appearance (e-ink, flexible displays, conductive fibers etc)

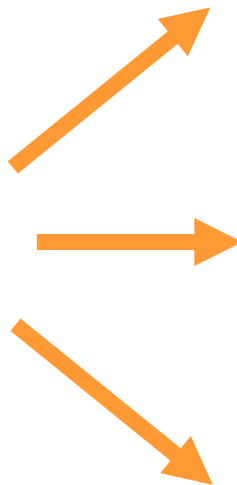
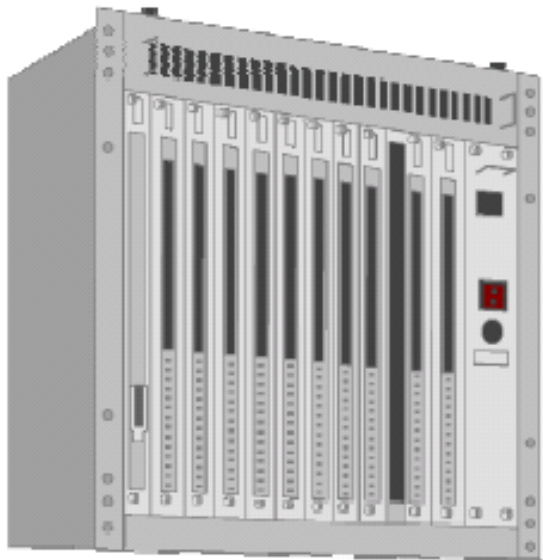


1GB in Flashcard format

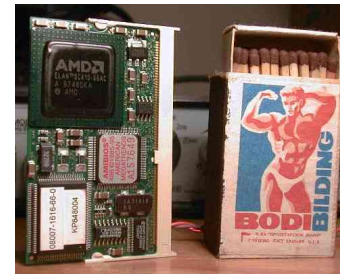


HWG 7

Scaling down



IBM WatchPad1.5

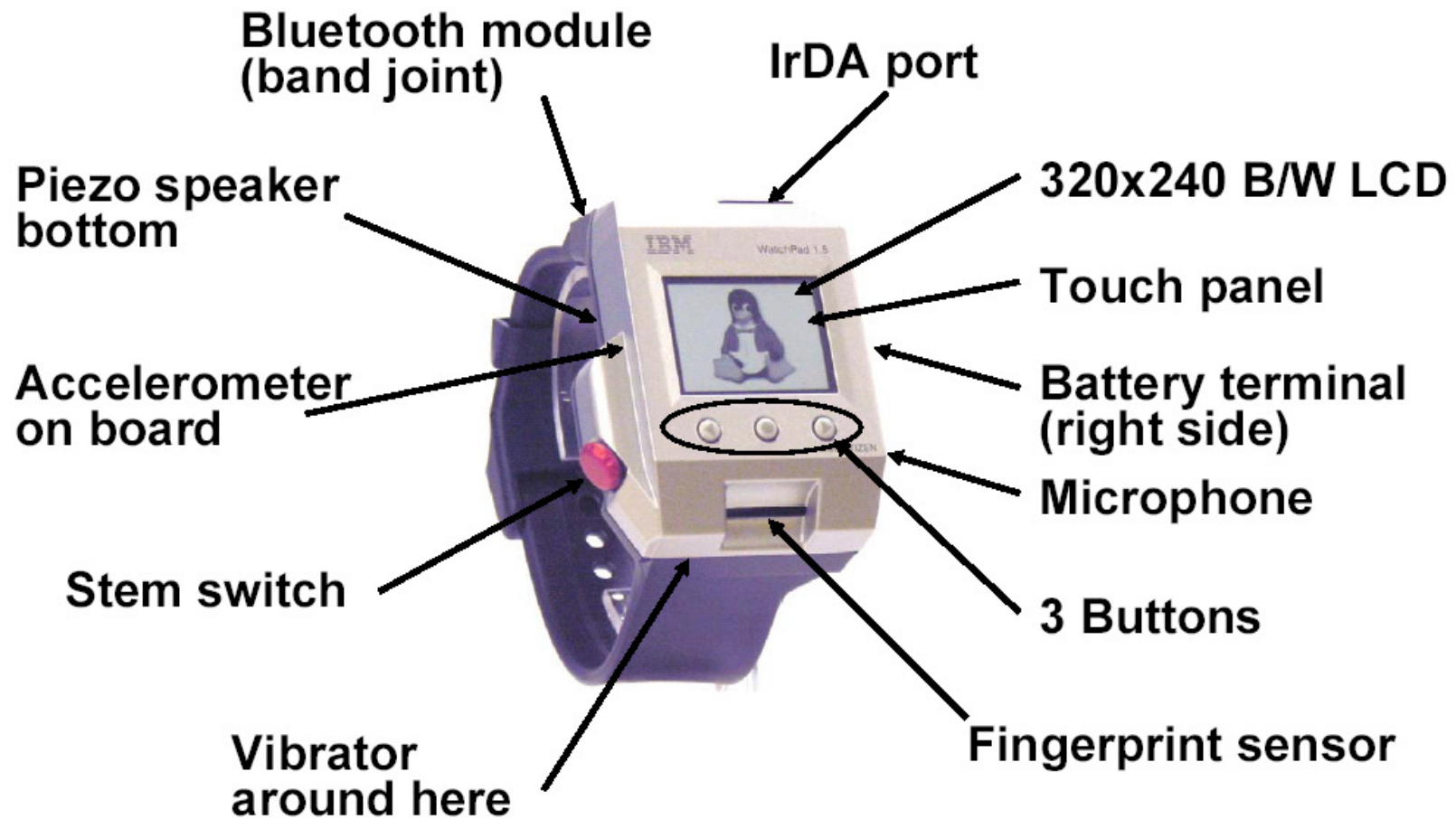


Stanford
Embedded
Web Server



Xerox PARC
Keychain Computer

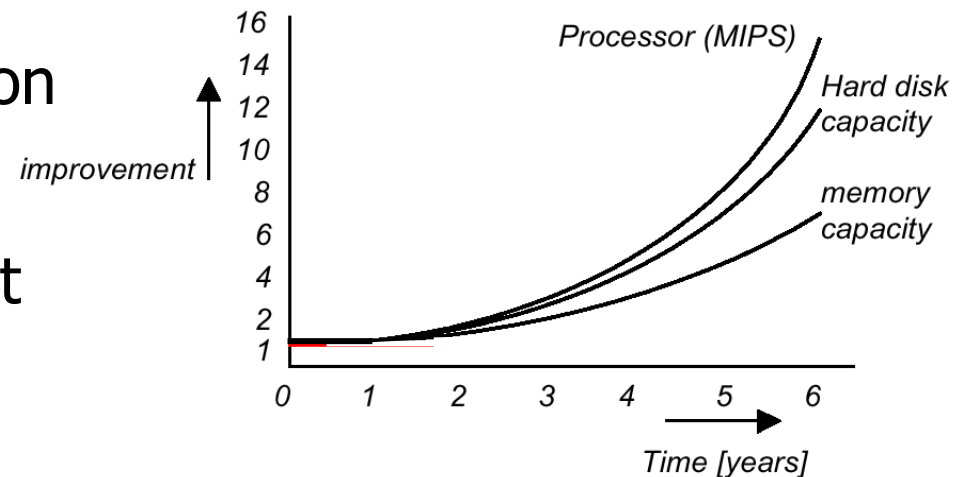
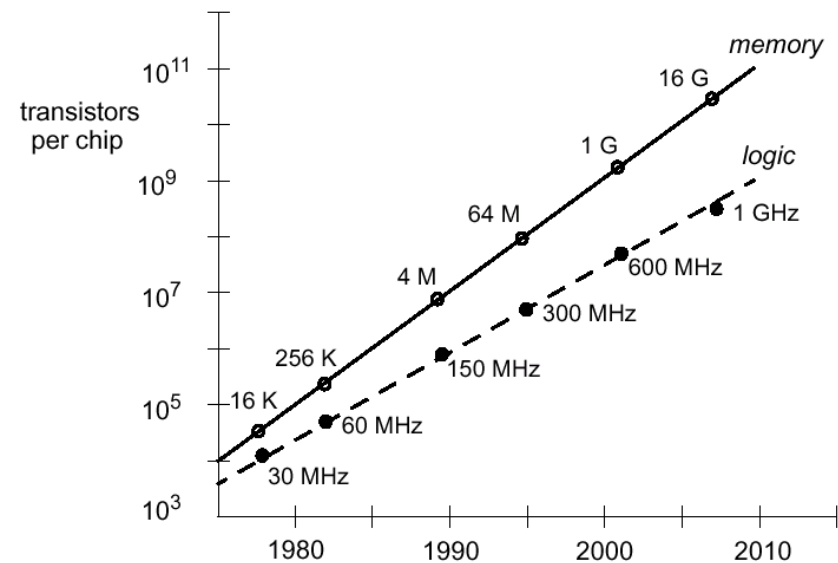
IBM WatchPad 1.5



Moore's Law

Exponential Increase

- Transistors per die
- *"Processing speed and storage capacity double every 18 months"*
- Cheaper, smaller, faster
- Similar for communication bandwidth
- Expected to hold at least for another 10 years



Moore's Law

Electronics, April 1965

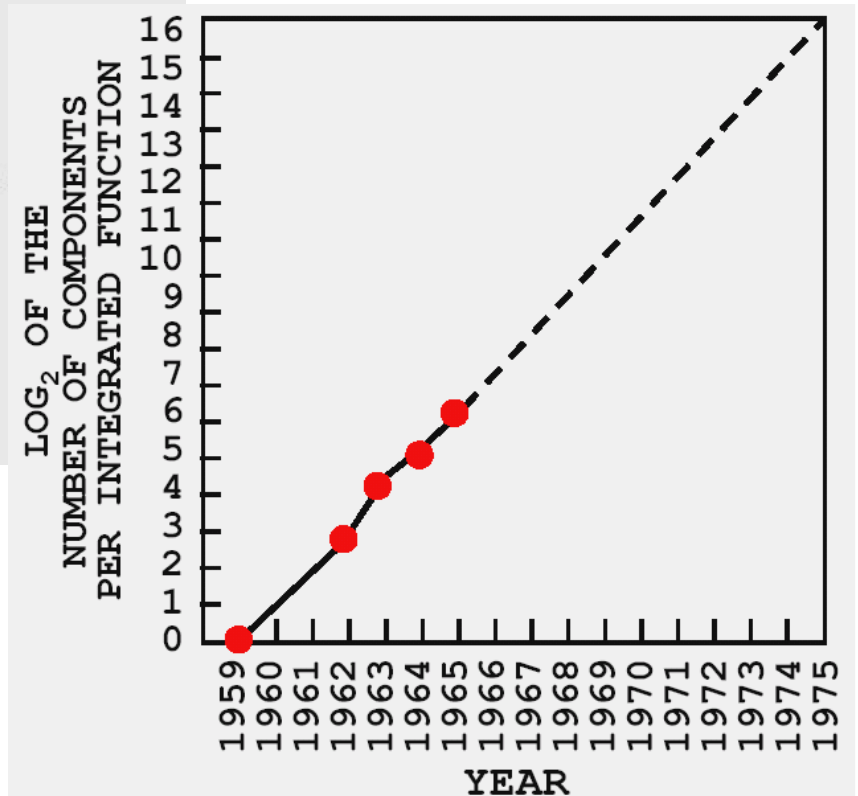
Cramming more components onto integrated circuits

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.

"... has increased at a rate of roughly a factor of two per year (see graph [...]). Certainly over the short term, the rate can be expected to continue, if not to increase. Over the longer term, the rate is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years. That means by 1975 ..."



Moore's Law

Electronics, April 1965

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

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.

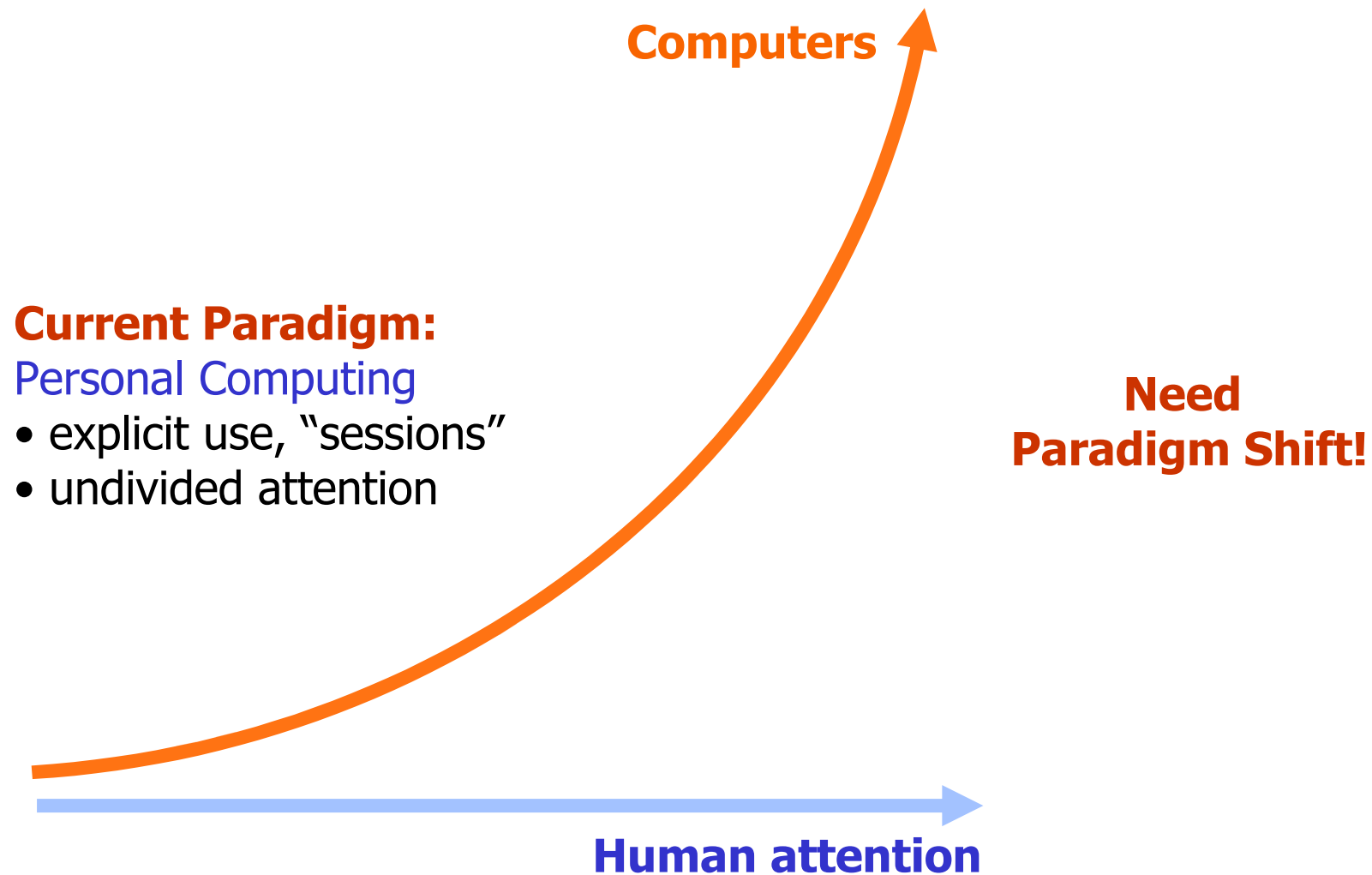


Not everything obeys Moore's Law!

People don't!

- Human attention is a limited resource
- People's willingness to devote bigger mind share to computing concerns is not likely to increase
- Past: computing time shared by many people
- Future: human time shared by many computers

Interacting with Computers



The Ubiquitous Computing Vision

Weiser's Vision



Mark Weiser (1952-1999)

- „Father of Ubicomp“
- Chief Technologist at Xerox PARC
- began Ubiquitous Computing Project at PARC in 1988
- Seminal article „The Computer of the 21st Century“, Sci.Amer., 1991

Weiser's Vision

Ubiquitous Computing

- Mass-deployment of computing in everyday life (*„move into the everyday, the small and the invisible“*)
- *„...[the] next generation computing environment in which each person is continually interacting with hundreds of nearby wirelessly connected computers. The point is to achieve the most effective kind of technology, that which is essentially invisible to the user ... I call this future world Ubiquitous Computing“.*



Ubiquitous Computing

Some key points in Weiser's Vision

- **Contrasting virtual reality:** embed computers in the real world, not the real world in the computer
- **Challenging the Personal Computing paradigm:** too focussed on the machine as opposed to the task
- Suggesting Ubicomp as **a New Era of Computing**, reconsidering the place of computers in our lives.

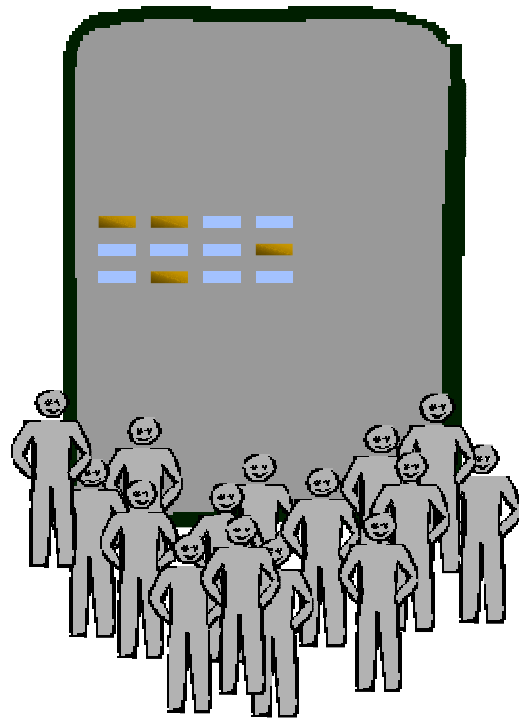
Ubiquitous Computing

Some key points in Weiser's Vision

- Key challenge: to overcome the disconnection of computers from the real world situations in which they are used
- *"The idea for UC first arose from contemplating the place of today's computer in actual activities of everyday life. [...] studies of work life teach us that people primarily work in a world of shared situations [...] However the computer today is isolated and isolating from the overall situation, and fails to get out of the way of the work."*

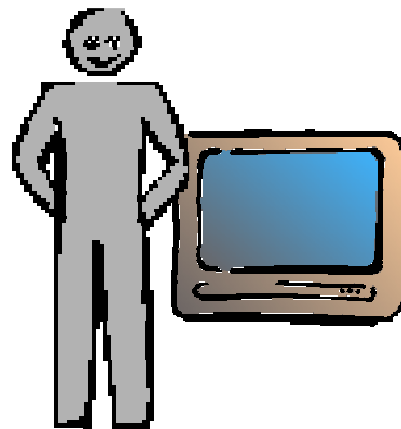
A New Era of Computing

Paradigm Shift in Interaction with Computers



Mainframe Era

- batch processing



PC Era

- direct manipulation



Ubicomp Era

- situated interaction

From Mainframe to PC: “Human Integration”

Mainframe Computing

- Machine-defined user interface
- Shared use
- Requiring Preparation

Paradigm Shift to Personal Computing

- Taking the Human in the Loop
- User interface software as main concern
- Human-Computer Interaction as discipline

From PC to Ubicomp: “Physical Integration”

Personal Computing

- Direct manipulation
- Isolated: not aware of context
- Isolating: Monopolizing attention

Paradigm Shift to Ubiquitous Computing

- Taking context of human-computer use into the loop
- Context: “what surrounds”
 - i.e. the location, the environment, the user’s activity, the situation

Physical Integration

Physical Integration

A Broad Concept

- Anything that relates computer use to physical circumstance
- Many ways in which we can think about physical integration
 - Location- and context-awareness: modelling the environment in the computer
 - Situated computing: directly linking computer services to real situations
 - Digital Presence: giving physical entities a digital presence
 - Tangible interaction: merging interaction with manipulation of physical world

Location-aware Computing

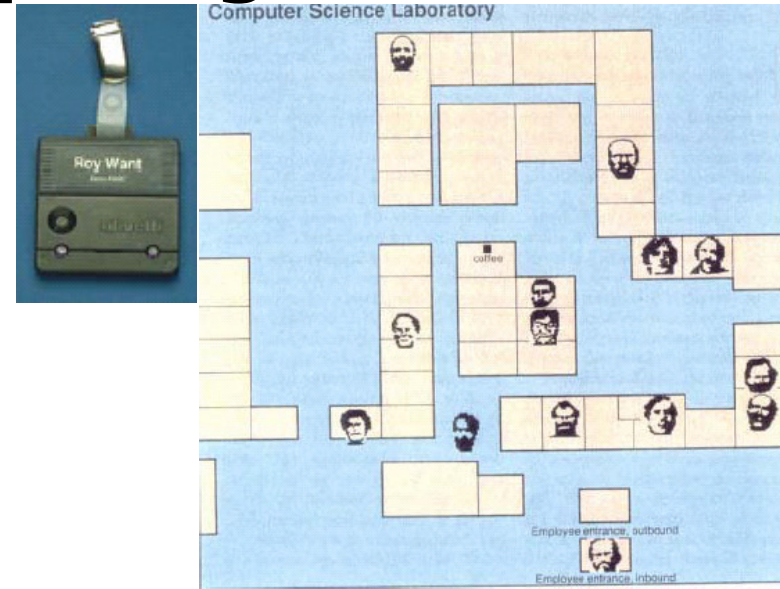
Location is universal

- Everything has a location: people, places, things, activities, events, situations
- Location information can be wonderfully processed in computers
 - powerful index to occurrences in the physical world
 - Geometric and symbolic modelling, location arithmetics and spatial reasoning
- *"if a computer merely knows what room it is in, it can adapt its behavior in significant ways without requiring even a hint of artificial intelligence"* (M. Weiser)

Location-aware Computing

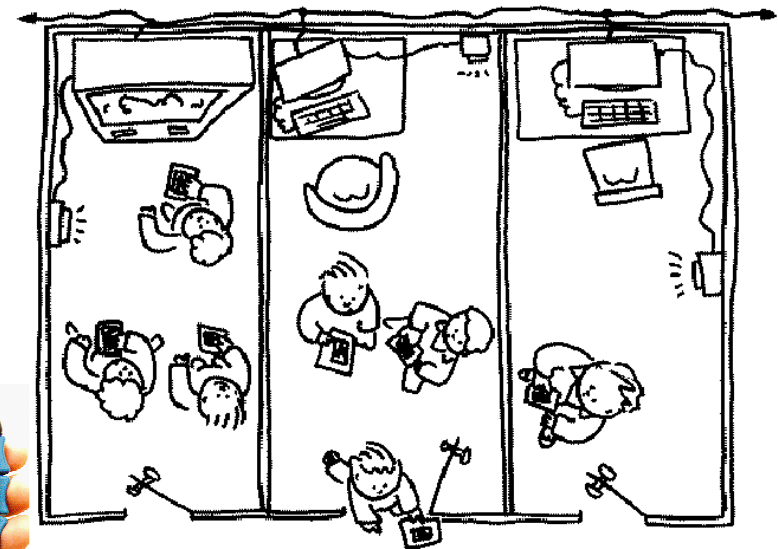
Active Badge Project

- ORL Cambridge, 1988-
- Indoor Location System
- Pioneered use of location in interactive applications



ParcTab Project, Xerox PARC

- Tab Computers with location infrastructure
- Inferring: user location, proximity of resources,...
- various applications



Location-aware Computing: Privacy

BIG BROTHER, PINNED TO YOUR CHEST

IDS that track employees offer efficiency—but what about privacy?

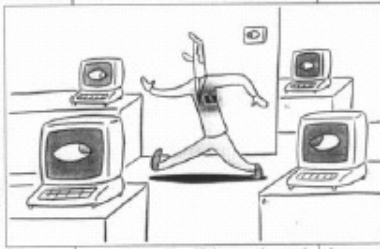
Alarms do not go off when Andy Hopper ducks out of his Olivetti Research Laboratory office in the middle of the afternoon, nor do red lights flash. Just the same, within 15 seconds of his departure, any colleague who checks the employee-tracking data base at the lab in Cambridge, England, will discover he's gone. Not only that: By tapping into the data base from afar, any of the 5 million users of the world-wide Internet computer network—utter strangers, even—can find out that Hopper has topped.

When he's in the office, inquisitors can usually find out when he has visitors—and exactly who they are. Hopper, director of the Olivetti lab, willingly sheds his privacy each day when he puts on his "active badge," a computer in the shape of a clip-on ID card. The badge signals its wearer's location by sending off infrared signals, which are read by sensors sprinkled around a building. The sensors, in turn, are wired to a

and track people in their daily activities. Already, global positioning systems keep tabs on cross-country trucks. And cellular phone systems act as tracking systems, since they must pin down the approximate location of every customer to deliver incoming calls via the closest antenna.

But as the use of such systems spreads, government and business increasingly will be challenged to balance the individual's right to privacy with cor-

places, increasingly the way they live. At the Massachusetts Institute of Technology, researchers, if systems of hospitals. Active badges monitor heart monitors they could quickly if they are working guard duty. Corp's Pal searchers W



Business Week '92

Track People with Active Badges



Electronic location technology tracks your location within a network site and allows your system resources to follow you

Such location systems raise ethical concerns, and they have the potential to be abused by unscrupulous managers to create an Orwellian surveillance system. But this could be used for other networks and to enhance monitoring devices that are already in use where needed properly.

[JOB strategies]

Coming: Employee trackers

Ray Want, inventor of the Active Badge, says that in professional settings where employees often stay from their desks, his badge is an efficient way to track someone down. The advantage to the employer: fewer missed phone calls and unnecessary interruptions. If the badge, made by Olivetti, indicates that you're in an office meeting with three or four other people, your boss or coworker may choose not to disturb you. Also, the badge could make a critical difference whenever employees need to be found fast—in hospitals, for instance, or potentially dangerous work environments like chemical plants.

But, warns Evan Hendricks, office of Privacy Theory, "Once the badge becomes easily available, there's nothing stopping lots of employers from using it to monitor their workers." In other words, the badge enables your boss to check your whereabouts around the office and, possibly, use what she finds against you.

Employees, take heart. The Active Badge isn't foolproof. Placed in a dark drawer or face-down on your desk, it temporarily shuts off.

—Susan Viscusi

Glamour Mag '93

PC World '90

9/27/2001

Orwellian Dream Come True: A Badge That Pinpoints You

By LEONARD SLOANE

Is Big Brother your boss? Another tool that lets "them" check upon "us"—where we are and with whom we are—is on the way. It is the active badge, a small clip-on microchip, about the size of an employee ID card, that transmits signals to a central system. As long as you wear the badge, the system can track your movements around an office building or even a larger area.

"When different people need to be found, I can ring directly to where they are," said Ray Want, who invented the active badge while at the Olivetti Research Laboratory in Cambridge, England, and who is now a member of the research staff at the Norris Research Center in Palo Alto, Calif. "It's in your interest as a professional to stay in touch with your colleagues."

Andy Harter, a research engineer at the Olivetti lab, added: "I get my communications so much faster when I carry the badge. And it's all completely hands-free."

For many people, however, privacy issues overwhelm any technological virtues of active badges. They use the badges as an intrusion into the lives of employees, eroding workplace privacy. And they require the badges with the already widely used electronic monitoring devices that can quantify the number of keystrokes on a terminal, look at video and computer mail messages or listen to employees' transacted business on the phone.

"George Orwell would have been pleased," said Donald A. Norman, chairman of the cognitive science department at the University of California at San Diego. "This technology makes snooping easy. Especially intrusive technology should be under the control of the person using it, not of management."



Illustration by Tom Brown

Evan Hendricks, editor of the Privacy Times newsletter, said: "There's a lot of surveillance in the workplace these days. They could say you were in the men's room or the cafeteria too long or that you were sitting in second-story office too long. It has the potential of changing the modern office use an electronic sweatshop."

Visions of an electronic sweatshop.

Mr. Harter of Olivetti said that although active badges were still being tested, there were plans to make them available commercially starting next year.

The target market includes not only office workers who are away from their desks, but also doctors and patients in hospitals or nursing homes, lawyers and laboratory scientists.

New York Times '92

Badges monitor staff

TWO OF THE STAFF AT THE LAB



Orwellian implications?—'Everyone tracks everyone else'

But a number of unnamed computer-makers looking at the technology, which was developed in-house by Olivetti, and Chipping admit it could be abused if used as a checking device in offices and factories. "I can see there could be problems. To some extent it depends on the attitude

of the management," he said. A spokesman for Olivetti said: "This system is sold open to abuse. We are very concerned that our technology such as this gets introduced with no safeguards to control its use. This could potentially invade people's privacy."

Context-aware Computing

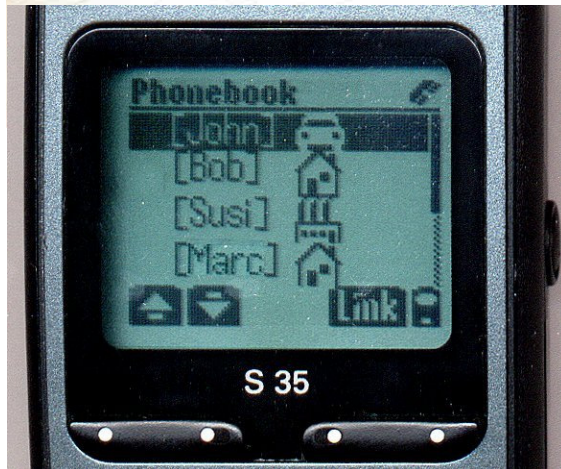
Beyond location

- Modelling user activity and situation
- Context acquisition
 - Sensor integration, perceptual computing
 - New type of sensing problem: associating sensor observations with user-level context
 - User activity: unstructured and unbound
- Context-aware applications
 - Associating observations with behaviour
 - Dealing with uncertainty

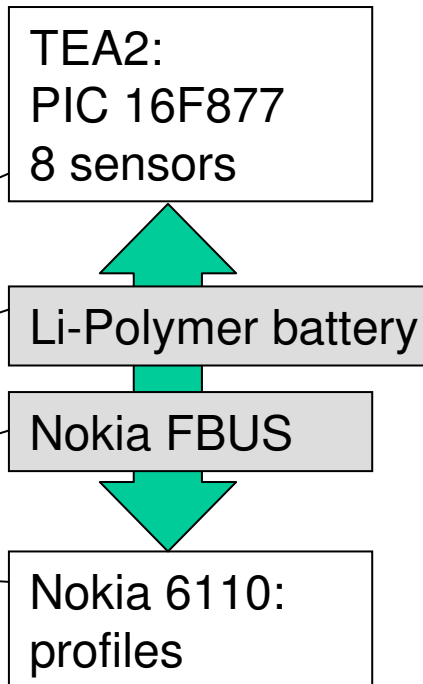
Context-aware Computing

TEA Mobile Phone

(Karlsruhe/Starlab/Nokia, 1998-2000)



Phonebook with
dynamic context
information



Situated computing

Context-aware vs. Situated

- Context-aware: acquire context continuously, react to it
- Situated: anchor service in particular situation
- iLink example

iLink, Accenture



Digital presence

Real World Entities with Digital Presence

- Context-aware: probing into the physical world
- Digital Presence: real things as “server” with information about themselves

Cooltown, HP Labs

- “Web Presence for People, Places, Things”
- Extending the Web to the Real World
 - the web maintains links between people, places, things as context for services
- New services based on queries that concern real places, real people, real things

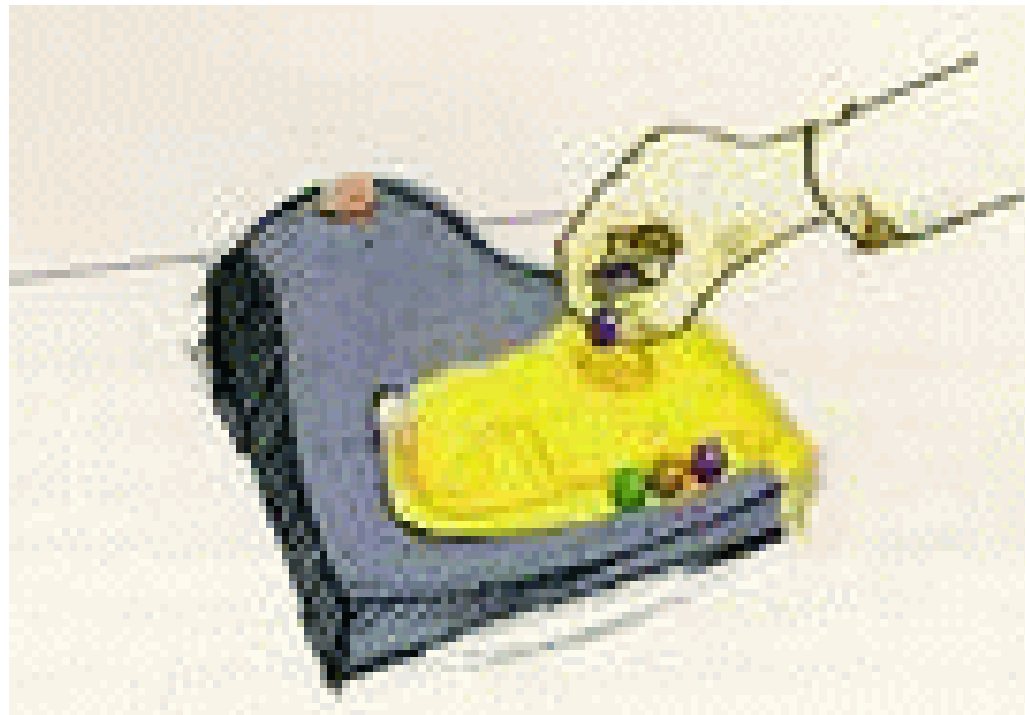
Tangible Interaction

Physical Interaction Experience

- Physical affordances: suggesting and guiding action
- Spatial organisation of action/communication
- Ambient interaction: “spatial attention model”
- Blurring the difference between action in the real world and interaction with computers

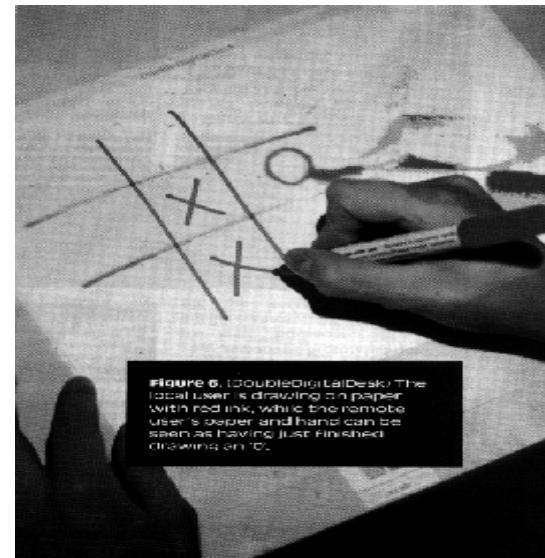
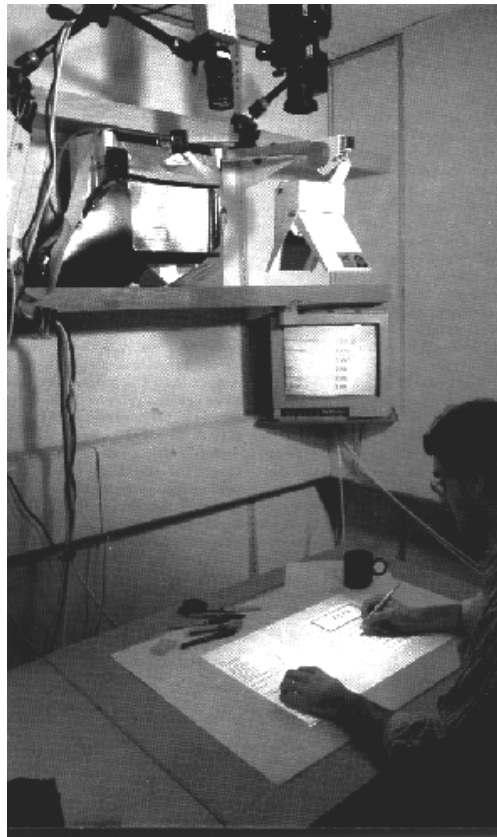
Bishop's Marble Answering Machine

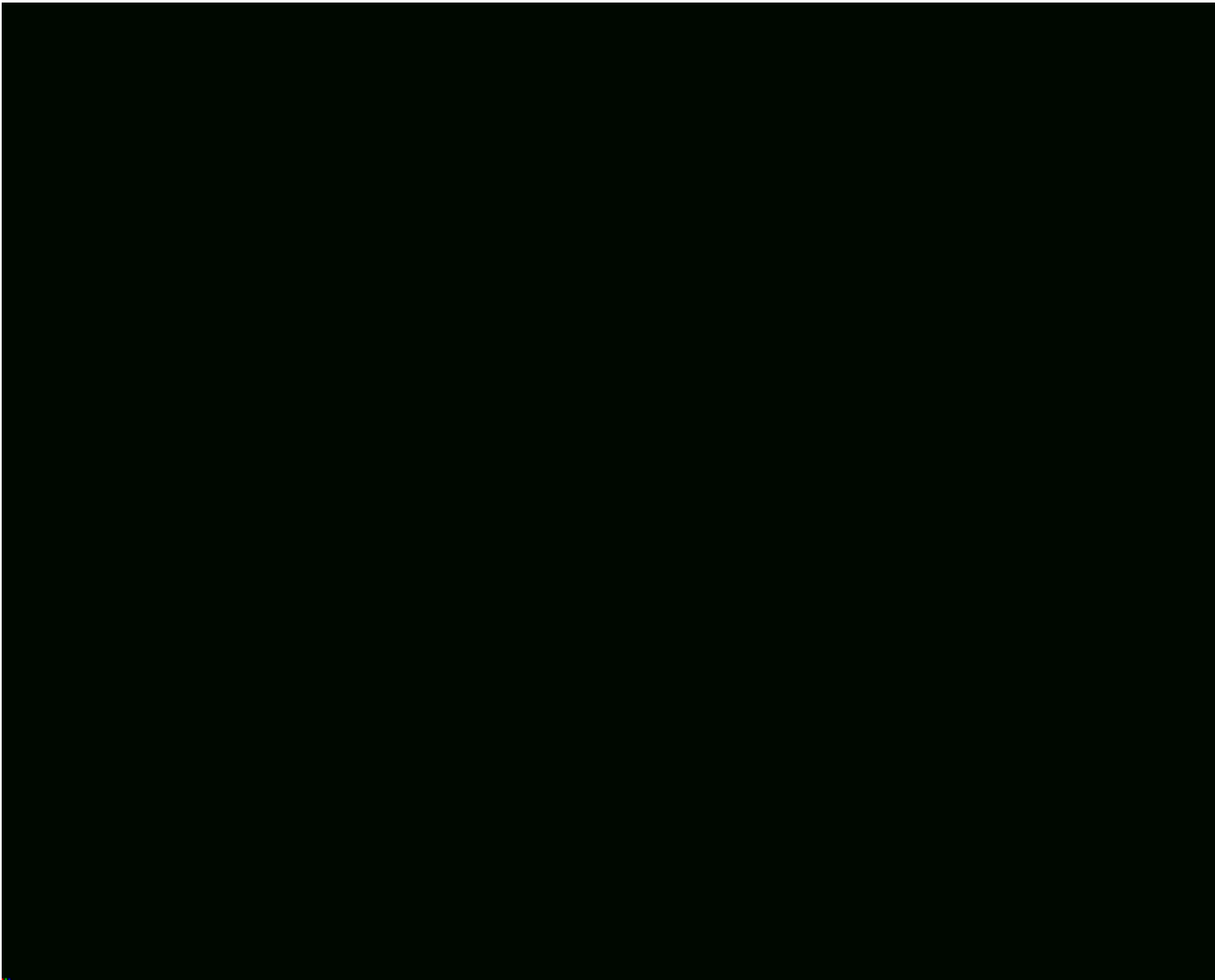
- Physical interaction with digital information



Wellner's Digital Desk

- Why a desktop metaphor when you can have a real desktop
- Seamless transitions: physical and digital interaction





Summary

- Technology trend vs. human attention to computing concerns
- Ubicomp: a new paradigm for interaction with computers
- Physical Integration: connecting computers to the physical reality in which they are used
- Can we integrate computers in their environment, so they become almost indistinguishable from it ?
 - “Examples of the Disappearing Computer”

Readings

Weiser's Vision

- [1] M. Weiser, "The Computer of the 21st Century", Scientific American, vol. 265, no. 3, Sept 1991, pp. 66-75 (reprinted in [2])
- [2] "Reaching for Weiser's Vision". Inaugural issue of IEEE Pervasive Computing, Jan-Mar 2002.
- [3] M. Weiser, "Some Computer Science Issues in Ubiquitous Computing, in [4]
- [4] "Back to the Real World", Comm. of the ACM, July 1993.
- [5] M. Weiser and J.S. Brown, "The Coming Age of Calm Technology", in Denning and Metcalfe (eds) "Beyond Calculation: The Next Fifty Years of Computing", Copernicus Heidelberg.
- [6] <http://www.ubiq.com/>

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- [8] D. Norman, "The Invisible Computer", MIT Press, Cambridge MA, 1998.
- [9] M. Satyanarayanan, "Pervasive Computing: Vision and Challenges", IEEE Personal Comm., vol. 8, no. 4, Aug 2001, pp. 10-17

Physical Integration

- [1] A. Harter and A. Hopper, "A Distributed Location System for the Active Office", IEEE Network, Vol. 8, No. 1, Jan 1994, pp. 62-70
- [2] R. Want et al, "An Overview of the ParcTab Ubiquitous Computing Experiment", IEEE Personal Comm., Vol. 2, No. 6, Dec 1995
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- [4] D. Estrin et al, "Connecting the Physical World with Pervasive Networks", in [2]
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- [6] A. Gershman et al, "Situating Computing: Bridging the Gap between Intention and Action", Proc. Intl. Symposium on Wearable Computing (ISWC '99), 18-19 October 1999, IEEE Press
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- [8] H. Ishii and B. Ullmer, "Tangible Bits: Towards Seamless Interfaces Between People, Bits and Atoms", Proc. ACM CHI'98, ACM Press, pp.234-241
- [9] P. Wellner, "Interacting with Paper on the Digital Desk", in [4]