An Introduction to Ubiquitous Computing

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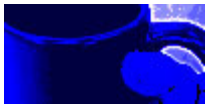
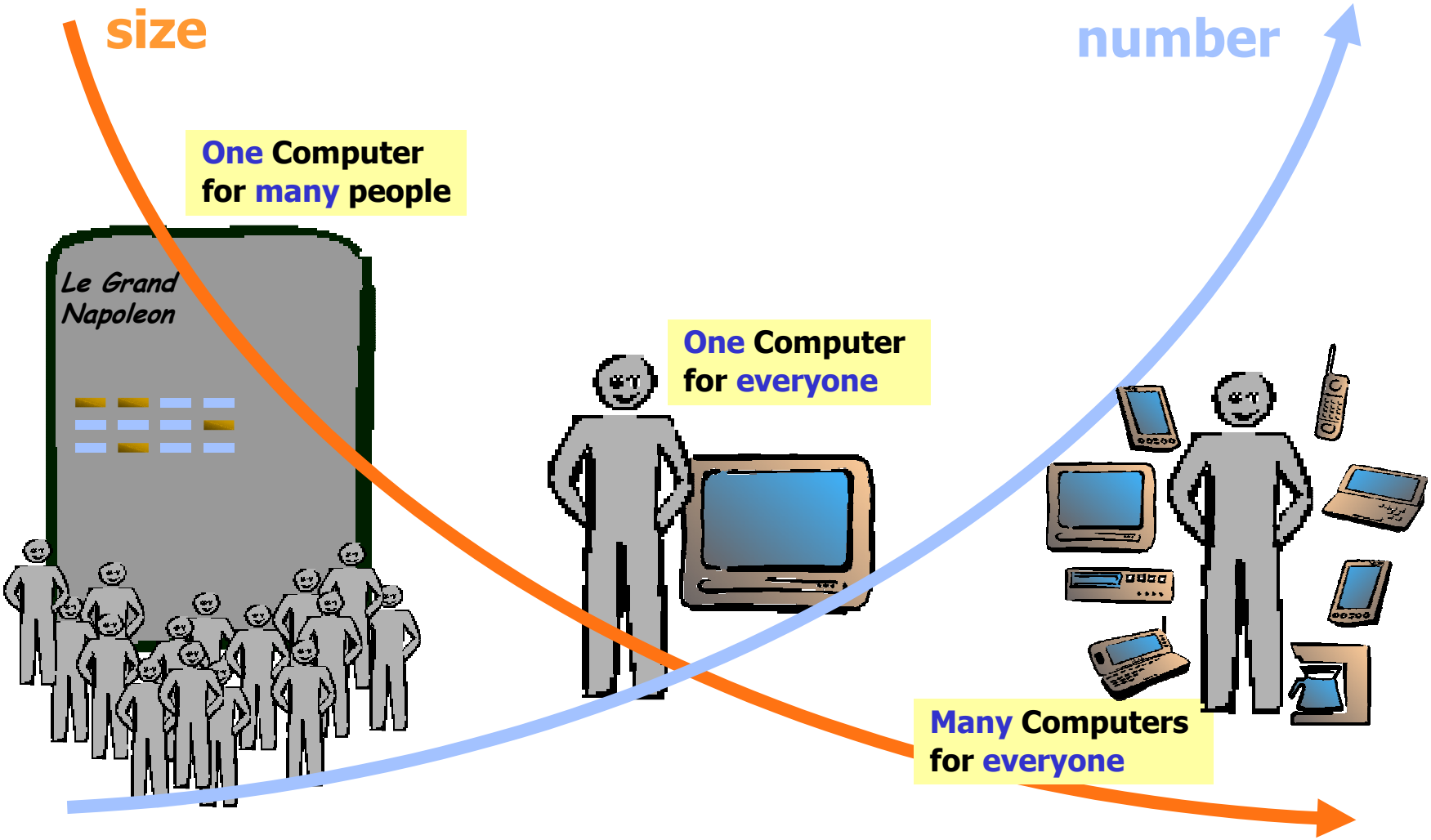


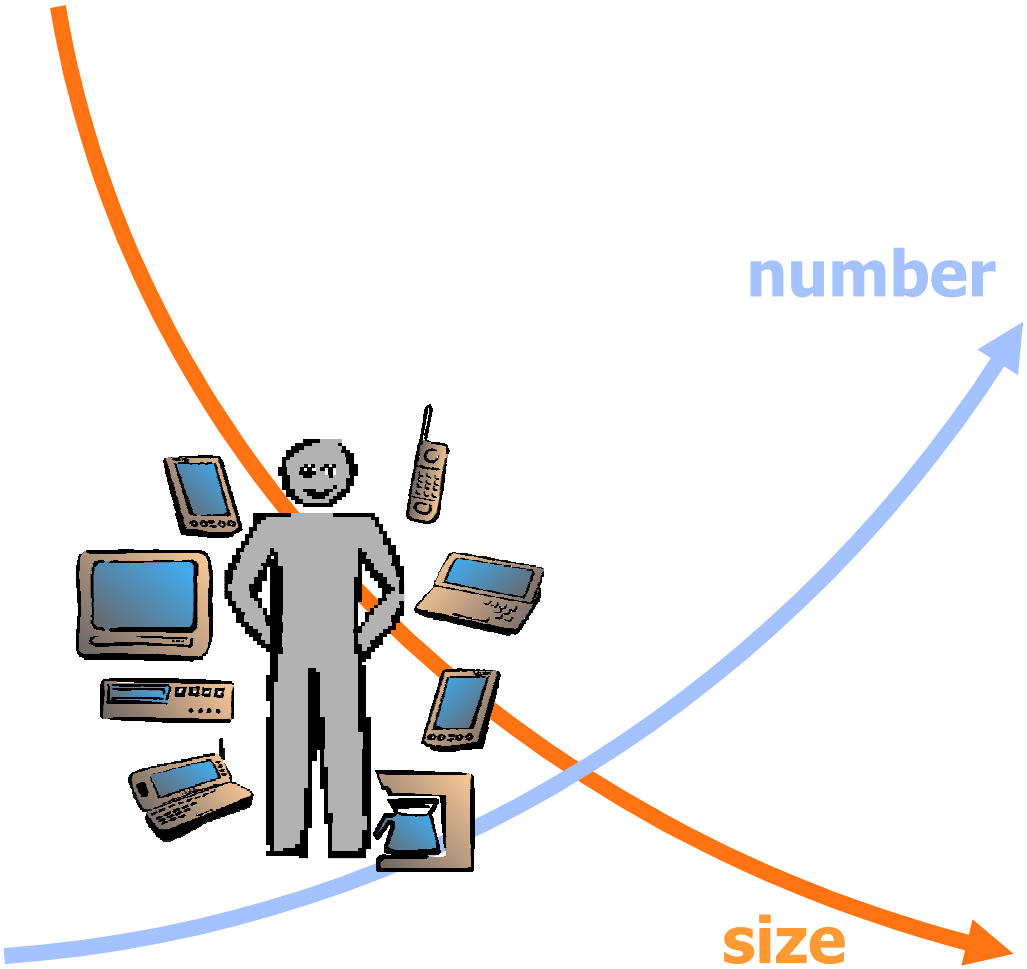
Computer Technology Trends

Computers: Size + Number



adapted from: F. Mattern, Dagstuhl 2002

Size + Number: What's next ?



Coursework:

Fill this space!

Submit to

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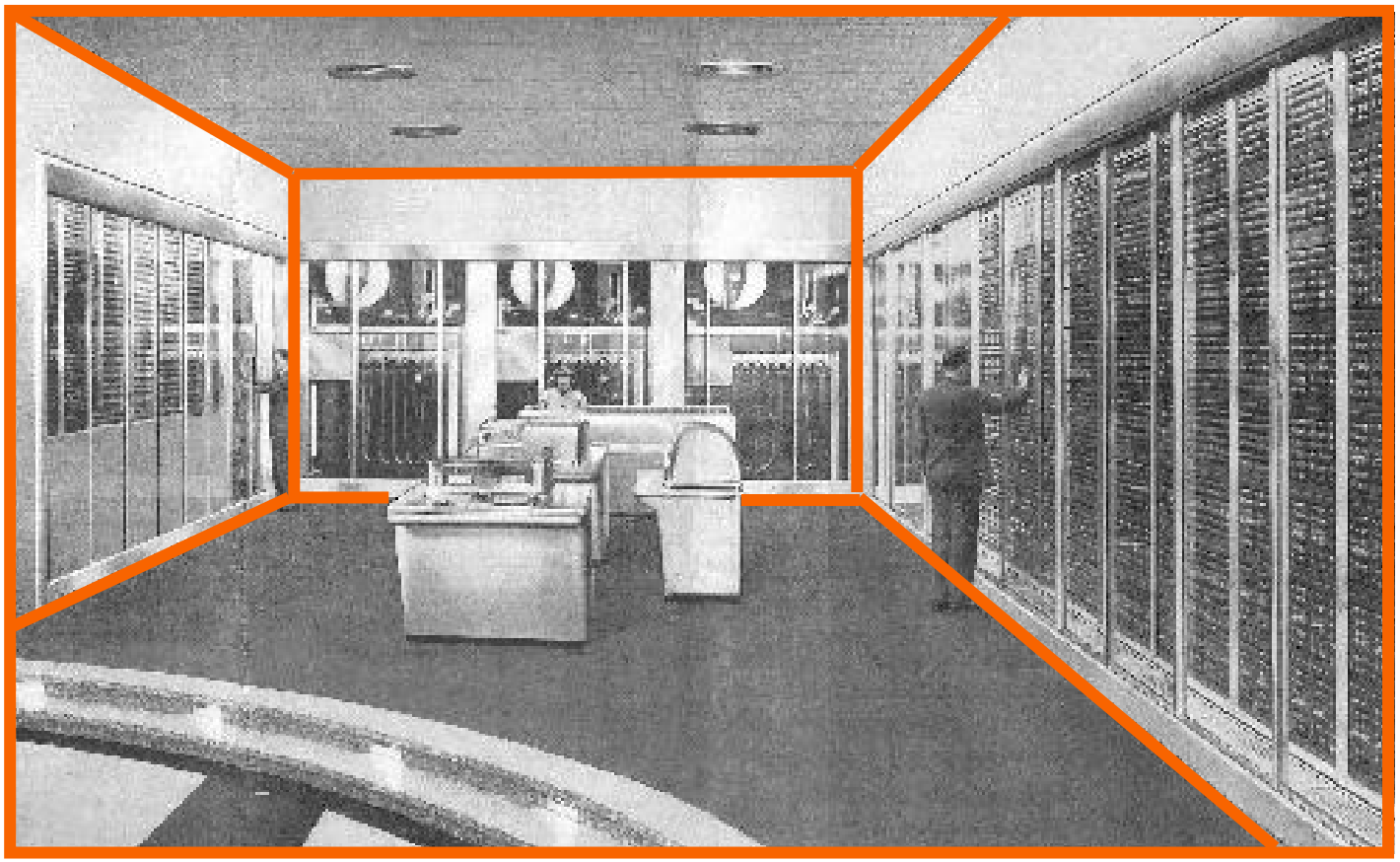
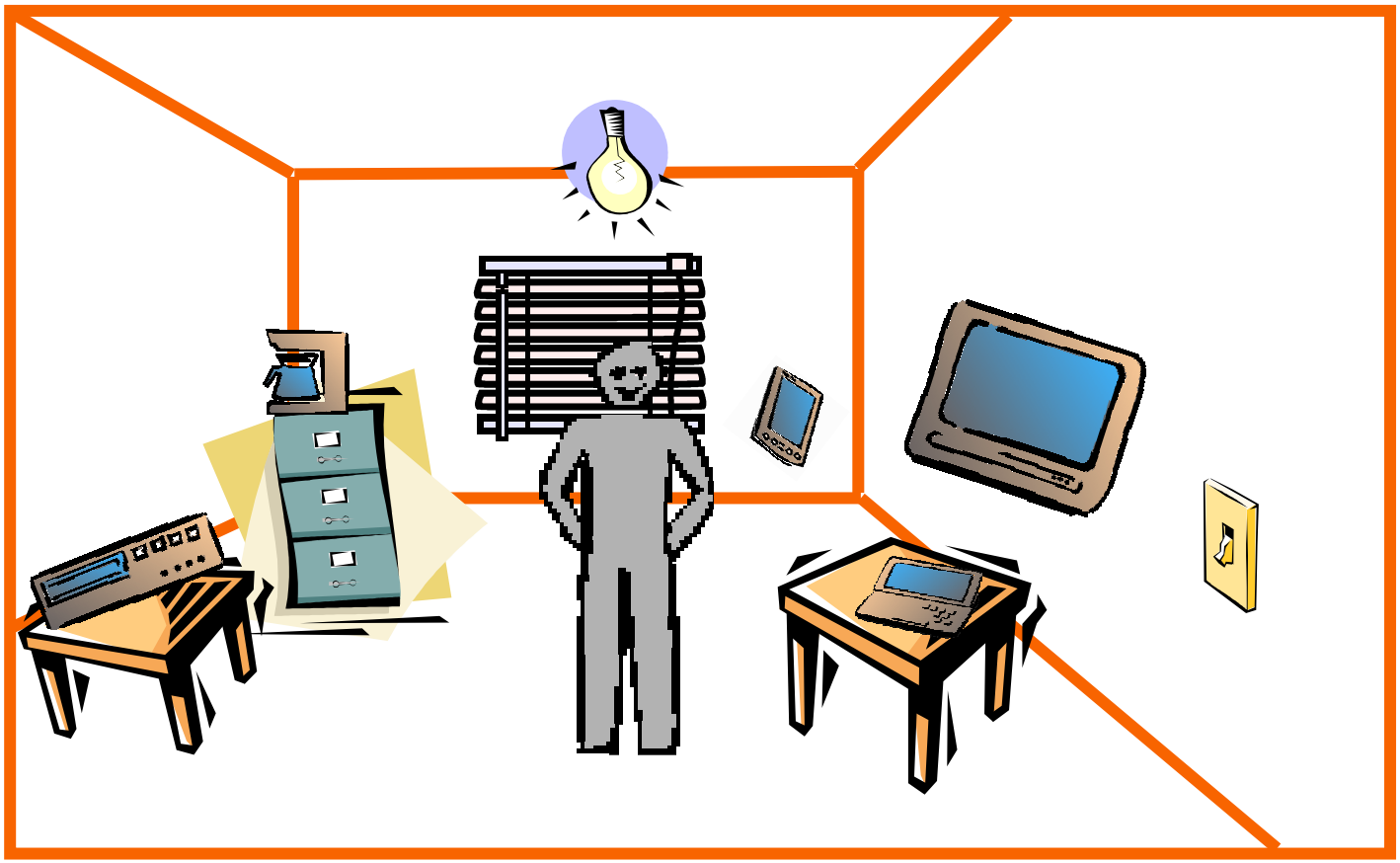
Yesterday's Computers filled Rooms



IBM Selective Sequence Electroinic Calculator, 1948

So will Tomorrow's!

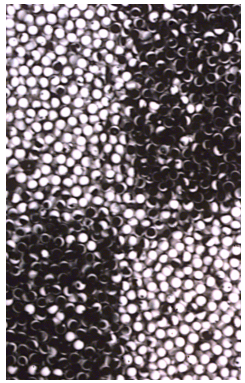


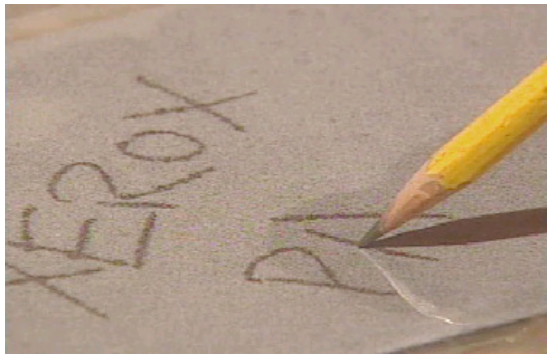
IBM Selective Sequence Electroinic Calculator, 1948

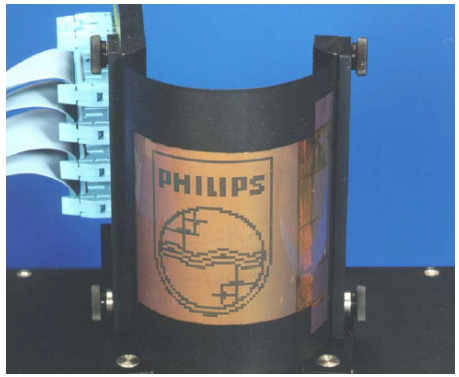
What makes this possible ?

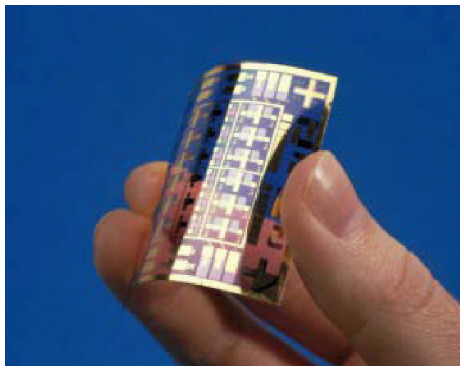
- Microprocessors so small that they can be embedded in practically everything
- Storage so inexpensive and dense that it can be provided everywhere
- Wireless networking for inexpensive short-range connectivity
- New materials for new forms of appearance (e-ink, flexible displays, conductive fibers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

1GB in Flashcard format

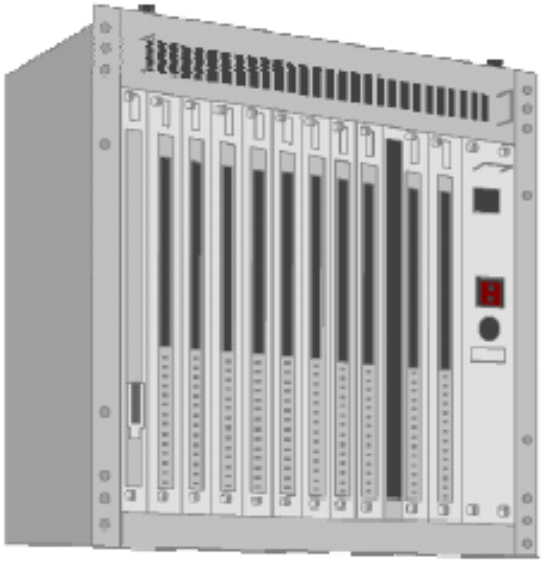




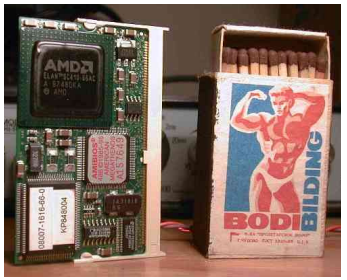




Scaling down



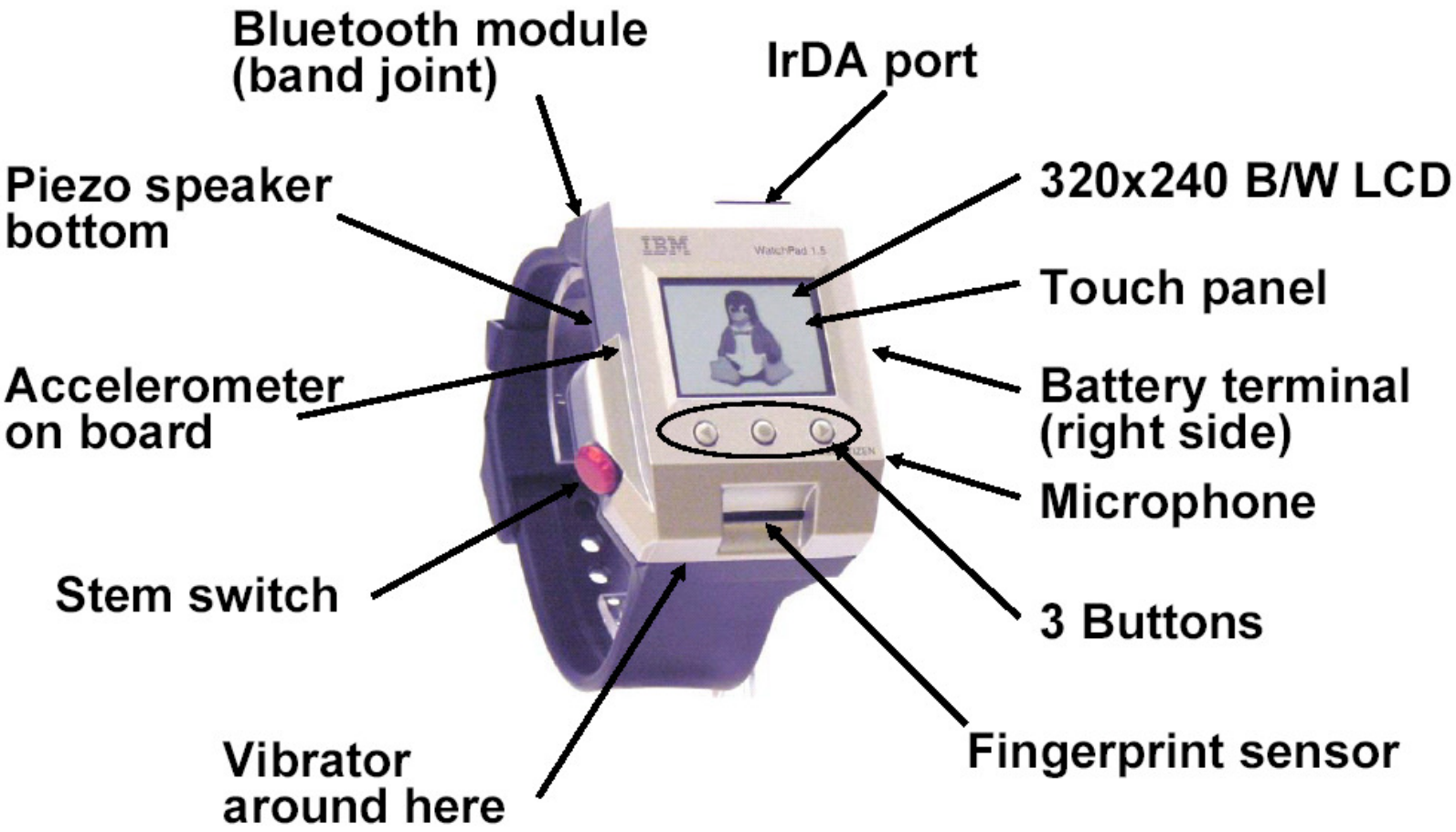
IBM WatchPad1.5



Stanford
Embedded
Web Server

Xerox PARC
Keychain Computer

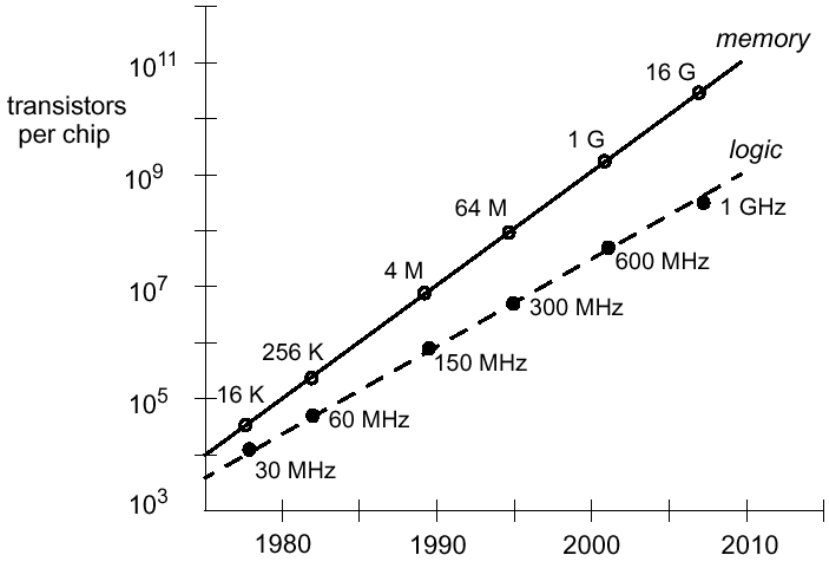
IBM WatchPad 1.5

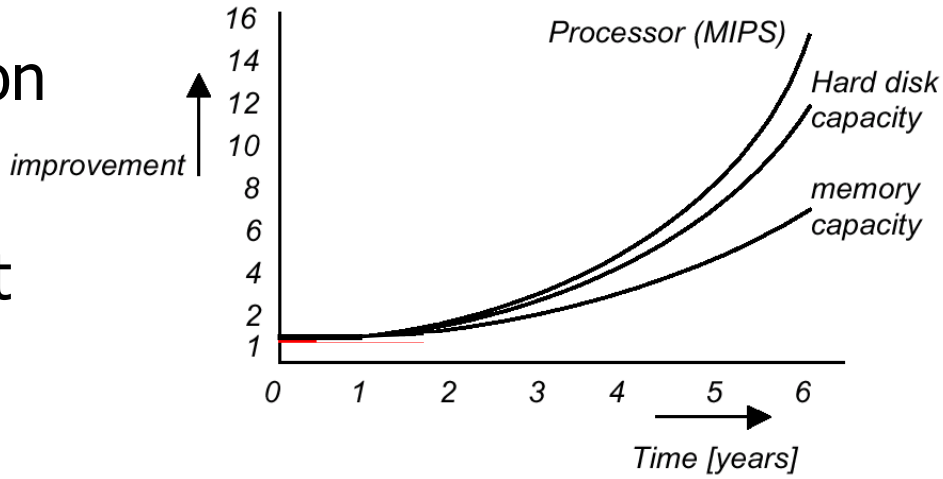


Moore's Law

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





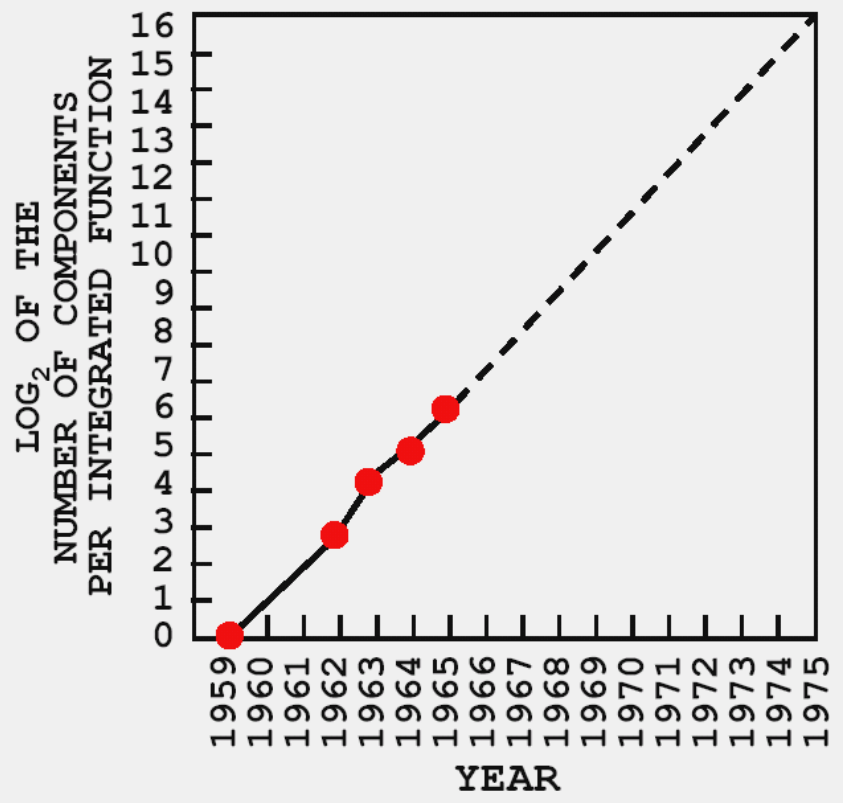
Moore's Law
Electronics, April 1965

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.

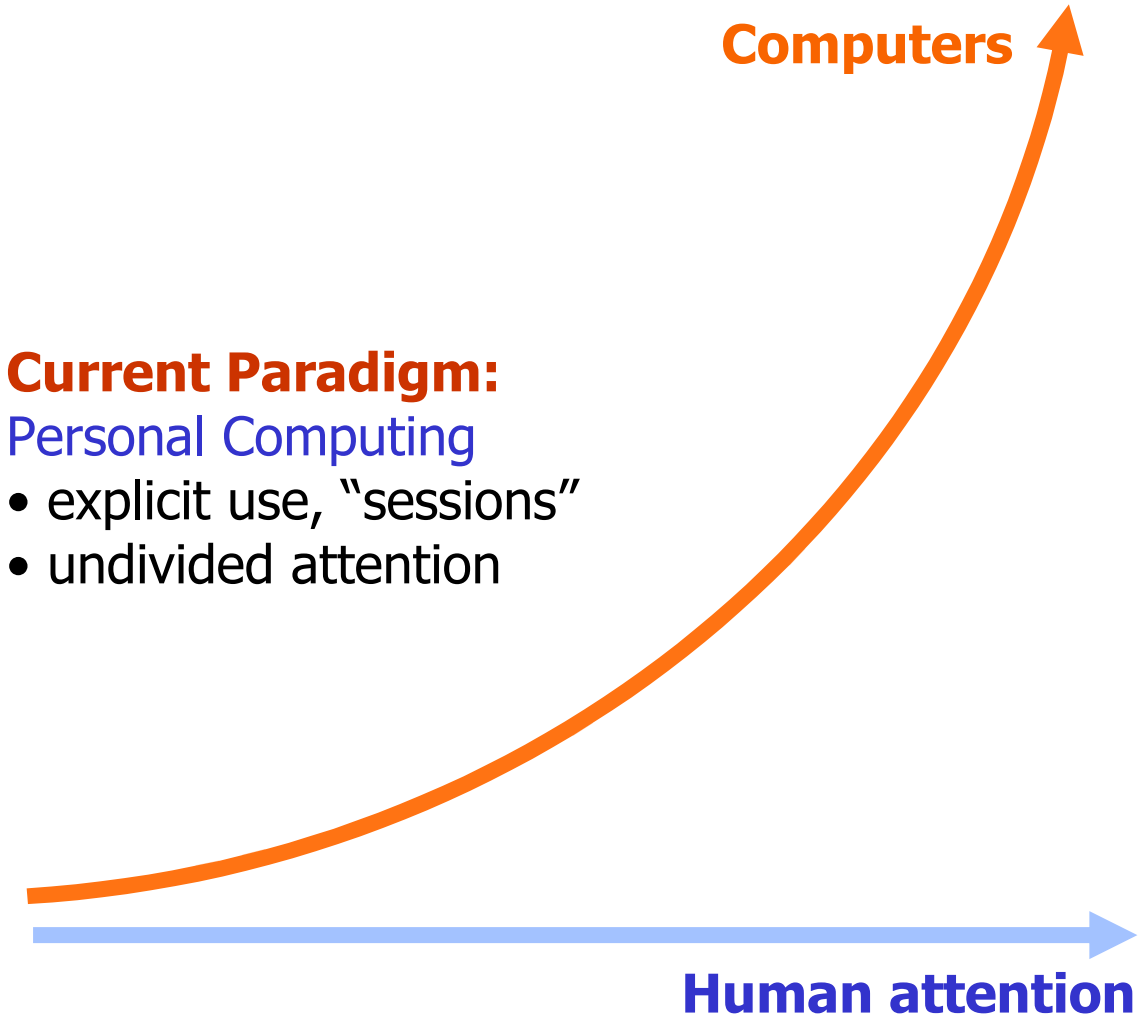
Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment.

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



Current Paradigm:
Personal Computing
- explicit use, "sessions"
- undivided attention

Need Paradigm Shift!

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.

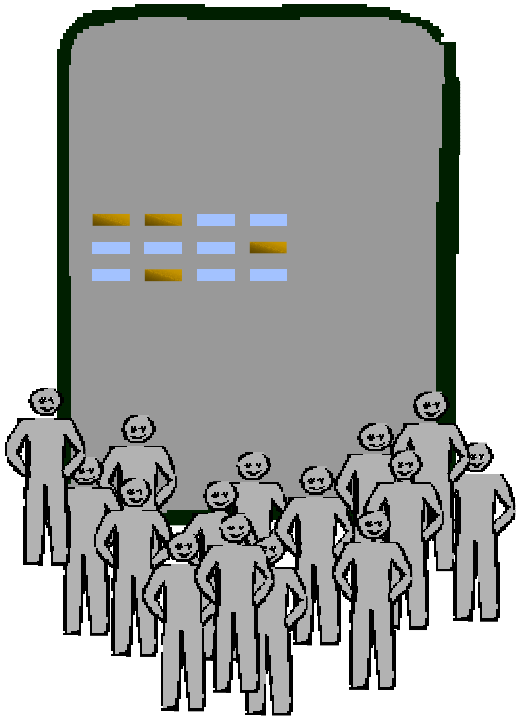
Ubiquitous Computing

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."*

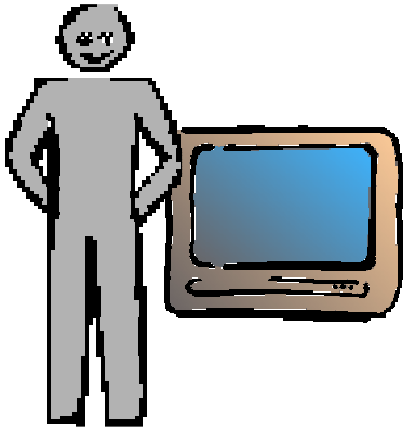
A New Era of Computing

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 Prepration

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

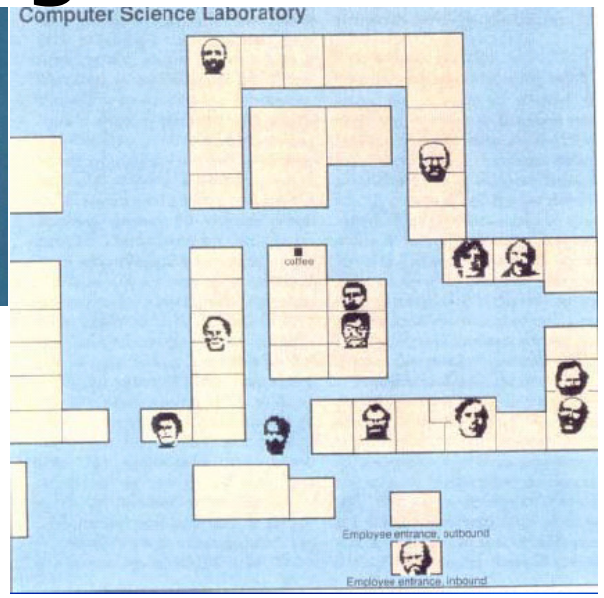
Location-aware Computing

Location is universal

- Everything has a location: people, places, things, activities, events, situations
- Location information can be wonderfully processed in computers
  - powerful index to occurences 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

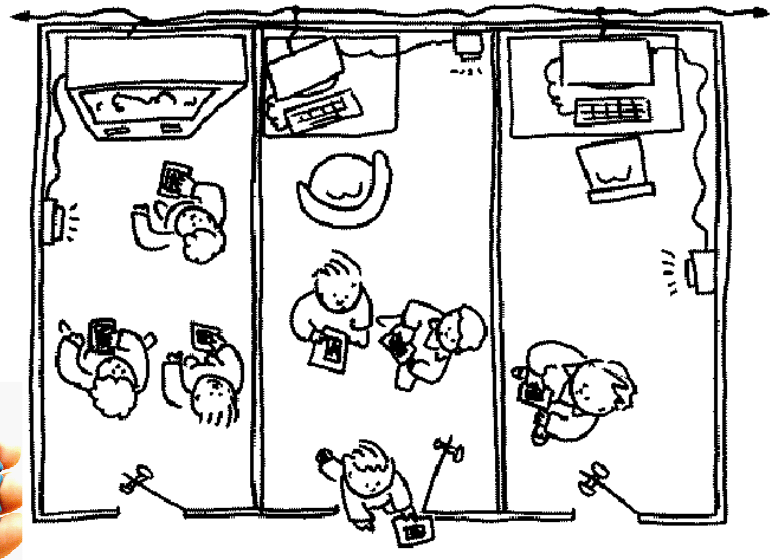


Active Badge Project

- 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

Source: Roy Want, Dagstuhl 2001

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

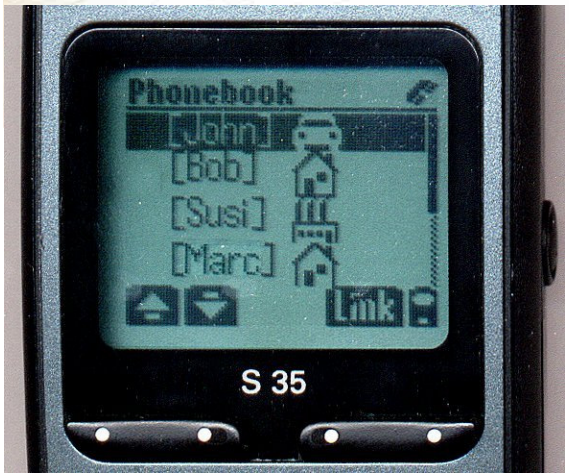
(Karlsruhe/Starlab/Nokia, 1998-2000)

TEA2:
PIC 16F877
8 sensors

Li-Polymer battery

Nokia FBUS

Nokia 6110:
profiles



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

iLinkshort

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

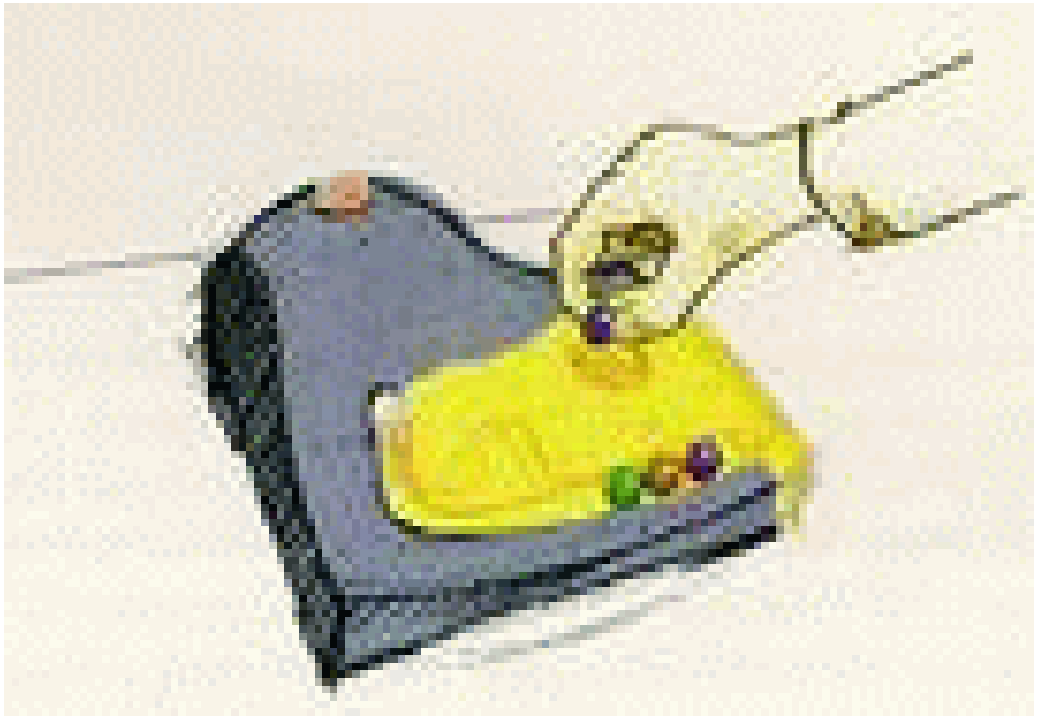
Physical Interaction Experience

- 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

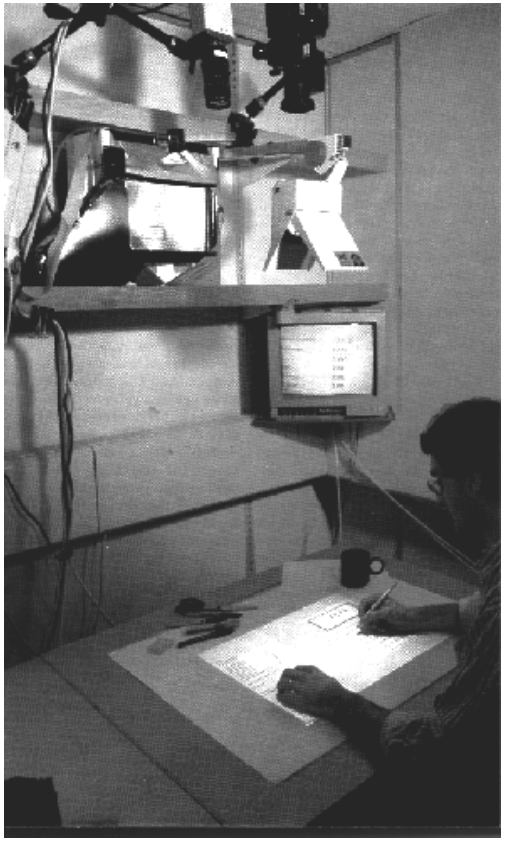
Bishop's Marble Answering Machine

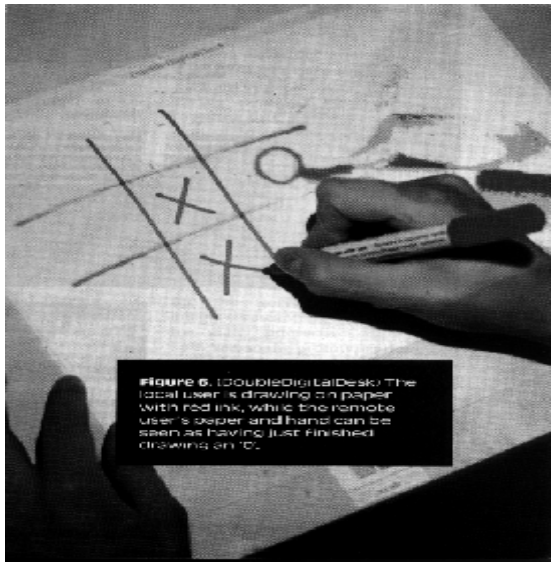
- Physical interaction with digital information

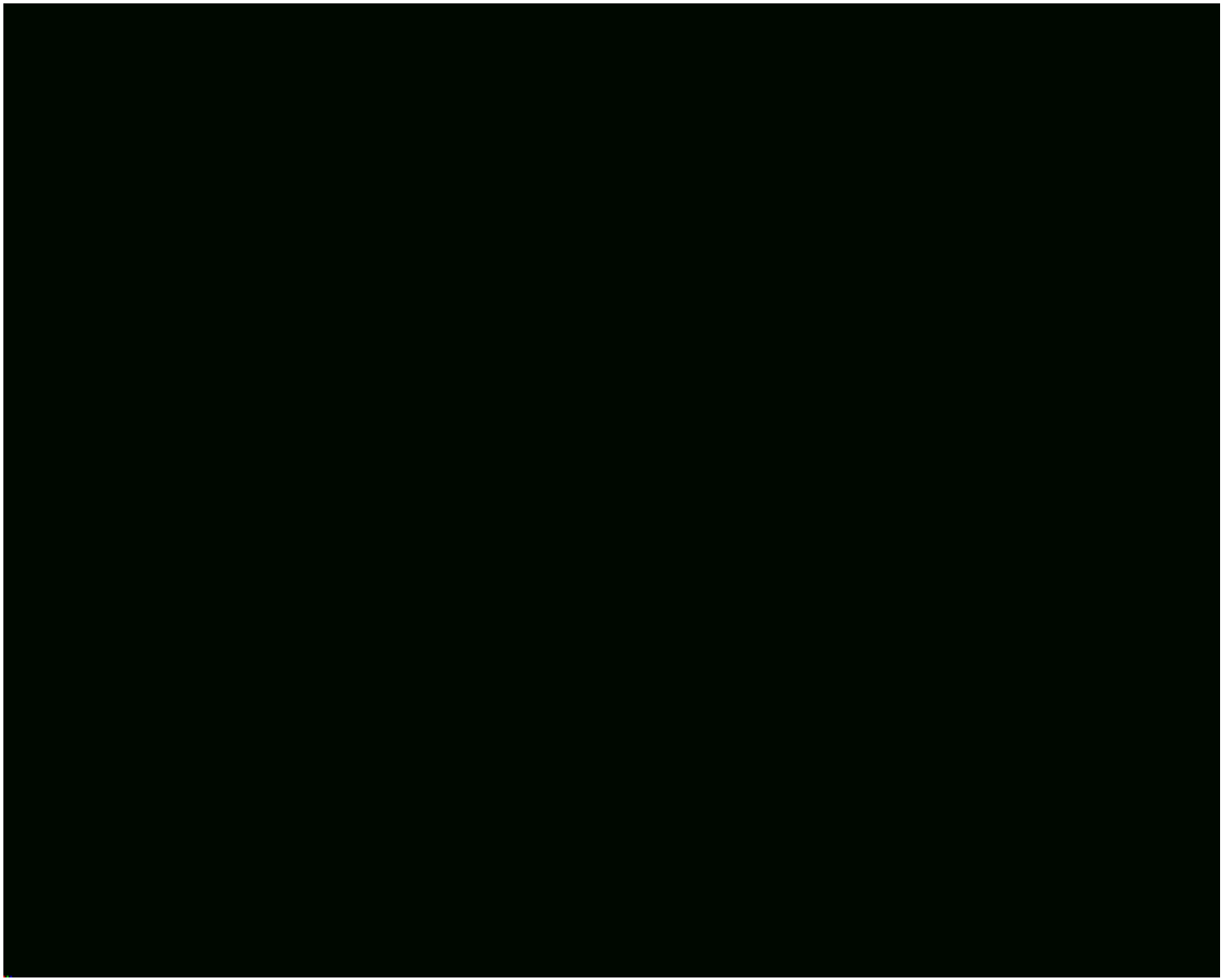


Wellner's Digital Desk

- 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/

Related Material

[7] G. Moore, "Cramming More Components onto Integrated Circuits", Electronics, Vol. 38, no. 8, April 1965, pp. 114-117

[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

[3] B.N. Schillit et al, "Context-Aware Computing Applications", Proc. Workshop on Mobile Computing Systems and Applications (WMCSA'94), IEEE Press, 1994, pp. 85-90

[4] D. Estrin et al, "Connecting the Physical World with Pervasive Networks", in [2]

[5] H. Gellersen et al, "Multi-Sensor Context-Awareness in Mobile Devices and Smart Artifacts", in Mobile Networks and Applications (MONET), Kluwer, Oct 2002

[6] A. Gershman et al, "Situated Computing: Bridging the Gap between Intention and Action", Proc. Intl. Symposium on Wearable Computing (ISWC '99), 18-19 October 1999, IEEE Press

[7] T. Kindberg et al, "People, Places, Things: Web Presence for the Real World", Proc. Workshop on Mobile Computing Systems and Applications (WMCSA'99), IEEE Press.

[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]