Emerging Computing for a Networked World

Mihaela Ulieru
Canada Research Chair

OVERVIEW

- The Vision of Ambient Intelligence
- MOTES – sensing the environment
- Creating Smart Spaces/Environments
- From Perception to Action: CONTEXT
- Context-Aware Computing
- Applications and Case Studies

AmI – The Origins

- “Ambient Intelligence”, a term coined by the European Commission’s Information Technologies Advisory Group (ISTAG) and Philips, is the vision of a world, in which we are surrounded by smart, intuitively operated devices that help us to organize, structure, and master our everyday life.

WWRF's vision of Ubiquitous Computing

- Personal networks
- Immediate environment
- Instant partners
- Radio access
- Interconnectivity
- Cyberworld

What is AmI

- The notion “Ambient Intelligence” specifically characterizes a new paradigm for the interaction between a person and his/her everyday environment:
- Ambient Intelligence enables this environment to become **aware** of the human that interacts with it, his goals and needs.

Goals for this Course

- Provide an overview of this new vision for HCI
- Read and discuss the most relevant articles in related areas: **Smart Environments**, Smart Networked Objects, Augmented Reality, Mixed Reality, **Ubiquitous Computing**, Pervasive Computing, Tangible Computing, Ambient Interfaces, Intelligent Interfaces, **Context-based Systems**, Personalization, **Awareness systems**, Wearable Computing, Smart materials.
- Focus on understanding <u>enabling technologies</u> and studying <u>applications</u> and <u>experiments</u>. To a lesser extend address the social-cultural impact.
- Come up with new ideas, start innovative projects in this area

Requirements for the students

- Students are required to participate extensively in literature research and class discussions
  - Read required readings ahead of class & prepare ½ page of questions & interesting points for discussion
  - Review & present at least one topic in class
  - Write one short “scenario” paper
  - Suggest additional papers to read
  - Suggest experiments & technologies to look at
- Students are required to design and implement an original project in this area and describe their project in a 3-page paper as well as make a presentation to the class

To Do's

- At next class: return expression of interest
- By January 18:
  - Read required 2 readings and prepare ½ page questions & comments, email to Ulieru@
- By Jan 23 Write application scenarios paper (1 or 2 pages)

The Backbone of AmI

- The vision of Ambient Intelligence is based on the ubiquity of information technology, the presence of computation, communication, and sensorial capabilities in an unlimited abundance of everyday appliances and environments.
- Today's experimental smart environments are carefully designed by hand, but future ambient intelligent infrastructures must be able to configure themselves (self-organize) from the available components in order to be effective in the real world.

Ubiquitous Computing

- From Webster:
  - Main Entry: **ubiq·ui·tous**
    Pronunciation: yü-'bi-kw&-t&s
    Function: *adjective*
    Date: 1837
    : existing or being everywhere at the same time **:** constantly encountered **:** **WIDESPREAD**
- First envisioned and formulated by Mark Weiser (Xerox PARC) c. 1990.
- Also Known As “pervasive computing” and “ambient intelligence”

Ubiquitous

- • American Heritage Dictionary:

being or seeming to be everywhere at the same time; omnipresent.

- • Merriam-Webster Dictionary: existing or being everywhere at the same time; constantly encountered; widespread
- • Ubiquitous computing?

Ubiquitous Computing

- • Mark Weiser, Xerox PARC 1988
- • “Ubiquitous computing enhances computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user.”
- Source: Weiser, 1993a

What UbiComp is NOT

- • Ubiquitous computing is not virtual reality, it is not a Personal Digital Assistant (PDA) such as Apple's Newton, it is not a personal or intimate computer with agents doing your bidding.
- – Unlike virtual reality, ubiquitous computing endeavors to integrate information displays into the everyday physical world.
- It considers the nuances of the real world to be wonderful, and aims only to augment them.
- – Unlike PDAs, ubiquitous computing envisions a world of fully connected devices, with cheap wireless networks everywhere;
- unlike PDAs, it postulates that you need not carry anything with you, since information will be accessible everywhere.
- – Unlike the intimate agent computer that responds to one's voice and is a personal friend and assistant, ubiquitous computing envisions computation primarily in the background where it may not even be noticed.
- Whereas the intimate computer does your bidding, the ubiquitous computer leaves you feeling as though you did it yourself.

Weiser's Vision

- • Idea of personal computer is misplaced
- • Vision of laptop machines, dynabooks and knowledge navigators is only a transitional step: these machines cannot make computing an integral, invisible part of life
- • Creating computers which vanish into the natural human environment
- • "Most profound technologies are those that disappear"

AmI VISION

- **Ambient Intelligence envisions a world where people are surrounded by intelligent and intuitive interfaces embedded in the everyday objects & physical environments around them. These interfaces recognize and respond to the presence and behaviors of an individual in a personalized and relevant way.**

Augmented physical environments

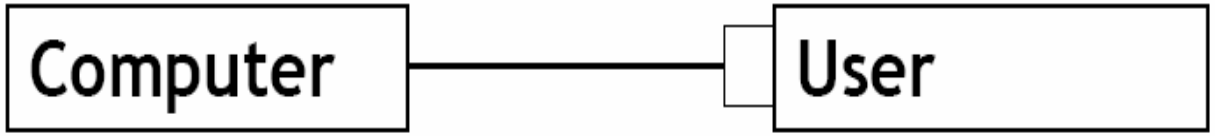
- Walking around town, system points out buildings/places of particular interest to a user (based on user's interests)
- Books on a bookshelf can "speak out" to you (or posters in corridor)

Augmented Reality

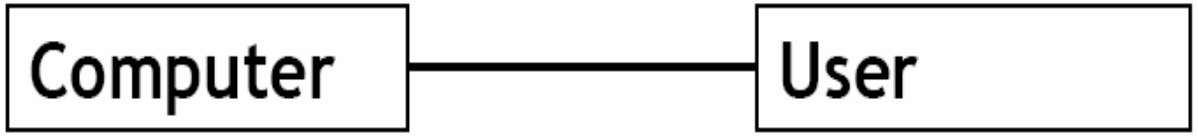
- Overlays a virtual layer to the physical environment and thereby makes computing power (mostly visually) appear in the environment although it is physically located elsewhere.

Ubiquitous Computing

- Phase I - The Mainframe Era



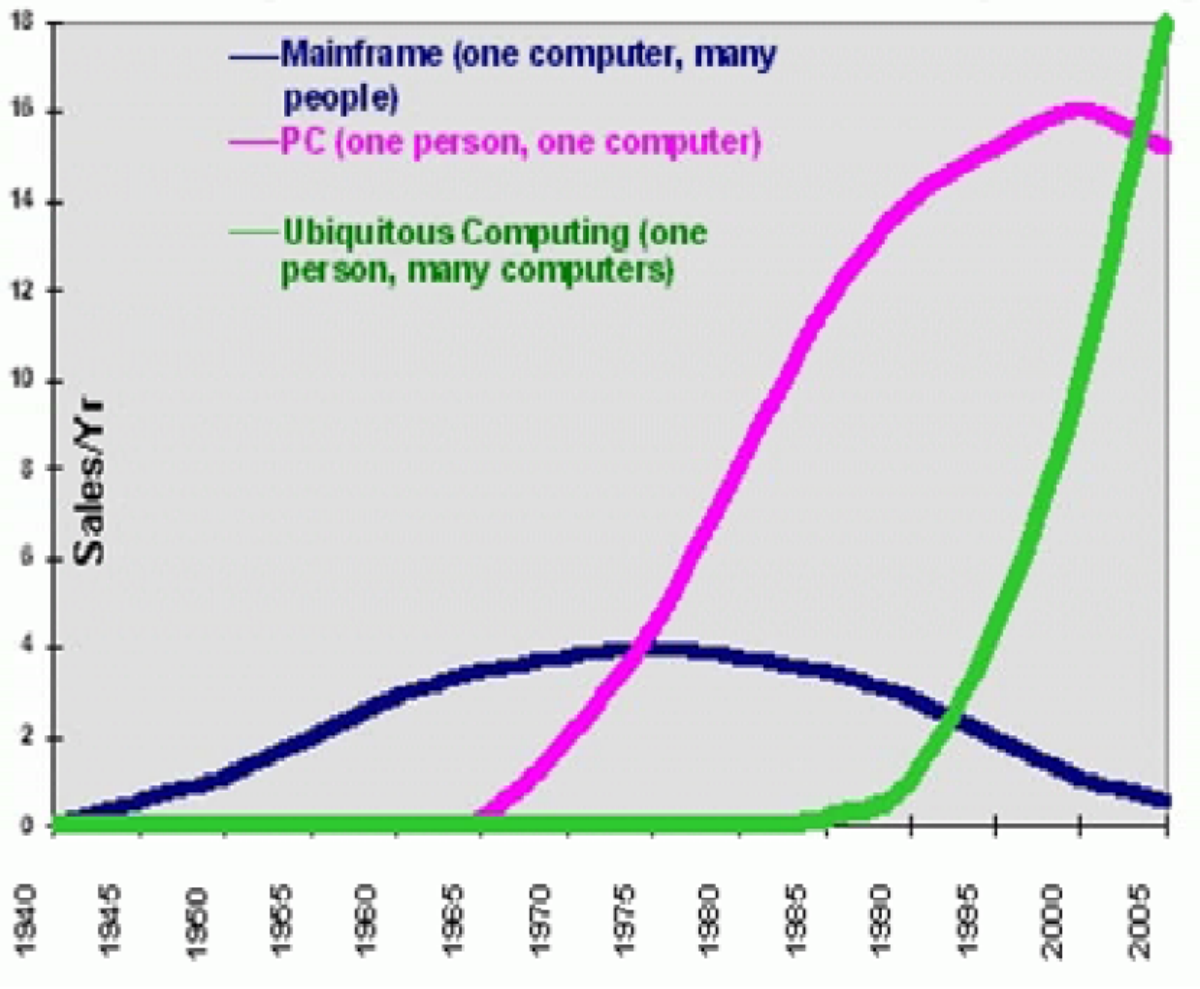
- Phase II - The PC Era



Transition: Internet and distributed computing

- Phase III - The UC Era

Major Trends in Computing



Source: Weiser, 1998

UbiComp Characteristics

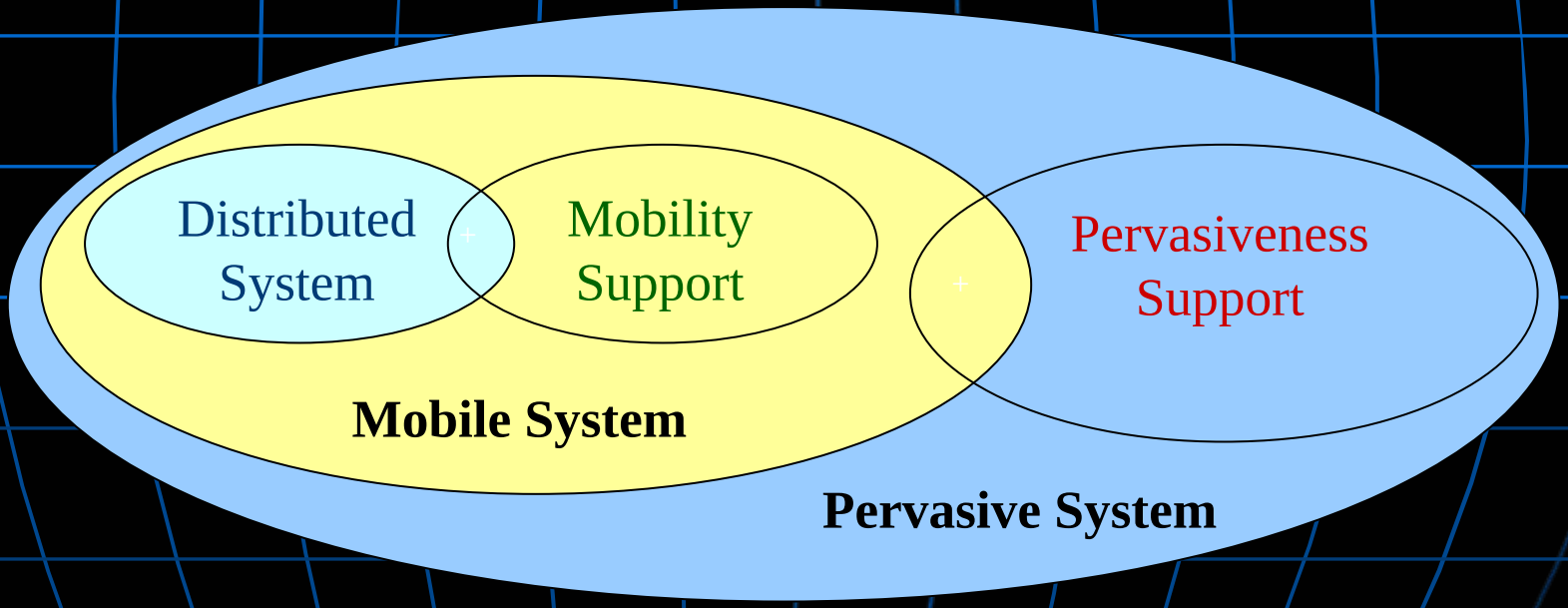
- **Calm technology**
  - Suggests but does not interrupt
  - As natural as thermostats or street lights
  - From interacting to “living with” computers
- **Depends on our peripheral attention**
  - Easy change between focus and periphery
  - User takes control by focusing
  - Example: car engine, we note problems fromstrange sounds

Pervasive Computing

- Closely related, almost synonymous term
- Pervasive: “that pervades or tends to pervade”
- To pervade: “to become diffused throughout every part of”
- Mobility, not just access to invisible computers
  - seamless mobility session mobility
  - adaptation to local capabilities
  - **environment senses** instead of explicit user interaction
  - from small dumb devices to PCs

Background Technologies

- Mobile Systems
- Pervasive Systems



Distributed Systems

- Research involving two or more computers connected by a network
- Areas foundational to pervasive computing:
  - **Remote communication**: protocol layering, RPC, end-to-end argument
  - **Fault tolerance**: atomic transactions, two phase commit
  - **High availability**: replica control, mirrored execution, recovery
  - **Remote information access**: caching, function shipping, distributed file system
  - **Security**: authentication, privacy

Mobile Computing (1/2)

- Research on building distributed systems with mobile clients
- Principles in distributed system design still apply
- 4 constraints to distinguish it from distributed systems and demand new research
  - Unpredictable variation in network quality
  - Lowered trust and robustness of mobile elements
  - Limited local resources imposed by weight and size
  - Battery power consumption

Mobile Computing (2/2)

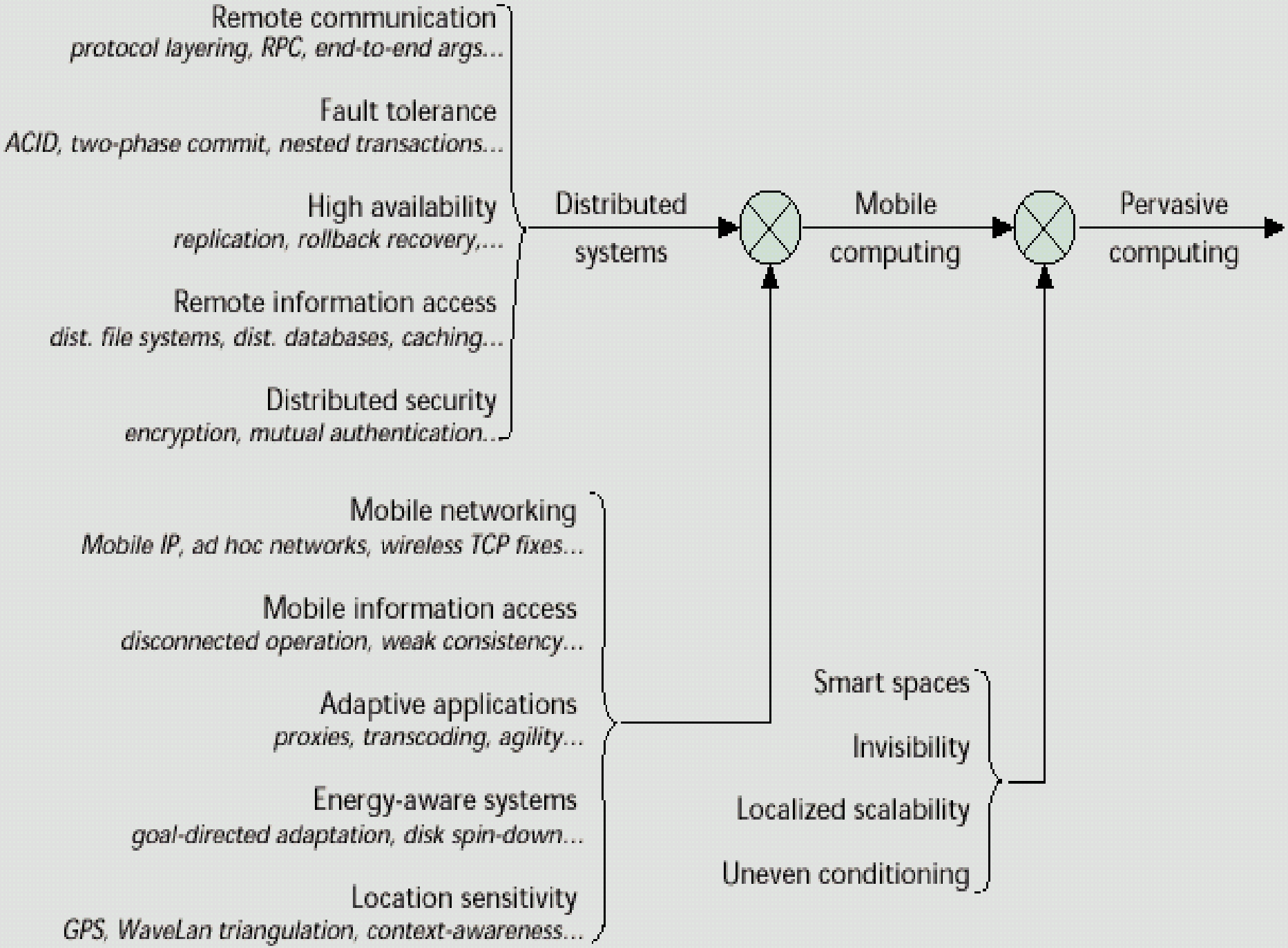
- Research areas:
  - **Mobile networking**: mobile IP, ad hoc protocols, improving TCP performance in wireless networks
  - **Mobile information access**: selective control of data consistency
  - **Support for adaptive applications**: transcoding by proxies
  - **System-level energy saving techniques**: energy-aware adaptation, variable speed processor scheduling
  - **Location sensitivity**: location sensing, location-aware system behavior

Distributed Mobile Systems

- Provide ubiquitous computing power by coordinating and integrating multiple mobile devices and distributing functionality across them.
- DMS is closest to the original ubiquitous computing concept and subsumes among others the term *context-aware computing*

Pervasive/Ubiquitous Computing

- Pervasive computing environment:
  - An environment saturated with computing and communication capability, yet so gracefully integrated with users that it becomes a "technology that disappears"
- Subsume distributed computing and mobile computing, but incorporate 4 additional research thrusts (next figure)


Remote communication
protocol layering, RPC, end-to-end args...
Fault tolerance
ACID, two-phase commit, nested transactions...
High availability
replication, rollback recovery,...
Remote information access
dist. file systems, dist. databases, caching...
Distributed security
encryption, mutual authentication...
Distributed systems
Mobile computing
Pervasive computing
Mobile networking
Mobile IP, ad hoc networks, wireless TCP fixes...
Mobile information access
disconnected operation, weak consistency...
Adaptive applications
proxies, transcoding, agility...
Energy-aware systems
goal-directed adaptation, disk spin-down...
Location sensitivity
GPS, WaveLan triangulation, context-awareness...
Smart spaces
Invisibility
Localized scalability
Uneven conditioning

Related Terms

- • Proactive Computing
- • Augmented Reality
- • Mobile Computing
- • Intelligent Environments
- • Ambient Intelligence
- • We will use the short term "UbiComp"

Information Appliances

- Information Appliances are computers that are specialized for a certain task
- Can work together
- Are based on a well-developed underlying infrastructure

UbiComp Vs. Information Appliances

- **Ubicomp**

– Computers invisible, embedded in the environment
– Peripheral
– Integrated

- **Information Appliances**

– Computers embedded in specialized tools
– Concrete, simple
– Functional
• In practice, the difference is smaller:

appliances become cognitively unnoticeable in time – e.g., a wrist watch

AmI Paradigm

- **Radically rethink the human-computer interactive experience:**
  - **Integrate digital world (information & services) and physical world (physical objects/environment)**
  - **Make interfaces more responsive and proactive (objects & environment monitor user and (proactively) present information & services relevant to user's current needs/interests)**

Some scenarios

- Ambient semantics or "enriching your every day experience"
  - Book tells you about friends/famous people that loved it
  - Book tells you about particularly interesting passages
  - Touching 2 books makes their connections appear
  - Picking up book makes relevant music play

Some scenarios (Cont.)

- Augmented physical environments
  - Objects around you can draw your attention (e.g. books on a bookshelf of specific interest to you)
  - Walking around town, system points out buildings/places of particular interest to a user (based on user's interests)

Aware Objects – David Gatenby (2004)

Objects in the user's vicinity exchange info with the user's cell phone (via bluetooth) and light up if they are relevant

Photowhere: Automated Annotation of Photographs

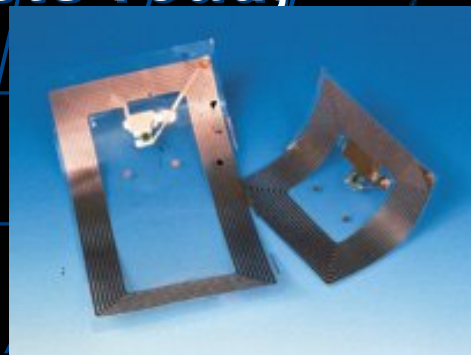
- Relihan (2004)

Phone Camera communicates with GPS device via bluetooth to record location of picture taken. Phone interfaces to www.metacarta.com to find urls about that location. Extracts and offers keywords for the picture taken (to be edited by the user).

Ambient semantics
Liu, Cooley & Maes (2004)

- User wears RFID reader (integrated in watch / bracelet)
- Every object that user picks up gets read (without requiring user's attention)
- "meaningful" knowledge is presented on nearby display (eg cell phone) (based on last object read, history of objects read, personal profile of user)

13.56 protocol fromTagsense

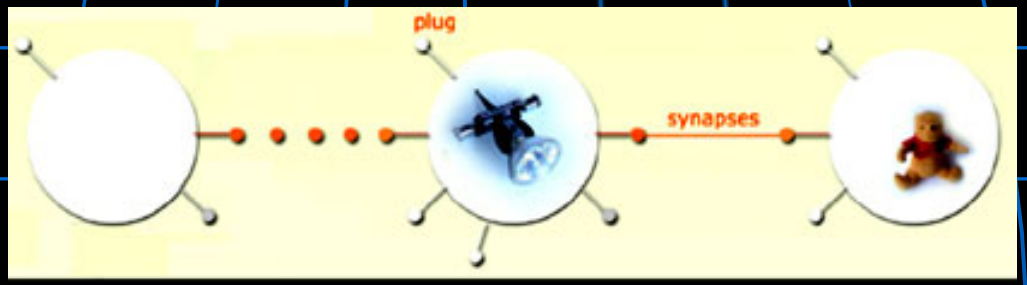


eGadgets

About 10 different objects are now converted to extrovert Gadgets.
A first prototype software tool, the Editor, helps to manipulate e-Gadgets and make synapse links between them.

http://flow.doorsofperception.com/content/mavrommati_trans.html

eGadgets



objects capabilities can be associated together via invisible links
in many possible ways

a collection of objects functioning together in this way
to serve one specific purpose is a Gadgetworld

The result of linking objects together via invisible links, is a Gadgetworld. A distinguishable, specific configuration of associated eGts formed purposefully by a designer, a user, or even an intelligent agent. A Gadgetworld consists of artifacts which communicate and collaborate in order to realize a collective function.

http://flow.doorsofperception.com/content/mavrommati_trans.html

Why UbiComp is not already a Reality?

- • Working systems a big challenge
- • No killer-app? Not a good reason!
- • Compare with the mouse:

– Mouse cheap; ubicomp components cheap but a full system may be expensive

– Mouse used to control all applications, not a killer-app; ubicomp environments need to become more common in general

- – Even the mouse took 20 years!

Design Exercise

- • Work in pairs
- • Think of ways for turning this lecture room into an ubiquitous room
- – What kind of services and applications would fit the ubicomp goals?
- – Are they technologically realistic?
- • In 5-10 minutes, we'll start collecting the ideas

UbiComp Lecture Room Ideas

Secure teacher identification for equipment adjustment

- – Making use of lecture room schedule
- Screens embedded in the desks
- – Access to the Internet (sources, dictionary) [booed by teacher]
- – Translation into different languages (student identification based on fingerprint?)
- – Personal note taking in class for later use
- – Solutions to group assignments projectable for all to see
- Speech interaction by teacher
- Student identification
- – Seeing names of students
- – Tracking student activity [booed by students]
- Remote attendance
- – Video conference facility
- – Automatic capturing of the lecture