Emerging Computing for a Networked World
Lecture 2

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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

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.

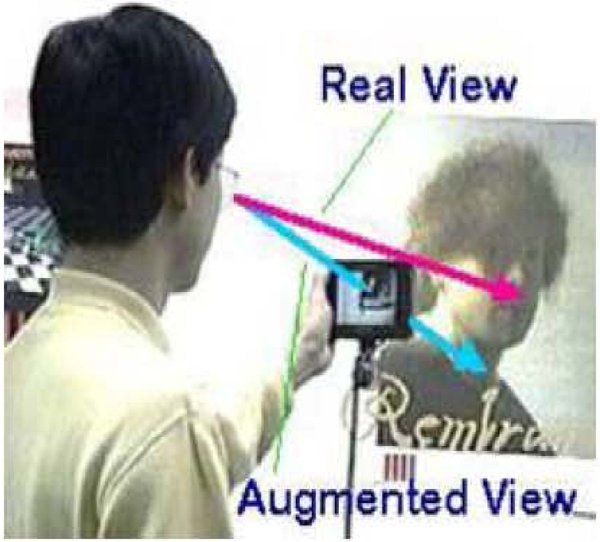
Assignment 1

- Illustrate with at least one example why augmented reality, PDAs and ‘intimate’ computers are NOT UbiComp.

- Hand in today
- Also hand in the class exercise from Lecture 1

Object Identification: Augmented Interaction

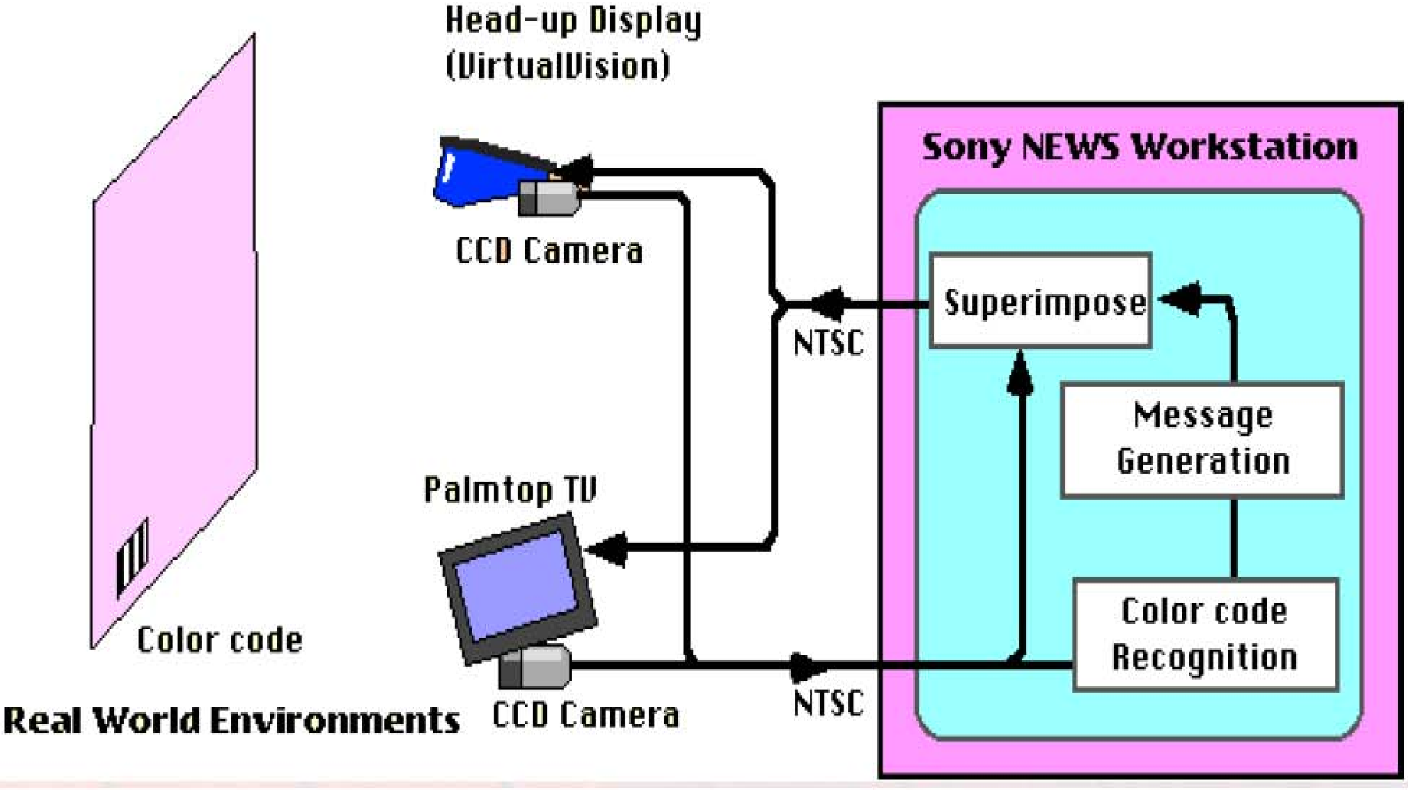
- Jun Rekimoto: Navicam
- Objects tagged with bar codes
- Objects identified with portable bar code readers
- Physical world augmented with additional information
- Observe:
  - Static id, dynamic content
  - User tracking object ⇒ need to carry along a special device



Source: http://www.csl.sony.co.jp/person/rekimoto/navi.html

Implementation of NaviCam

- Architecture: CCD camera (videocamera) and computer generated superimposed annotations about the real world environment
- Either PDA or head-up display



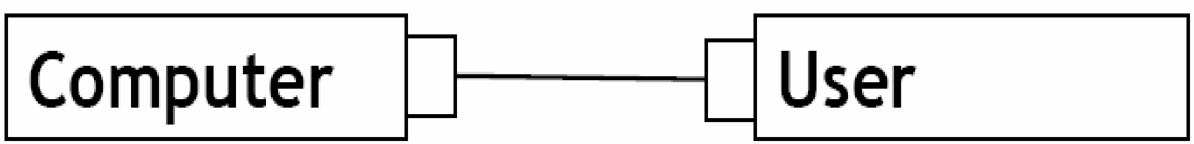
Ubiquitous Computing

- Phase I - The Mainframe Era

- Phase II - The PC Era

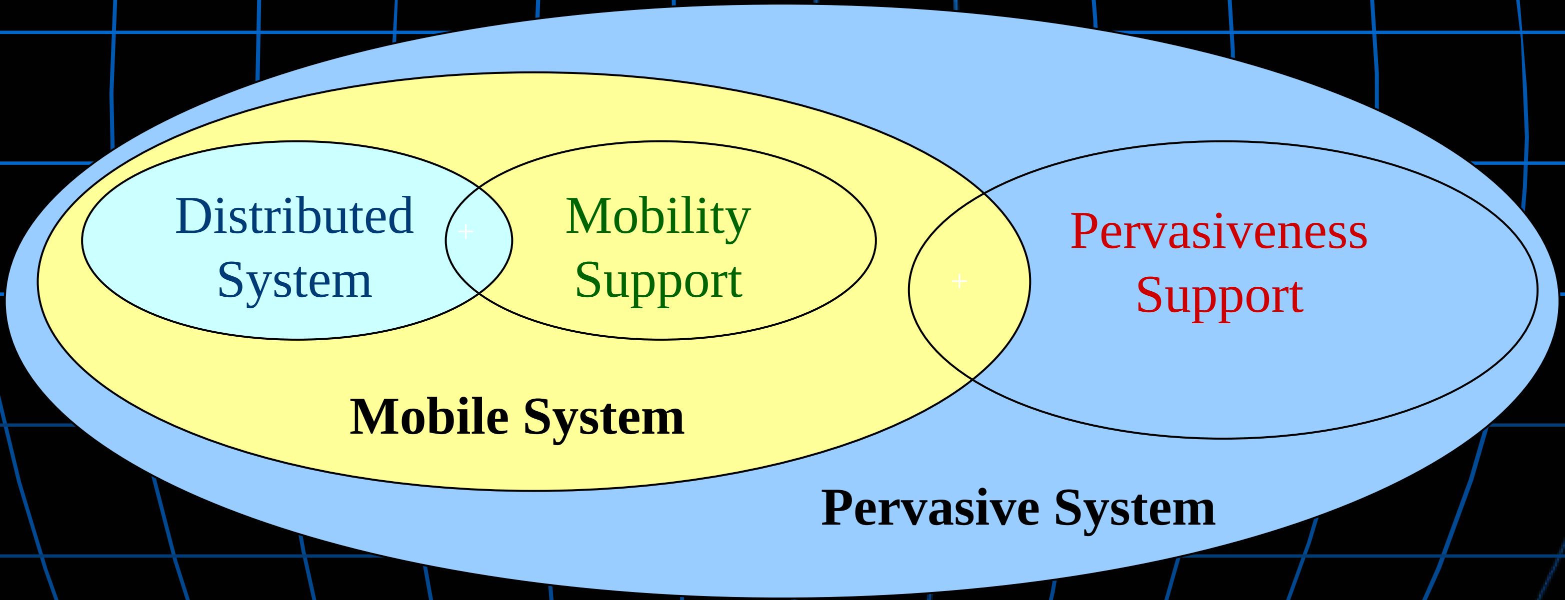
Transition: Internet and distributed computing

- Phase III - The UC Era



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)

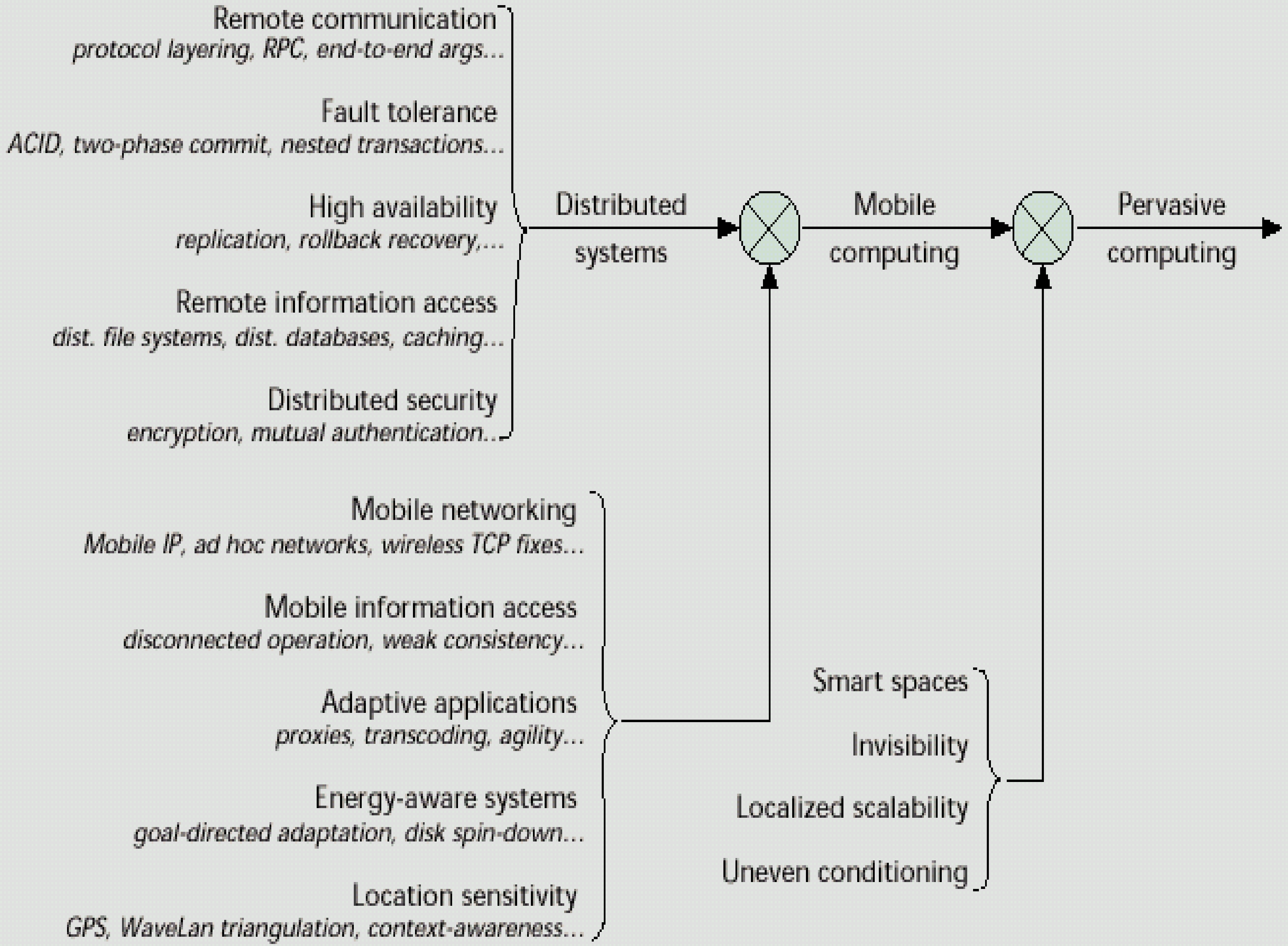
- Research areas:
  - **Mobile networking**: mobile IP, ad hoc protocols, improving TCP performance in wireless networks
  - **Mobile information access**: selective control of data consistency
  - **Support for adaptive applications**: transcoding by proxies
  - **System-level energy saving techniques**: 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

Intelligent Environments

- Human activity
  - Real physical objects → the computer monitor
    - Ex) E-mail, electron documents, visual presentation, ...

But, this general observation does not hold true When it comes to meetings and group work!

Intelligent Environments

- Embed sensors, actuators and/or processors into the environment and thereby achieve behavior which was previously impossible.
- Parts of the ubiquitous computing power therefore reside in the actual objects of the environment, while others are still located on backend systems.
- Also subsumes the terms smart spaces, instrumented rooms, as well as embedded systems.

Interaction

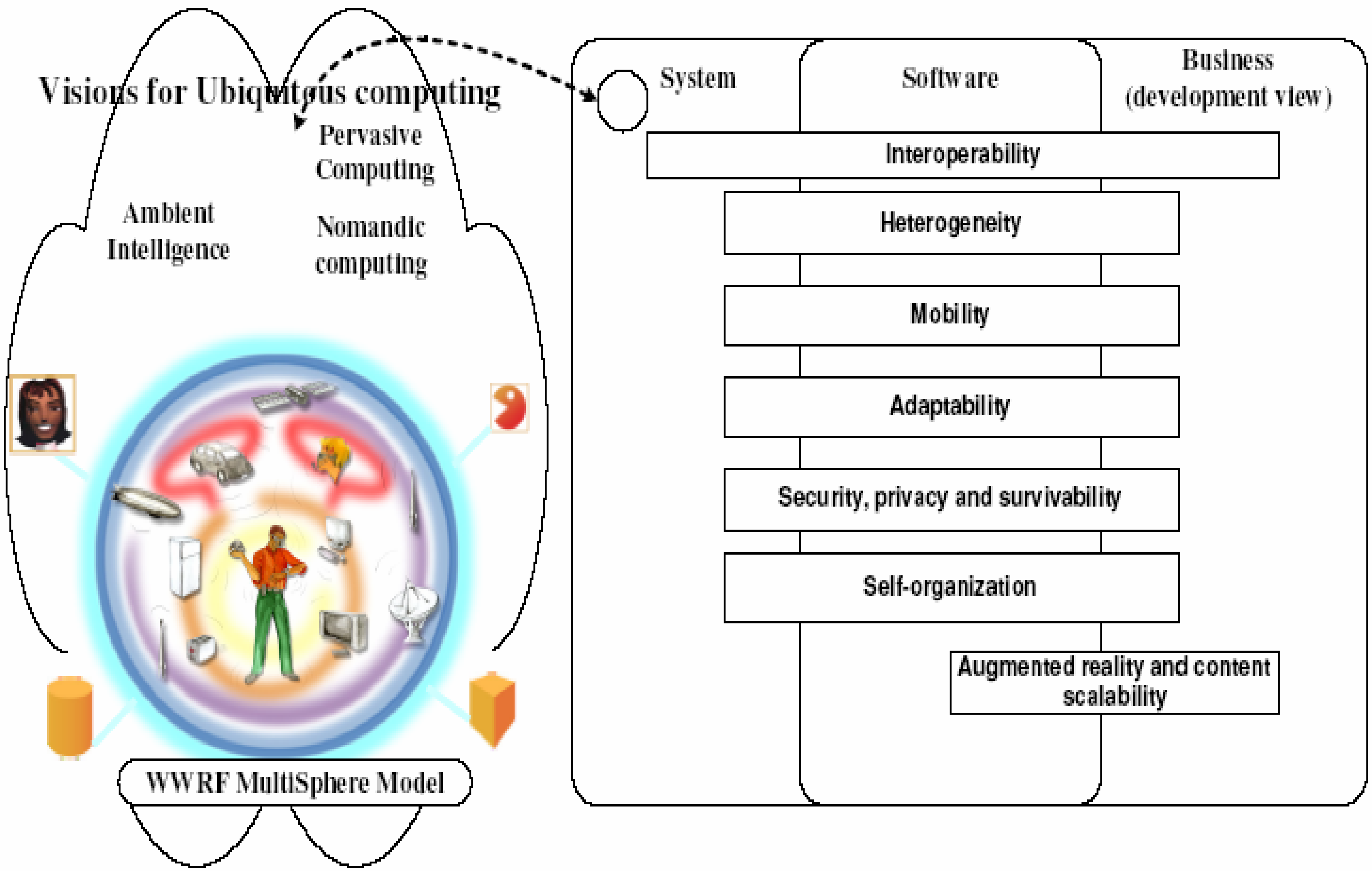
- Goal
  - To design environments that combine the affordances of real objects with potential computer-based support in the virtual world

Interaction moves into the foreground.
Computer disappears into the background.

- Research institution
  - Fraunhofer Integrated Publication and Information Systems Institute (IPSI) in Darmstadt, Germany

    (http://www.ipsi.fraunhofer.de/)

Challenges of Ubiquitous Software

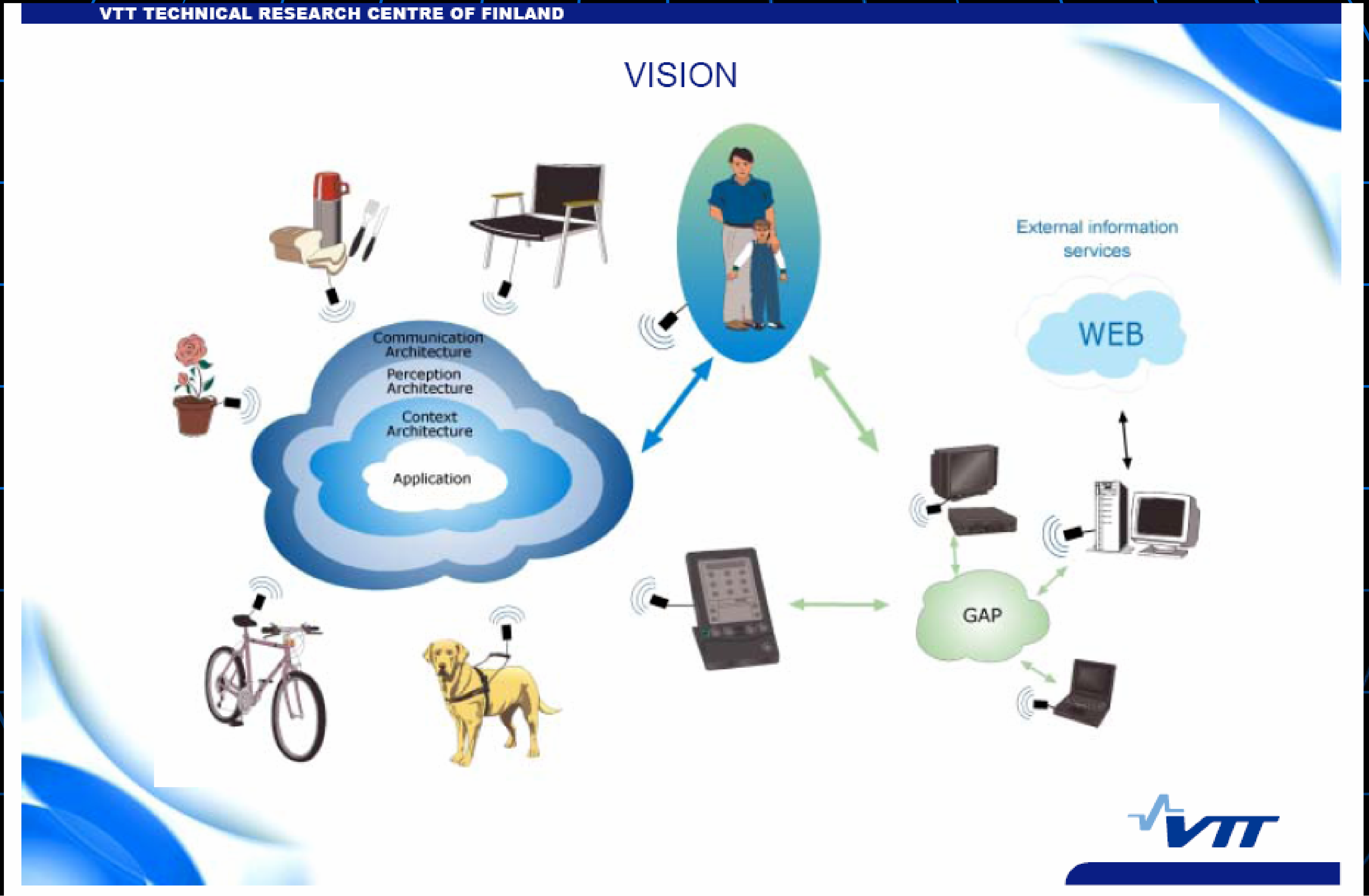


Assignment 2

- Due January 18 via email to ulieru@
- Write a max 1 pager synthesis of the article "**A Survey of Software Infrastructures and Frameworks for Ubiquitous Computing**" extracting the essence from your perspective (e.g. either praise or critique for the technologies presented)

Nota bene! Do not criticize the article itself, but express you opinion about the technologies presented and how you think they can be useful or not to implement the UbiComp vision.

How to Implement the Vision



Smart Objects/Spaces

- Provide **services**
  - **Location** (Where am I?)
  - **Context** (Are we in a meeting?)
  - **Event delivery** (Tell me whe ns)
  - **Brokering** (Find something th)
  - Directory, discovery, registry
  - Mobility, r
  - ...
- Requirements
  - Security, privacy, availability, reliability

For applications built with smart objects

For smart objects

How do we organize billions of mobile smart objects that are highly dynamic, short living,...?

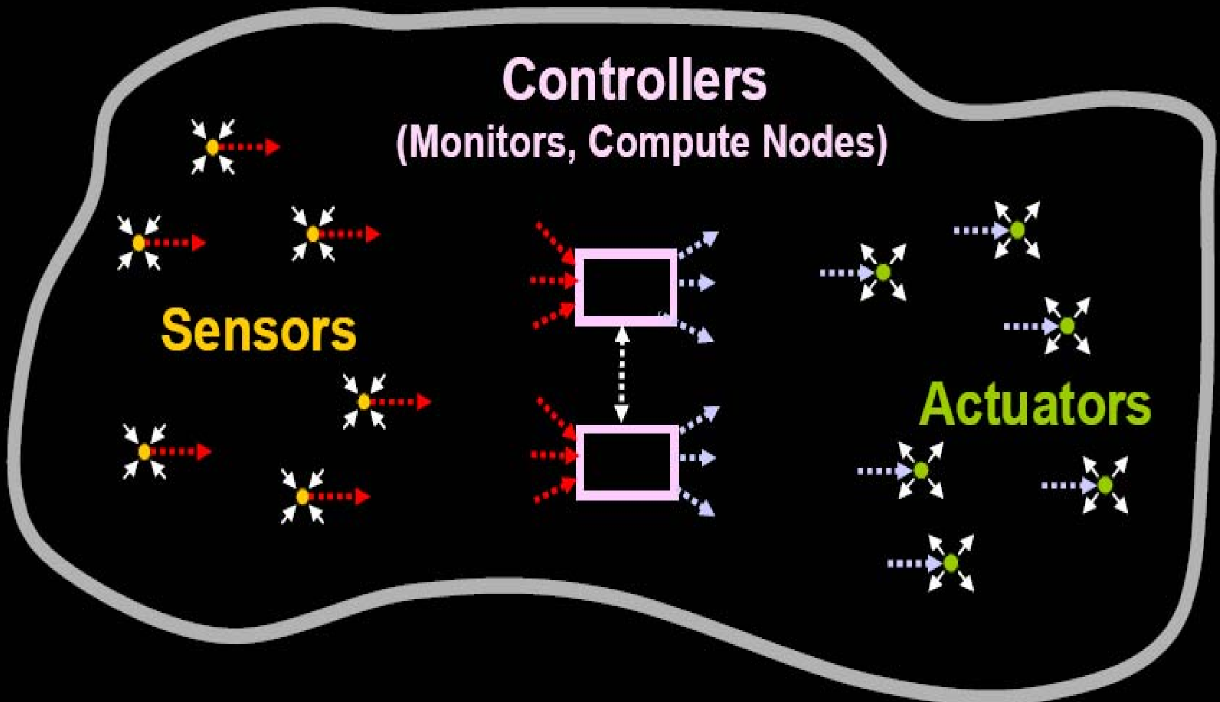
VTT Context Architecture aims:

- *“to devise an open architecture for context-aware applications”*
- providing means to advertise context information provision abilities
- defining a context information interchange format
- providing tools for creating higher-level collective contexts
- supporting the creation of context-aware applications

Context Architecture Requirements

- to be flexible and easily configurable
- independence of computing platform
- hide sensor and communication details from applications
- support collective awareness
- facilitate reuse of context recognition algorithms

Sensing The Ambient: Wireless Sensor Networks



A collection of cooperating algorithms (controllers) designed to achieve a set of common goals, aided by interactions with the environment through **distributed** measurements (sensors) and actions (actuators).

$150 millions sales in 2003

$7 billion in sales in 2010

On World Emerging Wireless Research, Feb 2004

BWRC

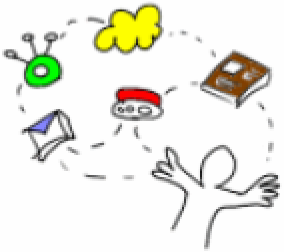
Smart-Its

- *Smart-Its* are intended as an enabling technology, which lets researchers build demonstrators and prototypes of context-aware applications with comparatively little overhead.

SMART-ITS

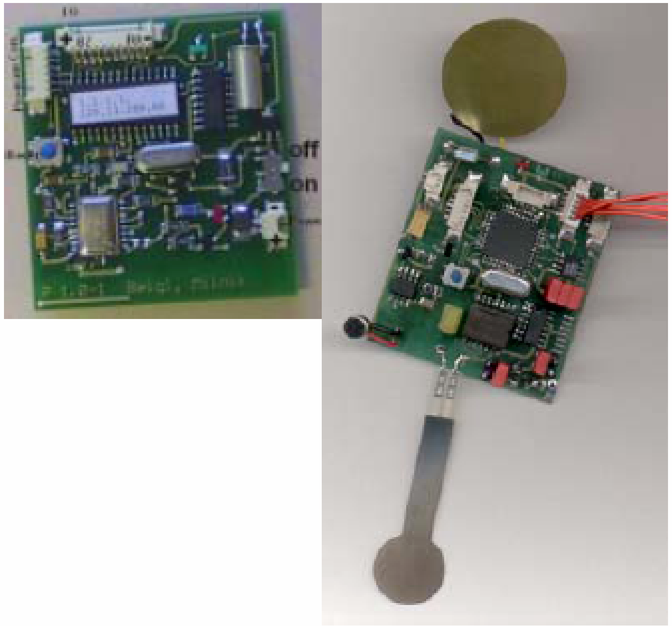
- Interconnected Embedded Technology for Smart Artefacts with Collective Awareness (http://www.smart-its.org/)
- European Community: Information Society Technologies / Future and Emerging Technologies / The Disappearing Computer
- Start: 01.01.01, 2.5 y, 321 PM, VTT 52 PM
- Consortium:

  ETH Zurich, Switzerland: Distributed Systems Group (http://www.inf.ethz.ch/vs/)
  ETH Zurich, Switzerland: Perceptual Computing and Computer Vision Group (http://www.vision.ethz.ch/pccv/)
  Interactive Institute, Sweden: PLAY Research Studio (http://www.playresearch.com/)
  Lancaster University, UK: Department of Computing (http://www.comp.lancs.ac.uk/)
  University of Karlsruhe, Germany: Telecooperation Office (TecO), (http://www.teco.edu/index2.html)
  VTT Electronics, Finland: Advanced Interactive Systems (http://www.vtt.fi/ele/research/ais/index.htm)



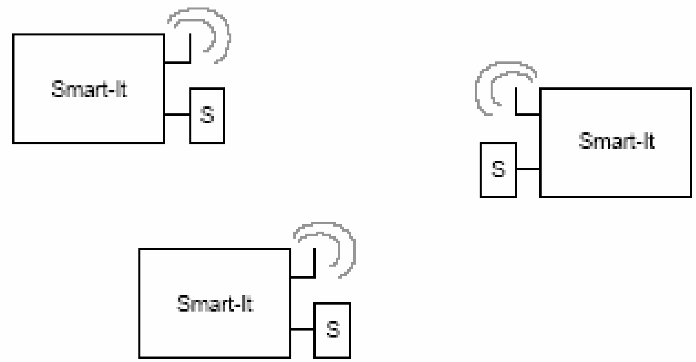
SMART-ITS HW

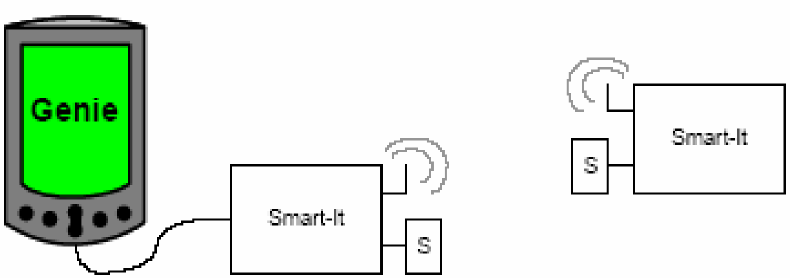
- Cheap, low energy consumption and small size
- Processing power, memory, sensors for perception, wireless communication and customisable behaviour
- Is used to empower and interconnect large families of everyday objects (e.g. toys, personal belongings, goods in a store, parts in processing chain)



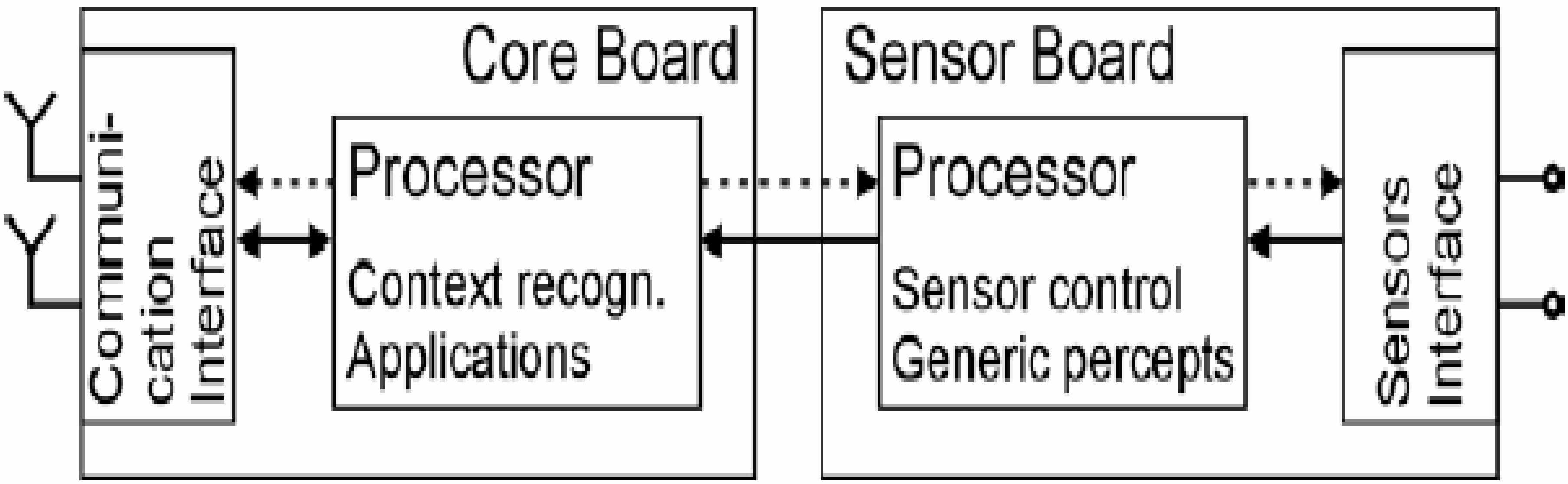
Smart-Its

- RF communication
- ad-hoc peer-to-peer networks
- the heart of a Smart-Its is PIC microcontroller
  ⇒ scarce resources compared to any PC
    - low calculation power
    - 15kByte FLASH ROM, 368 Byte RAM, 256 Byte EEPROM

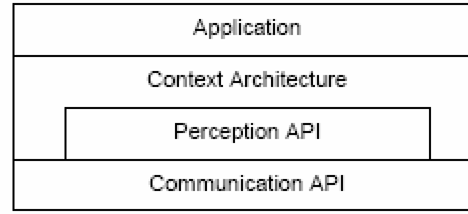


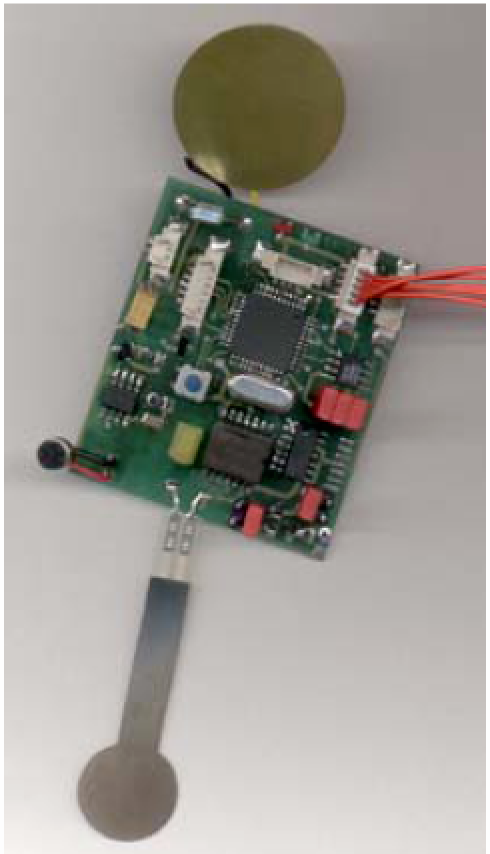


Smart-Its Device Architecture

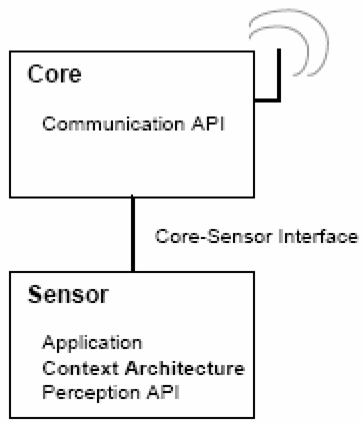


SW LAYERS OF SMART-ITS

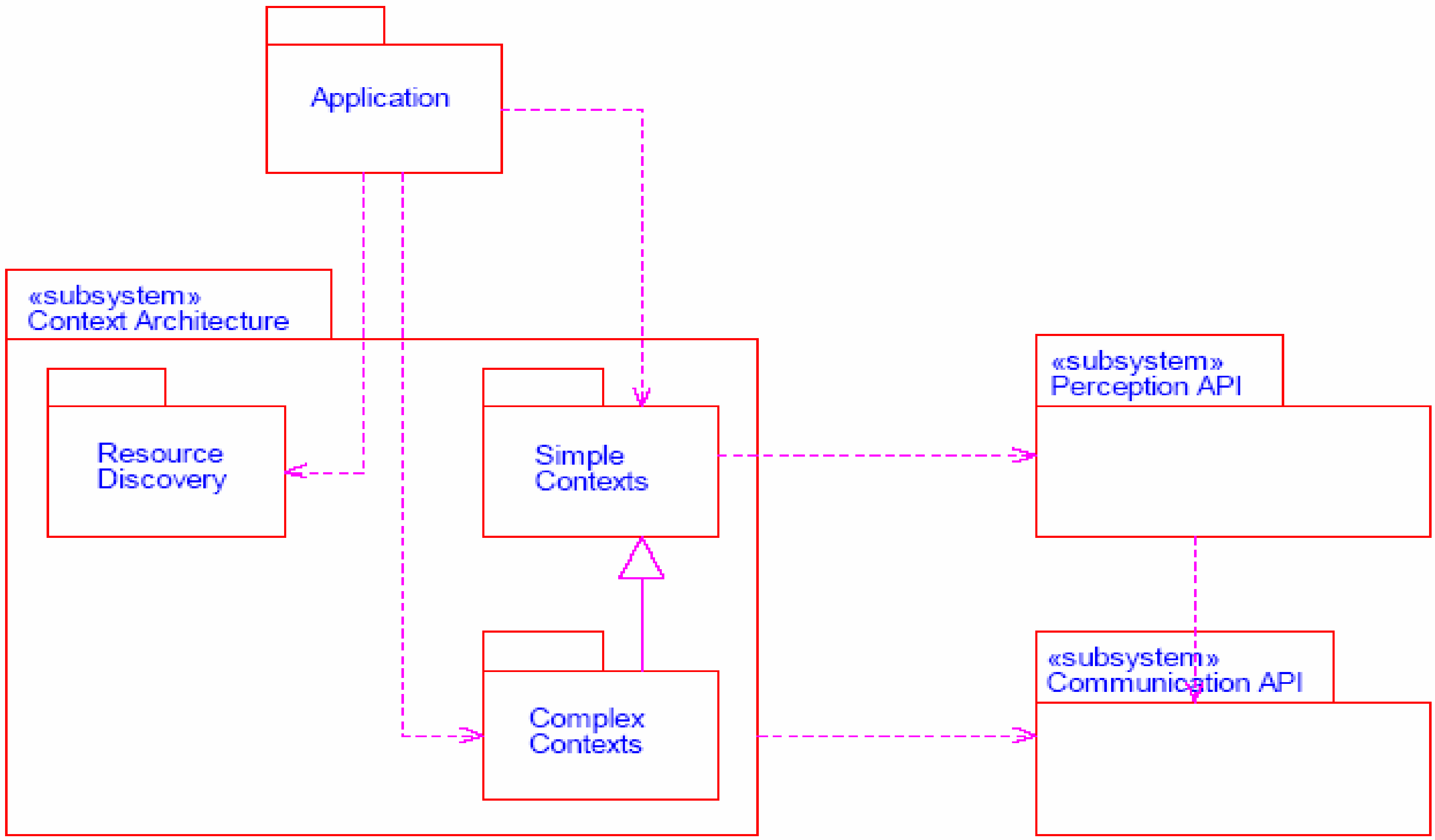




- project work is divided accordingly
- Application
- Context Architecture
  - support creation of context-aware applications
  - hide sensor and communication details
- Perception API
  - deal with sensor details
- Communication API
  - provide communication abilities

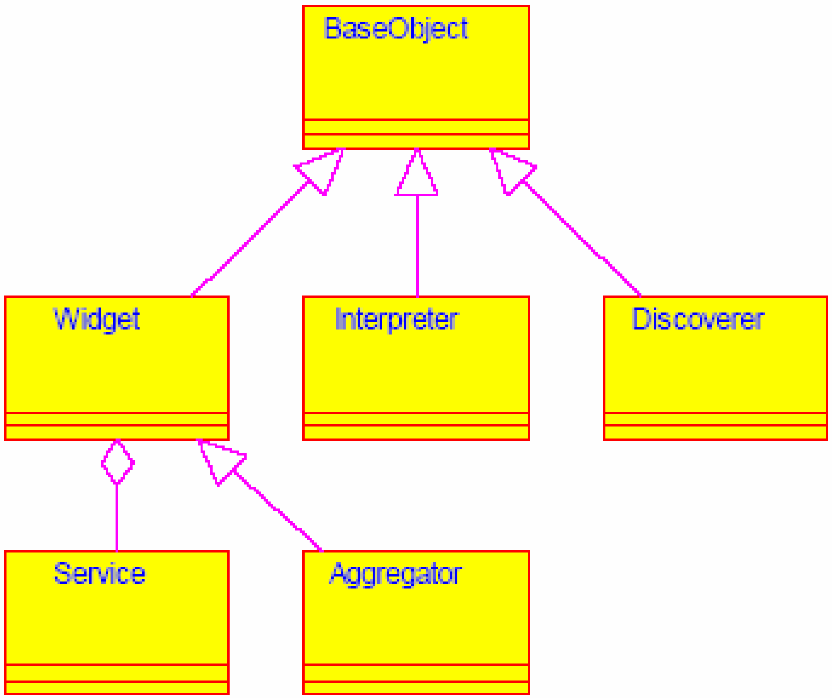


Package View of the Layers



CONTEXT TOOLKIT

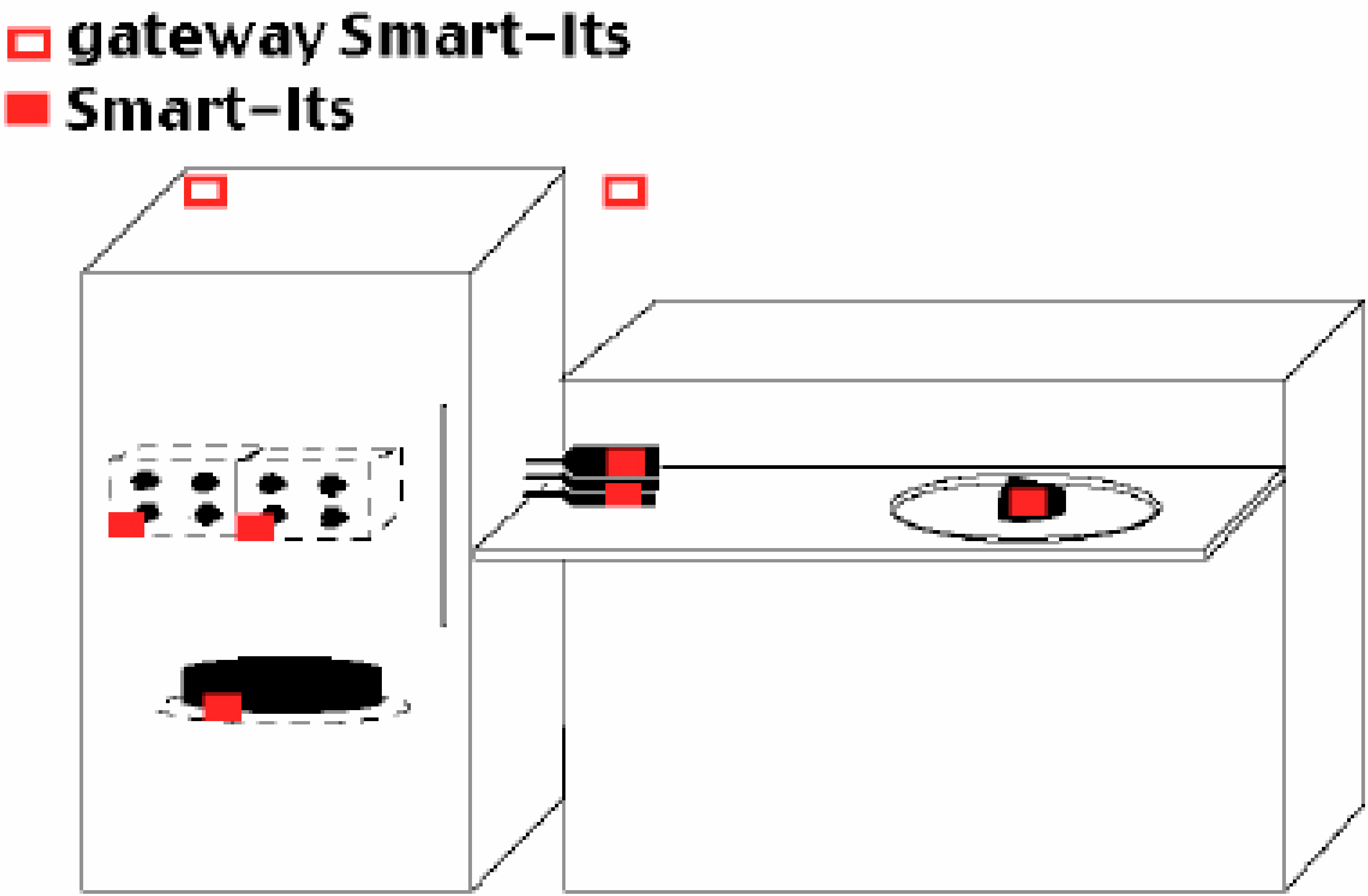
[Dey, Anind: Providing Architectural Support for Building Context-Aware Applications. PhD thesis, Dec 2000.]



- BaseObject
  - provides communication infrastructure
- Widget
  - separates context acquisition from its use
  - provides a uniform interface to apps
  - included Service component performs actuation of output to the environment
- Aggregator
  - all the context about a particular entity (person, place, object) by utilising Widgets
- Interpreter
  - maps between context representations
  - performs complex inferences on collections of context
- Discoverer
  - provides a resource discovery service

Implementation Issues

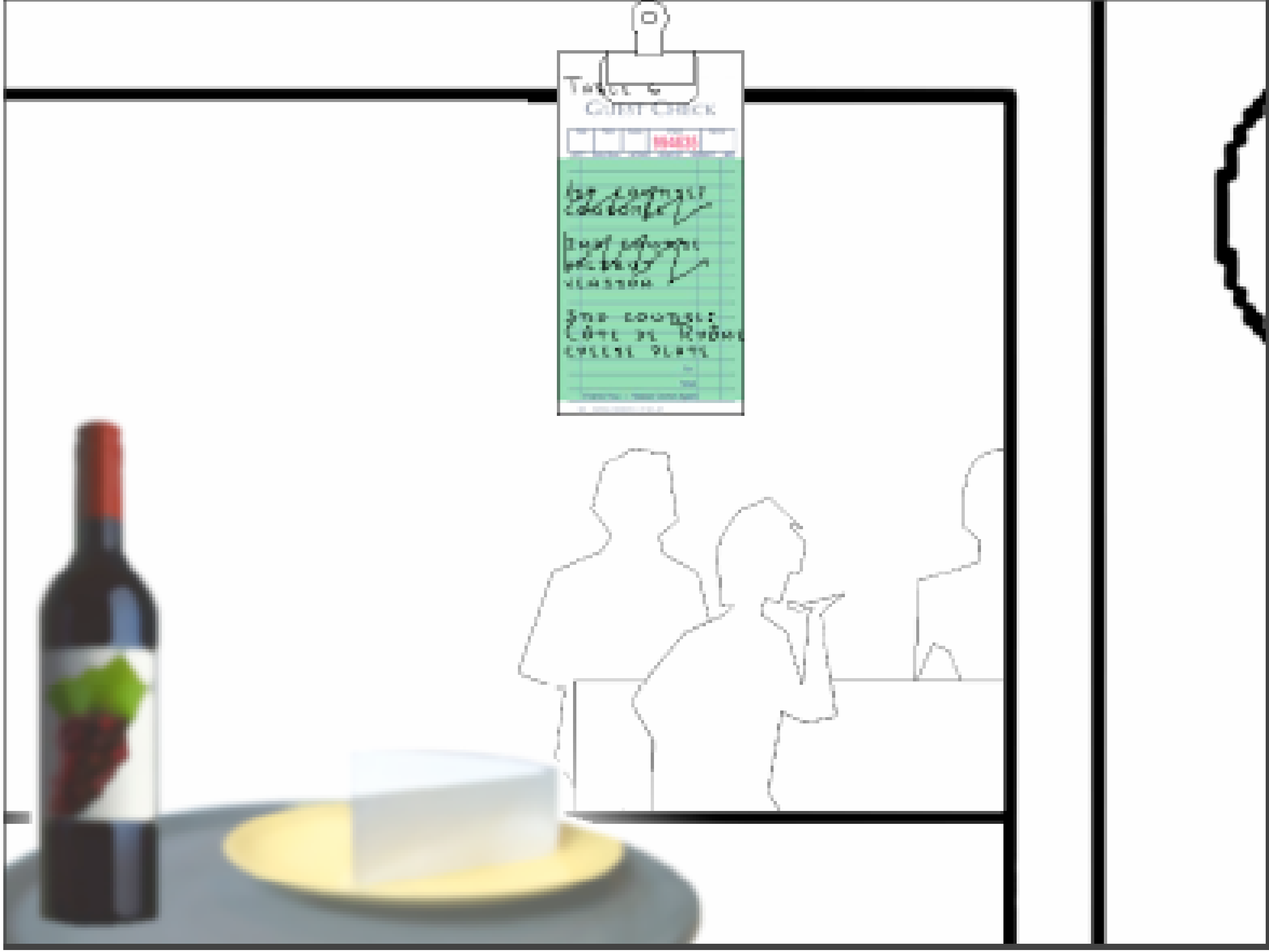
- no dynamic creation of objects (resource thing)
- only the last context is (can be) stored by Widgets and Aggregators;
- no actual context history on Smart-Its
- for example, context history could be stored by Genie, but then the availability of the history cannot be guaranteed
- registration of the resources of Smart-Its is static (Discoverer Pattern)
- Smart-Its implementation will be carried out with C


gateway Smart-Its
Smart-Its

‘Ready to be served’

The scenario demonstrates how collective awareness and ad-hoc groupings of smart artefacts facilitate logistics.

A combination of user involvement (the chef) and perception by multiple artefacts enable an order to know when it is ready to be served. Once all the right objects have been put on the serving tray, the chef moves the tray to another counter. The action of moving the items together groups them and signals that the order is complete. Once the order is complete and all the items are at the proper serving temperature, the tray will signal to the waiter that it is ready to be delivered to the customer’s table.


Guest Check
3rd course:
Côte de Rhône
cheese plate

Dynamic Menu

Items keep track of and can be queried as to their status, as well as signal when significant changes affect their quality. In this scenario, wine bottles keep track of their treatment (including temperature, exposure to light, excessive shaking etc.). This information is used to calculate the overall quality along a “decay curve” specific to each food item (wine and oysters naturally have different optimal temperatures and lifespans). The status of all items is dynamically calculated, prices are negotiated collectively among the items, and output as a dynamic restaurant menu, advertising billboard, and pricelist.

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PLAY studio, Interactive Institute, Sweden
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Future Applications Lab, Viktoria Institute, Sweden
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- When users perform different actions – such as taking the cheese out of the fridge or combining the wine and cheese on the serving tray to complete an order – the Smart-Its artefacts sense this and send information to a central server.

Disappearing Electronics and the "Ambient Intelligence" Concept

- An environment where technology is embedded, hidden in the background
- An environment that is sensitive, adaptive, and responsive to the presence of people and objects
- An environment that augments activities through smart non-explicit assistance
- An environment that preserves security, privacy and trustworthiness while utilizing information when needed and appropriate

Fred Boekhorst, Philips, ISSCC02

The Disappearing Computer **(DC)** is a EU-funded proactive initiative of the Future and Emerging Technologies (FET) activity of the Information Society Technologies (IST) research program.

The mission of the initiative is *to see how information technology can be diffused into everyday objects and settings, and to see how this can lead to new ways of supporting and enhancing people's lives that go above and beyond what is possible with the computer today*.

Specifically, the initiative focuses on three-interlinked objectives:

Create information artefacts based on new software and hardware architectures that are integrated into everyday objects.

Look at how collections of artefacts can act together, so as to produce new behaviour and new functionality.

Investigate the new approaches for designing for collections of artefacts in everyday settings, and how to ensure that people's experience in these new environments is coherent and engaging.

The initiative addresses these three objectives with a number of independent research projects and a number of support activities run by a network made up of a representation of all project partners.

Objective 1: Creating Artefacts.

In the vision of the ‘disappearing computer’, information artefacts are future forms of everyday objects that represent a merging of current everyday objects (tools, appliances, clothing, etc) with the capabilities of information processing and exchange (based on sensors, actuators, processors, mircosystems, etc).

These artefacts have the capability of communicating with other artefacts based on local (typically wireless) networks, as well as accessing or exchanging information at a distance via global networks. In this way, these artefacts posses the capability of both local and global inter-working. Individually, artefacts may have a small range of capabilities but together can exhibit a much broader range of behaviours. Alternatively, in certain cases, they may be designed to individually have a wider range of functions, but still working within an ensemble.

This objective focuses on how to create individual artefacts, particularly ones that will have the attributes of openness and connectivity, so that together they can form an open and adaptable system. How they can work together using this as a basis, is taken up in objective 2.

E-GADGETS

Extrovert Gadgets | IST-2000-25240

Website: www.extrovert-gadgets.net

Email: egadgets@cti.gr

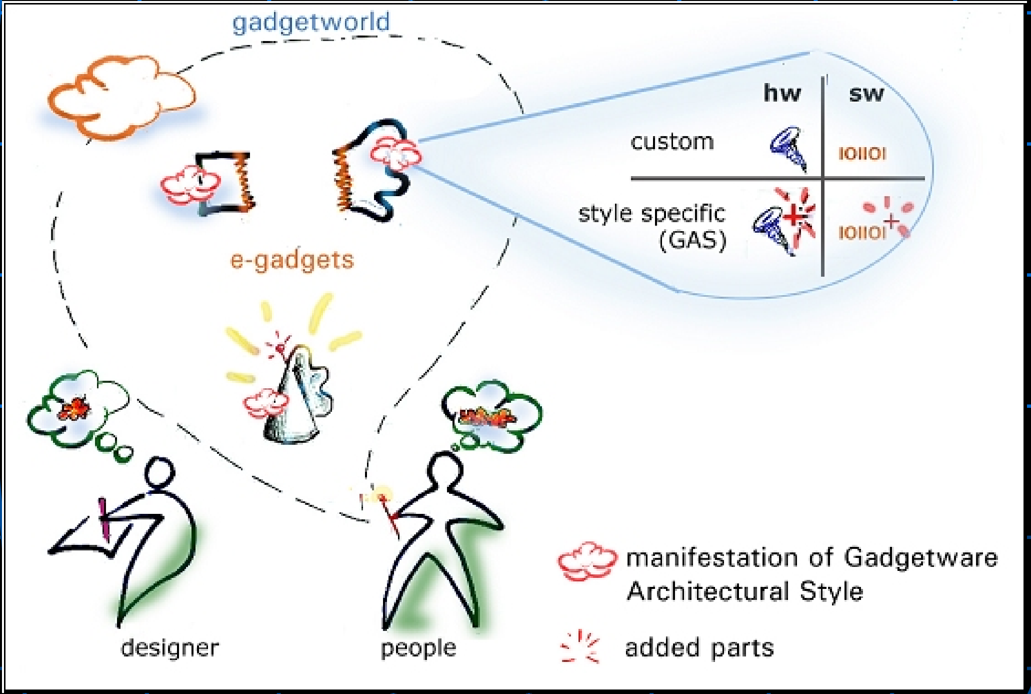
e-Gadgets will develop and validate an **architectural style** for tangible, communicating artefacts [=a Gadgetware Architectural Style (GAS)].

Extrovert Gadgets are *objects with communicative abilities. The objects and/or their environments can be enhanced by intelligence. A multitude of loosely coupled gadgets can be bound into ad-hoc interacting clusters which display collective function, thus forming a gadgetworld. The Gadgetware Architecture Style (GAS) provides a common conceptual framework for designers and people, to use e-gadgets as building blocks for composing gadgetworlds. Each e-gadget implements portions of style-specific hardware and software in addition to its custom behaviour. The GAS provides the infrastructure for the formation of gadgetworlds. The nature of the infrastructure (centralised or ambient) is a research issue. The GAS and its infrastructure will be defined within an iterative process of development and evaluation of usage scenarios and artefacts. GAS infrastructure and e-gadgets will build upon industry technological standards. In order for an everyday object to become a GAS-aware artefact, a hardware and software component must be added to it. Gadgetworlds can be used for the needs of mobility challenged people, young children, mature generations, and any ordinary people. Their collection in a space adds ambient intelligence to it.*

Extrovert Gadgets IST-2000-25240

e-Gadgets will: Develop and validate **an architectural style for tangible, communicating artefacts** [=a Gadgetware Architectural Style (GAS)]**.**

Design and develop an infrastructure and sample artefacts enabling the architectural issues and the GAS evaluation.



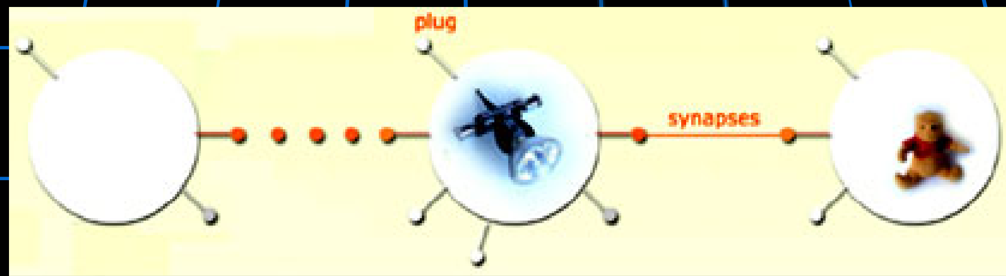
Extrovert Gadgets are *objects with communicative abilities*. The objects and/or their environment s can be enhanced by intelligence. A multitude of loosely coupled gadgets can be bound into ad-hoc interacting clusters which display collective function, thus forming a gadgetworld.

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

eGadgets

In principle, this approach can scale both "upwards" (towards the assembly of more complex objects, i.e. from objects to rooms, up to buildings, cities and so on) and "downwards" (towards the decomposition of eGts into smaller parts, i.e. towards the concept of 'smart dust').

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

New Architectures

The creation of artefacts requires research on new software and hardware **architectures**, **particularly ones that:**

- **Accommodate trade-offs between networking, computing, and power consumption.**
- **Form part of an open system that allows for wireless communication with other artefacts, for example to connect with global networks.**
- **Allow for adaptive behaviour, for example through the design of adaptive software architectures, or re-configurable hardware.**
- **Allow for an awareness of their context, for example with a system of sensors.**
- **Enable an artefact to be modular, either from the software or hardware points of view.**

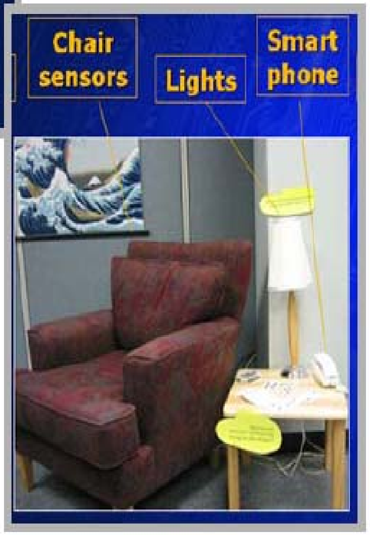
Embedding into Everyday Objects

In order to make information artefacts, the IT components have to fit them unobtrusively. This requires research into ways of merging information technology with objects and materials, including for example:

- Methods and techniques for adding-on or embedding IT components.
- Techniques for miniaturising components so as to allow easy embedding.
- Coating, or sticking components onto objects, or interweaving them with their constituent materials.
- Research could also consider approaches that would make it easy for people to embed IT components into everyday objects themselves, for example, with 'do-it-yourself' toolkits.

The "Smart" Home — A Prime Target

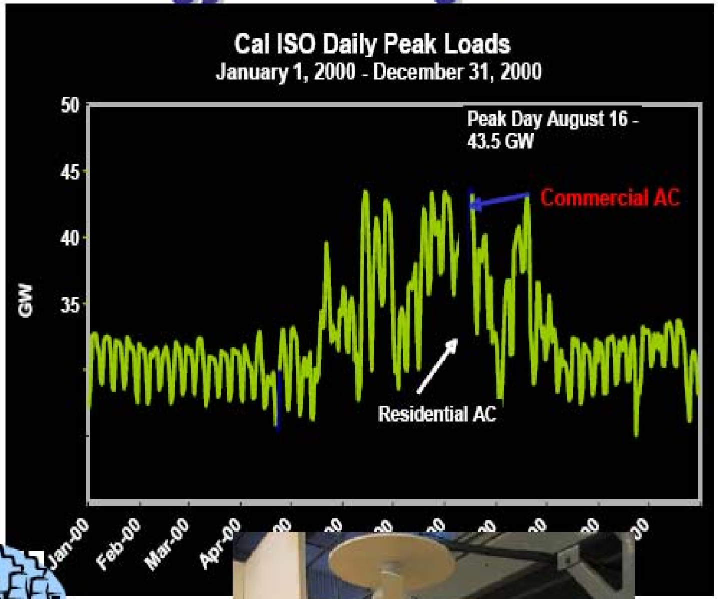
- Security
- Environment control
- Energy management
- Object tracking/inventory
- Advanced user interfaces
- Sense of presence and space

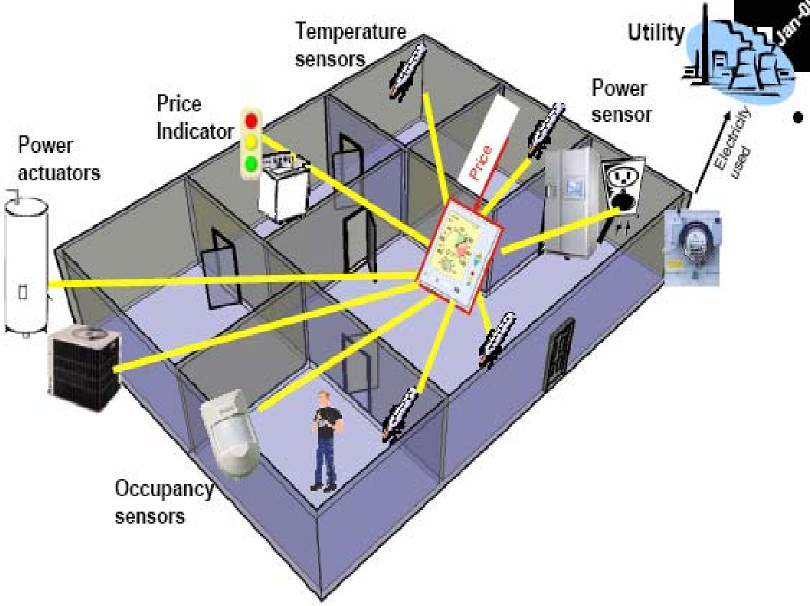


Demand Response and Energy Management

Make energy prices dependent upon time-of-use

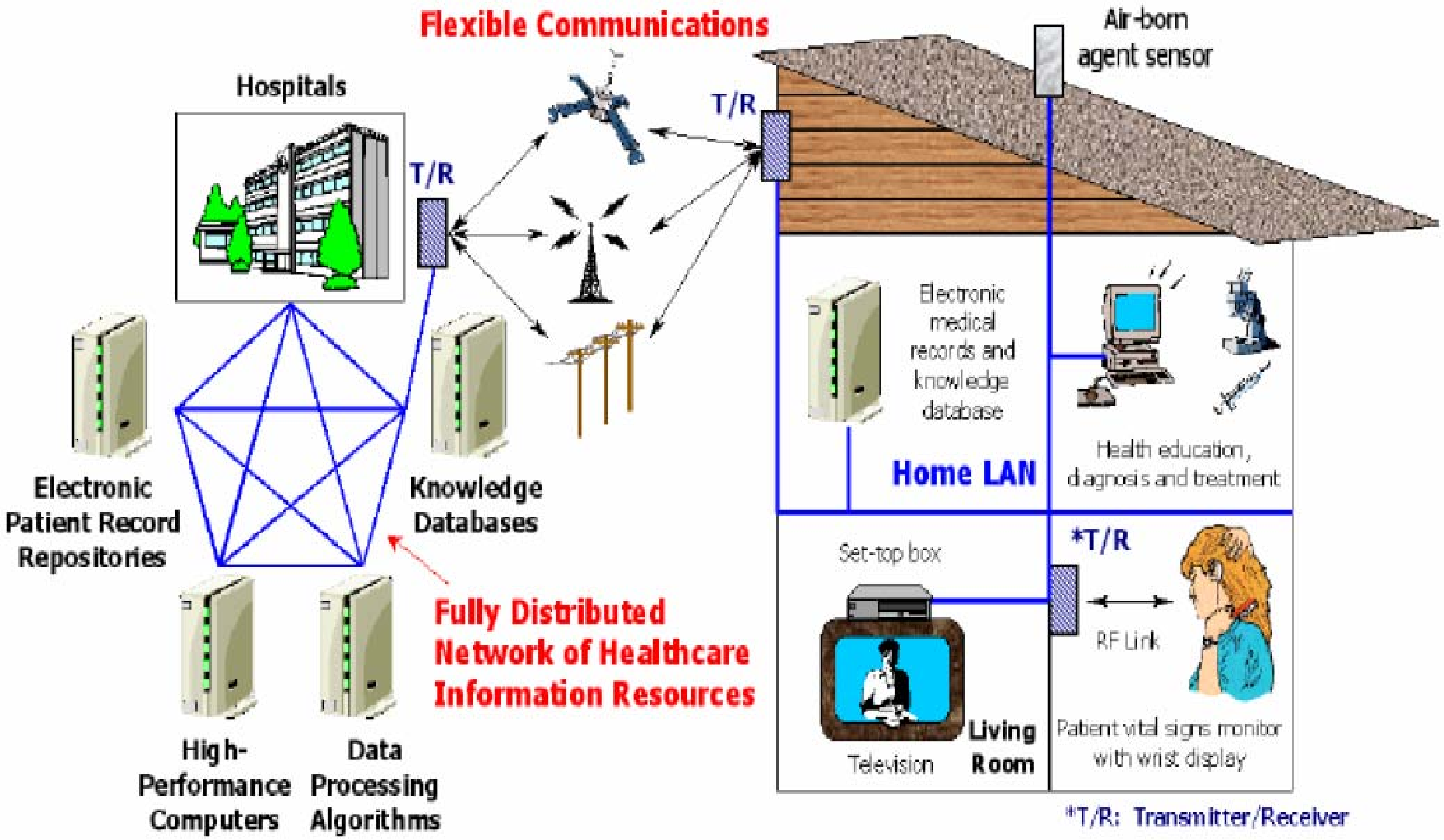
- Advanced thermostats operate on required level of comfort, energy cost, weather forecast and distributed measurements to offload peak times
- Appliances energy and cost aware





In collaboration with CEC

Home Layout for HealthCare Delivery



Objective 2: Emerging Functionality

The functionality of an artefact corresponds to the range of functions it exhibits or the experience it provides. In reality we may expect a range of different kinds of artefacts, some general purpose and some quite specific.

Even if an individual artefact has limited functionality, it can have more advanced behaviour when grouped with others. The aim is to look at how collections of artefacts can be made to work together, and in particular how they provide behaviour or functionality that exceeds the sum of their parts.

The basis for new functionality to emerge is due to the fact that artefacts have properties as described in the first objective, for instance:

- They are Modular
- They can Communicate with others
- They can adapt and learn from previous events
- They can be placed in various locations

These properties lay the basis for collections of artefacts to be able to behave as a complex interacting system. The main aim of this objective is to see how to take advantage of this inherent complexity so as to allow for the behaviours and functionalities of collections artefacts to be changeable and emergent.

Because artefacts can be re-configured, or recombined by people and because they can adapt and evolve, their collective behaviour is not static, and collections of artefacts can evolve to produce new behaviours. This is not just a random behaviour, but one that is guided by how artefacts are used or configured by people.

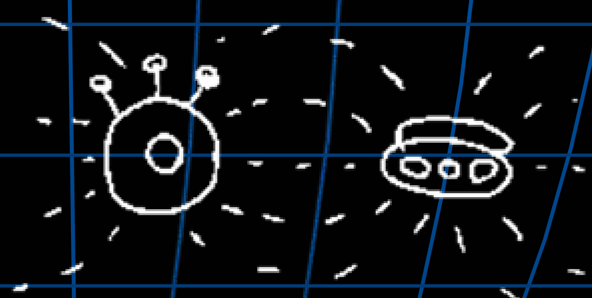
As a consequence, people are given 'things' with which to make 'new things', rather than only being supplying with fixed and un-changeable tools. This requires a 're-think' about the ways in which tools should be conceived of and designed, and this is taken up further in objective 3.

In order to lay the foundations for new functionality to emerge from collections of artefacts, this objective considers two main topics:

Working Together

Artefacts have to be able to work together in order to allow new ‘collective’ functions to emerge. As a basis for this, research is needed into:

- The ways in which artefacts communicate with other artefacts or other information sources (either globally or locally) and the protocols they should use.
- The structuring of different kinds of artefacts into collections or ‘families’, each with a different role and level of influence.
- The design of new forms of ‘adaptive operating systems’ that would provide a platform for more general software across a range of artefacts

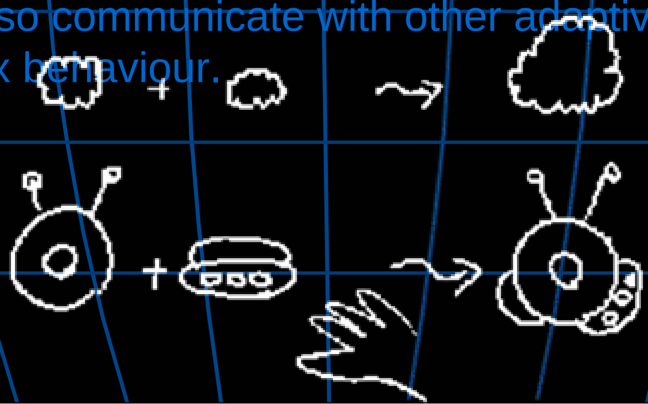


Emerging Functionality

Given that artefacts can **communicate**, **adapt** and are **modular**, the specific ways in which functionality can be designed for collections of artefacts have to be researched.

This should consider the ways in which functionality can be constructed and the specific ways or conditions for new functionality to emerge. Some indications are outlined below:

- Because artefacts are **modular** means that parts of them (either from the software, hardware or physical aspects) can be constructed, deconstructed or mixed, or added on to other artefacts. These kinds of changes would in turn create a new hybrid artefact with a new functionality. Combinations or various artefacts would lead to new functionality that would go beyond what individual artefacts could do.
- The fact that artefacts can **communicate** and can be aware of other artefacts, means that under certain conditions, artefacts could 'synergize' to produce new properties and behaviour that they otherwise they would not exhibit. For example, the proximity of a group of artefacts could trigger an interaction between them and a new functionality would become possible. This principle 'non-linear addition' or synergy could also be applied to certain groups of artefacts interacting over a distance.
- The fact that an artefact can **learn or adapt** from a history of past events, means that this knowledge can trigger new functionality that for example, emerges with time. An individually adaptive artefact may also communicate with other adaptive artefacts so that a group would produce a more complex behaviour.



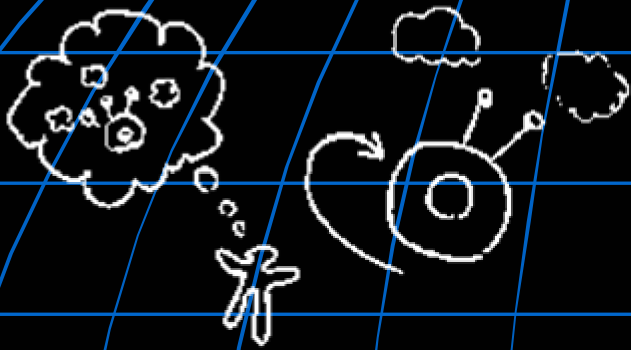
Objective 3: People's Experience

As described in the previous two objectives, collections of artefacts represent a **<u>'radical distribution' of computing and information processing</u>** that can inter-work to deliver new functionality and lead to new patterns of behaviour.

It is the integration of these concepts with real-world settings and with real objects, that offers opportunities for new ways of supporting people's everyday activities - ways that go above andbeyond what the personal computer (pc) can offer today.

In this respect, one can imagine groupings of artefacts could substitute some of the functions that the pc can perform today, however in a more distributed fashion and based a more natural form of interaction.In other cases, one can imagine groupings of artefacts designed to take advantage of the new context and support people's activities in a completely different ways.

It is therefore necessary to address ways in which people's activities can be supported or enhanced in such new environments. The basis for this is to consider how to **<u>design</u>** artefacts or how to design for collections of artefacts. Furthermore it is important to see how they can lead to coherent experience in real world settings and how can people participate in them.



De

Designing and Prototyping Artefacts

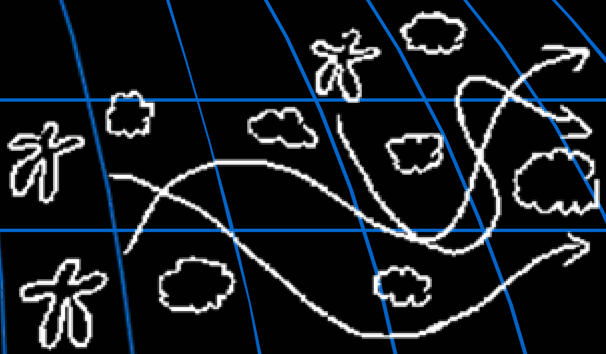
The nature of information artefacts, as described in **objective 1** and **objective 2**, **pose a number of challenges with regard of how artefacts should be designed. This includes for example:**

- **How to design an individual artefact, and how to integrate utility design with software/hardware constraints.**
- **The design of the functionality of an individual artefact and how this can be combined with that of others.**
- **Research on how to design for collections of interacting artefacts and how to design in the context of a collective and emerging functionality.**
- **The use of iterative prototyping and new evaluation methods.**

Coherence

A world full of interacting artefacts could easily confuse people. Research is needed in order to make sure that environments are coherent and understandable. This could include for example:

- **Ways to integrate artefacts with real places and locations.**
- **The use of metaphors, cognitive or semantic models, to guide the design of environments.**
- **Approaches that ensure ‘seamless interaction’, for example, for an activity that takes place across different locations and different stages in time.**



Engagement

In contrast to concentrated engagement in one location (as with a pc), the distributed nature of a collection of artefacts in **real locations** leads to a range of research issues on how to support people's activities in this context, for example:

- The ways in which both individuals and groups of people can participate in such environments.
- The design of engagement that is appropriate to an activity. This includes active engagement that requires concentration, through to relaxed participation that is 'laid-back', enjoyable or fun.
- The ways in which sequences of interaction and experience can be structured. For example, the use of 'interactive narratives', that can guide or engage people in space and time, and the ways in which such narratives can encompass pre-scripted elements as well as emergent, or unexpected events.

Diagrams >>>>>>>

Virtual / actual >>>>

AMBIENT AGORAS

Dynamic Information Controls
in a Hybrid World| IST-2000-25134
Website: www.Ambient-Agoras.org

The project "Ambient Agoras" aims at providing situated services, place-relevant information, and feeling of the place (genius loci) to the users, so that they feel at home in the office, by using information technology (IT) in an innovative way, e.g. mobile and embedded in the environment. "Ambient Agoras" adds a layer of information-based services to the place, enabling the user to communicate for help, guidance, work, or fun. It integrates information into architecture through smart artefacts, and will especially focus on providing the environment with memory, which will be accessible to users. The computer as a device will disappear, but the functionality will be available in a ubiquitous and invisible fashion. Finally, "Ambient Agoras" will augment reality by providing better "affordances " to existing places. It aims at turning every place into a social marketplace (= agora) of ideas and information where one can interact with people.

Scenarios

In order to inform our design also by user requirements, a large set of so called "bits of life" were created, i.e. short descriptions of snapshots of situations. They were aggregated to several scenarios. Subsets of these scenarios were instantiated by creating video mock-ups showing the envisioned functionality and interaction of real people with mock-ups of the artefacts and the software

Well-known topics like **"relationship between real and virtual worlds", "dislocation", "hybrids", "genius loci"** are discussed under aspects of architecture. Looking for the adequate architectural expression of these phenomena originally shaped by information technology, verbal metaphors mark the beginning of the reconfiguration of our workspaces in the age of digitalization.

Workspace will not be "dislocated", because people won't be either. Our body is transportable, but will not be placeless – like architecture. We will need located spaces in the future; the location of a building or an object is without doubt an important "anchor" of orientation for human perception, a parameter of variation and still a valid category of architectural design.

Ambient Agoras

Artefacts - InforMall

The InforMall (Prototype 1)

- The InforMall is an XL-size compound artefact with its own vertical display.

- The first prototype was build for the Jamboree'01 with only a SR sensing system. This was used to support exchanging information taken from the InfoRiver at the InforMall to a ViewPort.
- The InforMall has sensing technology and an interactive touch-sensitive display for processing information. It supports individual activities as well as small groups of people passing by and getting in touch with each other. It is equipped with a Port for exchanging information via portable M-size artefacts as e.g. the ViewPort, or S-size artefacts as e.g. SmartStones.

Ambient Agoras

Artefacts - ViewPort

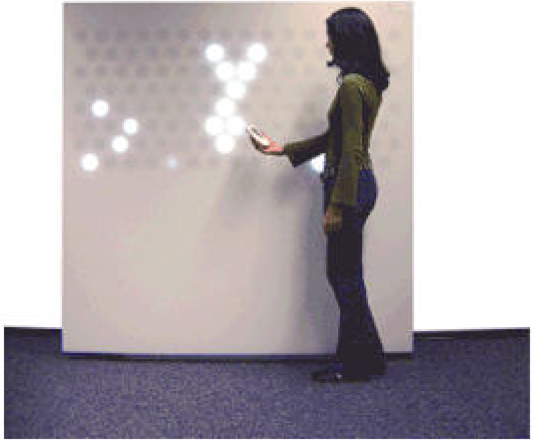
- **The ViewPort (Design Model 3)**
  - The ViewPort is an M-size portable compound artefact with its own display.

  - The ViewPort can be used for creating, disseminating, and receiving information.
  - It can also serve as a "borrowed display" for visualizing information available from other artefacts without displays, e.g., the GossipWall..

Artefacts - GossipWall

The GossipWall

- The GossipWall is an XL-size compound artefact *without* its own display.



- The GossipWall communicates ambient information via different patterns. It provides awareness and notification to people passing by.
- People can access information details via other devices e.g., the ViewPort.

Ambient Agoras

Artefacts - SmartSone

The SmartStones (Design Sketch)

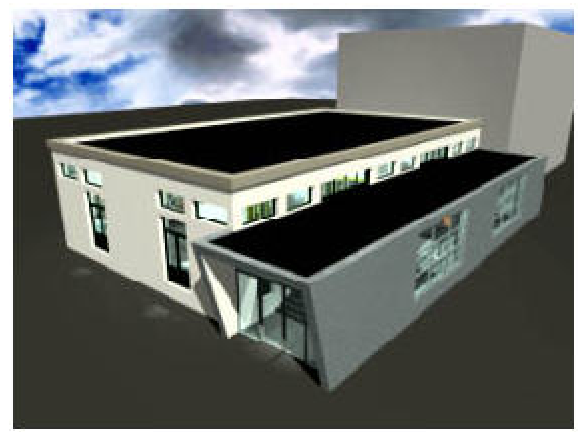
- The SmartStone is an S-size portable compound artefact without its own display communicates via „borrowing".

- SmartStones are used for exchanging information between artefacts. They contain tags for unique identification
- The form factor will match the physical affordances of other artefacts in order to facilitate intuitive interaction.

Ambient Agoras

Installation & Evaluation

The Ambient Agoras enviroment will be installed and evaluated in a real-life working environment at the K1 building of EDF that will be used as a testbed.



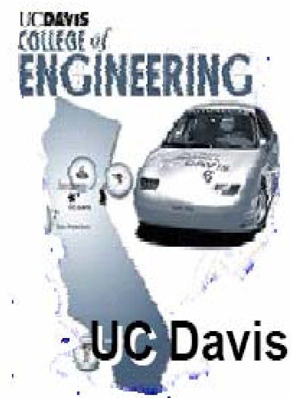
High Mobility and Pervasiveness

- The issues of high mobility in ad hoc environments are tackled by a probabilistic multicast protocol. This protocol specifically targets ad hoc environments where high node mobility and a frequently changing number of group members are present.
- Each node decides if it should forward a flooding message according to a probability pÎ(0,1] which is updated according to the number of duplicates that a node has received from its neighbouring nodes. This effectively minimises the number of unnecessary duplicate messages without sacrificing reliability as they have found experimentally through simulations.

The CITRIS Program

The purpose is inter-disciplinary, collaborative research on IT solutions to grand-challenge social and commercial problems affecting the quality of life of all citizens.

- Major new initiative started in 2001 jointly with UC Berkeley, UC Davis, UC Merced, and UC Santa Cruz
- Approximately 1000 researchers, including over 200 faculty from over 50 academic departments
- Many industrial partners
- Significant State, federal, and private support ($300 million over 4 years)
- CITRIS focuses on IT solutions to tough, ***Quality-of-life*** problems



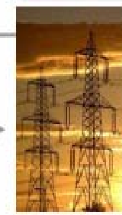
CITRIS
University of California

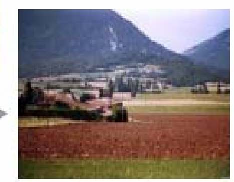
CITRIS GRAND CHALLENGES

CITRIS
University of California

- Education
- Emergency Preparedness & Home Defense
- Energy Efficiency
- Environmental Monitoring
- Health Care
- Transportation
- Service to the Third World Using IT

Test Beds





Enabling Large Testbeds

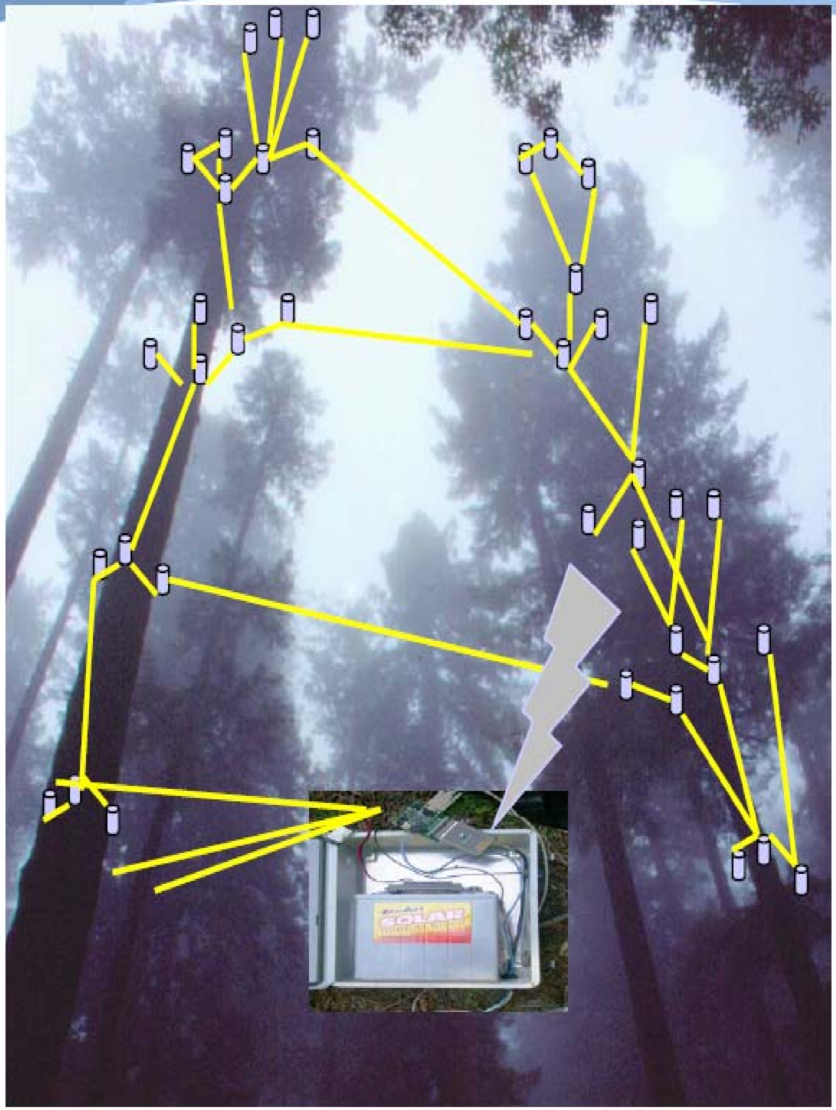
CITRIS
University of California

- Golden Gate Bridge Net (Profs. Fenves, Culler)
- Masada (Prof. Glaser)
- Wild Fire Monitoring (Prof. Glaser, Sitar)
- Botanical Gardens (Prof. Culler)

Others:

Duck Island habitat monitoring

Deployment and the Scientific Process



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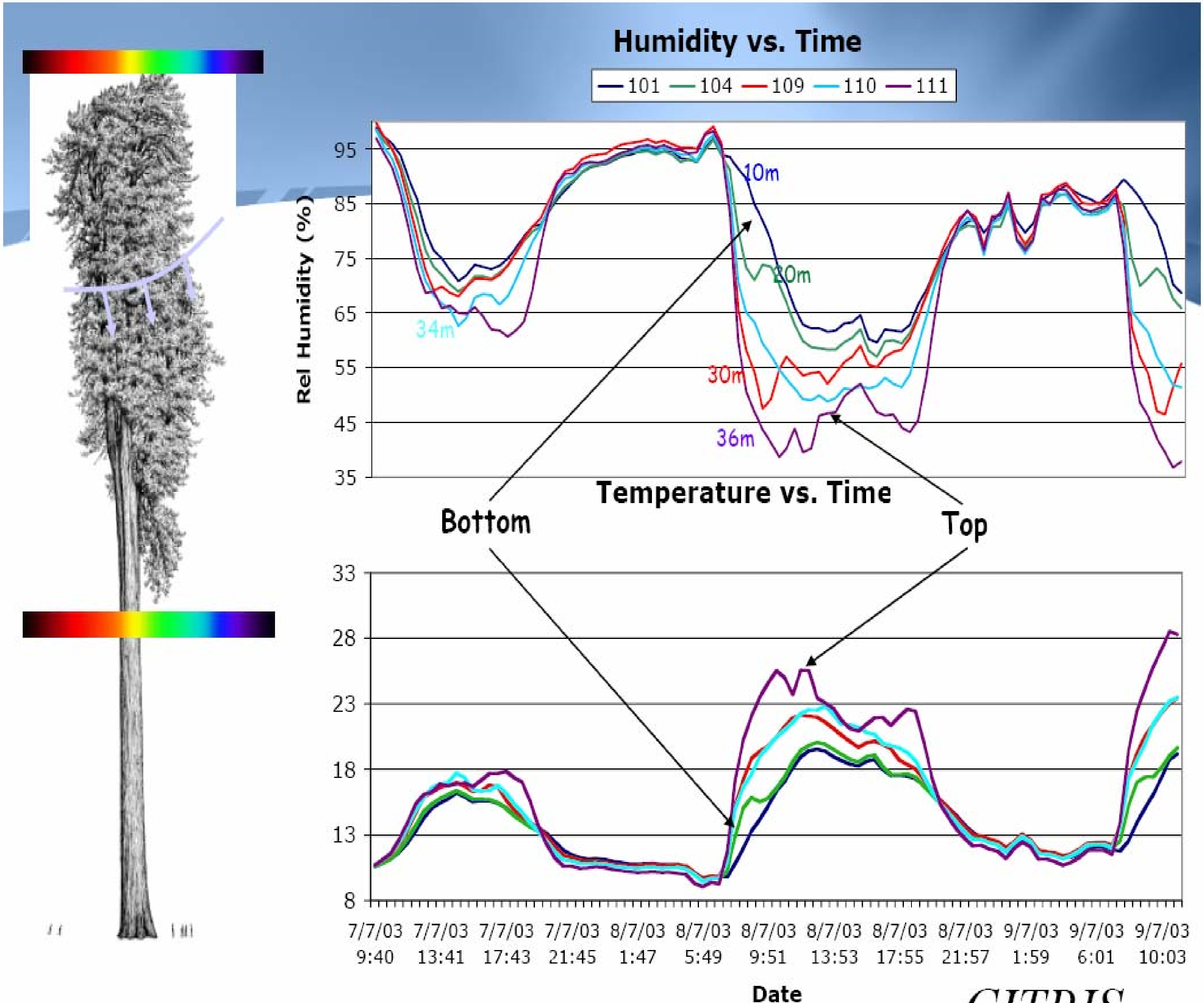


2003, unpublished

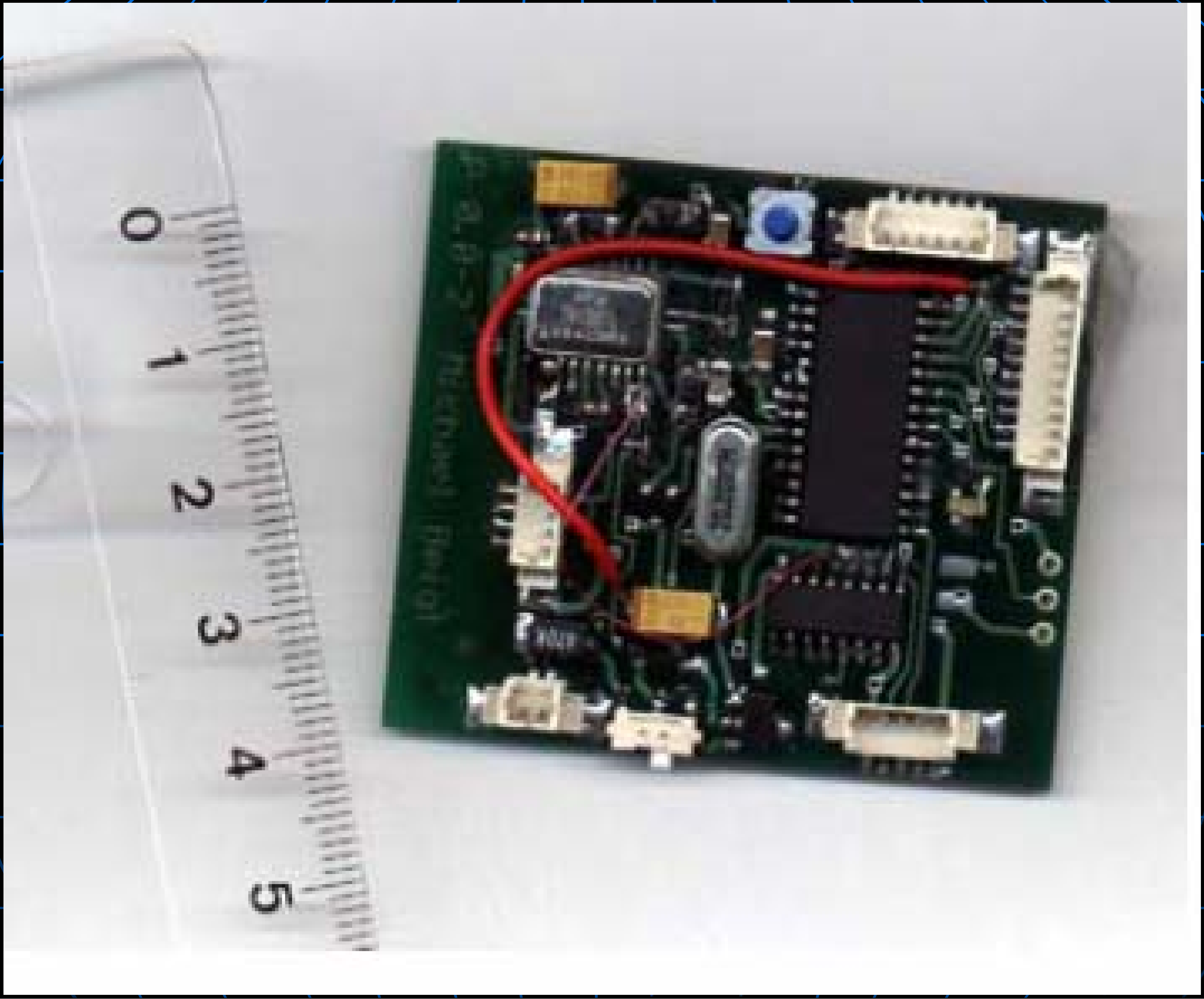
CITRIS
University of California

MOTES

- *MEMS* – Also referred to as “motes” or “smart dust”, are miniaturized sensing smart tags.
- MEMS = MicroElectroMechanical Sensors.
- MEMS are a class of devices that range from active, sensor-equipped e-tags to nanotechnology that combines integrated circuits with mechanical systems smaller than a grain of pollen.
- MEMS are capable of collecting data about various aspects of the physical environment ranging from temperature, humidity, sound, light, or movement of objects, and communicating that data as a node in a “peer-to-peer’ wireless sensor network
- Hoffman, T. (2003, March 24). Smart Dust. Computerworld. <http://www.computerworld.com/mobiletopics/mobile/story/0,10801,79572,00.html>

How Motes Work

- The core of a mote is a small, low-cost, low-power **computer**.
- The computer monitors one or more **sensors**. It is easy to imagine all sorts of sensors, including sensors for temperature, light, sound, position, acceleration, vibration, stress, weight, pressure, humidity, etc. Not all mote applications require sensors, but sensing applications are very common.
- The computer connects to the outside world with a **radio link**. The most common radio links allow a mote to transmit at a distance of something like 10 to 200 feet (3 to 61 meters). Power consumption, size and cost are the barriers to longer distances. Since a fundamental concept with motes is tiny size (and associated tiny cost), small and low-power radios are normal.



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MEMS Vision

- *"...the hallmark of the next thirty years of the silicon revolution will be the incorporation of new types of functionality onto the chip; structures that will enable the chip to not only think, but to sense, act and communicate as well. This revolution will be enabled by MEMS."*
- Brito, S. (2003). Vision for MEMS. Sandia National Laboratories. <http://www.sandia.gov/mstc/technologies/micromachines/vision.html>

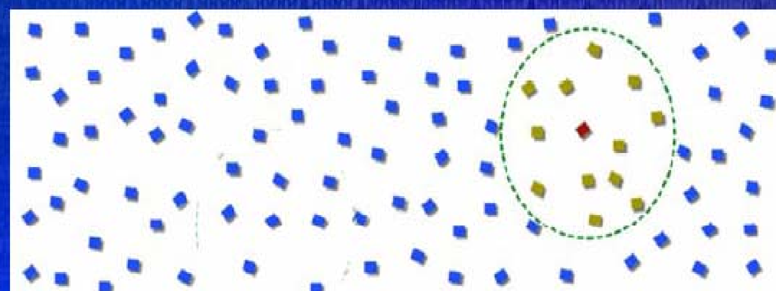
Sensor Nets: Challenges to be Addressed

- Complex distributed system behavior
- System development, deployment, configuration and management
  - Ease of use (see Theo Claasen presentation)
- Reliability
  - Power in the numbers
- Privacy/security/legality

Extrapolating into the Future

Paintable Computing

Each node fitted with a wireless comm system which supports network connectivity to spatially proximal nodes.



- communication radius < 2 cm
- node size < 2 mm^2

Ultra-dense networks of unreliable components providing very reliable computation and communication

Providing innovative human – environment – computer interfaces