Towards Distributed Awareness - An Artifact based Approach

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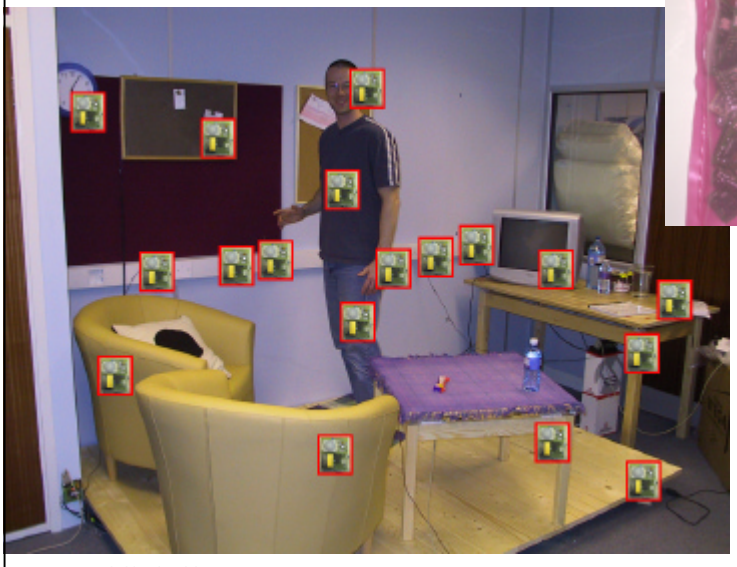
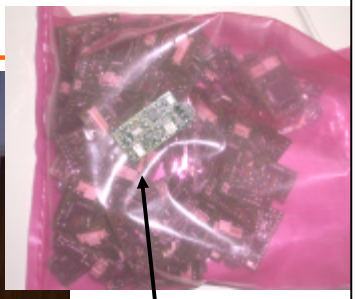
Our Vision of a Sensor Enriched Ubicomp Environment





Bunch of Devices

Distributed Awareness Approach

Context perception in a distributed sensing systems

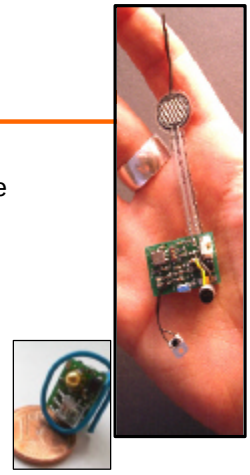
- Some requirements:
  - run several applications on top of these devices
  - reuse implemented parts for new applications
  - change one applications without interfering with another
  - improvement/changes of the infrastructure should not break applications
  - possible to implement on very small device
  - works without backend infrastructure (p2p)
- Based on experience gained in the Smart-Its project
  - Many demos and applications build successfully using this approach
  - Having changing environments using this approach

Artifact centric approach

Platform Smart-Its

Idea

- Device as secondary artefact, integrated into the object
- Independently operating, local deciding with peers
- Integrates Computation, Sensing & Communication
- Post-hoc attachable/embeddable or integratable
- Core and add-on boards



Smart-Its – A Ubiquitous Computing Platform

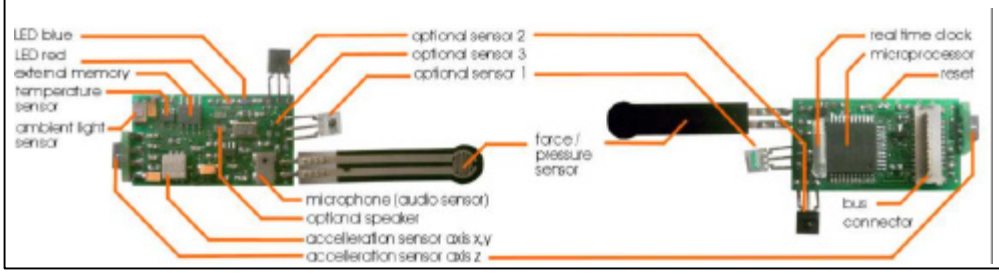
Means for exploring applications and new forms of physical interaction

Building scenarios

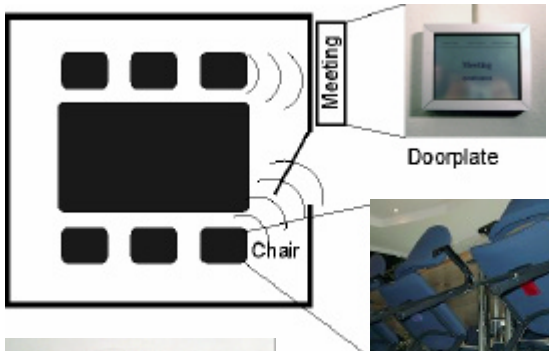
- Rapid-prototyping of interactive applications
- explore interaction with the Ubiquitous Computer

Characteristics

- Some technical parameters: up to 5 MIPS, 128kbyte program, 4k+512kbyte RAM, battery operated, various RF
- Down to 1cm³, lifetime up to several years, simple to program, simple to build/extend

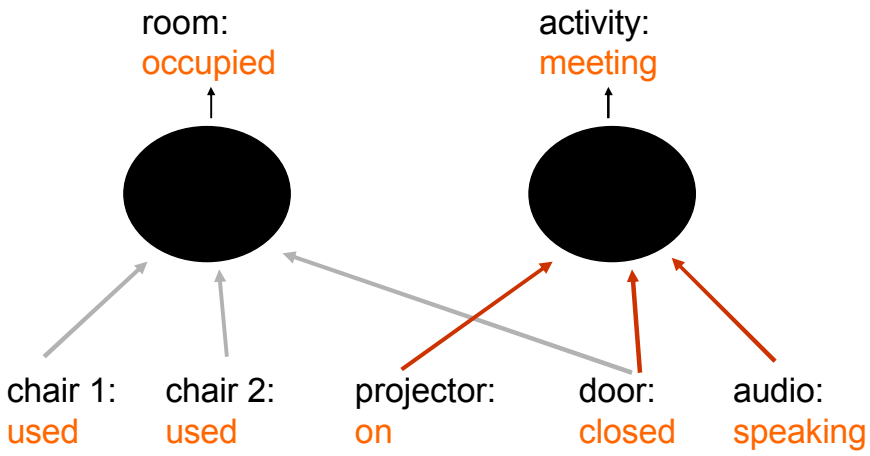


Office – Example Implementation



- **Aware artifacts**
  - Chairs
  - Pens
  - Signs
  - Coffee cups
  - ...

Context Correlation / Time and Space Example



Bottom-up Context Models

Context is Anchored in Artifacts
- Modeling and acquiring context on entity level
- More general properties
- Flexible, extensible, and simple model
- Exploiting domain knowledge

Augmenting Artifacts with
- Sensing
- (Actuation)
- Processing
- Communication

Context Related to Interaction with the Artifact
- Combining context on a higher level
- Time & space correlation

Bottom-up Context - Example

sofa
- free
- occupied with one person
- occupied with two people
- occupied with three people

door
- open
- closed
- degree of openness
- interaction

briefcase
- empty
- loaded
- open
- closed
- interaction

sofa (over the top)
- ...
- jumping on the sofa
- motion of people on the sofa
- temperature on the sofa
- pouring orange juice on the sofa
- pouring wine on the sofa
- pouring milk on the sofa
- cleaning the sofa
- moving the sofa
- sofa placed on the stairs
- sofa upright
- upside down
- sofa flying in midair
- ...

Artifact-based Perception Model

perception based on simple sensors

sensor reading are meaningful
- when related to a real world object that are attached to
- when related to other objects which are aware

implementing sensing and context recognition for a specific object is
- simpler than for a complete system
- more generic and applicable to several applications
- allows reuse of perceptual components

Context-aware Ubicomp systems can be modeled as
- set of networked context-aware artifacts
- time and space relation between these artifacts

A layered architecture for distributed context-aware systems

Artifact layer
- data collection,
- perception and recognition for the particular artifact

Setting layer
- tightly coupled group of artifacts
- all perception and recognition tasks in a group

Application layer
- application-specific perception and recognition
- context information relevant for the application is combined

Artifact Layer

- **Modeling a single artifact**
- **Usually a single sensing / perception node**

context primitives are determined by asking
- what is the artifact and what is its prime use?
- who are the users of such an artifact and in which situation do they use it?

tasks that are accomplished in the artifact layer
- Sensor data acquisition
- Artifact centric perception processing
- History and long term buffers

Artifact Layer API

Description	Function	Type
scan local artifact for sensors available	`scan_i2c() → [<sensor_1>, <sensor_2>, ..., <sensor_n>]`	Discovery
asking for the capabilities/features supported/provided by a local sensor	`cap_i2c(<sensor_j>) → [<feature _1>, <feature_2>, ..., <feature_n>]`	
to prepare feature calculation since get_i2c is blocking	`prepare(<sensor_j:feature_i>)`	Single request
poll sensors/features for values for most recent value	`get_i2c(<sensor_j:feature_i>) → value`	
specify condition: when sensor sends interrupt over I2C	`on_change(<sensor_j:feature_i>, condition )`	Condition trigger
create a buffer to collect sensor data	`create_buffer(<sensor_j:feature_i>, desired length, interval-ms, timewindow-ms, func-id)`	Subscription
access a buffer previously created	`get_buffer(<sensor_j:feature_i> )`	

Setting Layer

- tightly grouped set of artifacts or devices that are cooperating.
- cooperation between artifacts for the purpose of supporting a particular setting
- independent of a particular application

Questions to establish a setting

- What is the relationship among artifacts?
- What is the purpose of the setting?
- Who are the users?
- What perception primitives/contexts are provided?

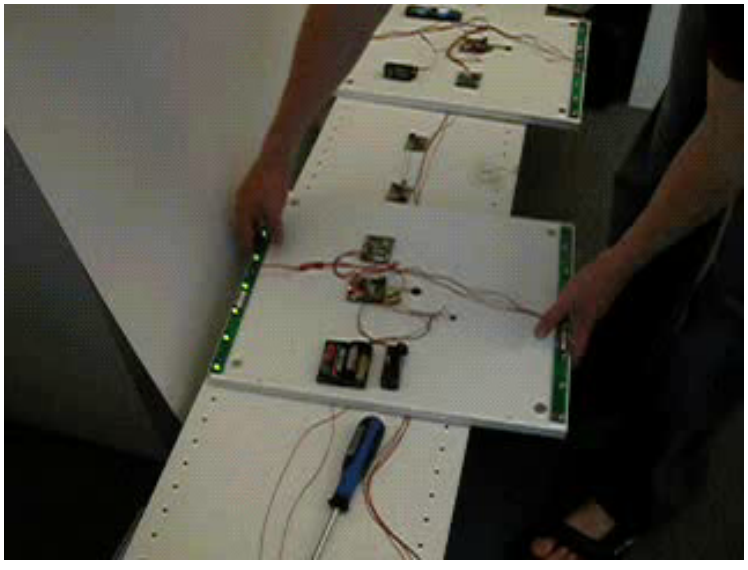
Tasks in the setting layer

- offering collective perception primitives
- collecting and providing setting history

Setting Layer API

Description	Function	Type
enquire for all devices in a certain physical distance	`hello(distance) → [<id_1>, <id_2>,…, <id_n>]`	Discovery
scan remote artifact for sensors available	`scan_id(<id>) → [<s_1>, <s_2>,…, <s_n>]`	
asking for the capabilities/features supported/provided by a remote sensor	`cap_sensor_id(<id:sensor >) → [<f_1>, < f_2>,…, < f_n >]`	
to prepare feature calculation on remote artifact	`prepare_rf(<id:sensor_j:feature_i>)`	Single request
poll sensors/features for values for most recent value from remote artifact	`get_rf(<id:sensor_j:feature_i>) → value`	
specifiy condition: when remote sensor notifies on condition	`on_remote_change(<id_k:sensor_j:feature_i>, condition )`	Condition trigger
create a remote buffer to collect sensor data	`create_remote_buffer( <id_k:sensor_j:feature_i>, desired length, interval-ms, timewindow-ms, func-id)`	Subscription
access a remote buffer previously created	`get_remote_buffer( <id_k:sensor_j:feature_i>, start_time, length )`	

Case Study: Proactive Instructions



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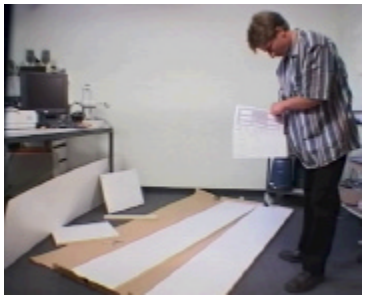
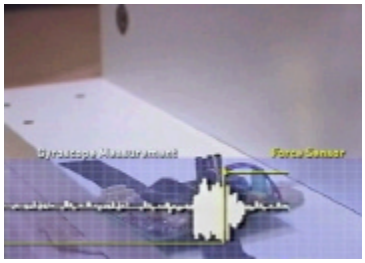
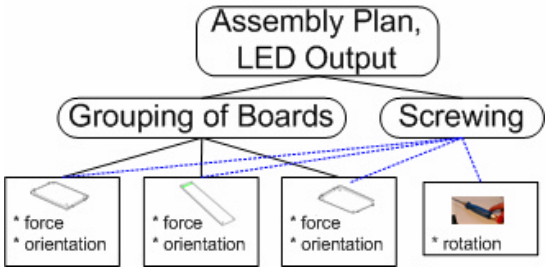




- **Boards and screw driver are the artifacts**
- **Settings layer infers the current assembly and activity**
- **Application layer**
  - displays embedded instructions
  - Compare steps to the plan



Case Studies / Evaluation

Several systems implemented / re-implemented

- proactive instructions
- A-life (avalanche rescue system)
- Demo of a restaurant with aware items
- Smart office
- Smart-Its Friends
- Load-sensing environment

Lessons learned

- **Implementing on artifact level allows separation of concerns**
- **Reuse of existing parts in a system**
- **Successful hiding of low-level functionality**
- **Further functionality and new applications are much quicker implemented**

Conclusions

Artifact centered view easies development of context-aware applications

Layered approach
- allows separation of concerns
- enables reuse of perceptual components
- eases application development

Implementation
- Smart-Its and PC
- similar API, C on the MCU, JAVA on PC

Approach successfully applied in several systems

Questions?

Smart-Its Consortium

- ETH Zurich, Switzerland,
- Lancaster University, UK
- TecO, University of Karlsruhe, Germany
- FAL, Victoria Institute, Sweden
- VTT, Oulu, Finland

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