Towards Distributed Awareness - An Artifact based Approach
WMCSA December 2, 2004

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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

- **Room**: occupied
- **Activity**: meeting
- **Chair 1**: used
- **Chair 2**: used
- **Projector**: on
- **Door**: closed
- **Audio**: speaking

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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

<table>
<thead>
<tr>
<th>Description</th>
<th>Function</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>scan local artifact for sensors available</td>
<td>scan_local_artifact() ( \rightarrow ) (&lt;\text{sensor}_1&gt;, \ldots, \langle\text{sensor}_n\rangle)</td>
<td>Discovery</td>
</tr>
<tr>
<td>asking for the capabilities/features supported/provided by a local sensor</td>
<td>cap_I2C(\langle\text{sensor}_j\rangle) ( \rightarrow ) (&lt;\text{feature}_1&gt;, \langle\text{feature}_2&gt;, \ldots, \langle\text{feature}_n\rangle)</td>
<td></td>
</tr>
<tr>
<td>to prepare feature calculation since get_I2C is blocking</td>
<td>prepare(\langle\text{sensor}_j\rangle; \langle\text{feature}_i\rangle)</td>
<td>Single request</td>
</tr>
<tr>
<td>poll sensors/features for values for most recent value</td>
<td>get_I2C(\langle\text{sensor}_j; \langle\text{feature}_i\rangle) ( \rightarrow ) value</td>
<td></td>
</tr>
<tr>
<td>specify condition: when sensor sends interrupt over I2C</td>
<td>on_change(\langle\text{sensor}_j; \langle\text{feature}_i\rangle; \langle\text{condition}\rangle)</td>
<td>Condition trigger</td>
</tr>
<tr>
<td>create a buffer to collect sensor data</td>
<td>create_buffer(\langle\text{sensor}_j; \langle\text{feature}_i\rangle; \langle\text{desired}\rangle length, interval-as, time-window-as, func-id)</td>
<td>Subscription</td>
</tr>
<tr>
<td>access a buffer previously created</td>
<td>get_buffer(\langle\text{sensor}_j; \langle\text{feature}_i\rangle)</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Enquire for all devices in a certain physical distance</td>
<td><code>hello(distance) \rightarrow \{id_1, id_2, \ldots, id_n\}</code></td>
<td>Discovery</td>
</tr>
<tr>
<td>Scan remote artifact for sensors available</td>
<td><code>scan_id(id) \rightarrow \{s_1, s_2, \ldots, s_n\}</code></td>
<td></td>
</tr>
<tr>
<td>Asking for the capabilities/features supported/provided by a remote sensor</td>
<td><code>cap_sensor_id(id, sensor) \rightarrow \{f_1, f_2, \ldots, f_m\}</code></td>
<td></td>
</tr>
<tr>
<td>To prepare feature calculation on remote artifact</td>
<td><code>prepare_fm(id, sensor, feature)</code></td>
<td>Single request</td>
</tr>
<tr>
<td>Poll sensors/features for values for most recent value from remote artifact</td>
<td><code>get_fm(id, sensor, feature)</code></td>
<td></td>
</tr>
<tr>
<td>Specify condition: when remote sensor notifies on condition</td>
<td><code>on_remote_change(id, sensor, feature, condition)</code></td>
<td>Condition trigger</td>
</tr>
<tr>
<td>Create a remote buffer to collect sensor data</td>
<td><code>create_remote_buffer(id, sensor, feature, desired_length, interval_ms, time_window_ms, func_id)</code></td>
<td>Subscription</td>
</tr>
<tr>
<td>Access a remote buffer previously created</td>
<td><code>get_remote_buffer(id, sensor, feature, start_time, length)</code></td>
<td></td>
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## Case Study: Proactive Instructions
Case Study: Proactive Instructions

- 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

Funded by the European Disappearing Computer Initiative