Towards the adaptive integration of multiple context reasoners in pervasive computing environments

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CoMoRea’10, Mannheim, Germany, March 29, 2010
Introduction

• Goal: deriving high-level context data in pervasive computing environments
  – Data sources are highly dynamic
  – Multiple reasoners can be used

• Approach:
  – Automatic discovery of context data sources
  – Dynamic integration of multiple reasoners
The COSAR system

- Coupled ontological-statistical context reasoning
  - To refine statistical predictions
  - To recognize complex human activities

- Context reasoning mainly executed on personal mobile devices

- Computationally-expensive tasks are executed by a server infrastructure
The COSAR system

EveryWare Lab

CoMoRea’10, Mannheim, Germany
March 29, 2010
COSAR extension

- COSAR relied on a fixed set of sensor data

- Extension:
  - Reasoners specify their data requirements
  - Sensors advertise their presence
  - A broker couples sensors and reasoners
  - Each reasoner works independently
  - An integrator provides aggregated predictions
Sensor publishing

- SensorML specifications describe sensor capabilities and placement
- Each sensor periodically broadcast its unique identifier
- When needed, COSAR asks the sensor for its spec
  - The sensor provides a SensorML instance doc
  - COSAR gets the full spec from the web (or from the sensor itself)

<table>
<thead>
<tr>
<th>description</th>
<th>Prototype of a smart watch worn on the right wrist</th>
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<tbody>
<tr>
<td>manufacturer</td>
<td>Sun Microsystems</td>
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<tr>
<td>sensorType</td>
<td>accelerometer</td>
</tr>
<tr>
<td>name</td>
<td>LIS3L02AQ Accelerometer</td>
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<tr>
<td>datum</td>
<td>The Z-axis is perpendicular to the Sun SPOT boards. The X-axis...</td>
</tr>
<tr>
<td>frequency</td>
<td>16Hz</td>
</tr>
<tr>
<td>quantity</td>
<td>accelerationX</td>
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<tr>
<td>unit</td>
<td>G</td>
</tr>
<tr>
<td>range</td>
<td>-6.0 6.0</td>
</tr>
<tr>
<td>quantity</td>
<td>tiltX</td>
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</table>

Table I
AN EXCERPT OF THE SMART WATCH SPECIFICATION
Reasoners subscription

- Reasoners specify their characteristics
  - Kind of algorithm, considered activities, frequency of predictions, model, ...

- Reasoners subscribe to those context data they need to operate
  - Kind of data, placement, sampling frequency, ...

- Specifications are expressed in a custom XML format

<table>
<thead>
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<th>reasoner</th>
<th>multiclass logistic regression</th>
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<td>model</td>
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<td>statistics</td>
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<td>16Hz</td>
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<tr>
<td>frequency</td>
<td>16Hz</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Table II
An excerpt of a reasoner specification
Integrating predictions

• Two classes of reasoners:
  – *Classifiers*
    • Provide confidence vectors, whose values represent the confidence of the reasoner regarding a predicted high-level context
    • E.g., statistical classifiers considering data from body-worn inertial sensors
  – *Filters*
    • Provide filter vectors specifying if a high-level context is feasible or not in the current situation
    • E.g., ontological reasoners considering user’s location and surrounding environment
Integrating predictions

- Currently, COSAR supports only snapshot integration
  - Complex temporal aspects are not captured
- Three main operations:
  - Balancing
    - The more high-level contexts are considered by a classifier, the less its average confidence
  - Aggregation
  - Pruning
Prototype implementation

- COSAR layer on the Android platform

- Sensor layer on Sun SPOT and Android embedded sensors

- Reasoners for ADL and physical activities
  - Classifiers based on inertial data and Multiclass Logistic Regression algorithm
  - Ontological and rule-based filters based on location and speed
Experiments

• Goal: recognition of 10 indoor/outdoor activities

• 5-hours activity data collected by 6 volunteers
  – Data: acceleration from wrist and hip; location and speed

• Our technique is compared with a “monolithic” one
  – Monolithic: a single classifier exploits the whole set of context data
  – The monolithic technique does not adapt to context changes

• Experiments with 3 different sensor configurations
Experiments

Accuracy is comparable, but COSAR has the advantage of adapting to context changes.

Computational cost of COSAR with an Android device (528MHz processor, 288MB RAM)

<table>
<thead>
<tr>
<th>H</th>
<th>W</th>
<th>H+W</th>
<th>H+W+L</th>
<th>W</th>
<th>H+W+L</th>
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</thead>
<tbody>
<tr>
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<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
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</tbody>
</table>

H: classifier with hip data; W: classifier with wrist data; L: location filter; S: speed filter
Symbol “+” denotes the COSAR integration of reasoners.
COSAR open issues

• Recognition of concurrent high-level contexts
  – This is supported only by the ontological module

• Modelling the temporal characterization of high-level contexts
  – Classifiers rely on a static segmentation
  – The ontology does not consider complex temporal relationships

• Support for uncertainty
  – Statistical reasoners assign a confidence degree to predictions; ontological ones do not.
Future work

- Recognition of concurrent high-level contexts
  - The ontology may derive which activities can (or cannot) be performed concurrently

- Modelling the temporal characterization of high-level contexts
  - Adjust segmentation based on candidate activities
  - Use of reasoning techniques for sequential data
  - Definition of duration and temporal relationships within a description logic framework

- Support for uncertainty
  - Investigate techniques to represent fuzzy and imprecise information with ontologies