A Framework for Real-Time Context Provision in Ubiquitous Sensing Environments

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Context Provisioning in Sensor Networks

Sensor Networks Today

- Sensors and sensor networks are widespread
- Information from sensors can be combined with the context in which it is generated

Challenges

- Enrich sensor data
- Uniform access to sensor, context, mixed information
- Ease of context configuration
- Support Real-time applications

Scenario & Contribution

Smart Building: monitor the environment within a building

- Buildings are generally organized in *spaces*, each with *contextual information*
- Spaces and Contextual information reorganized frequently
- Queries on streaming, contextual, mixed data
- The volume of data and queries can be high

UbiQuSE: Ubiquitous Queries for Sensing Environments

- An hybrid query interface to manage streaming, contextual and data mining queries
- Simplified context configuration
- Small footprint for real-time applications

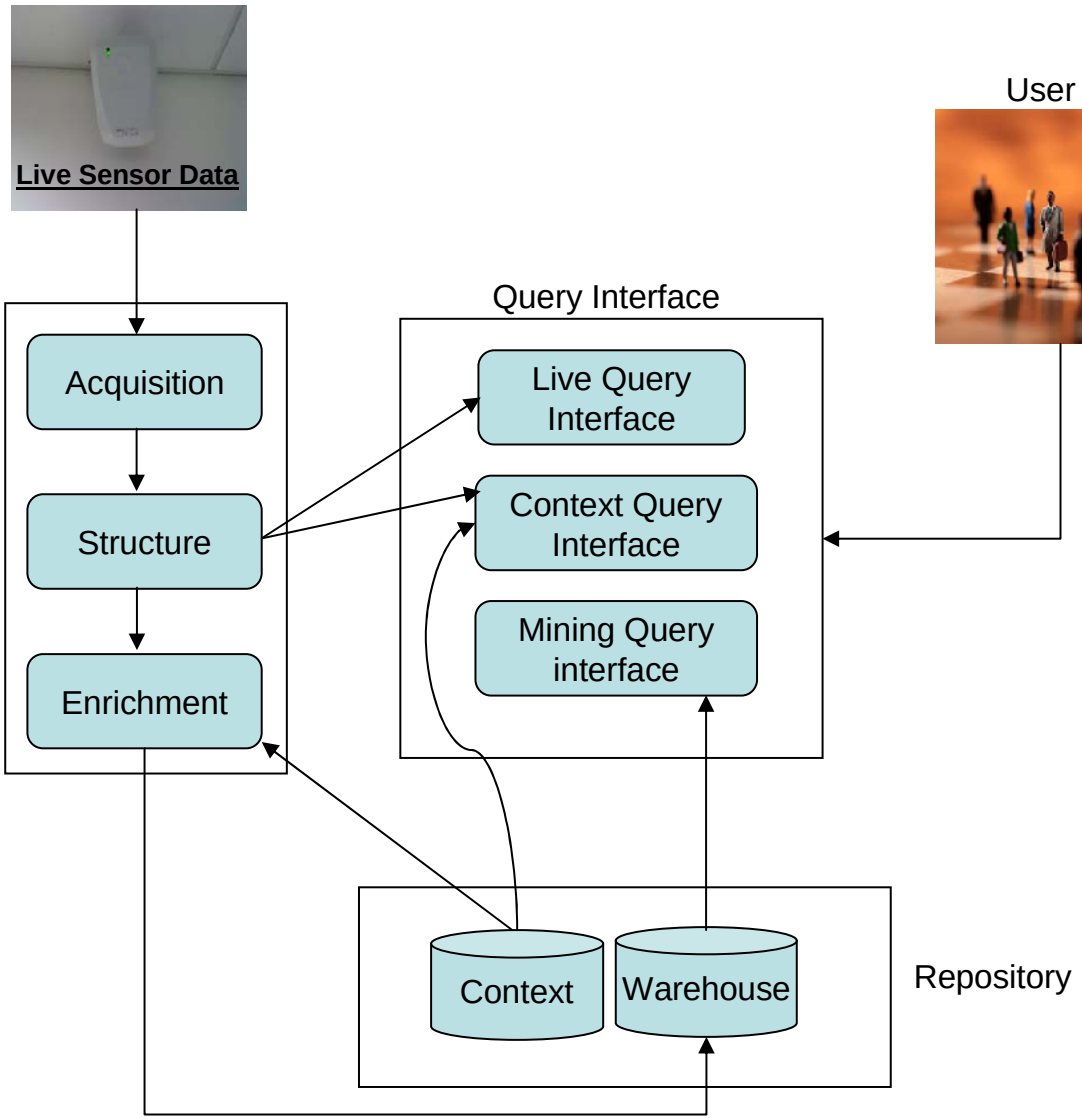
Query Classification

Query Classification

- Live (**L**): expressed on live data streams
- Context (**C**): expressed on the static context data or on a mix of static and live data
- Mining (**M**): expressed on stores of historical data

Type	***Query***
L	What is X's Current Location?
L	How many "people" are in this location?
C	What seervices are available in Space Z and adjacents?
C	Given current direction, what is next Space?
M	How long has X been in this Space?
M	What is the most popular service for this Space?

Architecture



Stream Processing

Data formatting

- Raw data is translated into structured, XML, data format
- A *template* describe the association between raw data and its semantic
  - Each value is associated with an XML attribute
- Raw data are "wrapped" with XML tags

Raw data format

Description	Sensed Data
Date	16/02/2010
Time of day	15:27:46
Dimension-X	19.0431594848633
Dimension-Y	0.91026896238327
Dimension-Z	1.21332836151123

Structured data format

```
1 <event_detect tagId="20000007106">
2  <session id="1">
3    <date>16/02/2010<date>
4    <time>15:27:46</time>
5    <x>19.0431</x>
6    <y>0.9102</y>
7    <z>1.21332</z>
8  </session>
9 </event_detect>
```

Querying live data

Live data

- Live data can be queried by XPath/XQuery expressions
  - Consolidated languages
  - Declarative expressions
  - Device independent
- The overhead of XML-izing live data is rather small because each event produces a small volume of data
- The overhead of executing XPath/XQuery queries remains low as the XML structure of live data is simple (generally one or two levels of nesting)

Querying context data

Static contextual data

- Static context information can be retrieved by static queries
  - Configuration of the spaces, services available, ...
- Static information is generally well structured and can be stored in a relational database

Dynamic contextual data

- Dynamic context queries retrieve mixed live and contextual information
- Live information from a device feed arguments to (static context) queries to retrieve contextual information associated with current device information

Query Repository

Predefining queries

- Queries are declarative: can be stored, added or edited without altering the application source code
- Both static and dynamic queries can be predefined and stored in a query repository
- In effect, users can interact with the system by choosing from available queries

Stream Processing: historic series

Data enriching

- Simplicistic sensor data is enriched with contextual information
- Enriched data is stored in a data warehouse

Structured Data

```
<event_detect tagId="20000007106">
 <session id="1">
   <date>16/02/2010<date>
   <time>15:27:46</time>
   <x>19.0431</x>
   <y>0.9102</y>
   <z>1.21332</z>
 </session>
</event_detect>
```

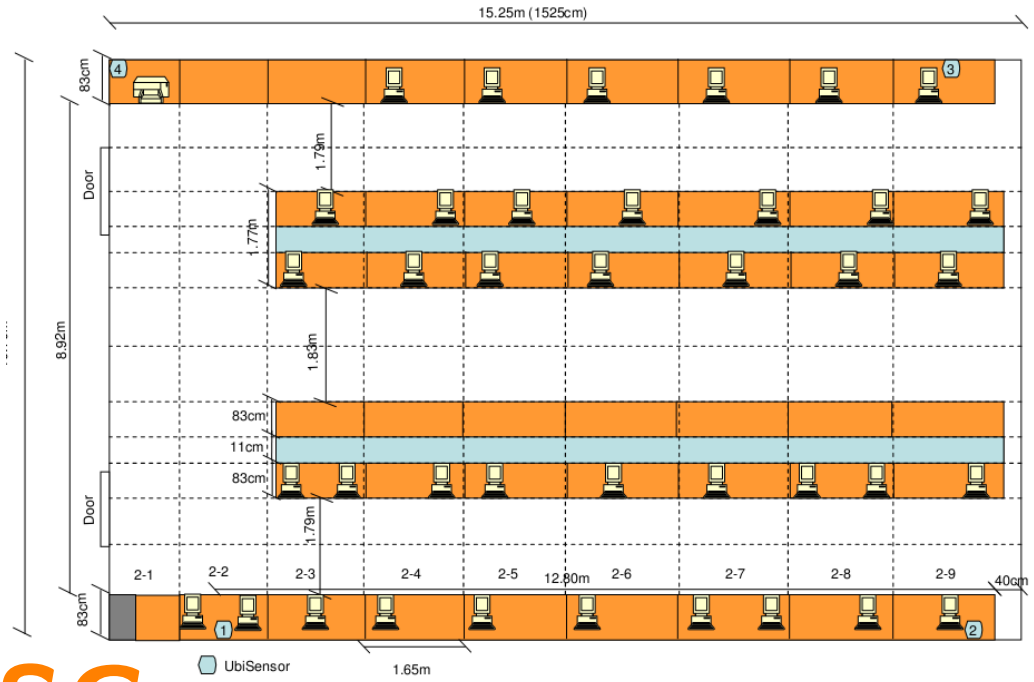
Enriched Data

```
<event_detect tagId="20000007106">
 <session id="1">
   <date>30/11/2009<date>
   <time>15:27:46</time>
   <x>19.0431</x>
   <y>0.9102</y>
   <z>1.21332</z>
   <zoneID>Zone 3-2</zoneID>
   <productlist>
    <productID>P015</productID>
   </productlist>
   <servicelist />
 </session>
</event_detect>
```

Experiments

Setting

- In-lab reproduction of business partner scenario
- 4 sensors per room, 4 mobile *tags* devices moving around
- System in a "push style" mode, where information is automatically and continuously passed to the user



Accuracy

- For (relatively) slow moving objects we measured

Area (cm)	Accuracy (%)
1 - 20	60
20 - 100	100

Experiments

Query performance: live queries

- Queries retrieving basic information (location, time, device-id) have execution time of ∼205ms, which is in the same order of the sensors' specs
- This demonstrate the little overhead the XML conversion and query adds to live data processing

Query performance: context queries

- The execution requires to retrieve live information to feed arguments to a query on the context database
- On relatively complex queries like "describe the information on the current and adjacent spaces" have an execution time of ∼26ms, on top of the time to retrieve live data

Conclusions & Future Work

Conclusions

- We have proposed a framework for real-time context provisioning in ubiquitous sensing environments
- Data can be accessed by standard query languages
  - Device independence
- Data is decoupled from the application logic

Future Work

- Scaling up to larger scenarios
  - Number of users, spaces
- Exploit the historical series in the data warehouse to analyze and, possibly, obtain predictions
  - Users behaviour, context evolution, sensors activity, ...

Thank you!

Questions

- "*Real-time...*"
- Or to paolo.cappellari@computing.dcu.ie

More details

- ISG web site: `http://www.computing.dcu.ie/~isg/`