SEMANTIC BMS: SEMANTICS-DRIVEN MIDDLEWARE LAYER FOR ANALYSIS OF BUILDING AUTOMATION SYSTEMS DATA

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Motivation – Use case

• **Goal:** Examining building operation *performance* and *efficiency* using building automation data

• **Use case:** Campus of Masaryk University (40 smart buildings, 1700 devices, 150 000 data points)

*Source: muni.cz*
Motivation – BAS Capabilities

Source: OFM SUKB MU
## Motivation – Analytical capabilities

<table>
<thead>
<tr>
<th>BAS</th>
<th>CAFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor data</td>
<td>Financial data</td>
</tr>
<tr>
<td>High detail</td>
<td>Low detail</td>
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<tr>
<td>Recent data</td>
<td>Delayed data</td>
</tr>
<tr>
<td>Simple applications</td>
<td>Complex applications</td>
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</table>

- How much does the electricity consumption differ across the campus?
- How much energy is consumed by air conditioning?
- What are the average room temperatures?
Aims – Query examples

1. Semantic query
   Location: Campus Bohunice; Building A11
   Grouping: Per floor
   Measured property: Air temperature
   Source device: Temperature sensor
   Data type: History
   Query output: BMS ID

2. Semantic result
   N01: {11400.TL5, 11500.TL5, 11600.TL1}
   N02: {12100.TL5, 12300.TL3, 12400.TL5}
   N03: {12500.TL1, 12600.TL1, 12800.TL1}

3. Data query
   Data points: Semantic result data
   Aggregate: temporal AVG
   Period: 09/2016 – 1/2017
   Aggregation Window: 1 day

4. Data result
   N01: {{2016-09-01, 23.8}, {2016-09-02, 24.8},
   {2016-09-03, 25.1}, {2016-09-04, 24.7}, ...}
   N02: {... }
   N03: {... }
Aims – Query examples

Room temperatures


Room temperatures

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Problem – Complexity of applications

- Data **access** (automation protocols, OLTP)
- Data **selection**, grouping & aggregation
- Analytical **methods**
- User **interface**
Problem – Unsuitable semantics

- Data points **identified by** network **address** in the BAS
- Data point properties carry **limited semantics**
- **Missing relation** to the physical world:
  - Location
  - Source device
  - Measuring environment (air, water,...)
  - ...
Aims – New semantics

• New approach to analysis of BAS data
  • Network **addresses are not used** as identifiers
  • Universal model relates **BAS** and **BIM** (**Building information model**) and also adds new information

Network address (BMS)

- Source device (BIM)
  - Device ID
  - Type
- Scope device/location (BIM)
  - Location
- Observed property
  - Physical quantity
  - Domain
- Sensing method
  - Time window
  - Aggregation
Methods – Ontology

• New semantics of BAS data can be described by Ontology language

• OWL – Web Ontology Language (W3C)
  • Designed for Semantic web & Linked Data
  • Based on RDF (Resource Definition Framework)
  • „Subject-Predicate-Object“
Methods – Ontology

• Semantic Sensor Network ontology
  • Uses upper-level ontology (Dolce UltraLite)
  • **Stimulus-Sensor-Observation** Pattern
  • Observations&Measurements translated to OWL
• Adjustments/Extensions to SSN to meet domain specific requirements:
  • Representation of facility elements (BIM data)
  • BMS Data points
  • Physical quantities (UCUM: http://unitsofmeasure.org/trac/)
  • Sensing methods
  • Device types (adapted from IFC 4)
Methods – Ontology

Source: Authors
Methods – Middleware layer

Source systems

Middleware layer

Front end applications

Users

- BMS on-line data
- Data Access API
- Technology data mart
- Data providers
- Semantic API
- Ontology repository
- BMS Archive server
- BIM
- Foreign keys
- Foreign keys (network topology)
- Monitoring & Fault Detection Applications
- Dedicated Analytical Applications
- CAFM
- BMS operator
- Facility manager
- Maintenance staff
Methods – Middleware layer

Semantic model: RDF, OWL, triple store, Queried by SPARQL
Methods – Middleware layer

Semantic API: Encapsulates semantic model – convenience functions & operators
Methods – Querying using SPARQL

- Location: *Site 02* - *Building 03*
- Grouping: *Per floor*
- Measured property: *Air temperature*
- Source device: *Temperature sensor*
- Value type: *History*
- Query output: *BMS ID*

```
SELECT ?trendbmsId ?group
WHERE
{
  ?datapoint sbms:hasBMSId ?bmsId ;
  sbms:expressesObservation ?obs .
  ?obs sbms:observedBy ?source ;
  sbms:featureOfInterest ?scope .
  ?scopeLocR sbim:hasBIMId "S02B03" .
  ?obs sbms:observedProperty ?property .
  ?property sbms:hasPhysicalQuality ucum:temperature ;
  sbms:hasPropertyDomain sbms:Air .
  ?groupR sbim:hasBIMId ?group ;
  a sbim:Floor .
  ?source a sbim:TemperatureSensor .
  ?trend sbms:trends ?datapoint ;
  sbms:hasBMSId ?trendbmsId
}
```

```
{ "head": { 
  "vars": [ "trendbmsId", "group" ] 
}, 
"results": { 
"bindings": [ 
  { "trendbmsId": { 
   "type": "literal" , 
   "value": "bactrend://02030101.TL1" } , 
  "group": { 
   "type": "literal" , 
   "value": "S02B03F01" } 
  }, 
  { "trendbmsId": { 
   "type": "literal" , 
   "value": "historian://TL857" } , 
  "group": { 
   "type": "literal" , 
   "value": "S02B03F01" } 
  }, ...
} 
```

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Methods – Querying using API

• Location: *Site 02 - Building 03*
• Grouping: *Per floor*
• Measured property: *Air temperature*

• Source device: *Temperature sensor*
• Value type: *History*
• Query output: *BMS ID*

```
http://.../sbms/semantics/trends/
?fields=bmsId
&grouping=scope.floor
&dataPoint.source.type=TemperatureSensor
&dataPoint.scope.location=S02B03
&dataPoint.property.domain=Air
&dataPoint.property.quality=temperature

{
  "groups": [
    "S02B03F01",
    "S02B03F02",
    "S02B03F03"
  ],
  "results": {
    "S02B03F01": [
      {
        "bmsId": "bactrend://02030101.TL1",
        "dataPoint": {
          "bmsId": "bacnet://02030101.AI1"
        }
      },
      {
        "bmsId": "historian://TL857",
        "dataPoint": {
          "bmsId": "bacnet://02030101.AI1"
        }
      }
    ],
    "S02B03F02": [
      {
        "bmsId": "bactrend://02030102.TL2",
        "dataPoint": {
          "bmsId": "bacnet://02030102.AI2"
        }
      }
    ],
    "S02B03F03": [
      {
        "bmsId": "bactrend://02030103.TL3",
        "dataPoint": {
          "bmsId": "bacnet://02030103.AI3"
        }
      }
    ]
  }
}
```
Results – Semantic API & Client
Results – Semantic API & Client
Future work – Middleware layer

Data access API:
- Encapsulates BAS protocols
- And DB schemes
Future work – End-user Applications

Source: Authors, Petr Zvoníček, FI MU
Summary & Conclusion

- **Area:** Building operation analysis using data from automation systems

- **Aims:**
  - Provide new semantics to BAS data
  - Simplify development of analytical tools

- **Method:** Middleware layer
  - Semantic information – Integrating BAS and BIM
  - Data access

- **Evaluation:** Implementation of benchmarks defined in *EN 15 221: Facility Management*
Thank you for your attention!

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- Project page:
  https://gitlab.fi.muni.cz/xkucer16/semanticBMS