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Making sense of sensor data using ontology: A discussion for residential building monitoring

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mmea
Measurement, Monitoring and Environmental Assessment

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Cluster for Energy and Environment

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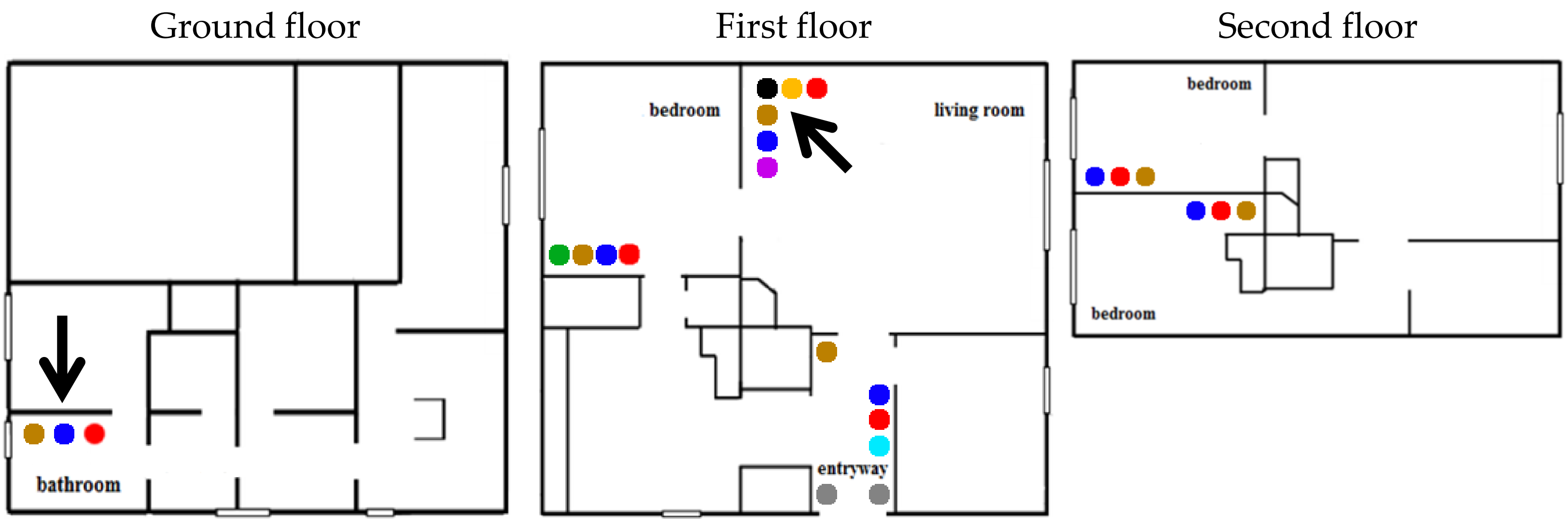
Introduction

- Common challenge for IS&S that build on sensor networks
  - Gap between raw sensor data and abstract domain terminology
  - IS&S in interaction with users should "understand" terminology
  - Sensor networks: "Too much data not enough knowledge" [1]
  - Making sense of sensor data a "huge challenge" [2]
- Use ontology for
  - Annotation of sensor networks and sensor data
  - Representation of knowledge about sensor observations
- We (mainly) discuss the second use
  - For a residential building monitoring case study
  - Detached, three-story house, in Kuopio, Finland

Materials and methods

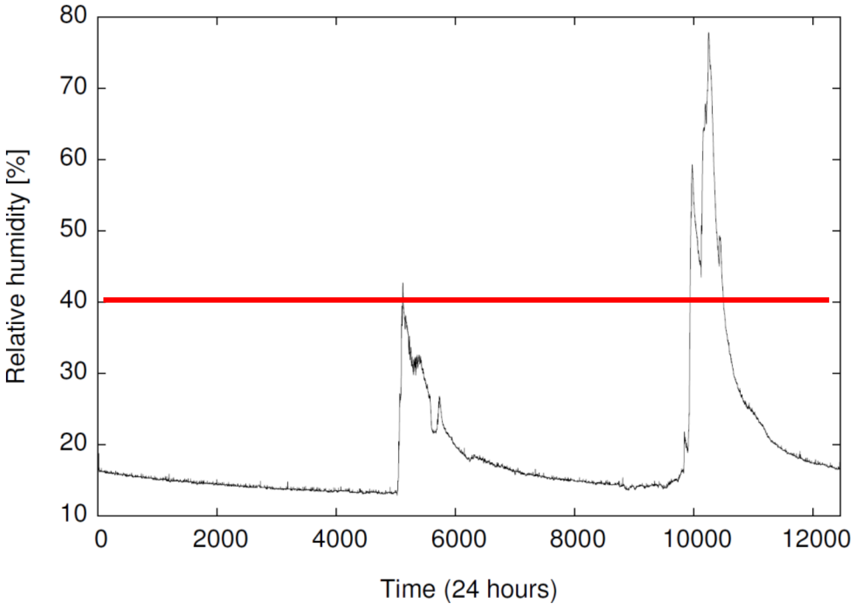


- Relative humidity
- Temperature
- Carbon dioxide
- Volatile organic compounds
- Fireplace temperature
- Carbon monoxide
- Passive infrared sensor
- Air pressure difference
- Particle counter

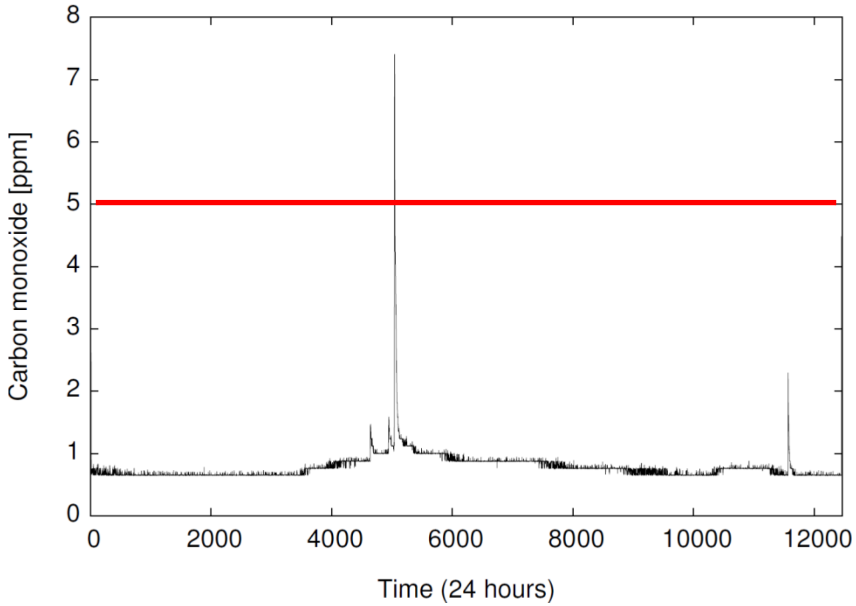
Materials and methods

- Sensor data transmitted and centrally stored (MySQL)
- Knowledge acquisition tasks on sensor data for events
  - Person taking a shower
  - Beyond average CO (5 ppm)
- Semantic Sensor Network (SSN) ontology (OWL)
  - Extended to accommodate domain knowledge, e.g. sensing devices
  - Represent knowledge extracted from sensor data, i.e.
  - Observations
    - Made by a sensor at a certain time
    - For a feature-of-interest, e.g. 'beyond average CO'
    - Feature-of-interest can have properties, e.g. concentration level or duration

Materials and methods
Detect and extract properties of events



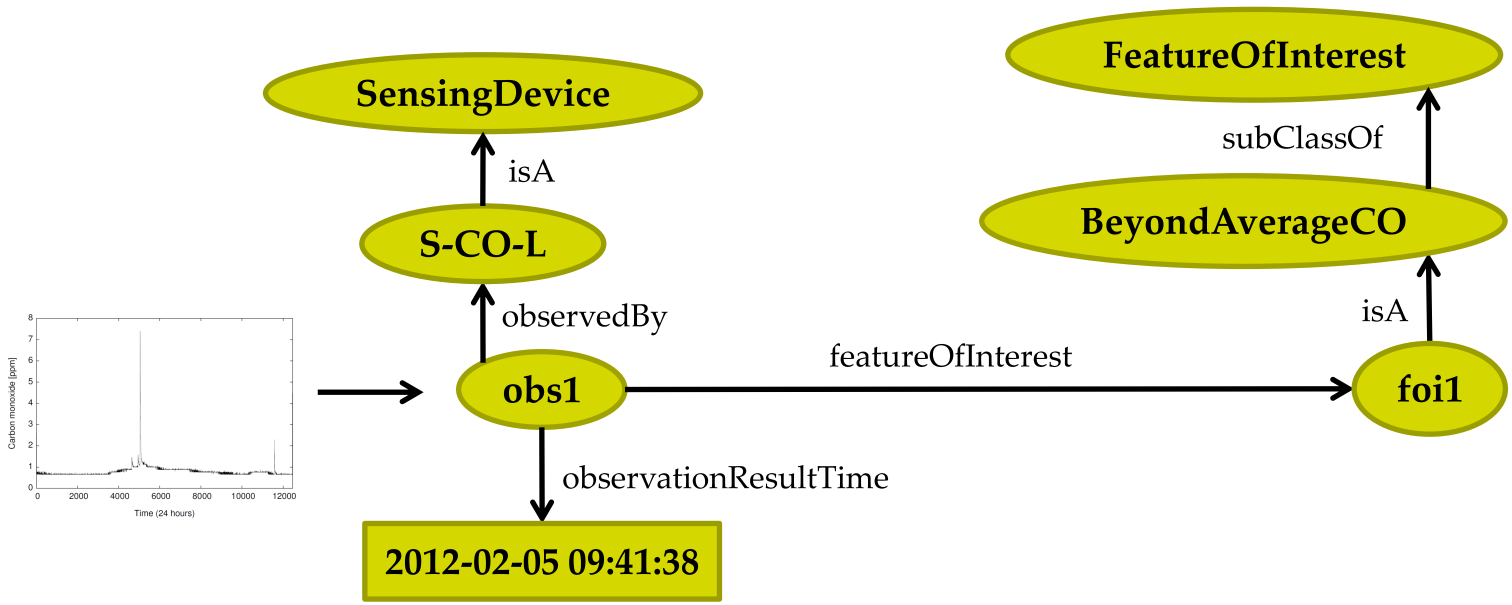
Relative humidity in bathroom (Feb. 5, 2012)



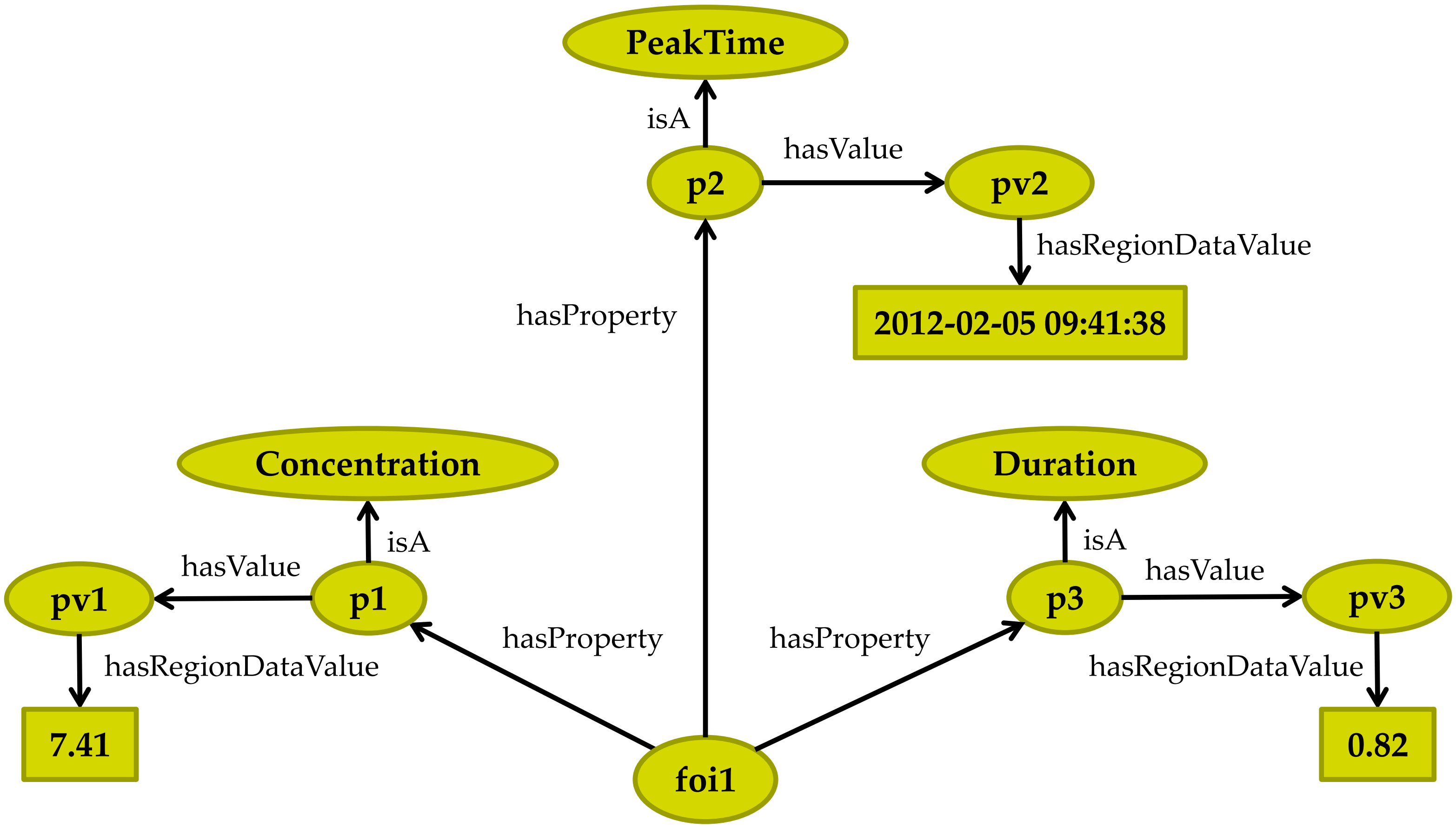
CO concentration in living room (Feb. 5, 2012)

Results
Observation

- Evaluation for the month of February 2012
  - 59 observations for ‘person taking a shower’
  - 2 observations for ‘beyond average CO’



Results
Feature of interest



Discussion

- Representation of knowledge acquired from sensor data
  - Using de-facto standards such as OWL and RDF
  - With existing upper ontologies, here the SSN ontology
  - Abstraction from sensor data, time series, data processing and analysis
  - Domain-oriented querying, knowledge integration and reuse
  - Automated symbolic reasoning
- Two ways to implement knowledge acquisition tasks
  - Beyond ontology (using ontology reasoning)
  - Before ontology (used here)

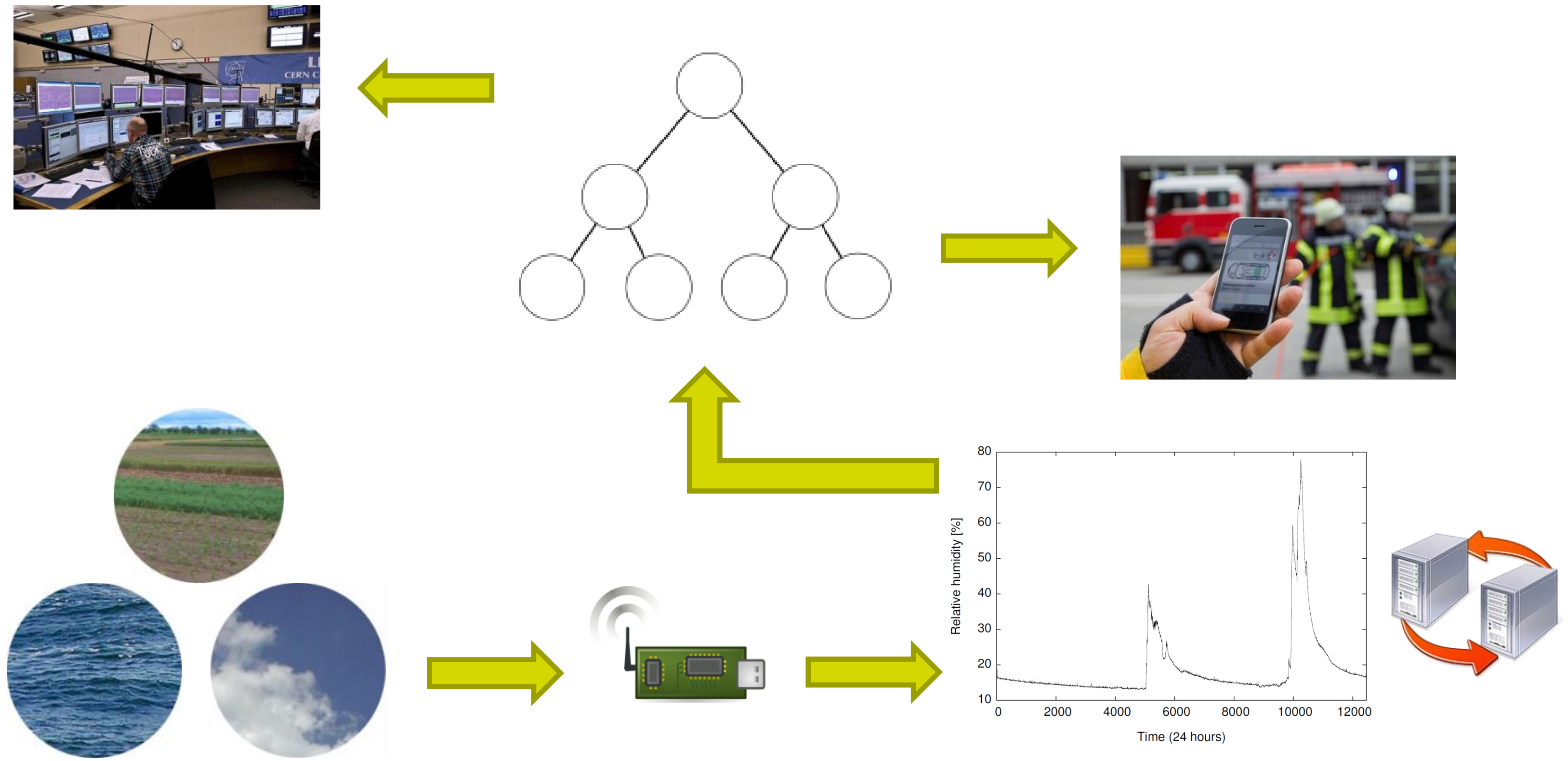
Discussion
Beyond ontology

- Implement knowledge acquisition task as rule
  - Over semantically enriched, explicitly represented, sensor data
  - Leverage rule-based and ontology inference
  - Generally applicable approach, domain independent
  - Formulation of rules relatively straightforward
  - No, or little, programming necessary
- Example
  - Inference of ‘high wind’ observations [3]
  - If wind observation result > some threshold, then ‘high wind’
- Drawbacks
  - Limited expressivity
  - Computational complexity

Discussion
Before ontology

- Implement knowledge acquisition task as software procedure
  - Input (multivariate) sensor data
  - Output ontology axioms
- Allows for "arbitrary" complex knowledge acquisition tasks
  - Including more interesting cases
- We can use signal analysis, machine learning, etc.
  - And a combination thereof
- For cases with too much sensor data to be represent explicitly
- Drawbacks
  - Expensive, domain specific implementation and programming
  - Error prone

Discussion
QoL IS



Related work

- Terminologies to describe sensor networks and sensor data [4]
- Extract from sensor data physiological properties of athletes [5]
- Generic architecture to extract information form sensor network [6]
- System that can be queried for high-level events in sensor data [7,8]
- Ontology-based environmental information systems [9,10]

Conclusions

- Representation of knowledge
  - Continuously acquired from sensor data
  - For a case study on residential building monitoring
  - Carbon monoxide example of interest to QoL
- Knowledge is acquired "before" ontology
  - Using methods for time series analysis
- Knowledge is represented using state-of-the-art technologies
  - In particular the Web Ontology Language
- Ontology layer is promising, abstraction, interaction, integration, …
- Open questions, e.g. implementing knowledge acquisition tasks

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Discussion
Future directions

- How to make it easier to implement “before” ontology?
  - Formalize the problem
  - Develop a declarative language
  - Unsupervised techniques
- Related to this case study
  - There are dozens of sensors, use more
  - Knowledge acquisition from multivariate data
  - Develop more interesting knowledge acquisition tasks
- Your ideas …

Related work

- Terminologies to describe sensor networks and sensor data [4]
- Extract from sensor data physiological properties of athletes [5]
  - Representation using XML
- Generic architecture to extract information form sensor network [6]
  - Three-layered architecture
  - Bridging sub symbolic layer (measurement) with symbolic layer
  - Via conceptual layer that implements a metric space (similarity)
- System that can be queried for high-level events [7,8]
  - Does not require handling of sensor data
- Ontology-based environmental information systems [9,10]