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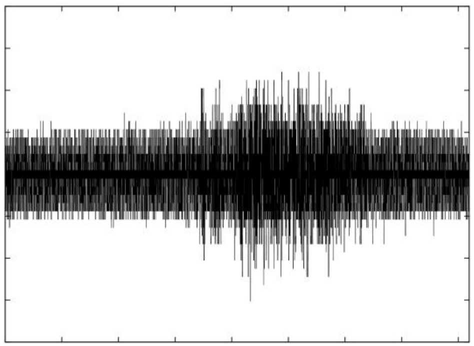
Aerosol Physics Group • University of Eastern Finland • March 21, 2013

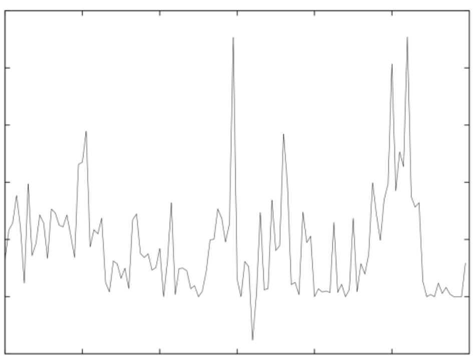
Wavellite

Continuous and automated representation of real-world knowledge acquired from sensor data

UNIVERSITY OF EASTERN FINLAND

Introduction
Sensor data makes *no* sense (almost)



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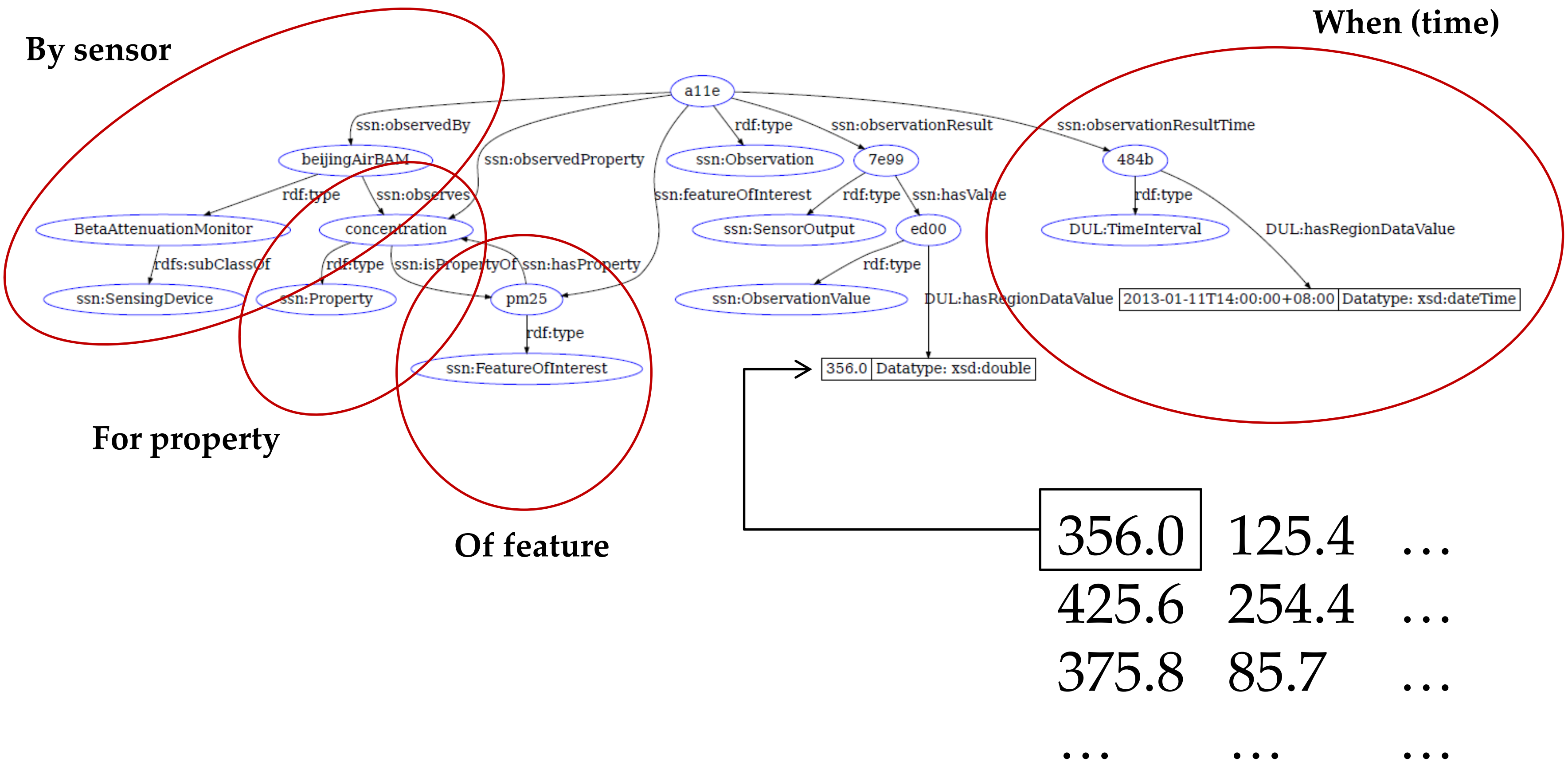
Introduction
… and

- There is lots of it, including in environmental science
- Typically automatically sampled, sometimes at "high frequency"
- More sensors; more data
- More information/knowledge?
- Probably, if we continue developing and improving
  - Management: processing, storage, and retrieval of sensor data
  - Acquisition: information and knowledge from sensor data
  - Integration, reuse, and sharing of data, information, and knowledge

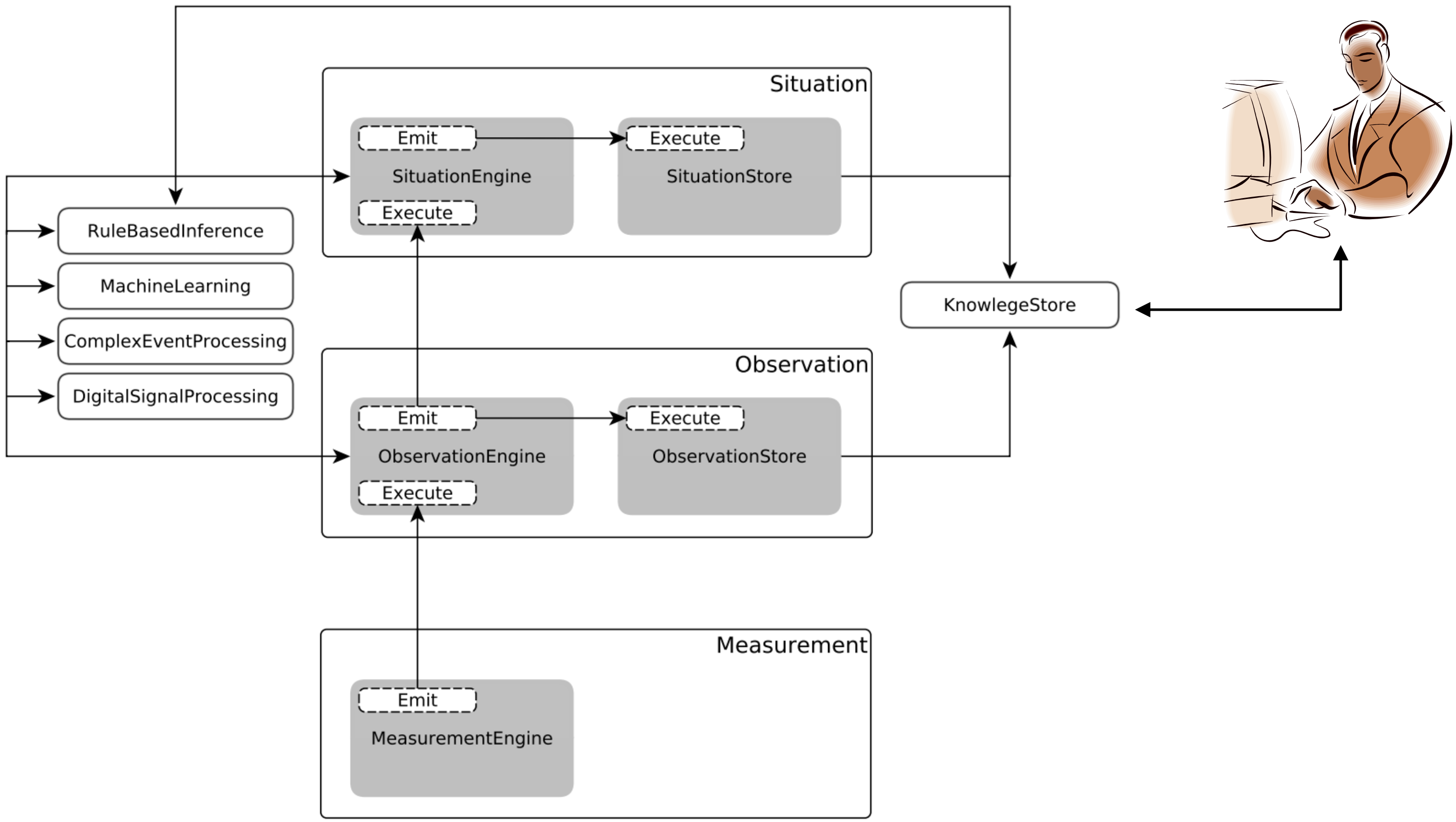
Introduction
Wavellite

- Manage sensor data *and* its metadata
  - Sensor data *and* the when-by-for-of (self-describing sensor data)
  - In other words, sensor data *and* information on
    - when is the sampling time
    - the sensor by which sampling occurs
    - the property for which measurement is performed
    - and the feature of which the property is measured
  - For instance, data sampled now by this beta attenuation monitor for the concentration of outdoor $PM_{2.5}$
- Represent knowledge for real-world phenomena observed by sensors
  - Events, episodes, scenes, changes: more generally situations
  - For instance, episodes of unhealthy exposure to $PM_{2.5}$
- Interact with represented observations and situations

Introduction
Self-describing sensor data



Materials and methods
Architecture



Materials and methods
Implementation (back end, server side)

- Continuous and automated
  - Sensor data acquisition and processing
  - Real-time knowledge acquisition and representation
- Computational intelligence for knowledge acquisition
  - ML, CEP, DSP
- Ontology for knowledge representation
  - Generic vocabulary
    - Used for all observations and situations
    - Shared by all software system components

Materials and methods
Implementation (back end, server side)

- Framework may be deployed on a single computer
  - Or on a cluster, for distributed processing (scalability)
- Domain-specific extensions
  - The framework implements generic functionality
  - Extend it to accommodate domain-specific requirements
    - Measurement engine implementation to acquire data from sensors
    - Situation engine implementation for knowledge acquisition tasks
- Use of
  - Semantic web technologies (RDF, OWL, SPARQL, knowledge store)
  - Storm as distributed real-time computation system
- Written in Java

Materials and methods
Implementation (front end, client side)

- Web enabled graphical user interface
  - Interaction between users and represented knowledge
  - Retrieve observations
    - Made by a sensor for a property of a feature within a time interval
    - Show results in tabular form, time-series plot, heat map, …
    - Show summary statistics (e.g. mean, sd, max, min, …)
    - Export data to various formats (e.g. Matlab, WEKA, …)
  - Browse situations along spatio-temporal dimensions
    - For instance on a map or timeline
- REST
  - Interaction between software and represented knowledge
  - HTTP requests and accept of various MIME media types

Example BeijingAir

- Sensor data acquired from @bejingair Twitter stream
- U.S. Embassy to Beijing runs a BAM for $PM_{2.5}$ monitoring
- One status update every hour, e.g.

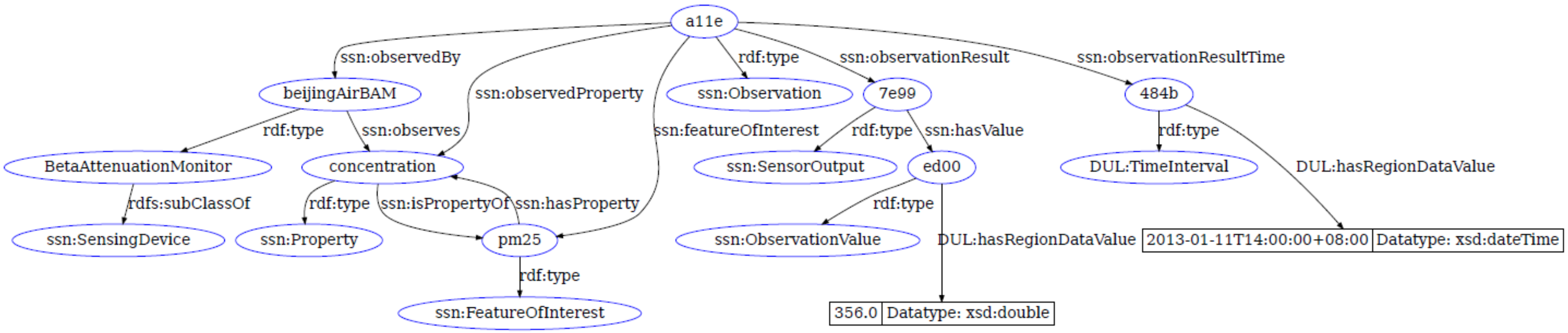
BeijingAir @BeijingAir 1h
04-02-2013 19:00; PM2.5; 108.0; 176; Unhealthy (at 24-hour exposure at this level)
Expand

BeijingAir @BeijingAir 2h
04-02-2013 18:00; PM2.5; 123.0; 184; Unhealthy (at 24-hour exposure at this level)
Expand

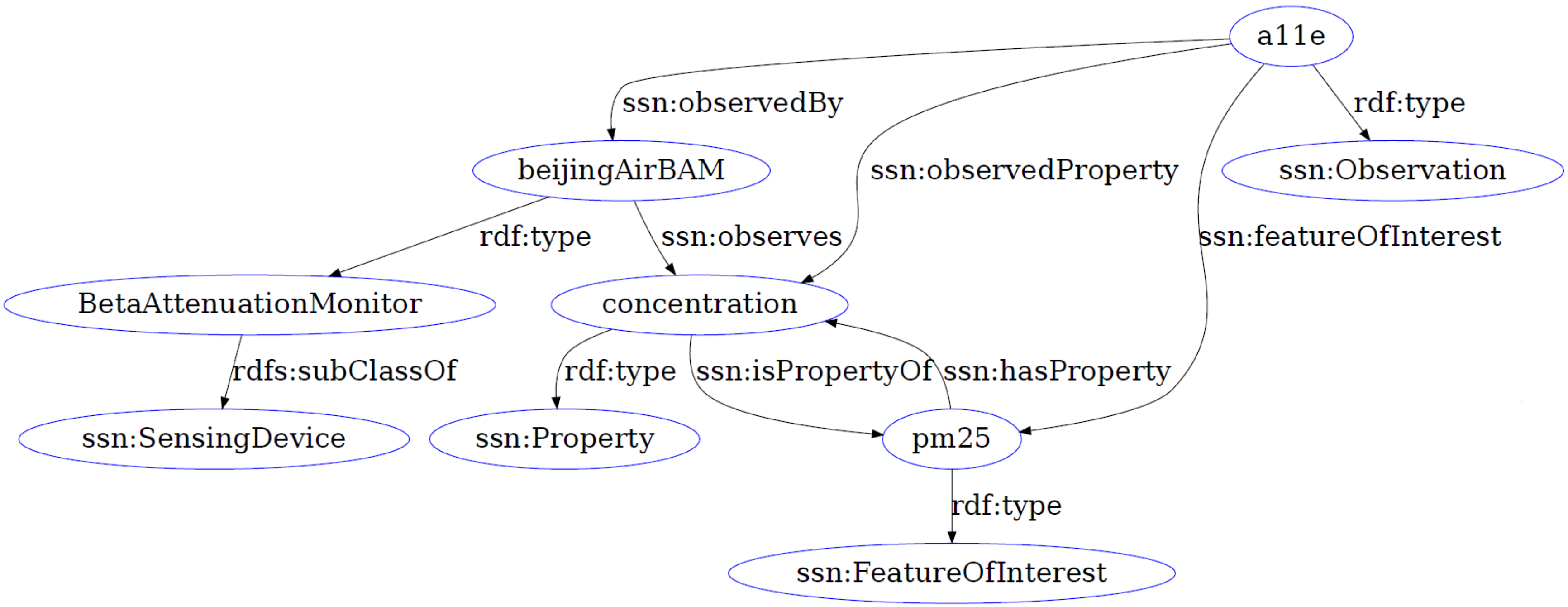
BeijingAir @BeijingAir 3h
04-02-2013 17:00; PM2.5; 130.0; 188; Unhealthy (at 24-hour exposure at this level)
Expand

- Statuses -> Measurement -> Observations -> Situations
- Situations of unhealthy exposure (> 65.5 µg/m^3; 24-hour)

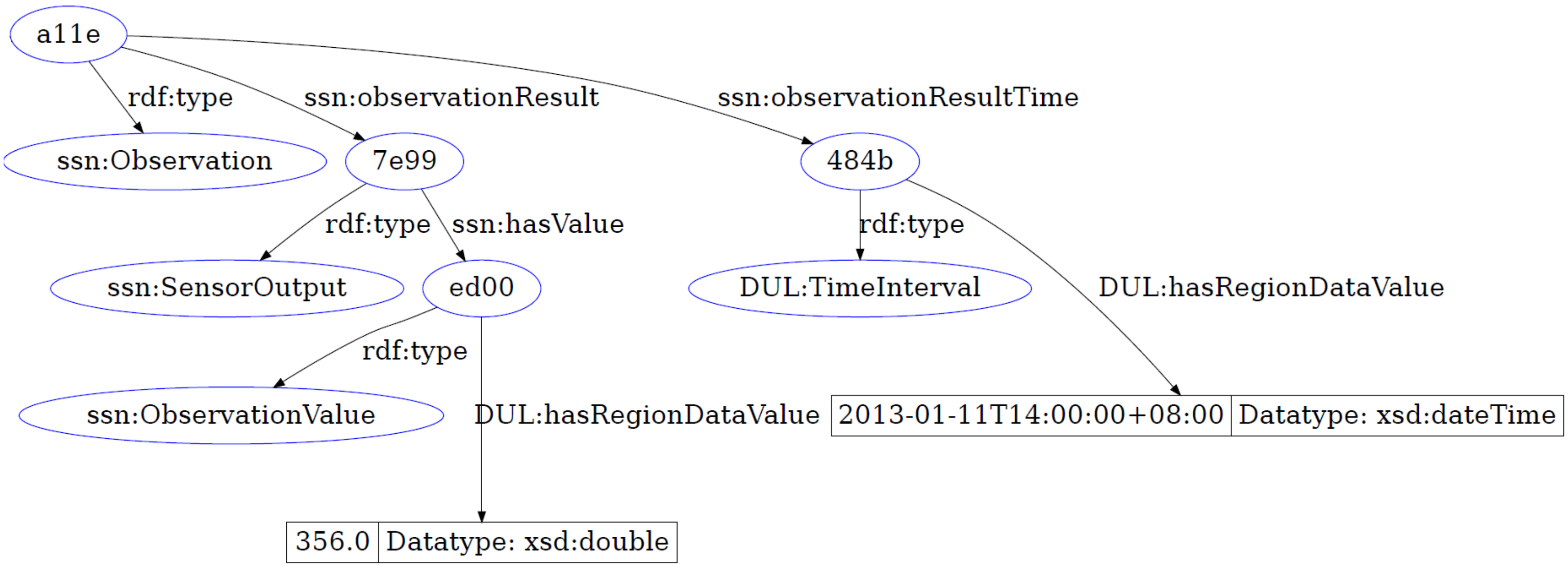
Example
BeijingAir (Observation)



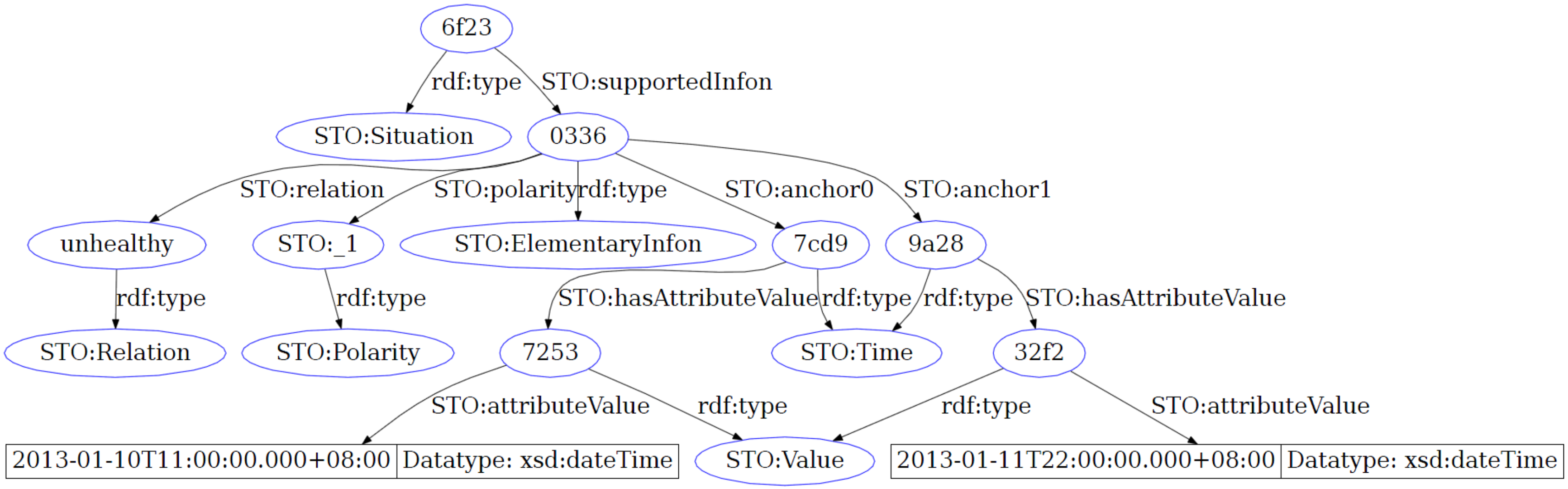
Example
BeijingAir (Observation metadata)



Example
BeijingAir (Observation data)



Example
BeijingAir (Situation)



Demo
BeijingAir in Wavellite

- Use Wavellite Web
  - visualize observations made by the BAM operated by the U.S. Embassy to Beijing
- Some basic functionality such as plotting of query results
- No situations of new particle formation, yet
- Available at
  - http://kuo-234195.uef.fi:8080/wavellite-web/
  - Under development and early stage
  - Expect bugs and limited features
  - Give feedback, including feature requests!

Next steps
New particle formation

- Get more powerful computer hardware!
- Import “all” Puijo DMPS, weather, and gas data
  - Possibly also other locations
- Develop knowledge acquisition task for NPF
  - Deploy it at situation layer
- Execute Wavellite over observation data
  - And let the framework represent knowledge for NPF
  - Situations, specifically events/episodes, of NPF with information for NPF class, as well as temporal and spatial locations
- Visualize results, e.g. by means of a timeline for NPF events

Next steps
And more …

- Continue developing Wavellite features, e.g.
  - Export functionality, heat maps, summary statistics
- Write papers and publish results
- Wavellite is in process towards open source publication at UEF
  - It should, thus, become available for free

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Materials and methods
Situation Theory

- A situation, *s*, supports (one or more) infon(s) σ
  - Formally, $s \models \sigma$
- An infon is a tuple $\ll R, a_i, \ldots a_m, 0/1 \gg$ where
  - *R* is a relation
  - $a_i, \ldots a_m$ are objects appropriate to the relation *R*
  - And *0/1* is the polarity, whereby *1* means that $a_i, \ldots a_m$ "stand in" *R*
- Example
  - A situation of "class 1 new particle formation located at Puijo today"
  - $s \models \ll npf, class1, puijo, 2013\text{-}03\text{-}21, 1 \gg$
- Developed by Barwise and Perry, extended by Devlin
- Relates to Situational Awareness by Endsley

Materials and methods
Ontology

- An ontology formally represents knowledge as a set of concepts within a domain, and the relationships between pairs of concepts [Wikipedia: Ontology (information science)]
- A document that describes concepts and relationships of a domain; such documents are “written” by means of a (ontology) language
- An ontology is external to, and shared among, software systems
- Software systems commit to one (or more) ontology by adopting the defined terminology and semantics
- Key technology in knowledge representation and reasoning
- Developed within artificial intelligence research
- Used in many domains, e.g. bioinformatics (see Gene Ontology)

Materials and methods
Semantic Sensor Network (SSN) ontology

- Vocabulary for the representation of knowledge for sensors, properties, features, observations, …
- Adopted at the Wavellite observation layer
- Domain-specific sensors and measured properties of features are accommodated by extending from SSN ontology
- Examples
  - DifferentialMobilityParticleSizer *subClassOf* ssn:SensingDevice
  - PolydisperseAerosol *subClassOf* ssn:FeatureOfInterest
  - ParticleConcentration *subClassOf* ssn:Property
  - puijoDMPS *isA* DifferentialMobilityParticleSize
  - puijoAerosol *isA* PolydisperseAerosol
  - particleConcentrationWithDiameter800nm *isA* ParticleConcentration

Materials and methods
Situation Theory Ontology

- Vocabulary for the representation of knowledge for situations
- Borrows from Situation Theory
- Adopted at the Wavellite situation layer
- Domain-specific situations and relations are accommodated by extending from STO
- Example
  - NewParticleFormationEvent *subClassOf* sto:Situation
  - npf *isA* sto:Relation