Semantic Sensor Web

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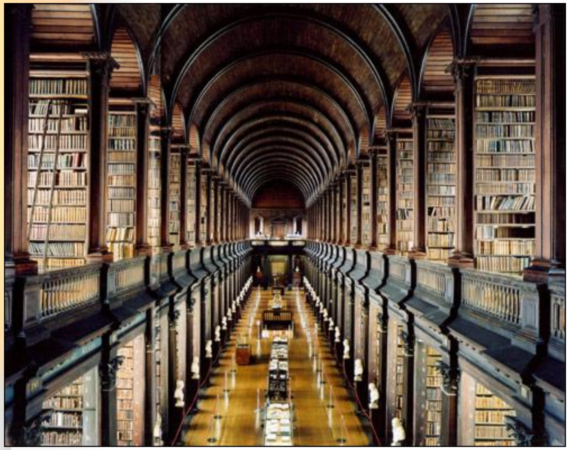
AgroSense

Introduction



Outline

- Semantic technologies and Semantic Web
- Semantic Sensor Web
- Representation Languages
- Ontologies for SSW
- Examples
- Conclusion

Semantics and Syntax

- Semantics – the study of meaning
  - relation between signifiers, such as words, phrases, signs and symbols, and what they stand for
- Syntax – the study of the principles and rules for constructing sentences in natural languages.
  - rules governing the behavior of mathematical systems, such as logic, artificial formal languages, and computer programming languages.

(Wikipedia)

Semantics and Syntax

Syntax

- Study of grammar
- All about the structure
- How to say something

Semantics

- Study of meaning
- The meaning of what I say

- Different **syntaxes** may have the same **semantic**
  - x = x + 1
  - x + = 1
  - x++

I love Slovenia

Semantics and Syntax

- Syntax and semantics are all about **communication**
  - Network protocols in networks
  - Languages (English, Slovenian) for humans
  - GUIs

Semantic Technologies

- Semantic Technologies are meaning centered

- Include software standards and methodologies that are aimed at providing more explicit meaning for data

- Refers to encoding meanings separately from data and content files, and separately from application code.
  - Metadata – providing context for data
  - Enables machines to understand and reason

Semantic Web

- A new form of Web content that is **meaningful to computers**

Tim Berners Lee et al., The Semantic Web, Scientific American Magazine, May 2001 Issue

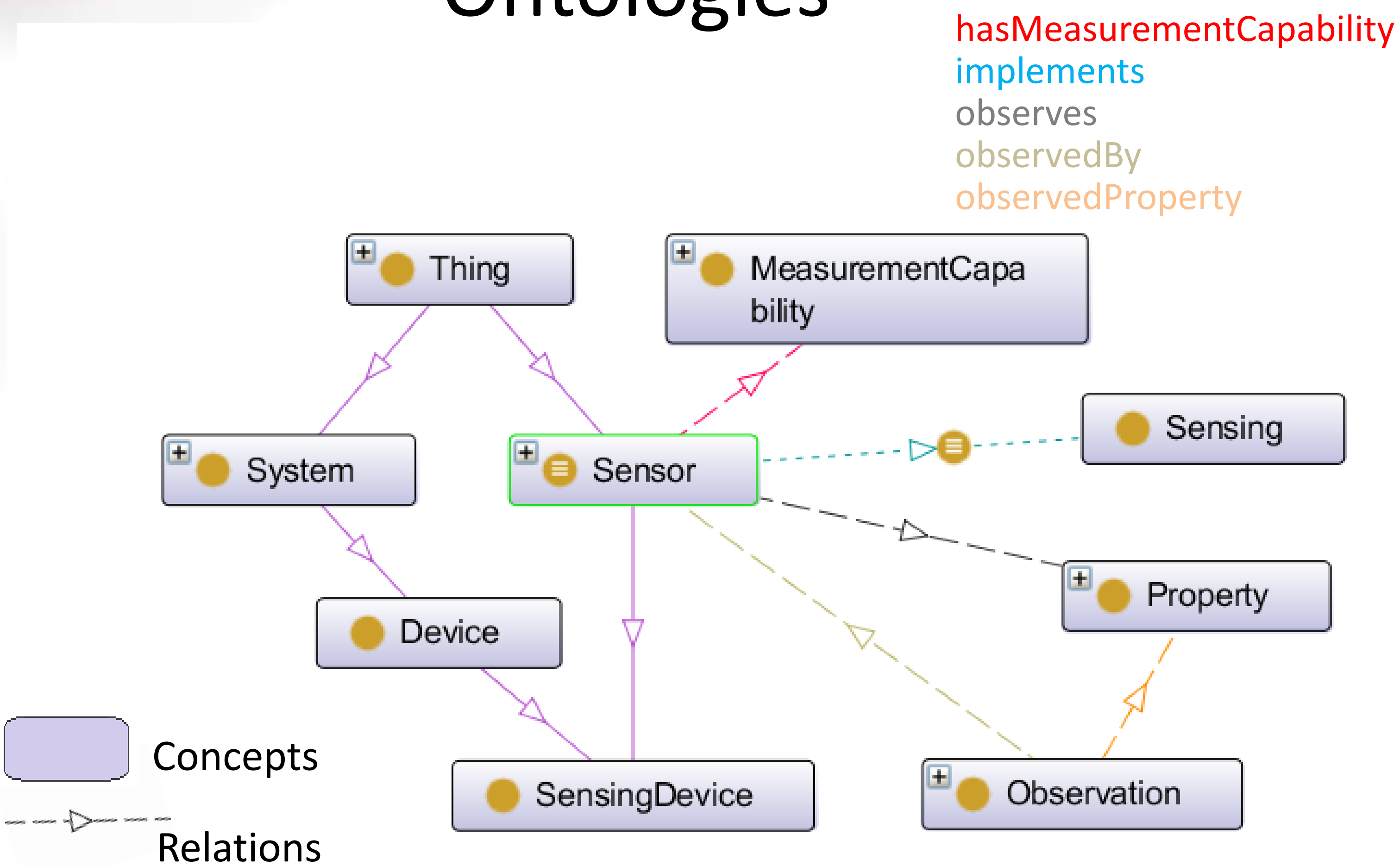
Semantic Web

- Make current web more machine accessible
  - currently all the intelligence is on the user side
- Motivating use-cases
  - Search, personalization, semantic linking, data integration
- How is this done:
  - Making data and meta-data available on the Web in machine-understandable form (**formalized languages**)
  - Structure the data and meta-data in **ontologies**

Ontologies

- **Ontology** – "a formal, explicit specification of a shared conceptualization" (T. Gruber)
- **Components:**
    - Set of concepts
    - Set of relationships
    - Set of instances
- Based on the level of **generality:**
    - **Domain** ontologies
    - **Upper** ontologies

Ontologies



From W3C SSN ontology (in development)

Representation Languages

- **Ontology Languages** – are used to encode the domain knowledge and the rules
- Requirements:
  - Intuitive **syntax**
  - Formally specified **semantics**
  - **Expressivity power**
- Description Logic (**DL**)
  - Can provide semantics and powerful **reasoning**

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Inference

- **DL** models:
  - Concepts
  - Roles
  - Individuals
  - Relationships – through axioms.

- **Inference** of new relationships
  - **Reasoning engine**: “deduce implicit knowledge from the explicit represented knowledge”

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Sensor Web

- Sensor Network – interconnects sensor devices in a computer accessible network

- Sensor Web – “Web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces” (OGC)

Semantic Sensor Web

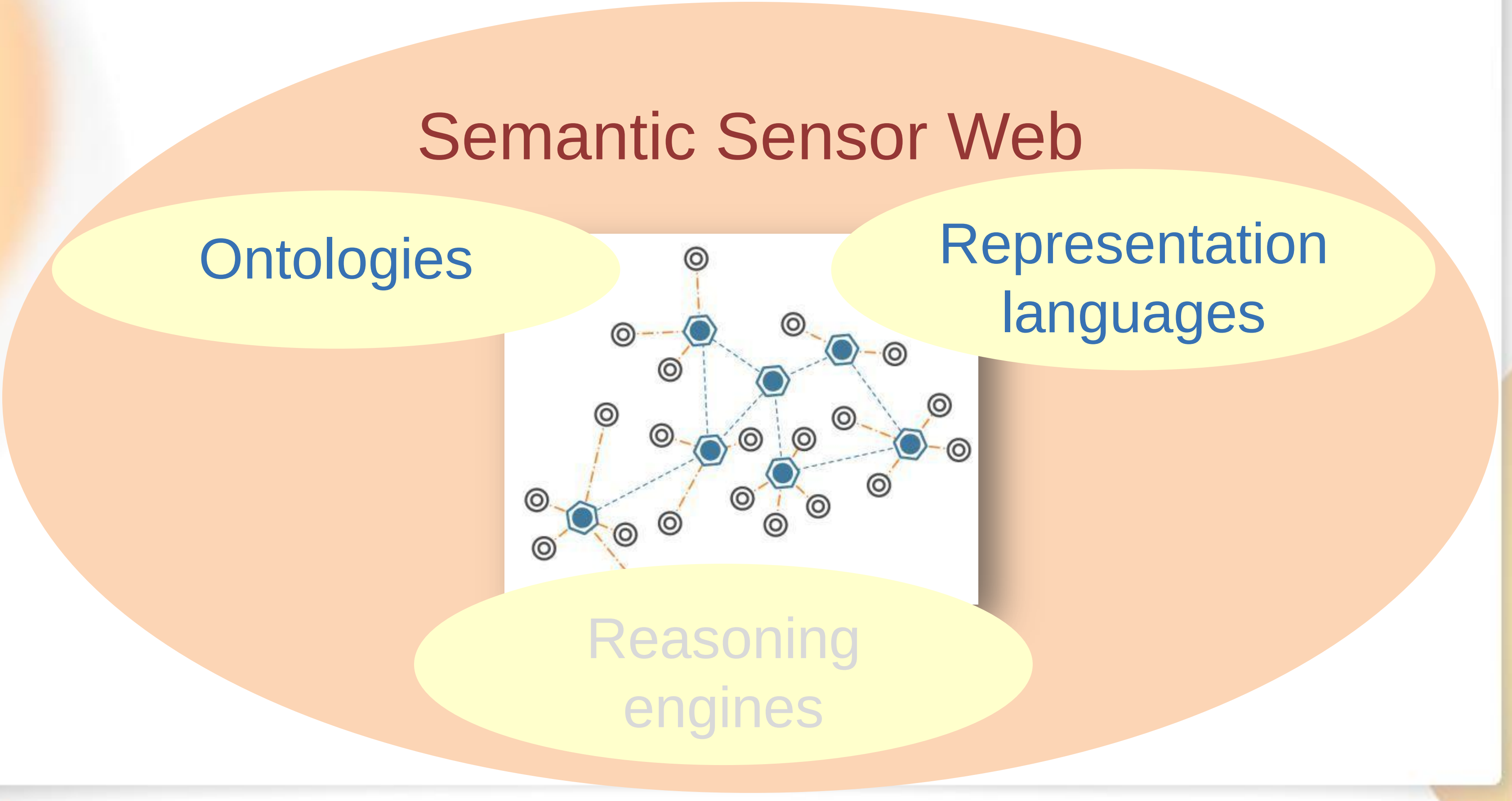
- “A **semantically rich sensor network** would provide **spatial, temporal, and thematic** information essential for discovering and analyzing sensor data”
- This is accomplished with **references to ontology concepts** that provide more expressive concept descriptions

Amit Sheth et al., Semantic Sensor Web, *Internet Computing, IEEE* In Internet Computing, IEEE, Vol. 12

Semantic Sensor Web

- Use declarative description of sensors, networks and domain concepts (ontologies) for:
  - Searching and Querying
  - Classification of sensor (functionality, measurement method)
  - Composition of sensors
  - Inference (reasoning)
  - Network management

Semantic Sensor Web



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Representation Languages

- Used for representing knowledge about sensor
- Structural
  - XML
  - SensorML
- Semantic
  - RDF and RDF-Schema (RDF-S)
  - OWL

SensorML

- General models and XML encoding
    - describing sensors systems and the processes
- Main Elements
    - Component
    - System
    - Process Chain
    - Process Model
- For interoperability -> complement with semantic specification

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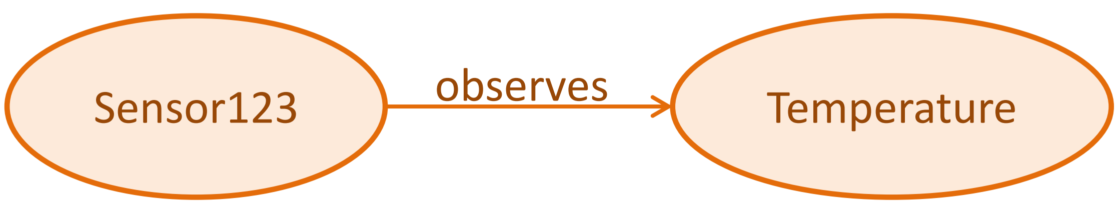
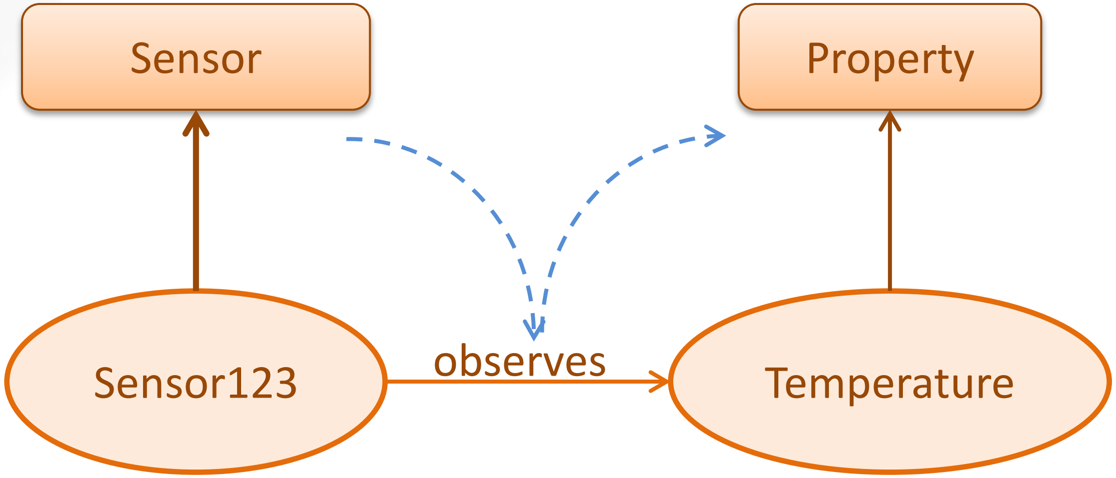
RDF

- Resource Description Framework
- **Graph** based data model
- *Subject-predicate-object* triple
    - Predicate correspond to an edge in the graph
    - All labels are actually web-addresses (URIs)



RDF-Schema

- Defines specific **domain vocabularies**
- Supports definition of **classes and properties**
- Defines the **semantics of concepts** used in a RDF data model



Representation Languages OWL1 and OWL2 (1)

- The Web Ontology Language
  - **Vocabulary** and **formal semantics** for better machine interoperability
- OWL1 three sublanguages:
  - **OWL Lite** – least expressive
    - » Constraints: cardinality(0,1), domain restriction, inequality, inverse, transitivity, symmetry
  - **OWL DL** – as expressive as possible (maintaining reasoning capabilities)
    - » Full cardinality, negation, disjunction, enumeration
  - **OWL Full** – maximum expressivity
    - » A class can be both collection and individual

Representation Languages OWL1 and OWL2 (2)

- OWL2 new features:
  - Property chains (rules)
  - Additional properties, extended annotation, etc
- OWL2 three sublanguages:
  - OWL2 EL (Existential Quantification)
    - » Large number of classes and properties
  - OWL2 QL (Query Language)
    - » Large large number of instances
  - OWL2 RL (Rule Language)
    - » Very large ontologies
    - » Can be used by rule-reasoners

Representation Languages

OWL2

Pr
asymmetric, r

OWL2 RL
Large no of classes and properties

OWL2 QL
Large no. of Individuals

OWL2 EL
Very large ontologies

OWL1 Full
Loses tractability
A class can be both collection and individual

OWL1 DL
Maximal expressivity (while maintaining tractability)

OWL1 Lite
Classification hierarchies, simple constraints

RDFS
Defines vocabulary
Organize Vocabulary in typed hierarchies

RDF
Data Interchange
Data Model – graph, building block - triple

SensorML
Specific domain: sensors

XML
Syntax

Expressivity

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Ontologies

- Major role in combining semantics with sensor networks
- Existing sensor networks ontologies
  - CSIRO
  - OntoSensor
  - CESN
- In development
  - W3C SSN Incubator Group

Ontologies – CSIRO (1)

- Provides a language for describing sensors
    - **technical aspects** (calibration, temporal resolution-sampling frequency, accuracy, what it measures)
    - information about **access to the sensor** for control and configuration
    - **location**, **meaning of data**

Ontologies – CSIRO (2)

- Structured into four clusters (groups) of concepts:
  - sensor description – *Sensor*
  - domain of sensing - *Feature*
  - physical component and location description - *SensorGrounding*
  - operational model – *OperationModel*
    - » Allows describing abstract sensor – as composition of concrete sensors

Ontologies – OntoSensor

- Purpose: build a general knowledge base for sensors
  - map hierarchical concepts form SensorML to OWL
    - Only partial success

- Based on sensor ML
  - Includes concepts from SUMO and ISO 19155

(schema for geographic information and services)

Ontologies – CESN

- Uses Sensor ML terminology
- Utilized on an application capable to reason about coastal storm
    - Scalable system
    - Not general enough ontology

Ontologies – W3C SSN

- W3C SSN Incubator Group
    - SSN Ontology – in development
    - Extending existing sensor network representation language with semantic annotation

Ontologies - Summary

- Common set of concepts
  - Taxonomy of different types of sensors
  - Physical properties
  - Data acquisition
  - Sensed domain
    - May vary depending on the application

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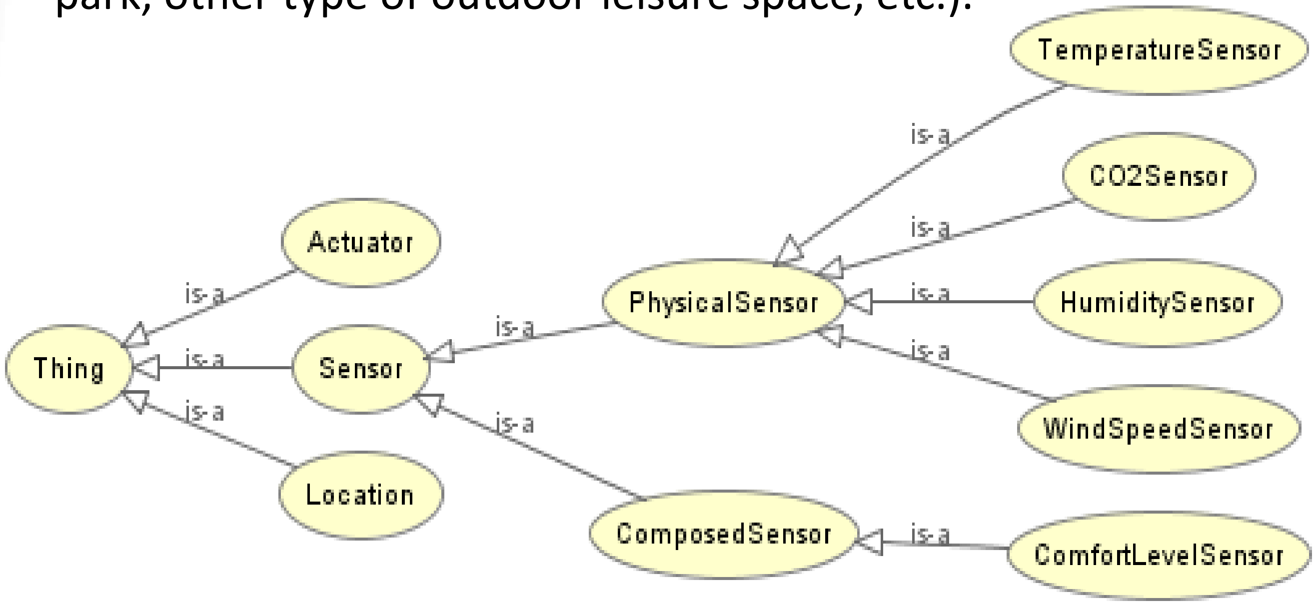
Illustrative Example
Calculating Level Of Comfort

- Sensors measuring temperature, humidity and wind speed are located in the same place, which is the interest for a user (e.g. a park, other type of outdoor leisure space, etc.).



Illustrative Example
Calculating Level Of Comfort

- Rule:

```
TemperatureSensor(?S1), HumiditySensor(?S2),
WindSpeedSensor(?S3), hasLocation(?S1, ?L),
hasLocation(?S2, ?L), hasLocation(?S3, ?L),
 ->
ComfortLevelSensor(?newVirtualSensor), hasLocation
(?newVirtualSensor, ?L)
```

- Query:
- What are the sensors measuring comfort level at a specific location?
  - without having to have the knowledge about all the other sensors needed for computing comfort level

Cyc and Pachube

- What is Cyc?
  - Collection of **concepts, facts, rules of thumbs** that represent common sense knowledge (KB)
  - Inference engine
  - Interfaces
- What is Pachube?
  - Web service that enables **storing, sharing & discovering of real-time sensor**,
  - Like YouTube, but instead of sharing *videos*, Pachube enables sharing *real time environmental data from sensors* that are connected to the internet.
- Idea
  - Collect sensor description and data
  - Use some of the existing rules and introduce new ones to perform reasoning using Cyc
  - Possible Applications
    - Complex searching, with multiple constraints
      - » Location, sensed features, tags

Cyc and Pachube


```
<title>Ship - LAGO MAGADI IMO:8825808</title>
<feed>http://www.pachube.com/api/feeds/3826.xml</feed>
<status>live</status>
<location domain="physical" exposure="outdoor" disposition="mobile">
  <lat>45.61304</lat>
  <lon>13.78468</lon>
</location>
<data id="0">
  <tag>latitude</tag>
  <value minValue="0.0" maxValue="45.67596">45.61304</value>
</data>
<data id="1">
  <tag>longitude</tag>
  <value minValue="0.0" maxValue="13.80876">13.78468</value>
</data>
<data id="2">
  <tag>average speed</tag>
  <value minValue="3.8" maxValue="7.3">6.7</value>
  <unit>knots</unit>
</data>
```


Individual : Sensor123

GAF Arg : 1

Mt : BaseKB

isa : Sensor

latitude : (Degree-UnitOfAngularMeasure 45.61304)

longitude : (Degree-UnitOfAngularMeasure 13.78)

sensorMeasures : Speed

Conclusion

- SSW = Semantics + Sensor Web
  - Their success depends on how fast the **semantics** will adapts to SN requirements
- Semantic technologies reviewed
  - SSW Ontologies
    - » CSIRO, OntoSensor, W3C SSN
  - Representation Languages
    - » SensorML, RDF, RDFS, OWL

Some References

- Semantic Web
  - G. Antoniu and F. van Harmelen: Semantic Web Primer, 2nd edition in 2008
- Semantic Sensor Web
  - Amit Sheth et al., Semantic Sensor Web, *Internet Computing, IEEE* In Internet Computing, IEEE, Vol. 12, No. 4. (2008), pp. 78-83
  - Semantic Sensor Network Incubator Group http://www.w3.org/2005/Incubator/ssn/charter


THE END!