TOWARDS SEMANTIC MODEL EXTENSIBILITY
IN INTEROPERABLE IOT DATA EXCHANGE PLATFORMS

YULIA SVETASHOVA (ROBERT BOSCH GMBH, KIT),
STEFAN SCHMID (ROBERT BOSCH GMBH),
ANDREAS HARTH (FAU ERLANGEN-NÜRNBERG)
Overview

- Context and motivation
  - Data marketplaces
  - Interoperability in IoT

- Problem statement
  - Extensibility
  - Ontologies
  - Challenges

- Solution
  - Modeling patterns
  - Annotation graphs
  - Dynamic form generation

- Benefits of the approach
CONTEXT
“Digital marketplaces are platforms that connect providers and consumers of data sets and data streams, ensuring high quality, consistency, and security.”*  

Context and Motivation

Semantic Models and Categorization

Two-fold purpose of the models:

• Categorize offerings
Context and Motivation
Semantic Models and Interoperability

Two-fold purpose of the models:
• Categorize offerings
• Describe data (→ enable interoperability)
Ontology, Knowledge Graph

- **Ontology**
  - “formal, explicit specification of a shared conceptualization” *
  - “formalized vocabularies of terms, often covering a specific domain and shared by a community of users. They specify the definitions of terms by describing their relationships with other terms in the ontology” **.

- **Knowledge graph**
  - graph-structured knowledge base in RDF (Resource Description Framework) format.

- Both models (= ontologies) and offering descriptions/queries are stored in an RDF triple store as a knowledge graph.

---

Context and Motivation

Modeling: Example (simplified)
Offering Description

```json
{
  providerId: "Parking_Provider",
  name: "ParkingSite_Information",
  category: "bigiot:Parking",
  subcategory: "bigiot:ParkingSite",
  outputData: [
    { name: "longitude", rdfAnnotation: "schema:longitude" },
    { name: "latitude", rdfAnnotation: "schema:latitude" },
    { name: "freeSpots", rdfAnnotation: "mobility:numberOfVacantSpaces" },
    { name: "dt", rdfAnnotation: "dbp:Unix-time" }
  ],
  endpoints: { uri: "http://bigiot/access/parkinginfo", type: "HTTP_GET" },
  licenseType: "OPEN_DATA_LICENSE",
  price: { money: { amount: 0.002000, currency: "EUR" }, accountingModel: "PER_ACCESS" }
}
```
PROBLEM
Offering Creation

```json
[
  {
    "address": "Plaza de Pío Baroja, 48001 Bilbao",
    "freeSpots": 50,
    "totalSpots": 100
  }
]
```
Problem Statement

Specifying the Output
Problem Statement

Missing Model Elements

```
[  
  {  
    "address":"Plaza de Pío Baroja, 48001 Bilbao",
    "freeSpots":50,
    "totalSpots":100
  }
]
```
Problem Statement

Missing Concept
Problem Statement

Challenges

- A new, suggested concept is not machine-understandable:
  - it lacks a precise characterization of its
    - meaning,
    - returned value type,
    - unit of measurement (for sensor data);
  - it has no links to other model elements;
  - it can reflect a very different approach to the modeling of the phenomenon.

- The suggested concept can be ambiguous or a duplicate, and further communication with a data provider might be needed to incorporate it into the model.

- Scalability of the approach need to be ensured.
APPROACH
Approach
Modeling Patterns

Initial broad categorization of a model element and a set of prototypical relations in the enclosing model.

Approach

Sensor Pattern - I, SOSA

Sensor, Observation, Sample, and Actuator design pattern*

Approach

Pattern → Annotation Graph

```
sosa:Observation
  sosa:hasFeatureOfInterest sosa:FeatureOfInterest;
  sosa:observedProperty sosa:ObservableProperty;
  sosa:hasResult sosa:Result [ 
    rdf:type qudt:QuantityValue;
    qudt:numericValue dtype:numericUnion;
    qudt:unit qudt:Unit ] .
```
Approach

Annotation Graph → User Interface Forms

<Output/Parking_Info/03>
sosa:hasFeatureOfInterest ?Feature .

<Output/Parking_Info/03>
sosa:observedProperty ?Property .

<Output/Parking_Info/03>
sosa:hasResult [ rdf:type ?Type ] .

Does the proposed output data relate to a Parking Site?

Which property of a Parking Site is being measured?

Is it a numeric value?

TotalNumberOfSpaces
Approach

Structured Annotations

```
proposed:TotalNumberOfSpaces

rdf:typeof ssn:Property, sosa:ObservableProperty;
ssn:isPropertyOf mobility:ParkingSite.
```

```
<Output/Parking/03>

core:rdfAnnotation [
  sosa:hasFeatureOfInterest mobility:ParkingSite;
  sosa:observedProperty proposed:TotalNumberOfSpaces;
  sosa:hasSimpleResult rdfs:Literal;
  core:name “totalSpots”.
]

→ Mobility model

→ Offerings’ metadata graph
```
BENEFITS
Benefits

- The approach
  - assures a more coherent and less ambiguous description of a proposed concept;
  - allows to contextualize a concept: to place it closely to the semantically related concepts;
  - reduces the risk of concept duplication and unconventional naming.

- The resulting structured descriptions
  - are machine-processable and partially machine-understandable;
  - can be shared with others as linked data;
  - are easier understood by data consumers and validated by ontology engineers.
THANK YOU

Marketplace: https://market.big-iot.org
Project website: http://big-iot.eu
Semantic models:
http://schema.big-iot.org/core/docs/schemas.html
http://schema.big-iot.org/mobility/docs/schemas.html
http://schema.big-iot.org/environment/docs/schemas.html

Contact:
yulia.svetashova@de.bosch.com
Yulia Svetashova
Appendix I: Approach

Relations

W3C: Ontologies “specify the definitions of terms by describing their relationships with other terms”

J. F. Sowa: Ontology is a “tightly interconnected collection of signs”

F. De Saussure: syntagmatic (co-occurrence) and paradigmatic (similarity) relations

<table>
<thead>
<tr>
<th>sosa:FeatureOfInterest</th>
<th>sosa:ObservableProperty</th>
<th>schema:unitCode</th>
</tr>
</thead>
<tbody>
<tr>
<td>schema:Car</td>
<td>mobility:speed</td>
<td>om:kilometre_per_hour</td>
</tr>
<tr>
<td>schema:Car</td>
<td>mobility:intakeMAP</td>
<td>qudt:KiloPascalAbsolute</td>
</tr>
<tr>
<td>schema:Car</td>
<td>mobility:intakeAirTemperature</td>
<td>om:DegreeCelsius</td>
</tr>
<tr>
<td>schema:City</td>
<td>environment:temperature</td>
<td>om:DegreeCelsius, om:DegreeFahrenheit</td>
</tr>
<tr>
<td>schema:City</td>
<td>environment:humidity</td>
<td>om:percent</td>
</tr>
</tbody>
</table>
Appendix II: Approach
Sensor Pattern - II, SOSA

environment:temperature

schema:City

schema:Number

qudt:unit