DOI 10.5162/SMSI2021/D1.2

# Representing Semantic Information in Sensor Networks

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**Summary:**
To pave the way towards (semi-) automated data-analysis, self-describing sensors and measurements become a key component in the context of Industry 4.0. We map concepts from existing knowledge bases into a coherent new ontology to fulfill metrological requirements of sensor and measurement descriptions. Use cases considered for this ontology cover sensor networks, network topology, network robustness, information fusion, calibration models for dynamic uncertainty, correct metrological representation and implementation performance.

**Keywords:** metadata, ontology, sensor network, information fusion, uncertainty

## Introduction and Considered Use Cases

Automating the analysis of an ever-growing number of sensors in industrial plants requires sensors that can self-provide information about themselves in an appropriate and machine-interpretable format [1-4]. Promising approaches to achieve these goals can be found by considering the developments of the semantic web group [5] and ontology engineers coming from diverse disciplines [6].

Consider a use case with a set of calibrated dynamic sensors with topological and geometrical relations. A physical effect that is constant in its intensity moves relative to the array of sensors, leading to spatial and temporal dependent sensor observations. Multiple questions arise in this context: (1) estimation/location of the physical effect, (2) detect sensor failures and (3) recalibration of sensors through information redundancy. Answering these questions requires the raw sensor readings, but also meta information about sensor properties and their relations. A common, flexible and machine-interpretable approach is to use an ontology to represent the meta information.

## Merge of Existing Data Schemes

Given the considered use cases, it is necessary to provide descriptions of the following three key components: (1) sensor, (2) observation and (3) calibration model. This can be achieved by merging and extending existing data schemes, vocabularies and ontologies, namely [7]:

- Digital SI (D-SI, [8])
- Semantic Sensor Network (SSN, [9])
- Sensor, Observation, Sampling and Actuation (SOSA, [10])
- Ontology of Units of Measure and Related Concepts (OM, [11])
- Geographic Query Language (GeoSPARQL, [12])
- Mathematical Markup Language (MathML, [13])

Calibration model information is represented by a merge of OM, MathML and D-SI. These data schemes are used to define the concepts of `Parameter`, `Variable`, `Equation`, `EquationModel` and `CalibrationModel`.

General sensor information such as identifiers, manufacturing details, measurement principle and location are represented using the SOSA/SSN ontologies. OM allows to specify the measurement quantity of the sensor. The location information is extended by GeoSPARQL for geometric and topological relations. A sensor is linked to its calibration model by the `hasCalibrationModel` attribute.

Observations are described by combining SOSA, D-SI and OM. The OM concept of `om:Measure` is extended to cover uncertainties of values. An observation is then characterized by time aspects from SOSA and a result of type `dsi:MeasureWithUncertainty`, which follows the D-SI data model. Observations are connected to a sensor via the `sosa:madeBySensor` attribute.

A brief overview of the suggested combination is illustrated in figure 1.

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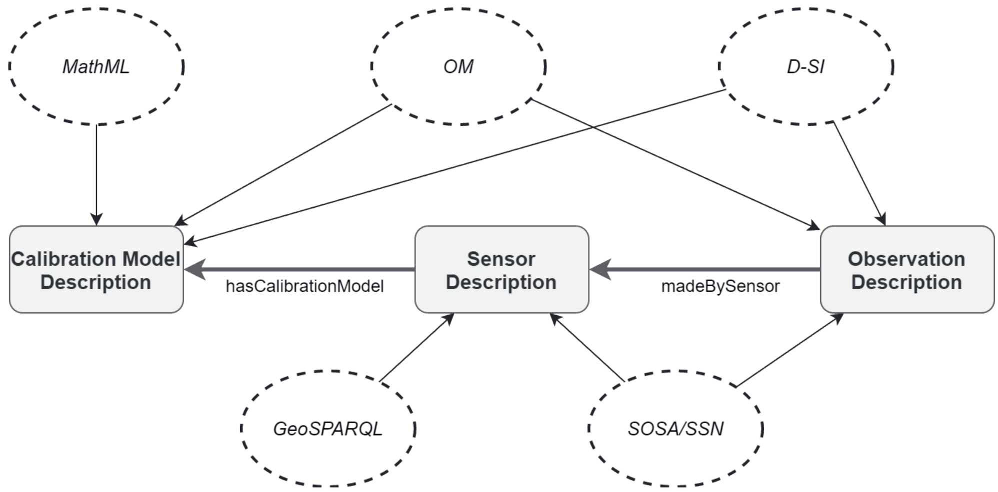


**Figure 1: Overview of proposed merge**

## Outlook

We presented a possible merge of ontologies to represent sensor networks and relations therein from a metrological viewpoint. Further research will focus on the semantic description of sensor models and their transfer behavior.

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