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Semantic Information in Sensor Networks

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Summary:
Self-describing sensors and measurements are a key component to establish (semi-) automated data-analysis in the context of Industry 4.0. By mapping concepts from existing knowledge bases into a coherent new ontology, we 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

In order to automate the analysis of an ever-growing number of sensors in industrial plants, sensors must be able to self-provide information about themselves in an appropriate and machine-interpretable format [1-4]. To achieve these goals, developments of the semantic web group [5] and ontology engineers coming from diverse disciplines are taken into account [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 itensity 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 reduncdancy. 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:

- Digital SI (D-SI, [7])
- Semantic Sensor Network (SSN, [8])
- Sensor, Observation, Sampling and Actuation (SOSA, [9])
- Ontology of Units of Measure and Related Concepts (OM, [10])
- Geographic Query Language (GeoSPARQL, [11])
- Mathematical Markup Language (MathML, [12])

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 is 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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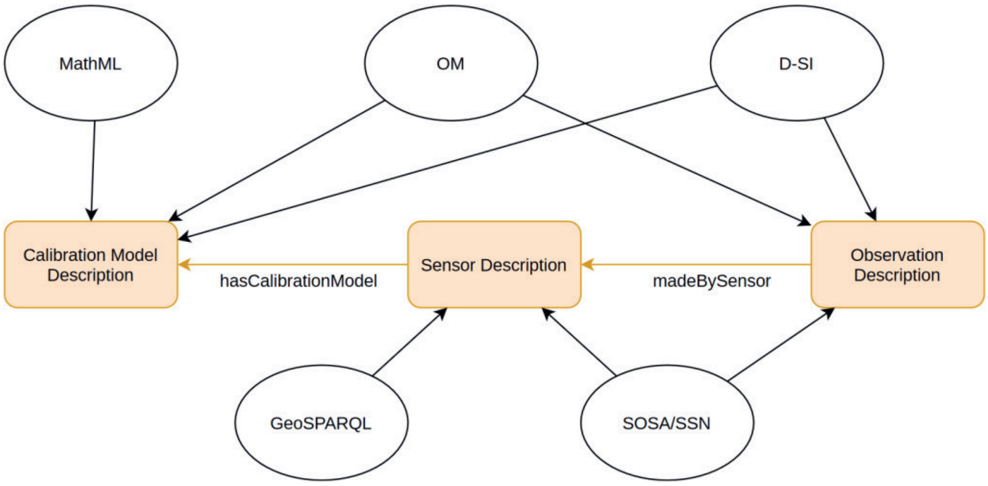

Figure 1: Overview of proposed merge

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