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Ontology paper

The SSN ontology of the W3C semantic sensor network incubator group

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ABSTRACT

The W3C Semantic Sensor Network Incubator group (the SSN-XG) produced an OWL 2 ontology to describe sensors and observations — the SSN ontology, available at http://purl.oclc.org/NET/ssnx/ssn. The SSN ontology can describe sensors in terms of capabilities, measurement processes, observations and deployments. This article describes the SSN ontology. It further gives an example and describes the use of the ontology in recent research projects.

1. Introduction

Observations, and the sensors that obtain them, are at the core of empirical science. Sensors are used in applications ranging from meteorology to medical care to environmental monitoring to security and surveillance. The use of sensing devices and networked sensing devices is increasing. This increase is accompanied by an increasing volume of data, as well as increasing heterogeneity of devices, data formats, and measurement procedures.

Therefore, as the prevalence of sensing devices and systems grows, ways to manage the sensors and accompanying volume of generated data become important. The Sensor Web Enablement (SWE) [1] initiative of the Open Geospatial Consortium (OGC) defined data encodings and Web services to store and access sensor-related data. These standards, for example, SensorML [2] and O&M [3,4], provide syntactic interoperability [5]. An additional layer is required to address semantic compatibility [6].

Semantic Web technologies have been proposed as a means to enable interoperability for sensors and sensing systems. Semantic Web technologies could be used in isolation or in augmenting SWE standards in the form of the Semantic Sensor Web [5].

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Semantic technologies can assist in managing, querying, and combining sensors and observation data. Thus allowing users to operate at abstraction levels above the technical details of format and integration, instead working with domain concepts and restrictions on quality. Machine-interpretable semantics allows autonomous or semi-autonomous agents to assist in collecting, processing, reasoning about, and acting on sensors and their observations. Linked Sensor Data [7,8] may serve as a means to interlink sensor data with external sources on the Web.

Shared semantic definitions help not only with data integration from multiple sources, but can also assist in integrating new data into historical, temporal and spatial contexts. Definitions of sensors and their capabilities are also useful for provenance and quality reasoning. For example, if the accuracy of a sensor depends on phenomena other than that which it measures, then a specification of this can be used as a guide to search for spatially and temporally related measurements of the phenomena on which the accuracy depends, allowing the calculation of quality metrics.

The W3C Semantic Sensor Network Incubator group (SSN-XG) defined an OWL 2 [9] ontology to describe the capabilities and properties of sensors, the act of sensing and the resulting observations. This article describes the ontology, its development, an example and current uses.

Paper contributions and organisation

This paper makes two contributions. The bulk of the paper relates to the first and central contribution: a description of the SSN ontology (Sections 2–7). An outline of the SSN-XG (Section 2) and development of the ontology (Section 2) is presented first, followed by the general structure of the ontology (Section 3). The detailed description of the ontology begins with a central pattern (Section 4), followed by sensor (Section 5), observation (Section 6) and system (Section 7) perspectives.

The second contribution is an example of the use of the ontology (Section 8.1) and a discussion of projects and applications in which it has been used (Section 8.2). This is followed by concluding remarks (Section 9).

2. The W3C semantic sensor network incubator group

W3C incubator groups are one-year (plus possible extensions) exploratory activities on emerging Web-related concepts, guidelines or activities. They can lead to further W3C activities, member submissions or recommendations. The SSN-XG was initiated by the CSIRO, Wright State University, and the OGC as a forum for the development of an OWL ontology for sensors and to further investigate annotation of, and links to, existing standards.

The SSN-XG ran from March 2009 to September 2010. Some 41 people, from 16 organisations, joined the group, with 20 members attending more than 10 meetings. The activities of the group were recorded on the group's wiki,[1] where the group's final report[2] can be found. The final report includes sections on use cases, the group's review of existing sensor and observation related ontologies, the SSN ontology, mappings of terms from the ontology to other standards and vocabularies, and material on the group's other main deliverable on semantic annotation of OGC Sensor Web Enablement standards.

Development of the SSN ontology

The group began by reviewing existing ontologies and standards, and developing use cases. The use cases were focused into four categories – entitled: data discovery and linking, device discovery and selection, provenance and diagnosis, and device operation, tasking and programming – with a prototypical example in each.

The device discovery and selection use case, for example, requires the ontology to represent sensor types, models, methods of operation and common metrological definitions like accuracy, precision, measurement range, and the like, thus allowing sensor capabilities to be defined relative to prevailing conditions. Such definitions would enable a sensor network designer to search a database for sensors matching required parameters of operation and accuracy, perhaps cross checking against recorded climatic conditions or running a simulator to analyse expected performance of such a network.

The data discovery and linking use case focused on finding and linking data, given qualitative, spatial or temporal bounds. It requires the sensor specifications from the device discovery and selection case, observation data and linkage to other data sources. While the provenance and diagnosis use case requires context information from sensor and observation data, deployment information, custodian descriptions, maintenance schedules and data linkage to derive trust levels or to further analyse previous measurements. The device operation, tasking and programming use case requires sufficient information to reprogram a device or understand the consequences, in terms of, say, energy usage or network cost, of a reprogramming.

In documenting the expectations of group members, such use cases also serve to expose the tension between completeness and focus in ontology modelling: the choice between an ontology that can model programming concepts, observed phenomena and maintenance schedules and one that is sensor only. Indeed, the review (see also [10]) showed that while there were a number of existing artefacts (twelve ontologies were reviewed) none covered the requirements of the use cases or satisfied a design goal of limiting to sensor specific concepts and relations.

Limiting the ontology to sensor only concepts should serve to increase modularity and reusability and became the inclusion criteria for the group. Thus, the ontology should enable the sensor aspects of the use cases, without needing to fulfil all the modelling requirements.

Discussions revealed different interpretations of concepts; even fundamental concepts like sensor – a single sensing device, or any sensing system; a single stimulus to observation sensor, or one that allows multiple calculations and combination of stimuli.

Thus, after much discussion, and a few false starts, the group consensus was to build an ontology to describe sensors, that was: as far as possible sensor specific; compatible with OGC standards, without being constrained by them; and that generally chose the broadest definition for concepts, so that subconcepts could be later defined for more specific interpretations. For example, the result for sensor was any entity capable of following some method to sense, allowing sensing devices as a subconcept.

The SSN ontology was developed by group consensus over a period of one year. First, the core concepts and relations were developed (sensors, features and properties, observations, and systems). Then, measuring capabilities, operating and survival restrictions, and deployments were added in turn. Finally, the alignment to DOLCE-UltraLite[3] (DUL) and the realisation of the core Stimulus–Sensor–Observation ontology design pattern [11] were added.

The alignment to a foundational ontology makes ontological commitments explicit, further explains concepts and relations, and restricts possible interpretations towards their intended

[1] http://www.w3.org/2005/Incubator/ssn/wiki/Main_Page (last accessed 11th May 2012).

[2] http://www.w3.org/2005/Incubator/ssn/XGR-ssn/ (last accessed 11th May 2012).

[3] http://www.loa-cnr.it/ontologies/DUL.owl (last accessed 11th May 2012).