A Contextualised Cognitive Perspective for Linked Sensor Data

Short paper

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Abstract. In this paper, we target a context-awareness approach to sensors, proposing a first extension of sensor ontologies in this direction. Our proposal aims at emulating the human cognitive ability, taking advantage of Linked Data, in order to improve the human understanding of reality through sensors.

Keywords: Semantic Sensor Web, Context-awareness, Linked Data, LOD Cloud, DOLCE

1 Introduction

Currently, basic aspects of sensor networks can be represented using concepts from existing sensor ontologies. Yet, there are still opportunities to enhance the representation of sensor data and to improve sensor discovery. In this paper, we propose means to improve context-awareness of sensor networks, by applying a human cognitiveness emulation approach. To do so, we extend and align various ontologies, providing means to better define a sensor's context using Semantic Web technologies.

To represent sensor data on the Semantic Web, ontologies have to represent all aspects of sensors, i.e., their capabilities, physical properties, observations, network characteristics, etc. First efforts towards sensor description come from the definition of standards such as IEEE 1451 [1], ANSI N42[2], or the Open Geospatial Consortium's Sensor Web Enablement (SWE)[3]. These standards have several limitations which the W3C Semantic Sensor Network Incubator Group (SSN-XG) [11] tries to overcome by developing a semantic sensor network ontology and a standard for semantic annotations to be integrated into the SWE standards. A key problem in this is the understanding and proper representation of measurements and qualities as a human description of qualities can be

[1] `http://ieee1451.nist.gov/`
[2] `http://standards.ieee.org/getN42/`
[3] `http://www.opengeospatial.org/ogc/markets-technologies/swe`

quite different from a scientific one. This problem was also identified by [7] who propose a division of the quality space into Scientific and Cognitive ones. Several other ontologies focus on other aspect, e.g., the MMI Device [10] and CSIRO [3] ontologies focus on system and capabilities, and process composition, while [6] addresses sensor self-discovery, self-description and classification of devices.

2 A Contextualised Cognitive Perspective

One goal of sensors is to extend human awareness about reality. Hence, a way to satisfy human expectations about sensor data representation and filtering is to emulate the human way of representing and filtering this data. Humans can understand an event better when it can be associated with a similar past experience stored in memory [2]. We try to use the same mechanism to let a sensor understand an event. This will improve/enable its understanding of what is happening around it (*reality*) and of what it is actually sensing (*self-awareness*).

Technologically, sensors can emulate these human cognitive and associative mechanism by searching for similar events from the past, using the Linking Open Data (LOD) cloud [1]. As opposed to the human memory,the "memory" of the LOD cloud is virtually unlimited and a *sensor acting like a human* would be potentially able to understand what is hidden behind raw data, better than humans could do. This view provides the dual approach to the *human acting like a sensor* as proposed by [5] and further investigated by [9].

2.1 Use-case

To illustrate the contextualised cognitive perspective, we assume an example, where we would need to know the amount of water we should provide to a particular plant to support its healthy growth.

Then a search engine should be able to retrieve all the sensors that are sensing daily feeding and growth data of that particular plant. This is possible only if sensors themselves expose information about what they are sensing. The question is: how can they understand automatically what they are sensing? Sensors could compare their data features to other similar ones, that are stored in the LOD cloud and have been already associated with their corresponding real event. Searching for similar data to link represent exactly the application of the Linked Data paradigm- Indeed the whole process of reasoning over the similar data found to infere what the sensor has currently sensed, corresponds to an emulation of the human cognitive approach, with which the same task is shared that is a better understanding of reality.

In this example, the LOD Cloud corresponds to human memory. Yet, while into the human memory, some past experiences could have been removed or modified, LOD is virtually unlimited and data is not subject to "corrosion over time" — which does not prevent to store previous state of an object, using provenance information. To fully realise this, correct description of sensor context and data in terms of ontologies is required following our human-cognitiveness-emulation approach. The starting point for such an ontology is presented in the next section.

2.2 Design choices

To achieve our goal, we are proposing an ontology to support a proper exposition of sensor self-awareness information. The ontology combines

- a domain-agnostic ontology to describe sensor-related concepts;
- an ontology to describe events and their relations; and
- an upper level ontology.

A domain-agnostic ontology to describe sensor-related concepts For the sensor ontology, we decided to use the one proposed by for the follwing reasons:

- Completeness: all basic aspects of sensor (and sensor data) are taken into consideration, and the ontology allows the user to further describe them by integrating external ontologies;
- Alignment with DOLCE+DnS Ultralite [4]. Ontology alignment with Foundational ontologies esures robustness of the ontology hierarchy structure and supports future interoperability with other ontologies;
- Likeliness to be integrated by other domain-specific external ontologies, and subsequently to make the integration process easier;
- Community within W3C, and possible further opportunities with W3C in terms of standardisation.

An ontology to describe events and their relations As the event description model, we choose the Event Model F [8] for the follwoing reasons:

- it allows us to describe relations among events, i.e., Correlation, Causality, Mereologic and Interpretation (see Fig. 2), in the most detailed way, as discussed in [8];
- it relies exclusively on ontology design pattern;
- it is aligned with the DOLCE+DnS Ultralite ontology.

An upper-level ontology We consider the description of sensor context to be critical for sensor discovery. To address this issue the Description and Situation (DnS) ontology is a very useful tool as it allows us to describe situations taking into account which entities are involved, their role, and the algorithm that they must satisfy with respect to the involving situation. This is also why we chose DOLCE+DnS Ultralite [4] as an upper ontology. On the one hand, both SSN-XG and Event F ontologies were already aligned with it; on the other hand, it does not contain high-level concepts that are unlikely to be linked directly such as perdurants and endurants.

Our proposal In order to show how DnS concepts can be useful and applied into the sensor and sensor network domain, we created the concepts of `SensorHierarchy`, `SensorProjectRole` and `SensorRole`. They are all sub-concepts of classes from DOLCE+DnS Ultralite (DUL). In particular they share the least common ancestors `SocialObject`, `Object` and `Event`. The rationale for these concepts is as follows:

- `SensorHierarchy` (see Fig. 1) is added as a sub-concept of `Design`, `Description`. We think that a description of the network topology (to automatically annotate it) could help in understanding the sensor data application domain and inferring more details over the specific location of the sensor into the environment. For example, if a sensor is part of a network focused on oceanographic monitoring, it is probably located under water.
- `SensorProjectRole` (see Fig. 2) is introduced as a sub-concept of `PlanExecution`, `Situation`. This can work as a bridge between our ontology and project or sensor project domain specific external ontologies. The aim of this description is to provide an additional refinement over the potential domain of the particular sensor data collected by a sensor.
- `SensorRole` (see Fig. 2) is a sub-concept of `Role`. The motivation follows the approach of the `SensorProjectRole` one: To provide a set of concepts relevant for a sensor with respect to the projects in which it is involved in and its own specific role within these projects, i.e., the role of a sensor might be analysing water in a project focused on monitoring the amount of some substances in the water of a river.

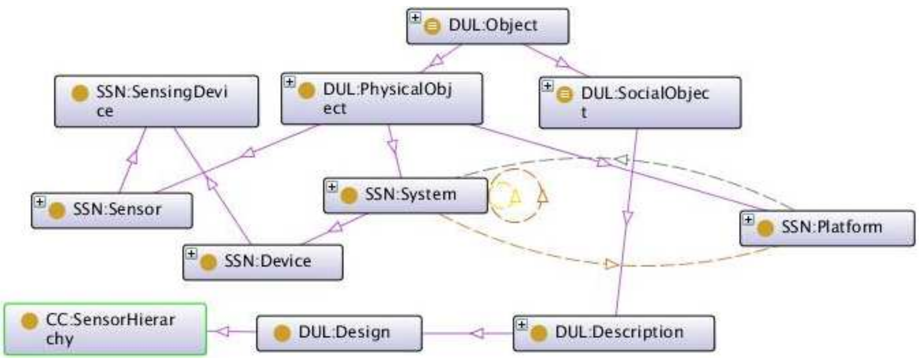

Fig. 1. Some of the main concepts regarding sensor network topology and devices. SSN is used as a namespace for the SSN-XG ontology; DUL for the DOLCE+DnS Ultralite; EventF for the Event-Model-F; CC for our own Contextualised-Cognitive ontology

Thanks to the above concepts, whenever it becomes necessary to automatically understand the kind of data collected by a sensor, we believe that it would be possible to query the LOD cloud by searching for sensor data that is already

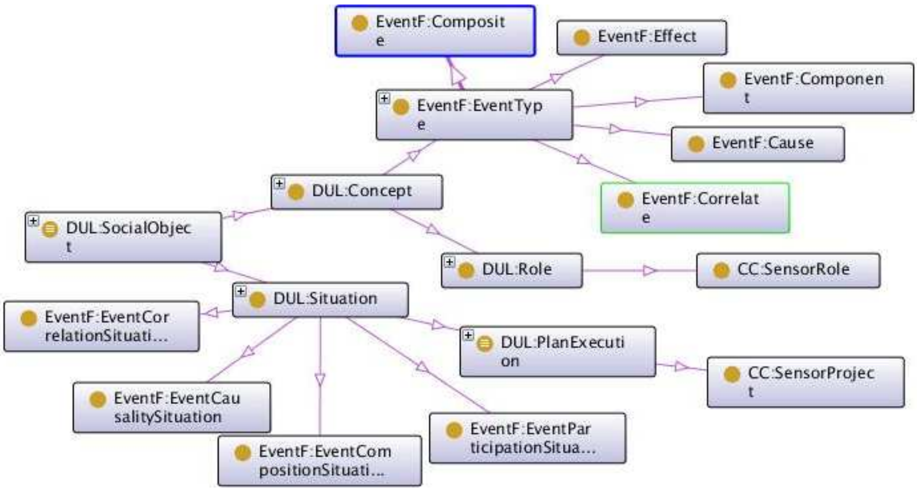

Fig. 2. The main concepts regarding definition of sensor role, events and major sensor project which the sensor is involved in. Same namespaces are used as in Fig. 1.

topic-tagged and similar to ours with respect to not only the raw sensor data features, i.e., time-stamp intervals, real quantities intervals, etc., but also in repsect to the sensor projects topics. For example, the probability of the two sensor data sets belonging to the same application domain could also be increased or decreased according to how often that application domain is related to that particular sensor type, i.e., water analyser), while it obviously has to be justified by experiments, that we will conduct in the future.

3 Conclusions and Future Work

In this paper, we proposed some means to emulate and improve human awareness about the environment, through emulation of the human cognitive process in sensors. We believe that considering the LOD cloud as a representative of human memory and Linked Data linkage as a representative of the associative nature of human minds, we can improve the understanding of reality. As a first step, we focused on the alignment of and some extensions to existing sensor ontologies to model this cognitive aspect of sensors.

Future work will be on validating our ontology modelling choices by experiments. In addition, we plan to build a platform which enables the detection of sensor context and expose it (as well as the sensor data itself) as Linked Open Data. Finally, we aim at integrating users in the process, to collect feedback regarding the accuracy of sensor data recognition. That way, humans will act as a means to support sensor data discovery.

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