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A Review for Semantic Sensor Web Research and Applications

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Abstract: To realize sharing and reuse of sensor data and improve interoperability, semantic sensor web (SSW) is proposed to add semantic information to existing sensor networks by utilizing domain, spatial and temporal anthologies and other related semantic technology. This paper presents state of the art of SSW from various aspects from the basic concepts, characters of SSW and the core technologies of SSW to the representative real world applications. Besides, it presents the challenges and the possible future research areas in SSW.

Keywords: sensor web enablement, semantic sensor web, ontology, semantic annotation

1 Introduction

Due to low cost and simple installment, many sensors collect various kinds of data. However, lack of unified operations and display standards, these data are isolated in information islands. It's difficult to discover useful information from large amounts of data. The Open Geospatial Consortium (OGC) [1][2] proposed SWE (Sensor Web Enablement [6]) and relevant standards, depicting the sensor web. While, its standards are purely syntactic standards [3], it's insufficient to realize knowledge-based reasoning and discovery and it doesn't state essence relations among data clearly [9].

In order to obtain further information and knowledge, researchers propose SSW by adding semantics through domain ontology and spatial and temporal ontology to the existing sensor network language standards. Sheth et al [5] leverage current standardization and semantic web and propose SSW in 2008. Durbha et al mentioned that SSW annotates sensor data with semantic metadata, increasing interoperability and providing contextual information essential for situational knowledge. The semantic data for sensor nodes uses temporal, spatial, thematic metadata [8]. Pileggi thought SSW is a progressive concept that would improve current sensor web model with a semantic layer in which the semantic or meaning of information is formally defined [13].

We believe SSW, combining SWE with semantic web and ontology, is considered as a framework that enhances the expressiveness of sensor data, provides abundant and meaningful semantic descriptions, and realizes sensor knowledge reasoning.

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Besides, SSW enables interoperability between heterogeneous multi-mode sensor data, and improves analysis capabilities of situational awareness as well.

The remaining of this paper is organized as follows. Section 2, we review the core technologies of SSW; Section 3, we give several representative applications about SSW, and Section 4 reveals the future research for SSW. Finally, Section 5 draws a conclusion of this study.

2 Core technologies of SSW

2.1 Semantic Web and SWE

Semantic web is an evolving extension of the World Wide Web. It is regarded as a platform of information and knowledge exchange for both man and machine [15]. Kong [11] described semantic web as a massive distributed database, the semantics of the data as its core, with the computer-understandable and computer-processable way to link up. Its goal is to define and interconnect the web and try to make the computer understand the meaning of information to some extent [17].

Mike Botts et al [2] introduce SWE being built is a unique and revolutionary framework for open standards. The models, encodings, and services of the SWE architecture allow implementation of interoperable and scalable service-oriented networks of heterogeneous sensor systems and client applications. Figure 1 shows the framework of SWE. Sheth et al [5] introduced a series of core language and service interface specifications of SWE framework; the goal of SWE is to allow all types of web and/or Internet-accessible sensors to be accessible and, where applicable, controllable via the web.

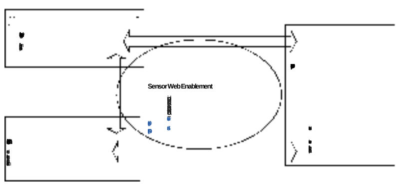

Figure 1. The framework of SWE.

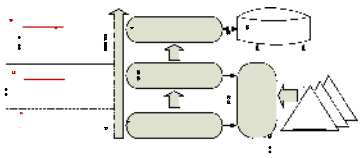

Figure 2. Semantic sensor Data-to-Knowledge architecture.

2.2 Ontology

To solve the problem that the same concept may have many lexical representations or the same word may have many meanings, it is necessary to apply ontology into the domain of Internet research [14]. It means a specification of a conceptualization, providing shared concept model for sense data sharing and reuse, achieving sensor knowledge reasoning, and offering favorable decision support [4].

2.3 Rule-Based Reasoning

Defining and using rules can get more additional knowledge from semantically annotated sensor data. Many rules languages and rule-processing systems are also being developed..The architecture of the semantic sensor Data-to-Knowledge is shown in Figure 2.

3 Semantic Sensor Web Applications

3.1 Add temporal semantics to video sensor data

Sheth introduced YouTube videos encoded in SensorML and semantically annotated with concepts from the OWL-Time ontology [5]. All videos in the prototype originate from in-dash cameras that contain temporal information within the video frames. The temporal metadata is extracted using optical character recognition engine. Users can retrieve videos by using semantic temporal concepts like within, contains, or overlaps for video and also can position the videos retrieved from the query results onto a Google map and play them within an information window.

3.2 SSW for Internet of Things

M. Alexandra proposed a system for publishing sensor data with the use of a relational database and providing integration with the semantic web [12]. A semantic layer is added in the proposed system, which enriches the sensor data and metadata. The system follows the principles of linked open data and uses standardized vocabulary for describing the data; the outputs of the system are data sets of semantic sensor description and real-time measurements. It realizes real-time web access, facilitates the publishing sensor data on the semantic web and makes contributions to the development of the Internet of Things.

3.3 A Service-based Architecture for Sensor Network Integration

Amato et al proposed a novel architecture to address the interoperability of sensor networks [9]. The architecture presents three horizontal layers. First layer provides a homogeneous view of the networks to the second layer; it adds semantics to sensor data, converts data to a common data model, and displays them to share the relevant information of observed phenomena. Second layer integrates data observing the same phenomenon from different networks, and provides to third layer to better understand the complex phenomenon. Third layer develops different types of applications for monitoring and elaborating the sensor data to realize decision support systems.

Another prototype application is the sensor observation service specified by SWE, using SSW frame to allow complex queries over weather data. The application collects and stores data, converting them into O&M and SML representation formats and semantically annotated these documents with spatial, temporal, and weather ontology. By combining with SSW semantic annotations, users can fluently execute complex queries over simple weather data. [5]

4 Future Research for Semantic Sensor Web

4.1 Real-time Search in Semantic Sensor Web

The information space of sensor web is much larger than that of Internet; besides, the sensor observations are highly dynamic, varying with environment and object. The reading has a very short life span [18]. Now, few of search methods in sensor web are depend on ontology to describe the object combining with semantic annotations to complete the search. Among these methods, none of them establishes similarity between the descriptions to the search elements; also, none of them try to associate a "context of search" to a request [16].

4.2 Ontology Construction for Semantic Sensor Web

Ontology is the core of SSW, also is the foundation for machines understandable semantics. However, to construct sensor ontology that is suitably applied to SSW is difficult. There are no standardizations in current sensor ontology construction. There are also no proved methods or framework to ensure the quality of the ontology construction. Moreover, mutual sharing and reuse of existing anthologies are also need to be explored.

4.3 Data Fusion in Semantic Sensor Web

Methods would be required to automatically enable the integration, fusion and processing of big data collected from sensors with different quality of service, different throughput as well as different geographical scope. Some research used semantic technology to complete the data integration and data fusion. Recent research trends focus on transforming the sensor-based data into RDF and making it available using HTTP with the help of sensor-related URIs. Other work being done is to provide semantic queries that are adapted to sensed-based data [10]. However, these methodologies still cannot complete the data integration or data fusion work.

4.4 Semantic Annotations in semantic Sensor Web

The challenges for semantic annotations are mainly from three aspects. First, how to annotate sensor data with contents that are explicit, unambiguous, and machine "understandable"; second, how to transform the archived or static data into data with explicit semantic information; third, the organization, storage and retrieval on the semantic content. To achieve the goal of semantic sensor web still needs a large number of standardized works [7].

4.5 Application Developments methodology for Semantic Sensor Web

Another problem the SSW faced is the challenge on the applications should be quickly developed to process sensor data. These applications are able to handle data integrity, authentication issues, as well as the common interface and formats among applications, databases, and sensor networks. So, applications with different resource models and different quality of services need to be developed to facilitate the interaction between sensor data from developers" and users" perspective [10].

5 Conclusion

By incorporating the standards of OGC and W3C, researchers have proposed semantic sensor web, which provides an environment for enhanced query and reasoning within the sensing domain. Great potential for SSW can be seen in various domains, including weather forecasting, oceanography, Event Web and so on. This paper gave a complete review on the current SSW research work and applications. The challenges that SSW researcher are facing and the valuable tasks to be solved is also presented.

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