Semantic Approach towards the Sensor Web Enablement

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Abstract - Sensor webs for science have evolved considerably over the past few years. Sensor web provides an infrastructure that coordinates distributed, heterogeneous, a large number of sensor data resources. Many of today's sensor webs employ little autonomy. The deployment and usage of sensors is usually tightly coupled with the specific location, application, and the type of sensors being used. Various applications for sensor webs require data from heterogeneous sensors and even integrating multiple sensor webs. To be effective, this will require a capability for publishing and discovering sensor resources. Once this infrastructure is in place, it will be much easier to pull additional sensors into a particular sensor web application. In the demand of providing autonomy capabilities to sensors, a semantic approach to the sensor web technology is applied. It provides a proposed solution towards the challenges for sensor web technology. This article proposes the resolution of challenges like interoperability, autonomy, data integration by semantic sensor web approach. It allows sensor networks to interact with other sensors.

Keywords: sensors, sensor webs, sensor web enablement, interoperability, semantics, semantic sensor web

1. INTRODUCTION

SENSOR networks are used in a broad variety of applications ranging from environmental monitoring and public health to disaster management and monitoring of public infrastructures. Sensors around the globe currently collect huge amount of data about the world. The rapid development and deployment of sensor networks and the lack of integration and communication between these networks is intensifying the existing problem of too much data and not enough knowledge. The combination of sensor networks with the Web, web services and database technologies, is termed as the Sensor Web. The term "Sensor Web" was first used by Kevin Delin of NASA in 1997, to describe a novel wireless sensor architecture where the individual pieces could act and coordinate as a whole.

As IP-enabled, affordable sensor devices of different types become available and are placed around, referred to as a "Sensing Cloud", in our environment, integrating the diverse sensory streams into the web can serve different user or machine queries.

General architecture of Sensor Web applications can be characterized by:

-variable and heterogeneous data, devices and networks.

-unreliable nodes and links, noise, uncertainty

- Vast data sources (sensors, images, GIS, etc.) in different settings (live, streaming, historical, and processed);
- Existence of multiple administrative domains
- need for managing multiple, concurrent, and uncoordinated queries to sensors.

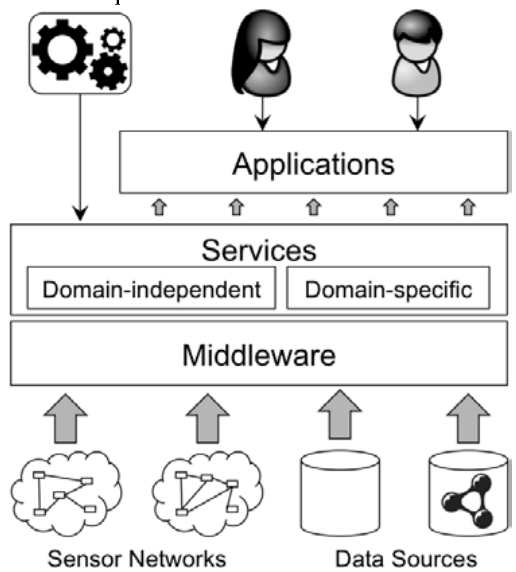

Figure 1. Working of sensor web

2. SENSOR WEB ENABLEMENT

Sensor technology, computer technology and network technology are advancing together while demand grows for ways to connect information systems with the real world. The SWE effort involves OGC members in developing the global framework of standards and best practices that make linking of diverse sensor related technologies fast and practical.

The Sensor Web Enablement (SWE) standards enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and useful via the Web. In much the same way that Hyper Text Markup Language (HTML) and Hypertext Transfer Protocol (HTTP) standards enabled the exchange of any type of information on the Web, the SWE initiative is focused on developing standards to enable the discovery, exchange, and processing of sensor observations, as well as the tasking of sensor systems. Sensor location is usually a critical parameter for sensors on the Web. The goal of SWE is to enable all types of Web and/or Internet-accessible sensors, instruments, and imaging devices to be accessible and, where applicable, controllable via the Web. It has a goal of allowing people to publish their sensor network data in such a way that other people's search and analysis systems can *automatically* find the information

The functionality that OCG has targeted within a sensor web includes:
-Discovery of sensor systems, observations, and observation processes that meet an application's or users immediate needs;
- Determination of a sensor's capabilities and quality of measurements;
- Access to sensor parameters that automatically allow software to process and geo-locate observations;
- Retrieval of real-time or time-series observations and coverage in standard encodings
- Tasking of sensors to acquire observations of interest;
- Subscription to and publishing of alerts to be issued by sensors or sensor services based upon certain criteria.

Sensor Web Enablement standards that have been built and prototyped by members of the OGC include the following pending OpenGIS Specifications:
1. **Observations & Measurements Schema (O&M)** – Schema for encoding observations and measurements from a sensor, both archived and real-time.
2. **Sensor Model Language (SensorML)** –Schema for describing sensors systems and processes; provides information needed for discovery of sensors, location of sensor observations, processing of low level sensor observations, and listing of taskable properties.
3. **Transducer Markup Language (TransducerML or TML)** – Schema for describing transducers and supporting real-time streaming of data to and from sensor systems.
4. **Sensor Observations Service (SOS)** - Standard web service interface for requesting, filtering, and retrieving observations and sensor system information. This is the intermediary between a client and an observation repository or near real-time sensor channel.
5. **Sensor Planning Service (SPS)** – Standard web service interface for requesting user-driven acquisitions and observations. This is the intermediary between a client and a sensor collection management environment.
6. **Sensor Alert Service (SAS)** – Standard web service interface for publishing and subscribing to alerts from sensors.
7. **Web Notification Services (WNS)** – Standard web service interface for asynchronous delivery of messages or alerts from SAS and SPS web services and other elements of service workflows.[2]

3. Management of sensor web data

The worldwide sensor web will generate too much data to visualize or analyze manually.
Most sensor network researchers would probably agree that we have placed too much attention on the networking of distributed sensing and too little on tools to manage, analyze, and understand the data. the sensor web must incorporate logical data abstractions and visualizations that can shield users from the complexities of the underlying sensing infrastructures but still propagate measures of uncertainty associated with calibration or sampling effects. A useful query on the worldwide sensor web might need to compare or combine data from many heterogeneous data sources maintained by independent entities. For example, while treating a patient, healthcare professionals might query hospitals for the patient's health profile and airports for his or her recent travels. They might then correlate this information with similar information from other patients suffering from similar diseases. [3]
SOS Implementation Specification is a critical element of the SWE architecture, defining the network centric data representations and operations for accessing and integrating observation data from sensor systems. The SOS is the intermediary between a client and an observation repository or near real-time sensor channel. Clients can also access SOS to obtain metadata information that describes the associated sensors, platforms, procedures and other metadata associated with observations. The client depends on registries that provide metadata for the different types of sensors and the kinds of data that they are capable of providing. Centralized registries for sensor-based data have appeared focused on the registration of sensor-based data sources, and on the provision of access to them in multiple ways.[6]

4. Challenges with Sensor Web Observations

Sensor webs encounters various challenges related to the characteristics of the data sources that are handled in typical Sensor Web applications and the creation of applications based on these data sources. Some of these challenges are discussed here.

First concern is related to the abstraction level in which sensor data can be obtained, processed and managed in general. Sensor data can be managed at a very low level, at the device- and network-centric levels, generally by means of using low-level programming languages and operating systems. But it can be also managed through higher-level formalisms (e.g., via declarative continuous queries over streams), thereby insulating clients and users from the infrastructural and syntactic heterogeneities of autonomously-deployed sensor networks
Second challenge is related to the adequate characterization and management of the quality of sensor

data. Issues like the unavailability of a piece of data over a period of time may have different meanings when seen from an application perspective: the sensor was not available, there was no event to trigger the data generation during that time, the communication with the sensor was broken, etc. Other issues like the accuracy of the sensed data may depend on a number of internal and external conditions to the sensor network. In summary, there are a number of quality characteristics that are relevant to the quality of service and that may affect the results obtained from a data observation process.

The sensor web is facing the problem of integration and fusion of data coming from autonomously-deployed sensor networks, with varying qualities of service and different throughput rates, geographical scales, etc. This is related not only with the integration of data coming from different sensor networks, but also with the combination of such data with data persisted in other sources, such as static data or archived sensor data. Even if the sensor web data sources used well-defined interfaces to publish their data, the complex and semantically disparate measures of data quality and uncertainty typically associated with sensor webs make data fusion a challenge.

It evolves in the problem of identify the location of relevant sensor-based data sources with which data integration and fusion tasks can be performed. The number of sensor networks being deployed in the real world is growing continuously,. As a result, more experiments and initiatives deploy sensor networks in different areas, and finding the right information to be used in integration and fusion tasks is highly relevant.

Finally, another important challenge has to do with the need to enable the rapid development of applications that are able to handle sensor data, taking into account the aforementioned characteristics and challenges. This includes dealing with data integrity and validation issues as well as the need for common interfaces and formats between applications, databases, sensor networks, etc. This challenge requires enabling the development of applications with different resource models and qualities of service (e.g., energy, bandwidth, processing, and storage) and facilitating the interaction with sensor data from the developer and user points of view.[4]

5. Semantic approach to sensor web-SEMANTIC SENSOR WEB

The sensible use of the term “semantics” refers to the meaning of *expressions* in a language. The semantics required to achieve interoperability is that of expressions built from symbols in service descriptions.

Much of the query-processing task in the worldwide sensor web will be automated; data must have a well-defined syntax and semantics. The Semantic Web can address many of the technical challenges of enabling interoperability among data from different sources. This technology enables information exchange by putting data with computer-processable meaning (semantics) on the World Wide Web.

The Semantic Web has three key aspects. First, data is encoded with self-describing XML identifiers, enabling a standard XML parser to parse the data. Second, the identifiers’ meanings (properties) are expressed using the Resource Description Framework. RDF encodes the meaning in sets of triples, each triple being like an elementary sentence’s subject, verb, and object, with each element defined by a URI (uniform resource identifier) on the Web. Ontologies express the relationships between identifiers. For example, two data sources can publish data in XML as “<Temperature><Celsius>20</Celsius></Temperature>” and “<Temperature> <Fahrenheit> 68 </Fahrenheit> </Temperature>.” An associated RDF document can describe that Celsius and Fahrenheit are temperature units, and ontology can define the relationship between Celsius and Fahrenheit. So, a data-processing system can automatically infer that these two data points represent the same temperature value. Major industries are working to establish their own ontological standards for the Semantic Web.

Previously, the data processed by a GIS as well as its methods had resided locally and contained information that was sufficiently unambiguous in the respective information community. Now, both data and methods may be retrieved and combined in an ad hoc way from anywhere in the world, escaping their local contexts. They contain attributes, data types, and operations with meanings that differ from those implied by locally-held catalogues and manuals. Since the semantics specified by these local resources is not machine-readable, it cannot be shared with other systems. [4,9]

One of the main open issues in the development of applications for sensor network management is the definition of interoperability mechanisms among the several monitoring systems and heterogeneous data. In the last years, the Service-Oriented Architecture (SOA) approach has become predominant in many sensor network projects as it enables the cooperation and interoperability of different sensor platforms at a higher level of abstraction. The Semantic Sensor Web (SSW) proposes that sensor data be annotated with semantic metadata that will both increase interoperability and provide contextual information essential for situational knowledge.[4]

A number of sensor network ontologies have been created, which aim at describing different aspects of sensor-based data, from the device point of view (focusing on the hardware that is being used in order to generate the data) to the domain point of view (focusing on the types of data that can be generated from sensors and sensor networks in the context of specific domains). Several aspects are relevant in the development of most of these ontologies, such as the distinction between raw observed data and derived data, the representation of aspects like accuracy, or the consideration of observations and measurements.

In the context of identifying and locating relevant sensor-based data in the real world, sensor data registry interfaces are defined, and an appropriate infrastructure that can cope with the types of queries that are usually handled in sensor-based applications is being developed. These registries should provide support for spatio-temporal queries (e.g., "get sensor data sources that contain information about the temperature in this region for the last two days") and for metadata queries related to existing sensor network ontologies.[6] Semantic queries that are adapted to sensor-based data are formulated. They provide declarative querying infrastructure to define logical views over sensor network data and open the way for view and ontology-based techniques to be used.

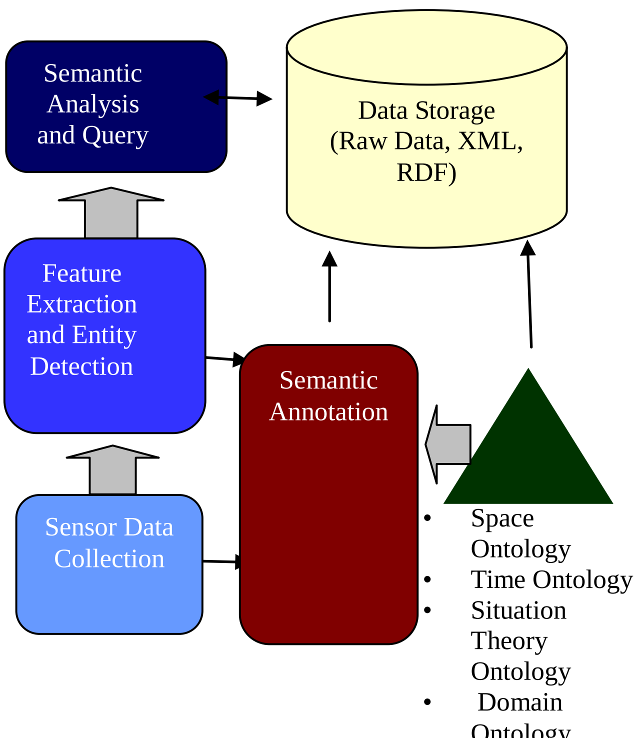

Figure 2. Semantically query processing

6. Conclusion

Building more effective sensor webs involves many different challenges in the areas of information standardization and autonomy. The challenges in information standardization have evolved from the difficulty in the collection and analysis of information from many different types of sensors. We need to create data standards so that the different sensor data and the models that use them can be fused together to answer complex scientific questions. Different users have different views of the sensor data depending on their particular need. This problem is being addressed with the evolving concept of semantic view to current syntactic web technology. In this respect, ontologies are being created that will infuse metadata into the sensor data. This will allow data that can be filtered, summarized, and transformed, and will also allow features to be extracted into higher level features. In addition, the same data can be reused for different applications. The next generation semantic sensor web can be an effective proposed solutions of today's traditional sensor web technology.

References

[1]. Vagan Terziyan and Oleksandr Kononenko, "Semantic Web Enabled Web Services: State-of-Art and Industrial Challenges",LNCS.

[2]. Mike Botts,George Percivall.Carl Reed,John Davidson," OGC® Sensor Web Enablement: Overview And High Level Architecture", *Proceedings of the 5th International ISCRAM Conference – Washington, DC, USA, May 2008* F. Fiedrich and B. Van de Walle, eds.

[3]. Magdalena Balazinska *University of Washington* Amol Deshpande *University of Maryland* Michael J. Franklin *University of California, Berkeley* Phillip B. Gibbons *Intel Research* Jim Gray and Suman Nath *Microsoft Research* Mark Hansen *University of California, Los Angeles* Michael Liebhold *Institute for the Future* Alexander Szalay *Johns Hopkins University* Vincent Tao *Microsot, "*Data Management in the Worldwide Sensor Web", PERVASIVEcomputing *Published by the IEEE Computer Society*

[4] Oscar Corcho and Raúl García-Castro," Five challenges for the Semantic Sensor Web"

[5] FREDDY DUITAMA,BRUNO DEFUDE ,AMEL BOUZEGHOUB,CLAIRE LECOCQ," A Framework for the Generation of Adaptive Courses Based on Semantic Metadata", 2005 Springer Science + Business Media, Inc. Manufactured in The Netherlands.

[6] Miao-Miao Wang;, Jian-Nong Cao2, Jing Li, and Sajal K. Dasi," Middleware for Wireless Sensor Networks: A Survey", A survey. JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY 23(3): 305,326 May 2008.

[7] Arne Br¨oring, Krzysztof Janowicz, Christoph Stasch, and Werner Kuhn," Semantic Challenges for Sensor Plug

and Play", W2GIS 2009, LNCS 5886, pp. 72–86, 2009. Springer-Verlag Berlin Heidelberg 2009.

[8] Beniamino Di Martino," An Ontology Matching Approach to Semantic Web Services Discovery", ISPA 2006 Ws, LNCS 4331, pp. 550 – 558, 2006. Springer-Verlag Berlin Heidelberg 2006

[9]. Sam Bacharach, Open Geospatial Consortium, Inc. (OGC)," Implementations of OGC Sensor Web Enablement Standards", Article for December 2007 Sensors Magazine.

[10] Nicholas J. Kings, Caroline Gale, and John Davies," Knowledge Sharing on the Semantic Web", ESWC 2007, LNCS 4519, pp. 281–295, 2007. © Springer-Verlag Berlin Heidelberg 2007.

[11] Amit Sheth ," Semantic Sensor Web" ARC Research Network on Intelligent Sensors, Sensor Networks and Information Processing – ISSNIP talk Melbourne, August 1, 2008