Semantic System Architecture Based on Service Provider for Context Data Acquisition in Sensor Networks

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Abstract

Recently, there are increasing numbers of sensors that report data from our physical environment. A sensor network consists of a number of spatially distributed and communicating sensor resources. Sensor networks have provided us with facilities to collect information and track certain phenomena in the physical environment based on the region of interest. W3C(World Wide Web Consortium) semantic sensor network group supports to develop an ontology to describe sensors and sensor networks for use in sensor network and sensor web applications. This paper proposes a semantic system architecture based on service provider for data acquisition from heterogeneous sensing sources. And, we design a semantic data model of service provider based on context Ontology. This architecture can help to make a meaning information for deciding an environment situation and assisting efficiently to manage facilities.

Keywords: Semantic system architecture, Data acquisition, Sensor networks

1. Introduction

A sensor network consists of a number of spatially distributed and communicating sensor resources. Sensor networks collect a phenomena data in the physical environment based on the region of interest. A sensor measures temperature, wind speed, and solar radiation, etc. While a sensor is the most basic unit, a sensor system is an aggregation of sensors, attached to a single platform. Examples are a weather station with attached sensors, or a combination of heart frequency and blood pressure sensors carried by a human or animal. A sensor or a sensor system may be abstracted as a sensor resource [1-3].

The OGC (Open Geospatial Consortium) SWE (Sensor Web Enablement) standards provide description and access to data and metadata for sensors, they do not provide facilities for abstraction, categorization, and reasoning offered by semantic technologies. W3C (World Wide Web Consortium) semantic sensor network group has studied and recommended methods for using the ontology to semantically enable applications developed according to available standards [4].

Systems architecture is the conceptual model that defines the structure, behavior, and more views of a system. An architecture describes a formal representation of a system, organized in a way that supports reasoning about the structures and behaviors of the system.

In this paper, we propose a semantic system architecture based on service provider for data acquisition in sensor networks. This architecture can help for data discovery and
linking, device discovery and selection in sensor networks. Additionally we design a semantic data model of service provider based on context Ontology. The semantics associated with the stored data and the reasoning capabilities enables the service provider to query non-relational information from the ontology.

The rest of the paper is structured as follows Section 2 presents the related work describing different semantic technologies, Section 3 provides the semantic system architecture based on service provider and Section 4 presents the semantic data model of service provider based on context Ontology. At the end, Section 5 presents the conclusions.

2. Related Work

The principal technologies for Semantic Web includes the data representation model called as Resource Description Framework (RDF), the ontology representation languages RDF Schema, the Web Ontology Language (OWL) [5], and SPARQL [6], an RDF query language is now a common method of querying the ontology data. Various domains can get benefits from these technologies mainly with issues like heterogeneity, complexity, and volume [7]. These technologies are helpful in managing, querying and combining sensors and observation data. Semantic web technologies could be used in isolation or in augmenting SWE standards in the form of Semantic Sensor Web [8]. In this paper we have developed a context ontology that reuses the existing SSN ontology. From the perspective of sensor networks, any physical entity e.g., a heater, a parcel to track, a piece of furniture in a room, or an industrial machine to monitor is termed as a Thing. The number of physical entities connectable to Sensor networks is increasing day by day. According to [10] there will be 25 billion devices connected to the internet by 2015 and 50 billion by 2020. These devices will need to connect and communicate in multiple ways. Due to the diversity of these devices from the perspective of manufacturers, operation, communication and interface etc., Sensor networks requires interoperability to support different tasks such as object discovery, tracking, information representation, storage and exchange. The research conducted in [11] is based on developing an ontology that acts as a mediator to hide the heterogeneity of Sensor networks entities. They focus on three different tasks that are a) the alignment of Sensor networks entities metadata and matchmaking, b) semantic registration of Sensor networks entities, and c) the alignment of message exchange during the device to application communication. The aim of developing the ontology is to hide the heterogeneity of the Sensor networks entities. The term ontology has been used in a variety of contexts. The idea of using ontology driven information system for sensor networks was introduced in [12]. The authors have presented a two phased solution that can be employed to enable a real world wireless sensor network to adapt itself to variations in environmental conditions. The first phase executes an efficient algorithm to dynamically calibrate sensed data, and the second phase executes an efficient ontology driven algorithm to determine the future state of the network under existing conditions. The ontology captures the most important features of a sensor node that describe its functionality and its current state. Use of sensing devices for collecting and connecting data is increasing due to its applications in wide areas. This increase is causing an upsurge of data with different data formats from different devices, which requires advanced analytical processing and interpretation by machines. This sensor data is becoming the focus for many researchers these days. The Sensor Web Enablement (SWE) [8] initiative of the Open Geospatial Consortium (OGC) defined data encodings and Web services to store and access sensor-related data. The models, encodings, and services of the SWE architecture enables implementation of the interoperable and scalable service oriented networks of heterogeneous sensor systems and client applications. SemSOS has proposed ontology models for sensor domain and sensor observations, with semantics annotated to the sensor data and using these models to
reason sensor observations. Thus providing the ability to query high level knowledge of the environment as well as low level raw sensor data [13]. An ontology based prototype sensor repository referred to as OntoSensor has been developed as illustrated in [14]. OntoSensor is a repository containing concepts and relations definitions from SensorML [15] and extends concepts from the IEEE SUMO ontology, and reference terms from ISO 19115. The authors approach is to use upper level ontologies to deploy a framework in which translation among different domain ontologies can be more readily accomplished. The definitions of high level concepts pertaining to sensors can be used as background knowledge for the integration of data from heterogeneous sensors.

3. Semantic System Architecture Based on Service Provider

Figure 1 illustrates the conceptual semantic system architecture based on service provider for monitoring underground facilities. This system is role of the intermediary and uses context ontology. And semantic service provider also stores the context information of each sensor node based on ontology. Sensor provider stores information about these units and the functionality based on ontology. Sensor provider can be added, updated, and deleted through Sparql queries run on the ontology. The service provider offers three services namely content service, sensing service and provider service. Provider service is used for data provision purpose, sensing service is used by sensor middleware to sense sensor data, and content service is used by sensor support toolbox for data manipulation purposes.

![Figure 1. Semantic System Architecture based on Service Provider in Sensor Networks](image_url)
The sensor provider connects a middleware, a service register, and a support toolbox. Sensor provider stores the context data related to SPARQL on the ontology. The service provider supports three services namely content service, sensing service and provider service. The provider service is used for data provision purpose, sensing service is used by sensor middleware to sense sensor data, and content service is used for data manipulation purposes.

4. Semantic Data Model of Service Provider Based on Context Ontology

This section represents the context Ontology design phase in detail. It discusses the different models describing the ontology from various aspects. Our main source for collecting vocabulary was the SSN ontology. The SSN ontology, available at http://purl.oclc.org/NET/ssnx/ssn, is organized, conceptually but not physically, into ten modules. It is built around a central Ontology Design Pattern (ODP) describing the relationships between sensors, stimulus, and observations, the Stimulus-Sensor-Observation (SSN) pattern. Our context ontology is maintained by the sensor provider as shown in Figure 3. The sensor provider provides services that can be used by the neighboring modules to manipulate data. It also stores the information about each device connected to it in the ontology. Sensor Support toolbox helps the semantic service provider to manage this data and make it available to users.

Figure 2. Context Ontology Model of Service Provider

Figure 2 illustrates the basic concepts and relationships of context ontology model of service provider. System, sensor, and device are reused by importing SSN ontology in the context ontology. The object properties implements, and detects is also reused from SSN ontology. Sensors are physical objects (dul:PhysicalObject) that observe, transforming incoming stimuli (ssn:detects) into another, often digital, representation. It shows that service provider offers three services namely content service, sensing service and provider service. Provider Service is used for data provisioning purpose, sensing service is used by
sensor middleware class to sense sensor data, and Content Service is used by sensor support toolbox class for data manipulation purposes. SP_Services class represents the services provided by the Sensor Service Provider. Type Information class stores information about the type of the sensor. Whereas Category class defines the sensing categories sensors can have. Management class defines the management functions provided by the Sensor Support Toolbox. Management has three subclasses namely Middleware Management, Provider Management, and Sensor Management.

Figure 3. Semantic Data Model of Service Provider based on Context Ontology

Figure 2 also shows the object properties definitions between all these classes. SSN: implements reused from SSN ontology shows how a sensor observers. SSN: detects shows a sensor observes the incoming signal. Has device describes that every system has a device and sensor is a device. Connects To property defines that every sensor is connected to a sensor middleware and sensor middleware is connected to service provider. Provides property exists between service provider class and the services it provides. Perform property defines the management functionality performed by the sensor support toolbox class. Uses property defines the relationship between any two modules that are connected to each other. In the context ontology it represents this relation between sensor middleware and sensing service and between sensor support toolbox and content service. Has category shows the categories a sensor belongs to whereas has type shows the type of the sensor.
Figure 3 shows the semantic data model of service provider based on context Ontology. It is a conceptual data model that shows how semantic information is presented in the ontology. It represents all the details about the information that makes the knowledge base of an ontology. It illustrates the concepts, data type properties, object properties, individual, and the subclass relations defined in the ontology. It also shows the subclass relations that exist between some of the classes for example SP-Services class has 3 subclasses namely Content Service class, Sensing Service class, and Provider Service class. Object properties define the relationships between two objects in OWL Ontology. Structurally, object properties are the edges that connect the nodes in an OWL ontology graph. Many object properties exist between the object defined in context ontology that are shown in Figure 3. “Connects To” is an object property that relates four individuals i.e., Sensor Middleware1 to Sensing Device1 and Sensor Middleware 1 to SSP1. “hasCategory” is an object property that connects the Sensing Device1 object to the Category 1 object. “hasType” object property connects Sensing Device1 to the individual Type Info1. “Is” Produced By object property defines in ssn ontology relates the Output class to the Sensing Device class. It shows that Sensing Devices in a network...
produces some outputs that are stored in the Output class. “Uses” is another object property that shows the classes that uses the services provided by the sensor service provider. It connects the CS individual which is a type of Content Service class to the SST1 individual which is a type of Sensor Support Toolbox class, it also connects the SS individual an instance of Sensing Service class to the Sensor Middleware 1 which is an instance of Sensor Middleware class. Provides and Performs are object properties that exists between Sensor Service Provider class and SP-Services class and Sensor Support Toolbox class and Management class respectively.

Figure 4 shows the hierarchical representation of hierarchical semantic data model of service provider using OwlViz generated graph. It shows the relationships between the various concepts in the domain in form of hierarchy. It shows the super and subclass relationship between different classes of the ontology. It covers the is-a relationship between the concepts in the ontology showing that each class in the ontology is a Thing. For example it describes that Sensing Device is a Sensor and Sensor is a Physical Object. As the SSN ontology has been imported into the context ontology, this graph shows all the classes included in the SSN ontology as well as in the context ontology.

Figure 5. Semantic Entities in Data Model using Protege

The hierarchical semantic data model of service provider based on context ontology is designed in the software Protégé 4.3, which is an open source editor. It is written in OWL/XML format which is the XML serialization of your OWL ontology. As defined in the [4] an OWL ontology is an RDF graph which in turn is a set of triples. As with any RDF graph an OWL ontology graph can be written in many different syntactic forms. Sparql is used for querying the ontology. Sparql i.e., Simple Protocol and RDF Query.
Language is a semantic query language that is able to retrieve and manipulate data stored in the RDF and OWL format [3].

Figure 5 shows a screen shot of the semantic entities in data model based on context ontology taken from Protégé. It shows the information of the context ontology as presented in protégé. This tab simultaneously shows all the classes, the individuals associated with each class, the data type values, and the object property assertions that are present in the ontology. As mentioned earlier we have used SSN ontology in our ontology, the class hierarchy tab includes all the classes from the SSN ontology and the context ontology.

```xml
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ssn:<http://purl.oclc.org/NET/ssnx/ssn#>
PREFIX spo:<http://www.semanticweb.org/faiza/ontologies/2015/0/serviceproviderontology#>

SELECT ?code ?name ?type ?connectsTo
WHERE{
  ?ind spo:NodeID "sd01"^^xsd:string;
  spo:NodeCode ?code;
  spo:NodeName ?name;
  spo:NodeExplain ?type;
  spo:ConnectsTo ?connectsTo
}
```

**Figure 6. Sparql Query in Semantic Data Model of Service Provider**

Figure 6 shows a simple SELECT sparql query that selects the data property and object property of one of the sensor stored in the ontology. It selects these attributes based on the ID of a sensor as each sensor in the ontology is given a unique identity.

5. Conclusions

In this paper, we present a semantic system architecture based on service provider for data acquisition from heterogeneous sensing sources. And, we design a semantic data model of service provider based on context Ontology. The proposed architecture provides an improved information storage and retrieval infrastructure suitable for the large numbers of devices as part of a sensor networks. And the proposed model improves the quality of device discovery in terms of relation to other environmental entities.
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