ICIC Express Letters
Volume **10**, Number **5**, May **2016**
ICIC International ©2016 ISSN 1881-803X
pp. 1115–1120

ONTOLOGY DEVELOPMENT FOR SENSOR NETWORKS IN THE IOT ENVIRONMENT

Haekyung Lee and Taioun Kim
Department of Industrial and Management Engineering
Kyungsung University
309 Sooyoung-ro, Nam-gu, Busan 48434, Korea
hshklee@naver.com; twkim@ks.ac.kr

Received November 2015; accepted February 2016

Abstract. *In the modern manufacturing facility with many sensors and devices, the way how to integrate and manage heterogeneous data is crucial. Therefore, the task of formal representation and interoperability is a big challenge. In these environments, there are various physical entities which need to be integrated and managed. Internet of things (IOT) enables a global connectivity between the real entities and the virtual world of entities. Various IoT entities need to be formally and explicitly represented and organized by appropriate abstraction methodologies. Ontology is well suited for formal representation and management. The purpose of this paper is to propose ontology framework for integrating various sensor data in the IoT environment. The workflow in the smart factory facility is modeled using ontology framework. The proposed model is realized on the Protégé 3.4 platform.*
Keywords: Ontology, Internet of things (IoT), Sensor networks, Smart factory, Interoperability, SOA

1. **Introduction.** In the future factories, we face a challenge to collect and analyze huge data from heterogeneous sensors and devices for manufacturing optimization. As there are many data sources and variety of data types, communication protocol and interoperability is a big issue.

As ontology is a set of concepts such as things, events, and relations in order to create an agreed-upon vocabulary for exchanging information, it is adopted for sharing knowledge via the specification of conceptualizations.

The Internet of things (IoT) generates a paradigm where everything is interconnected and redefines the way people interface with machines and the way they interact with the environments. The IoT describes a system where objects, sensors and software are connected to the Internet via wireless and wired network.

In order to be competitive globally, a production system should be an ecosystem where efficient and lean production can be implemented upon the network of interconnected sensors and devices. For this purpose, sensors and devices are embedded in the manufacturing and production facility, which resulted in a smart factory.

In the smart factory, various wireless technologies are implemented based on new protocols. They are supervisory communication using WLAN, decentralized process control based on RFID, wireless device network based on ZigBee and Bluetooth [1].

The purpose of this paper is to propose an ontology model for sensor networks in the IoT environment. The workflow in the manufacturing plant has been modeled as ontology. The model is implemented on the ontology platform of Protégé 3.4.

The strong point of the proposed ontology is the integration of various sensor data in the IoT environment. The workflow in the manufacturing environment is modeled based on the ontology framework. Things are self-organized and controlled in the Industry 4.0 which is the final platform of smart factory. In this research, the operation process chart, a classical control tool is adopted as a domain ontology. A new methodology is proposed that can interchange information among objects according to the operation process chart. In addition, upper ontology which is a high-level and domain independent ontology is adopted in order to implement domain and device ontology.

Section 2 describes IoT and ontology in the smart factory environment. Section 3 shows class definition in ontology model. Section 4 provides Protégé model implementing all the classes, properties and individuals. Finally, conclusion follows for summary and future research.

2. **IoT and Ontology.** ITU (International Telecommunications Union) defines IoT as a global infrastructure for the information society, enabling advanced services by interconnecting physical and virtual things based on existing and evolving interoperable information and communication technologies [2].

IoT will enable a global connectivity between physical objects and bring real-time machine-published information to the Web by combining ubiquitous access with the cloud intelligence.

The "things" in the IoT includes various physical entities that are of interests for the human being. Depending on the nature of these 'things', different technologies for connecting them to the IoT are used: a) identity devices such as barcodes or RFID tags, b) sensing and actuating devices such as pressure sensors, visual sensors or actuators and c) embedded electronics such as industrial machinery, smart phones and wearable devices that have embedded parts in the product [3].

In order to orchestrate and execute business processes, Service-oriented Architectures (SOA) has been adopted as it is an abstract concept for software architectures. SOA enables the flexibility and interoperability. As SOA is mainly focused on the syntactical format, it resulted in lack of semantics. Loskyll et al. [4] describe how semantic technologies can be applied to the dynamic context-based orchestration of technical manufacturing processes based on the concept of SOA.

The IoT is characterized as highly-distributed, heterogeneous, and resource-constrained. In order to resolve these problems, Ryu et al. [5] proposed an integrated semantic service platform (ISSP). The proposed ISSP handles and stores various service domain knowledge in a smart city using ontologies and then provides semantic interoperability between different service domains based on the integrated knowledge.

Ontology is a formal definition of the types, properties and their interrelationships of the entities existing in the domain of discourse. Ontology can share knowledge via the specification of conceptualization. Ontology may exist at many levels of abstraction. We group ontologies into three broad categories of upper, mid-level and domain ontology. A domain ontology represents concepts which belong to a specific point of interest. The same word may indicate different meanings according to the domain.

An upper ontology is a high-level and domain independent ontology. It provides a framework from which more domain-specific ontologies may be derived. Widely used upper ontologies are DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering) and Semantic Sensor Network Ontology (SSN). DOLCE aims at capturing the ontological categories underlying natural language and human common sense. DOLCE is developed by Nicola Guarino and his associates at the Laboratory for Applied Ontology (LOA) [6]. SSN describes sensors, observations and related concepts. Utilizing the upper ontology concept, the architecture of proposed ontology model is shown in Figure 1.

3. **Class Definition in Ontology Model.** In order to construct a smart factory and to organize information acquired from various sensors, workflow class for ontology model is defined as Figure 2. Workflow is adopted for operation process chart which is used in the factory with production operation. Factory class has a property of 'Has product',

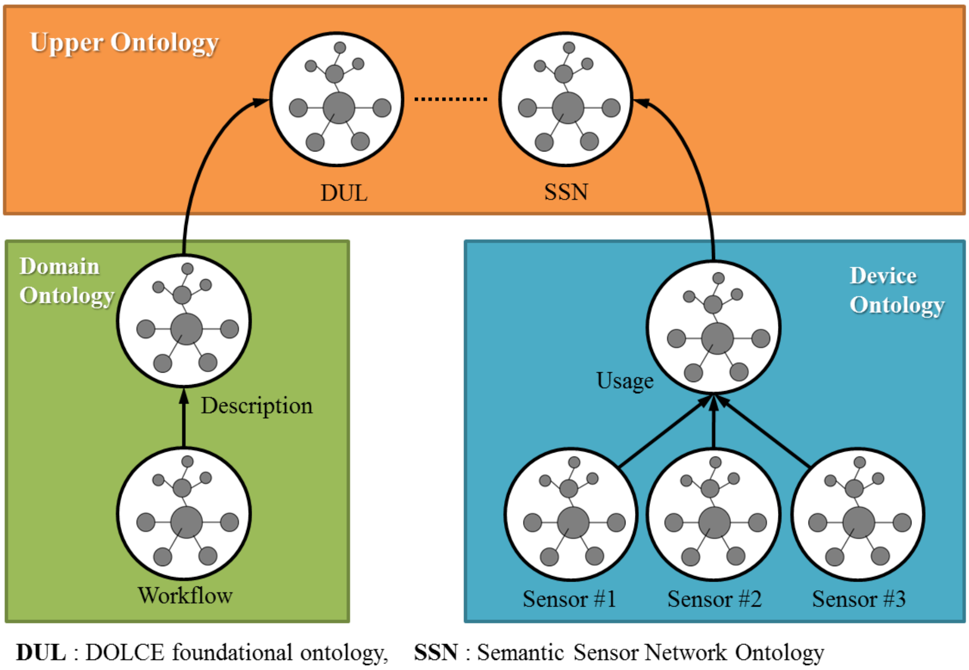

Figure 1. Architecture of ontology model

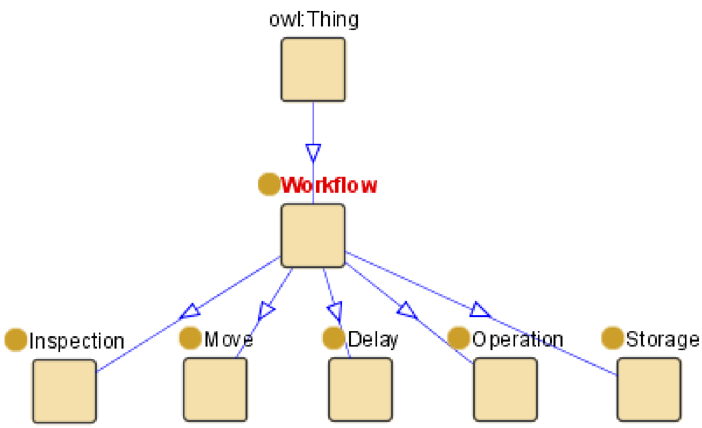

Figure 2. Workflow class

and has a range of ‘Product class’. ‘Product class’ has ‘Workflow’ in order to produce a real ‘Product’. Work flow process is composed of inspection, move, delay, operation and storage. The five classes are important processes which have been adopted in the classical analysis methodology of operation process chart.

Workflow class has ‘Description class’ as a range. It describes the point of interest in each workflow. It searches available sensors in each process through semantic inference of sensor usage. Figure 3 shows ‘Description class’ which defines part’s characteristics required in each process. For example, in the process of inspecting part’s dimension, the objective of ‘Description class’ is specifying the dimension for making decision of a good product. Also this class can be utilized to evaluate sensors whether the accuracy of each sensor has the precision required in each process.

The dotted line represents upper ontology. DUL means DOLCE Ontology explained in Section 2. The property of interest is inherited from upper ontology DOLCE.

Next, we need to define sensor structure which is used to acquire the factory data. The device class structure is represented in Figure 4. In the past utilizing sensor requires a

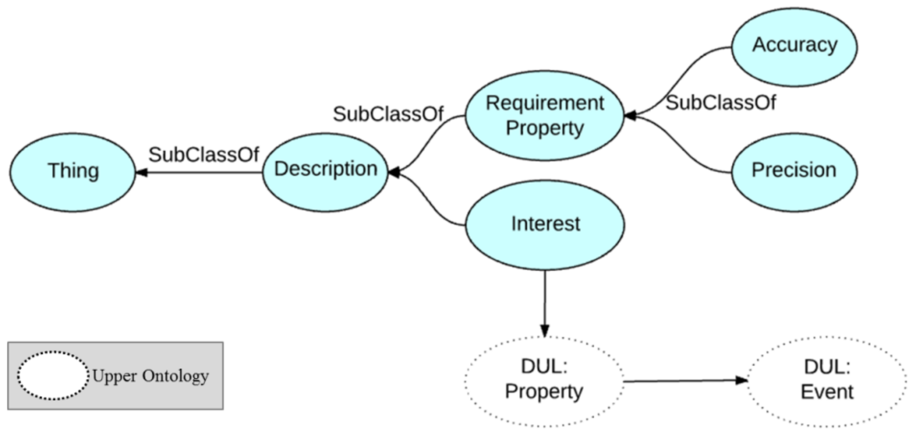

FIGURE 3. Description class

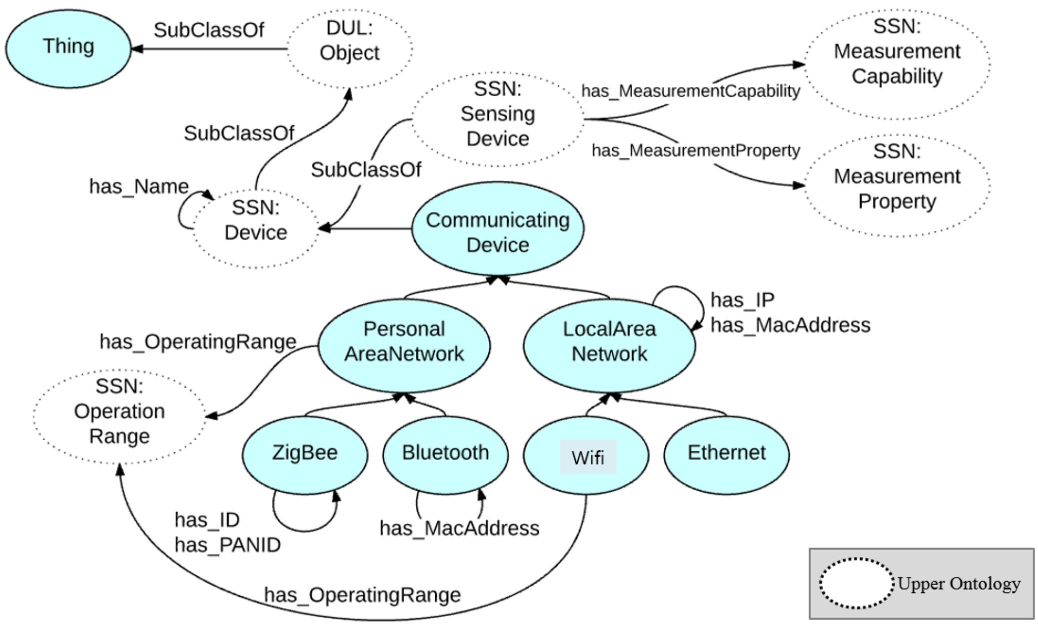

FIGURE 4. Device class

professional device in order to install sensor and acquire data. Nowadays with the introduction of micro computer such as MCU based Arduino in the smart factory environment, it is possible to get various sensors with low prices. The sensors adopted in this paper are Zigbee and Bluetooth for a personal area network and Wifi and Ethernet for a local area network. Upper ontologies inherited from SSN such as 'measurement capability', 'measurement property' and 'operation range' are used in device class. Upper ontology, 'object' inherited from DUL is utilized also.

4. **Implementation.** A new rule can be generated from individual and class property using SWRL (Semantic Web Rule Language). SWRL is a proposed language for the Semantic Web used to express rules and logic. It utilizes Rule Markup Language. The Operation class has a 'has_Interest' which should be performed in each stage in the SWRL reasoning process. It has the precision accuracy via the 'has_Accuracy' property. The Sensor class has a 'has_Measurementcapability' property, which represents the usage of sensors. In addition, the Sensor class has a 'has_Accuracy' property, which represents the accuracy of sensor data. Based on this idea, the sensor reasoning process of searching for an available sensor is shown in Figure 5.

Operation(?a) ^ has_Interest(?a, ?b) ^ has_Accuracy(?a, ?c) ^ has_Precision(?a, ?d) ^ SensorDevice(?e) ^ has_MeasurementCapability(?e, ?f) ^ has_Accuracy(?e, ?g) ^ has_Precision(?e, ?h) ^ sameAs(?b, ?f) ^ swrlb:lessThanOrEqual(?g, ?c) ^ swrlb:lessThanOrEqual(?h, ?d) → has_available_sensor(?a, ?e)

Figure 5. SWRL reasoning rule

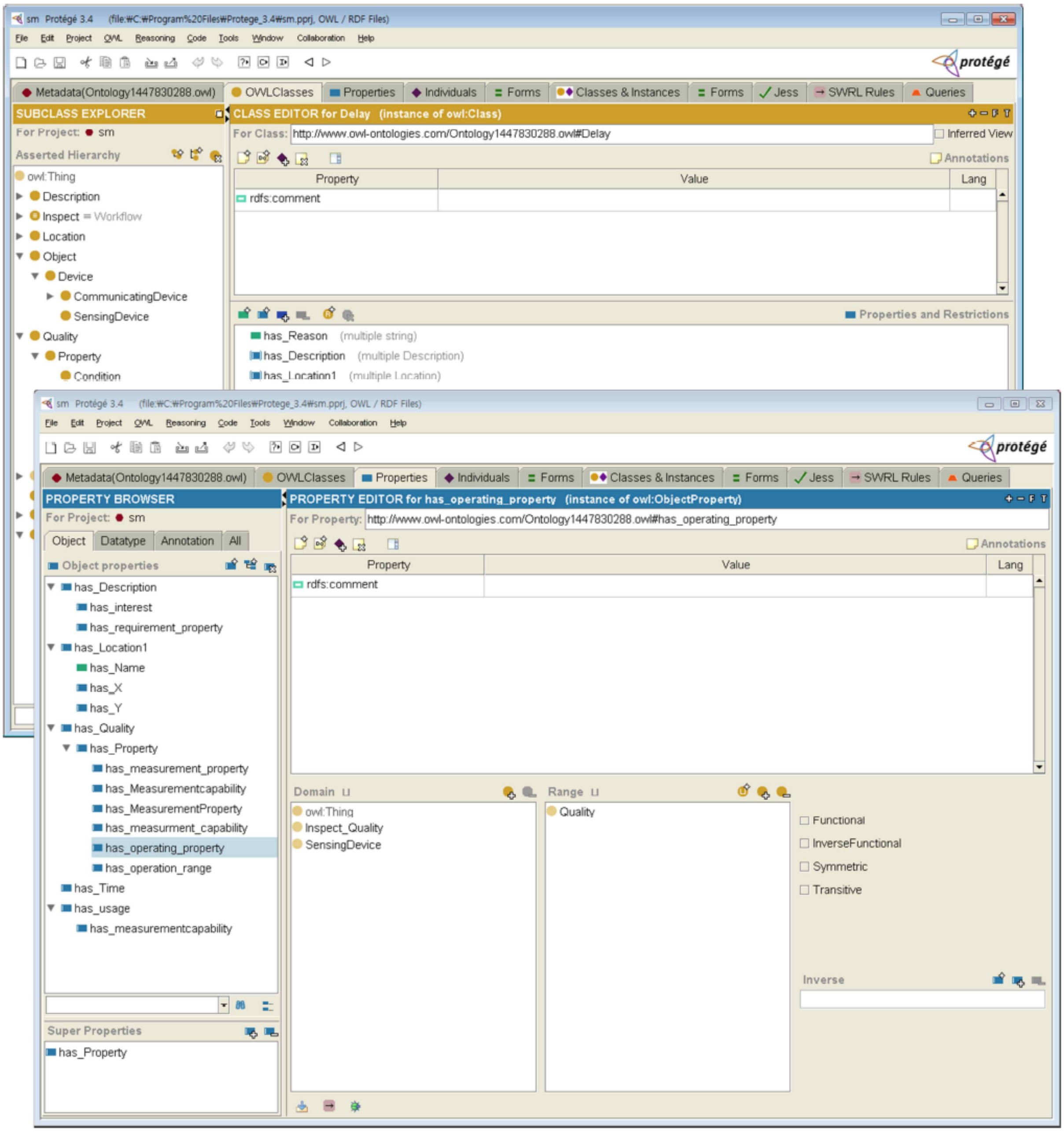

Figure 6. Implementation result in the Protégé 3.4

The proposed ontology model is implemented on the Protégé 3.4 platform. The ontology model including all the classes defined in Section 3 is shown in Figure 6. All classes, their properties and individuals which represent specific cases are given. As an example, Workflow class has a property of 'has_Description'. Object class has a subclass Device. It consists of CommuncationDevice class and SensingDevice. SensingDevice has properties of 'has_Measurementcapability', 'has_MasurementProperty' and 'has_Quality'.

5. **Conclusion.** Ontology will play a major role for the realization of smart factory in the IoT environment. This paper proposed an ontology model with semantic characteristics integrating various sensor data. The model is realized in the Protégé 3.4 platform. The ontology has the advantage of reuse and categorization of entities.

Future work includes further elaboration of ontology, modularization and adaptability to an actual smart factory environment. Searching and providing a service for manufacturing requirement is also a big challenge.

Acknowledgement. This research was supported by Kyungsung University Research Grants in 2016.

REFERENCES

[1] H. Lee and T. Kim, Prototype of IoT enabled smart factory, *Proc. of the 10th International Conference on Innovative Computing, Information and Control*, Dalian, China, 2015.
[2] ITU-T, *Internet of Things Global Standards Initiative*, http://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx, 2014.
[3] K. Kotis and A. Katasonov, Semantic interoperability on the web of things: The smart gateway framework, *Proc. of the 6th International Conference on Complex, Intelligent, and Software Intensive Systems*, Palermo, 2012.
[4] M. Loskyll, I. Heck, J. Schlick and M. Schwarz, Context-based orchestration for control of resource-efficient manufacturing processes, *Future Internet*, vol.4, pp.737-761, 2012.
[5] M. Ryu, J. Kim and J. Yun, Integrated semantics service platform for the Internet of things: A case study of a smart office, *Sensors*, vol.15, pp.2137-2160, 2015.
[6] *DOLCE*, http://www.loa.istc.cnr.it/old/DOLCE.html, 2015.