

## Research on the ontology-based collaborative description model of IoT resources

Jiaqi Dong<sup>1, a</sup>, Zhiping Zhou<sup>2, b</sup>

<sup>1</sup> School of Management, Hefei University of Technology, Hefei, 230009, China

<sup>2</sup> School of Management, Hefei University of Technology, Hefei, 230009, China

<sup>a</sup> Email: dongjiaqi1991@126.com, <sup>b</sup> Email: zzpcnm@126.com

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**Abstract.** Researches of collaboration of the internet of things (IoT) resources so far have been limited to a certain aspect. This paper describes the features of similar IoT resources and relationships of different IoT resources to reflect synchronous and sequential relations of the collaborative system. An ontology construction method is first proposed according to the features of IoT resources, the domain ontology method and the seven-step ontology method. Based on our proposed ontology construction method, we establish a collaboration model to describe the IoT resource ontology. Then the model is tested by *Protege* software. A case study of intelligent inventory management system is finally conducted. We share the knowledge of the general collaboration of IoT resources to improve its general collaboration level by establishing the ontology-based collaborative description model of IoT resources.

### Introduction

The internet of things (IoT) has recently received increasing attention from both scholars and practitioners. The rapid development of the IoT technology has brought people great convenience, together with challenges. These mainly include resource addressing, resource accessing, resource management and resource collaboration [1]. The previous three areas have been well studied. Kong et al. [2] proposed a universal model of IoT resources addressing to solve the addressing conflict problem by analyzing features of IoT resources addressing and extending the layered iteration model of internet resource addressing. Zhang et al. [3] applied *Zigbee* to IoT resources addressing system, which contributes to saving the resources addressing time tremendously. A frame of IoT resource accessing, which can update and add internal components dynamically, was proposed based on *OSGi* to achieve the configuration, unified access and management of IoT resources. It can also change the configuration of resources accessing according to the underlying environment [4]. Zuo [5] constructed a resource management platform which can achieve resource access, adaptation and data analysis. Tomas [6] pointed that IoT resources can be managed using clustering, software agents and synchronous technologies. Research of IoT resource collaboration, however, was limited to the IoT information collaboration [7], while lacks the study of general collaboration of IoT resources.

In this paper, we study the general collaboration of IoT resources and propose a collaborative model of IoT resources based on ontology. A resource collaboration system should ensure the sequential and synchronous relations of collaborative tasks, or in other words, a collaborative system of resources should ensure the sequential and synchronous relations of system resources [8]. Synchronous relations are embodied in common properties of similar IoT resources. Meanwhile sequential relations are embodied in relationships of different IoT resources.

Act as the core of semantic web technologies, ontology can describe relations of various resources [9]. Gomez et al. [10] mainly described the class hierarchy, related concepts and relations of IoT front-end equipment based on ontology. A collaborative model of virtual manufacturing resources was established by Tao et al. [11] using the expandable markup language and Web ontology language. The core concept of ontology is knowledge sharing, aiming at providing a

unified framework and a specification model for an organization or a working group. Moreover, it makes it possible that people with different backgrounds and viewpoints can understand, communicate with each other and keep the consistency of semantic [12]. We establish a collaborative model of IoT resources description based on an improved ontology method and test it by *Protege* software. A case study of intelligent inventory management system is finally conducted, thus achieving the knowledge sharing of IoT resource collaboration.

### Ontology construction method

Researches on ontology have progressively focused on practical application so far. Methods of ontology construction and implementation processes vary with the differences of the research fields. However, there is no special standard set for ontology construction yet at home or abroad [13]. Among them are some more prominent methods covering the enterprise modeling method, skeleton method, life-cycle method and seven-step method. Procedure of the seven-step method includes links that are: determine a professional field of ontology, examine the reusability of ontology, list important terms of ontology, define ranking hierarchies of classes, define properties of classes, define categories of properties and build an instance [14]. In addition, Li and Zhang [15] proposed an industrialized domain ontology construction method which includes the following procedures: determine the domain and scope of ontology, collect and analyze the domain information, determine the main concepts and relations, build an ontology framework, formalize the code evaluate and evolve.

Features of IoT resources should be grasped to build an ontology construction method. These features are embodied in the similar features of same-kind resources and restrictive relations of different-kind resources. Thus, we describe the concepts and relations of IoT resources learning from the seven-step method. Moreover, we adopt the formalized code in the domain ontology method since knowledge can only be expressed by computer after it is defined accurately. For building ontology, it is necessary to take an example. Then we adopt the seven-step method in our model. Instance construction procedure of seven-step method is also referred to verify our proposed ontology construction model of IoT resources. This means that our improved ontology construction method is based on both domain ontology method and seven-step method. As shown in figure 1, its specific procedures include demand analysis, resource description, code formalization, model evaluation and instance construction. Unlike the seven-step method, we mainly describe the hierarchies and concept relations of IoT resources. Formal code is achieved by *Protege* software. Evaluation stage is processed according to five principles [16]. Finally, we create an instance.

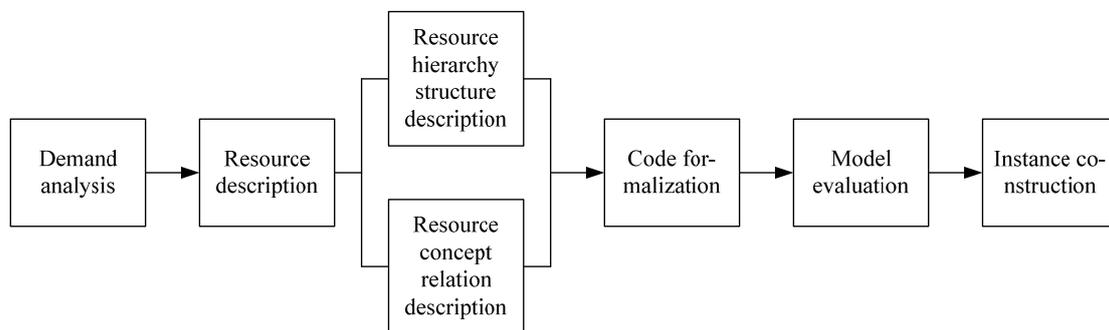


Fig.1 The improved ontology construction method

### Ontology-based collaborative description model of IoT resources

**Resource description and code formalization.** This paper analyzes the hierarchy of IoT resources mainly using the top-down approach with the IoT resources serving as the ancestor class. In our classification, the first level mainly includes basic resources, perceptual resources, transmission resources, middleware resources and cloud platform resources according to the IoT structure. Considering the composition of the first level resources, it is then subdivided into more

detailed second level resources. Basic resources include labelled resources and unlabelled resources. The scanner, RFID, GPS and sensor make up perceptual resources. Transmission resources include wire transmission and wireless transmission resources. Middleware resources are composed of the reading and writing device management module, event processing management module and integrated interface management module [17]. Processing layer, storage layer and display layer, make up cloud platform. What we mainly concern is the features of similar resources and relations of different resources. Although the resources involved in each specific IoT system differ with each other, they have the same resource features. Thus, we only need to consider the two-level structured IoT resources as introduced in figure 2.

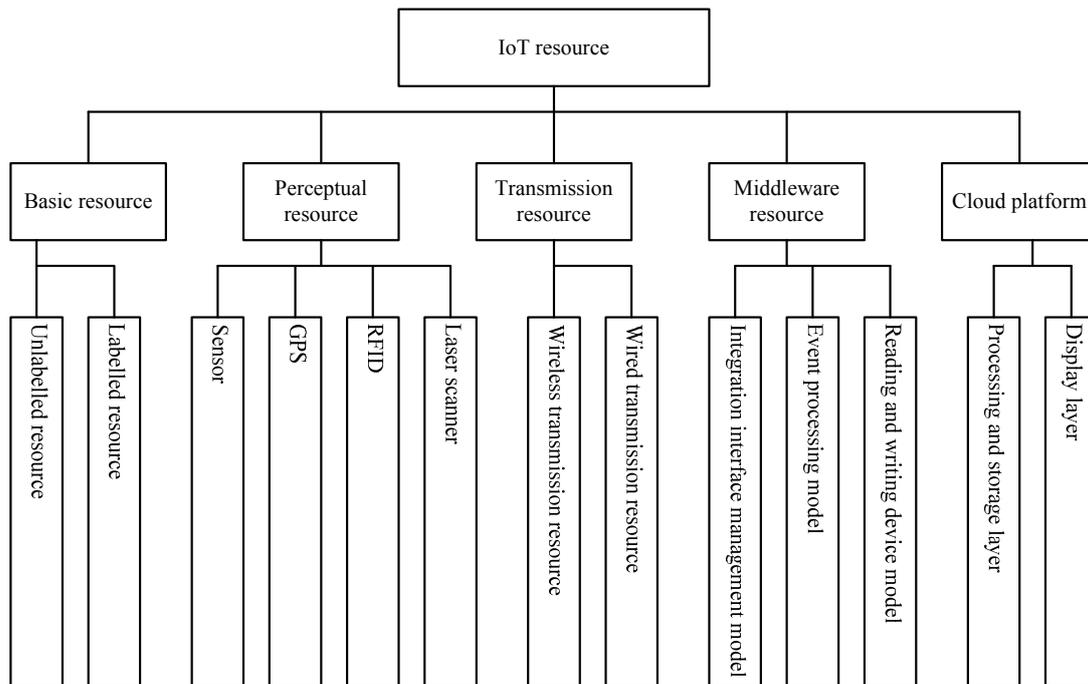


Fig.2 The hierarchy structure of IoT resources

In figure 2, the common features of resources in the second level are respectively refined as information carrying, perception, transmission, processing and displaying. Resources of common features can work in parallel. In the inventory management system, for example, the inventory checking system collects information using RFID and transfers it to the database of the inventory management system. Meanwhile, the inventory environment detection system perceives information through sensors and also transfers it to the same database. RFID and sensor are resources of common features and can work in parallel in the inventory management system. Relations of different resources mainly include acquire, channel, handle, use, transmission, storage and display. Information carrying is the main feature of basic resources. IoT can track and manage the information of basic resources. Information of basic resources can be perceived and acquired by various perceptual resources. Transmission resources have the feature of information transmitting and transfer information of basic resources to middleware resources. Middleware resources have the function of information processing. The general resource collaborating process reflect sequential and restrictive relations of resources and can be described as follows: the perceptual resources transfer information to the read & write device module through twisted pair cable; the event processing module will process these data; then the data is transferred to processing and storage layer by the integrated interface module and finally shown in the display layer. We get the IoT resource collaborative description model as shown in figure 3 when testing these concepts and relations using *Protege* software. In the figure, relations of hierarchy, display, transmission, acquire, storage, usage of classes are represented as purple solid line, purple dotted line, yellow dotted line, brown dotted line, green dotted line and gray dotted line respectively.

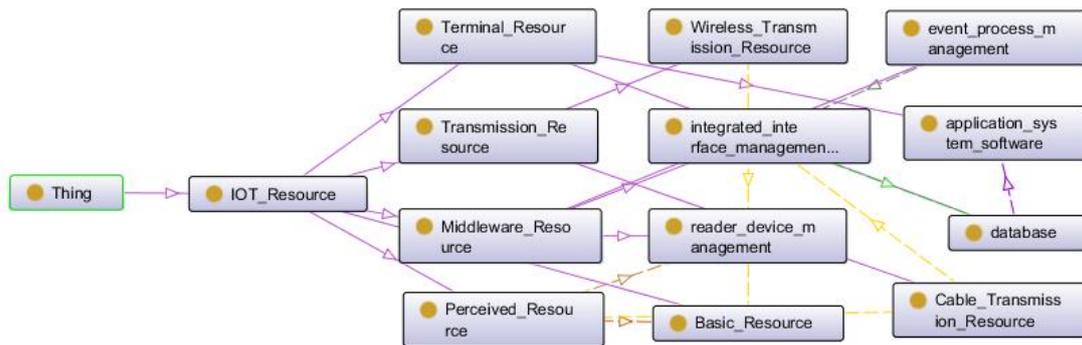


Fig.3 The ontology-based collaborative description model of IoT resources

**Evaluation of the ontology-based collaborative description model.** Since ontology construction is a behavior of subjective awareness, it is inevitable to generate errors. We adopt five principles suggested by Gruber [16] to evaluate our ontology-based collaborative description model of IoT resources. These five principles include clarity, integrity, consistency, extendibility and least constraints. Clarity and integrity means to express semantic implications clearly and completely. Our ontology model confirms with the clarity and integrity since we describe resources by defining concepts properties and concepts relations. Extendibility requires that when common or specialized terms are added to an ontology model, one don't need to modify the original contents. When we construct an instance of our ontology model, relations of resources of the instance are not modified as shown in figure 4. So our ontology model satisfies the extendibility. Principle of least constrains means to list constraint conditions as few as possible. Only the information transitive relations among resources are constrained in our model. Thus, it satisfies the least-constrain principle. Moreover, considering that resource relations in both inventory model and ontology model are consistent, our ontology model confirms with the five principles above to achieve the evaluation of our model.

**Instance construction.** This paper takes the example of intelligent inventory management system for case study. Functions of intelligent inventory management system mainly include warehouse entry, delivery of cargo from storage, inventory checking and inventory environment monitoring. When there is entry of warehouse, cargo information is acquired by RFID through radio waves. Then RFID transfers information to the read & write device module through the twisted pair cable. After processed by event processing module, information is transferred to the backend Oracle database by integrated interface management module. Finally, Oracle updates information and inventory management system displays them. When there is delivery of cargo from storage, information is maintained in the database in the same way. Inventory checking acquires information of cargoes by RFID and returns it to the backend database to compares them with the current inventory. The system software displays the result at last.

In addition to cargo management, it is necessary to conduct environment monitoring of the inventory to assure the quality of cargoes. Temperature and humidity sensors acquire information of by radio waves and transfer it to the read & write device module through the twisted pair cable. After processed in the event processing module, the information is transmitted to the backend database and finally displayed in the system. The whole instance description model is showed in figure 4.

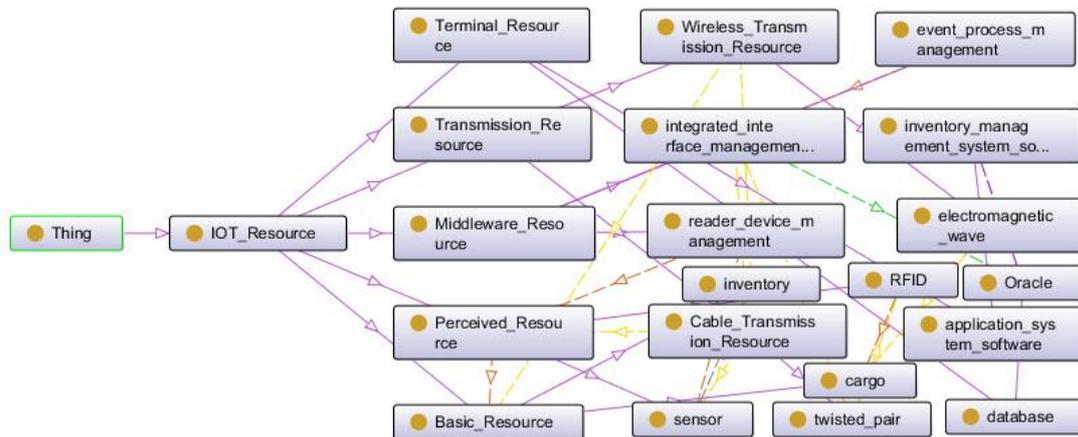


Fig.4 The ontology-based collaborative description model of the intelligent inventory system

## Summary

This paper studies the general collaboration of IoT resources which has not been deeply studied. An ontology-based collaborative description model of IoT resources is established based on the improved ontology construction method by analyzing features of IoT resources and referring to domain ontology method and seven-step ontology method. In the construction process, the general hierarchy structure of IoT resources is first established. Meanwhile features of similar resources and relations of different resources are described to achieve synchronous and sequential relations. We test the model using *Protege* software afterwards. Relations of resources are represented by lines of different types in the result figures to find that resource relations in our constructed instance are the same as that of our constructed ontology model. Finally, we create an instance of the intelligent inventory management. We share the general collaborative knowledge of IoT resources to promote the general collaboration of IoT resources by describing the collaborative model of IoT resources based on the improved ontology method.

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