Knowledge modeling of coal mining equipments based on ontology

Baolong Zhang, Xiangqian Wang*, Huizong Li and Miaomiao Jiang

School of Economics and Management, Anhui University of Science and Technology, Huainan , 232001, China

*Corresponding author: xqwaust@163.com

Abstract. The problems of information redundancy and sharing are universe in coal mining equipment management. In order to improve the using efficiency of knowledge of coal mining equipments, this paper proposed a new method of knowledge modeling based on ontology. On the basis of analyzing the structures and internal relations of coal mining equipment knowledge, taking OWL as ontology construct language, the ontology model of coal mining equipment knowledge is built with the help of Protégé 4.3 software tools. The knowledge description method will lay the foundation for the high effective knowledge management and sharing, which is very significant for improving the production management level of coal mining enterprises.

1 Introduction

Productive characteristics of coal mine industry determines that it must use a large number of devices, while complex geological features, labor quality condition and enterprise culture differences will put forward different requirements of mine equipment performance and function.

As energy heavy industry, coal mine enterprises always use a large number of equipments and devices to reduce labor intensity and keep safe. And with complex geological features, different labor quality conditions and enterprise culture differences, these equipments and device require different parameters and performances, which bring out big challenges for management and design of coal mining equipments and devices. What's more, these equipments and devices involve mathematics, mechanics, electricity and other relevant disciplines knowledge, as well as the existing problems of incomplete and unified descriptions.

How to find knowledge and information related to design and management of mining equipments and devices quickly and accurately? An effective knowledge description model is necessary.

Ontology is originally concerned with analyzing various types or modes of existence, often with special attention to the relations between particulars and universals, between intrinsic and extrinsic properties, and between essence and existence[1]. Since the mid-1970s, ontology has been applied in computer and information science. As a good carrier of knowledge, ontology not only has a good concept hierarchy and effective support for logical reasoning, but also can describe information from the angle of semantic and knowledge level in detail, which provides a new way to realize the retrieval, sharing and reusing of information model effectively [2].Base on this, This paper proposed a new way to describe knowledge and information of mining equipments and devices based on ontology, and built a information and knowledge model to solve the problems of sharing and retrieval of product information and shorten the development cycle and management cost of mining equipments and devices.

2 Overview of ontology

Ontology arises out of the branch of philosophy known as metaphysics, which deals with the nature of reality – of what exists (from Wikipedia). Subsequently, the ontology concept is applied in the computer fields and information science to facilitate knowledge management more easily and effectively. Gruber defined ontology as clear specification of the conceptual model[3]. Scholar Borst amended the definition made by Gruber, and defined that ontology is the formalized specification of shared conceptual domain model[4].On the basis of definitions made by Gruber and Borst, scholars Studer proposed that ontology is the formalized and clear specification of shared conceptual model[5].

As a kind of conceptual modeling tool to describe system information on the semantic and knowledge level, ontology can be applied to express knowledge of mining equipments and devices uniformly and clearly. That way, the heterogeneous data can be integrated and interacted based on semantic information[6], and it is easy to realize the sharing and reuse of domain knowledge.

Ontology can be defined with a triple :

$$KO =< KA，\ Re，\ Rule, In >$$

Where KO, is the abbreviation of knowledge ontology;

KA, is the abbreviation of knowledge atom, which represents the minimum unit of knowledge model. It can be a class, axiom and the basic operating relationship, namely:

$$KA = \left\{ b_i \middle| 1 \le i \le n, b_i \in Q \right\}$$

Here b_i says knowledge atoms in the knowledge fields Q, Re is the abbreviation of relation, which says the set of relations of interaction between atoms, knowledge entities composed of knowledge atoms, namely:

$$\mathrm{Re} = \left\{ R_{ij}(b_i, b_j) \vee R_{kl}(m_k, m_l) \middle| 1 \le i, j, k, l \le n \right\}$$

Where m represents knowledge entities comprised of knowledge atoms, namely:

$$m = \left\{ \sum b_i b_j \vee \prod b_i b_j \middle| 1 \le i, j \le n; b_i, b_j \in Q \right\}$$

Rij (bi, bj) represents the relations between knowledge atoms bi and bj ; Rkl (mk, ml) represents the relationship between knowledge entities mk and ml

Where In is the abbreviation of instance, which represents the specific entity of the concept.

3 Mining equipments and devices ontology construction

According to the principle of ontology construction, namely clarity, consistency, extensibility, minimum coding preference and minimum commitment of ontology[7], this paper turned to construct mining equipments and devices ontology. The steps to build domain ontology mainly were as follows:

Step 1: determining the scope and targets of knowledge ontology. Based on the research area or task, taking mining equipments and devices as the study object, this paper aims to solve the problems of information sharing, knowledge reuse and extension of ontology, and realize the informatization and intelligent management and design of mining equipments and devices for coal enterprises.

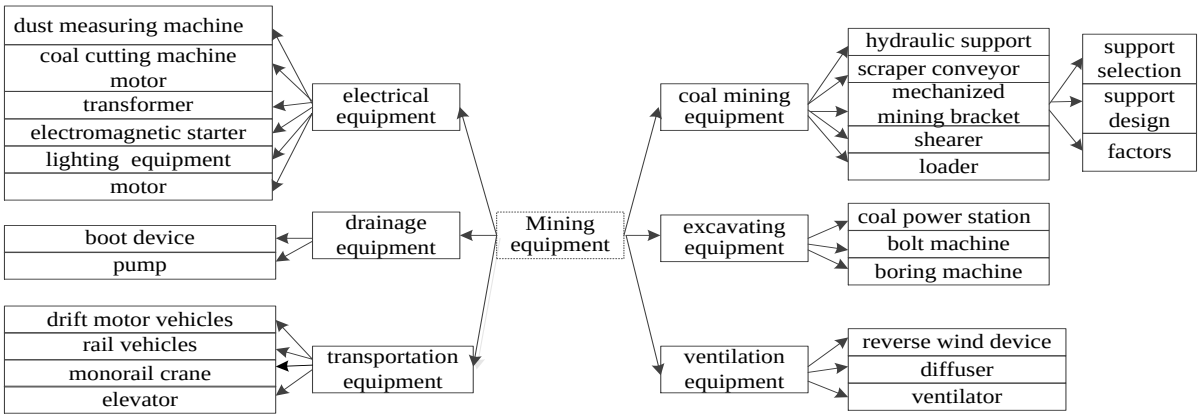

Figure 1. Parts of class of mining equipment ontology

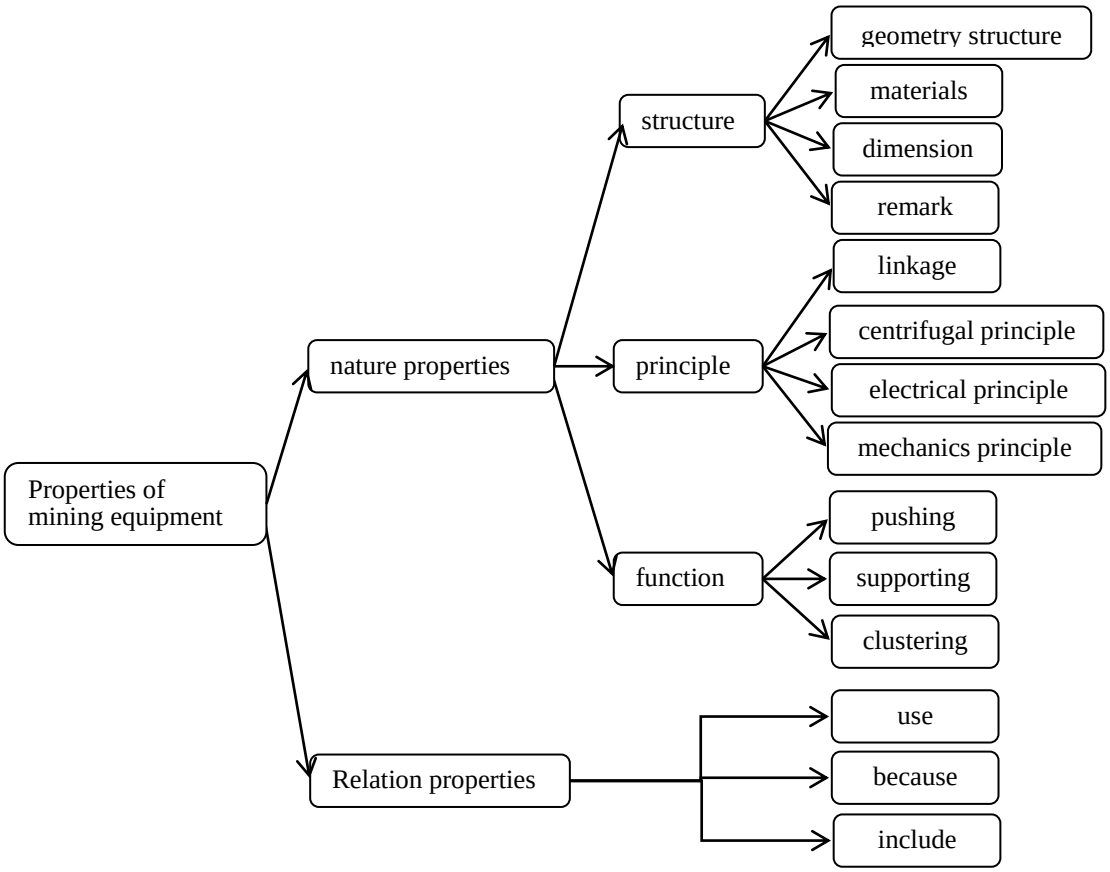

Figure 2. Parts of properties of mining equipment ontology

Step 2: ontology analysis. The task at stage of ontology analysis mainly includes listing of important terms, defining class and class rank, as well as extracting the attributes of a class. In this paper, the main terms are as follows: level 1 term ,namely mining equipments and devices; level 2 terms, including coal mining equipment, excavating equipment, electrical equipment transportation equipment, ventilation equipment, drainage equipment and other equipments and devices; Level 3 terms, including the mechanized mining bracket, loader, hydraulic support, shearer, scraper conveyor, boring machine, bolt machine, coal-fired power station, electric motors, transformers, mine cutting machine motor, electric locomotive electromagnetic starter, belt conveyor, drift motor vehicles, rail vehicles, monorail crane, elevator, gear car, capsule conveyor, ventilator, diffuser, reverse wind device, pump, meter, start-up equipment, piping and piping fittings, lighting equipment, crusher, dust measuring machine. The properties includes structure (including material, size, geometry, tolerance, and mark), principle (including connecting rod mechanism, hydraulic controlled check valve, control valve, hydraulic cylinder, etc.), function (pushing, supporting, preventing slippery, crushing, lighting, mining, etc.). Parts of classes of mining equipments and devices ontology are shown in figure 1.

The properties of mining equipments and devices ontology include natural properties and relationship properties. Parts of properties are displayed in figure 2.

Step 3: ontology construction. This article selects the OWL (Ontology Web Language) as ontology description language, which can describe fundamentally ontology by the way of defining class, subclass, properties, etc. by adding primitives such as rdfs: Class, rdfs: subClassOf, rdfs: subPropertyOf [8]. In addition, OWL can realize ontology reasoning well, and has been one of the international general ontology languages. Then we choose protégé 4.3 as tool software for ontology construction of mining equipments and devices, which is the most powerful and widest used tool[9].

Here the ontology construction only covers a part of the knowledge information of mining equipments and devices. With the increasingly rich information, the ontology construction will

involves more and more knowledge and become more and more capable of sharing knowledge and retrieving information. And protégé 4.3 can add ontology manually, which make the ontology construction more adaptable[10]. The class diagram of ontology construction of mining equipments and devices is shown as figure 3.

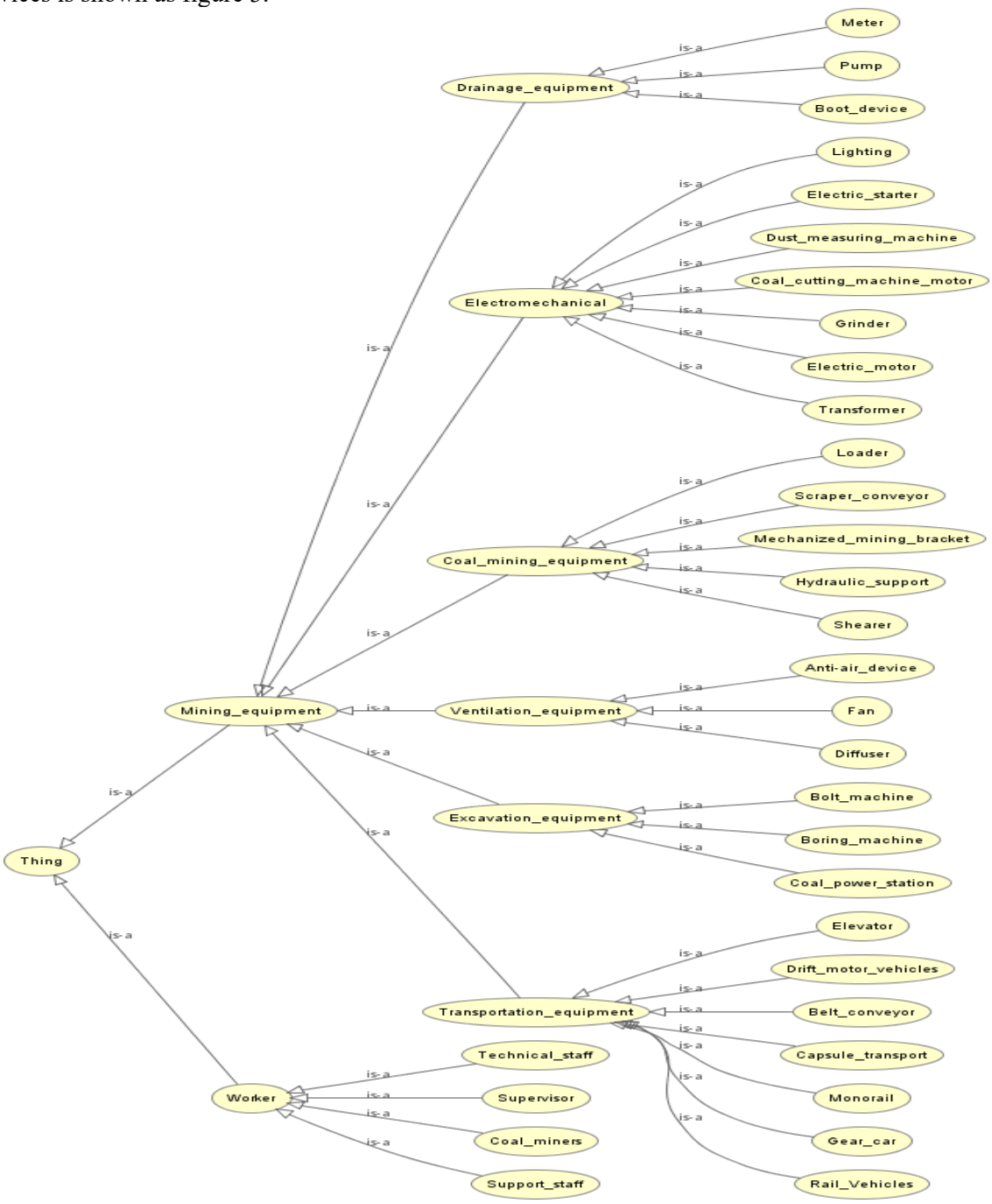

Figure 3. Parts of class diagram of ontology construction of mining equipments and devices

Parts of OWL code generated are as follows:

```
<rdf:RDF
<owl:Class rdf:ID="Mining equipment"/>
</rdfs:subClassOf>
</owl:Class>
```

<rdfs:subClassOf>
<owl:Class rdf:ID="Coal mining equipment"/>
</rdfs:subClassOf>
</owl:Class>
<owl:ObjectProperty rdf:about="#use">
<owl:inverseOf rdf:resource="#beused"/>
<rdfs:domain rdf:resource="#worker"/>
</owl:ObjectProperty>
……
</rdf:Description>
</rdf:RDF>

Step 4: ontology instantiation. When the ontology of mining equipments and devices has been built, the next important step is instantiation of these ontologies. This paper took ontology of hydraulic drill rig of coal mine as example to construct instance from structure layer, principle layer and functional layer [11,14]. We adopted 3D Studio Max software to model the geometric structure of hydraulic drilling rig and carried out instantiation by mapping relation. Specific instances were shown in figure 4.

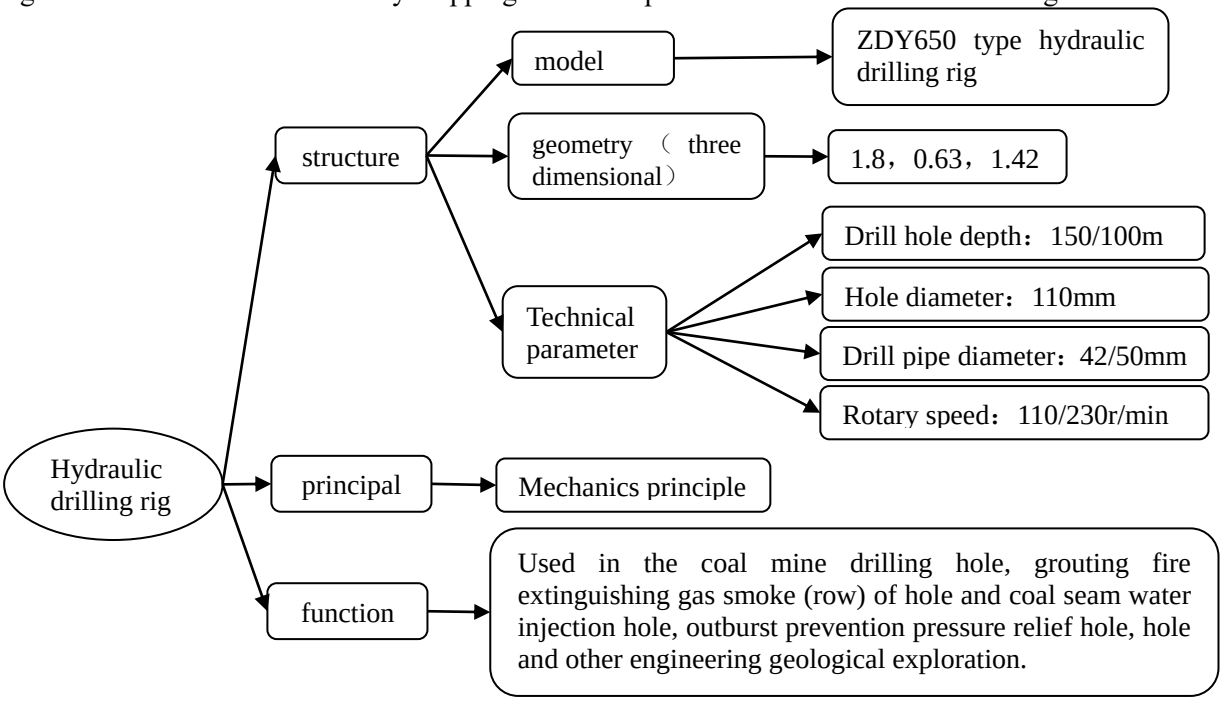

Figure 4. Instances of ontology of mining equipments and devices

4 Conclusions

In the paper, we applied ontology theory to knowledge description and information presentation of mineral industry, and constructed ontology of mining equipments and devices. The practice shows that OWL is an effective ontology modeling language with good extensibility and capability, especially when work with protege 4.3 tool software. These ontologies are very easy to extend, improve and reuse. The users can increasingly rich information of mining equipments and devices by adding related concept, attributes and relationship as needed. The attempt not only gives a new way to management of knowledge of mining equipments and devices but also offers an example for ontology construction in other industries.

Acknowledgments

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