IFC-Based Construction Engineering Domain Otology Development

Jin Si , Yanzhong Wang

Abstract—The essence of the 21st century is knowledge economy. Knowledge has become the key resource of economic growth and social development. Construction industry is no exception. Because of the characteristic of complexity, project manager can't depend only on information management. The only way to improve the level of construction project management is to set up a kind of effective knowledge accumulation mechanism. This paper first introduced the IFC standard and the concept of ontology. Then put forward the construction method of the architectural engineering domain ontology based on IFC. And finally build up the concepts, properties and the relationship between the concepts of the ontology. The deficiency of this paper is also pointed out.

Keywords—Construction Engineering; IFC; Ontology

I. INTRODUCTION

THE life cycle of construction project is very long. It is a complex and integrated operation, involving many participants and areas of expertise. However each person's knowledge is limited and not proficient in all areas of construction engineering. Thus, knowledge sharing and reuse is very important in the construction field. Knowledge sharing is based on information sharing, but because of the differences in data formats and data structures of different construction software, it is necessary to establish the interface between the software in order to achieve the exchange of information between different software. To change this haphazard information exchange status in construction industry, International Mutual Collaboration IAI (International Alliance for Interoperability) developed IFC (Industry Foundation Class) standards for construction information representation and exchange in early 1997. IFC standard provides a common data model and standard expression for the civil construction industry and the goal is to achieve effective building information exchange among different professions and different software [1] [2]. On the ISO international conference held in Seoul, Korea in November 2002, IFC has been formally accepted as the ISO / PAS international standard [2].

Although IFC provides a uniform data exchange standard for the construction field, but it did not achieve effective knowledge sharing and reuse. While ontology just can make up for this defect. Ontology is originally a philosophical concept. It is an objective explanation of a system, concerned with the abstract nature of objective reality. Later on, Neches and others introduced the concept into artificial intelligence field.

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Although the application of ontology in the field of construction seldom, ontology began to gradually attract attention of scholars with the rise of BIM in recent years. Nora M. and Tamer E. built construction process ontology and it was evaluated through technical evaluation and user evaluation [3]. Then they made a ontology integrator in the AEC field, which can achieve the integration of concepts, relations and axioms, so as to promote the interoperability between ontologies [4]. L. Zhang and R.R.A. Issa proposed an ontology and semantic web services framework based on IFC for the construction industry to improve the interaction problems between the application software [5]. They also constructed an ontology with OWL language based on IFC which helped to information retrieval in IFC models [6]. IFC provides a unified standard for construction engineering data exchange, but the application of IFC is mostly stay in the level of data exchange, not from the perspective of knowledge reuse. On the other hand, ontology can make knowledge reuse possible while different areas and users will lead to different ontologies. There is no fixed standard to follow which resulted in ontology heterogeneity. Therefore this article attempts to combine ontology with IFC standards to build a common ontology in construction field. This ontology can not only achieve knowledge reuse in construction engineering but also avoid information exchange problem caused by ontology heterogeneity.

II. IFC-BASED CONSTRUCTION ENGINEERING DOMAIN OTOLOGY FRAMEWORK

A. Ontology construction method

Although there are many studies of ontology building methods, currently there's not a standard ontology construction method because ontologies are mostly for specific areas. Now a comparison between relatively mature ontology construction methods is given as follows.

TABLE I
PROCESS COMPARISON OF ONTOLOGY CONSTRUCTION METHODS

Name	Plan	Reuse	Analysis	Evaluation and optimization
TOVE	√		√	√
METHONTOLOGY	√		√	√
SKELETAL METHODOLOGY	√		√	√
KACTUS	√		√	
SENSUS			√	
IDEF5	√		√	
7 STEP	√	√	√	

From Table I we can see that each method has its own characteristics and field of application [7]. Therefore, in the construction of the ontology we should choose suitable method according to the actual situation.

This article presents an iteration method to construct IFC-CE-Onto (IFC based construction engineering domain ontology). According to the hierarchical characteristics of construction industry concept, top-down method is used to establish the concept of class. First, needs analysis of construction ontology is made to determine the concept of ontology and the relationship between concepts in order to build domain ontology. Then an evolution is conducted to the already built ontology including ontology integration and ontology consistency checking to see if there is a conflict. Finally, an evaluation of performance and applicability of the IFC-CE-Onto is made. If satisfied, the ontology is set up; if not, then redefine the concept relationships and class (see Fig1).
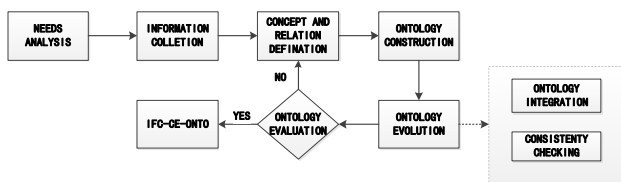

Fig. 1 IFC-CE-Onto construction method

B. IFC-based construction domain ontology framework

The framework of IFC-CE-Onto proposed in this article is divided into three layers, from top to bottom are the management layer, operation layer and meta-ontology layer (see Fig2).
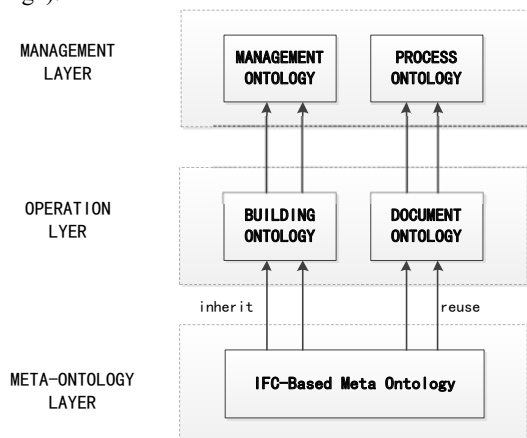

Fig. 2 IFC-based construction domain ontology framework

a) Management layer: including construction management level ontology. Based on the different perspectives of construction management, the management layer mainly contains two ontologies: management ontology and process ontology. Management ontology presents the necessary knowledge when carrying out project management. The process ontology presents all the processes involved in every stage of the project life cycle.

b) Operation layer: including the ontology involved during construction engineering information exchange and sharing. Building ontology is the main about the entity components of a building. Document ontology involves various types of documents during the whole construction life cycle.

c) Meta-ontology layer: the most basic ontology about construction information which is not targeted at specific industry but scattered ontology describing the whole IFC-CE-Onto framework.

III. DEVELOPMENT OF IFC-CE-ONTO

The construction of ontology includes five aspects: concepts, attributes, relations, axioms and instances. This study only builds the concepts, attributes and relationships of IFC-CE-Onto.

1. Define concepts and establish their hierarchy

a) Management layer ontology construction

PMBOK (Project Management Body of Knowledge) is a general description of the necessary knowledge, skills and tools of project management proposed by the U.S. Project Management Institute (PMI). Knowledge areas of project management are divided into nine categories in the PMBOK. Meanwhile from the process point of view, the PMBOK divides project management into 42 processes, which are classified into five process groups according to their logical relationship. As the description of project management in PMBOK is more standardized, the concept classification of process ontology and management ontology in this study is based on PMBOK (see Fig3).
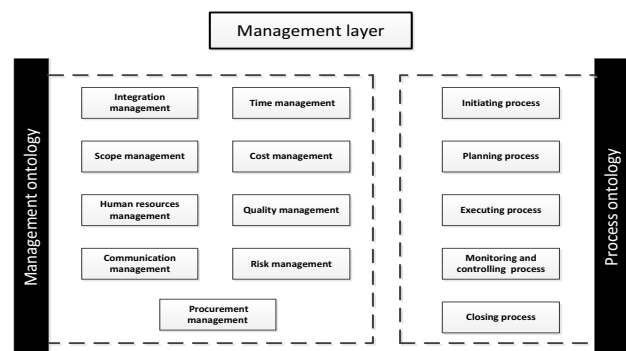
Fig. 3 Concept construction of management layer ontology

b) Operation layer ontology construction

In this study, concepts of building ontology in operational layer are classified based on the national standards "Uniform Standards of Building Construction Quality Acceptance". There are nine categories and each category contains several sub concepts. The document ontology contains all documents throughout the whole project life cycle (see Fig4).
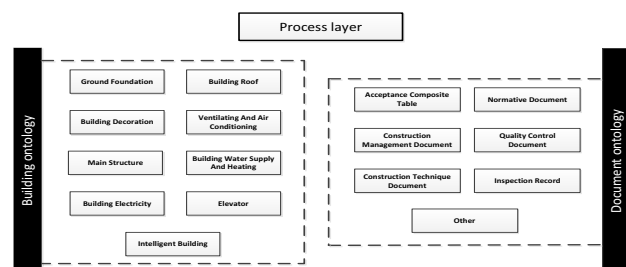
Fig. 4 Concept construction of process layer ontology

c) IFC-based meta ontology

The resource layer in IFC standard provides a unified description of the basic building information from the perspective of concept, attributes and relations. So in this study each module of the resource layer in IFC is used as the meta-ontology to serve the upper ontology. IFC standard is mainly used for building information modeling, so there is a lot of description on geometric expression which is not meaningful for the ontology construction. Therefore in this study only six modules are extracted from the IFC as the meta-ontology of the framework. The concepts of the meta-ontology can be further broken down according to description of each module in the resource layer of IFC (see Fig 5).

Fig. 5 IFC-based meta ontology (part)

2. Define attributes and establish their hierarchy

Attributes should be added to each concept after concepts and conceptual level established. According to the property description of entities in IFC standard, property can be divided into the following two categories:

a) Measurable attributes: describe measurable information of the concept, such as length, width, height, area, volume, perimeter, volume, weight, angle, etc.

b) Affiliated attributes: describe immeasurable information of the concept, such as name, address, materials, time, participants, etc. Each property of the affiliated properties can be break down in order to build an attribute hierarchy.

3. Define relationships between concepts

The relationships between the entities have been classified into five categories in the core layer of IFC standard: distribution, association, decomposition, definition and connection. According to the description of the relationships in IFC, the relationship between concepts in IFC-CE-Onto will be divided into two categories:

a) General relationship: there are four general relationship Part-of relationship, Kind-of relationship, Equivalent-to relations and Attribute of relationships. These four relationships have been identified during the construction of the concept.

b) Special relationship based on IFC: special relationship between concepts is established based on the specific needs of the construction engineering. In this study the special relationship is constructed as follows:

① Assignment relationship: the specific association through which one object (the client) applies the services of other objects (the suppliers), or through which one object may navigate to other objects, including assigned to the process, assigned to the product, assigned to the control, assigned to the resources and assigned to the participant.

② Decomposition relationship: the decomposition relationship denotes a whole/part hierarchy with the ability to navigate from the whole (the composition) to the parts and vice versa, including aggregate relationship and nest relationship.

③ Association relationship: the association relationship refers to external sources of information (most notably a classification, library or document), including document association relationship, library association relationship and classification association relationship.

④ Connectivity relationship: a connectivity relationship that connects objects under some criteria.

The final IFC-CE-Onto is (part) as follows:

IV. CONCLUSION
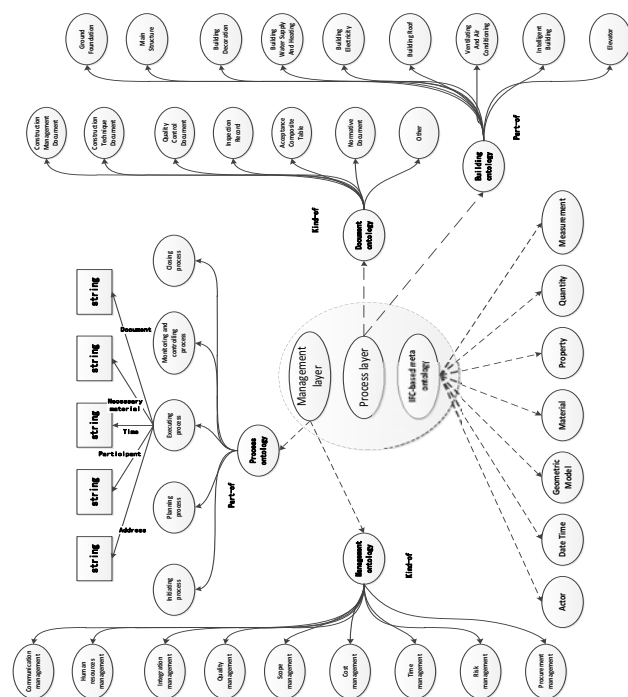
This paper firstly analyzes the structure and content of the construction data exchange standard IFC and discusses the application of ontology in the field of construction engineering. Then a three-layer framework is developed based on the characteristics of construction industry using a cyclic iterative method. Finally the entire IFC-CE-Onto is constructed after an in-depth analysis of, construction engineering domain.

The domain ontology constructed in this study is far from perfect. First, this study only defines the concept of the domain ontology, but the axioms are not given. Secondly, the ontology of this paper is divided into three layers.

The information exchange and knowledge sharing could not be achieved without the mapping mechanism which is not

concerned in this study. Finally, this paper builds the domain ontology only from the theoretical point of view so its performance and applicability remains to be tested. These are the questions to be studied in future research.

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