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BUILDING ONTOLOGY TO IMPLEMENT THE BIM(BUILDING INFORMATION MODELING) FOCUSED ON PRE-DESIGN STAGE

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ABSTRACT

Pre-planning stage is a most important stage to determine the success of the project throughout the construction lifecycle. Therefore, all information generated from the pre-planning stage must be processed and retained in the format which all the project participants can share. Furthermore, using object-oriented attributes and meta-data in BIM (Building Information Modeling) for easy control of the space objects are actively being studied. This paper investigates ontology and its description logic (OWLDL) and establishes it in the pre-planning stage of construction project and will also carry out a case study based on a real project in Korea. The special objects will be created and the relationship of these special objects will be defined. An ontology diagram will be suggested that will control the special objects with the constraints applied.

KEYWORDS

Ontology, OWL DL, BIM (Building Information Modeling), Space Object

1. INTRODUCTION

1.1. Background and purpose of this study

Recently, the ontology, which is a kind of IT (Information Technology), has begun affect to construction industry more and more. As the BIM (Building Information Modeling) has been applied to AEC industry, the necessity to control the space objects and manager the information resources has been on the rise in terms of the project life-cycle management. It is really sensitive work to control and manage the space object (building object), because each object has many properties, such as size, height, material, cost, and position etc. But these functions might be core competency of BIM. To control the space objects in the BIM, the ontology can be answer. Ontology is special language that can identify the properties of object and descript the logic. There have been conducted many researches about the application of ontology to the AEC industry internationally. But in case of South-Korea, there is no research conducted about an application of ontology to AEC industry. And also, it is only a short time since BIM research has been started.

This paper contributes to build the ontology so that space objects can be controlled by computing in BIM-based construction project.

1.2. Scope and methodology of this study

The limit of application of the BIM to project life-cycle covers whole the project life-cycle (from planning stage to maintenance stage), so that all the information resources which is derived from each stage can be managed and arranged by specific logic. This study is aimed at building ontology to control the building object on BIM-based tool (Revit Architecture, ArchiCAD, etc). Especially, the OWL DL (Ontology Web Language Description Logic) is essential topic that we deal with in this paper.

We built the model in OWL DL which is a natural choice for designing a knowledge representation language since it was developed explicitly for the task of knowledge representation [2]. Description logic can be seen as a set of logical statements that are translated without changing their semantic interpretation [3, 5].

This research is composed of three parts as following:

First of all, we describe the concept of BIM (Building Information Modeling), ontology and OWL DL. Then, it is required to develop the ontology of BIM (building information modeling) in OWL DL. Finally, this OWL DL is inserted into test-bed model (Gunpo Worker's Welfare Centre).

2. THEORETICAL STUDY

2.1. BIM (Building Information Modeling)

BIM has functions as a tool or platform clearly, but it seems so right that BIM is a super ordinate concept which includes these functions, because building, information, and modeling that are included in BIM have the concepts as following:

- Building – the whole life-cycle of the building.
- Information – all information derived from each stage.
- Modeling – the integrated tool or platform which produces and controls these information resources.

BIM offers essential advantages beside the advanced graphic environment. In the BIM platform, user can control and manage the information resources such as cost, schedule, materials, client's needs, technical requirements, etc, and it lets architects or engineers make a decision faster.

While construction project is progressed, each stakeholder who stays at different place can shares all information resources effectively using BIM-based management environment. This fact means BIM offers collaboration environment to all project participants (see Figure 1).

2.2. Ontology

The ontology used at IT' is not same at all with 'the ontology which is appropriated at philosophy. Ontology of IT is organized with specific terms that describe the reality. There are many definitions about ontology that is mentioned by researchers [4, 6, 7].

Kim, Grobler [1] defines the ontology as an explicit specification of a conceptualization. Guarino agreeing with Gruber and presents a refined distinction between the ontology and the conceptualization: the ontology is a logical theory accounting for the intended meaning of a formal vocabulary, i.e., its ontological commitment to a particular conceptualization of the world. The intended models of a logical language using such a vocabulary are constrained by its ontological commitment. This commitment and the underlying conceptualization are reflected in the ontology by the approximation of these intended models. Guarino advises against using ontology just as a fancy name denoting the result of activities like conceptual analysis and domain modeling.

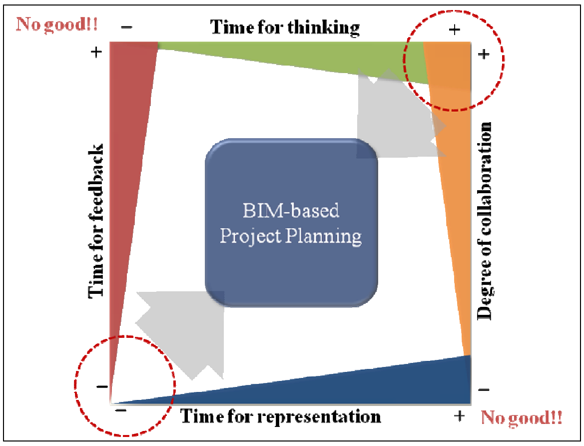

Figure 1. Effectiveness of BIM-based Planning

According to the definition of Nicola Guarino, he used the term ontology for knowledge bases. He presented a possible interpretation of the term "Ontology" as following (see Figure 2):

1. as a Philosophical discipline
2. as an informal conceptual system
3. as a formal semantic account
4. as a specification of a conceptualization
5. as a representation of a conceptual system via a logical theory
    5.1 characterized by specific formal properties
    5.2 characterized only by its specific purposes
6. as the vocabulary used by a logical theory
7. as a (meta-level) specification of a logical theory

Figure 2. Possible interpretations of the term "ontology" Quoted from "Ontologies and Knowledge Bases"

2.3. OWL Description Logic

OWL (Ontology Web Language) was developed by W3C to complement problems of RDF/RDF Schema. Today, OWL is by far the best language in the field of ability to express, reasoning. And this language is divided into three types (OWL Lite, OWL DL, and OWL Full).

OWL Lite is a language that describes the most simple classifications and constraints. This language contains a few portions in all OWL terms, and it makes RDF expand restrictively.

OWL DL (Description Logic) is organized by same terms with the terms of OWL Full. This language is suitable for some users who want to make full use of expression while maintaining the computational completeness and decidability. But this language is fenced in by some constraints. There exist many constraints about voluntary class expression:

Class or property has to be declared explicitly.

Transitive property can't to use the relation order.

URI that denotes the classes, properties, and objects can't be mixed with the others. – One resource is permitted to be expressed as only one type among class, property, and object.

Although OWL Full uses same vocabularies with OWL DL, OWL Full is more unrestricted as compared with OWL DL. OWL Full has no reasoning software, so this language is suitable to someone who want to make full use of RDF (because its grammar is supple to apply)

A Table, below, shows a method to represent the building component in OWL DL (H, Kim, "Building Ontology to Support Reasoning In Early Design" [8]), and we followed this way (see Figure 3).

3. ONTOLOGY OF BIM IN OWL

3.1. Relation of Building Components

To present a property and relation of each object or class (Wall, Floor, and Roof), we illustrated the class hierarchy diagram of building components. (Lee, Yun-Gil, "Data Modeling for Smart Apartment Facility Management Based on Well Defined Spatial Information") (see Figure 4).

Logical semantics	Description	Example statement
$\neg C$	General concept negation	“not a building component”
$\leq\ R.C,\ \geq\ R.C$	Qualified number restrictions	“bigger in size for a certain relationship of a class C”
$R\ \ = \langle y,x \rangle \mid \langle x,y \rangle \in R$	Inverse roles	“Contains is the inverse of IsInsideOf.”
$(\langle x,y \rangle \in R)\ \wedge\ (\langle y,z \rangle \in R)$ $\Rightarrow (\langle x,z \rangle \in R)$	Transitive Roles	“Product is the descendant of object and element is the descendant of product. So element is the descendant of object.”

Figure 3. Representing Building Components in OWL DL

Class and its Property can be represented by using OWL. There are some examples that describe the class and its relations of the building object, also each class or object has their own properties.

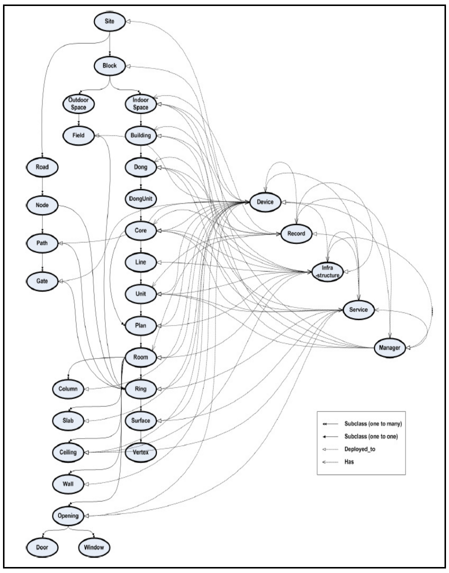

Figure 4. Relation of Building Components

3.2. Representation of Class and Its Property

Boolean Operator of Class

```
<owl : Class rdf : ID=”Building”>
   <owl : UnionOf>
      <owl : Class rdf : ID=”Wall”>
      <owl : Class rdf : ID=”Floor”>
      <owl : Class rdf : ID=”Roof”>
   </owl : UnionOf>
</owl : Class>
```

disjointWith

```
<owl : Class rdf : ID=”Apartment”>
   <owl : disjointWith rdf : resource=”#detached house”>
</owl : Class>
```

Transitive Property

Transitive property means property of a mathematical relation such that if the relation holds between A and B and between B and C, then it also exists between A and C. The equality relation, for example, is transitive because if a = b and b = c, then a = c. Other transitive relations include greater than (>), less than (<), greater than or equal to (≥), and less than or equal to (≤).

This is an example about the application of transitive property.


```
<owl : ObjectProperty rdf : ID=”isLargerThan”>
<rdf : type rdf : resource=”&owl ; TransitiveProperty”/>
</owl : ObjectProperty>
```

```
<owl : Class rdf : ID=”Room1”>
<isLargerThan rdf : resource=”#Room2”/>
</owl : Class>
```

```
<owl : Class rdf : ID=”Room2”>
<isLargerThan rdf : resource=”#Room3”/>
</owl : Class>
```

In addition to these functions, there are many specific and specialized functions in OWL DL.

4. CASE STUDY

Gunpo Worker’s Welfare Centre was designated at once in two ways (2D-based design and BIM-based design). We summarized the client’s needs through a interview with the architect who had taken charge of designing ‘Gunpo Worker’s Welfare Centre’ at that time. Based on this data, we could gather the client’s needs, such as construction cost, size of main room, number of toilet, etc. In terms of ontology, client’s needs are representation of instances by constraint of property. So, we converted the needs into constraints by using OWL DL.

Then, some constraints are applied to space objects on the floor plan, and details are like below (see Table 1):

From the constraints of building, we could control the size, position, and number of space objects. Then This plan was converted to Revit 2008 file to design in detail as following (see Figure 5).

Table 1. Constraints of Building

Subclass	Constraints of a building
General	* Total_㎡≤900(㎡) * Total_breadth≤35m * Total_width≤50m
Rooms	* building⊑∃object.space & floor & story & wall * 3= number_of_Building.babyroom 50(=7m×7m) minimum_size_of_each_babyroom * 2= number_of_Building.babyclass 30(=6m×5m) minimum_size_of_each_babyclass * 1= number_of_Building.displayroom 140≤size_of_each_displayroom≤160 * 1= number_of_Building.utility 100≤size_of_each_utility≤110 * 1= number_of_Building.teacher's room * 2= number_of_Building.stairwell * 4= number_of_Building.toilet
Toilet	* Three toilet ⊑∃located next to babyroom 30≤size_of_each_toilet≤35 * one toilet ⊑∃located next to displayroom 40≤minimum_size_of_toilet
Stairway	* Two stairway⊑∃located on the each corner * stairway⊑∃connects_story

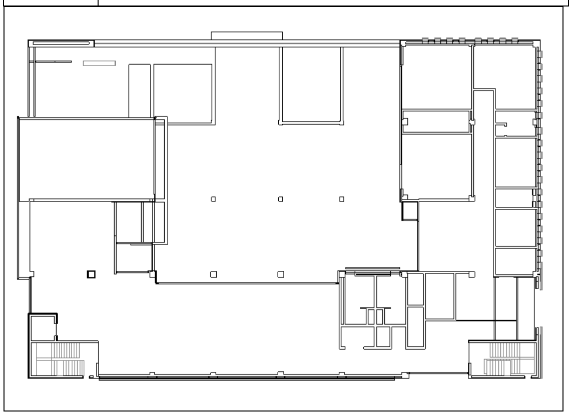

Figure 5. Floor Plan of Gunpo Worker's Wellfare Centre

5. CONCLUSION

According to case study, we reached a conclusion that is possible to control the objects, vest properties into object, and drawing a kind a schematic programming that is available to use at design stage.

From now on it will be key point to deal with objects which is segmented in detail. So the research about develop the knowledge-based management system will be required also.

Besides, to develop the efficient BIM-based project management system, it is needed to build object library, and OWL DL database to maintain the information resources about building object.

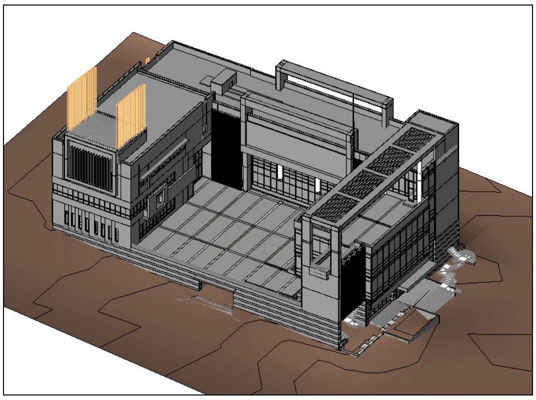

Figure 6. Revit 3D View

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