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Ontology as a Tool for Building Life Cycle Modelling

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Abstract. In this on research-based article, models presented further are representing complex concepts and facilitating their understanding. The models describe the categorization of the recorded knowledge obtained from the analysis of the monitored processes. Some of these models are descriptive (for example, the Venn diagram representing the interconnection of BIM spaces), others are predictive (e.g. a model representing the effects of BIM on the life cycle of a project), and others will be instructive-clarifying the sequence of actions that follow on to achieve a predefined output, such as a workflow model, representing authorization, identification, classification, aggregation, and usage. We can look at BIM as a framework modelling set of minimal sets of principles needed to model the basic building characteristics, along with a clear categorization of knowledge in identified and recorded models. Taxonomy is an effective and efficient way to organize and consolidate knowledge. A well-structured taxonomy allows for "meaningful gathering of experience". As we develop specialized taxonomies for organizing BIM domain knowledge, we will try to adopt the guidelines introduced by research. That is, the taxonomy is expected to be complex and complete; including classes that covering all the phenomena of our interest; based on decision-making rules, which are simple and stingy to assign instances to classes; and classes should be mutually exclusive. Moreover, because taxonomy is here as a tool for better understanding, these classes should be comprehensible and look natural.

1. Introduction

Models are representations and concepts describing in a simplified way the "vast wealth of this world" [1],). A well-designed model, according to [1],), "provides a denser representation of the original from the real world." It contributes to sharing knowledge by reducing complexity and ambiguity, resulting in "understanding better transferable among people". In order to accurately represent the external phenomenon, the model designer must demonstrate a high degree of judgment in identifying both observations / compaction data without losing any essential attributes of the phenomenon but also identifying the right level of simplicity and complexity for model creation to "facilitate understanding" of a given phenomenon [1]. In contrast, in mathematical or statistical models [2] that represent data and their relationships, the conceptual model contains a set of concepts, "characteristics associated with certain events, objects or conditions, to represent or describe (not to explain) object or process ".

2. Model and their principles

2.1. Principal of the central model

The basic idea is the intention to simplify the interconnection of a large number of nodes. To reduce the large number of interconnections we use one central node. Nodes in this model can be partial models of different applications, domains, libraries, and other elements.

In practice, this approach is, of course, more complicated than at first glance. Here, in the case of the central node, it will be a relatively large model that will be responsible for many individual, sub-information needs, connected applications, and will maintain connectivity and knowledge in many sources from which the application can draw specific information [3].

This size of the system means it cannot be implemented in its entirety, but it will be better to divide it into parts such as AP (application protocols), CC (Conformance classes)

Moreover, the importance of information is often determined by the context, the question is whether this data exchange model really comes to avoid the loss of information in terms of loss of meaning.

Also, data sharing through a shared database is not sufficient for information needs because the semantics of information in the context of individual applications cannot be reliably secured by a managed database system, albeit sophisticated.

Therefore, other scenarios that are the subject of research and testing of new paths appear. One is SOA (Service Oriented Architecture), where users do not use applications as a tool for exchange of information, but they are offered this particular application accessible over the Internet. This avoids different interpretations of information by different applications, but this solution still does not provide a solution for exchanging information or sharing it between different kinds of applications.

To solve the latter problem, it turns out that the development of ontologies could be a possible solution. Ontology is not just a specification of semantic or knowledge objects, but can also create an executable environment that can be accessed through many applications over the Internet. Ontology thus ensures the consistency of semantic data interpretation by individual applications.

For building modelling, this is not enough, and as stated above, BIM aims to provide sufficient, consistent, unambiguous and non-redundant data. This means that for any fact held in the model, only one master copy will be accepted. All other copies of the same facts must be in the "derived" or "secondary" mode.

2.2. Object – oriented modelling

It is clear that both product models and BIM models will have the task of retaining all kinds of product characteristics in the information model. This is very similar to the basic principles of object-oriented programming and modelling. This object orientation means that everything is viewed as objects with their characteristics and behaviour. Of course, such products as walls, ceilings, floors, etc. are very easy to describe as objects with certain properties and behaviours. However, in the case of discrete or intangible phenomena, such modelling will be more difficult. E.g. how can we objectify such natural phenomena as wind, rain, sunlight, watercourses, people's behaviour?

Object oriented modelling uses terms such as classes and instances, encapsulation, inheritance, and polymorphism. These terms are also the basic concepts of Building Information Models. There is a lot of literature where these terms are described in detail, for example in [4].

2.3. Modelling of movable objects and structures

Building Information Models can become very complicated. It will always be good to start with a simple BIM (Model) that will be tied to the physical object or structure of a building. E.g.:

- building objects such as walls, windows or doors and their properties,
- relationships, connections and dependencies between these objects,
- level of composition (units or parts) of buildings, building sections, building elements, building components, etc.,
- building systems: building structures, heating systems, etc.

With the above-mentioned concepts, it is possible to bundle a number of building information. At this point, the first BIM (Modelling) tasks may emerge to be resolved. For example, the building composition will easily describe the relationship between the object and its parts. But what does it really mean? Is the whole the same as the sum of all its parts? Can objects be part of a larger construction? Can there be overlaps between construction compositions?

It turns out that design structures are related to system concepts and, in general, to system thinking. We should outline the difference between subsystems and functional or organizational systems. If we use subsystems for modelling, the building will be gradually composed of parts that have a common (geographic or spatial) location: the northern part of the building, the upper floor,

In the case of organizational system approach and system thinking methods [5] such organizational systems perform certain activities or perform a certain function. They are also called functional systems. The construction is composed of parts that share a "role in time".

3. Taxonomy modelling

In the research, several BIM specific taxonomies were proposed to clarify knowledge structures essential to the BIM domain and facilitate the development of conceptual models and tools needed to improve performance. E.g. the organizational hierarchy, the BIM hierarchy of competencies, and the BIM Knowledge Taxonomy are common conceptual tools to support the performance evaluation of individuals and organizations or the entire construction market (e.g. in a particular country). Each of the proposed taxonomies is "a means to make a number of different conclusions; one of the conclusions may be to provide a direction and / or a guideline for widening, generalizing knowledge "[2],

4. Partonomy modelling

Another way of illustrating (representing) knowledge is a partonomy. "Knowledge can be organized through taxonomy or partonomy" [7] Partonomy (sometimes referred to as meronomy) is a type of hierarchy that deals with relationships between parts and units (which is just right for organizing knowledge about BIM objects or BIM capabilities). This is the fundamental difference from taxonomy, the categorization of which is based on discrete sets. This implies that partonomy will be more usable wherever it is object-oriented programming or modelling.

Tversky and Hemenway [7] are concerned with the use of the knowledge representation partonomies as a hierarchy representing the composition of parts and entities. He points out that classical studies of parts and units are based on 3 axioms:

- Transitional - "parts of parts are parts of the whole" - if W is part B and B is part C, then A is part C.
- Reflective - "everything is part of itself" - And it is part A
- Antisymmetric - "Nothing is part of its part" - if A is part B and $A \neq B$ then B is not part A

Partonomies can be represented by Semantic Web languages, such as OWL, which model some general domain and specific ontologies.

5. Modelling the knowledge classification

Classification is a "meaningful collection of experience" and "lies at the heart of every scientific area". Classification is also a "heuristic tool useful in formative degrees of discovery, analysis and theorizing". For example, when browsing existing literature, the classification is a "simple method of organizing concepts and allowing appropriate patterns to appear".

a) Ontology models

Ontologies are theories of content about object types, object properties, and relationships between objects that are possible in a specific domain of knowledge. Provide Possible Terms for Describing Our Knowledge of the Domain According to [8] there are several types of ontologies, including application, domain, representative ontologies. Domain ontologies play an important role in obtaining, analysing, and re-using domain knowledge by creating implicit assumptions and facilitating people-to-people communication. Through ontology, it is possible to formalize the domain concepts and their

relationships to each other by using the acquisition, self-observation and representation of knowledge, which in turn can form the basis for further knowledge acquisition.
BIM ontology is intended as a domain vocabulary for the representation of BIM concepts and their relationships among themselves; facilitating the recording of knowledge from experts in the field; and sharing domain knowledge. Also a categorization of recorded / acquired knowledge will be a necessary part.

b) Ontology as the basis of the "generic code" of a building
Ontology is not just a knowledge model that is described by the language of higher expressive power, ontology also serves as the primary means of achieving interoperability on the Web. The term ontology originally came from philosophy; Thomas Gruber defined its use for the purposes of knowledge engineering as a formal and explicit specification of the shared conceptualization of a certain domain. (The meaning of this definition is as follows:

- "Formal and explicit" means that ontology expresses knowledge using a certain ontological language with some expressive ability, and which has a formal logical basis.
- "Sharing" means that ontology is used by all members of the community. Each member of this community undertakes to use ontology to describe the concepts of the domain. Ontology thus becomes a social commitment for a given community.
- "Conceptualization" means that ontology defines domain concepts at a certain level of abstraction that matches the modelling requirements of a domain.

c) Advantages of using ontologies
Ontologies have a huge advantage in being intelligible to humans and machine-readable. Ontologies are most often divided according to the source of conceptualization:

- generic ontology (also higher order ontology) - capturing general patterns
- domain ontology - designed for a specific subject area (most common)
- Task ontology (also representative ontology or metaontology) - focused on derivation processes
- application ontology - adapted to a specific application (the most specific, usually including both domain and task part)
- looking, at least partially, from a library perspective for ontology, then we can compare them to thesauri. Ontologies are based, to a certain extent, on the functions and purpose of the thesaurus, but in a significant way they go much further.

Just because ontology resembles a thesaurus or cross-references, the question within construction industry community arises of whether is a good way to become an ontology manager, in the sense of creating extensive dictionaries based on taxonomy.

Ontologies for the web typically consist of a taxonomy and a set of derived rules. Taxonomy defines object classes and their relationships. Classes, subclasses and relationships are a powerful tool, because we can express a great deal of relationships between entities. It also follows that the subclass inherits the properties of the classes.

Creation of ontology usually consists of the following steps:

1. Determining scope and objectives of ontology
2. Identify entity-specific domains
3. Organization of entities in the hierarchy
4. Definition of entities
5. Entity Properties
6. Identification of relationships
7. Refinements and extensions

d) Interoperability of ontologies.
The mission of ontologies, especially for designing the metamodel, which is the BIM Framework and which we are dealing with, is to ensure interoperability through knowledge sharing. However,

realistically, one cannot assume that there will always be one ontology that describes the complete environment. The individual application domains do not have clearly defined boundaries, so there are overlaps between them. Sometimes it is also difficult to achieve consensus in creating ontologies (either for organizational reasons or for reasons of mutual misunderstanding), so they can develop similar developmental branches in the development of ontologies. For this reason, it is important to ensure interoperability of ontologies by mapping the concepts of one particular ontology to the concepts of the second ontology [9]. In the semantic Web 3.0 designs, this mapping is referred to as alignment.

Ontology mapping defines two phases:

(1) engineer, using the appropriate tools, maps the concepts of source ontology to the concepts of the target ontology

(2) software (mediator) physically transforms instances that correspond to those concepts

Current research on ontology mapping uses language rules to describe mapping in the form of semantic relationships that exist between two ontologies. In particular, using such rules, we can say that classes of one ontology are equivalent to classes of the second ontology. Using logical expressions, we can describe rules that uniquely define how the data contained in the instance of the source class can be contained in the target class instance.

Most organizations doing business in the construction industry face a huge challenge. As already mentioned, BIM technology, like the new Web 2.0 technologies, can be well and seamlessly adopted by the new generation, sometimes called "net generation", which has grown since childhood on the Internet, mobile phones and computer games [9].

Relying on this phenomenon in the sense that, when workers are exchanged, we will manage new technologies, but they risk losing the knowledge of the previous generation. We stand by the challenge of using these technologies to capture these potentially leaking knowledge along with their bearers.

Here's analogy between the BIM implementation and Web 2.0 technologies. Web 2.0 is a phenomenon in itself, and BIM has this potential, as well. Recall that, unlike Web 1.0 technologies that were based on the then classic client-server architecture, these are computer-based applications with built-in SW capabilities that make it possible to create connections between the people who use this SW. This presents the distinctive mathematical properties and potential of these networks, which are increasingly referred to as the basic arguments for the commercial use of these.

Conscious of all these aspects, Jackson [9] is concluding:

The introduction and use of Web 2.0 technologies in enterprise systems will ensure a successful answer to these questions, opportunities and challenges:

- flood of e-mail reproduction information
- need for greater returns from the costs involved in creating and retaining knowledge as a key asset of the company
- meet the expectations and preferences of a new generation of workers (net generation)
- preventing the loss of the vast knowledge of the generation that is about to retire
- connectivity opportunities offered by huge network dynamics
- need to improve decision-making processes by engaging as many other people as possible on the network
- the ability to produce large sophisticated knowledge products by allowing many small contributors to participate in this work
- fragmentation of the value chain of work processes into several smaller parts
- distribution of work over any distance
- creating and distributing new knowledge by supporting fast, but consistently controlled conversations
- expand outsourcing of certain jobs to suppliers and short-term workers
- using software that will in itself form employee expectations as to how corporate software should look

- need for companies to manage all communications on the basis of statutory and regulatory obligations and purposes

However, it is known that the devil is hidden in details. The scissors between these statements, albeit on the basis of facts, and the reality of business and its decision-making processes, are extremely open. Because there is still not enough published and quality research to confirm these points, there is enough space for sceptics. In addition, there are many indicators that not everything could work as stated. According to Jackson [9] let's take a look at how it is with organizations in the construction industry:

- Retirement generations often overlap for several years and there is no risk of a radical and rapid loss of knowledge
- To achieve an effective networking effect, there must be a sufficient number of connecting nodes in the organization, which is not common in a number of organizations (many still have an IT-based client-server architecture)
- The wisdom of sharing a large number of people needs to involve this number of people - but in many societies, experts are alone
- The new generation uses new technologies naturally and skillfully, but after entering companies, it must adapt the inertia and rigidity of processes inside, where sharing and interactivity are not perceived positively
- New management styles are needed, but management and control in a form often associated with privileges and protections is still a priority for many executives
- Flexibility is desirable, but too much scope for complexity and prolongation of a particular production leads to loss of efficiency as long as possible

These experiences from Web2.0 adoption processes can be generalized to accept any other technology based on the robust development of both SW and changes in the way communication is made possible by the current development of communication networks and channels. That's why BIM and its implementation will be faced with similar problems.

e) The suitability of knowledge management ontologies in BIM

In philosophy, ontology is understood as a doctrine (or a set of teachings) about "being," or as a universal system of knowledge describing the objects, phenomena and laws of the world. In computer science, ontology is specified as "explicit specification of conceptualization". Conceptualisation (ie a system of concepts modelling a certain part of the world) must be explicitly specified, ie not just "hidden" in the author's head. The purpose of ontologies is to promote understanding among people, to promote communication between computer systems and to support the design of knowledge-based systems.

Types of ontologies:

- Terminology - Advanced Thesaurus - Dictionaries. They are used in librarianship and fields focused mainly on text information.
- Information - Development of Database Conceptual Schemes. They provide abstraction and higher integrity checks
- Knowledge - representations of artificial intelligence. Objects and relationships between objects are consistently defined using formal language.

As it turns out in practice, communication through (human) language is a way that contributes to mutual understanding and effective transfer of knowledge among individuals - participants in communication. "In order for information to be exchanged efficiently, it is essential that these communication participants share a common vocabulary (lexicon) and also share the general model of creating this vocabulary. Such a model can be represented by an ontology whose own function is to group similar concepts, define their interrelationships, promote inheritance and other deductions "[10].

Let's try, according to Oltamari [10], first to look at the integration of ontologies and dictionaries (such as the BIM building component library) as a prerequisite for "representing, deriving and exchanging knowledge content in information systems, web services, text documents and other application domains. In such a variety of contexts, digital dictionaries (such as the diverse national or corporate BIM components libraries) and digitally generated ontologies converge into semantic descriptions of knowledge content. "Here we show how the ontologies and dictionaries differ, while digital dictionaries contain units from the top layer and supporting different (and linguistic) approaches to knowledge content, ontology captures and co-creates a logical structure linking this knowledge content. Together, "digital dictionaries and ontologies contribute to characterizing the sub-elements of a given semantic space and specifying the different relationships that are created between them."

6. Conclusion

As a digital dictionary and ontology, everyone will gather and work with another type of information. Linguistic-specific syntactic and morphological information will be contained in the dictionaries, moreover, they will always be more than a set of names used to designate concepts defined by ontologies. Ontology, as we assume "linguistically neutral, contains and assembles the formal meanings of concepts and the interrelationships between concepts that are not contained in the dictionaries. The ontology radius will be appropriately applied especially where we deal with the semantic properties of information, natural language, etc. Texts in native language do not only contain basic conceptual relationships between entities in a specific domain, such as structural design, architectural design and construction, but typically cover very complex aspects of human communication, including uncertainties, risk management, new knowledge, emotions and social relationships.

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