Ontology Supported Recombination of Multi-Models

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Abstract. Current practice in the construction industry is that participants apply their own method to develop their information model, apply software of their preference and hence choose data formats that suit them better. Hence, diversity appears. The concept of multi-models is introduced to handle this diversity. By employing multi-models, each participant will be able to collaborate despite having different resources. Information exchange can be accomplished by using multi-model containers as transport medium. An ontology model is used as a resource to gather, store and manage the meta-information about the multi-models. As a part of Semantic Web technology, the ontology is able to describe the meaning of each multi-model. Furthermore, it creates the possibility of inferring information to a logical pattern. With this ability, the ontology can support participants to retrieve information they need much more properly and precisely than object or relational data structures would allow.

Keywords: Ontology, Multi-Model

1 Introduction

In construction projects, different information models are used which are strongly interrelated. Each of the models has its own domain, purpose and information. Each stakeholder creates his own model, at least for company internal use. The ideal vision, that there is only one common model, was never touching reality. This is because the construction industry is too granular and each project is a one-of-a-kind project with always a one-of-a-kind-consortium. Hence, the virtual enterprise established for construction projects has to find new ways of ICT and cannot be based on one common virtual enterprise modeling method. This is common for most other industry sectors. Former attempts are based on the approach of structuring the common model in several dimensions, see e.g. [1, 2]. This helps to manage complexity, but does not meet stakeholders' needs sufficiently. Therefore the multi-model method was introduced by [3] and continuously developed during the last years. Multi-models are the assembly of several information models or information model views, which are completed with one or more link models. They can contain information models based on different data models, as long as the data models follow the basic paradigm that each data entity has a unique ID or at least is uniquely defined such that a unique ID can be generated [4].

2 Models and Ontologies in Construction

For several decades, the vision was followed to establish one common data model which can be served by all participants in a construction project. This was the vision of many large software companies, which resulted in software company specific models not interoperable with other companies´ models. However, the vision of construction industry companies resulted in an attempt to establish a standardized publicly available model. The first attempt was done in the 80s resulting in several parts of ISO 10303 (STEP) and later on in the construction specific ISO 16739 (IFC). The latter is meanwhile implemented by all leading CAD software companies in construction.

2.1 Building Information Modeling (BIM)

The most recent technology in Architecture, Engineering and Construction (AEC) is Building Information Modeling (BIM). BIM is a building design and documentation methodology based on coordinated, reliable, high quality information [5]. It enables design and construction teams to create and manage information about building projects consistently and reliably across different scopes of projects. BIM consists of many different models, like the raw building model, HVAC model, furniture model or structural system model. BIM plays an important role in the construction process and the vision is that the information is stored in one single building model. This ensures that the information is coordinated, consistent and complete. By adopting BIM, project participants (e.g. architects, engineers, contractors and the owner) can easily create coordinated digital design information and documentation. BIM can be represented using the IFC (Industry Foundation Classes) data model, which is standardized as ISO 16739. IFC is expressed in EXPRESS (ISO 10303) and can be exchanged in STEP physical file format (SPF) for 3D modeling. This format can be read by most BIM software, as well as IFC viewers and browsers. It is worth to mention that BIM models can but must not necessarily be expressed in IFC.

2.2 Cost Estimation Modeling

Beside BIM, which represents the building itself, there are also models which deal with the estimation of costs. They are known as Bill of Quantity (BoQ) or Quantity Takeoff (QTO) models. These models generally integrate mathematical algorithms used to estimate the cost of a project. The models typically function through the input of the parameters that describe the attributes of the project. This involves counting the number of items associated with the construction project, determining the associated materials and labor costs, as well as formulating or estimating as part of the bidding process. The participants who create such a model are often called cost estimators or cost engineers and are also known as quantity surveyors.

2.3 Schedule Model

The schedule model is helpful in creating the overall schedule for a project. By knowing the timing of activities and tasks, the management will be able to make more efficient use of their resources. The schedule model proves to be the most effective when used with software programs designed to analyze the schedule network. The software used to create the finalized schedule applies this analysis. At present there exists no ISO standardized model in the construction industry. In practice, the most commonly used model is the Microsoft Project exchange data format.

2.4 Multi-model Approach

With the variety of models in construction, a multi-model approach is a good solution to combine all the difference models. The idea is to go through the borders of disciplines / trades in a construction project and reach a horizontal integration based on different information and data models. To be able to exchange multi-model information, the so called Container Method was introduced [6] which defines a superstructure to encapsulate different kinds of models. As a result, the multi-model can be exchanged, filtered and applied in any discipline. A framework bases on an ontology was suggested in [7] and was developed and implemented in a stepwise manner in the multi-model approach [8]. The purpose behind this was to handle efficiently the needed metadata and to describe and classify the Multi-Model Containers (MMC) and all models within them.

3 Recombination of Multi-Models

3.1 Multi-model Container, Multi-model Template and Elementary Model

Multi-models consist of multiple related models, which can be compiled and evaluated with a certain software application, and exchanged by using multi-model containers. A multi-model template is a container which contains the requirement of the requested or desired elementary models. The idea of a multi-model is to combine both engineering and management models in a single information resource. The elementary models in the container are bound together with the help of a Link Model. Through the introduction of a link model, a consistent multi-model that represents a certain status of a project as well as the general information of the project can be achieved [9]. Participants can use software applications, such as e.g. iTWO (RIB Software AG), GRANID (gibGreiner GmbH) and SolidWorks (SolidWorks GmbH) to create their own multi-model container. An elementary model can be any kind of either engineering model or management model, such as IFC. It is used for the exchange of building information models (BIM) or GAEBXML[1] (German Joint

[1] http://www.gaeb.de/produkte505.php

Committee for Electronic Data in Construction), as a standard for construction information exchanged during construction bidding, contracting and invoicing as well as during construction execution. Therefore, a multi-model container can consist of a 3D building model and calculated quantities deduced from its elements. These can be interlinked with the items in a BoQ and a corresponding cost calculation as well as with the activities of a time schedule. With multi-models, different aspects of the different relevant tasks and respective auxiliary measures can be transparently presented.

3.1.1 Multi-model Containers

Communication between participants in a multi-model platform shall use multi-model containers as an exchange format. The container defines a structure to bundle different kinds of elementary models. Elementary models are treated as independent information resources with their application domain, data schema and data formalization. In this way multi-models can be applied in any domain [9]. Each multi-model container is realized by an compressed exchange file. The container contains an XML-based description of its contents [6]. It provides metadata on the particular subject and information about the data formats of the different elementary models as well as the creators or contributors for each elementary model.

Metadata consist of information about the elementary models inside the container. Besides, metadata can also build a multi-model template that prescribe the requirements regarding which content and formalization of elementary models are needed for a certain task [9]. In principal, multi-model containers consist of elementary models from different domains and project participants can independently process each model. They have the opportunity to create or develop their own elementary models and link them with existing models. This opportunity creates a possibility for all participants to recombine the multi-models based on (1) what they specifically need, and (2) the general requirements of the project and individual domain tasks.

3.1.2 Multi-model Templates

Although project participants are allowed to construct their own model, they should use multi-model templates (MMT) to get the elementary models from the model storage. End users should not create MMT; they should use one of the MMT that have been provided by their company. MMT is a reference model, which may consist of partially filled MMC with metadata about the required elementary models [3]. Participants might have different skills and have to carry out different tasks. It is not necessary for them to know all models in all their technical aspects. Therefore a MMT and MMC management supporting tool is to be asked for. As described in the developed Project Collaboration Ontology [10], template retrieval starts by selecting suitable registered content fitting the described situation. Based on the detected content, templates can be chosen whose characteristics allow processing information for this context. Thereby templates can already contain preset models as basis for subsequent processing.

When a participant accepts a suggested template, the corresponding container with possible preset models is generated. Otherwise, on the basis of existing templates and in conjunction with the ontology, it is also possible to establish and add new templates. As said before, that should only be done by an authorized person of the company because templates are Quality Management items of the company. As a result, we can ensure that the involved end user retrieves task and situation-specific MMTs matching the current state of all project entities, and hence fulfilling good collaboration requirements. The basic idea is to describe the product model instances and templates for better assignments of participants and process [10].

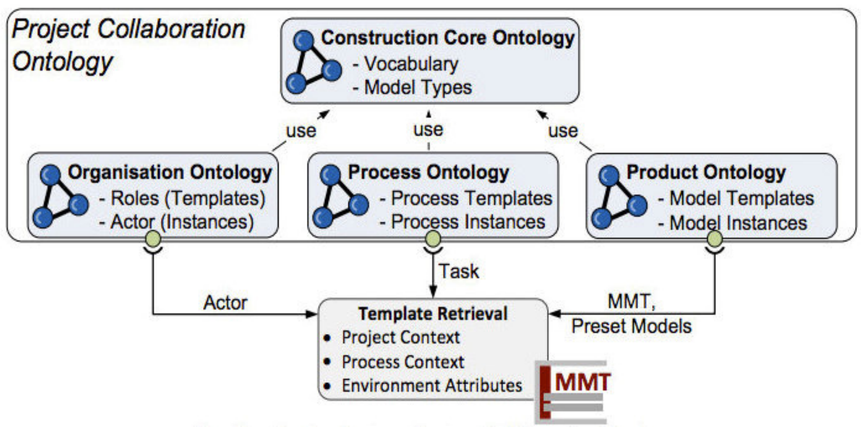

Fig. 1. MMT Retrieval in Project Collaboration Ontology

3.2 Multi-model Recombination Scenario

Two scenarios will be introduced in this section. The first scenario is to register a new elementary model inside a MMC into the Multi-Model Ontology (MMO). The second scenario is to get the information from MMO about the existence of required elementary models as shown in Figure 2. It is assumed that each participant has the same role to create and request meta-information about an elementary model.

Beside creating and requesting, project participants also have to store their created elementary models in a particular storage, which can be accessed by other participants. They should provide the information about the storage URL when registering the new elementary model. It is important to keep in mind that all elementary models are bundled in a multi-model container. An MMC consists of one or more elementary models, such as BIM, Cost-Pricing, Scheduling. Each Elementary Model can be in different file formats such as ifc, cpixml, gaebxml, or plain xml. All participants have approved these different kinds of file formats as a readable format in their systems. Along with the agreement of the format, it is also important to have an agreement regarding the vocabulary, which includes languages, abbreviations, etc.

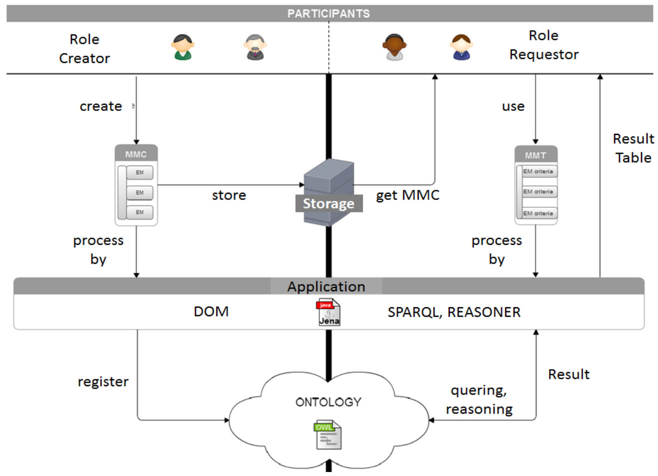

Fig. 2. General Scenario for ontology supported Collaboration using Multi-models

3.2.1 Creator Role Scenario

As already mentioned, project participants have the opportunity to construct their own elementary models. There can be many kinds of elementary models, depending on the roles and needs of each participant. In the previous section, it was explained that all elementary models belong to one context, e.g. one or several related tasks are bundled in a MMC. As can be seen in Figure 3, after creating the MMC, participants have to register their new container, which includes their new elementary models. Registration does not mean to insert the multi-model in certain storage, but only to add information about new multi-models which contain particular elementary models.

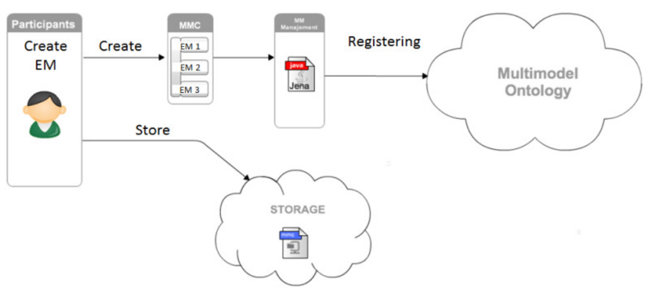

Fig. 3. Creator Role Scenario

3.2.2 Requestor Role Scenario

Project participants might need some elementary models, which are established by other participants. The role Requestor does not mean that one participant sends a request to other participants, but a participant sends a request to the MMO to get the information whether their required elementary models are already created or not. To create a MMC, participants need to use a MMT. They can create the template themselves or they can get it from a MMT provider. With this MMT, participants can send a request to the MMO. After sending a request, they will get the list of appropriate elementary models available. The result might comprise one or more elementary models, and the participants have to choose which elementary model fits their request. The requestor can get the requested MMC from the URL address provided by the creator. The mechanism of how to get the MMC from the storage will not be discussed in detail here. Important is to note that the requestor can always get the multi-model by having access to the storage, given by the creator.

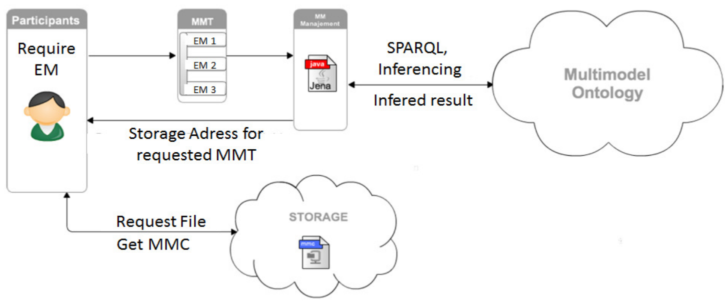

Fig. 4. Requestor Role

3.2.3 Combination of a New Multi-model

As the result of both shown roles, the combination of new multi-models can be made. It is called New Combination because it consists of elementary models, which were inside the previous multi-model created by another participant, plus the new elementary model(s). The new multi-model should have a unique name or ID, otherwise it cannot be registered in the MMO. It will reject any kind of the same instance names as this can cause inconsistency in the ontology. The elementary models inside the new multi-model might have exactly the same properties with one of the registered elementary models. These elementary models will be registered to the ontology as a different instance with a different ID because they are bundled in a different multi-model container, and the naming of a new elementary model will follow the name of the multi-model container's ID. Thus it is possible that there is an elementary model with two different IDs due to their role concerning the MMC they belong to.

4. Conclusion

The technologies of information systems have been progressing in a rapid pace. Information systems are now being called upon to support knowledge management, not just to process data or information. The key to provide a useful support for knowledge management lies in how meaning is embedded in information models, which can be done explicitly through ontologies. The special feature in our approach is not only the ability to compose new models from existing multi-models, but also to include existing workflows and to calculate with them an expected virtual information space. The use of the developed ontology can be especially effective and useful for the support of project collaboration management through knowledge management.

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