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Context-dependent information space for construction information processes

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Context-dependent information space for construction information processes

Hilbert F¹, Schülbe R², Fuchs S²

¹Technische Universität Dresden, Germany; ²TragWerk Software, Germany

frank.hilbert@tu-dresden.de

Abstract. The planning and construction of buildings and structures is based on collaborative building information processes. The information supply of these processes is characterized by the exchange of heterogeneous domain-specific information. For the treatment of most problems in the construction industry, the information involved is rarely considered in isolation, but rather elements from different information models are linked with each other. The concept of the information space has established itself for the persistence of such linked information models. For sustainable building, the continuous use of existing information models or information spaces is indispensable. Various implementation approaches exist for information spaces in civil engineering. One approach that is currently in the initial phase of standardisation and will therefore spread further in the construction industry is the multimodel approach. For large construction projects or more complex buildings, multimodels become very large and often contain information that is unnecessary for the respective processing situation. This makes the handling of such multimodels cumbersome and slows down the acceptance. One approach to reducing multimodels is to adapt them to the information needs of the respective information process. Information processes are embedded in a task context that essentially determines the information requirements of the process. In order to anticipate such situational information needs, this paper presents a method to define context-adaptive multimodel templates based on a formalization of the context dependencies of the information requirements. These can be evaluated at the time of application towards situation-specific information requirements and form a basis for the creation of situational information spaces for the realization of a context-oriented information supply.

1. Introduction

1.1. Interoperability in Construction

In construction projects, various organizational and functional information must be processed together. This information describes architecture, engineering and management aspects for both, the representation of physical and functional properties of a building and for its construction and is bundled by various model-based domain-specific information models (e.g. cost models, time models or construction models) or as unstructured project information (e.g. catalogs, examples, contract bases). For the construction industry the information formats are established and can therefore not be changed without great effort. The processes for generating and using digital information models for the planning, construction and operation of buildings during their entire life cycle are dealt with by the Building



Information Modeling (BIM)[1]. Digital information models form the basis for a common effective information logistics for all parties involved in the construction process.

1.2. Applications and Collaboration Platforms

The information models are created and processed by specific software applications (e.g. CAD, FEM or planning software). Their native exchange formats are highly heterogeneous. However, the special applications that are customary for different application areas have reached such a high degree of maturity that their use is indispensable. The collaborative processing of these information models takes place within cross-model, cross-format, cross-domain and cross-organizational building information processes. In order to achieve project-wide interoperability of the information models, adaptations or new developments would be necessary, which are too expensive for the mostly small-structured companies in the construction industry. Instead, the concept of integrating existing applications via cooperation platforms is favored for collaboration [2][3]. The collaboration platforms frequently used in construction projects offer different components and services depending on the level of integration and often contain their own information logistics components that enable data exchange between heterogeneous software tools of the project partners without the need for special coordination. The approach proposed in this paper for the context-oriented provision of information for building information processes is based on such a platform architecture. The structure of the platform and the composition and use of contextual information is only briefly presented in this paper for reasons of space. More detailed information on the proposed context-aware collaboration platform can be found under [13]. For more detailed information on the use of context, please read [16].

1.3. Information spaces

However, for most problems in the construction industry, the individual information models are rarely processed in isolation. Often elements of different information models, which are separated by the data technology, refer to same aspects and must be linked together for the treatment model and format-spreading. In particular, building-specific 4-D and 5-D software applications (e.g. iTWO, Navis-works, Synchro or Visco Office Suite) connects building structures with elements of planning and control models. The dependencies of the model elements are usually mapped into the data structures of the respective specialist application and are stored in a proprietary data format after the information process or are even discarded altogether. To avoid having to recreate this link information each time, it makes more sense to save the dependencies together with the information models concerned. The term information space has established for such a networked information model. [4]. The use of linked model elements in an information space comprising formats, models and domains leads to an increased information potential compared to originally separate information models, which is indispensable for the processing of many tasks in the construction industry. If, for example, the positions of a bill of quantities are linked with the operations of a preliminary model and elements of a building model, time, quantity, geometric or cost-oriented statements can be derived relatively simple. Two essential approaches exist for the exchange of information spaces in the building industry.

One approach is the generic multimodel [5]. This approach makes it possible to model the relationships between unchanged information models by linking their elements externally in a special link model. The links are multivalent, which means that more than two elements can be linked and these elements can come from more than two different information models. In addition to the domain-oriented models and the Link Models, a multimodel contains additional meta-information describing the general properties of the whole multimodel as well as the properties of the Link Models and the interlinked information models. For the exchange of information, multimodels are serialized as multimodel containers (MMC) with project-wide unique annotation vocabulary. Figure 1 illustrates the structure of a multimodel container on the left. Two linkmodels (left) combine the logically connected elements of different subject models for different intentions. The exchange format is published as MMC 2.0 container by BuildingSmart [6]. The multimodel approach is standardized by DIN SPEC 91350 for BIM-

LV containers (IFC + GAEB). There are currently efforts to define further specialized containers (e.g. ecological construction data containers, fire protection containers, etc.).

In addition to these approaches from Germany, an interdisciplinary container for the exchange of information in construction projects was also developed in the Netherlands as part of the COINS research project [7]. The goal of the project was the standardization of a flexible information container for the connection of the entire building data set with networked data approaches.

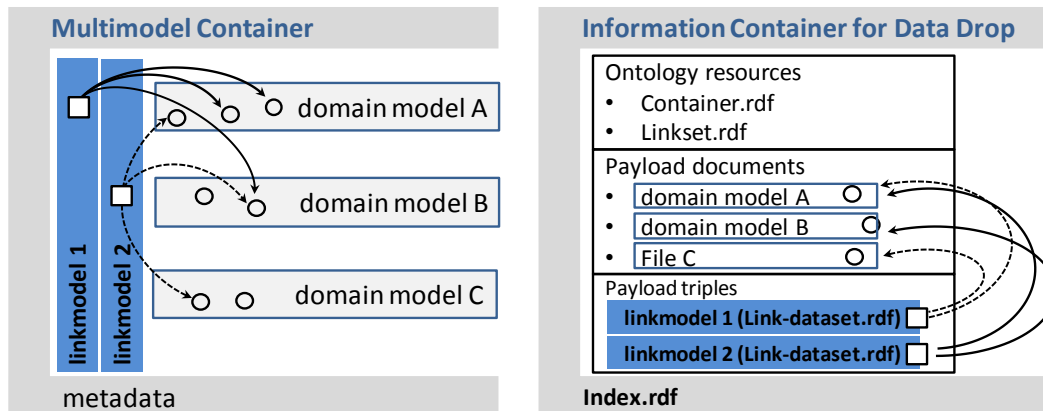


Figure 1. multimodel container structure vs. ICDD container structure

For this purpose, two versions of an information space container were published in 2010 and 2014. These versions are the predecessors of the Information Container for Data Drop (ICDD), which, similar to the multimodel, are intended to establish semantic interoperability between data or information with different data formats and domain affiliations. The main difference to the multimodel is the use of ontologies. Interdependencies between data elements are formulated as triples within the XML-based format RDF. The standardization of the ICDD takes place in two parts by the ISO, whereby ISO/CD 21597-1 describes the contents of the container format and ISO/CD 21597-2 contains the description of the semantic ontology. Both parts were accepted by ISO and CEN at the end of 2018 and ISO certification is expected in 2019 [8]. Since DINSPEC91350 is technically compatible with the ICDD-ISO on a .xml basis, multimodels can be expressed and transformed into the ICDD format. Figure 1 shows the Structure of the ICDD Container on right.

1.4. Information space enabled collaboration platforms

For the exchange of information spaces in construction projects the information logistics of the involved collaboration platforms must be upgraded accordingly. A corresponding service platform, which connects the software systems used by the construction project partners and provides the infrastructure for the collaborative use of multimodel containers, was presented in the Mefisto research project [9]. As an example, the existing GRANID specialist applications were prototypically linked with the platform services of gibGREINER GmbH (for use by the customer) and the RIB iTWO of RIB Software AG (for use by the contractor). The structure of the cooperation platform, its functionality and its use as a virtual organization of a construction project is described in [10].

1.5. Information space issues

With the increasing complexity of the building and the construction project as well as the increasing number of actors and domains involved, the quantity, scope and granularity of the information models used are increasing correspondingly. In the planning phase in particular a large number of information models are created, which, in addition to the building itself, also affect the building permit or the organization of the later realization phase. Depending on the type and size of the construction project, different types of construction plans, documents and CAD files are exchanged between the parties involved in the construction. This can range from 2000 documents (shell construction) to up to 4000 (turnkey construction for shopping center) (see Figure 2). The reason for this development, in addition

to the increasing complexity of construction projects and buildings, are the increasing quality requirements placed on the used information models as a result of the extended scope of tasks. In addition to the changed legal regulations, new, more complex production processes, special work steps and a number of new requirements must be taken into account, which concentrate on specific questions such as of energy efficiency, sustainability or additional life cycle considerations and areas of responsibility.

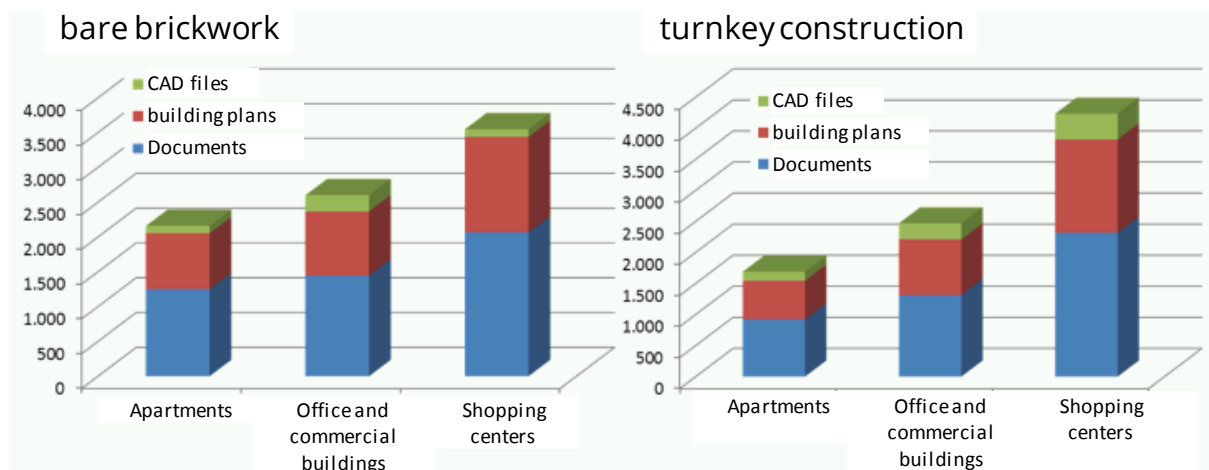


Figure 2. Average number of document types for construction projects, (source: planConnect GmbH Dresden)

With the information models, the resulting information spaces also grow and hinder the effective cooperation between the project partners. Especially in large, complex data structures the orientation effort is increased and a targeted search for required partial information as well as the tracking of model dependencies becomes more and more difficult. In addition, the semantic interpretation of the model contents is also a major hurdle for laypersons and machines. Therefore, it is difficult for those involved to estimate which parts of the information space are relevant for a current task. Against the background of this initial situation and the expected further increase in the volume of data, the targeted provision of precisely tailored information is becoming increasingly important for project success [11]. Such a provision requires intelligent information logistics that reduce the scope and complexity of the information models to be exchanged and thus ensure that the information processes are provided with information that is appropriate to the situation

2. Approach

Many tasks in the building industry require specific model sections, model qualities and model interrelationships. Often only, certain building parts, corresponding properties and allocation units or individual dates and time windows are considered. For the determination of precisely fitting information spaces for construction information processes an estimation of the information requirement is therefore necessary. Here a context dependence of the information need can be recognized. In this different aspects of the respective processing context determine the concrete extent and the quality as well as the linkage depth of the currently needed information spaces. For this reason, it is necessary to take a close look at the processing situation in order to anticipate the expected need for information. Building information processes are embedded in a processing context, which is primarily determined by three main elements: Process, actor and resource. In order to represent this processing context in a machine-readable way, a context model is required that formally represents the processing situation in a hierarchical structure [12]. Such a context model is presented under [13]. This model bundles the three main aspects and the associated sub-aspects (see Figure 3).

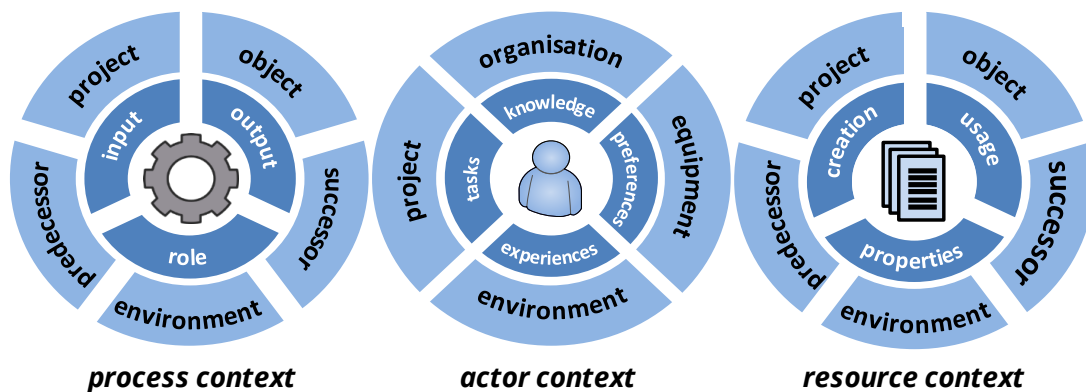


Figure 3. Context Areas [16]

There are two main points to consider when using contextual information. On the one hand, the individual context aspects have a different influence on the information requirements and on the other hand, the information logistics context information differs in relation to its update rate. Thus the relatively static actor context differs from the more dynamic resource context and from the highly dynamic interaction context. Therefore, not all context information can be determined in advance, but must be considered at the time of application. Only the selection of the context information relevant to information requirements and the type and scope of its influence on the information requirements can be estimated in advance.

In order to describe information needs in this work, the multi-model approach is preferred to the ICDD approach, since the former offers the possibility of formulating specific information space templates. Therefore, the multi-model approach is used and extended in the following to describe a situational information need. In order to make multimodel-based information spaces accessible for automatic processing by information systems, the multimodel approach offers a comprehensive semantic description of the information models and link models involved [14]. The semantic description of the multimodel can also be used prescriptively for the specification of required information spaces. In this way, requirements for a multimodel-based information space can be formalized as so-called multimodel templates (MMT) without embedded or referenced model instances (as also defined in DIN SPEC 91350). Descriptive properties of the information models involved are specified, which define their model qualities (e.g. excerpts, granularity and specialization). Figure 4 illustrates a multimodel template for the tendering of construction works and the corresponding multimodel container.

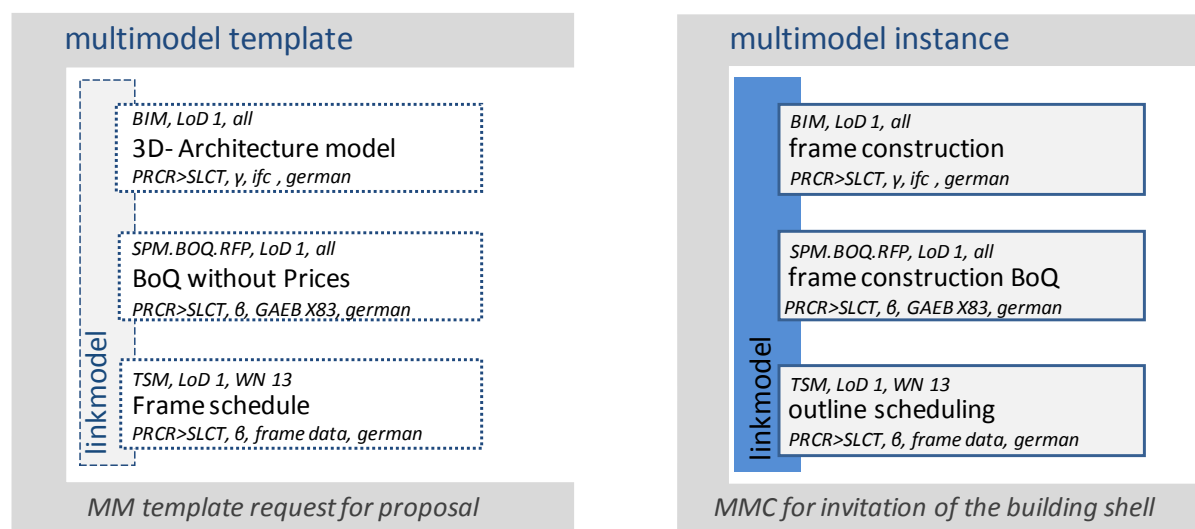


Figure 4. A multimodel template and corresponding multimodel container [16]

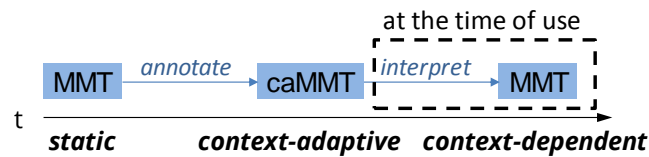


Figure 5. Creation of Context-compliant multimodel templates

The multimodel template shown here requires a multimodel that combines the logically connected elements of a 3D-Architecture model (building objects), a quantity list (BoQ items) and a general plan map (frame schedule). Static constraints describe the requirements for the quality and detail of the information models involved (e.g. model domains, project phases, levels of detail and processing status). The link depth is described using the metadata of the link models. In order to formulate the influence of context aspects on the design of situational information requirements, this static multimodel template is to be extended to a context-adaptive multimodel template. In a first step, the context-dependent components of the information requirement must be identified.

In order to formalize the influence of context attributes on the information requirement as contextual relationships, the static template attributes must be exchanged for context-adaptive attributes for the context-dependent components. Information logistics context dependencies of the context-adaptive attributes can be described by contextual relationships. In [13] the scripting language ContextScript for formalizing context relationships was introduced, which enables mapping between interacting context factors and affected information space parameters. At the time of execution, the context transformations can be evaluated with current context values in these context-adaptive multimodel templates, resulting in a context-based multimodel template. Thus, a context-dependent information need can be anticipated. Of the basis of this need a context-oriented multimodel can be created, which corresponds to the situational information requirements of the respective information process. Figure 5 illustrates the procedure: A static multimodel template (MMT) is provided with ContextScript annotations and creates a context-adaptive multimodel template (caMMT). The contextScripts of the template are evaluated at the time of execution according to the current context values and processed to a context-dependent multimodel template (MMT) (see Figure 5).

2.1. Context gathering and Integration

The prerequisite for evaluating the context dependencies is that the relevant context information is determined at the time of application. HENRICKSEN ET. AL. identified in [15] five essential phases for the integration of context information in context-related applications and distinguishes between context gathering, context reception, context management, context query and context adaptation. These five phases of operational context integration are preceded by the conceptual phase of context modeling (see Figure 6). The context gathering phase deals with the management of context sources and the insertion of recorded context information into the context model. Context information is not only collected and stored, but also further processed in order to determine high-quality context information. The context management phase organizes the administration and distribution of the available context information.

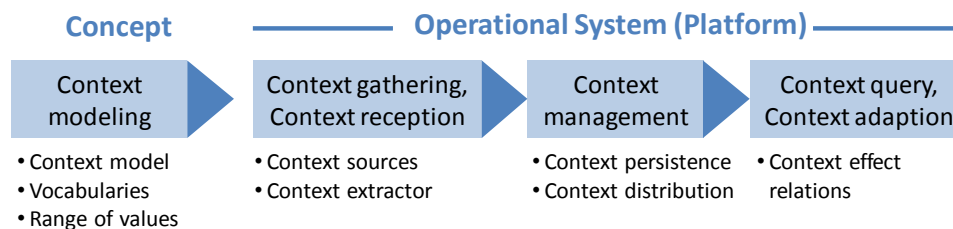


Figure 6. Phases of the operational context integration of a collaboration platform

For this purpose, the various context information obtained by the context determination must be maintained persistently and consistently. In the context usage phase (context query, context adaptation), the context model is a prerequisite for adapting the application behavior to the current context. For this purpose, the applications are provided with context information by answering context queries.

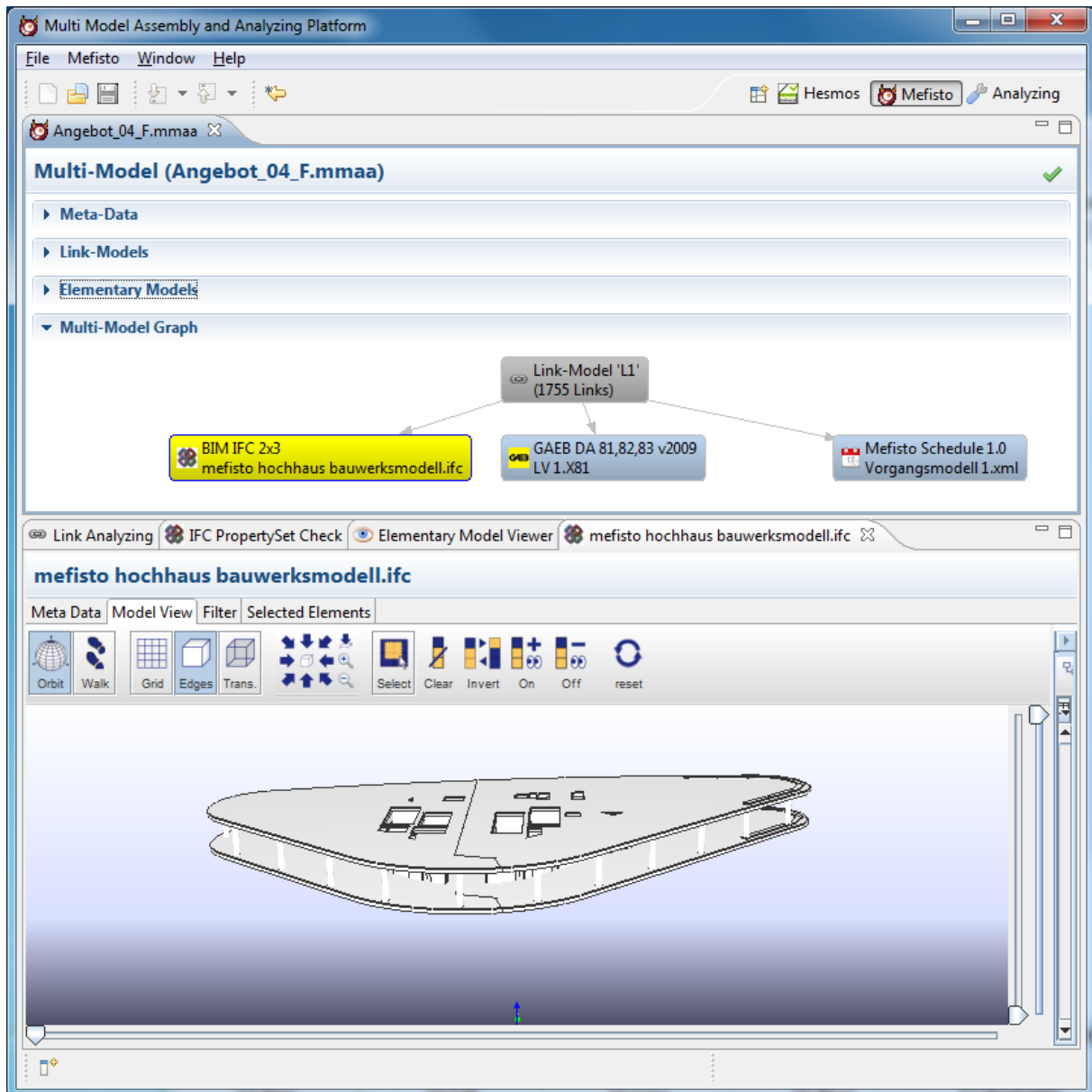


Figure 7. Evaluated multimodel container for the section of a building shell

2.2. Context aware platforms

For the implementation of context integration it is necessary to enable the collaboration platforms used in construction projects to become context conscious. In particular, information logistics must be expanded and the phases of operative context integration must be integrated into the elements of the platform. Depending on the level of integration, collaboration platforms already offer various components (e.g. content management system, user administration, workflow management system). These typical platform components can be used to collect context information. To do this, their functionality for integrating context information must be extended accordingly. For example, a

workflow management system can determine the operational context by using the control data of the managed processes and the corresponding information resources as context sources. A document management component can be extended to determine the resource context by using the metadata of the information resources exchanged on the platform. A user management component can provide the actor context. During the usage phase of the context (context query, context adaptation), the adaptation of the application behaviour to the current context is realized. This requires additional components for contextualizing the multimodel templates. Context-dependent information spaces are generated in three stages. In the first step, the contextual relationships of the multimodel templates are evaluated on the basis of current context information. Then a context-specific information request is created as a multimodel template (see [16]). In a second step, suitable information models are determined from the project information space of the platform and adapted via adaptation services (e.g. multimodel filter services) (see [17], [18]). Finally, a multimodel generator service combines the adapted application models and generates a context-related multimodel (see [19]). In [13] a platform architecture is proposed in detail, which realizes a context-related provision of information. In Figure 7 an example of an evaluated multimodel container for the section of a building shell is shown. Table 1 shows the reduction of the information space size of the corresponding multimodel container and a coarse excerpt from the underlying context aspects.

Table 1. Example context excerpt and the Reduction of the context dependent information space

<i>Example context excerpt</i> Offer carcass 12th floor Process.project.phase: PRCR>BDDG (Bidding) Process detail: 5th OG Process Role: contractor Actor.language: german Actor.Environment.Software: ITwo Actor.Environment.Software.File.Format: IFC, DXF, SKP, 3DM Actor.experience: good	information model	contextual invariant MMC	contextual MMC
	BIM building model (buildingmodel.ifc)	19,18 kB	1,56 kB
	SPM bill of quantities (GAEB LV1.X81)	606,00 kB	545,15 kB
	TSW general schedule (processmodell.xml)	190,32 kB	171,21 kB
	linkmodel	2.964 Links	1.755 Links

3. Conclusion and Outlook

It is indisputable that the use of information spaces leads to an increased information potential compared to separate and unrelated information models. However, due to their growing size and complexity, comprehensive information spaces quickly become unwieldy and rarely meet the situation-related information requirements of building information processes. For the generation of precisely fitting information spaces, a multi-stage approach for the generation of contextually appropriate information spaces was developed in this article. In a first step, a method was presented to formalize the influence of context attributes on information requirements as contextual relationships in multimodel templates. In addition to the ContextScript language, a context model was introduced that covers the information-relevant aspects of the editing context. In a second step, the situation-related information requirement is anticipated on the basis of the current processing context only at the time of application. In a third step, the project-wide information pool and multimodel filter services are used to generate context-specific information spaces. For this approach, this paper outlines a context-conscious collaboration platform as a conceptual framework for the implementation of an information logistics system that implements the context-oriented information supply for information processes in the construction industry. Since this contribution focuses only on the use of context-related information for the derivation of a multimodel-based information requirement, the remaining (context-invariant) system functionality of the collaboration platform was only outlined (e.g. domain model adaptation and multimodel generation). For detailed information on the outlined context-conscious collaboration platform, please refer to [13].

In particular, the approach of an extended virtual project information space is highlighted and its application for the determination of usable and producible information models is shown. For sustainable building, a continuous use of information is indispensable. However, due to the increasing size and complexity of the information models used, this is only possible through context-specific views. The integration of context information for the situational determination of information needs and the targeted provision of context-specific multi-models presented in this paper provides a basis for this.

For the future, we must expect a steady increase in the volume of information in the construction industry. According to this trend, the importance of demand-oriented information supply will increase, because only in this way can efficient information processing be achieved by the actors. For the future, we must expect a steady increase in the volume of information in the construction industry. According to this trend, the importance of demand-oriented information supply will increase, because only in this way can efficient information processing be achieved by the actors. The approach presented in this paper is a step in this direction. However, until the methods of context processing can be established as an integral part of future application systems, some hurdles still have to be overcome and details have to be optimized. Starting points for further research include automatic model links. A manual linking of interdependent model elements is complex and error-prone. There is still a lack of methods for automatic link generation, e.g. with the help of reference link models. MAZAIRAC AND BEETZ [20] as well as FUCHS AND SCHERER [17] present first approaches for automatic link generation with multimodal query languages. On the other hand, the context-specific adaptation of domain-specific domain models was only described very abstractly. For a practicable application of the described concept, suitable model filters are required for the adaptation of the domain-specific models with regard to quality, granularity and detail. Initial work in this direction comes from [17] and [18].

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