INFORMATION RETRIEVAL IN BUILDING LIFE CYCLE – MODULAR NAVIGATION TOOLS FOR A DYNAMIC INTEGRATION BASE

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ABSTRACT

A lot of disciplines are involved in planning and revitalization processes during the whole life cycle of a building. To enable an efficient interaction and cooperation an efficient information exchange is an essential prerequisite. Currently available software systems however provide insular solutions focusing on particular sub-processes without concerning a project as a whole.

Our research work in general aims at the cross-disciplinary provision of building related information by a shared information space. So an integrative platform was realized based on a descriptive object oriented building model approach, which allows the participating disciplines to define and modify their building models at run time. Class definitions as well as instances can be added or changed at run time, thus any type of object oriented building model, also models based on existing ISO specifications, can be integrated.

Tools enabling a cross-disciplinary navigation and searching within the information space are necessary to efficiently determine the information relevant for a particular design problem.

This paper focuses on an approach to realizing configurable searching tools based on the established concepts of data management and integration. A framework defines the essential types of searching and navigation modules as well as their interaction principles. Particular searching functionality is realized by instantiating these module types. Thus new functionality can be integrated according to any specific requirements.

KEY WORDS

Building model integration, building information system, process integration, navigation in information spaces, decision making, design and decision support.

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INTRODUCTION

A lot of disciplines are involved in planning and revitalization processes during the whole life cycle of a building. There is a high degree of specialization among the participating engineers. And quite often teams are acting geographically distributed. Highly specialized software systems are used by each discipline. But most of these systems focus on a particular task or sub-process without concerning the project as a whole (Eastman 1999). At the same time there is an intensive interaction and strong interrelationship between the activities of each engineer. So particular sub-processes usually base on the results of other preceding or parallel sub-processes. But communication and data exchange is usually based on file exchange, thus causing a loss of data by transformation. So the integration of all processes and life phases of a building in terms of a continuous completion and re-using of building data is not supported appropriately.

CURRENT RESEARCH WORK

The current research activities at the chair in Information and Knowledge Engineering aim at a cross-disciplinary provision of building related information during the whole life cycle of a building. The developed approach focuses on a cross-disciplinary integration based on a common in formation space or ‘data pool’. It does not set any restrictions regarding the particular processes and thus there are no limitations regarding project specific requirements. Within the research work of the Collaborative Research Center 524 “Materials and Structures in Revitalization of Buildings” a system concept for an integration platform was developed and realized, that aims at the integrated management of all discipline related data. There are no restrictions regarding the use of any object oriented model and the way how data is produced or manipulated. These tasks remain within the responsibility of the discipline specific applications. Thus the technical substructure of a network is established which is open for the participation and integration of any engineer or discipline and their specific software tools.

CONCEPT OF AN INTEGRATION PLATFORM

Each building has to fit for a unique constellation of local factors and functional requirements. As for buildings lifetimes of +80 years are realistic. Therefore also the building model has to deal with this long lifetime. Within this period several changes might occur, for example modifications of the building substance, changes of law and technical norms or the development of new materials and construction technologies. Processes of planning, erection, changes of use, alteration and destruction are individual and can not be foreseen in detail. So the requirements regarding the information to be stored and managed can change over time and vary by particular projects. That means the integration platform has to provide the flexibility to be adapted to those changes.

DATA MANAGEMENT AND INTEGRATION

Because of the constraints explained above a complete and universal pre-definition of a building model is impossible. Approaches to the standardization of building models like IFC (ISO 16739) or STEP (ISO 10303) provide extensive specifications, but do not meet the defined requirements completely. The approach of an over-all building model including all potentially participating disciplines does necessarily cause a high degree of complexity. On the other hand the case may occur, that project specific particularities require data structures, which are not contained within the specification. An alternative solution is to leave the definition and modification of the required data structures up to the users, that means, the engineers or disciplines participating in a particular project.

The approach introduced in this paper bases on the object oriented paradigm and allows the participating disciplines to define and modify their building models at run time. It does not determine any pre-defined model structure. The entire building model is conceptually divided into discipline specific partial models, which can be defined or chosen by each discipline themselves (figure 1). Thus models based on the IFC or STEP specifications can be integrated as well. The common integration platform provides functionality for the storage, management, modification and cross-disciplinary provision of the models. A detailed introduction to this approach can be found in (Hauschild 2002, and Hauschild et. al.2003).

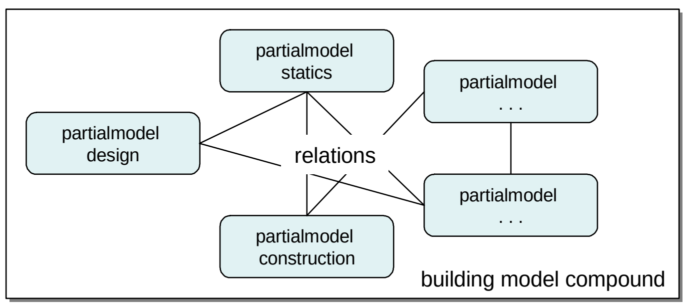

Figure 1: building model as model compound consisting of several partial models

The entire building model consists of all the participating partial models plus their interrelationships. The number of partial models as well as their structures and content can vary by the project as well as during a project's life time. Relations between partial models must be defined and modified at run time. These relations are stored as explicitly defined links between particular partial model elements. They represent cross-disciplinary data requirements between partial models. In (Willenbacher 2002, Willenbacher and Hübler 2002, and Willenbacher and Hübler 2004) the approach of link-based modeling is explained in detail. For a brief introduction see as well in (Willenbacher et. al. 2006).

SYSTEM ARCHITECTURE

The management of the entire building model bases on a distributed system (figure 2). Each of the partial models is managed by its own model server / model management system (MMS). Partial model clients are responsible for the communication of the engineer's applications and the discipline specific partial model. A central project information service provides for the registration, log-in and log-out of the partial models. Thus this service provides a central index of all participating models and their availability at a certain moment. For the storage and management of the cross-disciplinary links a separate partial model was established. Technically the partial model compound is realized based on the software agent technology. A multi agent system is responsible for the management and processing of links as well as for the establishment of the central project information service.

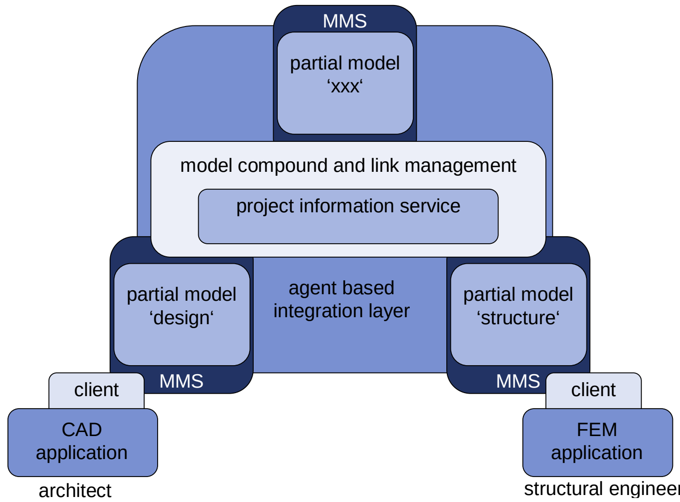

Figure 2: system architecture of the distributed partial model compound.

NAVIGATION AND SEEKING FOR INFORMATION

The following sections describe constraints, objectives and the approach of the cross-disciplinary provision of information contained within the partial model compound. The aim is to support an engineer while determining the information relevant to a particular design problem.

RESTRICTIONS AND REQUIREMENTS OF INFORMATION SEEKING

Depending on the knowledge a user has got regarding the content and structures of an information space he or she chooses a certain strategy of searching. The process of searching usually contains several steps of iteration and can not be foreseen in detail (Taube 1998). The required information related to planning tasks in detail depends on the individual project situation and the particular problem or question and can not be foreseen as well. But several tasks in general are done as routine for each project (HOAI, Joedicke 1976).

By building and construction industry several discipline specific forms of documentation and presentation are used. They are strongly related to the specific purpose and type of the documentation, presentation or visualization (Berger 1999). Especially by currently available computer supported technologies these documentation and presentation techniques evolve. So a universal choice of a set of representation / visualization techniques for navigation tools can not be done.

On the technical level some aspects have to be taken into account as well: The layers of data management and integration ignore the semantic of the models in terms of providing flexibility. The only pre-defined data structure is the meta model, which defines the basic elements (schema, package, class, instance) to describe the partial models. It provides only generic functionality to access the partial models. But representations based on this generic level cannot comply with the conventions of documentation and presentation. The established model management system provides an API for the access to particular model elements. This API is defined as a static CORBA interface using CORBA-IDL.

REQUIREMENTS REGARDING NAVIGATION TOOLS

Considering the restrictions named in the previous sections the navigation tools have to meet the following requirements:

- Provision of searching functionality that supports declarative and explorative strategies of searching by providing tools for the definition of formal requests as well as tools for visual navigation
- Provision of seraching functionality on the level of schema definition (definition and modification of classes) and on the level of model data modification (modification of instances)
- Provision of differenciated functionality for searching and navigation within any partial model on different levels of semantic: form a simple generic level based on the meta model up to discipline specific functionality including specific tpey of representation and visualization techniques.
- Flexibility regarding the future integration of new representation or query techniques
- Flexibility regarding the future integration of specialized tools to support discipline specific information needs

CAE systems provide functionality to represent and manipulate building related data. But since these systems focus on a sub-set of the entire building model they can not provide sufficient representations for the navigation within the entire partial model compound (Eastman 1999). Therefore the integration platform has to provide functionality to represent all structures and content of the model compound without any restrictions to discipline specific particularities. As a requirement of usability on the other hand the representations used for navigation have to comply with a minimal level of the documentation and representation conventions of building and construction industry.

OBJECTIVES AND APPROACH OF A FLEXIBLE NAVIGATION LAYER

Our current research activities focus on the establishment of a flexible navigation layer that enables a cross-disciplinary provision of the data stored within the partial model compound. This navigation layer provides basic searching and navigation functionality by generic representations but can be extended by any specialized representation or searching technology if needed to support discipline specific requirements or semantics. The proposed concept bases on a modular organization of the navigation layer. Different types of functionality are realized by different types of modules. The essential types of modules and their interaction principles are defined by a framework. Particular navigation or searching functionality is realized by instances of these module types. Based on the framework the participating modules are integrated to a flexible and adaptable navigation layer. According to the requirements of a particular project or discipline modules can be changed or extended.

A FRAMEWORK AS TECHNICAL BASIS FOR A MODULAR NAVIGATION LAYER

Within the following sections the framework concept of the navigation layer is described and the different module types including their functionality are explained. The framework definition is currently in progress. To verify the current state of work the module types are instantiated to provide a minimal level of searching and navigation functionality.

MODULE TYPES AND INTERACTION PRINCIPLES

The tasks the navigation layer has to support can be divided into four main fields. Each of these fields is represented by a specific module type:

- Support of explorative searching strategies – viewer modules
- Support of declarative searching stretegies – query modules
- Processing of formal requests to determine the matching model elements – evaluation modules
- Integration of the modules and communication with the partial model compound – central framework management component

Viewer modules mainly provide graphical representations that enable visual navigation through the model compound. In detail each viewer module has to support the following set of functionality:

- Graphical representation of the entire model compound or of a sub-set of partial model elements
- Definition of sub-sets by graphical selection of partial model elements
- Highlighting of selected elements
- Exchange of selections with other modules
- Displaying of information related to a selected element on demand

The choice of representation techniques has to respect the differences between classes as an abstract model structure and instances as concrete building related data. Several representation techniques are insufficient to represent classes others might not be suitable to represent a large number of instances. Therefore different sub-types of viewer modules are distinguished:

- Viewer modules supporting tasks of schema definition, that only represent the abstract concept of classes and their interrelationships, for example by UML diagrams
- Viewer modules supporting navigation within partial model data (instances), for example by 3D representations of a building or a sub-set of its elements

- Viewer modules supporting both levels of functionality

Query modules focus on declarative searching strategies by formal requests. They have to support:

- The defintion of formal requests consisting of detailed searcing criteria
- Communication with evaluation modules for processing of requests and return of the matching sub-sets of model elements
- Handing over of matching sub-sets to other modules
- Taking over of sub-sets (selections) to limit the field of searching while processing a request
- Storage and management of requests for re-use

Evaluation modules are responsible for the communication between query modules and the model management systems storing the partial models. They process the requests defined by query modules and transform the formal searching criteria into calls of the API of the model management systems. Therefore the following functionality is necessary:

- Communication with the central framework management component to determine available partialmodels and to get references on the particular model management systems
- Access to the partial models using the API of the model management systems
- Processing of queries
- Communication with query modules to take over searching criteria and to hand over determined matching sub-sets of moel elements

In addition to these three module types the framework contains a central management component, which is responsible for the registration and integration of the modules. Therefore after a module was registered, its type, functionality and – if exists – its relation to a particular discipline is written to a central index of available functionality. By the central management component particular modules can be synchronized regarding their selection, for example if the user wants the same elements to be displayed and/or selected in different viewers. Furthermore the central component connects the framework and thus the navigation layer to the partial model compound by communication with the central project information service.

According to the mentioned functionality there are two different entities to be exchanged by the modules in terms of their communication:

- Formal searching criteria, e.g. to determine all elements having a certain type and/or specific attributes
- Selections as sets of partial model elements, either defined by graphical selection (by mouse click) or as determinded elements matching a particular request.

These entities have to be included to the framework definition to enable the communication of the modules as it is illustrated in figure 3.

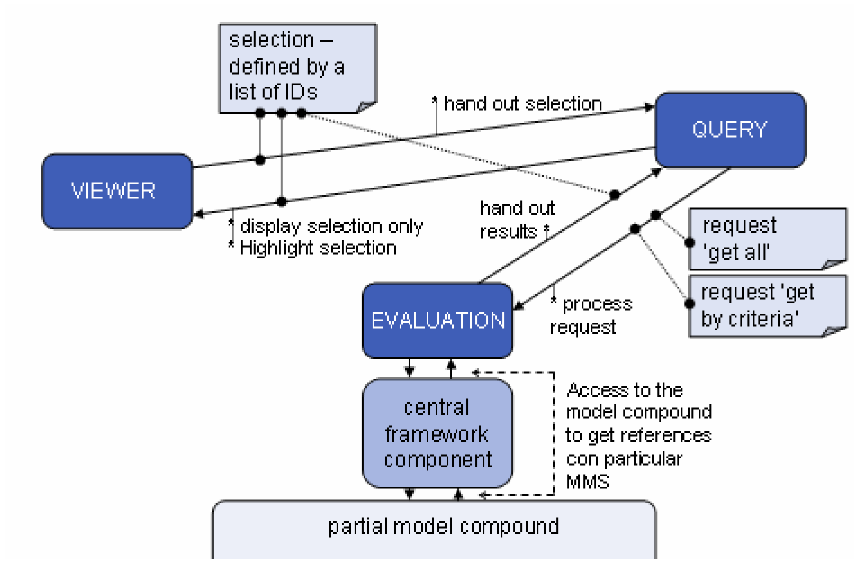

Figure 3: module types and their interaction

APPROACH OF TECHNICAL REALIZATION

Based on the approaches of data management and integration introduced by the first sections of this paper there are a few technical facts and requirements to be considered:

- The access to the partial model elements has to rely on calling the API of the model management systems. But therefore a reference to the particular model management system is needed. Before such a reference can be provided the availability of the partial model has to be checked by the central project information service. This means the navigation layer has to cooperate closely with the central project information service.
- The central project information servise was realized as part of a multi agent system. So the navigation layer has to interact with software agents.

Some additional requirements are defined by the framework concept:

- The amount of participating modules can not be pre-defined, but new modules have to be integrated at any time.
- The modules have to be able to communicate with each other, especially for the exchange of element sets / selections and searching criteria.
- Each of the modules has to perform independently from the availability of other modules.

Considering these conceptual requirements related to the fact, that for the management of the partial model compound a multi agent system already exists, the agent technology provides an appropriate approach for the technical realization of the framework.

The navigation framework forms an additional layer on top of the partial model compound (figure 4). Both layers are plugged together mainly by the central framework management component and the central project information service. Each of the modules as well as the central component a software agent is assigned to. These agents are responsible for the communication among the modules. The central component furthermore provides a directory service, which registers all participating modules and their functionality and provides access to them by registering their agents. This directory service can be used by users directly as well as by other agents.

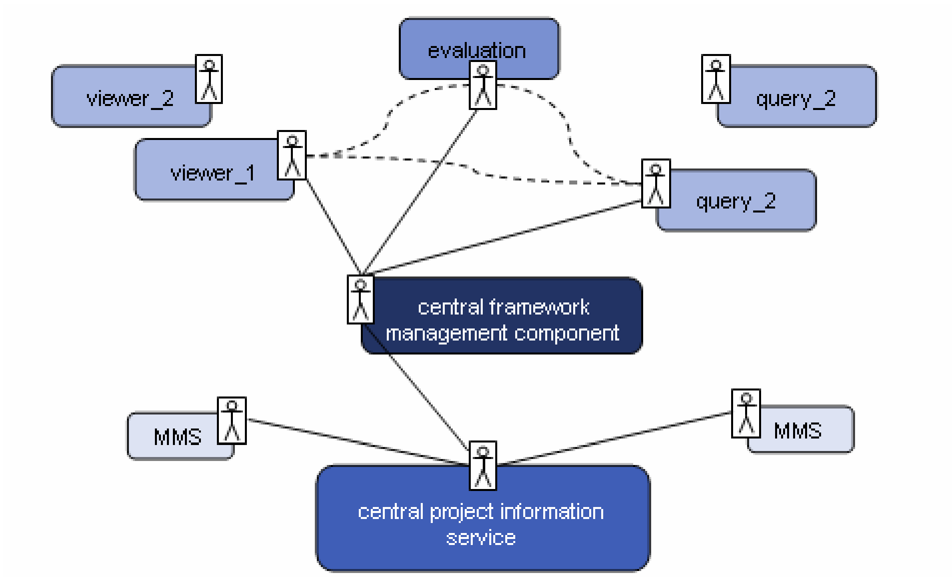

Figure 4: concept of the realization of the framework based on the agent technology

While creating representations for navigation or while supporting the definition of searching criteria the modules need to access the partial models directly to determine the relevant data. Therefore the agents have to get and hand over references to the model management systems by interaction with those agents realizing the central project information service.

CONCLUSIONS

This paper has introduced approaches to realize a cross-disciplinary integration platform for planning processes during the whole building life cycle. The concepts and the technical realization of the layers of data management and data integration were outlined and the resulting requirements for a navigation layer were described. Based on this a concept for the establishment of a modular and flexible navigation and searching layer was introduced. This layer enables the access to the entire partial model compound by supporting explorative and declarative strategies of searching.

Currently the first step of verification of the developed concept is in progress. Therefore a minimal instantiation of the framework by three modules is realized, which provides basic navigation and searching functionality on the generic level of the model management API.

The currently developed modules provide an initial test bed for the framework concept and the module type definitions. Especially in terms of representations their functionality is extremely limited and not suitable for the navigation within partial models containing larger numbers of instances. Based on the knowledge resulting from this initial instantiation the framework concept has to be reviewed. Within a second step representation techniques focusing on partial model data have to be integrated. Therefore especially techniques of graphical 2 or 3 dimensional representations as examined in (Willenbacher et. al. 2006) are considered. These techniques define further requirements the framework has to comply with and will cause a second iteration of review. Finally the integration of discipline specific searching functionality has to be examined exemplarily. Therefore technologies to improve the support of an architects routine tasks and the related information needs have to be defined. This final step will complete the framework definition. It does not aim on the completion of its functionality, since this might be impossible because of the variety of the requirements each discipline defines. It just has to prove that the functionality of the navigation layer can be extended by specialized discipline specific tools as well.

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