A Modular Navigation Layer for Information Retrieval in the Building Life Cycle
Integrated support of specific and recurrent information needs

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Abstract. *One cause for the mostly inconsistent and incomplete transfer of data within the building life-cycle is the insular nature of currently available software solutions for building planning / facility management. An IT-supported integrative platform could ensure the integration not only of all planning participants and their respective tasks but also all phases of the building life-cycle. A platform of this kind must provide flexibility on several levels: modelling / administration, model integration and of course data navigation and information retrieval. Because of the uniqueness and long lifetime of buildings it is impossible to develop a comprehensive and generically applicable building model as well as information requirements occurring during the life-cycle cannot be precisely defined in advance. A basic feature of the proposed approach is the ability to modify the building model (i.e. data structure) at run-time of the system. As a fundamental requirement the navigation layer of the integrative platform must support a variety of search strategies and be open for the integration of new modules. We describe an approach for an integrated platform for information retrieval across the entire life cycle of a building using a digital building model as a basis. The system architecture developed for the data and integration layers is described and problems associated with information provision for supporting decisions are examined. Based on the demands identified, an approach for a navigation and online search layer is formulated.*

Keywords. *Information retrieval: building life cycle, building model, planning process, decision process.*

Motivation

During the life cycle of a building, data is continually being produced that is potentially or directly relevant to later phases. The consistent and complete transfer of such data during the process is often not possible. One cause is the insular nature of currently available software solutions for building planning.

An IT-supported integrative platform could ensure the integration not only of all planning participants and their respective tasks but also all phases of the building life-cycle. A platform of this kind must be able to manage both existing as well as future information and be able to provide these to the respective tasks and processes.

The building model – Defining data structures in building

The specifics of context and location of a building and their individual functional requirements mean that buildings, unlike most other industrially produced goods, are unique. In general, buildings also have a long lifetime of 80-100 years or more. During this period requirements change, adaptations are made and fittings and technical infrastructure are upgraded according to changing demands and regulations. New building materials and construction methods are developed, new functional requirements arise.

It is therefore impossible to develop a comprehensive and generally applicable model that fits all kinds of buildings whether existing or yet to be built.

Likewise it is just as difficult to develop generally applicable descriptions of information requirements for all aspects of the building planning, construction, usage scenarios, renovation works etc. It is not possible to conclusively define which kinds of information at what level of detail are required for which processes.

As a result, an integrative platform must be able to support the inclusion of information requirements not known in advance. This means that building models must be defined, customized and stored as well as the building model data must be made available to planning processes, construction processes and usage processes.

The requirements in general are as follows:

Modelling and administration:

• Flexibility with regard to data structure as well as form of the data.

Integration:

• Flexibility with regard to inclusion of new models

• Flexibility with regard to definition of relationships between the models

Navigation and information retrieval:

• Flexibility with regard to information research and retrieval strategies

Integrative platform for revitalisation processes in building

Within the following sections we describe the approach of an integrative platform developed by the subproject D3 of the Collaborative Research Center ‘Materials and Structures in Revitalisation of Buildings’ (CRC 524) founded by ‘Deutsche Forschungsgemeinschaft’ (DFG).

The digital building model as a basis for integration

The activities of all participants (processes) during all life cycle phases are related to the same subject: the existing building (to be renovated or converted). All data related to the building is of potential interest and relevance to all participants and life cycle phases.

A common data base in the form of a digital building model is a basis for integrating the different processes. Such building models must be as flexible as possible but at the same time must also be manageable for the different participants in the building process. Current approaches to standardised building models do not fulfil such requirements. Due to their complexity and complicated handling, user-acceptance is comparatively low.

A basic feature of the proposed approach is the ability to modify the building model at run-time of the system. Only through this approach can the model be adapted to fit new structures and contents not yet envisaged and so react to changing demands during the life cycle of the building as mentioned earlier.

System architecture for an integrative platform

The proposed system architecture follows a hybrid approach that combines central and decentralised elements (see figure 1): Each of the participating disciplines is assigned their own domain-model server administering their respective domain-models. The administration (creation, editing, modification) of these domain-models is the responsibility of the respective professional discipline, as only they have the appropriate professional expertise. Each of the models represents the specific information of that domain according to the object oriented approach in the form of classes with attributes and relations as well as inheritance hierarchies. The data of a concrete project is associated to the domain model as instances of the domain model classes (building model data).

A central project information server is responsible for integrating the models at a technical level. Much like the "yellow pages" directories, the server collates and administers the information provided by the different partners and contained in all the models available at any time, as well as the access rights to this information for authorised/registered users. Depending upon the specific project requirements at any one time, models can be added or removed from the integrative platform, or where necessary replaced.

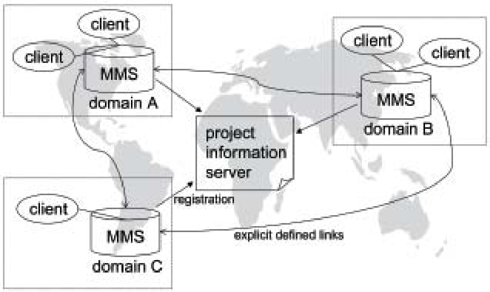

Figure 1. System architecture realized for the platform.

At a semantic level, the domain-models are integrated with the help of a link-based modelling approach: a wide variety of different relationships exist between the models. These relationships are defined explicitly as "links" between the models. There a different types of links:

• Informative – when a value is modified the target model is notified.

• Propagative – when a value is modified, a particular process is initiated.

• Generative – a value is carried over from one model to the other according to a predefined logic so that the respective element in the target model is created

As with the principles of the data level, at the integrative level the links are also separated into type definitions and instances. Type definitions link classes or their attributes at an abstract, generally applicable level. Instances for each type relate to the 'concrete data' of a particular project, i.e. the instance of a class.

A further basic principle is the reusability of existing elementary building elements: based upon simple link types complex relationships can be defined through combination. Link management and administration is realised using software agents.

[Hauschild03], [Willenbacher02], [Willenbacher04]

Cross-disciplinary data navigation and information retrieval

The data administration and model integration levels have already been successfully realised according the principle described above. The navigation and information retrieval level is the focus of current research work..

At present the user's "viewing" options for the building model (combination of partially-linked models) are limited to basic tools and primarily generative representations (figure 2).

First prototypes of graphic-visual navigation tools based upon geographic information systems have been explored. At present a set of independent tools exist which, for the moment, address only individual aspects of information research and retrieval.

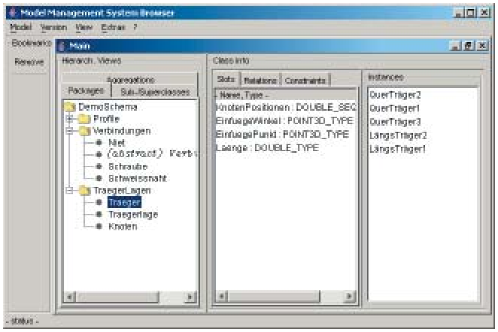

Figure 2. Screen of the MMS Browser.

Requirements from the user's point of view

As a basic premise, one should assume that information requirements cannot be precisely defined in advance. The extent and form of information required depends largely upon the task at hand and the questions it presents (e.g. To what extent can the plot be built upon? Is it possible to remove such and such a wall to connect two rooms? What options are available for solar protection? etc.)

From the user's point of view, the information necessary for such decisions can be obtained through a variety of search strategies. The choice and combination of these strategies depends both on the user's preferential way of working and on the distinctiveness of the information to be retrieved as well as the user's knowledge of the structure and content of the data in the building model.

Very often a search process can be an iterative procedure employing a combination of search strategies, in which irrelevant information is gradually filtered out as the user's knowledge of the data structure becomes better. Therefore, the most general requirement for search and retrieval tools is the integrated support of different search strategies. [Wender02]

A definitive approach to the design and planning process is not as yet formalised and approaches differ from person to person [Lorenz04].

The German tariff regulations for architects and engineers [HOAI] offers a breakdown of the different tasks an architect or engineer offers and their respective level of accuracy (given in plan scale). However this structure is too generalised as to be able to list a catalogue of information requirements for each of the particular planning aspects. What it does provide is an indication of particular tasks that are regularly undertaken in a more or less similar fashion during the planning process of most buildings:

- Fulfilment of inter-building minimum distance requirements and other plot or context related stipulations.
- Production of a room log and allocation of existing or required building structures as well as their functional interrelationships.
- The production of a fire safety concept according the statutory building regulations.
- Calculation of the capacity of technical installations.
- A series of different proofs (structural safety, thermal performance, noise insulation.

Such sub-tasks can provide a starting point for further deliberations. Similar sub-tasks are characterised by similar information requirements. As a result a number of reusable information modules can be developed for the purposes of common information retrieval tasks. The identification, creation, administration and provision of such "information modules" for repeated application is therefore an essential prerequisite for supporting information research requirements.

Research tools must further support a number of different representational forms for the selection of certain content, and the choice of method should be up to the user and not stipulated by the system. In addition it must be possible to expand the system by providing other (not yet considered) forms of representation.

The navigation layer must therefore provide a number of different levels of functionality for enabling information research and retrieval. The lowest level consists of “core” basic functionality, a browsing of the data model. These tools provide a graphical means of navigating the model. The next level consists of simple search requests, available at a mouse-click and without needing any particular search syntax. A further level provides extended search functionality with context-related provision of information. None of these levels are independent of the other but should instead be integrated with one another. For instance, not all situations can be covered by specialised context-related information. On the other hand, without such specialised tools, certain information would need to be searched and selected manually each time (whether browsed or as simple search-request).

A fixed definition of search functionality is therefore not possible or indeed sensible. Instead a basic functionality framework needs to be defined and developed with the ability to add extensions for new (not yet envisaged) tools and functionality.

The following basic principles should be taken into consideration when developing the navigation layer:

Dynamic combination and Modularity.

A fixed definition of functionality for information research contradicts the basic dynamic nature of information during the building’s life cycle. Instead, individual research modules should be usable in combination with one another (e.g. to formulate search requests or graphically limit the extent of a search request, to combine several simple requests to context-related filters, to be able to examine search results in several different representations).

Open structure

The ability to add further research modules as extensions must be provided (in the technical realisation). New modules should be able to link with existing modules and “work together” with them, i.e. to be usable in combination as described above.

Separation of content and presentation (analogue to MVC paradigm)

For all tools which produce data requests (i.e. automatic assessment of user-formulated conditions with a view to obtaining a number of relevant data objects) the functionality for formulating and assessing the request/search criteria and the functionality for representing the search results should be independent of one another. Depending upon the purpose of the information search, a number of different representation methods may be necessary or sensible. It is not possible to say with certainty which representational method is most appropriate. It should be possible to integrate new representational forms, not yet envisaged, in the navigation level.

Re-usability of existing search modules

Approaches to technical realisation

From the user’s point of view (figure 3), the navigational functionality and information research and retrieval represents a further level above that of the partial-model and integration layer. This navigation layer consists of two sub-layers: the user interface including interaction technology on the one hand and the actual research modules for requests, filters and profiling on the other. These produce more or less complex conditions or criteria according to which certain elements from the individual partial-models are to be retrieved.

Using these sub-layers, the navigation layer can provide a number of different levels of research functionality: Viewers use graphical or alphanumeric navigational representations to

browse the partial data models in integrated form. They are also used to represent the results of formal requests. Search requests (queries) are the most elementary research modules. The definition or formulation of search criteria can be undertaken simply using class definitions without the need for special search syntax: the user selects the required classes from a list of all those available, and where necessary enters a value for the appropriate class attributes as search criteria. Previous search queries should be made available to all other users who may wish to select the same information.
Several elementary search requests can be combined to form complex requests or query bundles. The combination of several filters and/or requests can be saved as context-related profiles.

The realised integration level consisting of links and project information server is realised as a series of agents: a central domain controller in the form of a software agent provides a directory of all included models, all currently available models online, all users and their access rights and all current users logged-on.

Each domain is allocated a client which registers the respective domain with the domain controller. This functionality is likewise provided by a software agent which communicates with the domain controller.

The to-be-developed navigation layer builds upon the basis provided by the integration layer (figure 4). As with the domain controller, the central navigation controller provides a ‘Yellow Pages” di-

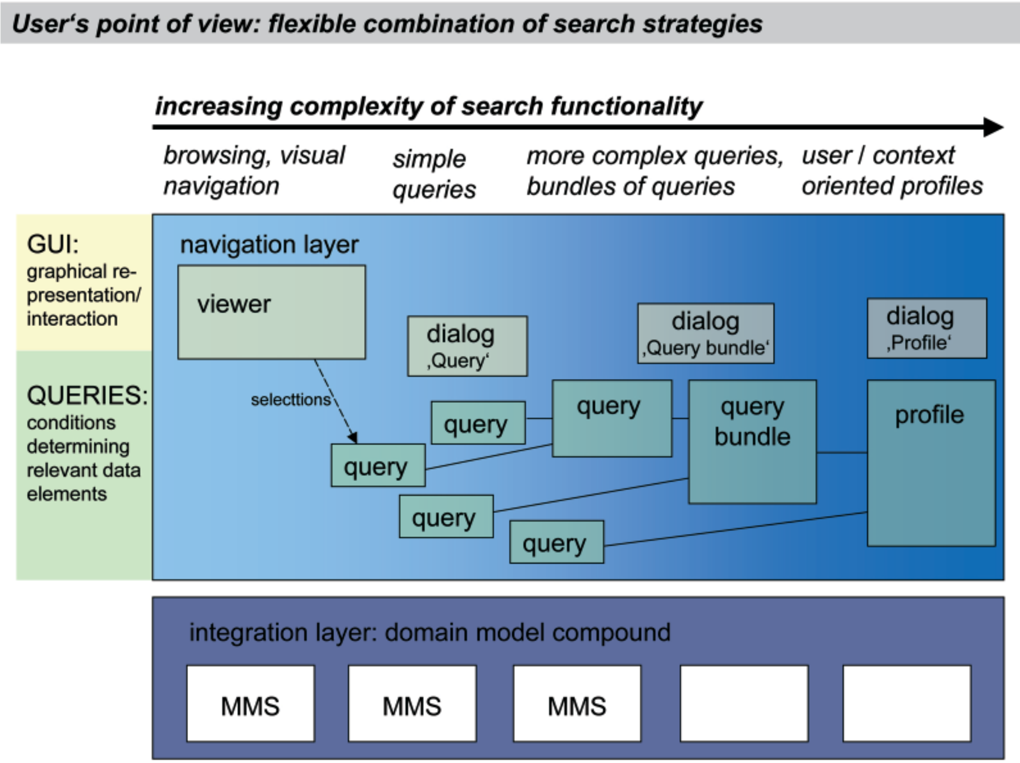

Figure 3. Functionality of the navigation layer

rectory of available search queries, query bundles, (context-related) profiles and viewers.

Navigation clients represent particular users. These clients collect all queries, query bundles and profile settings created by 'their' users. Standard viewing settings of a navigation client can be defined for the viewer, request mask or profiles to determine how and which information is to be presented when the navigation client session is started.

As the permanent online access to particular domain models an not be ensured and there is no binding static data structure, the software modules of the navigation layer must be able to manage the access to the currently available resources. If there are modifications of the environment, modules must perceive and act accordingly.

The software agent technology provides most of these features. 'Social skills' of agents and communication principle allow a flexible set of research functionality. Instead of a hard-defined set at any time new modules can be added and completely integrated by communication with existing software modules. By partial representation of the environment particular agents have, several search strategies can be realized by separate but integrated modules. Modules in the form of software agents can act autonomously, so they collect relevant data as soon as the respective models are accessible without explicit commands coming from the user.

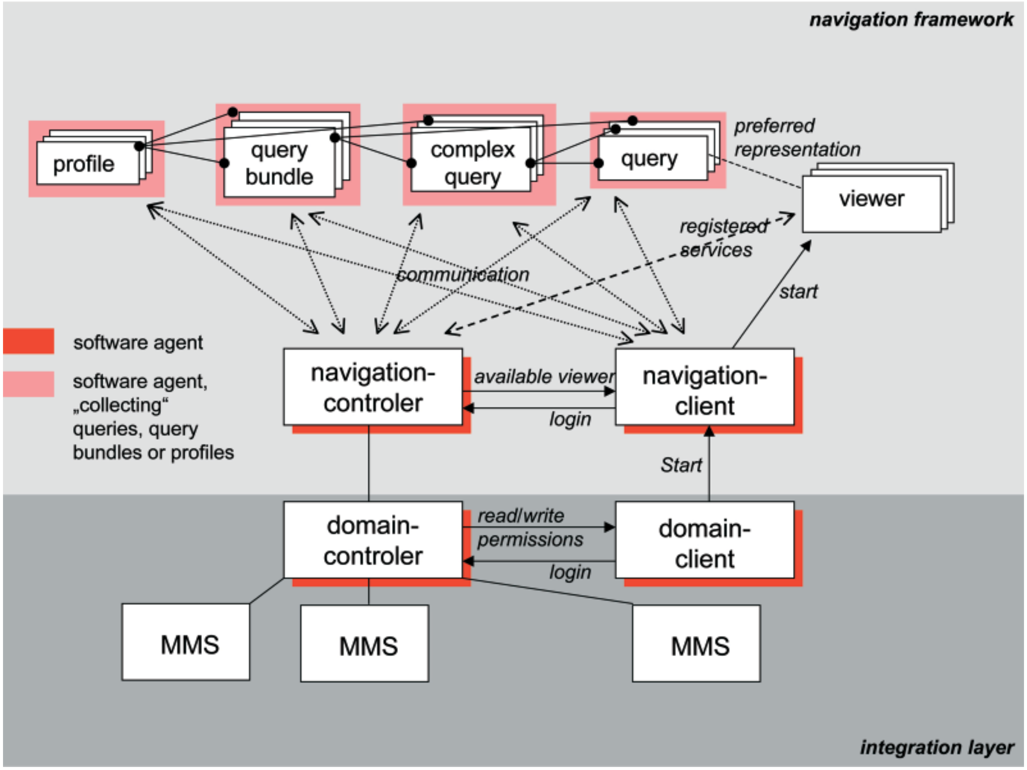

Figure 4. System architecture of the integration and navigation layer .

Conclusion and Prospects

In this paper we have described an approach for an integrated platform for information retrieval across the entire life cycle of a building using a digital building model as a basis. The system architecture developed for the data and integration layers was described and problems associated with information provision for supporting decisions were examined. Based on the demands identified, an approach for a navigation and online search layer has been formulated.

The next step involves verifying the proposed concept in prototypical implementations, as well as the preliminary realisation of appropriate navigation modules. The framework as described represents only the first stage of the navigation layer, i.e. the elementary prerequisites necessary for realising and integrating individual viewer and navigation/search tools.

Two primary issues present themselves in this next stage of realisation: In order to support exploratory visual navigation it will be necessary to graphically present the domain model (incl. any dynamically occurring modifications). This could be achieved through a further model in the model-constellation for visually representing applicable geometric objects. The link-based modelling approach is a suitable starting point for defining the necessary transfer logic.

In addition, automatic and semi-automatic techniques for helping the user to define re-usable information retrieval queries (queries, filters, profiles) should be examined and supported. We expect that user trials and observation will uncover a series of different approaches

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