GIS-FUNCTIONALITY FOR BUILDING MODEL INTEGRATION AND ANALYSIS

Heiko Willenbacher[1], Reinhard Hübler[2], and Katrin Wender[3]

ABSTRACT

A successful information exchange between the processes, their participants and the involved software is a necessity for the efficient work on the complex planning processes in the building lifecycle. The identification of existing dependencies between the processes is a prerequisite for that. Within a descriptive oriented building model approach for this, a process-spanning, spatial analysis, which focuses on the geometry and topology of the objects, can make an important contribution.

The presented research work focuses on the conception and realization of a 3D GIS component as a basis for the identification of relations between elements of different partial models. This component is able to apply the known spatial analyses that are offered by geographic information systems (GIS) for 3D building objects.

On the other hand the paper shows, how this component is included in the concept of a descriptive object oriented integrated planning environment for the building lifecycle. Here, with the help of the agent technology, the component is used as a part of an “intelligent building element”, to inform about or to recognize changes in its environment.

The result is a very flexible building information system, which contributes to an efficient decision making by the improvement of the cooperation and communication.

KEY WORDS

building model integration, building information system, process integration, geographic information systems, spatial analyses

[1] Chair in Information and Knowledge Engineering, Bauhaus-Universität Weimar University, 99421 Weimar, Germany, Phone +49-3643-584262, FAX +49-3643-584265, heiko.willenbacher@informatik.uni-weimar.de

[2] Chair in Information and Knowledge Engineering, Bauhaus-Universität Weimar University, 99421 Weimar, Germany, Phone +49-3643-584261, FAX +49-3643-584265, reinhard.huebler@informatik.uni-weimar.de

[3] Chair in Information and Knowledge Engineering, Bauhaus-Universität Weimar University, 99421 Weimar, Germany, Phone +49-3643-584292, FAX +49-3643-584265, katrin.wender@bauing.uni-weimar.de

MOTIVATION

The processes in the lifecycle of a building and especially in the planning oriented phases become more and more complex. So, there is a specialization of the involved participants and the related software. The several processes can not be managed independently. Within the most processes there is a need of information from parallel or earlier processed tasks.

Therefore information in terms of data has to be exchanged between the processes and consequently between the participants and software, too. The currently used software systems (“islands of automation”) (Eastman 1999) as well as the way the participants work are not suitable for this situation in the building life cycle. The necessary data exchange between the processes is presently not realizable because of the very different views of the participants and the different formats of the data they use.

BASICS

The coordinated integration of the several processes and of their participants and software is the fundamental way to improve the cooperation and communication in the building lifecycle. There are two main possibilities:

- Integration by a process model – Here the processes are described by their tasks, the persons who solve the tasks and by the data which are needed and / or created. Due to the low structured processes and the fact that it is impossible to define all information requirements at startup, this way is nearly impossible to realize.
- Integration by product model (building model) – The structured description of the building that has to be planned, erected or revitalized is the basis of the integration. The building is represented as a ”virtual building” inside the computer and all participants and software access this model to provide or to get information.

The integration by a building model is generally accepted (STEP – IFC). The main problem here is the a priori and complete definition of the virtual building by adequate structures (classes, database schemata). Either the model becomes to complex to handle or there are not enough elements to store the necessary data.

GENERAL APPROACH

The descriptive modeling of a building as the basis for the process integration can be seen as a general approach to improve the cooperation and communication (Willenbacher 2002). The above mentioned problems with the definition of a general accepted building model depend especially on the complexity and the non deterministic data structures. In the context of the Collaborative Research Center 524 “Materials and Structures in Revitalization of Buildings” a new way of building model definition and management was developed, which minimizes these problems. This generic, dynamical integration approach is briefly detailed.

CONCEPTION – MODEL MANAGEMENT SYSTEM (MMS) BASED INEGRATION APPROACH

In this approach the building model is a building model compound. The compound consists of different domain and process specific partial models. The numbers of partial models as well as their combinations vary during life time of the building. The individual partial models are object-oriented structured. However neither the classes nor their attributes and relations to other classes are fixed. The several elements (classes, relations, attributes) and the whole structure (structure of the meta level) are modifiable during runtime. This capability of changing the meta level during runtime is denoted as the dynamic of the approach.

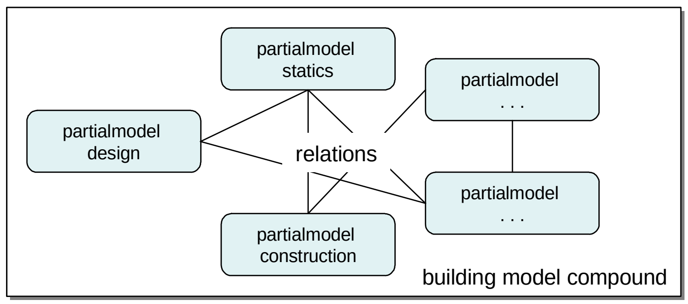

Figure 1: concept of the mms based building model compound

The compound of partial models evolves from a user defined relation structure between the partial models (s. figure 1). The relations (links) are defined between elements of the partial models like classes, instances, attributes, values …) (Willenbacher 2004). These links represent the dependencies between the several elements, which mainly results from the different views of the processes and participants in the building life cycle. The main task of these links is to inform about changes on source elements and to propagate the affects of changes to target elements. So the links make an important contribution to the improvement of the cooperation and communication in building life cycle.

REALIZATION - MMS BASED INEGRATION APPROACH

This conception is realized by special model management systems (mms). For every partial model a mms is used to manage the structures and data and especially to provide the functionality for the access and the handling of the described dynamic. A special application programming interface exists for the handling of the dynamic which is able to operate on the meta as well as on the data level. This interface is called AKO (s. figure 2).

The compound of the partial models is realized by an on top of AKO operating agent based management layer. The agents observe the source elements. In case of relevant changes on the source elements the agents perform the specific transforming logic, which belongs to the related links of the source elements.

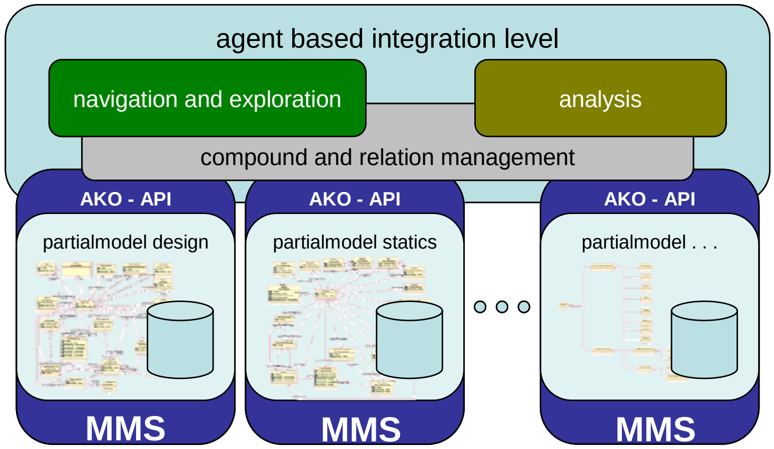

Figure 2: system realization of the mms based integration approach

PROBLEM

By reasons of its conception and realization the described approach can be optimal used as a descriptive data integration system for the whole building life cycle. The generic model and data access allows the combination of arbitrary dynamically modifiable partial models.

Besides the reduced possibilities to provide predefined algorithms for calculations or representations (drawing) the main problem is to find the dependencies between the elements of different partial models.

In a former phase of the research project possibilities and technologies were already investigated, which supports the generic model mapping. Methods were tested, which aim at the recognition of similarities between the attributes or the relations of the elements. That was especially experimented on the 3D representation of elements (Willenbacher and Hübler 2003).

These methods support a planner in finding relations between elements but the expressions about the semantic of a relation are too weak.

THE GIS IDEA AS A KEY TO DEPENDENCY IDENTIFICATION

As a solution for the problem of finding relations between dependent elements of different models geographic information systems (GIS) were investigated, because there are a lot of similarities in the conception of modern GIS and our research work. It is the way how data of different data sources are combined by spatial analysis methods, which makes GIS technology so interesting for our approach. These spatial analysis methods should be used to identify relations between elements of different partial models inside our building model compound.

GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems are used to manage, represent and to analyze data with geographical or spatial references. Real world objects are represented in the computer. The referencing to the objects is done by their geographic position. The representation of the objects is strongly abstracted by simple geometrical features like point, line or polygon. The objects can contain more data in terms of additional attributes, which can be used in different queries and filters.

The particularity of GIS in opposition to DBMS or information retrieval systems is their ability to find relations between objects on the basis of their geometry and topology by spatial analysis.

Modern GIS are based on the warehouse concept. Thereby GIS are able to access very different data sources and formats. GIS are able to represent all the data together and to use the different data for comprehensive and complex analysis and queries. The queries to the warehouse are mostly realized by the generic SQL (structured query language).

SPATIAL ANALYSIS FOR THE IDENTIFICATION OF RELATED ELEMENTS

Spatial analysis methods, how are used in GIS, are very interesting for the problem of finding relations between elements in a descriptive building model.

Spatial filters like:

- in distance of,
- touched,
- intersects,
- contains,
- are contained by

are powerful instruments to identify related objects in different views of different planers. With the help of such filters generic questions can be answered, like:

- are there openings from a different planner in a wall
- are there constructive connections
- are there cables or wires in or on a wall
- are there some special elements on a floor and so on?

By these defined relations between elements a planner working on one partial model can be informed about changes on elements in other partial models. That’s a very good and necessary way to improve the whole planning and to reduce mistakes and inconsistencies.

INVESTIGATION OF EXITING GIS

GIS are very similar to our approach especially by these two aspects:

- integration of different independent data sources and
- generic data access.

For that reason in a first step existing GIS were investigated whether these systems are suitable to be a basis for our integration and management layer for the building life cycle.

The partial models of our building model compound were integrated in the GIS in the natural way GIS should be used or by the help of the different application programming interfaces of the systems. For representation purposes the elements were used which were offered by the different systems. Geomedia Professional only offers 2D representation objects like point, line and polygon (s. figure 3).

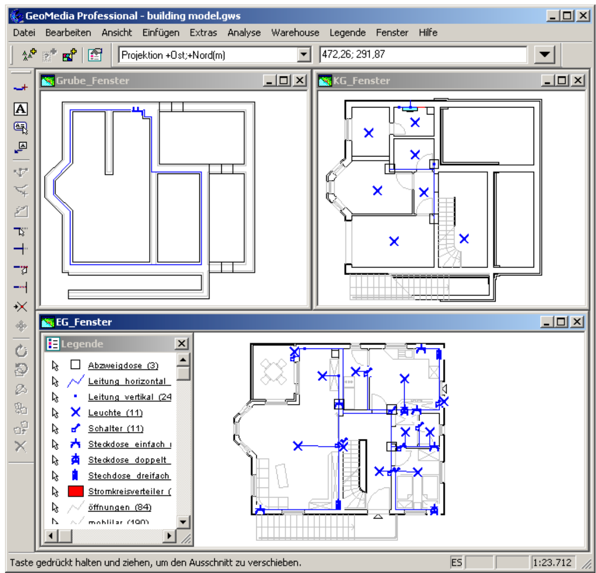

Figure 3: 2D representaton of building mdel data in a GIS

In ESRI ArcGIS and the extension 3D Analyst it is possible to define 3D objects as representations of the building elements (s. figure 4). This representation is more suitable for the work of the planner, because it is very much easier to analyze elements and to navigate through the virtual building.

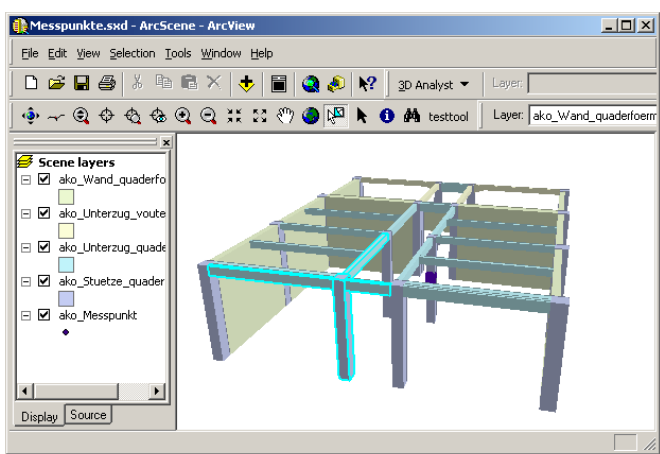

Figure 4: 3D represenation of building model data in a GIS

GIS offers a lot of functionality for analyzing elements and spatial relations between elements. There is a lot of functionality for changing and switching views by a layer technique and the use of very different symbols and styles.

However the main problem of existing GIS is the lack of 3D analysis functionality. All the sophisticated analysis methods like intersection and so on are only working in 2D.

In addition GIS and especially the API of these systems do not offer the necessary functionality to support the dynamic of our approach or to support the change notification and propagation.

For that reasons GIS are not suitable to be the technological basis of our integrated building model. However spatial analyses are so important for the identification of relations between elements that we decided to concept and to realize our own 3D spatial analysis component.

COMPONENT FOR 3D SPATIAL ANALYSES OF BUILDING MODELS

A component was developed, which offers the 3D spatial analysis methods and which is able to mange and to represent the objects of a building model as 3D objects (s. figure 5). For that several geometry descriptions are available. In our approach the objects can be defined by the BRep (boundary representation) or by the CSG (constructive solid geometry) model.

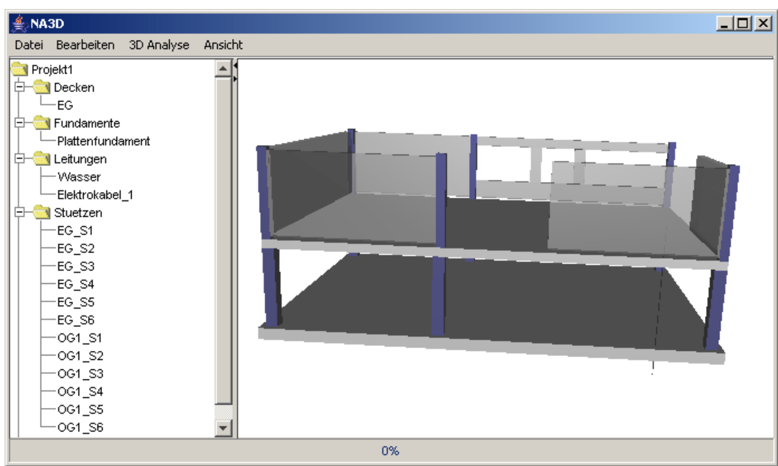

Figure 5: 3D spatial analyses and represenatation component

The most important functionality of the components is formed by the ability to analyze the geometry and the topology of the objects (Weiß 2005). Three different kinds of analyses can be distinguished:

- Object analyses: By the analyses of the geometry of a single object some calculations are made like: volume, surface, centre of gravity.
- Relation anylyses: These analyses include selections of topological related objects. There are spatial filters like: touch, overlapp, contained by, contains and in distance with.

- Intersection analyses: This third category contains spatial operators like intersection, union and difference to generate new geometries (objects).

BRep and CSG are not suitable to realize especially the operations of the last two categories. For that reason all objects that should be analyzed are transformed into another geometrical representation. For the analyses a cell decomposition method (e.g. Coors and Zipf 2005) is used. With the objects as small cells the analyses functions can be efficiently executed on the basis of quantity operations.

INTEGRATION SCENARIO

There are two ways this component is integrated into our system concept. The first way is to use this component as a 3D viewer and analysis module in our framework for navigation and exploration of building information. This approach is represented in another paper (Wender et al. 2006) at this conference.

In a second way this component is used to inform about changes on spatially related elements in a building model environment. Therefore the component is realized as an agent in our multi agent system. For every building element of the different partial models can be decided whether such a spatial agent should be used to observe this element and its environment. For that reason the agent has to be installed on the element and the agent has to be configured to state, which objects should be informed in case of a change that is which spatial filter should be used to identify the related objects.

CONCLUSIONS

The suggested approach of integrating spatial analyses in our integrated building model management system to find more relations between elements of different partial models is a very important step. By the use of spatial filters and operation like touch, in distance with or e.g. intersections much more expression and knowledge about the relationships can be extracted in our generic and dynamic environment.

Especially the use of the 3D spatial component as a part of the agent base management leads to an improved cooperation and communication between different planners. The agents as part of the intelligent building elements recognize changes on their elements and propagate these to potentially affected elements of their environment according to the configured settings.

So planner and the related software systems can be immediately informed about changes on other elements in other partial models (processes).

This is an important contribution to minimize mistakes and inconsistencies during building life cycle.

REFERENCES

Eastman, C.M. (1999). Building Product Models: Computer Environments Supporting Design and Construction. CRC Press LLC

Willenbacher, H. (2002). Interaktive verknüpfungsbasierte Bauwerksmodellierung als Integrationsplattform für den Bauwerkslebenszyklus, doctoral thesis, bauhaus-university weimar

Willenbacher, H. and Hübler, R. (2004) Intelligent Link Management for the Support of Integration in Building Life Cycle X^{th} ICCCBE 2004, Weimar

Willenbacher, H. and Hübler, R. and Koch, C. (2003) Intelligentes Verknüpfungsmanagement am Beispiel einer 3D_Visualisierung. IKM 2003, Weimar

Weiß, T. (2005) Theoretische und praktische Untersuchung 3 dimensionaler Analysefunktionalität im Kontext dynamischer Modellverwaltungssysteme, dilpmoa thesis, Bauhaus-Universität university, Weimar

Coors, V. and Zipf, A. (ed.) (2005) 3D-Geoinformationssysteme, Grundlagen und Anwendungen, Herbert Wichmann Verlag, Hüthig GmbH & Co. KG, Heidelberg

Wender, K. and Hübler, R. and Willenbacher, H.(2006) Information retrieval in building life cycle – modular navigation tools for a dynamic integration base, abstract accepted at this conference