The IMAP principle in Building Information Systems

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SUMMARY

Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology [IFMA Definition]. CAFM Systems (Computer Aided Facility Management) store data in order to support facility managers in making decisions and in efficiently communicating the information. Input, Management, Analysis and data Presentation (IMAP) are the main functional components in any Information system. The IMAP principle is well known to the GIS community. What are the concrete functional components of a CAFM System?
How are these components related? How can CAFM developers benefit from GIS and Surveying knowledge?

These questions will be discussed with respect to a new developed CAFM System. This system mainly focuses on a simple but consistent data acquisition. Based on new parameterization of geometry and the consequent usage of topology, the functional components of management, analysis and presentation had to be redesigned as well. Most CAFM Systems store alphanumerical information in databases or spreadsheets and associate drawing files that keep the geometry of floor plans. However, a main advantage of the presented new approach is its integration of geometry and thematic data.

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1. INTRODUCTION

Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology [IFMA Definition]. Spatiotemporal Information is the appropriate reference frame for Integration. Having a time related topology and geometry of the built environment, any FM (Facilities Management) participant is able to annotate additional information to the Building Information Model (BIM). Today, geometric and topologic data of the building structure are often not available or not up to date. Furthermore, these data, if present, are given heterogeneously. Input data vary from scanned floor plans to vectorised drawing models. Using CAD, the semantics of drawing elements is modelled with discrete layers. But the mapping from "meaning" to "layer" is not standardised. Moreover does "drawing exchange" prevent the specification of topologic relationships and object composition. The International Alliance for Interoperability [IAI] addresses this problem by defining the IFC (*Industry Foundation Classes*), a model based and object oriented schema to describe structures and processes in BIM. Besides this industry driven modelling activity lots of academic institutions, for example [DFG 1103][CIFE], are working on schema integration and workflow management in building construction and facility engineering. Theses approaches assume that the geometry and topology of already existing buildings is in place - ready for calculation and visualisation. It is neglected, that the real world has to be measured. In practical applications, the absence of an integrated "surveying engineering domain" in existing data models avoids for example a nominal/actual comparison or the specification of accuracy and correctness. FM-projects fail because traditional data acquisition is much too expensive, especially if the building model has to be maintained frequently.

In [Gründig 2002][Gielsdorf 2006][Clemen 2005] a new modelling approach was presented. The following assertions recapitulate the main ideas:

- The topology of a building structure is the leading information and is modelled as a cell-complex. (0-cell = vertex, 1-cell=edge, 2-cell = mesh, 3-cell = solid)
- Geometric form functions are assigned to 2-cells.
- Relative measurements specify the parameters of the form functions indirectly.

Within a planning, construction and maintenance activities, topologic information changes less frequently than geometric or thematic information does. A wall's width, for example, is more often modified than the topologic information, that it encloses a certain room. Applying version management and simulation to a building model, it is useful to have an N:M cardinality between geometry and topology.

Relative measurements, like distance between parallel meshes or angles are modelled as random variables, because no measurement is ever infinitely exact. Any observation is mathematically described as a function of the unknown form parameters. The entirety of all observation equations is an equation system. If there are not enough observations, the geometry of the building structure is not to be determined. If the minimum number of observations for solving the equation system is exceeded there are two ways to use this over parameterisation. Either measurement values are classified as “determining” or “controlling” measure or all measurements are used to estimate the “best fitting” result, considering the measuring accuracy. The second practice is called adjustment. Adjustment technique, usually using the least squares adjustment, provides indications of quality for both, input data (measurements, constraints) and output data (form parameters). In order to keep the equation system small, which also means to keep the number of necessary measurements small, a plane based parameterisation is introduced. Additionally, geometric constraints like parallelism and perpendicularity are described implicit.

This approach does not end in itself. It allows a simple but consistent data acquisition. This article exemplifies how certain aspects of the CAFM’s functional components Input, Management, Analysis and Presentation differ from common approaches. While considering CAFM as an information system, we focus on the building structure.

2. INPUT

In GIS input data are categorized as primary or secondary data. Primary base data are measurements for example terrestrial survey, GPS – base lines or satellite images. Primary thematic data are polls or collected statistics. Secondary base data are scanned maps or already existing vector data sets. Secondary thematic data are for example administrative statistics. This article is focusing on geometric and topological primary data in CAFM. In the following the input functionality is discussed for topology, observations and thematic data.

2.1. Topology

The main paradigm of the described approach is that topology is the leading information. The process of specifying the topology is informally spoken “sketching”, because it is not a geometric exact drawing. Several approaches have been tested in order to find a simple user – interface that supports a consistent topology specification. An idealistic or approximate geometric representation has to be calculated in order to visualize the topology. Note, that the geometric representation of the specified topology is not used for any geometric calculation on the building model. It is only needed for visualization. One approach, for topological sketching” uses the ACIS [ACIS 2001] geometry modeller and the HOOPS [HOOPS] OpenGL visualisation.

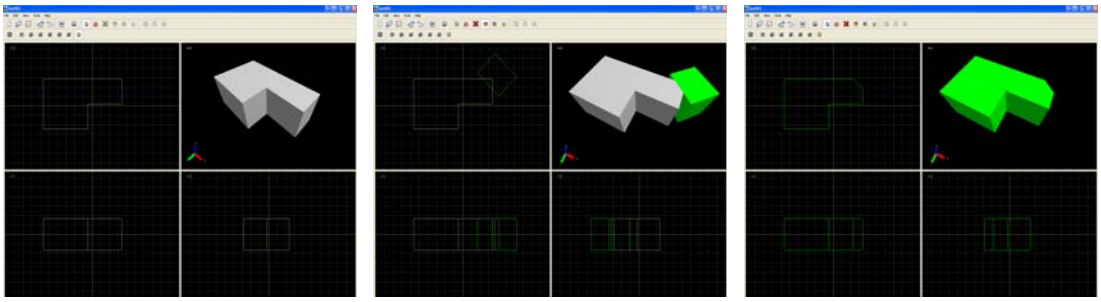

Fig 1. CSG modelling with 4 views using ACIS/HOOPS

Here, the user specifies volumetric primitives and arranges them with geometric transformations (translation and rotation). In order to have the topology for one single solid, boolean operations (union, difference and intersection) are applied to the solids. This type of modelling technique is called "Constructive Solid Geometry" (CSG). The ACIS Modeller translates the CSG-Model to a Boundary-representation (B-Rep) and checks weather the topological integrity is given or not. In a next step an algorithm maps the ACIS B-Rep model to the new developed schema. CSG modelling is well known by civil engineers and architects but not intuitively understandable.

Another prototype for interactive 3D topology specification has been implemented. The topologic structure is defined by sketching a 2D polygon, which is afterwards extruded along the normal of a 3D drawing plane. The 3D-drawing plane can be specified by a special selection mode (pink arrow in Fig 2.)

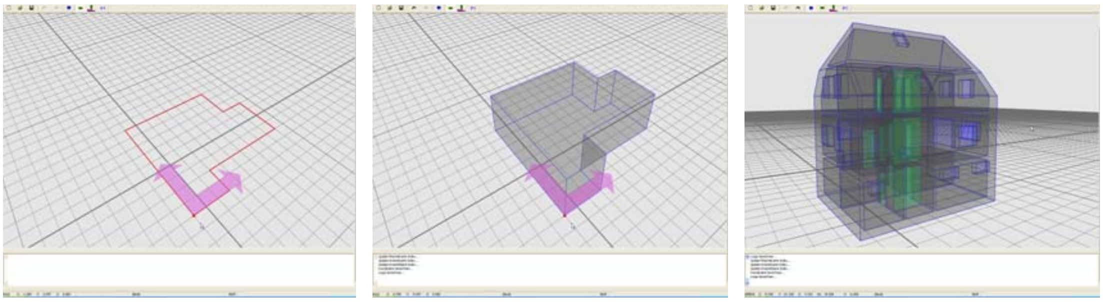

Fig 2. Sketching topology in three dimensions

This application is easy to apply. The internal data management does not use any third party geometry modeller. The inserted rooms are represented in the intended data model. The result of the topology specification is a set of vertices, edges, meshes and spaces that fulfil constraints concerning the referential integrity, the topologic constraints (Euler-Poincaré relation) and the data model's structure. Please note again, that so far no geometric information had been specified.

2.2. Observations

Relative measurements specify the parameters of the form functions indirectly. In contrast to traditional "point based" observations, our approach does directly connect measurement values with plane-parameters. That’s why we could avoid the time consuming action of aiming a discrete point target that represents an edge of the built structure. This accelerates both, the “real world” measurement and the graphical input to the information system. A tool was implemented [NICHELMANN 2007] that allows the user to insert relative distance measures. The software supports the user in defining the observation topology and the measurement values.

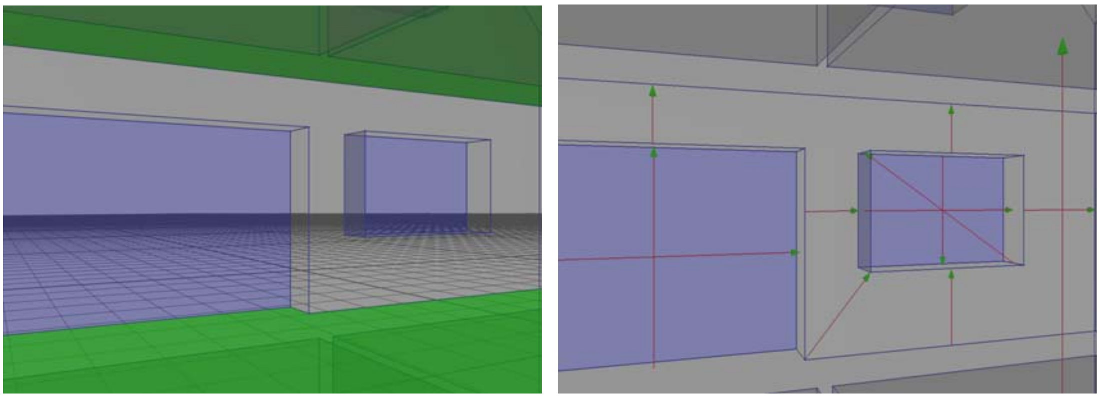

Fig 3. 3D Selection (right) and Specification of observations (left) [NICHELMANN 2007]

An OpenGL based 3D-Selection-Mode for topological elements has been developed (see green elements in Fig 3.) and several algorithms from the “computational geometry domain” have been implemented. The software is to receive the measurement value from Leica’s handheld laser instruments (Disto A6) via BlueTooth [Leica 2006][Kersten 2007]. Further exploration will introduce polar measurements from total stations and pre-processed laser scanning data to this interactive 3D Tool.

2.3. Thematic Data

Geometry and Topology constitute the Building Structure. This information is considered to be the reference frame for any other data. While the schema for the build structure is static the thematic information model is a subject to change. Depending on the project’s demands, the requirements range from simple room related attributes to sophisticated graph based schedule tools. Due to the variability of the thematic schema it is not useful to implement a static input dialog for these kinds of data. Having two XML Schemas, one (static) for the building structure and one (variable) that is modelling the thematic application domain, the required entity types can be joint in a XForm model. The input’s form representation can be specified with XSL.

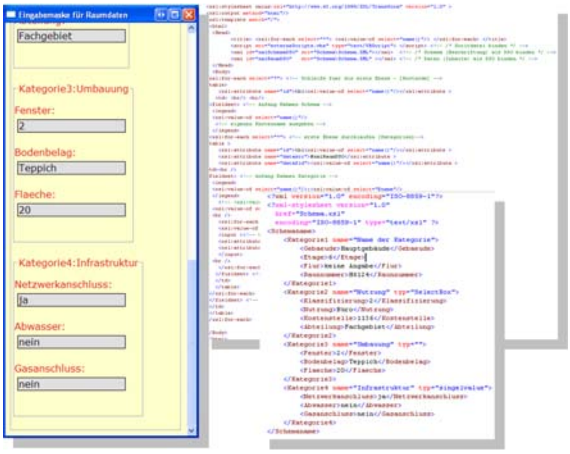

Fig 4. HTA-Form, XSL-Presentation Schema and XML-Data (simple room related attributes)

Further exploration will focus on semantically richer models and better usability. Especially when designing user interfaces for FM data collection, the appliance must be intuitively understandable and time consuming interaction must be avoided. The application should integrate the ability to define FM related application domain schemas (XSD) and the corresponding input forms (XForm, XSL).

3. MANAGEMENT

The described new approach has several impacts on the functional component “management”. Even though the semantic of the new model is similar to traditional data models (vertex, edge, mesh, room and point, line, surface, solid) the structure differs. Traditional approaches associate geometry with topology on the 0-cell level: Every vertex (0-cell) is assigned to a 3D point, which constitutes the geometry. In the discussed model this association is done on a higher dimension. Geometric form functions are assigned to 2-cells. This has an impact on how to manage the data. Point-coordinates are no longer stored as primary data in a relation (table). Instead of that, point coordinates are a view on the data, they are calculated on demand. As long as planes are used for form function, this algorithm is implemented as a simple SQL-statement. The topology defines which planes intersect.

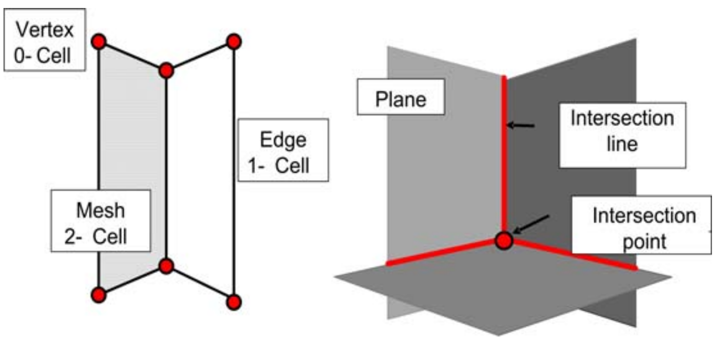

Fig 5. Topology defines which planes intersect. Point coordinateds are views

Beside the building's topologic structure the measurements are stored as primary data. Note, that measurements define relative dimensions, whereas the parameters of the form function describe the absolute geometry. The plane parameters are calculated by means of adjustment.
Due to the observations' redundancy and the stochastic model, quality measures of both, observations and absolute-geometric parameters can be determined (estimated). In terms of "functional components" the adjustment tool belongs to the intersection set of "Management" and "Analysis". Determining the absolute geometry belongs to the "management" function, whereas the estimation of quality measures belongs to the "analysis" component. Spoken in a data base terminology, the process of adjustment is a "long transaction".

Basically, two schema definitions are used in the existing prototypes: Relational data base DDL and XML-Schema. In Fig 6. both data definitions are illustrated.

Fig 6. XML Schema and SQL-DDL Definition of the Model

Within the data management component both data models use standard validation tool. Referential Integrity is checked by the DBMS. Standard XML Parsers allow validating XML data files against given XML Schema. Note, that geometric and topological integrity can not be expressed by means of referential integrity only. Additional algorithms are applied at run time to assure consistency.

4. ANALYSIS

In any information system, the „Analysis" component generates new information by means of integration. In GIS applications "Analysis" constitutes spatial interrelationships. In the following four domains are discussed: Observation analysis, geometric analysis, topologic analysis, thematic analysis.

The Observation analysis checks the availability of the requisite measurements and consistency of observation topology. The post adjustment module investigates the correctness of the stochastical and functional model, the accuracy and the inner and outer reliability. The results are used to support user decisions, for example in examine, whether further measurements are to be measured. These modules are already implemented.

Geometric analysis provides for example surface areas of composed floor meshes like storey area or window area. For instance, the coplanarity of façade elements can be easily tested due to the plane-based parameterisation of geometry. Note, that stochastic information is attached to any geometric parameter. Tests do not simply use threshold values, but methods of statistical testing theory.

Topological Analysis answer questions like “how many rooms do I have to traverse in order to go from room A to room B”. This is important for escape route planning or indoor navigation. In [HUHNT / GIELSDORF 2006] the described model is the base for the denotation objects in a building. Here it is shown, that denotation and classification can be specified by the civil engineer during the construction process without referring any geometric elements.

Further investigations are to be carried out on thematic analysis. Issues under consideration are for example room management, where statistic like “lodger per square”, “cleaning cost per zone” or “roaming of WLAN” can be applied.

5. PRESENTATION

In Fig. 2 and Fig. 3 the three dimensional presentation of the buildings structure and the observations is shown. The “Presentation” or “Visualisation” component benefits from the discussed topologic and geometric model. The implemented 3D Tool uses OpenGL for rendering. In order to apply lighting models, any polygon is attached with a plane normal. Having “point-based” geometry models, the normal vector has to be calculated. In the discussed geometry model, the normal of any plane is given within the model and can be send to the Graphic Processing Unit (GPU) without any further computation.

The implemented 3D Tool supports 2D projections and several 3D visualisation modes.

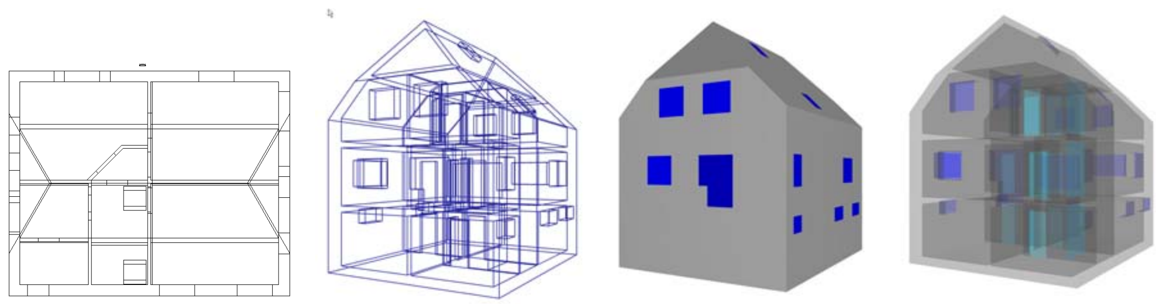

Fig 7. 2D Projection and 3D Display Modes

Further investigations are to be undertaken regarding the visualisation of analysis results. For example should the software enable the user to explore post adjustment analysis results visually.

6. CONCLUSION AND OUTLOOK

The impact on Input, Management, Analysis and Presentation was discussed by examples. Ongoing research activities have been described. Further efforts will explore richer semantic models, temporal models and surfaces of higher order. The article gave a glimpse on how different functional components of a Building Information System are affected by introducing a new data model. Therefore we can conclude that the new data model is useful for practical issues.

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BIOGRAPHICAL NOTES

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