Computer-Aided Building Modeling

- **a couple of viewpoints,**
- **a bunch of standards and**
- **a lot of tools**

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Abstract

The subject of computer-aided building modeling is often discussed in various contexts, sometimes without clear explanation of what is modelled. Usually modeling refers to 3-dimensional geometric modeling, but nowadays also conceptual modeling and mathematical simulation aspects are more and more evident. Building modeling should though be considered more widely than just plain geometric visualization. This paper establishes one common framework for discussion about different building modeling viewpoints arranging discipline viewpoints, approach methods, existing standards and application tools within one context. Although several viewpoints are declared, conceptual building modeling is regarded the main emphasis of this paper, since it definitely will be one of the key issues in developing methods and tools for computer integrated construction (CIC) in the future.

The Beginning

Building data is in this paper understood as covering all the possible building information. This means all the data in a project during it's whole life cycle, no matter whether earliest design ideas, concerning construction process, component details or maintenance years.

The nature of these data-items varies from abstract outlining concepts, such as a building envelope or spatial openness, to concrete building components, such as walls, windows, columns and beams. The refinement of the items from rough outlines to exact details is also evident. The amount of data is naturally growing all the time from earliest user needs, up to smallest details in working drawings.

All the information can be described as digitized data in computerized form, if needed. Already today's tools will allow digitizing of whatsoever data, and this will also be the case in the future, when the term computer-integrated construction (CIC) is regarded as a normal situation, even if the term is not used, but it is obvious.

A model overall is an abstraction or simplified artificial image of some important or interesting features of reality. just some features, cause pointing them out and modeling them clearly helps understanding their nature. *A building model* hence is an image of some of building's features. The model is always a projection of the building and it is inspected just by some of it's features, some of chosen viewpoints.

One guideline to help follow through this text is to find the juxtapositions of some self-evident poles, such as hardware and software, or theory and practise. Also the refinement of information offers a general guideline to understand this approach.

- a couple of - a bunch of - a lot of.

The Viewpoints

Bills of materials and cost estimation are good examples of clearly sectored viewpoints to building information. Both examples consider one covering view to all information, but just from one limited aspect. Most application software, such as calculation programs, offer also limited capabilities to handle building information, either expensies, volumes, heat losses and gains, or CAD-systems even graphical images such as lines, arcs and text, but seldom programs offer all of these together. In creating a general context about building modeling, one single building model covering all the needed and, even more idealistic, all the possible viewpoints of a building is probably an unattainable goal, but it is an ideal research target anyway.

Construction Disciplines

One single wall in a certain building.
Architect's wall is still totally different than constructor's wall.

The education and occupation of a person forms his viewpoint to building information. Even if people are talking about a same building component, such as a certain wall, the views tend do differ quite a lot from each others.

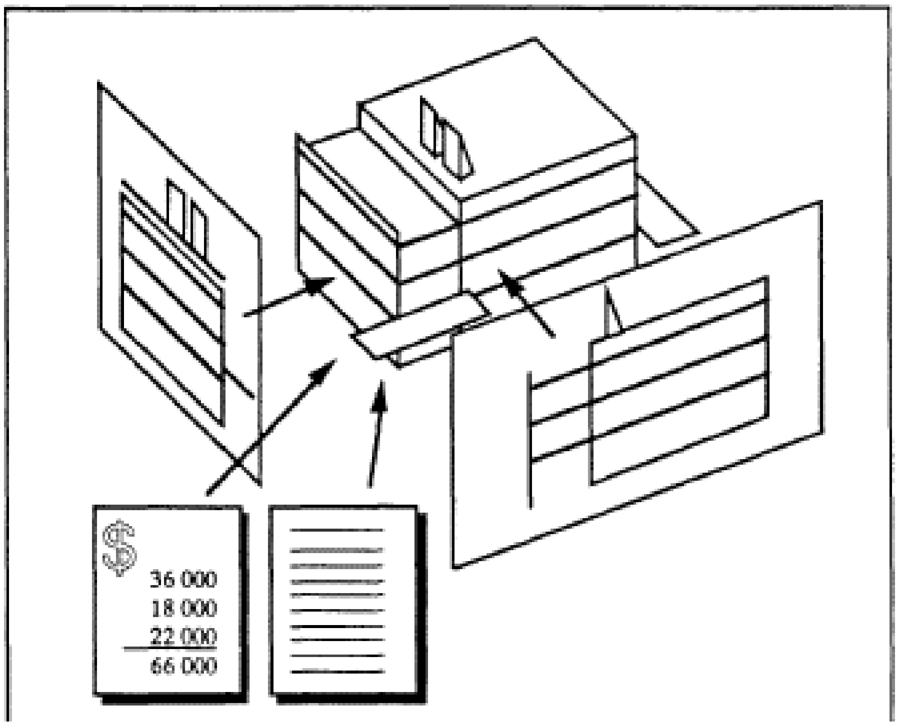

Figure 1. The discipline viewpoints cover projections of building data such as facades are projections of buildings visual form.

The design team deals mostly with ideal data of yet unfinished work - it is working to create a model of the building. Architect has to create design solutions which will match functionally and visually to clients' and users' needs. Building's functional performance can nowadays be mathematically analysed and simulated,[*] but the data needed for lighting analysis or energy consumption about one single wall is again different. Additionally to describe wall's visual characteristics needs another kind of data - another kind of building model. Construction engineer also needs different attributes and a different model to describe walls strength and structural features.

Builders in construction companies have to deal with real materials, real resources, work, and combine sometimes ideal design solutions with these practical facts. Their work is also very tightly tied to time. All actions on site and in the factories are guided by a time schedule. Mathematical *functional modeling,* such as IDEF0,(IDEF0) for example, is needed to describe all the work and it's variables in a process to produce a network or procedure of actions which erects the building.

Manufacturers' and materials producers' viewpoint is very product oriented. Products' materials and features are important, not so much their context in a building. Re-

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[*] see Building Simulation

search and development in this field has lead to product *modeling,* which means describing all product's parts as sub-parts and forming the product structure, the product's topology.

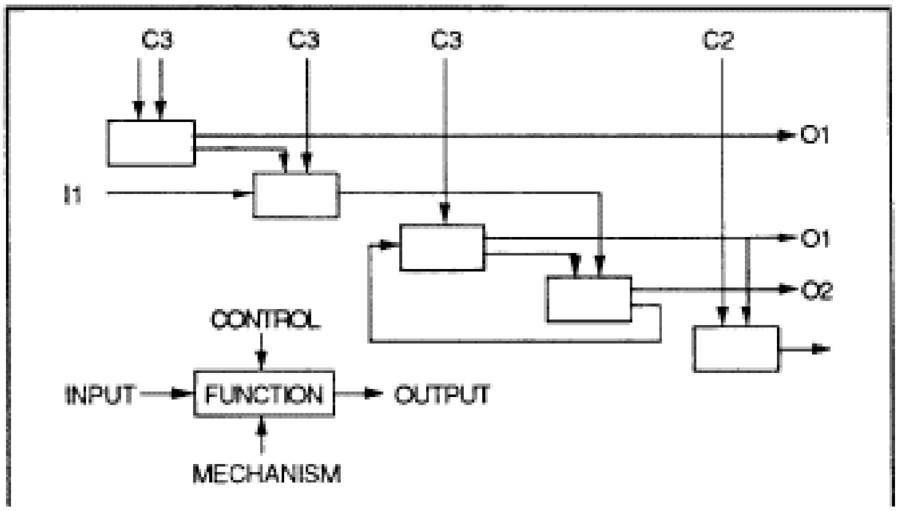

Figure 2. A schematic drawing of a process flowchart (IDEF0).

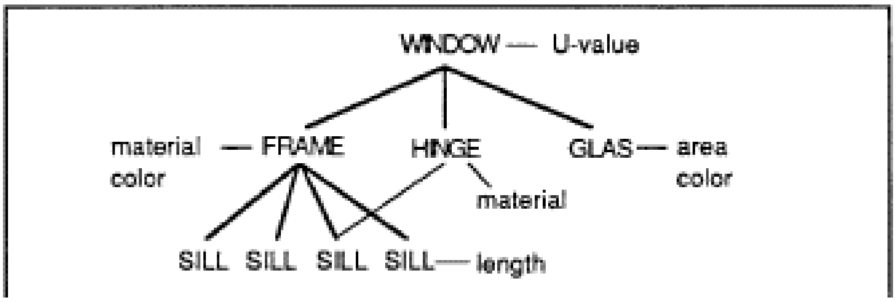

Figure 3. A schematic drawing of a hierarchical product model of a window.

In conclusion all the disciplines and viewpoints would like to use a building model which best would describe a building from their aspect - naturally. Combining all these into a single computerized model would although give us an advantage in using all the data so far gathered in the project, and avoid overlapping of data. A widely used, some kind of slogan "loosely couple databases" has manifested lately that a centralized building model couldn't be created at all, but at the same time a trend in combining different modeling strategies is also noticeable. (Gielingh, Turner, Björk)

Generalization and Characterization

The abstraction of building information allows a general tool to cut the information content into smaller slices. High level summary-kind-of overviews of building data are necessary to master the project and guide it in connection with it's surroundings, but insufficient when dealing with details. *Generalization is* a conceptual tool to gather the most important information from part's sub-parts to form a *composite object* of building information. General aspects tend to be more abstract. Detail level design produces also so much data, that some generalization is necessary to control the totality. When generalizating, one loses some details.

Characterization additionally is a tool to define more subpart objects to a building object. It is a tool to refine the data and create details. When characterizing, one always loses some overview, since it is hard to handle several approach scales at the same time.

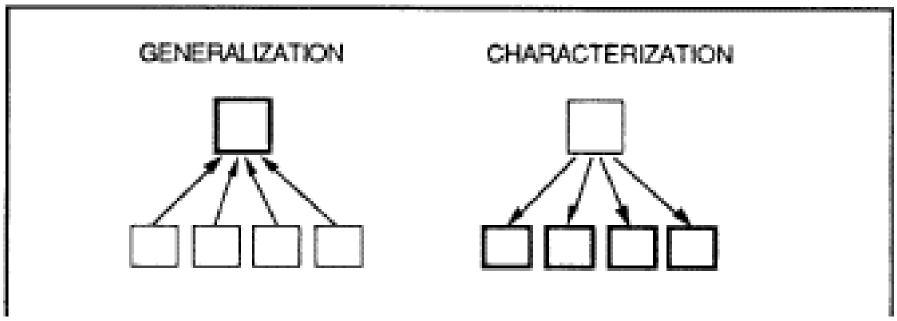

Figure 4. Generalization and characterization.

Viewpoints should be seen as some selected collections of the mass of building data. Different viewpoints can even contain incorrect data when compared with each others, but if all viewpoints could be combined, a general and comprehensive building data model could be created.

Theoretical vs. Practical Approaches

There is no use of theory without practise. Construction field especially is so material dependant, that practical results should always be the final aim of our work - even if working with buildings' modeling. Modeling and computerized methods especially need to be inspected also from a more theoretical viewpoint, to produce common and sensible results. *The complexity of a building,* seen as a process or as a product, has during the time being proved to be extremely difficult to handle without any theoretical or abstract model about it. The amount of participants in construction processes, and the amount of pure data is so huge, that general rules in *information exchange* have sometimes been hard to follow. Difficulties in coordinating the information flows makes it even more important to create some kind of general building model.

Defining a construction area information system and all information flows in it, is the first step to produce practical construction area software application tools. Information intents, user needs and viewpoints have to be established in the beginning. Information items have then to be modeled into computable data-items. If information flows and purity in data modeling is quite theoretical, dealing with actual computer software is very practical with clear aims in using data efficiently in digitized form. Practise needs theory, and theory needs practise to be approved.

Conceptual Modeling

A conceptual building model is a research and development goal to produce a working information basis for construction field. Within the field of conceptual modeling concepts are described as concepts, object classes or entity types. (Danner) *Concept* refers merely to generalizations than building object instances. To define a conceptual model of, say, a building, requires not just concepts but also their *properties.*

A concept WINDOW has a properties U-VALUE and WINDOW AREA.

Another important tool in conceptual modeling is the ability to define *relations* between concepts, and create a structural network or hierarchy of concepts.

A concept WINDOW has a connection to a concept WALL.

Common methods have been developed for conceptual information model in g. (Brodie) For example methods EntityRelationship model (E-R model), Nijssen Information Analysis Method (NIAM) and IDEF1X offer standardized techniques and symbolic visualization graphics to describe the features of reality in a conceptual model.

Standards

Some organizations, such as the International Standardization Organization ISO, are at the moment developing conceptual models for construction area. General AEC Reference Model (GARM)(Gielingh) and Building Systems' Model (Turner) are abstract structures to define a building by defining all it's components and their numerous relations to each others. Both are developed under ISO's STEP/PDES[*] effort. STEP/PDES will probably reach a status of international standard by 1991 or 1992.

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[*] STEP = Standard for the Exchange of Product Data
PDES = Product Data Exchange Specification, which follows the US IGES-effort
IGES = Initial Graphics Exchange Standard

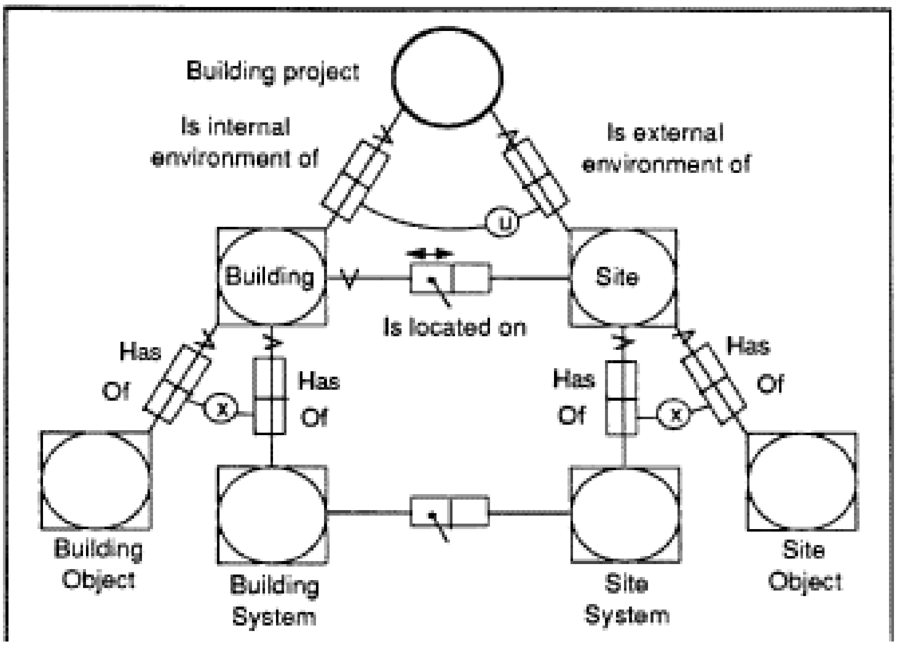

Figure 5. Example of a NIAM-diagram describing a building project. (Turner)

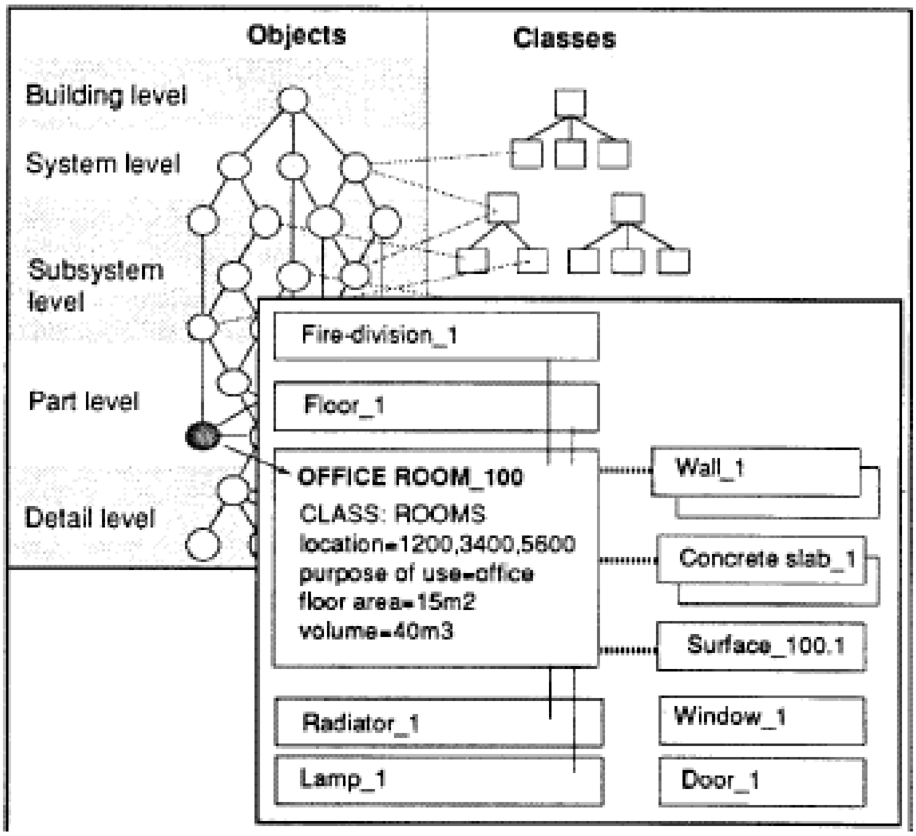

Figure 6. Overall view of the RATAS Building Product Model.

A Finnish RATAS Building Product Model is another similar conceptual structure to offer tools for the whole construction field to handle digitized building data in the future.[(Björk)] RATAS is so far not intended to become a standard, but merely work as a general guideline for researchers, software developers and users and construction companies to increase their effectivity in CIC.

These conceptual building models all share a quite abstract approach to construction area practise, so applications of theory are also needed to make use of these models.

Software Tools

Several software products allow usable tools to bring conceptual model structures into practical model solutions and equipment to really work with. Conceptual model is useless if there is not equipment to apply it into. Information models seem also to act like common information sharing methods, to form more or less neutral basis for building data exchange.

Software applications applicable to the construction field could be classified to alphanumeric or graphic software products. *Alphanumeric* (a/n) applications, such as calculation programs or databases can deal with building components' alphanumeric information. Several data models, such as hierarchical, network or relational models, have been used to define database structures. *Graphical* programs, such as CAD-programs have tools to describe components' graphic properties. CAD-systems' data models tend to be very file oriented - a drawing is a file. *Knowledge* engineering has produced tools to manage for example rule-based information - knowledge - which could be seen as a different method to structure data, not just in alphanumeric strings.

Software tools tend to tie their users' flexibility in defining and using the building data. Software tools, i.e. application programs, such as 2-D drafting software or database applications, include either implicitly a description of a building, or they simply don't have it at all. The description of building elements, such as walls, windows, etc., could be seen as a building model.

If a building model exists in some form in the application, the building data has to be input with this existing framework, and it is often very difficult to change these pre-set options. If there doesn't exist any building model, as it most often seems to be, it either has to be created with software tools, or it just "will be implicitly behind the data" on an abstract level, without any kind of precise definition.

Geometric Modeling

A geometric model is a collection of real life objects' geometric features, such as location in space, geometric form or visual features, such as color, invisibility, etc. Geometric models are used to visualise or analyse some of these characteristics. Building modeling is most often connected just with geometric modeling.

2-D Drafting

CAD-systems offer tools to create 2-dimensional drawings with basic graphic primitives such as lines, arcs, curves or text-elements. The elements can be modified, cut, joined and moved and they can also be combined into larger primitive groups, often called symbols or blocks. A common method to structure this 2-D drawing data, is to put it into separate "drawing layers" which then can be viewed as needed - all together or selected.

Drafting systems are mainly used to produce working drawings substituting hand drawing, since their features seem to match best into this work. Some other additional features and tools, such as micro programming capabilities or a/n attributes have though made it possible to use the software also in other design tasks, which entitles one to use the term CAD-system.

A building model created with a 2-D drafting system is a collection of symbolic graphical elements organized into discipline layers and stored in a file. Drawings are separated from each other, i.e. wall's projections usually don't have a link to each other. One can really not talk about a building model, since it is as implicite as in hand made drawings. One could call a digitized drawing file a building model, but several features described above in conceptual modeling still misses.

3-D Modeling

CAD-systems to offer tools for spatial elements, whether points, lines or "real 3-D spatial objects", such as cubes or cylinders, add one dimension to drafting. Still in symbolic form, building elements can be described more realistic, especially if one can add some extra visualising features, such as colors, light, shading or material's texture.

Some CAD-systems offer a combined 2-D - 3-D capability, to describe the geometric model better, but seem to lack descriptive textual features, calculation capabilities or tools to relate elements to each other, for instance to relate a window to a wall.

A model created with a common 3-D CAD-system is purely a geometric model with information about geometric basic primitives - just symbolically representing building components or concepts.

Building Simulation

Mathematical simulation provides models to analyse and simulate building performance. If simulating energy consumption, an energy model has to be created. If simulating lighting, a specified model has to be created. Acoustics again need a complicated mathematical model of it's own.

Object-oriented programming methods have been applied at least to energy simulation during the last years. In some cases also coupling energy simulation software with commercial CAD-systems or geometric modeller has been tested.

One of the targets of the Finnish RATAS model is to act as a general database also for simulation data. No matter whether energy consumption or acoustical absorption, features of a building component can be stored into the component's data structure and evaluated with simulation software. The results of an analysis can then be stored in a higher level object, such as the *energy consumption of a building* (per one year) is an attribute to an object called A BUILDING.

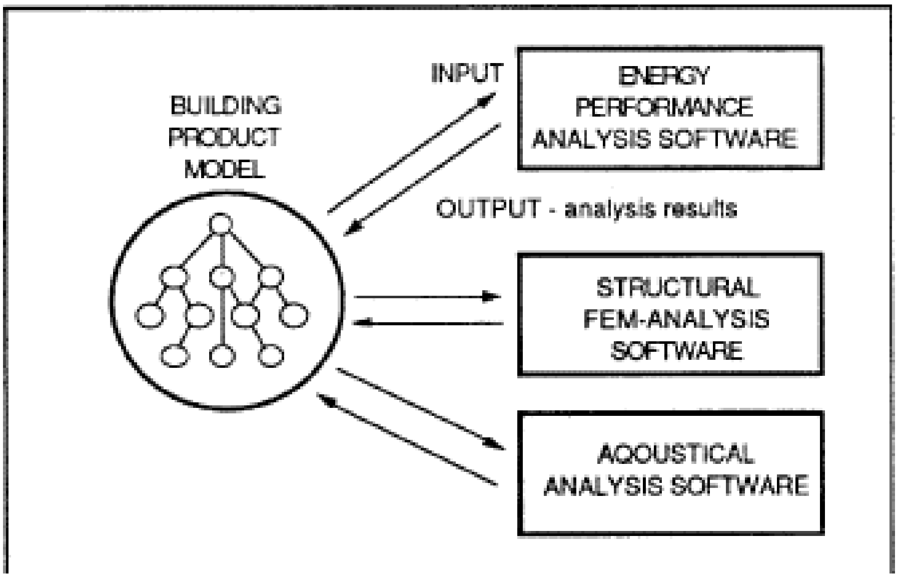

Figure 7. A schematic vision or simulation programs and a building model. Programs find their input-data from the model and store the analysing results as output-data back into a single building model.

The Conclusions

As seen, all modeling aspects seem to treat a building with different methods and structuring tools. Hence a general common building model should be established to unify the syntax when dealing with building information as digitized data. A clear vision and understanding of the information should be the basis to create the model, and it should be done without too tight connections to practical software applications, at least in the beginning, since the tools seem to guide working too much.

The variety of different software applications and their digitized tools at market confuses often construction people. Just buying software doesn't solve our actual problems in dealing with building information - the problems or tasks to perform have to be formulated first, and the details have to be worked out after that.

Since a building model is an abstraction of some features of reality, modeling very often offers a restricted view of all the building data. To keep track of all the digitized building data, requires currently several different models of building data. On an application software level these models may be impossible to combine, but on a more abstract conceptual level general building models already exist.

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