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Methods for the classification of building components in CAD systems

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Abstract

This paper describes and analyzes methods and systems for the classification, sorting and searching for the information created during the designing of a building. On the basis of a CAD model (product-model), drawings, lists of quantities, data for calculations, etc. can be generated. This presupposes a structured division of the information which together makes up the CAD model. In this paper, some principles for the classification, search and processing of design data, are discussed. A point of departure for this paper is that some of the questions in regarding product modelling has more to do with the classification of design data and the cognitive aspects of classification, than with the development of computer technologies as such.

In our joint research project at the Royal Institute of Technology and FFNS Ltd we have used the GDS CAD system and the swedish classification system BSAB to study these problems. A final report of this project has been published (Lundberg, Lundequist, Lotz 1990).

In this paper, some fundamental concepts of product modelling have been investigated. After that the paper discusses the logical and psychological principles of classification. The paper ends with some proposals for the future development of CAD product modelling.

The design of a building with the support of computer aided product modelling, makes special demands on the classification of data vital to that project. The objective of the research project presented here has been to arrive at rational principles for the classification, search and processing of the data which is needed.

Key concepts

CAD model, product model, classification, calculation, object oriented CAD, building design.

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Introduction

In this paper, some principles for the classification, search and processing of design data, are discussed. The design of a building with the support of computer aided product modelling, makes special demands on the classification of data vital to that project. The objective of the research project presented here has been to arrive at rational principles for the classification, search and processing of the data which is needed.

The background to the basic question to be discussed here is:

* Into which structures ought one to feed data so that the product model can be rationally used as a tool in architectural design?

Other important questions are:

* What should the breakdown of information be?
* What is a psychologically suitable basis for the breakdown?
* Which are the smallest possible bits of information which can be processed rationally?

The traditional design process presupposes a continuous degree of *determination*[1].

The *design loop* therefore ought to be a characteristic of all CAD systems, which means that the process of design ought to be characterized by systematic interaction and *feedback* between drawing, description, estimation of quantities and calculation.

Here follows an example of a possible loop:

Quantities are derived on the basis of the available drawings and delivered to the calculator for a preliminary calculation of costs. This data will then be commented on and the quantities and drawings will be economically evaluated, before the architect or structural engineer is contacted again to make certain changes to the design of the building. Thereafter the architect or structural engineer will make certain changes (though not necessarily those desired by the calculator) and will produce new data for the calculator to work on. In this way, by interaction, communication, development and processing of the project under construction, CAD can reinforce the process of design at successive levels of decision-making.

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[1] Determination is an extensive and complicated concept. It includes, e.g. "cause", "factor", "reason" and "motive". A number of determinations "lead to" event E. They are the factors that together make E possible. Sometimes one also says that an individual, NN, had the following reasons for doing E or for allowing E to occur. NN's motives then was that he wanted E to be done. Of significance, in this connection, is that there were a number of determinations which together provided the necessary and sufficient conditions for E. When determining products, this can be formulated as "the determinations, $d_1 \dots d_n$, are the reason or the cause for the product P to have the properties $p_1 \dots p_n$".

The term 'conceptual modelling of a building project' is used to mean: -Those PMs, calculations, drawings, CAD drawings, etc. which are derived during the process of design and which together make a product model of the developing building. By *product model* is meant all the available data on the project. This product model should be stored in the storage device of the CAD system, in such a way that it is simple to gain access to information on the building in the form of projections. These projections can be represented in different ways, like lists, drawings, descriptive text, etc.

A significant part of CAD design work is also to define each *object*. It is important for all who participate in a project to use the same system of subdivision and classification, since the designers use each others' drawings as a basis for their own work.

In the future many CAD system will be built up round *relational data bases*, a network of data sets connected to each other in different types of relations. For CAD this means that every *object* can be allocated a number of *relations* which clearly indicate where, when and in which way the object occurs in the CAD model. Then one stores defined building components, etc. as objects in a data base. Object properties can be linked to each object and it is possible to define the relations which apply between all the objects.

To be able to use the relational data base, objects ought to be classified as belonging to several different structures, i.e. there should be networks of relations between objects. In principle, a *structure* is a sorting concept, where a number of objects, 'a, b, c ... n' are related to each other in a pattern. The principle is based on the same object being able to fit into a large number of structures. Sometimes the term *class* is used instead, when one wants to say that each object can belong to several classes. A *coding system* is used to represent the structures and to be able to search in the data base.

The classification of objects ought to be so simple that it is not unnecessarily restrictive for CAD designers but should still include all the parts, components and functions of a building in the classification.

It is perfectly possible to make detailed *estimations of quantities* with the assistance of CAD, but that this requires a considerable overelaboration of the CAD model, compared to the amount of work required for simply doing a drawing.

Precision in estimating quantities depends on how detailed the descriptions are. But there is always a certain degree of discrepancy in this kind of estimating. One is unlikely to arrive at a higher degree of certainty than 95% of the correct amount. It is not worth the effort to check the entire file, so that completely accurate quantities are derived. It is, however, in principle possible to do this, if it should prove to be necessary.

For *calculations* in the early phases, one would like to apply a 20 - 80% rule for the precision and coverage of the materials. From the perspective of the calculator, the primary concern is to include all the relevant posts, even if they are not precise. The quickest way to do this is to roughly estimate directly from the drawing to provide a very preliminary review of the costs. Accuracy in making the calculation does not necessarily grow in proportion to the number of variables.

Classifying

The task of the designer is to present information on the building project in the form of drawings, descriptions, lists and specifications. This information should prescribe, describe and determine the attributes of the building as exhaustively, accurately and didactically as possible [2].

* To be exhaustive, the information must incorporate all the relevant facts;
* To be accurate, the information may not include inconsistent facts, (e.g. a component should have the same measurements every time it is presented);
* To be didactic, the volume of information in a presentation must be as small as possible, it should be easy to grasp and it should be sub-divided and structured to fit the needs of the recipient.

One classifies material in order to structure and order it when it is otherwise difficult to survey.[3] Often

[2] See Alchourron and Bulygin, 1971, pp. 5-17, 44-81, 149, 167-170.

[3] Principles of class logics according to Rosing, 1984, pp. 87-94.

one would like to create a structure to which one can add elements as they arise. Classification means that one divides the material into *classes*. Objects which occur in the material must be assigned to the adequate class. The term 'class' is here used to refer to a number of specific objects.

Objects ought to be classified according to specified principles. One such, is the principle that a certain number of objects with a specific qualities in common belong to the same class.

It is important to be able to delimit the class in a clear and simple way. Sometimes one can be satisfied by simply counting the number of objects in that class. The class of all fruit includes apples, bananas, pears, etc. Enumerating objects is time-consuming and complicated, which means that it is preferable to define the principle which determines whether an object belongs to a particular class or not. Such a principle isolates the relevant criteria or characteristics of the objects. When we try to determine whether a specific object belongs to a specific class, there are often several reasonable criteria to choose between. All these criteria do not necessarily have to apply to all the objects which are regarded as belonging to the same class:

* The objects which belong to the same class are called the members or elements of that class.
* Two classes are said to be mutually exclusive if they do not have a member in common. The class of women is mutually exclusive of the class of men.
* A class is said to have universal coverage if every member of a domain is a member of the same class. Two classes can together have universal coverage: the class of all women together with the class of all men cover the universe or domain of humanity.
* Each class can, in turn, belong to a superior class. Every element in a class may also form a sub-class, with members of its own. This ranking in terms of meta-class, class and sub-class forms a hierarchy. As a rule, a system of classification is hierarchically ordered, with concepts ranked in superior and inferior classes.

There are a few simple rules of thumb for classification:

* Uniform basis for division, i.e. simple and clear criteria for classification;
* Together the classes ought to cover the selected universe;
* The classification ought to be fruitful; its object clearly stated and relevant to the context;
* The hierarchy chosen ought to be clear and logically built up.

To classify is to subdivide things and phenomena around us under general concepts. In this way, apples, plums, pears and bananas, etc, make up the class of fruit. Grouping named phenomena under general concepts in this way forms systems of concepts.

Identification is the kernel of a system of classification. It means that different users must be able to identify the same object as belonging to the same class. In order to facilitate communication, the primary objective of classification, as many as possible within a specialist area should agree on how their system of classification ought to be used.

For coordination it is also necessary that information be organized so that each recipient can rapidly locate what is of interest. It is obvious that the same "language" should be used to name and draw each object, so that it is possible to divide the work between several designers. A system of classification can also provide a model for the division of tasks within projects.

When using CAD, classification, always significant in designing, becomes even more important. Every object that is drawn must be given a name and be ordered in a system of classification. Thereafter the object must be stored in the data base in such a way that it can easily be located and so that it is easy to assemble it together with other components in various combinations

. When designing with GDS, the CAD designer can chose at which level of detail he or she wishes to enter information. One conceivable division into four levels is shown below:

"Level 4" building, section of building, relationship between rooms, area, etc.

"Level 3" rooms, stairs, corridors, outer walls ...

"Level 2" walls, windows, doors ...

"Level 1" lines, points, surfaces ...

Designing with CAD entails that the designer to a great extent has to sort the most important architectural ideas with the aid of the following sorting concepts: time, level, place. The concept "wall" comes in at a certain point in the process of design and at a specific level of detail in the documents as well as in certain places in the building, as specified in the documents.

The levels of the work of calculation are interesting in this context as one can make estimates of the costs of the project with the factor of uncertainty entered. This way of working corresponds to the drawing work of the architect, but with a different kind of division of the stages in the work process.

When determining the product, attempts are also made to establish an hierarchical structure so that superior concepts are ranked at higher levels. The "relation between rooms" is, for instance, a concept that is superior to "room". Thus, it is preferable to solve the questions concerned with the relations between rooms before solving the problems connected with the individual rooms.

Relatively often, however, this order of work must be reversed and elements at the level of relation between rooms must be revised because of events at the level of the room. Feedback between the various levels must always be possible.

It is a classification system's own *search rules* that constitute the system. At the same time these search rules are the rules according to which a designer defines the objects or drawing symbols he would like to feed into the CAD system [4].

The cognitive-psychological basis

Research in cognitive psychology today shows that a whole range of factors ought to be of significance for the design and use of CAD systems. A common error is to load too many tasks onto a CAD operator and to give him or her too much information to deal with at the same time in the same context. Cognitive psychologists have now shown that an individual seldom succeeds in dealing with more than 7 ± 2 bits of information at any one time, which makes it unsuitable to force a CAD designer to deal with information which is too abbreviated or subdivided in too much detail.

Classification ought to be based on a few fairly simple cognitive-psychological principles [5]. Cognitive-psychology deals with human thinking and problem solving: how one can communicate, learn new things and solve problems. Here thinking is defined as the collection, storage and processing of symbols.

The human memory is divided into short- and long-term memory. What is stored in our long-term memory is, in principle, never lost, but may be so difficult to find that we do not have access to data which was once stored in our infinitely large long-term memory. We store our impressions and knowledge in the long-term memory through coding, i.e. through giving a recognisable name or other symbol to each unit in the memory. Coding is often hierarchical. This means, e.g., that we rank concrete concepts like "apple", "banana" and "orange" below a more abstract concept, "fruit".

Our short-term memory is limited. In principle it can only deal with 7 ± 2 meaningful "chunks" of information at any time. It is, however, possible to improve one's short-term memory by recoding

[4] We can, for instance, regard a certain amount of information about a specified building project as being a normative or prescriptive system. Such a system, according to Piaget, has the following characteristics. "A structure ... is a system of transformations... Characteristic for a system is, thus, the three qualities of wholeness, transformation and self-regulation." (Translated from Piaget, 1972.)

Viktor has reformulated this so that the meaning of the term is somewhat easier to grasp: "What constitutes a system as a system are certain notions about the system:

A The system has an independent existence (is a possible object that can be known);

B The system is integrated and consistent (i.e. can be analyzed);

C In principle the system can answer all conceivable questions (even if the answer is that the question is irrelevant). (Viktor, 1977.)

For A above to be valid, it must be possible to make predictions about the system which are true, in some meaning of the word. For B above to be valid, it must be possible to take decisions in accordance with the system. For C above to be valid, the system must include rules on what is dependent and independent of the system, i.e. what is relevant or irrelevant.

[5] Following Waern and Waern, 1984.

memory units. A chunk of information may consist of a single percept or image or it may be holistic or a gestalt, in which a number of perceptions are organized into a meaningful pattern. In our surroundings we grasp, i.e. perceive phenomena, in gestalts and patterns. When, e.g. we remember a person's appearance, we recall the whole rather than the details.

We structure our memorized knowledge, as, for instance, we learn the names of the months of the year in chronological order. Try reciting them in alphabetical order instead! One of the most basic human characteristics is our tendency to organize knowledge and impressions in meaningful structures.

We also want to organize our knowledge at various levels of complexity. The structures we use in our thinking at a higher level need to be so generalized and abstract, i.e. unencumbered by details, that we can concentrate on the relevant problems, for example, the architects' traditional scale of 1:400, 1:200, 1:100, etc.

In reality, before every action, we must first decide to execute that action. This decision is based partly on perceptions gained directly from our surroundings and partly on units or chunks of memory.

In searching through our memories we actively reconstruct the whole chunk of information that is desired. In this work we start with the small fragments which first become accessible and successively build up the whole unit of information.

Herbert Simon formulated a theory about how high competence in a specific field, e.g. playing chess, is linked to an ability to retain a large number of "vocabulary patterns", i.e. subconsciously remembered patterns, in one's long term memory. A very clever chess player sees and recognizes interesting and relevant patterns in the positions of the pieces on the board. The good chess player bases decisions concerning the next moves on knowledge of how to act rationally in a certain position, when a specific pattern appears.It is typical that a competent and experienced professional in almost every conceivable field has a large vocabulary of typical patterns gathered and developed during a long career[6].

Conclusions

Questions relating to the subdivision and classification of information ought to be linked to questions of how a CAD deigner actually thinks, searches for information, solves problems, as well as how he or she presents and reports on problems and solutions.

Building design is intended to succcesively increase the number of attributes, or degree of determination, in a building project as progress is made in its design. Design is a way of "determination of the undetermined".

One ought to adopt a holistic view of design and try to integrate the sequence Drawing - Estimating Quantities - Describing - Calculating with an increasing *degree of determination* of the building project.

A central phase in the work of design is to arrive at a common judgement of the design alternatives that have been produced. *Feedback* is, thus, very important to enable one to judge proposals on a sound basis of calculations and evaluations, which are based on estimations of quantities and preliminary calculations. The process of design ought to be characterized by systematic interaction and feedback between drawing, describing, estimating quantities and calculating. The process of design is not a linear one, but is dependent on continuous *feedback loops* and interaction between various levels of abstraction and phases in the design process.

Designers and others make continuous evaluations of the product model and adjust its properties if necessary. The model of the building project gradually becomes more accurate as different questions are successively dealt with.

As far as possible one ought to trust the perceptual ability of people (i.e. their ability to see and experience the world around them in patterns and wholes), rather than rely on a memory function that is relatively defective and unreliable when it comes to memorizing codes and series of numbers.

The very large amounts of information that are dealt with in the design process can be comfortably dealt with thanks to architects and other building designers being trained in the art of *recognizing patterns and wholes* in the relevant information. Professional competence is displayed in the ability to

[6] According to Peters & Waterman, 1987.

recognize patterns, i.e. in the ability to assess rich and complex amounts of material. Thus it would be unfortunate if CAD technology started to be used to break up the design process into fragments, e.g. by designing the CAD system so that the user cannot use his or her professional competence, which is the ability to survey the whole. It is, thus, important to use as much information as possible in graphic form, at the same time as the CAD designer is not expected to work with bits of information that are too small.

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