Theme:

Title: **An Integrated Platform for Case-based Design**

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Abstract: This paper investigates methods for information management through the rational application of IT within design. Empirical knowledge plays a significant role in the human reasoning process since previous experiences help in understanding and solving new problems. Therefore, we intent to integrate the platforms of case-based reasoning (CBR) and information structures into an information management system for case-based design (CBD). In order to be of practical use, a CBD-system ought to handle all kinds of information created and used during the design process. Although the significance of standard product models is largely recognized today, heterogeneous weakly structured information e.g. construction briefs, calculation documents, 2D-drawings, and raw data: images, audio and video data, is still necessary in a CBD-system. We combine existing techniques (CAD-tools, word processors, WWW, etc.) and standards (IFC, XML, etc.) into a prototype of a tool for supporting the activities of architects and structural engineers. Structured information is represented by IFC; XML manages weakly structured information, while WWW deals with raw data. In this way, the heterogeneous information used in design can be managed and reused and CBD-systems can become a natural and valuable tool for designers.

Keywords: *Case-based reasoning, XML, product models, information structures, weakly structured information, design process*

Background

At present, the actors in the construction industry are aware of the need of effective information sharing during the design, construction, and management process. The segmented construction process causes insufficient feedback from previous projects resulting in loss of knowledge (Kalay 1997 and Lindgren 1992) and a higher cost of failure. In the 1980-ies, IT was mostly associated with the automation of specific tasks and new techniques (Fruchter and Clayton 1993); later on, communication, case-based design (CBD) systems, and shared product and information models were brought to light. In the 1990-ies, the development lead to efforts like ISO 12006-2 (by the International Standardization Organisation) and Industry Foundation Classes (IFC) initiated by the International Alliance for Interoperability.

More than half of the daily work done by designers is routine design that consists of modifying past work (Moore 1993). It should be, therefore, of great use to create a case-base in order to reuse old cases in similar future projects. Nevertheless, the methodology of case-based reasoning (CBR) in design is rarely used, probably due to the problems with structuring the database and finding easy ways for saving and reusing the information i.e. the issue of standards for information exchange.

Today, we should scrutinise our work and ask ourselves what ought to change in our projects. The answers are conceptualised during a pre-project stage of the design and construction process. They are derived analysing and matching the client's needs with the experience of the designers. By integrating these issues in the design process, we can add value to the client through the use of information management systems supporting the reuse of design information.

The research problem

Our research focuses on the rational application of IT in CBD and, especially, on methods for achieving an integrated platform for architects and structural engineers. At this stage, we present a possible way of combining the platforms of information structuring and CBR into an information management system for CBD (Johansson 2000, Popova et al. 2001). Here, the product models are used to structure design information and together with the CBD-methodology to search, retrieve, reuse, and evolve the information. Probably, the most significant feature of CBD is motivating the designers to save structured, reusable information. The general concepts are based on our previous participation in the cross-disciplinary effort *Project Wide Databases* at Chalmers (Johansson 1996, Popova 1997).

Case-based reasoning and case-based design

CBR originates from the cognitive observation that humans often rely on past experience to solve new problems. Schank (1982) created a model describing how case-specific information can be stored in a memory and retrieved when needed. The same knowledge structure is used in remembering, understanding, experiencing, and learning, and it changes as a result of its experience. This model has evolved focusing on indexing, storing cases, and adaptation to new situations thus becoming CBR (Kolodner 1993). Because of the importance of experience in design, many CBD-systems have been implemented for problem solving (Maher et al. 1997). The results have proved that case-specific information and CBR are usable in a design system (Hartvig 1999).

Information structures concerning CBD

Today, we have standard product models like ISO 12006-2 and IFC, and national classification systems such as the BSAB-system in Sweden (BSAB-96 1999). The ISO standard is a frame for information exchange e.g. in CAD, specifications, and cost estimates (ISO 1997). Since it does not contain classification tables, the use of regional and national ones is recommended. The IFC model is a framework of classes for information exchange between computer systems, aiming at software interoperability in the AEC/FM domain.

Design rationale (intent) is the rationale behind decision-making and the information about the design evolution (de la Garza and Oralkan 1995). A conceptual framework for the AEC industry is needed in order to represent this knowledge since it facilitates CBD (Simoff and Maher 1998). At present, ISO 12006-2 and IFC cannot serve as a conceptual framework since they still do not support all the stages in the design process (Ekholm and Tarandi 2000). We believe that the overall goal of the product models should be to assist the activities of the design team (Popova 1997, Turk1998), to allow the creation of new types of objects (Fisher 1994), and to support the evolution of their information structure.

Structured, weakly structured, and raw data

The acquisition of information is a common problem when using integrated information structures and CBD-systems. The alphanumerical and graphical information used by designers is divided into three categories (Simoff and Maher 1998):

- *Structured data*, e.g. information covered by the standardized product models and created by applications promoting their use, attribute-value pairs, relational tables, object-oriented structures;
- *Weakly structured data*, e.g. information not covered by the product models, texts, tables, calculation documents, construction briefs (programmes);
- *Raw data*, e.g. raster and animated images, sketches, audio and video data.

IFC and the national classification systems, such as BSAB 96, deal with structured data. Besides information exchange, IFC enables the information acquisition into a case-base where CBR-sessions can be conducted. Consequently, product models should be used for representing structured data; for weakly structured data, the task is more complicated. Design calculation documents used by structural engineers contain weakly structured information unavailable elsewhere: concepts (e.g. frame), solutions, and, to some extent, the design rationale in the process. Similarly, architects work with weakly structured information in the form of construction briefs (programmes) as well as with raw data. CBD-systems need information from all the groups for CBR-sessions.

XML as a common format for CBD

Usually, a CBD-system needs information from several applications for CBR-sessions, which requires an independent format. Although most CBD-systems can use the ASCII- and the HTML-format there are limitations: values of calculated variables are not stored in the ASCII-format while the equations created by Mathcad are stored as pictures in the HTML-format. The Extensible Markup Language (XML) can solve the problem <www.w3c.org/XML/>. We use the format in our work because it is neutral, flexible, and lets us define our own tags to tag both structured and weakly data. The Mathematical Markup Language (MathML) <www.w3c.org/TR/MathML2> is an XML-application for expressing mathematical notations. As the XML-standard becomes a mature tool with a query language and other useful features, it will most probably replace the ASCII- and the HTML-format.

The work with mapping the EXPRESS-schemas of the IFC product models to XML progresses (Liebich 2000). The project *Application of IFC in Sweden* proves that classification codes can be attached to a CAD-model and the information can be translated into the IFC Part21- and XML-format (Ekholm and Tarandi 2000). The BSAB Demonstrator shows that national classification tables can be structured with XML-tags and texts written in MS Word can be exported as XML-files (Häggström et al. 2000). Once in this format, the information in classification systems and product models can be used together in CBR-sessions. Figure 1 illustrates our concept of the information structure using XML as a common platform:

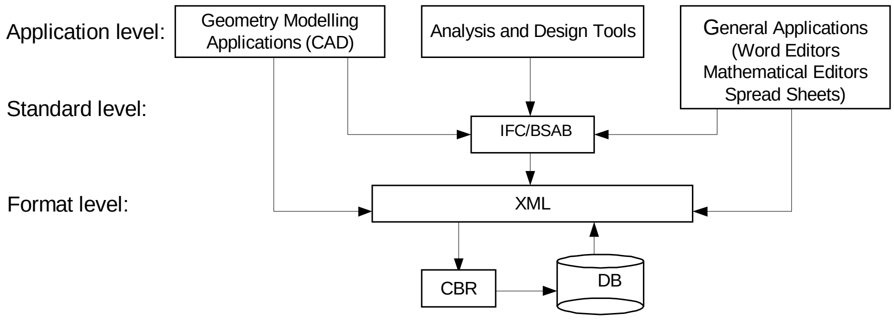


Figure 1. Representation of the information structure

The Prototype Kit of Design Parts

Our work focuses on developing applications based on available technology: WWW, XML, CAD etc., and existing standards: IFC and BSAB 96. The outlined background shows a new way of understanding and dealing with structured, weakly structured, and raw data. It is possible to build a standardised and yet user-friendly information management system for CBD. According to our experience, even persons with limited computer skills can learn the basics and understand the prototype. When fully developed this integrated platform for information management will enable the design team to acquire and reuse structured and weakly structured information from different stages of a building project: construction briefs, calculation documents, and details among other things.

Role of the construction brief

Knowledge about the different aspects of the design and building process can be called the core of the architect's profession. Generally speaking, a professional needs information about the activities and the functions a structure will house, and about the technical basis for the construction. In the earliest stages, the co-ordination of information about conditions, necessities, and visions aims at formulating a construction brief (programme) and producing the first sketches. Conditions and goals in design often change, thus forcing the architect to go back, revise, and reconsider the solution. " Numerous feedback loops-relations between phases along which information about the design situation was seen to flow - were incorporated to account for the observable tracing back through the process in order to respond to new information or difficulties" (Rowe, 1987).

Throughout the design process, the architect explores a wide range of fields in order to define correctly the problems and find a solution. The construction brief is defined as a systematic method for examining and describing the context in which the design is being conducted as well as for identifying the objectives successful design should meet (Duerk 1993). Other researchers go further and state: "The program is the design" (Hershberger, 1999). Yet others with a more process-oriented approach define briefing as a process "throughout the construction project by which means the client's requirements are progressively captured and translated into effect" (Barret and Stanley, 1999). In the course of a project, the designers continuously go back to the construction brief in order to consult it and even revise it.

Many researchers point out that the process of briefing starts when the need for improvement is first recognised and ends after the improvement has been carried out and evaluated (Ryd 2001). None the less, briefing is often regarded as a cost and architects feel pressed to minimise the time spent on conceiving and elaborating the brief. In our opinion, the main reason for this failure is the segmented sector, which still tends to evaluate each project stage separately.

A brief in Swedish design and construction projects usually resembles the structure of the BSAB-system been in use since the 1940-ies (BSAB 96). This suggests that the information should be easy to reuse and the design team should be able to benefit from previous experience. Based on interviews with architects, we have come to the conclusion that there are some factors that hamper the information reuse in future projects. The first is a matter of organising and updating a project archive at the office; the other is the inconsequence in the structure of the information in the briefs. When comparing briefs by Abako Arkitektkontor AB in Gothenburg, a relatively large firm founded in 1979, we noticed that the brief structure had changed a few times over the years making comparison and reuse of information more difficult. Even though the forms for briefs are based on the BSAB-system, we can observe some inconsistency of concepts and headings rendering information reuse by the design team problematic.

Using the BSAB-system

Since the construction brief is an important carrier of weakly structured information more effective ways of structuring and managing the information should be strived after. The first step, in our opinion, should be to use a brief model following the structure of BSAB 96. The model should even respond to the already identified needs for a detailed classification of structures and spaces because spatial design is a central concept in architecture (Häggström et al. 2000). The recently proposed model of a brief (Bergenudd, et al. 2001) based on new research results and recommendations answers well to the needs in new building projects, reconstruction, and facility management. The information structure reflecting the BSAB 96 provides a clearer overview of the brief contents as well as well-defined criteria for information search in a CBD-system. An important characteristic is the ambition to support information and knowledge reuse throughout the life cycle of an artefact: i.e. from concept to post-occupancy.

'Translating' the brief to IFC

Using the new brief model should eliminate the problem of 'translating' briefs authored by different designers before the information can be reused. In an attempt to take the information reuse of construction briefs a step further, we have investigated ways to map a model of a brief based on BSAB 96 to the IFC model. According to our experience, the mapping is fully possible to achieve since the most important concepts are already defined in details in the IFC object-oriented model. In this way, a part of the originally weakly structured information found in a construction brief evolves and becomes structured information. At present, a brief model proposed by Bergenudd (Bergenudd et al 2001) has developed the classification of structures and spaces to a higher level than the IFC-model. Never the less, we are confident that in a near future it will be possible to describe spaces and structures using entirely IFC. At present, most of the information in a construction brief can be represented by IFC and BSAB 96 as structured information while the rest remains as weakly structured. Thus, a CBD-system will acquire chiefly structured information according to the IFC and the BSAB 96 concepts respectively.

Technically, it is done in the following way: a brief model is created as a text file (an MS Word document, for instance) and then saved in the XML-format. The information is divided into headings and subheadings according to IFC and BSAB 96, the concepts not covered by these standards are left as weakly structured. The CBD-system can search in the XML-file and present the information according to IFC and BSAB 96 i.e. as structured information. The information not yet defined by the standards will be presented as weakly structured.

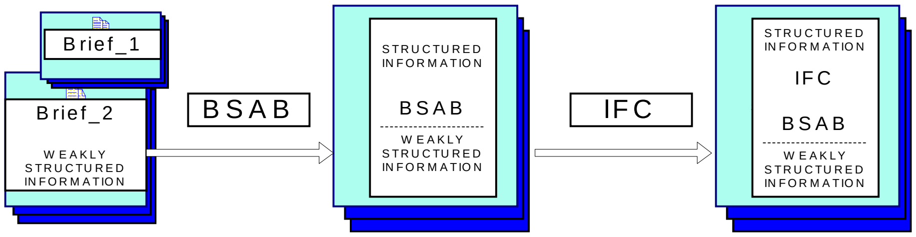
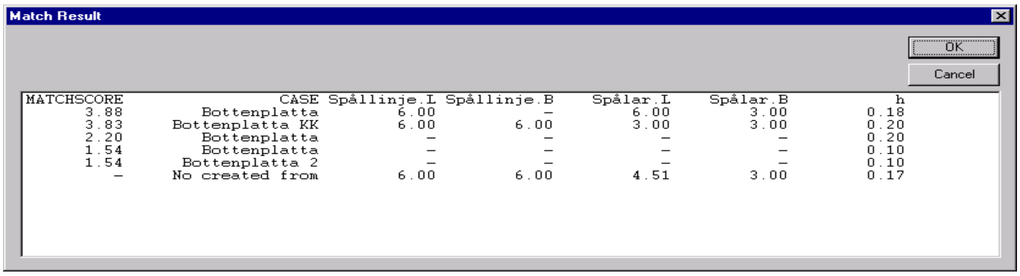


Figure 2. Transforming weakly structured information in construction briefs to structured information.

Design calculation documents

The role of design calculation documents in structural design is analogous to that of the construction brief in architectural design. ARCADE is a prototype investigating how to automate the process of capturing, retrieval, reuse, and evolution of weakly structured data in design calculation documents (Johansson 2000). Also, we have focused on using the process information in these documents in CBD. A document is subdivided into sections by headings on different hierarchical levels. It can contain a list of variable definitions with a name, a physical unit, and a value as well as pictures and comments. ARCADE uses the format of Mathcad 6.0 and acquires cases by using variable definitions, dependency structure, and headings.

Here, the case-base contains calculation documents from six projects done by structural designers in Gothenburg. These documents contain information about the main geometry and the functions of the building (a warehouse) as well as the load calculations. The engineer starts designing the foundation by describing the known and the unknown variables. ARCADE performs a retrieval session by matching relevant old cases where the heading describes the class (concept) of a section (Fig 3).



MATCHSCORE	CASE	Spållinje.L	Spållinje.B	Spålar.L	Spålar.B	h
3.88	Bottenplatta	6.00	–	6.00	3.00	0.18
3.83	Bottenplatta KK	6.00	6.00	3.00	3.00	0.20
2.20	Bottenplatta	–	–	–	–	0.20
1.54	Bottenplatta	–	–	–	–	0.10
1.54	Bottenplatta 2	–	–	–	–	0.10
–	No created from	6.00	6.00	4.51	3.00	0.17

Figure 3. The match results.

The five most similar cases are retrieved. After the matching, two main questions must be answered:

1. *Does the old case contain the information we need?*
2. *Does the document contain the variables that the old case needs defined?*

A goal state match answers the first question; the second – by a footprint match. ARCADE handles these through the dependency structure at acquisition time:

Foundation Slab** (Bottenplatta):** q_{NLk} (Live load) and S_L (Centre distance of the columns at length);

Foundation Slab KK** (Bottenplatta KK)**: q_{NLk} , S_L and S_B (Centre distance of the columns at width).

If the footprint variables from a new case are found in the present design document, the similarity is calculated as that of a member variable. We achieve a better retrieval of information about the design process by using these variables. The value of q_{NLk} in the case *Foundation Slab* gets a higher match score than in *Foundation Slab KK* since it corresponds better to the variable value in the current case. If the structural designer now chooses to reuse the retrieved values, it will be registered by the system as a measure of the case's generality. Thus, the development of ARCADE is a step towards learning in a CBD-system, an important feature for every CBD-tool (Heylighen and Neuckermans 2001).

Reuse of details

A prototype focusing on the reuse of 2D steel details for structural design has been developed and presented as a master's thesis at Chalmers (Kalikauskas 2002). Here, creating a database of old cases and searching in it are fully automated processes not requiring any extra efforts by the designers. The working platform for the prototype has been AutoCAD AD2.0 with the integrated tools AutoLISP and AEC Details; the information is structured using XML. Whenever the structural engineer creates a steel detail, object-oriented information describing it is saved to an XML-file. While working on a new solution in the future, the designer will be able to search the database for similar old cases. A retrieval processor presents the names of the five most suitable examples as well as the respective projects where they have been previously used. Then, a simple click on the best match will open the drawing file and zoom up the selected 2D steel detail. Now, the designer has to decide whether to adapt and reuse the old case in the current project or not. Architectural details can be dealt with in a similar manner. Though some improvements are necessary before the prototype can be used in design projects, it is a step towards an integrated platform in CBD.

A database of about 100 cases is considered sufficient for performing CDR-sessions, which makes the method useful even to small design firms (Schmitt et al. 1997). The database should be easily managed with automatic information acquisition otherwise the designers would find the method time-consuming. Other issues are the routines and the user rights i.e. the consequent use of standards (IFC and BSAB), the systematic storing of design information, editing should be supervised by the project manager; each user should be provided an own space etc.

The final step in our project will be to combine the prototypes into one CBD-system accessible through a common interface (Fig. 4). The system will enable us to perform CBR-sessions by using weakly structured data produced by architects and structural designers. Since both professionals will use the product models in order to structure information, we can expect a higher efficiency and quality of design.

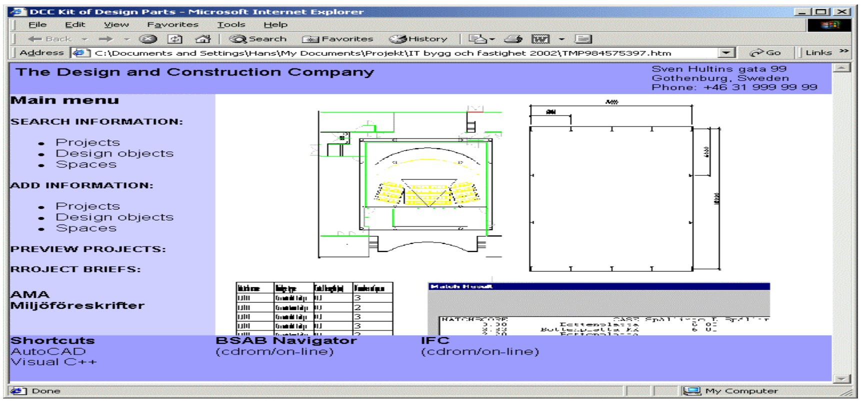


Figure 4. The interface of the Kit of design parts.

Conclusions

Our work so far has shown that the concepts of product models and CBR can support efficient information management in design. CBD-systems cannot replace the designer's expertise but they can manage great information quantities and provide a basis for problem solving. The construction brief plays a significant role in all the phases of the design and construction process thus being an important information carrier to be considered in CBD. ARCADE proves that weakly structured information can be acquired automatically during design and then used for CBR-sessions. It is also possible to store object-oriented information about 2D details and reuse them in CBD.

Every time the information is adapted to a new project it becomes not only more general but also more reusable. Designers should extend their use of integrated product models in order to produce and share information. The systematic use of models and CBD-systems will promote the evolution of the design process, the storage and retrieval of information becoming a natural part. In short, the implementing of new work methods and routines is indispensable for the transition from a sequential building process to a more efficient and an integrated one.

Litterature

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