INFORMATION RETRIEVAL - A CONCEPT OF AN ENGINEERING DATABASE SERVER FOR PREFABRICATED ELEMENTS

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ABSTRACT: A concept for an engineering database server for retrieving information on the use of prefabricated elements will be discussed. The methods for the re-use of design solutions stored in this structural library are based on database technologies for a client-server architecture and advanced concepts of object-oriented modelling techniques. The objective is to optimise the cognitive effort in the early design stage by actively supporting the choice and adaptation of a structural solution depending on the constraints of the design situation. Because of the great number of prefabricated concrete slab floors used in construction we have chosen this very promising domain to demonstrate our model.

KEYWORDS: Information retrieval, Client-Server Database, Routine design

1. INTRODUCTION

In modern building design architects and civil engineers can choose from a great number of standardised elements, prefabricated compound units and structural members with a high influence on cost-effectiveness of building and design. The necessary planning documents with detailed descriptions of the elements are provided by the fabricators. Unfortunately, this information for the choice of structural solutions is not uniformly and well structured and not predeterminable. Therefore a comparison between different solutions on the basis of design criteria (e.g. geometry, structural behavior, physics relating to construction, costs) in the daily design routine is often not justifiable, because it takes a great deal of time.

For this reason, we investigate a concept of an engineering database server using the methods of database technology and object-oriented modelling to support the cognitive process of design. The aim of the project is to provide a goal-directed access to the design criteria for prefabricated compound units and structural members. With the potentialities of network communication the information flow between the suppliers of prefabricated elements and the designers can be essentially improved.

2. OBJECTIVES AND REQUIREMENTS

The knowledge and information transfer by means of network communication gains more and more importance also in the field of architecture and building construction. Since the amount of available design information is steadily increasing it is desirable that design systems support a domain and goal oriented search for the correct and relevant information.

The engineering database server for structural elements is intended to link the product oriented view of the suppliers on the one hand and the requirements of the design situation, which are important for the designer, on the other hand by a homogeneous model. In consequence the existing project

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descriptions are transformed into entities of an entity relationship model. The model is derived from the structure of the given information.

A key requirement for the acceptance of a system of this kind is to enable the manufacturer to make the information related to his products available in the database without special knowledge about the internal data structures.

From the designer's point of view, who uses the access to structural solutions it is important that it is possible to specify requirements given by the actual perceived design situation and, thus, to focus the solution variety. Thereby the available knowledge related to the design solutions in the database should be used as far as possible. Related and similar solutions should be recognised. The result of a query to the system is an overview about advantages and disadvantages of the applicable design solutions and related elements.

For the implementation of a prototype, we investigate the constraints for a library for prefabricated slab floors. However we consider the modelling approach derived for this testbed domain to be useful for the entire range of prefabricated elements as well as for a central inquiry about standardisation rules.

3. ARCHITECTURE OF ENGINEERING CLIENT - SERVER DATABASE

As a concept for an integrated environment of consisting CAD/CAE tools and an engineering server database, which meets the potentialities and requirements of data flow in a network system of connected design agents, we introduce an architecture comprising a central engineering database server, client-tools for the navigation inside the database and a network communication manager.

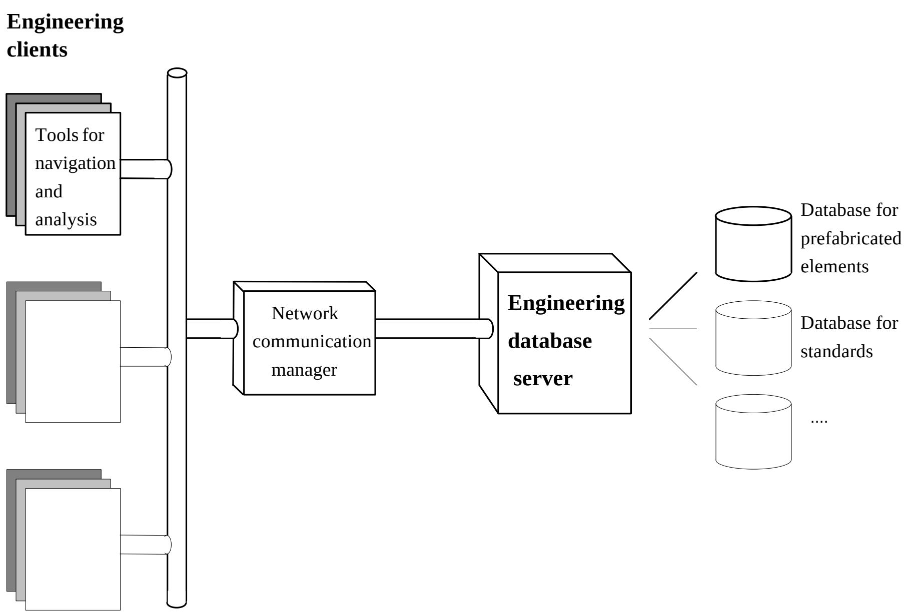

FIG. 1: Scheme of client-server architecture for an engineering database

The following list describes the basic elements of the client-server architecture shown in the figure above:

- On the database server, product oriented data of the prefabricated product elements will be stored as objects mapped onto a relational data model.
- The task of the client tools is to support project oriented inquiry of the designer with means of browsing tools, navigation and estimation algorithms.
- A network communication manager controls the data and information exchange between client and server on the technical level.

3.1 Engineering Database Server - Scheme and Data Structure

A database for storage of prefabricated compound units and structural members is the kernel of the server level of engineering database. The requirements on the concept of this database are determined by the existing product descriptions. The information given by the manufacturers is not in a consistent structure, that means the database model must complete and gather the necessary amount of properties of the solution members and manage different fabricator-dependent views.

In order to reduce the different design aspects to a common determinator for the description, it makes sense to assign the product data to generic tables for managing the different design aspects. The normalisation of the database with design aspects will facilitate the search of design criteria to be compared with the requirements of the design task.

Besides the properties of prefabricated elements, which are described by specific parameters and values, also constructional principles and structural details play an important role for the realisation and efficiency of a design solution. This engineering know-how which is represented in different formats, such as verbal descriptions, CAD-drawings and photographs, should be retrievable in connection with the appropriate prefabricated slab floors.

3.2 Client - Tools for Browsing, Navigation and Estimation

The quality and usefulness of a central engineering database is decisively influenced by the methods that help the designer to navigate through the database and to find a good solution for the design task. We investigate an advanced algorithm for navigation and estimation, which is different from conventional methods for retrieving information from databases, because the algorithm supports a methodical line of actions in the cognitive process of design.

Design with prefabricated elements means the selection of a solution from a number of detailed described alternatives. The problem is the comparison of the properties of the prefabricated elements with the requirements given by the design task. For this process, that is commonly known as routine design, three distinct steps can be identified:

1. The first step is the description of the design task by finding out the requirements and constraints. The more complex the problem is, the more essential it is to support a structured description of aspects of the design by the system. The user should have the possibility to focus the solution space and to bring in his preferences.
2. The process of searching for solutions which fulfil the given constraints should be done by automatically accessing the engineering database. It is necessary to present the possible solutions in a way that allows to gain a fast overview. Similar solutions should be grouped.
3. The final step is the selection of a solution scheme and its adaptation to the given design problem. To support this step credit assignment and estimation algorithms should be provided to obtain a ranking of the possible solutions based on the given relative design requirements.

The above process is not necessarily sequential. The specified requirements might be subject to changes during the specification and selection process. Thus iterations may be necessary to restrict or to extend the set of applicable solutions.

To support a methodical approach to the specification, selection and evaluation process for the user we use a scheme consisting of three different database inspection views. From the user´s point of view these are organised like card index boxes. There is a separate card box for the applicable product examples as well as for requirement definition and for credit assignment. The contents and the predefinitions in the boxes for requirements and credit assignment have an influence on presentation and structure of the solution examples. The navigation mechanism allows to quickly reach an economically and technically justified solution without overlooking any of the feasible alternatives available in the library. The following outlines the used card index metaphor in more detail. The figure below shows the user's view and the used internal model for the client tools.

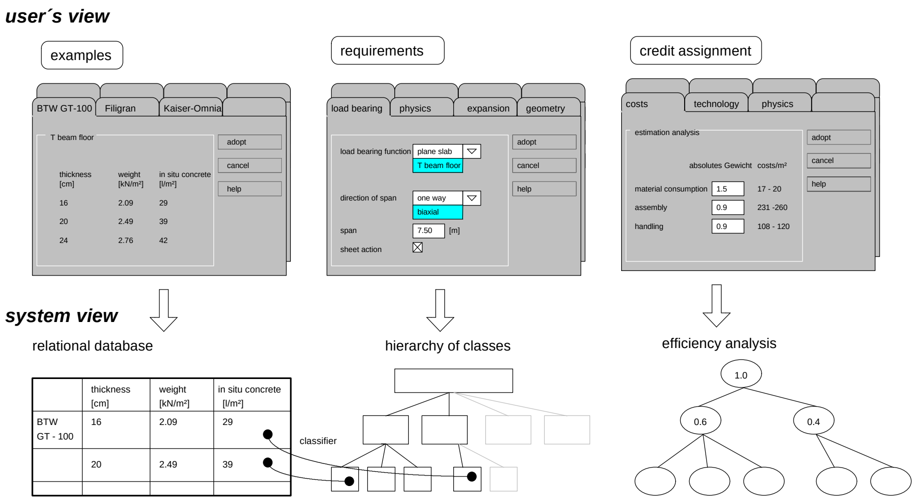

FIG. 2: Navigation through the solution library
with requirements and estimated credit assignment

- <u>Providing of structural solutions</u> takes place in the box "examples". This card index box represents the interface to the engineering server database and will allow to browse through the stored information or to deduce requirements which may be refined with the requirement box.
- For the <u>query by requirements</u> made in the box "requirements", the specification of absolute requirements derived from several structural aspects (load bearing function, physics relating to construction, technology, costs, etc.) is possible. The designer controls the access to the database with the help of the descriptions of constraints, that means the contents in the card index box "examples" will be reduced by all those structural solutions that cannot fulfil the requirements and constraints given. The more exact the specification of the requirements is, the more exact the choice can be realised by the system, i.e. the set of possible solutions is narrowed.
- The method of efficiency analysis is used for the <u>quality estimation of structural solutions</u> in the box "credit assignment". This method is based on a hierarchic structure of criteria subdivided in major goal, minor and partial goals. With a weighing controllable by the designer in the several levels of the goal system an estimation within a credit assignment matrix is carried out. As a result of the estimation process, a reasonably ordered listing of all solutions meeting the absolute requirements is presented.

3.3 Instance centred approach for the transition from relational to object oriented model

Important for the navigation process is the transition from the relational model of the product database to an object-oriented model. This transformation is situated at the transition from the database entities to the presentation in the card index boxes via a mapping to an object-oriented model. A conventional class-centred object-oriented paradigm is not suitable for our approach. Concerning the engineering database server the following particularities can be identified:

- It is not a priori possible to assign a solution category class to a given instance, since the category classes that will be focused by the user are not known at the beginning. The interpretation of the membership in the distinct (partial-) categories must be carried out dynamically after the instance is created.
- The number and type of attributes for the characterisation of the solution instances differ due to manufacturer-dependent structures of the product specifications. Nevertheless it is desirable that instances can be classified independently from subsequently added attributes.
- The common definition of class membership at creation time of an instance does not allow deductive reasoning when evolution of a solution instance takes place. Instance evolution is caused by changing requirements and target categories. To allow deduction a specification mechanism for class membership that explicitly uses logic is necessary.

As a consequence we use an object-oriented paradigm connected with description logic to form an instance-centred approach. Starting with the specification of absolute requirements derived from several structural aspects a dynamic hierarchy of classes is built. Resulting from the requirements a list of classification rules is obtained. These rules serve as means for a classifier to match the object-instances (structural solutions from the database) to the classes. This instance-centred approach allows to create a flexible classification structure. When an instance is classified the default attributes and methods for the analysis of the prefabricated compound units and structural members are assigned.

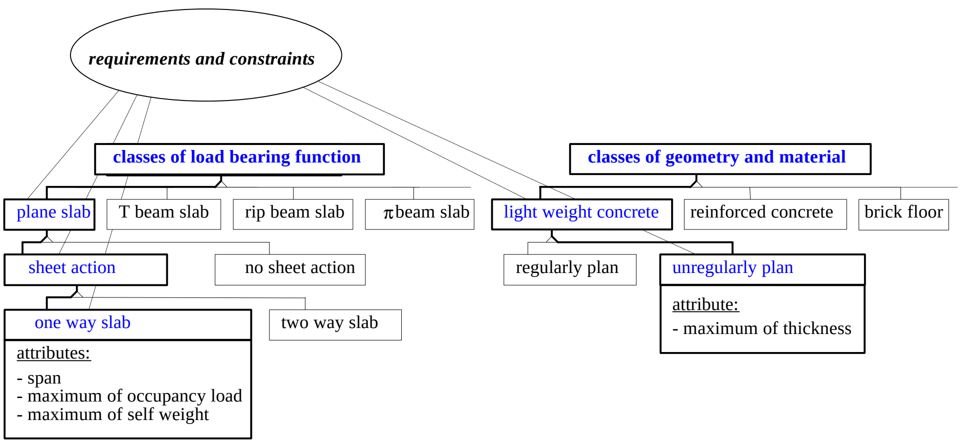

FIG. 3: Hierarchy of classes andinstantiations according to the requirements and constraints

3.4 Interface to CAD / CAE systems

Most of the CAD systems in the field of architecture and building construction use internal databases for standardised elements. The standardised elements are provided as drawing macro elements. The application of an external database for prefabricated elements shall offer functionality in the same way. That means, when a solution is selected the corresponding database objects should be exportable from the database directly into the CAD drawing.

An interface between the described engineering database server and a CAD program is investigated as an example for an intelligent CAD system for preliminary structural design. The CAD system should pass the generated constraints of geometry and loads automatically to the database client and receives the results of the associated database queries in return.

The necessary data exchange will technically be realised on the basis of schemes and formats in conformity with STEP. The aim of the connection of CAD / CAE tools and engineering database server is the evaluation of such database methods useable for design tasks that require a minimum of information flow between computer and user.

4. BENEFITS FOR ROUTINE DESIGN PRACTISE

The design process is characterised by a high degree of uncertainty and a low degree of formalisation. Both of these features have a decisive influence on the costs for the building to be planned. Assessment and evaluation of the available alternatives is a sophisticated process dealing with a great amount of various information.

The table below shows an example for a checklist for selecting a type of prefabricated slab floors for a multi-storeyed residential and commercial building in an example design situation.

design aspects	properties	absolute requirements	relative requirements
geometry	• maximum of thickness • floor construction	≤ 18 cm plane slab	
load bearing function	• occupancy load • direction of span • span • sheet action	≥ 6 kN one span 5.80 m required	
physics relating to construction	• heat conduction • sound insulation • fire resistance	 F 90	low high
technology	• assemblage • assemblage time • time of curing • formwork • intermediate columns	-	- low low no formwork required no columns required
costs	• working time • cost per square meter		low low

Although the design of slab floors is a routine design task, a number of parameters have to be considered. Beside the fulfilment of absolute requirements given by the ground plan, structural behaviour and fire resistance, the aspects of technology (assemblage, transport, machines, assemblage time) are playing an important role and will finally influence the time and cost factor decisively.

The search for a solution means choosing from more than one hundred manufacturers who offer prefabricated floor slabs, selecting among of 17 different structural systems and comparing 5 different materials of concrete and stone. Even though the use of an information service via catalogue and fax is already common practise, the recherche demands a high effort of cost and working hours. We assume that information retrieval combined with network technology will gain more importance compared topredeterminable product catalogues.

5. CONCLUSIONS

A concept of an information retrieval system used for storing retrieving, comparing and evaluating design solutions has been introduced. As main results of our investigation in the field of information retrieval of engineering knowledge we are going to base our system on the following hypotheses.

The storage of information for the purpose of architecture and engineering design should involve descriptions, drawings and photographs in addition to the pure product model data. Because of the amount of various information on the one hand and the not well structured data on the other hand, we assume that the use of a relational database in connection with an object-oriented retrieval agent is the most favourable solution to store information of producers and experts independently from programming of database.

Advanced methods for searching and selection are decisive for the effectiveness of a system for information retrieval. A book of a big library whose key number has get lost is still physically existing but is practically not detectable. This is similar to the situation of rapidly increasing available information and the lack of methods and tools for domain oriented search. Search of information should be more than searching for text strings in a document. The investigation of client-tools for goal directed navigation is important for retrieving of design know-how for architects and engineers.

An information server with network communication should compensate the disadvantages of dedicated internal databases of programs. A main shortcoming in nowadays use of information technology for design information retrieval is that mostly internal databases are used that are hard-wired connected with one single CAD/CAE system. The search for structural elements in these databases is presently only supported for geometry aspects.

The use of modern network communication will improve the information flow from the fabricator to the user and the data exchange via STEP directly in the CAD system.

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