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Expert System for Building Design

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ABSTRACT

At the DBECT at the University of Rome, an interactive Expert System for architecture is being implemented to supervise building design at every stage of development.
The System operates by checking the consistency of design choices against given sets of constraints, and by automatically checking the design process.
It is therefore an innovation with respect to current architectural software developed as specific design aids.
The System is based on a general representation of building objects (from components to the whole building) by means of semantic nets and a set of inferential procedures.
The general representation is developed by making explicit the relational structures according to which architects organize their knowledge about building objects.
To do this, the 'Frame' formalism is used: this is a knowledge representation technique used in the field of artificial intelligence.
It will then be shown that such an Expert CAAD System is a general purpose tool for architectural design, enabling architects to assess any constraint and/or building attribute by means of a declarative method, which in no way affects their own specific design methodologies.

Système Expert pour les Projets du Bâtiment

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MOTS-CLES

Project de Bâtiments, Systèmes Experts, Structure de la Représentation

SOMMAIRE

Dans de DTBCA de l'Université de Rome, un système expert pour le bâtiment a été développé, pouvant de façon interactive, superviser à chaque niveau de définition, les projets de construction.
Un tel système est appliqué en vérifiant que les choix des projets correspondent à un ensemble d'exigences, et en contrôlant automatiquement le processus de planification.
Il représente, donc, un dépassement des systèmes software actuels d'architecture, réalisés dans le but de fournir un instrument pouvant résoudre des problèmes spécifiques des projets.
Le système est basé sur une représentation générale des objets du bâtiment (de la composante individuelle au bâtiment entier), s'appuyant sur un système de réseaux sémantiques et de procédés déductifs.
Cette représentation a été réalisée en précisant les structures relationelles selon lequelles l'auteur du projet organise, à des fins opérationnelles, sa propre connaissance des objets du bâtiment.
Dans ce but, on a employé le formalisme des 'Frames', des techniques de représentation de la connaissance dans le cadre de l'intelligence artificielle.
On montrera enfin comment un tel système CAO Expert constitue un instrument flexible dont l'emploi peut permettre à l'architecte de définir n'importe quel type de lien ou caractéristique du projet, par une méthode de déclaration sans effet sur sa propre méthodologie de programmation.

1 INTRODUCTION

The research being conducted at the CAAD laboratory of the DBECT of Rome University is geared to the production of an Expert System for architectural design, which is able to perform interactive design tasks and help to provide an accurate and complete description of the buildings in question.
The Expert System is intended to control the design process, continually ensuring consistency between the definitions of the designer and a given set of constraints.
Accordingly, the System must be able to determine the effects of choices taken at different stages of definition, performing the necessary calculations and checks.
The System is based on a general representation of the building objects, from individual components to the whole building defined in terms of a number of hierarchical, topological and functional relational structures resulting from earlier research conducted into the automatic management of architectural design at the CABD-LAB at the Department of Building and Environmental Control Technologies since 1975.

2 METHODOLOGY

Two basic methodologies underlie the approach used to build the proposed Expert System.
The first is the use of the formalisms and languages of Artificial Intelligence; the second is that the System has been built to incorporate all the programs actually available today for architectural design, such as data bases, 2D and 3D drafting, calculation and checking programs.

2.1. THE KNOWLEDGE BASE

The formalism of Frames is used to build up the System's knowledge base. This is able to represent the real objects through a system of Slots, Facets and values linked to them, organizing them into a generalized hierarchy of information through the definition of Prototypes and Instances (2,3,17,24,25).
In the System the Prototypes are used as tools to represent classes of real building objects, defining the features of the constituent elements, the classes and the fields of variation of the values connected to them. The definition of the Prototypes can be varied as the designer proceeds to adapt the representation to his own requirements case by case, and to define the set of constraints taken into account, introducing the features to

be constrained and the values they require.
Inheritance procedures are used to check the consistency of the given definitions against both the Prototypes of the building objects and the set of constraints being considered. The generalization procedures are used to enhance the Prototypes on the basis of the defined Instances.
The information in the knowledge base is addressed by the designer along a path identified by the name of the object, the feature under consideration, and the value relating to it.
Depending on the status of the knowledge base, the definition of a PATH will cause a new Instance to be created and all the relevant checks to be carried out, or the available information in the object under consideration to be visualized.

2.2. THE LANGUAGE

LISP, and especially its most common dialect, COMMON LISP, has been chosen to create the knowledge base and implement the Frames-based formalism.
There are two main reasons for having chosen this language.
Firstly, it makes it possible to handle the Frames-based system simply and efficiently, and secondly, it can be used to create the Procedural attachment.
A restricted number of elementary instructions in this language can be used to implement a Frames-based system thanks to the fact that the formal structure of the Frames is virtually identical to that of LISP.
A Frame, like any LISP program, can be formally defined as a generalized list in which each element can be recursively a list of elements.
It is because the data and calculation programs have the same presentation that the Procedural Attachment is possible: this makes it possible to model even complex relations between building objects using calculation procedures linked to the Frames that represent them.
These procedures are performed automatically, operating on the knowledge base, when these aspects related to the building objects in question are involved.

2.3.THE STRUCTURE OF THE EXPERT SYSTEM

The structure of the Expert System differs from the usual SW systems of the same type.
In addition to the knowledge base and all the inferential procedures that operate on it, the need to interface with conven-

tional software systems has made it necessary to add both another logic component to the System, comprising a set of operating procedures, and the research phases needed to define it.
To permit the System to interface with the set of design programs currently available, a set of procedures is going to be defined so that the System can produce a representation of the building aspects as the need arises, using logic elements and the operations permitted by them. Furthermore, to ensure that these procedures are independent of the individual programs used, they have to be defined a posteriori - namely, on the basis of a thorough trial using these programs to design concrete examples.
For the Drafting systems, procedures are going to be designed to move from two-dimensional to three-dimensional representations, and for each type of representation it is necessary to define the way in which the logic elements and the operations allowed by these types of programs can be used to represent the building objects under consideration.
Furthermore, an analysis will be made of the operating procedures used by the designer to represent information on technological, economic and production aspects using the logic available in the present DBMS systems (hierarchical, networking, relational), and indications will be provided on the way in which these may be related to the graphic representations of the building objects.
Lastly, for the calculation and checking procedures, we shall define the operational sequence of information required derived from graphic representations or technological descriptions.
The procedures comprising the output of the experimental period are subsequently going to be translated into calculation programs and used to provide the System with the required procedural knowledge to enable it to perform the operations described above.

3. CONCLUSIONS

The proposed Expert System is a vast improvement on the programs currently available for architectural design.
The System has been designed to supervise the design phase, continually verifying the design choices made in each phase, and automatically checking the representation produced.

3.1. VERIFICATION OF DESIGN CHOICES

The design choices are verified by the System, whatever the work phase or the features of the building objects under consideration.
It is designed using Inheritance procedures that make it possible to propagate the constraints defined with the prototypes through to the Instances defined by the designer.
This verification is performed by the System whenever any particular Instance is declared to belong to a class known to the system. The definitions are therefore verified by comparing the required values defined with the Prototype against those specified by the designer using the Instances.
The Inheritance procedures also enable the System to explicitly request features of the Prototypes which are not specified by the designer.

3.2. AUTOMATIC CHECKING

The system automatically checks the representation using the Procedural Attachment.
This check is necessary to prevent local variations in the knowledge base from producing contradictory information in it.
The check is performed automatically by determining the effects produced by each definition used by the designer following the relevant procedures for checking given values. These procedures, called Demons, will be linked to appropriate Facets (Advices) and will be performed whenever the System requires.

3.3 FUTURE DEVELOPMENTS

The proposed System can be used as the basis of a CAD system that could be extremely useful for defining building objects.
In this connection, it may be possible to define a system of semantic primitives based on the representation structure, through which every design activity can 'explode'.
These primitives can be used to express the differences between the built-up representation and the assigned constraints, so that operations can be defined that modify the former in order to comply with the latter.
In other words, by looping the definition and checking phases, the System can produce an optimum solution to specific problems posed by the designer.

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A knowledge-based 'expert system' for brickwork cladding design & production

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ABSTRACT

Increasing use is being made of 'special shapes' for bricks and brickwork elements in cladding UK buildings. Certain colours and textures are also required for these proposed elevational forms. When selecting one or more types of brick from a wide 'material range', verification is necessary to ensure that structural and weathering criteria will be fully satisfied in any proposal. It is also necessary to know the implications for brick component manufacture and brickwork assembly of the particular shape/material combination proposed. This paper describes a computer aided design system which addresses both aspects of the task of brickwork design. There are two parts to the system. The first part is a 3-d graphics facility which allows the designer to visualize proposed elevations and details. The second part is an expert system which uses data about the characteristics of available bricks, information about the demands of the particular design context and experiential knowledge of 'good practice' in brickwork. This is to ensure the chosen design is functionally satisfactory and all the implications for manufacture and assembly have been considered. The system is being developed in conjunction with a major brick manufacturer, whose design staff are providing the experiential knowledge which is incorporated in the system using an expert system language.