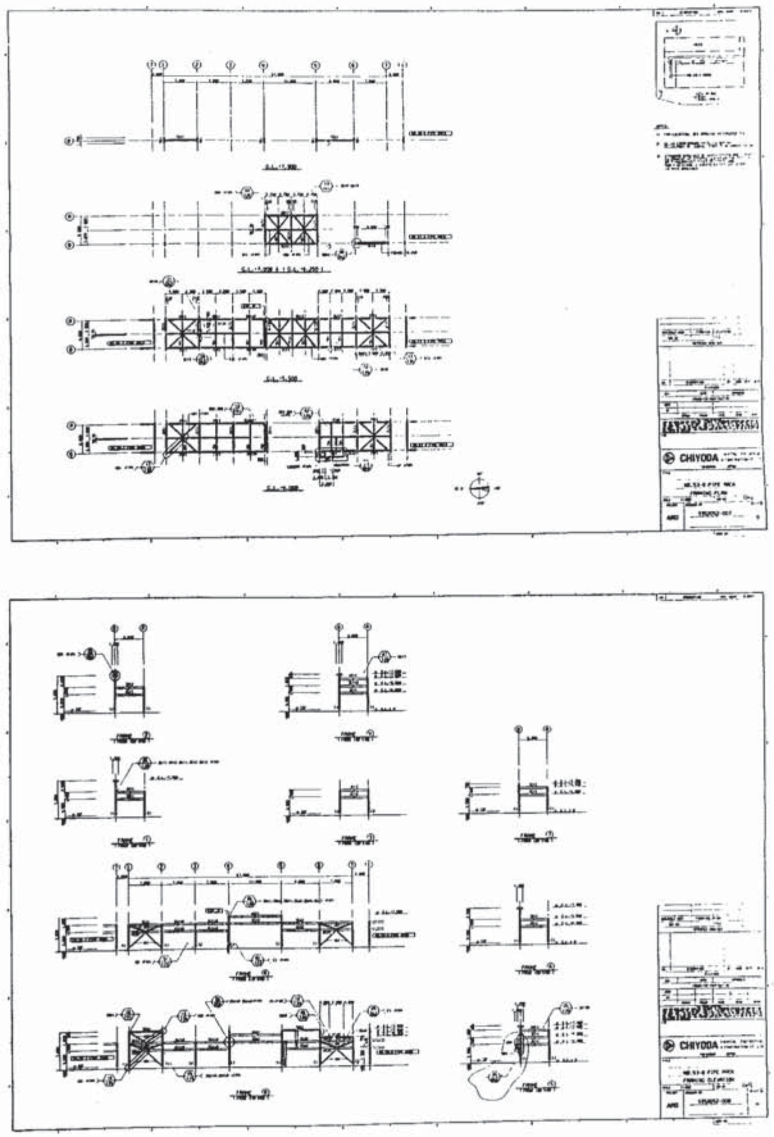

Fig. 3 An example of drawings

Knowledge-Based Building Design

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KEYWORDS

Knowledge Engineering, Building Design, Computer-Aided Design.

SUMMARY

Building design is unquestionably a knowledge-based activity, yet few existing computer-aided design systems make any explicit representation or explanation of the knowledge they assume and embody. This paper presents work towards the development of a new generation of knowledge-based computer design tools which is being carried out in the University of Sydney, Australia. It describes the philosophy of knowledge accessibility which underlies the work and its practical demonstration in diagnostic and generative expert systems, in the induction of knowledge from observed examples, and in the development of grammars of design based on production systems. It is suggested that a rigorous knowledge-based approach provides a theoretical basis for extending the role of computer-aided design into the core areas of professional design activity.

The examples used to illustrate the discussion will come from current work on expert systems for building regulations and passive solar energy design, on planning for the design of building layouts and for ithe assembly of building components, and on the induction of production rule representations of knowledge about window design from data on window performance.

Utilisation de Bases de Connaissances
pour la Conception de Batiment

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MOTS-CLES

Bases de connaissances, conception de batiment, conception assistee par ordinateur.

SOMMAIRE

La conception de batiment est incontestablement une activite qui requiert des connaissances, cependant peu de systemes de conception assistee par ordinateur rendent explicite la representation ou l'explication de l'ensemble des connaissances qu'ils assument et integrent.

Cet article presente une etude, effectuee a l'Universite de Sydney en Australie, l'etude porte sur le developement d'une nouvelle generation d'outils de CAO qui utilisent des bases de connaissances. L'article decrit la philosophie de "l'accessibilite de la connaissance" qui sous tend ce travail et ses applications dans le domaine des systemes experts generatifs et d'aide au diagnostic, dans l'apprentissage des connaissances a partir d'exemples et dans le developpement de grammaires qui se rapportent a la conception; ces grammaires etant exprimees sous forme de regles de production. Nous suggerons qu'une approche rigoureuse s'appuyant sur l'utilisation de connaissances explicites, fournit une base theorique qui permet d'etendre le role de la CAO aux activites professionnelles.

Les exemples utilises pour illustrer la discussion sont extraits des travaux en cours sur les systemes experts appliques a: la reglementation dans le batiment; l'utilisation de l'energie solaire; la planification concernant des problems d'allocation spatiale; l'assemblages des composants du batiment; l'exploitation des connaissances dans le domaine de l'aide a la decision; l'extraction de regles de production - application a des problemes de conception de fenetres a partir de donnees ayant trait a leurs performances fonctionnelles.

INTRODUCTION

All design must be based on knowledge, but most is based on knowledge which is not explicitly defined or delineated as an entity applying to the particular design problem. The use of the right knowledge depends not only on its availability but also on the designer recognising that it is needed. The great majority of failures in building design and construction come from the non-application of existing, recorded, knowledge; the designer either could not find the right information, or never recognised that the existing basis for making design decisions was inadequate in a new context.

This paper describes some work towards the development of knowledge-based computer-aided design tools in which the knowledge is explicit, explained and open to modification. The philosophy behind the work is that design is almost always better if it is based on better knowledge, and that knowledge should be linked as closely as possible to the design activity. Rather than rely on a theoretical discussion, we shall make some brief statements about the nature of such knowledge-based systems and then give some working examples from the Architectural Computing Unit in the University of Sydney.

ADVISORS, CRITICS AND GENERATORS

There are three places where computer resident knowledge can be injected into the design process: before the synthesis of a design, as an advisor; after the synthesis of the design, as a critic; and during the synthesis of the design, as a generator.

Advisors provide expert advice in text and/or graphic form on matters such as establishing a brief, the interpretation of regulations, exploiting passive solar energy potential and so on[1]. They can be integrated with or separate from the medium for design development. Critics evaluate a design or partial design given a domain of knowledge about good practice and/or compliance with regulations. They parallel the performance prediction of simulation and quantitative analysis in computer-aided design as well as evaluating the results. They are best integrated with the design medium and the major implementation difficulty is matching a geometric model of a design to a semantic model (what the parts are and mean) within which the knowledge can operate. The design generator approach questions whether this interpretation problem is really necessary: why not simply get the design right in the first place by implementing generative rather than evaluative rules? Generators transform a specification of the design in terms of performance or intentions into a specification in terms of design decisions. They parallel the solution specification of optimization in design, but are not limited to a statement of intention in terms of quantifiable objectives. The major implementation difficulty is in controlling the generation process. In all these approaches there is also a question of obtaining the best knowledge for the system, from human experts or by extracting knowledge from examples or design studies.

REPRESENTING KNOWLEDGE AND DESIGNS

We are accustomed to representing knowledge using algebra and mathematics. This limits us largely to numerical knowledge whilst much of the knowledge about designs and design processes is not of this form. New schemata provide the means to represent phenomenological and experiential knowledge in addition to causal and logical knowledge.

Production rules or production systems of the form IF...THEN... modeled in predicate logic provide a rich medium for representing knowledge in expert systems. A typical example from a kitchen design expert system[2] encodes some cultural design performance knowledge:

IF window shares wall with counter
AND location of window is not in the corner
THEN best location for sink is under the window.

Production rules have also been used to model the object being designed[3] as well as the processes which control the generation of designs.[4]

Frames appear to provide a tool for better representing semantic knowledge about designs. They provide a method for structuring a wide range of prototypical situations in an object-oriented sense. Figure 1 shows the dialogue between an expert system and a frame-based representation of an apartment as well as the frame representation itself.

EXPERT SYSTEMS

An expert system is a computer program which deals in a specialized field requiring some expertise to provide solutions to problems and/or to give advice. Expertise is that knowledge which is acquired over many years of experience. An expert system attempts to emulate an expert but does not necessarily model precisely his processes.

The prototype expert system BUILD was first developed to analyse the requirements of an expert system for building regulations. It was written in Prolog 1 (from Expert Systems Limited) running on an 8088/8086 microcomputer in an MS.DOS environment.[5] It has since been upgraded to a more general system and the latest version is written in Quintus Prolog (from Quintus Computer Systems Inc) and a compiled version runs on a SUN Microsystem workstation under the Unix operating system.

BUILD is based on a production system as the representation is simple and general. BUILD uses a restricted English form which can easily be expanded by the addition of extra operators thus making the knowledge base easily readable. The system supports both goal

driven and data driven processes. The explanation facility provides an explanation of how a particular goal was reached or what failed in arriving at a particular conclusion or why a particular goal was not reached.

BUILD has been:

(1) used to analyse examples of building regulations[6];
(2) interfaced with an interactive graphics system to provide a system for the design and analysis of kitchens[2] (see figure 2);
(3) used in a system called RETWALL to design retaining walls[7,8].

Further work is at present being carried out by Coates using BUILD in designing the system SOLARBUILD, a passive solar expert system, and by Manago in combining BUILD with a frame system so as to provide a comprehensive knowledge-based building design system.

AN EXPERT SYSTEMS APPROACH TO OPTIMAL DESIGN

OPTIMA is an expert system which formulates a design problem described in a mixture of English keywords and a minimal algebra into a canonical form of optimization model.[9] Developed by Balachandran, the system also recognizes the type of decision variables, design constraints and objective functions involved in the problem. Once the model is correctly recognized then an appropriate algorithm may be invoked to solve it, figure 3. The system aims to include well understood expert knowledge in computer systems and is written in LISP, PROLOG and C. The knowledge is encoded in production rules and frames. An example rule for the recognition of a model and for the selection of a method is given below:

IF all the variables are of continuous type
AND all the constraints are linear
AND the objective function is linear
THEN conclude that the model is linear programming
AND executive LP algorithm.

The system demonstrates a number of features which are normally difficult to achieve in more conventional CAD systems. The performance of this prototype promises a better design assistant to produce better designs.

GENERATIVE SYSTEMS

A knowledge-based system for spatial layout design has been developed by Coyne[10]. The system is based on the use of production rules which are generative rather than of the type used for inference. The rules transform sets of procedures (plans) for constructing layouts rather than operating on the spaces themselves. Knowledge about the resolution of conflicts between competing actions is also represented in the form of rules. The implementation of these rules is controlled by scheduling knowledge.

The system therefore operates by means of explicit hierarchical control knowledge and exploits the inherent redundancy in certain design problems. The layout task can be visualised: as organizing nodes on an adjacency network; as organizing sequences of actions about the placement of spaces; and as the configuration of geometrical entities. Each of these views contributes to the solution, and each has its own pertinent body of knowledge. The system has been implemented on a SUN Microsystems SUN 2 workstation in Quintus Prolog. Figure 4 is a screen display of the system showing the various stages in the synthesis process. The top left window shows the tasks being processed, the bottom left window shows a network representation of the problem structure, the bottom right window shows the plan of actions and the top right window shows the resulting layout after executing the plan of actions.

This approach resembles that of the blackboard paradigm of the HEARSAY speech understanding system[11]. It appears to provide the greatest scope for the representation and manipulation of design knowledge, as it permits the representation of diverse types of knowledge. Design is a loosely structured, knowledge-rich activity and as such requires a medium for representation which allows free rein to that knowledge.

LEARNING FROM DESIGNS

If we assume that the design process is characterized by a set of coherent decisions which have an observable effect on the final artifact, then it may be possible to work backwards from a set of existing designs and extract knowledge about the decision process. This represents the discovery of design heuristics which may be employed in expert systems or as didactic knowledge for inexperienced designers.

PARE is a prototype system that extracts design decision knowledge from data and expresses it in both quantitative and qualitative rules. To facilitate the extraction of design decision knowledge, it is necessary to structure the data in a way that matches not only the objects that are to be discovered, but also the process through which such objects arise. One structuring method which satisfies these needs is multicriteria optimization which is a means of identifying a set of design solutions among which a best solution for any group of evaluable goals must lie. The use of multicriteria optimization as a design paradigm has been discussed elsewhere[12-13]. In particular, Pareto optimal data sets exhibit simple structures that allows the extraction of decision knowledge through pattern recognition. Pareto optimization allows a mapping to connect the design decision space to the set of optimal design perfomances in a performance space. The mapping allows the identification of particular decisions that give rise to optimal performances. The relative number and positions of the corresponding decisions in the performance space can be exploited for knowledge on their sensitivity and importance. These can be interpreted in the form of production rules which represent design knowledge.

CONCLUSION

In the above examples we have given an outline of the work of the Architectural Computing Unit at Sydney University and its relationship to a unifying philosophy of knowledge-based systems. The interested reader should refer to the references for detail[14]. Work so far confirms our belief that a rigorous knowledge-based approach to computer-aided design systems provides a theoretical basis for extending their role into the core areas of building design synthesis.

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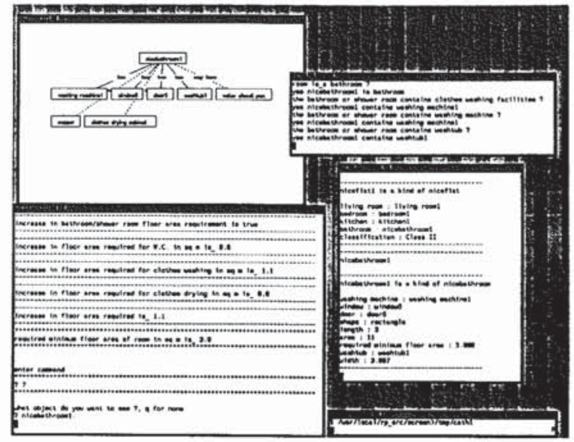
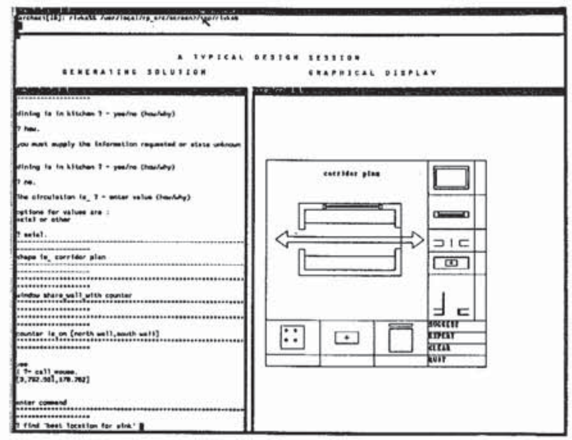
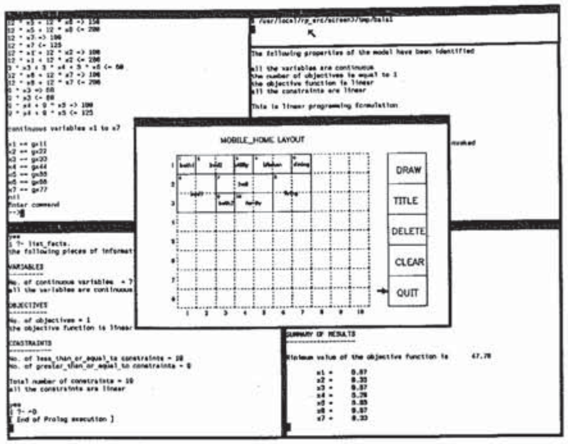


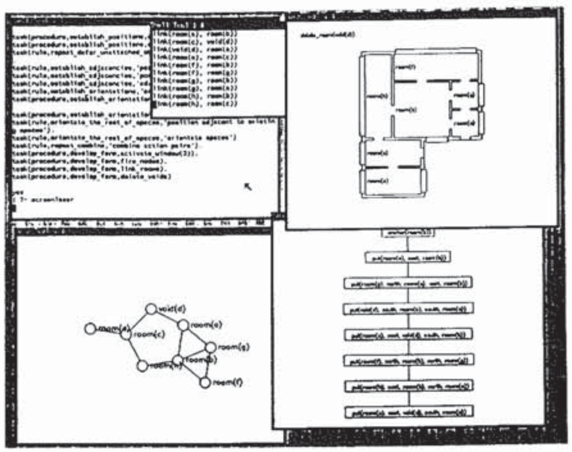
1. Screen dump of an expert system (lower left window) carrying out a dialogue (upper right window) with a frame-based representation of an apartment called 'niceflat' (centre right window) which includes the frame for the bathroom. The upper left window shows a graphical representation of the bottom frame.



2. The BUILD expert system shell with a knowledge base for the design of kitchens, here used as a generative system. The expert system will also act as a design critic if the user designs the kitchen layout.



3. A screen image of the OPTIMA system. The graphics window shows a mobile-home plan graphically input to the system. The top left window shows the optimization model constructed to find optimal dimensions of the layout. The bottom left window lists the information generated from the algebraic model. the bottom right window shows the final results with the decisions listed.



4. Screen dump of the various stages in an expert planning system for the design of room layouts.

Perfection of Designing Technology of Unified Reinforced Concrete Sturctures of Industrial Buildings at the Basis of Optimal and Computer Design

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KEYWORDS

Automatized Design, Industrial Construction, Optimization, Reinforced Concrete Structures, Technological Line, Unification

ABSTRACT

The system of unified structures particularly reinforced concrete ones is the basis of industrial building construction in the Soviet Union. Efficiency of this system is ensured by definite methods at each stage of their development, their manufacturing and erection as well. TsNIIpromzdaniy has worked out a methodology of optimal designing including general approach to the designing of catalogue of unified structures, economical/ mathematic models of design projects, methods of obtaining initial information and search of optimal solution. This methodology covers all analytical stages of the design process. Application of this methodology contributes to 8-10 % reduction of unified structures cost. Modelling of projects and tasks allowed to formalize the process of design and interprete it as the problem of plotting the catalogue of unified sructures. Automatized "TLP TZhBK" system intended for computer designing of unified (standard) precast reinforced concrete structures for the construction of single- and multi-storey industrial buildings has been worked out. When applying "TLP TZhBK" system the functions of designers include: elaboration of technical specifications for design, filling in the incoming documents of the system; analysis and taking the solutions at intermediate stages of automatized design and choice of the final version. Design documentation on manufacturing of structures and auxiliary materials which simplify the designing of projects is the result of automatized design.